NAPA VALLEY GROUNDWATER SUSTAINABILITY

A Basin Analysis Report for the Napa Valley Subbasin

APPENDICES A - D

Part 1 of 2

FINAL DRAFT REPORT

Prepared by

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

November 30, 2016

NAPA VALLEY GROUNDWATER SUSTAINABILITY:

A BASIN ANALYSIS REPORT FOR THE NAPA VALLEY SUBBASIN

APPENDIX A:

Groundwater Sustainability Objectives

Appendix A

GROUNDWATER SUSTAINABILITY OBJECTIVES

GROUNDWATER SUSTAINABILITY OBJECTIVES AD-HOC COMMITTEE

Napa County Groundwater Resources Advisory Committee (GRAC)

February 27, 2014, GRAC Meeting

1. Goal of Developing Groundwater Sustainability Objectives

The use of groundwater is essential to protecting the quality of life in Napa County. Therefore the overarching goal of developing sustainability objectives is to protect the groundwater resources of Napa County for all the people who live and work here, regardless of the source of their water supply. This builds on the County's General Plan and associated actions.

2. Definition of Groundwater Sustainability

Based on the GRAC's charge from the Board of Supervisors and a review of definitions in published literature, we define "groundwater sustainability" as follows:

> *Groundwater sustainability depends on the development and use of groundwater in a manner that can be maintained indefinitely without causing unacceptable economic, environmental, or social consequences, while protecting economic, environmental, and social benefits.*

As such, groundwater sustainability is both a goal and a process.

Examples of unacceptable consequences included: insufficient water supplies for agriculture, wine production, and business operations; loss of groundwater wells; loss of real estate value; environmental damages; and increased governmental intervention.

Examples of benefits included: protection of quality of life, small town rural setting, agricultural communities, the county's economy, and groundwater in the valley; healthy streams; and proactively avoiding state and County intervention.

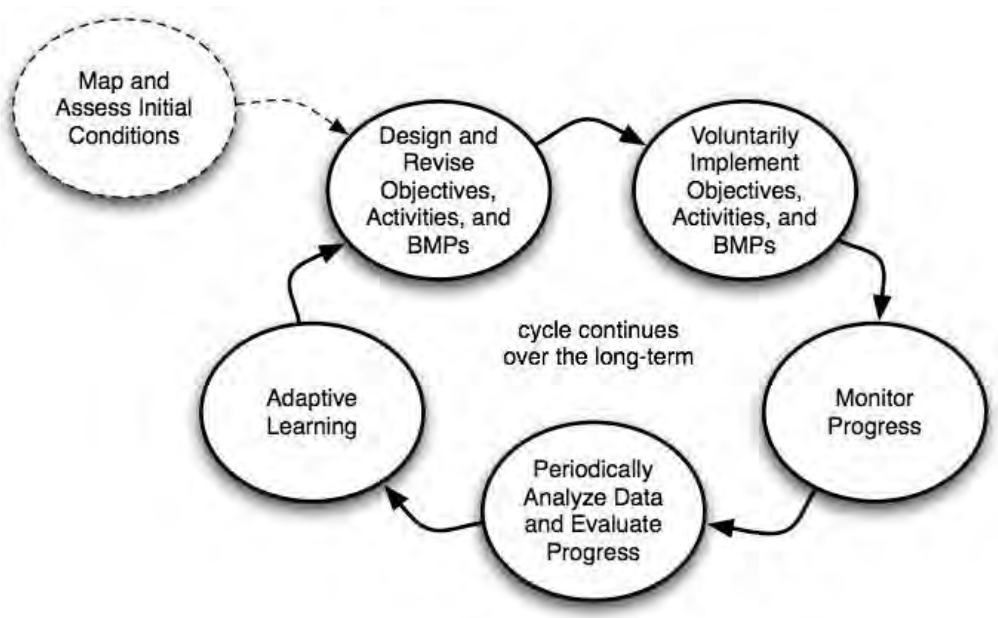
3. Shared Responsibility for Groundwater Sustainability

Groundwater sustainability involves cities, private well owners, residents, and workers, as well as the County and unincorporated areas. Everyone who lives and works in the County shares responsibility and has a stake in protecting groundwater resources, including groundwater supplies, quality, and associated watersheds. Without this resource the character of the County would be significantly different in terms of its economy, communities, rural character, ecology, housing, and lifestyles. In this context, healthy agriculture cannot be separated from healthy communities and healthy environments; none of these exist in isolation. The County would not be the same if any of these components were adversely affected.

4. Monitoring as a Means to Achieving Groundwater Sustainability

Groundwater

Monitoring is not a goal in itself, rather it is an activity that supports the larger goal of sustainability. Ensuring groundwater sustainability is an adaptive process that, among other things, maintains the ability of future generations to make choices about how they use groundwater resources. Monitoring is only one step in the larger adaptive cycle, albeit an important one, along with evaluating progress toward meeting objectives, learning from activities (adaptive learning), revising objectives and activities and best management practices (BMPs), and voluntarily implementing these. The following diagram summarizes the process.



5. Principles underlying the Objectives

- The objectives are to be "achieved through voluntary means and incentives", per the charge from the Board of Supervisors.
- The objectives build directly off the County's General Plan Conservation Element, the GRAC's associated Monitoring Plan, and existing County climate change policies.
- The objectives acknowledge that groundwater management policies already exist in some areas. Stewardship of groundwater use currently occurs and can be strengthened through enhanced private responsibility, as well as existing regulations, programs, and mandates. Further regulation is not an objective.
- The objectives acknowledge that many private individuals are already taking care of their groundwater resources. Their participation in the monitoring program will help ensure that their ongoing stewardship activities are meeting the goal of groundwater sustainability.

6. Groundwater Sustainability Objectives

Goal: To protect and enhance groundwater quantity and quality for all the people who live and work in Napa County, regardless of the source of their water supply.

Objectives:

1. Initiate and carry out outreach and education efforts.
    a. Develop public outreach programs and materials to make everyone who lives and works in the County aware that the protection of our water supplies is a shared responsibility, and everyone needs to participate.
    b. Through education, enable people to take action.
2. Optimize existing water supplies and systems.
    a. Support landowners in implementing best sustainable practices
    b. Enhance the water supply system and infrastructure – including but not limited to system efficiencies, reservoir dredging, recycled water, groundwater storage and recharge, conjunctive use – to improve water supply reliability.
3. Continue long-term monitoring and evaluation.
    a. Collect groundwater and surface water data and maintain a usable database that can provide information about the status of the county's groundwater and surface water resources and help forecast future supplies.
    b. Evaluate data using best analytical methods in order to better understand characteristics of the county's groundwater and water resources systems, including but not limited to a county-level groundwater inflow/outflow estimation.
    c. Share data and results of related analytical efforts while following appropriate confidentiality standards.
4. Improve our scientific understanding of groundwater recharge and groundwater-surface water interactions.
5. Improve preparedness to address groundwater issues that might emerge.
    a. Improve preparedness for responding to long-term trends and evolving issues, such as adverse groundwater trends (including level and quality), changes in precipitation and temperature patterns, and saltwater intrusion.
    b. Improve preparedness for responding to acute crises, such as water supply disruptions and multiyear drought conditions.

Supplemental recommendations:

1. Support the WICC and RCD in implementing the objectives.
2. If a County or sub-regional groundwater stewardship and sustainability plan is developed in the future, these should be the foundational objectives.

GROUNDWATER SUSTAINABILITY OBJECTIVES AD-HOC COMMITTEE
27-February-2014

General Objective	Specific Objective	Basis/Strategy	Metric	Timeframe	Who Will Implement?	Cost Range
I. Conduct Outreach and Education	a. Develop and widely distribute public outreach programs and materials	Make everyone who lives and works in the County aware that the protection of our water supplies is a shared responsibility, and everyone needs to participate	No. of individuals and organizations reached	Short-term – develop and distribute materials, On-going long-term – continue outreach effort, update information as needed	County and cities through professional/ educational and community organizations*	Low
	b. Educate people about opportunities for taking action	Provide a direct pathway to taking action	No. of individuals taking action to reduce water use	Short-term, On-going long-term	County and cities through professional/ educational and community organizations*	Low to moderate (if funding is made available to implement some measures)
II. Optimize Existing Water Supplies	a. Support landowners in implementing best sustainable practices	Solicit information on, and widely share best practices with regard to water use in vineyards, wineries, and other agricultural/commercial applications	No. of individuals and organizations reached	Short-term - solicit best practices information and rank for effectiveness, start outreach effort to share information; On-going long-term – Continue to solicit information and share with appropriate audiences	County through professional/ educational organizations*	Low to moderate (if funding is made available to implement some measures)

* Professional/educational and community organizations: RCD, NVG, NFB, NVV, UC Davis, UC Berkeley, Chamber of Commerce and others

General Objective	Specific Objective	Basis/Strategy	Metric	Timeframe	Who Will Implement?	Cost Range
	b. Enhance the water supply system and infrastructure to improve water supply reliability.	May include, but is not limited to system efficiencies, reservoir dredging, recycled water, groundwater storage and recharge, conjunctive use	Potential water savings generated by various actions	Short-term – evaluate and rank opportunities Long-term – seek funding and implement high-value projects	County and cities	Moderate to high
III. Continue Long-Term Monitoring and Evaluation	a. Collect groundwater and surface water data and maintain a usable database that can provide information about the status of the county's groundwater and surface water resources and help forecast future supplies.	On-going monitoring is crucial to understand trends.	No. of high quality wells monitored; no. of surface water monitoring locations; all data entered into database	On-going: refine monitoring program over time	County with support of private & public landowners, and professional organizations WICC**	Low to Moderate, depending on number of wells monitored
	b. Evaluate data using best analytical methods to better understand characteristics of the county's groundwater and water resources systems, including but not limited to a county-level groundwater inflow/outflow estimation.		Reassess groundwater trends at least every 3 years, including inflow/outflow estimation when sufficient data are available	On-going: Every 3 years minimum Annual update: WICC	County & outside consultants (LSCE, others) WICC	Low to moderate, depending on extent of evaluation
	c. Share data and results of related analytical efforts while following appropriate confidentiality standards.	Having good information allows organizations and individuals to make better decisions	Appropriate use of existing data becomes routine within the County	Short-term; On-going long-term On-going updates through WICC	County & outside consultants (LSCE, others) WICC	Low

** WICC : Watershed Information Center and Conservancy of Napa County

General Objective	Specific Objective	Basis/Strategy	Metric	Timeframe	Who Will Implement?	Cost Range
IV. Improve our scientific understanding of groundwater recharge and groundwater-surface water interactions.		Potential connectivity between groundwater and surface water in various locations in the County is not well understood.	Extent of groundwater-surface interaction in key areas of the County is understood.	Short-term – clarify data needs; intermediate to long-term – collect and evaluate data	County and outside consultants (LSCE, others)	Moderate
V. Improve preparedness to address groundwater issues that might emerge	a. Improve preparedness for responding to long-term trends and evolving issues	Increase ability to address adverse groundwater trends (including level and quality), changes in precipitation and temperature patterns, and saltwater		Long-term	County and cities with outside consultants (LSCE, others)	Low; primarily a planning effort
	b. Improve preparedness for responding to acute crises, such as water supply disruptions and multiyear drought conditions			Long-term	County and cities with outside consultants (LSCE, others)	Low; primarily a planning effort

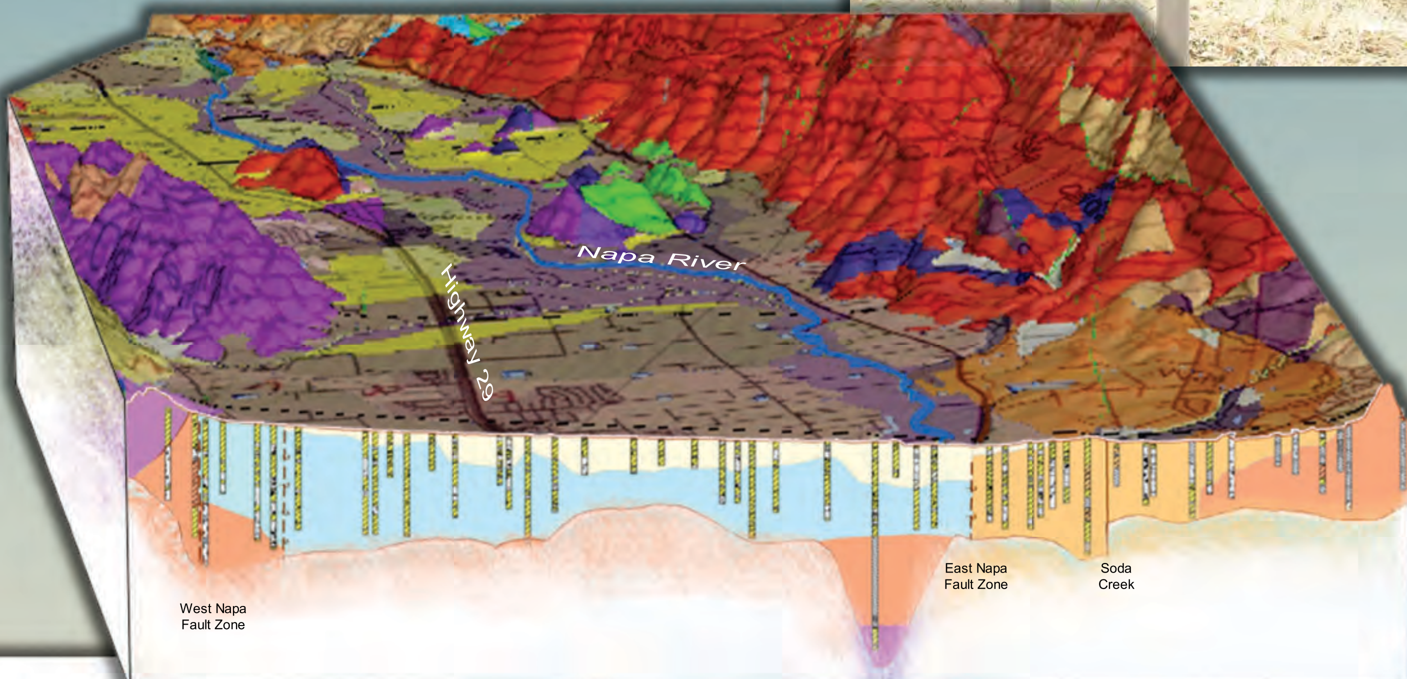
NAPA VALLEY GROUNDWATER SUSTAINABILITY:

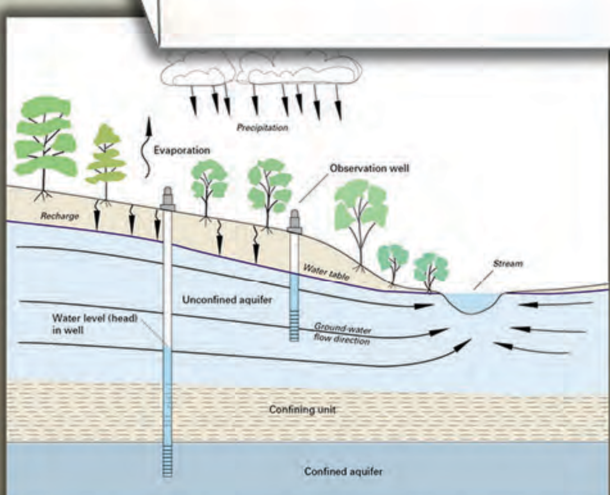
A BASIN ANALYSIS REPORT FOR THE NAPA VALLEY SUBBASIN

APPENDIX B:

Updated Hydrogeologic Conceptualization and Characterization of Conditions

Updated Hydrogeologic Conceptualization and Characterization of Conditions





January, 2013

LUHDORFF & SCALMANINI CONSULTING ENGINEERS and MBK ENGINEERS CONSULTING ENGINEERS

Updated Hydrogeologic Conceptualization and Characterization of Conditions

Prepared for

Napa County

Prepared by

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January, 2013

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EXECUTIVE SUMMARY

Groundwater and surface water are highly important natural resources in Napa County. Currently, municipal and private stakeholders are actively engaged in assessing the reliability of current and future demands and supplies. Important sources of water include both groundwater and surface water of good quality and quantity, to meet future urban, rural, and agricultural water demands. Similar to other areas in California, businesses and residents of Napa County face many water-related challenges. To address these challenges, long-term, systematic monitoring programs are essential to provide data that allow for improved evaluation of water resources conditions and to facilitate effective water resources planning. Establishment of a groundwater and surface water monitoring network results in the collection of data necessary to distinguish long-term trends from short-term fluctuations, anticipate unintended consequences due to current and historical land uses, identify emerging issues, and design appropriate water resources planning and management strategies.

ES 1.1 Background

In 2009, Napa County embarked on a countywide project referred to as the "Comprehensive Groundwater Monitoring Program, Data Review, and Policy Recommendations for Napa County's Groundwater Resources" (Comprehensive Groundwater Monitoring Program), to meet identified action items in the 2008 General Plan update (Napa County, 2008). Napa County's Comprehensive Groundwater Monitoring Program involved many tasks that led to the preparation of five technical memorandums and a report on Napa County Groundwater Conditions and Groundwater Monitoring Recommendations (LSCE, 2011a). This report and the other related documents can be found at: http://www.countyofnapa.org/bos/grac/.

The program emphasizes developing a sound understanding of groundwater conditions and implementing an expanded groundwater monitoring and data management program as a foundation for future coordinated, integrated water resources planning and dissemination of water resources information. The program covers the continuation and refinement of countywide groundwater level and quality monitoring efforts (including many basins, subbasins and/or subareas throughout the county) for the purpose of understanding groundwater conditions (i.e., seasonal and long-term groundwater level trends and also quality trends) and availability. This information is critical to enable integrated water resources planning and the dissemination of water resources information to the public and state and local decision-makers.

Napa County's combined efforts through the Comprehensive Groundwater Monitoring Program along with the related AB 303 Public Outreach Project on groundwater (CCP, 2010) and the efforts of the Watershed Information Center and Conservancy (WICC) of Napa County create a foundation for the County's continued efforts to increase public outreach and participation in water resources understanding, planning, and management.

On June 28, 2011, the County Board of Supervisors adopted a resolution establishing a Groundwater Resources Advisory Committee (GRAC). Two of the tasks assigned to the GRAC include: 1) assisting with the synthesis of the existing groundwater information and identifying critical data needs; and 2) providing input on the furtherance of the ongoing countywide groundwater monitoring program. During the implementation of the study discussed herein, input from this committee was coordinated to optimize additional groundwater monitoring locations that serve to meet the objectives of the County's Comprehensive Groundwater Monitoring Program and also the California Statewide Groundwater Elevation Monitoring (CASGEM) program, which is a subset of the countywide groundwater monitoring program.

ES 1.2 Purpose

The purpose of this Napa County Updated Hydrogeologic Conceptualization and Characterization of Conditions Report (Report) is to describe the work conducted by Luhdorff and Scalmanini, Consulting Engineers (LSCE) together with MBK Engineers (MBK) on behalf of the County to implement a number of the recommendations pertaining to the County's Comprehensive Groundwater Monitoring Program, including:

1. Prepare an updated hydrogeologic conceptualization and characterization of conditions in various areas of Napa County;
2. Analyze the potential for surface water/groundwater interactions;
3. Refine and further characterize areas of the greatest recharge potential; and
4. Link well construction information to groundwater level monitoring data, and provide groundwater monitoring recommendations.

Forthcoming in a separate document, the County is also developing an approach to determine whether there are locations where groundwater pumping near a surface water course (such as might occur for a proposed project) would be anticipated to effect groundwater discharge to the surface water available for endangered species. Conversely, the approach is also intended to enable the determination of locations where groundwater pumping would not have such an effect. The approach will be informed by the updated hydrogeologic conceptualization of conditions (as can be identified with existing data), including the accompanying groundwater monitoring recommendations, summarized in this Report.

ES 1.3 Updated Hydrogeologic Conceptualization and Characterization of Conditions

The Napa Valley study area is located in the southern-central Coast Range Province north of the San Francisco Bay region. This region of the Coast Range is characterized by northwest trending low mountainous ridges separated by intervening stream valleys. The Napa Valley is a relatively narrow, flat-floored stream valley drained by the Napa River. The valley floor descends from elevations of about 420 feet at the northwest end of the Valley to about sea level at the southern end.

ES 1.3.1 Geologic and Hydrogeologic Conditions

Historical Geologic and Hydrogeologic Studies and Mapping Efforts

Understanding the hydrogeology of Napa County is essential to determine how much water is available and to what extent it can be sustainably produced. Previous hydrogeologic studies have focused on the Milliken-Sarco-Tulucay (MST) Subarea and northern portion of the Napa Valley without much attention to the other areas within the county. With the exception of the Farrar and Metzger (2003) study, which looked at the MST, all of these studies are more than 30 years old. Since these studies, hundreds of new wells have been drilled to greater depths than previously reached, supplying a potential abundance of new data.

The surficial geology of the Napa Valley area has been mapped by various authors for over a hundred years. The reports and geologic maps differ through time in the detail of mapping, characterization of rock types, and nomenclature of various units. In the last forty years, the development of radiometric-age dating techniques and the evolution of plate tectonic theory have led to a better understanding of the geologic history of the region.

However, even the most recent geologic reports and maps exhibit conflicting map units, lithology, and nomenclature. Since the earliest geologic maps, three major geologic units in the Napa Valley area have been recognized and remain largely unchanged, except in details, names, and interpretation of how they were formed. These three units are Mesozoic rocks, Tertiary volcanic and sedimentary rocks, and Quaternary sedimentary deposits.

Previous hydrogeologic studies have focused on the Quaternary alluvium and most studies did not attempt to subdivide the Sonoma Volcanics in the subsurface. Previous geologic cross-sections were largely in the City of Napa area (Kunkel and Upson, 1960). Faye (1973) presented no cross-sections north of the City of Napa, but he mapped the thickness of the alluvium. In the MST area, Johnson (1977) and Farrar and Metzger (2003) subdivided the Sonoma Volcanics on their cross sections. Sweetkind and Taylor (2010) presented digital cross-sections, but the data used were pre-1952 drillers' reports from Kunkel and Upson (1960). As such, the data represent wells drilled before 1952 and located largely in the southern portion of the valley. As a result, there are sixty years of additional water well construction information which encompasses over 5,600 new wells, not considered in Sweetkind and Taylor's and other more recent reports.

Extremely Complex Geologic and Hydrogeologic Setting

The structural geology of the Napa Valley area is extremely complex. This Report examines in greater detail the geology below the Napa Valley Floor in relation to groundwater. From a previous reconnaissance study of the entire county (LSCE, 2011a), it was known that several thousand water well drillers' reports existed on the Napa Valley Floor. A majority of these drillers' reports post-dated 1970 and apparently had not been used in more recent published geologic and hydrogeologic reports. Accordingly, a series of geologic cross-sections were recommended to examine the subsurface geology, including derivative maps of alluvium thickness and Sonoma Volcanics rock types. This Report summarizes the work conducted to implement these recommendations.

As part of this study to update the hydrogeologic conceptualization and further evaluate the subsurface geology of the Napa Valley, eight geologic cross-sections have been prepared. During this study, over 1,300 wells were located by using the information on drillers' reports. These were for lithologic control for the development of the cross sections; however, wells were also located outside the cross section areas to evaluate the thickness and nature of the alluvium. The alluvium deposits are represented by the facies of the depositional environment which formed them, including the fluvial facies, the alluvial plain facies formed by alluvial fans of tributary channels, and the sedimentary facies which consist of finer-grained deposits near the southern end of the Napa Valley with some thicker sand and gravel beds interbedded that represent a broader floodplain to deltaic depositional environment.

Concurrent with the process to locate wells and identify the alluvium thickness, the nature of the underlying older Sonoma Volcanic-aged deposits was examined. The initial step was to subtract the alluvium thickness from the surface elevation to yield the elevation of the older deposits at each well site. These elevations were then contoured to produce the structure contour, or elevation map, on the top of the Sonoma Volcanics-aged geologic units. Classification of the Sonoma Volcanics-aged units was problematic due to the wide and varied drillers' descriptions of these units. In most areas, it was necessary to examine all of the located wells to interpret the rock type encountered. It became advantageous to construct working cross sections in different areas to show to scale the various rock types in numerous wells. From these broader patterns, rock types and relationships became apparent.

Cross-sections constructed in this study depict the interpreted subsurface shape and thickness of geologic units and movement of faults based on surface geologic mapping and subsurface lithology from well information. **Figure ES-1** illustrates how geologic interpretations from surface and subsurface geologic information can be visualized to understand the geologic setting and relate subsurface geologic features to surface geology and topography at a cross-section in the vicinity of the City of Napa.

The distribution and quantity of groundwater recharge occurring in Napa County is primarily a function of the geologic units which precipitation encounters, either as rainfall or runoff. Groundwater recharge to the alluvium of the Napa Valley Floor (specifically the Calistoga, St. Helena, Yountville, and Napa Subareas) occurs by infiltration of precipitation, percolation from streams/rivers, and subsurface inflow from the surrounding subareas. The high permeability of the alluvial sediments permits precipitation and surface water to readily infiltrate and recharge groundwater throughout the majority of the Valley. These high permeability soils combined with the large volume of water that flows through the Napa River create the potential for significant recharge to occur.

ES 1.3.2 Groundwater/Surface Water Interaction

The nature of interactions between groundwater and surface water depend largely on the gradient for water flow between groundwater and surface water systems. Water flows from higher elevations to lower elevations. Groundwater elevation contours represent lines of equal groundwater elevation and are independent of ground surface topography. Contours of groundwater elevation provide a snapshot of the direction and relative magnitude of the groundwater flow gradient. Characterizing the relationship between surface water elevations and groundwater elevations is important for understanding the nature of groundwater-surface water communication. In an unconfined groundwater setting, groundwater and surface water will interact and exchange water according to the elevation gradient between these water bodies. The hydrogeologic synthesis and groundwater elevation contours presented in this Report provide the foundation for better understanding this component of the Napa Valley hydrologic system.

The groundwater surface elevation and the estimated stream thalweg elevation data are important components for characterizing the groundwater-surface water relationship in the Napa Valley area. The Spring 2010 contours of equal groundwater elevation are used to provide a snapshot representation of groundwater conditions with which to compare the vertical relationship between the groundwater and surface water (see Section 7). This spatial relationship assists in developing an understanding of the nature of water exchange between the groundwater and surface water systems. This analysis focuses specifically on the degree of connectivity between the Napa River thalweg and the elevation of the regional groundwater surface in the Napa Valley in Spring 2010.

Groundwater/surface water interaction is characterized in this Report by comparing the elevation of surface water to the shallowest adjacent groundwater. Detailed remotely sensed elevation data of the mainstem Napa River and several major tributaries were obtained for this purpose. These LiDAR data provide sub-meter precision elevation data and have been sampled at 3 foot intervals along each watercourse. These data are paired with groundwater level data to evaluate the interconnectedness of groundwater and surface water, particularly in the main Napa Valley Floor.

Calculated depths to groundwater below the estimated thalweg alignment indicate that for Spring 2010 the interpreted groundwater elevation was above the bottom of the Napa River thalweg. The data suggest areas where a direct connection between the water table and the river may have existed in Spring 2010 and where groundwater has the potential to discharge into the stream channel. In other areas, the depth to groundwater is below the bottom of the Napa River thalweg such that surface flows in the river have the potential to percolate and recharge the groundwater system. The results of this study provide an insight into reaches where a direct connection between the Napa River and the alluvial aquifer are not likely under the conditions documented in Spring 2010. These areas include reaches along the northern boundary of the Napa and MST subareas at the Soda Creek Fault, adjacent to a previously documented area of lower groundwater elevations.

Despite the uncertainty in the data in parts of the valley, depths to groundwater (both measured and calculated) show generally shallow groundwater throughout much of the valley, particularly in the northern end of the valley. Areas where calculated depth to water is negative generally coincide with areas of the valley lacking sufficient monitoring site density. The calculated depths to groundwater appear to be reasonably represented in the Napa Subarea because this area has the greatest density of monitored sites, particularly along the lower elevation eastern edge.

Future expansion of the groundwater/surface water evaluation using more refined spatial representations of the groundwater surface and at different time periods will improve the understanding of the dynamics in this relationship. A definitive evaluation of the relationship between the river and groundwater would require accurate data for the river stage (i.e., elevation of water in the river) and more data about depth to groundwater in areas adjacent to the river at the time for which the depth to groundwater is represented. The product of such an evaluation depends greatly on the ability to accurately interpret groundwater levels throughout the valley. This Report recommends an expanded groundwater monitoring network to provide data for a more refined interpretation of the groundwater surface.

ES 1.3.3 Characterization of Groundwater Recharge

Updating the hydrogeologic conceptualization and characterization of conditions in Napa County involves refining understanding of the hydrologic processes for groundwater storage and movement, particularly in the aquifer system underlying the main Napa Valley Floor. These processes involve many complex pathways at many different time scales. A key County General Plan goal (Napa County, 2008) is to “Conserve, enhance and manage water resources on a sustainable basis to attempt to ensure that sufficient amounts of water will be available for the uses allowed by this General Plan, for the natural environment, and for future generations." Construction of a water budget, also known as a water balance, is a tool scientists can employ to assess the quantity of groundwater in storage. A conceptual illustration of the components of a water balance in a watershed is shown in **Figure ES-2** (figure from Healy et al., 2007).

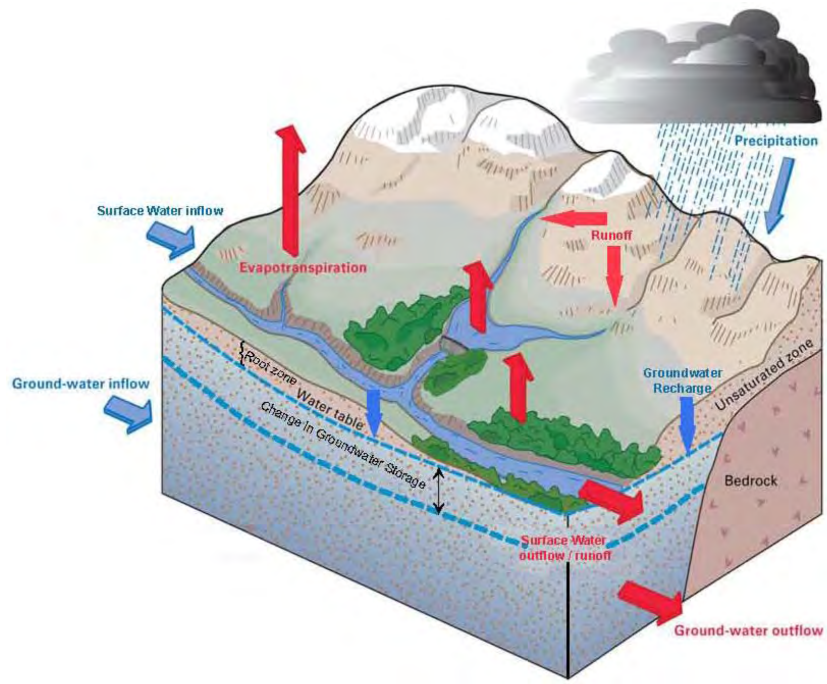


Figure ES-2. Conceptual Diagram of a Watershed Water Balance

A water balance can be used to observe how the quantity of groundwater in storage may vary over time. This tool relies upon a defined accounting unit of volume, for example a groundwater basin or other hydrologic unit of analysis. Measurements of water flowing into and out of the defined unit are used to determine the change in water storage. In the simplest form, the equation for this is:

Inflows – Outflows = Change in Storage

Typical Inflows and Outflows are summarized below (DWR, 2003):

Inflows
- Natural recharge from precipitation;
- Seepage from surface water channels;
- Intentional recharge via ponds, ditches, and injection wells;
- Net recharge of applied water for agricultural and other irrigation uses;
- Unintentional recharge from leaky conveyance pipelines; and
- Subsurface inflows from outside basin boundaries.

Outflows
- Groundwater extraction by wells;
- Groundwater discharge to surface water bodies and springs;
- Evapotranspiration; and
- Subsurface outflow across basin or subbasin boundaries.

Calculating change in storage using data for each inflow and outflow component provides the best approximation of the change in storage. A simple way of estimating the change in storage in a basin is through the determination of the average change in groundwater elevations over the groundwater basin for a period of time. This change in water levels is then multiplied by the area overlying the basin and the average specific yield (in the case of an unconfined aquifer system, or storativity in the case of a confined aquifer system). Change in groundwater levels is best determined over a specific study period that considers different water year types (wet, normal, dry, multiple dry years), but it is common for shorter time periods (e.g., one year's spring to spring groundwater elevations) to be used. This simplistic approach to calculating a change in storage does not provide an indication of the total volume of groundwater storage or the storage available for use. Rather, this computation provides a "snapshot" perspective of short-term trends. The quick calculation should only be considered as an indicator; a more complete groundwater balance evaluation is much preferred (e.g., groundwater flow model). For example, if stresses on the aquifer system induce additional surface water infiltration, the change in groundwater storage may not be apparent (DWR, 2003).

Groundwater recharge is a key component when assessing the water budget of a groundwater basin. Understanding recharge and other fluxes is important in evaluating groundwater conditions and understanding the effects of land development on groundwater resources. This study included characterizing groundwater recharge with an emphasis on the Napa Valley.

The groundwater recharge process begins in the shallow soil column when precipitation or applied water infiltrates below the ground surface. At shallow depths within the plant root-zone water is consumed by plant evapotranspiration and can also be stored as soil moisture. When soil moisture exceeds its holding capacity, water percolates below the root-zone as groundwater recharge. If plant consumptive needs are met and soil moisture storage is below its holding capacity, infiltrated water is stored within the root zone.

Root-Zone Water Balance

In this Report, a mass balance method is used to estimate regional and local recharge. Groundwater recharge can be estimated based on a mass balance analysis of the root zone to estimate the amount of groundwater recharge occurring below the root zone. Flux terms for the “natural” root-zone water balance include precipitation (P), runoff (RO), evapotranspiration (ET), recharge (R), and change in soil moisture storage (ΔS). The natural root-zone water balance expression can be written as:

$$P - RO - ET - R = \Delta S \qquad [1]$$

Figure ES-3 illustrates the components of the root-zone water balance.

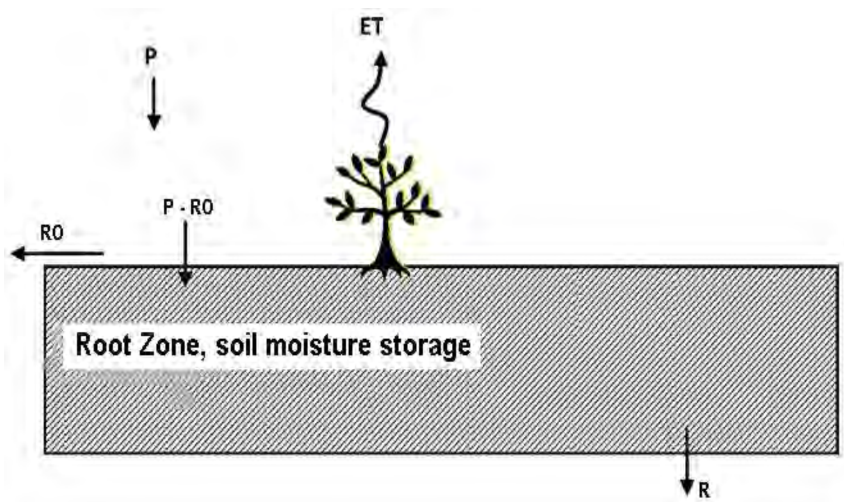


Figure ES-3. Conceptual Diagram of the Water Balance within the Root Zone

Infiltration is defined as precipitation minus runoff and is implicit in the root-zone water balance expression [1]. The natural root-zone water balance can also be expressed to solve for recharge as R = P – RO – ET – ΔS. Although this expression shows a solution for natural groundwater recharge with respect to the root-zone water balance, the estimations of groundwater recharge derived as part of this study are based on methods of calculating recharge from physical processes within the root zone. Instead, this analysis calculates natural groundwater recharge using three physical processes models as a function of ending soil moisture storage and soil texture parameters. Change in soil moisture storage (ΔS) becomes the closing term. A spreadsheet, referred to as the root-zone water balance model, was developed on monthly time-steps to calculate this natural root-zone water balance in the Napa Valley area and is described in this Report.

Mass balance recharge estimates are presented for the Napa River watershed and major tributary watersheds using a range of available data. Available records for streamflow, precipitation, land use, and vegetative cover throughout these watersheds have been used to develop spatially-distributed estimates of annual hydrologic inputs and outputs in order to solve for the volume of groundwater recharge. This Report describes the quantification of: the distribution of precipitation across the land surface, the amount of water returned to the atmosphere by evapotranspiration, and the hydraulic properties of soil and alluvial materials through which water must infiltrate to reach groundwater. Recharge estimates developed through the mass balance approach are evaluated using a sensitivity analysis to determine the degree to which any individual or set of inputs affects the estimate. The results of the mass balance recharge estimates are summarized in **Table ES-1**.

Table ES-1. Summary of Water Balance Model Results

	Average Annual (acre-feet)					Range (acre-feet)	Recharge (% of Precip.)
Watershed	**Precip.**	**Outflow**	**Infilt.**	**ET**	**Recharge**	**Recharge**	**Recharge**
Napa River near Napa	**418,500**	**146,800**	**271,700**	**201,900**	**70,600**	**8,300 - 185,900**	**17%**
- Conn Creek	98,200	24,600	73,600	52,200	21,100	4,300 - 40,700	21%
- Dry Creek	33,000	14,200	18,700	16,400	2,000	500 - 6,300	6%
- Napa River at St. Helena	161,400	67,000	94,400	72,500	22,000	2,500 - 60,900	14%
-- Napa River at Calistoga	54,200	23,600	30,600	19,700	10,500	2,000 - 17,200	19%
Milliken Creek	**33,000**	**16,800**	**16,200**	**13,500**	**2,500**	**100 - 7,100**	**8%**
Tulucay Creek	**19,500**	**9,100**	**10,400**	**9,500**	**1,000**	**100 - 2,300**	**5%**
Redwood Creek	**19,300**	**7,800**	**11,500**	**9,500**	**1,900**	**400 - 5,000**	**10%**
Napa Creek at Napa	**32,100**	**14,800**	**17,300**	**13,700**	**3,600**	**600 - 6,900**	**11%**

Results from the recharge analysis showed that recharge (on a % of precipitation basis) within the Napa River near Napa watershed groundwater recharge is higher in the Conn Creek watershed in the northern portion of the watershed above Calistoga. Precipitation also is higher in these areas, which may contribute to higher groundwater recharge amounts in this area. Estimates from the root-zone water balance model indicate that the Tulucay Creek watershed has the lowest amount of groundwater recharge. This may be because approximately 23 percent of the Tulucay Creek watershed is represented by urban land uses, the highest of all watersheds analyzed.

Potential explanations for the spatial variability of recharge are presented, including differences in watershed soils and geology, slope, and land uses. Previous work by LSCE (2011) analyzed geology and slope in Napa County and developed a map showing areas of highest recharge potential. This map is presented in this Report and illustrates identified geologic units with the greatest recharge potential and areas where ground surface slopes exceed 30 degrees. This Report summarizes the land area for the geologic units of greatest recharge potential by watershed.

ES 1.4 Groundwater Level Monitoring and Recommendations

An important element in Napa County's Comprehensive Groundwater Monitoring Program is an evaluation of the construction information for wells with water level monitoring data. Understanding the exposure of monitored wells to aquifers in their vicinity is critical to analyzing the data collected from those wells. The two most important pieces of construction information for monitored wells, in addition to accurate location information, are information about the geologic material encountered when the well was drilled and a record of the depth of the well screens. These things allow the data collected from a well to be placed in a larger hydrogeologic context, enabling a better understanding of subsurface conditions. This Report presents the results of an inventory of wells in Napa County with any record of water level data. Findings from the inventory are presented in light of results from the updated hydrogeologic characterization and provide information to support the refinement and expansion of on-going monitoring efforts.

Construction records for current and historic groundwater level monitoring wells have been reviewed and compiled. In cases where construction information was incomplete or missing, efforts were made to locate missing information. Construction details were also cross referenced with results from the current hydrogeologic characterization of geologic and aquifer units in order to identify the aquifers in which wells are completed. This Report presents the results of that inventory of water level monitoring wells.

Due to the large proportion of wells lacking complete construction information, efforts to locate construction information for monitored wells focused on the high priority subareas in the Napa

Valley Floor and the Carneros Subarea. Additional efforts were made to identify monitored wells adjacent to the Napa River to evaluate potential groundwater/surface water monitoring sites.

Although this Report focuses on the extent of groundwater level monitoring in Napa County, a summary review of current groundwater quality monitoring sites has been conducted for the Napa County Groundwater Monitoring Plan 2013. That review found 177 sites in Napa County, across all monitoring networks, with groundwater quality data collected since 2008 (LSCE, 2013). The current monitoring networks for groundwater levels and groundwater quality differ according to monitoring entity, data collection frequency, and monitoring goals. Given these differences, a similar inventory of the groundwater quality monitoring networks is advisable in light of the County's intention to increase its capacity to consider groundwater quality in future groundwater resources management decisions.

The proposed inventory should include an effort to locate construction information and identify aquifers encountered by sites monitored for groundwater quality. The updated hydrogeologic conceptualization presented here as well as previously published studies would guide the inventory. Goals of the proposed inventory include an evaluation of the extent and quality of data provided by currently monitored groundwater quality sites and historically monitored sites with the potential for reactivation. The proposed inventory should also consider Napa County's groundwater quality monitoring needs and develop proposals to meet those needs with data from currently monitored wells, where feasible, or wells added to the Napa County monitoring network.

ES 1.4.1 Recommendations to Expand Groundwater Monitoring Well Network

Figure ES-4 illustrates the distribution of current groundwater level monitoring locations, which is primarily located in the Napa Valley Floor-Napa and MST Subareas. Very little groundwater level monitoring is currently conducted elsewhere in Napa County outside these two subareas. A few scattered locations of groundwater level monitoring occur in the Berryessa, Pope Valley, the southern portion of the Central Interior Valleys, Jameson/American Canyon, and in the NVF-Calistoga, NVF-St. Helena, and NVF-Yountville Subareas. Groundwater level monitoring is not currently conducted in the Carneros, Livermore Ranch, Angwin, Southern Interior Valleys, and Western Mountains Subareas. Section 9 of this Report summarizes the number of wells in each subarea that are currently monitored for groundwater levels. Groundwater level measurements have been recorded at a total of 87 sites since 2011. Of these sites where groundwater levels are measured, some type of well construction information (depth and/or perforated interval(s)) is available for 67 sites (41 non-regulated sites and 26 regulated sites). Most current groundwater level monitoring occurs on a semi-annual frequency.

A preliminary ranking and priorities for improving or expanding groundwater level monitoring were prepared for each county subarea. Six subareas are given a relatively higher priority for improving the groundwater level monitoring network based on factors of current population and groundwater utilization relative to other parts of the county, and/or the need to improve understanding of groundwater/surface water interactions. Some factors are given greater consideration in areas that currently use more groundwater than other areas. These areas include:

- NVF-Calistoga,
- NVF-St. Helena,
- NVF-Yountville,
- NVF- MST,
- NVF-Napa, and
- Carneros Subareas

The monitoring network gaps in these six subareas might be addressed by:

1) Investigating the potential to restart monitoring where historical records are available but monitoring was discontinued;
2) Identifying existing wells of suitable construction that might be volunteered for inclusion through County and GRAC education and outreach efforts (this may include wells that are already being monitored for groundwater quality); and
3) Constructing new dedicated monitoring wells if suitable existing wells either do not exist in the area of interest or are otherwise not available.

Monitoring in other subareas with relatively medium to lower priorities is suggested to be addressed with volunteered wells. The Napa County CASGEM Network Plan submitted to DWR in September 2011 (LSCE, 2011b) also describes the County's intent to include at least one additional monitoring well in the Pope Valley and Berryessa Valley Groundwater Basins.

The County will conduct additional public outreach to inform more private well owners of the value of understanding the groundwater resources in the County and to encourage their voluntary participation in the Comprehensive Groundwater Monitoring Program and/or CASGEM program (LSCE, 2013). The County anticipates additional wells to be included in the CASGEM program over the coming years. Wells will be included based upon input from the County's GRAC and in concert with their work to meet the objectives of the County's Comprehensive Groundwater Monitoring Program and the CASGEM program.

For each county subarea, this Report describes the existing groundwater monitoring sites, provides recommendations for the number and location of additional monitoring areas, and describes the key groundwater level monitoring objectives to be addressed. Altogether, it is recommended that approximately six groundwater/surface water monitoring sites for purposes of evaluating groundwater/surface water interactions and about 18 other areas of interest be added to the network (**Figure ES-4**).

The six proposed groundwater monitoring sites are located along the main Napa Valley Floor from the City of Napa north to St. Helena adjacent to the Napa River system (**Figure ES-4**). These facilities are planned to be located near to existing stream gaging stations and/or near areas where stream monitoring can also be conducted. The proposed groundwater monitoring facilities are also being sited, where possible, adjacent to existing groundwater monitoring facilities (i.e., typically water supply wells constructed to greater depths in the aquifer system). The proposed monitoring wells will enable focused data collection regarding groundwater elevations and water quality to identify and characterize interactions with surface water.

ES 1.5 Additional Recommendations

This study led to a broader awareness of the available geologic data, including drillers' reports, that were used to update the hydrogeologic conceptualization of Napa Valley Floor. This work also identified factors related to future assessment of groundwater availability. Spatial data coverage for stream gaging stations and groundwater level monitoring was good for some County subareas; however, for other subareas, additional stream gaging locations and monitoring network enhancements are needed. It was also learned better data are needed to develop aquifer characteristics that more accurately represent aquifers developed for groundwater utilization. Recommendations are presented to enhance and expand countywide monitoring to facilitate understanding of groundwater availability and integrated regional water management and planning efforts. Some of these recommendations, particularly recommendations related to the Carneros, Jameson/American Canyon, and Napa River Marshes Subareas, were previously discussed in reconnaissance work for the County's Comprehensive Groundwater Monitoring Program (LSCE, 2011). The scope of the present study did not include the latter two subareas, so these recommendations still apply. The present study did attempt to develop a geologic cross-section in the Carneros Subarea and found geologic information to be lacking.

ES 1.5.1 Carneros Subarea Hydrogeology

Limited data are available that describe the hydrogeologic setting of the Carneros Subarea. The available data suggest that groundwater resources are limited due to the generally low yielding nature of the formations in this area and poor groundwater quality at some location (LSCE, 2011a). Future planning decisions require knowledge of current groundwater conditions and the possible impacts that may result from additional pumping. A complete analysis of the Carneros Subarea is recommended, including:

- Monitoring groundwater levels[1];
- Monitoring groundwater quality[1];
- Collection and interpretation of geologic data (primarily from well drillers' reports)
- Estimation of groundwater recharge using both mass balance;
- Determination of the extent and properties of aquifer materials; and
- Investigation of the influence of natural and induced hydrologic stresses occurring in neighboring subareas.

Since stream gaging information are lacking in the south part of the county, it is recommended that the focus be on enhancing the groundwater monitoring network (as discussed below) and development of additional geologic data, as feasible.

ES 1.5.2 Hydrogeology and Saltwater Intrusion Potential for the Jameson/American Canyon and Napa River Marshes Subareas

Similar to the Carneros Subarea, limited data are available for the Jameson/American Canyons and Napa River Marshes Subareas which make up the southern County area. The two main issues facing this area are potential saltwater intrusion and the possibility that current water resources will not be sufficient to meet future demand. To establish current conditions and obtain information necessary for future development planning, further analysis is recommended that includes:

- Monitoring groundwater levels;
- Monitoring groundwater quality;
- Collection and interpretation of geologic data (primarily from well drillers' reports);
- Analysis of streamflow and precipitation;
- Estimation of recharge and discharge using both mass balance and streamflow infiltration methods; and
- Determination of the extent and properties of aquifer materials.

The current lack of groundwater data makes it difficult to determine the source and distribution of salinity in the southern County area with any certainty. A series of multi-level monitoring well clusters installed stepping south from the City of Napa toward San Pablo Bay would help in determining the geology of the Napa River Marsh Subarea and distribution of high salinity groundwater. This further subsurface exploration and characterization of the aquifer system, in conjunction with efforts to estimate subsurface outflow from the Napa Valley, would also help determine if freshwater within the Napa River Marshes Subarea could possibly be used to sustain increasing demand in the Jameson/American Canyon Subarea.

[1] Actions to implement additional groundwater level and quality monitoring are underway (LSCE, 2013).

Aquifer Testing

As explained in this Report, the distribution of the hydraulic conductivities in the Napa Valley as presented by Faye (1973) was based on data recorded on historical drillers' reports. During the current study, it became evident, based on the approximately 1,300 reports reviewed, that most of the "test" data are insufficient to adequately determine or estimate aquifer characteristics, since most of these data were recorded during airlift operations rather than a pumping test. Currently, test methods accepted in the County's Well and Groundwater Ordinance allow bailing, airlifting, pumping, or any manner of testing generally acceptable within the well drilling industry to determine well yield. Recommendations for modifying the Napa County's Well and Groundwater Ordinance (Title 13, Chapter 13.04) have been proposed to improve the quality of data received by Environmental Management concerning reporting of well yield (LSCE, 2011). These recommendations included removal of bailing and airlifting as acceptable methods; pumping is recommended to gather the appropriate data to reliably determine well yield, particularly in areas where such information along with aquifer characteristics is determined to be important to accomplish other County groundwater objectives.

Stream Gaging Stations

One of the major limitations in this study is the spatial and temporal availability of streamflow gage data. The limited availability of data from gaged streamflow locations precludes developing a more spatially distributed estimate of recharge using this method. Because streamflow as measured at a gage is an aggregate for the upstream drainage area, infiltration is assumed to be uniform throughout each gaged watershed and across all land use categories.

In order to estimate streamflow from ungaged watersheds, a rainfall-runoff model could be developed and calibrated with records from gaged watersheds. A rainfall-runoff model may also help improve the spatial resolution of infiltration within gaged watersheds. Several different platforms are available for these types of models.

The Putah Creek watershed represents approximately 46 percent of Napa County and is an ungaged watershed; however, it may be possible to estimate runoff from this watershed by calculating inflow to Lake Berryessa. Reservoir inflow calculations require close quality control of inputs and may not be possible if flood control releases from Monticello Dam are not accurate. If it is possible to calculate inflow to Lake Berryessa, this time-series could be used as the outflow component in the water balance model to estimate groundwater recharge for this area of the county.

ES 1.5.3 Future Groundwater Modeling Efforts

As described earlier in this Report, a groundwater flow model was developed for the Napa River watershed which was generally conceptualized as a large basin of impermeable rock overlain in three distinct areas by more permeable units (DHI, 2006a). The three areas that were the focus of the groundwater model were the north Napa Valley area and the MST and Carneros Subareas. The groundwater model encompasses the Napa River watershed and consists of two layers. The upper layer was designated as being unconfined and the lower layer was designated as confined. Each of the three modeled areas was represented as a separate water-producing geologic unit. The geologic unit that was conceptualized as the primary source for groundwater in the north Napa Valley area was the alluvium. Aquifer parameters and their distribution were based on previous work presented in Faye (1973), and extrapolated to the rest of the Napa Valley Floor to the south.

A model is a tool that can help facilitate the examination of water resources management scenarios, including the effects of climate change and other stresses on surface and groundwater resources. Large regional models can be especially useful tools to examine complicated scenarios. As described in this Report, the geologic and hydrogeologic setting in Napa County and specifically the Napa Valley Floor is extremely complex. The updated hydrogeologic conceptualization presented herein shows that the subsurface is so complex that the current two-layer model for the north Napa Valley area, which focuses on the alluvium with unconfined and semi-confined aquifer characteristics, needs significant refinement for future use and to improve the models' predicative utility. Such refinement includes, but is not limited to, incorporation of the updated physical hydrogeologic conceptualization in the model structure and consideration of revised aquifer parameters and/or sensitivity analyses of parameters until such parameters can be refined through proper testing.

1 INTRODUCTION

Groundwater and surface water are highly important natural resources in Napa County. Currently, municipal and private stakeholders are actively engaged in assessing the reliability of current and future demands and supplies. Important sources of water include both groundwater and surface water of good quality and quantity, to meet future urban, rural, and agricultural water demands. Similar to other areas in California, businesses and residents of Napa County face many water-related challenges. To address these challenges, long-term, systematic monitoring programs are essential to provide data that allow for improved evaluation of water resources conditions and to facilitate effective water resources planning. Establishment of a groundwater and surface water monitoring network results in the collection of data necessary to distinguish long-term trends from short-term fluctuations, anticipate unintended consequences due to current and historical land uses, identify emerging issues, and design appropriate water resources planning and management strategies.

1.1 Background

In 2009, Napa County embarked on a countywide project referred to as the “Comprehensive Groundwater Monitoring Program, Data Review, and Policy Recommendations for Napa County’s Groundwater Resources” (Comprehensive Groundwater Monitoring Program), to meet identified action items in the 2008 General Plan update (Napa County, 2008). The program emphasizes developing a sound understanding of groundwater conditions and implementing an expanded groundwater monitoring and data management program as a foundation for future coordinated, integrated water resources planning and dissemination of water resources information. The program covers the continuation and refinement of countywide groundwater level and quality monitoring efforts (including many basins, subbasins and/or subareas throughout the county) for the purpose of understanding groundwater conditions (i.e., seasonal and long-term groundwater level trends and also quality trends) and availability. This information is critical to enable integrated water resources planning and the dissemination of water resources information to the public and state and local decision-makers. Napa County’s combined efforts through the Comprehensive Groundwater Monitoring Program along with the related AB 303 Public Outreach Project on groundwater (CCP, 2010) and the efforts of the Watershed Information Center and Conservancy (WICC) of Napa County create a foundation for the County’s continued efforts to increase public outreach and participation in water resources understanding, planning, and management. Napa County’s Comprehensive Groundwater Monitoring Program involved many tasks that led to the preparation of five technical memorandums and a report on Napa County Groundwater Conditions and Groundwater Monitoring Recommendations (LSCE, 2011a). This report and the other related documents can be found at: http://www.countyofnapa.org/bos/grac/.

1.2 Groundwater Resources Advisory Committee

On June 28, 2011, the County Board of Supervisors adopted a resolution establishing a Groundwater Resources Advisory Committee (GRAC). Two of the tasks assigned to the GRAC include: 1) assisting with the synthesis of the existing groundwater information and identifying critical data needs; and 2) providing input on the furtherance of the ongoing countywide groundwater monitoring program. During the implementation of the study discussed herein, input from this committee was coordinated to optimize additional groundwater monitoring locations that serve to meet the objectives of the County's Comprehensive Groundwater Monitoring Program and also the California Statewide Groundwater Elevation Monitoring (CASGEM) program, which is a subset of the countywide groundwater monitoring program.

1.3 Purpose

The purpose of this Napa County Updated Hydrogeologic Conceptualization and Characterization of Conditions Report (Report) is to describe the work conducted by Luhdorff and Scalmanini, Consulting Engineers (LSCE) together with MBK Engineers (MBK) on behalf of the County to implement a number of the recommendations pertaining to the County's Comprehensive Groundwater Monitoring Program, including:

1. Prepare an updated hydrogeologic conceptualization and characterization of conditions in various areas of Napa County;
2. Analyze the potential for surface water/groundwater interactions;
3. Refine and further characterize areas of the greatest recharge potential; and
4. Link well construction information to groundwater level monitoring data, and provide groundwater monitoring recommendations.

Forthcoming in a separate document, the County is also developing an approach to determine whether there are locations where groundwater pumping near a surface water course (such as might occur for a proposed project) would be anticipated to effect groundwater discharge to the surface water available for endangered species. And, conversely, whether there are locations where groundwater pumping would not have such an effect. The approach being developed is being informed by the updated hydrogeologic conceptualization of conditions (as can be identified with existing data), including the accompanying groundwater monitoring recommendations, summarized in this Report.

1.3.1 Updated Hydrogeologic Conceptualization

Understanding the hydrogeology of Napa County is essential to determine how much water is available and to what extent it can be sustainably produced. Previous hydrogeologic studies have focused on the Milliken-Sarco-Tulucay (MST) Subarea and northern portion of the Napa Valley without much attention to the other areas within the county. With the exception of the Farrar and Metzger (2003) study, which looked at the MST, all of these studies are more than 30 years old. Since these studies, hundreds of new wells have been drilled to greater depths than previously reached, supplying a potential abundance of new data. Due in part to the scarcity of hydrogeologic data available for the majority of Napa County, data collection and analysis need to be prioritized; the highest priority needs are presented below.

Published hydrogeologic studies of the Napa County have been largely based on pre-1970 water well drillers' reports and focused on the higher yielding Quaternary alluvium deposits of Napa Valley (Kunkel and Upson, 1960; Faye, 1973). Most previous hydrogeologic cross sections have been constructed in the southern portion of the valley near and to the east of the City of Napa (Kunkel and Upson, 1960; Sweetkind and Taylor, 2010; Farrar and Metzger 2003). The northern valley has been characterized by alluvium thickness maps (Faye, 1973) with little attention paid to the older deposits and Sonoma Volcanics.

Since the Kunkel and Upson study, plate tectonics theory has been introduced, which significantly expanded the understanding of the relationship between individual geologic units within the County and the structures (faults, folds, and fractures) that accompany these relationships. Also, a large number of new wells (and therefore new well logs) have been added to the Valley, which expanded the breadth and depth of the aquifer materials explored and developed for groundwater production.

Groundwater/surface water interaction is characterized in this Report by comparing the elevation of surface water to the shallowest adjacent groundwater. Detailed remotely sensed elevation data of the mainstem Napa River and several major tributaries have been obtained for this purpose. These LiDAR data provide sub-meter precision elevation data and have been sampled at 3 foot intervals along each watercourse. These data are paired with groundwater level data to evaluate the interconnectedness of groundwater and surface water, particularly in the main Napa Valley Floor.

1.3.2 Characterization of Groundwater Recharge

Another important feature of the updated hydrogeologic conceptualization presented in this Report is the development of improved characterization of groundwater recharge in the areas of greatest groundwater development, with an emphasis on Napa Valley. Understanding the volume of and mechanisms driving groundwater recharge in the county is essential in determining where and how much groundwater can be produced without incurring negative impacts (LSCE, 2011a). Currently, evaluation of recharge mechanisms and volumes within Napa County has been limited to the Napa Valley (Faye, 1973) and the MST Subarea (Johnson, 1977; Farrar and Metzger, 2003).

The high permeability of the alluvial sediments in the Napa Valley permits precipitation and surface water to readily infiltrate and recharge groundwater throughout the majority of the valley. These high permeability soils combined with the large volume of water that flows through the Napa River create the potential for significant recharge to occur under the hydrologic circumstances and hydraulic gradient that allow for recharge from the river to groundwater to occur.

In this Report, mass balance and streamflow infiltration methods are used to estimate regional and local recharge. Mass balance recharge estimates are presented for the Napa River watershed and major tributary watersheds using a range of available data. Available records for streamflow, precipitation, land use, and vegetative cover throughout these watersheds have been used to develop spatially-distributed estimates of annual hydrologic inputs and outputs in order to solve for the volume of groundwater recharge. This Report describes the quantification of: the distribution of precipitation across the land surface, the amount of water returned to the atmosphere by evapotranspiration, and the hydraulic properties of soil and alluvial materials through which water must infiltrate to reach groundwater. Recharge estimates developed through the mass balance approach are evaluated using a sensitivity analysis to determine the degree to which any individual or set of inputs affects the estimate.

1.3.3 Groundwater Level Monitoring and Recommendations

As part of the updated hydrogeologic characterization, existing monitoring well construction data from all available public sources were reviewed to determine the distribution of aquifer-specific monitoring data in Napa Valley. This effort addresses recommendations of the Comprehensive Groundwater Management Program to identify and fill data gaps that will allow for analysis of groundwater occurrence and flow as a more robust understanding of the extent of groundwater resources in the county is developed. A major component of this work has been to identify construction information for previously monitored wells in Napa Valley.

Groundwater level monitoring needs identified through the Comprehensive Groundwater Management Program include improved spatial distribution of groundwater level monitoring, additional characterization of subsurface geologic conditions in each subarea to identify aquifer characteristics, further examination of well construction information to define which portion of the aquifer system is represented by water levels measured in the currently monitored wells (and in many cases to link construction information to the monitored wells), and improve the understanding of surface water/groundwater interactions and relationships.

1.4 Report Organization

The results of this work provide the updated physical hydrogeologic conceptualization and characterization necessary to ensure that future groundwater evaluations consider the structure and hydrologic mechanisms, including recharge to and discharge from groundwater basins and mountain recharge areas that govern groundwater conditions. This Report addresses the following key components:

1. Updated hydrogeologic conceptualization and characterization of conditions in various areas of Napa County;
2. Potential for surface water/groundwater interactions;
3. Characterization of areas of the greatest recharge potential; and
4. Description of the current groundwater monitoring level monitoring network and groundwater monitoring recommendations.

This Report includes the following sections:

<u>Section 2: Regional Geology and Previous Studies</u>

- DWR Basins/Subbasins and County Subareas
- Regional Geologic Setting
- Significant Previous Studies

<u>Section 3: Surficial Geology</u>

- Mesozoic Rocks
- Late Tertiary Volcanic and Sedimentary Rocks

<u>Section 4: Structural Geology</u>

- Late Tertiary Deformation
- Quaternary Faulting

<u>Section 5: Subsurface Geology</u>

- Subsurface Information
- Methodology

<u>Section 6: Hydrogeology</u>

- Alluvium
- Sonoma Volcanics and Tertiary Sediments

<u>Section 7. Surface Water/Groundwater Interactions</u>

- Napa Valley Groundwater Levels
- Stream Thalweg Mapping

- Surface Water/Groundwater Interactions in Napa Valley

Section 8. Groundwater Recharge

- Estimating Recharge
- Physical Processes
- Data Development
- Results and Summary
- Sensitivity Analysis
- Extrapolation to Remaining Areas
- Future Considerations
- Considerations Related to Overall Water Balance

Section 9. Supplemental Groundwater Monitoring in High Priority Subareas

- Available Location and Construction Information for Groundwater Level Monitoring Sites
- Completion of Groundwater Level Monitoring Sites Relative to Aquifer System and Geologic Units
- Recommendations for Napa County Groundwater Level Monitoring Network Expansion

Section 10. Recommendations

- Carneros Subarea Hydrogeology
- Hydrogeology and Saltwater Intrusion Potential for Jameson/American Canyon and Napa River Marshes Subareas
- Aquifer Testing
- Stream Gaging
- Groundwater Monitoring Network
- Future Groundwater Modeling Efforts

2 REGIONAL GEOLOGY AND PREVIOUS STUDIES

2.1 DWR Basins/Subbasins and County Subareas

DWR has identified the major groundwater basins and subbasins in and around Napa County; these include the Napa-Sonoma Valley (which in Napa County includes the Napa Valley and Napa-Sonoma Lowlands Subbasins), Berryessa Valley, Pope Valley, and a very small part of the Suisun-Fairfield Valley Groundwater Basins (**Figure 2-1**). These basins and subbasins are generally defined based on boundaries to groundwater flow and the presence of water-bearing geologic units. These groundwater basins defined by DWR are not confined within county boundaries, and DWR-designated “basin” or “subbasin” designations do not cover all of Napa County.

Groundwater conditions outside of the DWR-designated areas are also very important in Napa County. An example of such an area is the MST area, a locally identified groundwater deficient area. For purposes of local planning, understanding, and studies, the County has been subdivided into a series of groundwater subareas (**Figure 2-2**). These subareas were delineated based on the main watersheds, groundwater basins, and the County’s environmental resource planning areas. These subareas include the Knoxville, Livermore Ranch, Pope Valley, Berryessa, Angwin, Central Interior Valleys, Eastern Mountains, Southern Interior Valleys, Jameson/American Canyon, Napa River Marshes, Carneros, Western Mountains Subareas and five Napa Valley Floor Subareas (Calistoga, St. Helena, Yountville, Napa, and MST). The County subarea nomenclature is sometimes referred to in this study.

2.2 Regional Setting

The Napa Valley study area is located in the southern-central Coast Range Province north of the San Francisco Bay region. This region of the Coast Range is characterized by northwest trending low mountainous ridges separated by intervening stream valleys. The Napa Valley is a relatively narrow, flat-floored stream valley drained by the Napa River. The valley floor descends from elevations of about 420 feet at the northwest end to about sea level at the southern end.

The Napa Valley is bound by the north, east, and west by mountainous areas. The mountains to the north are dominated by Mount St. Helena at a height of 4,343 feet. The lower mountainous area to the east of the Valley is the Howell Mountains declining from 2,889 feet southward through lower elevations at 2,037 feet above Stag’s Leap, 1,877 feet at Mount George, and 1,630 feet at Sugarloaf south of the MST area. To the west of Napa Valley, the Mayacamas Mountains decline from peaks to 2,200 feet in the north, to about 1,500 feet northwest of Napa. Farther south, the mountainous area declines to elevations of 200 to 100 feet, then disappears beneath the plains of the Carneros area that borders the San Pablo Bay.

2.3 Napa Valley Floor Geologic Subareas

The Napa Valley Floor is informally divided into four areas for this Report. The upper valley extends from the northern end of the valley just north of the town of St. Helena. This area is about nine miles long and about one mile or less in width. Except for near St. Helena, the upper valley was not examined for this study.

Calistoga to St. Helena – Upper Valley

The upper valley area encompasses the County's Calistoga subarea and the northern mile of the County's St. Helena subarea. The upper valley area was defined by the width of the valley floor and the nature of the geologic units found beneath the valley floor during the course of this study.

St. Helena to Oakville – Middle Valley

The middle valley extends from St. Helena to the town of Oakville. This area is about seven miles long, and the Valley Floor widens to about two miles at the north to about 3 ½ miles at the south. The middle valley area corresponds roughly to the County's St. Helena Subarea, except as noted above.

Yountville Narrows

The next area is termed the Yountville Narrows, which extends about five miles to Ragatz Lane, about half-way between Yountville and Oak Knoll. This area is characterized by numerous low knobs and hills of older geologic units that rise like islands above the stream valley. The central valley floor narrows to less than a mile. The entire valley encompasses the County's Napa Subarea. From the main mountainous side slopes, the total valley width ranges up to about three miles.

Napa to Suscol – Lower Valley

The lower valley extends about ten miles to the south beyond the City of Napa and trends more southerly to Suscol. The valley floor widens to about three miles north of Napa and then narrows to about 2 miles. At the southern end at Suscol, the valley floor narrows to about 2,000 feet constricted by older geologic units.

Lower Valley

To the east of the City of Napa, there is a unique feature of a low elevation nearly circular ring around a central low highland. The area is drained by the tributary Milliken, Sarco, and Tulucay Creeks headed on the higher mountainous area to the north, east, and south. This area is termed the MST area from the contraction of the tributary creeks. The MST area has been extensively studied previously by others and was not examined further for this study.

South of Suscol the Napa Valley merges with the marshland and tidal flats of the County's Napa River Marshes Subarea. To the north of the marshlands occurs the County's Carneros Subarea, a low southward sloping plain. Both of these areas (Carneros and Napa River Marshes) were not extensively examined for this study. The County's Jameson/American Canyon Subarea lies to the east of the Napa River marshes and was not examined for this study.

2.3.1 Major Geologic Units

In the Napa Valley area, the geologic units are divisible into two broad categories based on geologic age, degree of lithification (i.e., the hardness or rock-like nature), and the amount of deformation (i.e., deformed by folding and faulting). These two categories are Mesozoic (older than 63 million years (m.y.)) rocks and Cenozoic (younger than 63 m.y.) rocks and unconsolidated deposits.

The Mesozoic rocks are considered the bedrock in the area as they are very old, well lithified, and highly deformed resulting in limited groundwater in fractures (crack-like openings in the rocks). The Mesozoic rocks are divisible into two main groups: the Franciscan Complex and the Great Valley Complex. The Mesozoic rocks occur beneath all of the Napa Valley, but these rocks are most widely exposed at the surface in the adjacent mountain areas. Beneath the Napa Valley and the San Pablo Bay to the south, the Mesozoic rocks are covered by great thicknesses (possibly several thousands of feet) of younger rocks and deposits. The sole exception to this is a small area in the eastern Yountville Narrows where the Mesozoic rocks are exposed by deformation uplift. The Mesozoic rocks will be described further in a later section.

The Cenozoic geologic units are divisible into two main groups: 1) the older Tertiary (post 63 m.y. – 2.5 m.y.) volcanic and sedimentary rocks, 2) and the Quaternary (2.5 m.y. – present) sedimentary deposits. The Tertiary rocks include a group of the oldest Tertiary sedimentary rocks which occur south of the Napa Valley below the San Pablo Bay, some small exposures near the south end of the Mayacamas Mountains, and south of the Howell Mountains. These rocks are largely low-groundwater yielding, of limited extent, and outside the Napa Valley study area.

The main Tertiary rocks in the Napa Valley area are of the youngest age, largely Pliocene (5 m.y to 2.5 m.y). These consist of volcanic rocks and sedimentary rocks which are interfingered and interbedded. The volcanic rocks are composed of a complex sequence, including lava flows and fine-grained volcanic ejecta composed of ash and flow tuffs. Variations in mineral composition, types of volcanic processes, and the location of eruption sites lead to complex relationships in the volcanic deposits which make surface mapping difficult.

The Tertiary volcanic rocks have been termed the Sonoma Volcanics; these rocks extend across much of the Napa Valley area and across much of Sonoma County to the west. In the Napa Valley area, the Sonoma Volcanics are exposed at the surface over large areas around the upper valley, across large areas in the Howell Mountains to the east, and at more limited areas along the west margin of the Napa Valley. Beneath the Napa Valley Floor, the Sonoma Volcanics occur largely buried beneath younger geologic units. In the Yountville Narrows, there are many small knobs of Sonoma Volcanics. In the MST area, the Sonoma Volcanics occur in the surrounding mountains, the central upland, and beneath the entire area.

The Tertiary sedimentary rocks are more limited in surface exposures and commonly referred to as the Huichica Formation. North of Conn Creek, these rocks occur in a small area on the Napa Valley Floor margin and a larger area occurs in the adjacent mountainous area. In the MST area, Tertiary sedimentary rocks occur on the north margin and lap into the Napa Valley Floor margin. A large area of Tertiary sedimentary rocks is exposed across most of the Carneros area to the southwest of the Napa Valley. The relationship between these three areas and to the Sonoma Volcanics is not entirely clear. The possible presence and extent of the Tertiary sedimentary rocks below the Napa Valley Floor were examined in this study.

The Sonoma Volcanics units which were formed at high temperatures as (e.g., lava flows and flow tuffs) appear to be well lithified, Sonoma Volcanics units formed at lower temperatures, such as landslide tuffs, ash falls, and volcanic-sedimentary interbeds appear to be weakly to moderately lithified. The thicker Tertiary sedimentary rocks also appear to be moderately to well lithified. Both the Sonoma Volcanics and the Tertiary sedimentary rocks are strongly deformed as evidenced by the commonality of steeply dipping beds, folding, and faulting.

The Quaternary (post 2.5 m.y) sedimentary deposits collectively termed alluvium cover the Napa Valley Floor. The youngest deposits of the current streams and alluvial fans are of Holocene age (100,000 years to present). Older deposits exposed as terraces, alluvial fans, and beneath the Holocene deposits are of Pleistocene age (2.5 m.y. to 100,000 years). At the south end of the Napa Valley marshland, tidal flat and estuary deposits occur. The Quaternary deposits appear to be only slightly deformed and weakly consolidated to unconsolidated.

2.4 Significant Previous Studies

Previous hydrogeologic studies of Napa County and also mapping efforts are divisible into geologic studies and groundwater studies. The more significant studies and mapping efforts are mentioned in this section. **Table 2-1** shows the chronological sequence of these efforts that span more than six decades.

Charles E. Weaver (1949) compiled geologic maps covering much of the Napa Valley and the Coast Range from the Sacramento Valley to the ocean. His geologic mapping was conducted between 1903 and 1933. Detailed additional work and manuscript preparation continued for 15 years until final publications. Weaver's geologic observations, mapping and interpretations have remained the foundation for the study area.

Kunkel and Upson's study (1960) is the hydrogeologic equivalent to Weaver's work and covers the groundwater in Napa and Sonoma Valleys. Field work, geologic mapping, and well locating were conducted between 1949 and 1952. Notably, most well information predates 1952. Geologic cross sections presented in Napa Valley are all in the lower valley area near the City of Napa.

The next significant reports are a pair of more detailed geologic maps of the Napa Valley area (Fox and others, 1973, and Sims and others, 1973). Besides the more detailed mapping, especially of the Sonoma Volcanics, these maps have more modern, detailed topographic base maps than Weaver's or Kunkel and Upson's maps. These maps have remained the main source for recent digital map compilations, with some additional new mapping, by the U.S. Geological Survey (USGS), including Graymer and others (2002) and Graymer and others (2007).

The California Geological Survey (CGS) has been releasing a series of even more detailed geologic maps of the Napa Valley area, which are based on 7 ½ minute topographic quadrangles (scale: 1 inch = 24,000 inches, or 2,000 feet). These quadrangles include the Cuttings Wharf (Bezore and others, 2002), Napa (Clahan and others, 2004), Mount George (Bezore and others, 2004), and Yountville Rutherford (Clahan and others 2005). (Bezore and others, 2005). The advantages of these maps are their uniform size, and the maps subdivide the Sonoma Volcanics into named members based on rock type, age, and stratigraphic position.

A series of reports and geologic maps have focused on the Quaternary deposits of Napa Valley. The U.S. Soil Conservation Service published the soil survey of Napa County (Lambert and Kashimagi, 1978). A study of the Quaternary flatland deposits of the entire San Francisco Bay region, including Napa Valley, is contained in Helley and others (1979). A more recent publication on the Quaternary geologic deposits is in Sowers and others (1998).

Following Kunkel and Upson (1960), the USGS continued hydrogeologic studies in the Napa Valley. A series of publications collected additional information on wells by 7 ½ minute quadrangle: Napa 1973, Rutherford 1973, Yountville 1973, and Calistoga 1973. Faye (1973) examined the groundwater of the northern Napa Valley from Oak Knoll Avenue north, an area largely unexamined in detail by Kunkel and Upson. Faye's report was largely concerned with groundwater contained in the Quaternary alluvium beneath the Napa Valley and included an isopach (equal-thickness) map of the alluvium and other derivative maps of hydraulic conductivity and groundwater levels. Similar to Kunkel and Upson, Faye did not present geologic cross-sections for the northern valley; he also did not present subdivisions of the Sonoma Volcanics, probably due to the lack of deep well control, the complexity of the units, and the low water yielding nature of the Sonoma Volcanics.

Michael Johnson (1977) studied the MST area east of Napa. Groundwater extraction in this area is mostly from the Sonoma Volcanics, and declining groundwater levels have been observed. The MST area is somewhat unique in that it is considered a collapsed volcanic structure (caldera) and contains a sequence of Sonoma Volcanics which may be unique to the MST area. Johnson presented a series of geologic cross-sections across the MST area.

Farrar and Metzgar (2003) reviewed conditions in the MST area since Johnson and re-presented Johnson's geologic cross-sections. Because these two reports are detailed studies of the MST area, this study did limited evaluation of the area (see Section 5 of this Report). Sweetkind and Taylor (2010) presented digital information of water well information extracted from selected previous USGS studies. In Napa Valley, the data appear to be drawn from Kunkel and Upson (1960). As such, the data represent wells drilled before 1952 and located largely in the southern portion of the valley. As a result, there are sixty years of additional water well construction information which encompasses over 5,600 new wells, not considered in Sweetkind and Taylor's more recent reports.

The following reports are about regional geologic relationships or the plate tectonic setting. Mankinen (1972) reported radiometric age dating results for the Sonoma Volcanics. Wagner and Bortugno (1982) present a regional scale geologic map that covers much of the southern portion of the Coast Range and summarizes the stratigraphic and age relationships. Fox (1983) summarizes the tectonic setting of the Tertiary and Quaternary rocks in the area. Fox and others (1985a) relate the implications of a series of volcanic rocks along coastal California, including the Sonoma Volcanics, in relationship to the evolution of the San Andreas Fault zone.

Langenheim and others (2006) present an isostatic gravity map of the Sonoma Volcanics field in the Napa and Sonoma County area. The principle behind that study is that the bedrock Mesozoic rocks are of higher density than the overlying Tertiary volcanic and sedimentary rocks. In the Napa Valley area, the gravity map shows two gravity low basins where thick Tertiary rocks occur over the Mesozoic bedrock. The north gravity basin extends north westward from the middle valley to the end of the upper valley. The second smaller gravity basin extends from south of the Yountville Narrows to below Napa at the Suscol Narrows. To the east of Napa, a complex semi-circular gravity pattern appears to reflect the MST area caldera feature. South of Suscol, the gravity map shows a deep, large gravity low beneath the San Pablo Bay.

In 2005 to 2007, DHI Water & Environment (DHI) contributed to the 2005 Napa County Baseline Data Report (DHI, 2006b and Jones & Stokes et al., 2005) which was part of the County's General Plan update (Napa County, 2008). A groundwater model was developed by DHI in conjunction with the Napa Valley and Lake Berryessa Surface Water models to simulate existing groundwater and surface water conditions on a regional basis primarily in the North Napa Valley and the MST and Carneros Subareas (DHI, 2006a). In the Napa River watershed, the model was generally conceptualized as a large basin of impermeable rock overlain in three distinct areas by more permeable units. The three areas that were the focus of the groundwater model were the north Napa Valley area and the MST and Carneros Subareas. The groundwater model encompasses the Napa River watershed and consists of two layers. The upper layer was designated as being unconfined and the lower layer was designated as confined. Each of the three modeled areas was represented as a separate water-producing geologic unit. The geologic unit that was conceptualized as the primary source for groundwater in the north Napa Valley area was the alluvium. Values and distribution of hydraulic conductivity for the north Napa Valley area reflected a similar distribution as was presented in Faye (1973), and extrapolated to the rest of the Napa Valley Floor to the south. A 2007 technical memorandum, Modeling Analysis in Support of Vineyard Development Scenarios Evaluation (DHI, 2007), was prepared to document the groundwater model update which was used to evaluate various vineyard development scenarios.

Additional geologic maps, groundwater studies, and reports are listed in the references of the Groundwater Report (LSCE, 2011a). As recommended in the Groundwater Report and described in this Report, LSCE and MBK have conducted additional work to update the hydrogeologic conceptualization and characterization of conditions, particularly for the Napa Valley Floor. As elaborated later in this Report, this updated hydrogeologic characterization and conceptualization of the hydrostratigraphy is key to the County's successful, future use of modeling tools and for improvement of the models' predicative utility.

Table 2-1. Summary and Chronology of Hydrogeologic and Geologic Studies and mapping Efforts in Napa

Hydrogeologic and/or Geologic Studies and Mapping Efforts	Year of Report or Map Publication							
	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010-2019
Weaver, 1949	◆ (red)							
Kunkel and Upson,1960			◆ (red)					
DWR 1962			◆ (blue)					
Koenig, 1963			◆ (orange)					
Fox et al., 1973				◆ (blue)				
Sims et al., 1973				◆ (orange)				
Faye, 1973				◆ (red)				
Johnson, 1977				◆ (blue)				
Helley et al., 1979				◆ (red)				
Wagner and Bortugno, 1982					◆ (orange)			
Fox, 1983					◆ (red)			
Graymer et al., 2002							◆ (orange)	
Farrar and Metzger, 2003							◆ (red)	
Graymer et al., 2007							◆ (orange)	
DHI, 2006 and 2007							◆ (blue)	
LSCE, 2011								◆ (blue)
LSCE and MBK, 2013 (this Report)								◆ (red)

◆ (red) = Report and Map produced

◆ (blue) = Report only

◆ (orange) = Map only

3 SURFICIAL GEOLOGY

The surficial geology of the Napa Valley area has been mapped by various authors for over a hundred years. The reports and geologic maps differ through time in the detail of mapping, characterization of rock types, and nomenclature of various units. In the last forty years, the development of radiometric-age dating techniques and the evolution of plate tectonic theory have led to a better understanding of the geologic history of the region.

However, even the most recent geologic reports and maps exhibit conflicting map units, lithology, and nomenclature. Since the earliest geologic maps, three major geologic units in the Napa Valley area have been recognized and remain largely unchanged, except in details, names, and interpretation of how they were formed. These three units are Mesozoic rocks, Tertiary volcanic and sedimentary rocks, and Quaternary sedimentary deposits. This report presents a review of previous surficial geology mapping efforts, developed to inform the interpretations of subsurface geology and hydrogeology presented in Sections 5 and 6. **Figure 3-1a** highlights the major rock types and deposits in the Napa Valley study area, presenting them according to relative time of formation. **Figure 3-1a** also serves as a legend for surficial geologic units presented throughout the report. Minor rock types and deposits are not described in this report; however, they are available from the original sources published by Bezore and others (2002, 2004 and 2005) and Clahan and others (2004 and 2005) by the California Geological Survey and Graymer and others (2002, 2006 and 2007) by the United States Geological Survey. **Figure 3-1b** depicts the study area surficial geology.

3.1 Mesozoic Rocks

The oldest geologic unit in the Napa Valley area is the Mesozoic (pre-63 m.y.) rocks which are largely exposed in the surrounding mountains. The Mesozoic rocks are highly deformed and well lithified. The two main divisions are the Great Valley Complex and the Franciscan Complex.

3.1.1 Great Valley Complex

The Great Valley Complex is composed of the Coast Range ophiolite and the Great Valley Sequence. The ophiolite consists largely of fault-bound masses of serpentinite (rock type based on the mineralogy) in the Napa Valley area and igneous rocks elsewhere in the region; Coast Range ophiolite represents former oceanic crust tectonically accreted to the North American Plate.

The Great Valley Sequence consists of deep-water marine deposited sedimentary rocks of sandstone, shale, and conglomerate. The sequence is divided into an older lower member and a younger upper member that contains conglomerate beds. The Great Valley Sequence was originally deposited on the Coast Range ophiolite, but this relationship has largely been destroyed by tectonic deformation.

The Great Valley Sequence is largely exposed in the Macaymas Mountain west of Napa Valley. Smaller areas occur east of the valley and in the Yountville Narrows area. The Coast Range ophiolite occurs as smaller fault-band areas in the mountainous areas.

The Great Valley Complex is considered low-groundwater yielding; at best, it produces a few gallons per minute to water wells, which is sufficient for domestic supply. The low yield results from the highly deformed and well-lithified nature of the rocks, where groundwater is mostly contained in fractures and cracks within the rocks.

3.1.2 Franciscan Complex

The second main Mesozoic rock group is the Franciscan Complex, which is composed of weakly to strongly metamorphosed, deep-marine deposited sedimentary rocks, (sandstone with high clay-sized content (greywacke), shale, clay, chert, and limestone), and igneous rocks of basalt and serpentinites. A complex rock type is termed mélange, composed of sheared shale, clay, and greywacke matrix containing small (pebble-sized) to large (several hundred feet) blocks and lenses of other rock types.

The complex nature of the Franciscan Complex reflects the complicated history of its formation. The Complex was formed in a tectonic subduction zone where the oceanic crust beneath the Pacific Ocean was carried below the Great Valley Complex attached to the North American Plate. Fragments of the oceanic plate and overlying sedimentary deposits were sheared and mixed in the subduction process. Blocks of Great Valley Complex were added to the mixing process probably by tectonic movements and marine landsliding in the subduction trench. The contact between the Great Valley Complex and the Franciscan Complex is almost always a fault contact in the Napa Valley area.

The Franciscan Complex is exposed in the mountainous regions surrounding the Napa Valley area. The Franciscan Complex is considered low to non-groundwater yielding. Water wells constructed in the Complex at best produce a few gallons per minute, which is sufficient for domestic supply. However, the Franciscan Complex tends to have more “dry” test holes drilled in it than any other geologic unit. This occurs due to the fine-grained texture and well-lithified nature of the rock types, and the high degree of deformation.

3.2 Late Tertiary Volcanic and Sedimentary Rocks

The next major geologic unit in the Napa Valley area is the late Tertiary, largely Pliocene (5.0-2.5 m.y.), volcanic rocks of the Sonoma Volcanics and the interrelated sedimentary rocks. The Sonoma Volcanics are widely exposed in the mountainous areas especially to the east and north surrounding the valley. The Sonoma Volcanics are more limited to the west in smaller faulted exposures along the valley side and small hills in the Yountville Narrows. The late Tertiary sedimentary rocks are limited to exposures in the Conn Creek area, the MST area, and the Carneros area.

3.2.1 Sonoma Volcanics

Weaver (1949) named the Sonoma Volcanics from his mapping of Napa and Sonoma Counties, superseding an earlier division of the unit into three named units: the Mark West Andesite, the Sonoma Tuff, and the St. Helena Rhyolite in decreasing age. Weaver did not map separately 'the Andesite and Sonoma Tuff' units, but he did map the St. Helena Rhyolite. His mapping and nomenclature remained the basis for subsequent reports for over twenty years (Kunkel and Upson 1960; Faye, 1973).

USGS geologists (Fox and others, 1973; Sims and others, 1973) performed more detailed geologic mapping based on the various rock types of the volcanic rocks. However, no stratigraphic or age relationships were proposed for the Sonoma Volcanics. From their mapping, the St. Helena Rhyolite was found to be more complex than previously envisioned. Separate and discrete rhyolite bodies occurred within the entire Sonoma Volcanics as opposed to being a single unit of one age.

Subsequent studies, including radiometric age-dating, subdivided the Sonoma Volcanics into the informal lower and upper members (Fox and others, 1983; Fox and others 1985a; Fox and others, 1985b). The lower member is dominated by andesite lava flows with some tuffs with radiometric ages of 5.4 to 4.2 m.y. near Mount George east of Napa indicating a largely early Pliocene age. The lower member roughly corresponds to the previously named Mark West Andesite. The upper member corresponds to the previously named Sonoma Tuff and occurs largely to the north around the upper valley area. The age of a tuff is reported as 3.4 m.y., and the rhyolite on Mount St. Helena is reported as 2.6 m.y. indicating a Pliocene age.
Lower Member – Andesite Flows

The lower member of the Sonoma Volcanics occurs in the Howell Mountains from Conn Creek south through Atlas Peak, Mount George, and around the south side of the MST area. The member is dominated by basalt, andesite, and dacite lava flows representing variable mineralogic, chemical, and crystalline composition. Weaver (1949) notes that individual lava flows show great variability and change in a short distance from a few feet thick to several hundred feet thick; the flows are dense and vesicular (numerous gas-formed bubble spheres). Similarly, lava flow texture can change over short distances from dense and fine-grained, to vesicular, to flow breccias (foot-sized or larger blocks). Interbedded with the lava flows are subordinate pyroclastic (aerially ejected from a volcanic vent) beds of ash and tuff flows, rhyolite flows, and thin beds of volcano-sedimentary rocks. Interbedded with the lava flows are subordinate fewer ash flows and rhyolite flows and flow breccias.

The lower member was termed by Fox and others (1985a) as the Andesite of Atlas Peak. Recent mapping by the CGS (Bezore and others, 2005; Clahan and others, 2005) of the same geologic unit in the Howell Mountains termed them as andesite flows and flow breccias of Stag's Leap. Similar to Fox and others, (1985a), these maps show the lower member andesite extending across the valley in the hills of the Yountville Narrows. However, the CGS maps differentiate an andesite flow breccias unit across the Narrows and along the west side of the Valley.
MST Caldera Area East of Napa, the MST area is a unique feature in the Sonoma Volcanics. The semi-circular area is considered a collapse caldera (Fox and others, 1985a), where a 'plug' like mass of volcanic materials subsides into an underlying magma chamber. The low hills in the center of the caldera are believed to be a resurgent dome of dacite breccias formed after the collapse.

The groundwater hydrology and geology in the MST area were studied in detail by Johnson (1977) and Farrar and Metzger (2003). Recent geologic maps include Bezore and others (2004) and Clahan and others (2004). The stratigraphy in the caldera consists of a lower member andesite unit overlain by a tuff unit (?). Unique volcanic units and sedimentary units occur overlying these, including a tuffaceous, diatomaceous lacustrine deposit. Fox and others (1985a) placed these caldera units as a portion of the upper member of the Sonoma Volcanics at all ages of 3.8 to 3.4 m.y. Because of the unique nature of the MST area and the previous detailed studies, this report does examine the area in detail.

<u>Upper Member – Tuffs and Rhyolites</u>

The upper member of the Sonoma Volcanics is exposed north of Conn Creek on the east side of the valley and surrounds the upper valley extending northward to Mount St. Helena. In contrast to the lava-flow dominated lower member, the upper member is characterized by pyroclastic volcanic deposits formed by being explosively or aerially ejected from a volcanic vent. Depending upon the nature of the volcanic process and increasing size of the ejecta material, a variety of deposits can be formed, such as ash flow tuffs, tuffs, tuff breccias, and agglomerates (foot-sized ejecta). Ejecta material generally decreases in size away from the source vent and the bed thickness decreases. However, processes at the vent may change or multiple vents may lay down overlapping and intermingled deposits. Finally, surficial processes such as stream erosion and mass movements, i.e., landsliding and mud flows, may ultimately modify pyroclastic deposits into sedimentary deposits.

Fox and others (1985a) termed the tuffaceous beds and interbedded minor andesitic lava flows as the Tuff of Petrified Forest. Radiometric age dates of tuffs west of the upper valley are about 3.3 – 3.2 m.y. Overlying the tuffaceous deposits is a sequence of rhyolite lava flows and flow breccias largely in the upper valley area and further north. Fox and others (1985a) termed these upper member deposits as the Rhyolite of Calistoga. A radiometric age near the top of these units on Mount Saint Helena is reported as about 2.9 m.y. Small, faulted bodies of rhyolite on the west side of the middle valley appear to be part of the upper member (Fox and others, 1985a); although like other isolated rhyolite exposures the relationship is not totally clear.

Tertiary Sedimentary Rocks – 'Huichica' Formation

Weaver (1949) termed relatively undeformed stratified gravel, sand, reworked tuff, clay and conglomerate in the Carneros area as the Huichica Formation. He mapped similar deposits as Huichica Formation near the mouth of Conn Creek. The third major exposure in the Napa Valley in the MST area, he termed the Montezuma Formation. Kunkel and Upson (1960) include these deposits in their Huichica Formation.

Weaver considered the Huichica Formation as Quaternary age, probably based on its undeformed nature and since it overlies the andesites of the Sonoma Volcanics. A tuff bed near the bottom of the Huichica Formation in the Carneros area has been radiometric age-dated at 3.9 m.y., which indicates a Pliocene Age. The detailed mapping by Sims and others (1973) retained the Huichica Formation nomenclature, but they reported them as Tertiary aged deposits. Fox (1985a) continued with the Huichica Formation nomenclature, and he placed the unit as stratigraphically younger than the andesitic-lower member of the Sonoma Volcanics. In the Conn Creek and Conn Valley areas, these sedimentary rocks appear to interfinger and interbed and are overlain by tuff beds of the upper member of the Sonoma Volcanics.

In the MST area, the Tertiary sedimentary rocks consist of sand, gravel, and clay beds with a tuffaceous component. Johnson (1977) and Farrar and Metzger (2003) show the sedimentary rocks overlying the tuff deposits and the diatomaceous beds. Again the stratigraphic relationships and age appear to be at least partially equivalent to the upper member of the Sonoma Volcanics.

To further complicate matters, the USGS authors Graymer and others (2002), Graymer and others (2007), and Farrar and Metzger (2003) have dropped the name Huichica Formation for the Conn Creek and MST areas. They have replaced it by a Tertiary Sonoma Volcanics sedimentary unit (Tss) described as volcanic sand and gravel. Graymer and others (2002) retained the Huichica name for the Carneros area, but they modified the term to Huichica and Glen Ellen (found in the Sonoma Valley) Formations of early Pleistocene (?) and Pliocene age. The final complexity is that recent mapping efforts for the Napa Valley area by the CGS retain the nomenclature of Huichica Formation (Th) for the three main areas of exposures.

The implication of these various nomenclatures is that the same geologic exposure may be named and labeled differently on different maps. For example, in the MST area, the same geologic unit is shown as Huichica Formation (Th) on older USGS maps (Kunkel and Upson, 1960; Fox, 1985a) and newer CGS maps (Bezore and others, 2005 and Clahan and others, 2004). However, on recent USGS maps is shown as Tertiary Sonoma Volcanics sedimentary rocks (Tss) such as Graymer and others (2002), Farrar and Metzger (2003), and Graymer and others (2007).

While the term Huichica Formation is deeply embedded in the geologic and hydrogeologic studies of the Napa Valley, the term is somewhat misleading and obscures the nature of the deposits. The three main surface exposures are relatively small, isolated from one another, and exhibit somewhat different stratigraphic nature. The Conn Creek and Conn Valley area is interbedded and overlain by the tuffaceous upper member of the Sonoma Volcanics, and it is strongly deformed. In the Carneros area, the deposits are weakly deformed, overlie the lower member Sonoma Volcanics, have minor tuffaceous interbeds, and may range in age from Pliocene to early Pleistocene.

Because of these nomenclature conflicts, the complexity of the stratigraphic relationships, and the isolated nature of the main exposures, this Report applies a hybrid nomenclature for late Tertiary sedimentary rocks modified from Graymer and others (2002) and Bezore and others (2002). In the Carneros area, the Huichica Formation (QTh) will be used. In the Conn Creek/Conn Valley and MST areas, the Tertiary Sonoma Volcanics sedimentary rock (Tss/h) will be used.

Quaternary Sedimentary Deposits

Quaternary (post 2.5 m.y.) sedimentary deposits cover the Napa Valley Floor. They have been divided on surficial geologic maps into Holocene (post 100,000 years to present) deposits of present stream channels, terrace, floodplain, and alluvial fans. Older Pleistocene (2.5 m.y. to 100,000 years) deposits have been divided into terrace, alluvial fan, and older alluvium. South of Napa, Holocene Bay muds (Qh) of marshland and estuary origin extend and merge with similar deposits of San Pablo Bay.

The surficial deposits are separated by topographic expression, aerial photographs, and soil maps with older units exhibiting thicker well-developed soils. The deposits are unconsolidated becoming weakly consolidated with increasing age and deformed only by faulting.

The Quaternary deposits are highly complex and variable in composition. Stream channel deposits are composed of thicker beds of sand and gravel, and they are lenticular and elongated in nature. They are interbedded with floodplain deposits of silt and clay with mixtures of sand and gravel, and flood-flow thin sheets of sand with gravel. Alluvial fans spreading out from the valley sides and tributaries tend to be broad, gravelly sandy silt and clay beds formed by flood flows with lenticular sand and gravel interbeds formed by the streams. The alluvial fan deposits tend to thin and become finer-grained towards the valley center merging into the floodplain deposits. The bay muds, as the name implies, are composed of fine-grained silts and clays; the bay muds tend to be blue or gray in color as a result of reducing conditions and constant saturation. Some interbedded lenses of finer sand beds occur formed by streams or estuary channels.

Faye (1973) examined the thickness of the Quaternary deposits (alluvium) in the northern Napa Valley. He found that the alluvium occurred as a relatively narrow band from over 200 feet thick in the south to less than 100 feet thick just north of St. Helena. Towards the valley edges, the alluvium thins progressively to zero. This Report re-examines the nature of the Quaternary deposits using some forty years of additional information from water well drillers' reports.

4 STRUCTURAL GEOLOGY

4.1 Structural Geology

The structural geology of the Napa Valley area is extremely complex. Deformational features and structures of the pre-Sonoma Volcanics geologic units are largely unimportant for this study, as these units occur outside the valley, or are at a great depth below the valley. The collapse caldera in the MST area, while fascinating and locally important, is more stratigraphically significant in its age relationship within the Sonoma Volcanics and the Napa Valley.

4.2 Napa Valley Graben

The simplest, generalization of the structure of the Napa Valley is to describe it as a graben, a fault-bound, down-dropped block relative to the adjacent uplifted blocks. The best visualization of this is the isostatic gravity map of Langenheim and others (2006). The northern gravity-low basin extends northwestward beneath the middle valley, indicating, thick low density Sonoma Volcanics over older geologic units. A higher gravity ridge occurs beneath the Yountville Narrows indicating thinner Sonoma Volcanics and the exposure of older rocks on the east side of the valley. The smaller southern, gravity-low basin extends south to the Suscol Narrows, where a narrow higher gravity ridge separates it from the larger, deeper gravity-low basin below San Pablo Bay.

4.3 West Boundary Fault Zone

The graben bounding faults have been mapped variously on the different geologic maps. The best depictions of the faults are Graymer and others (2007) and the more detailed CGS maps (see previous sections). The west boundary fault is the West Napa Fault Zone which separates the Mesozoic rocks to the west from the small Sonoma Volcanics exposures along the valley side. The main fault appears to be a steeply west-dipping reverse fault with movement up on the west side, but also right lateral movement, northwestward, strike-slip faulting reported.

The West Napa Fault Zone appears to be composed of a complex of multiple faults subparallel to one another, east of the main fault. A strand of faults (?) appears to diverge more northward just west of the City of Napa and trends east of the Sonoma Volcanics hills through Yountville and on the east side of the Yountville Hills.

4.4 East Valley Fault Zone

The east boundary fault has been more elusive to map. A concealed fault extending northward just east of or below the river from Suscol to the Soda Creek fault in the northwest MST area has some evidence from subsurface information and from the isostatic gravity map (Langenheim and others, 2006). The study reported herein found some subsurface evidence that a concealed fault may extend northward below the trend of Napa River parallel to the valley side. This possible fault may extend further north on the east side of the Yountville Narrows as shown on the CGS map of the Yountville Quad (Bezore and others, 2005). A linear feature just south of the Yountville Narrows may be either a fault or possibly an erosional feature.

4.5 Strike and Dip of Bedding

An eastern boundary fault along the eastern part of the northern Yountville Narrows and northward to Conn Creek has not been discerned. Some subsurface information in the present study indicates some possible concealed fault traces west of the valley side. At the mouth of Conn Creek Canyon, complex parallel faults occur in the Sonoma Volcanics and Tertiary sedimentary rocks; these extend northward parallel to the valley.

The final structural element to consider is the strike and dip of beds, i.e., the geographic direction of the bed and the angle that the bed slopes into the subsurface. Around the middle valley in the north, Sonoma and Tertiary sedimentary beds trend parallel to the valley and dip steeply (greater than 45°) towards the valley center, giving a synclinal aspect to the gravity basin. In the Yountville Narrows area, strike and dips are more variable, but generally exhibit lower dip. Around the lower valley, strike and dips of the Sonoma Volcanics are poorly known. The strike and dip of the beds must be considered when evaluating the subsurface geology.

5 SUBSURFACE GEOLOGY

This section examines in greater detail the geology below the Napa Valley Floor in relation to groundwater. Previous hydrogeologic studies have focused on the Quaternary alluvium and did not attempt to subdivide the Sonoma Volcanics in the subsurface (**Figure 5-1a**). A representative cross section from Kunkel and Upson (1960) is shown in **Figure 5-1a** together with an annotated version of the cross section (**Figure 5-1b**) that shows geologic features identified during the recent work for this study. Previous geologic cross-sections were largely in the Napa area (Kunkel and Upson, 1960). Faye (1973) presented no cross-sections north of the City of Napa, but he mapped the thickness of the alluvium. In the MST area, Johnson (1977) and Farrar and Metzger (2003) subdivided the Sonoma Volcanics on their cross sections. Sweetkind and Taylor (2010) presented digital cross-sections, but the data used were pre-1952 drillers' reports from Kunkel and Upson (1960).

From a previous reconnaissance study of the entire County (LSCE, 2011a), it was known that several thousand water well drillers' reports existed on the Napa Valley Floor. A majority of these reports post-dated 1970 and apparently had not been used in published reports. A series of geologic cross-sections were recommended to examine the subsurface geology, including derivative maps of alluvium thickness and Sonoma Volcanics rock types. This Report summarizes the work conducted to implement these recommendations. The upper Napa Valley and the MST area were largely excluded from the present study because of the small size of the upper valley and the previous detailed studies of the MST.

5.1 Subsurface Information

Subsurface information for groundwater studies is largely based on water well drillers' reports. These reports have been mandated for the last 60 years to be filled out on a state form for all water well or borehole drilling activities performed by drilling companies and submitted to DWR. Information for some wells, which predated the mandated drillers' report, was collected by governmental agencies (e.g., USGS and DWR) and from well owners or drilling companies for older hydrologic studies.

5.1.1 Water Well Drillers' Reports

The water well drillers' report form has evolved over 60 years, but it has three main features that have been retained through all the form changes: a location element; a lithologic description of material encountered (more simply, lithologic log or log); and well construction details, including estimated water yield. Shortly after the form was introduced, sequential identification numbers were added to be able to differentiate reports. In theory, this well ID number was supposed to be unique to a particular report and therefore to a well. In reality, numbers were used several times during printing additional forms, or when new formats of forms were introduced. With the dawn of the digital age, a prefix of 'e' and subsequently 'E', was added to the number to indicate an electronic version of the form. For further confusion, older well reports on a variety of forms, early water well drillers' reports without numbers, and some of the early numbered reports were given County identification numbers. For Napa County, this was in the form of 28-001, 28-002, etc.

5.1.2 Well Location

The most important information on a water well driller's report is the location of the well. Initially, a written description of the location was required, and distances to the grid-location by Township and Range and Section were to be shown. Unfortunately, only selected reports were located. Heat-exchange well reports were also ignored much of the Napa Valley Floor was not surveyed on topographic maps. Often, drillers did not fill out the form. Subsequently, DWR requested a map showing distances to roads or geographic features. This also proved relatively inadequate. Eventually, about 1970, DWR requested the assessor's parcel number. But parcel numbers can change or be misidentified. When the water well driller's report was submitted, DWR assigned a Township/Range/Section identifier with an alphabetic subdivision for each of sixteen unique 40 acres in the square mile section. The wells were then numbered in chronological order as drilled. This task proved to be impossible for the personnel and resources assigned, given the quantity of well reports and the quality of the location information. Most drillers' reports within the last 40 years tend to be assigned only to the Section square mile area. This problem was exacerbated in the last 30 years by hundreds of shallow monitoring wells installed at fuel stations and hazardous materials sites.

In summary, while the well location for the driller's report is the most important item, each report must generally be approached as though the location is unknown. Using the street address, any map descriptions, and parcel number, the location must be identified, if possible. The DWR location must be examined until confirmed. In many cases, the DWR location is wrong for various reasons, such as by being in an adjacent section; in some cases, the location may be off by miles by a misreading of the Township and/or Range.

During this study, over 1,300 wells were located by using the information on the reports. The parcel numbers on reports from the last 30 years proved fairly reliable. Older parcel numbers tended to be more difficult to confirm. Drillers' reports prior to 1970 were the most difficult to locate as information was lacking or could not be related to present conditions. A few critical deep well reports were traced by file search on parcel numbers or County permit numbers.

Shallow (less than 100 feet deep), hazardous-site monitoring wells were largely ignored. Shallow domestic well reports, located where deeper adjacent well drillers' reports also existed, were mostly ignored. In areas where a high density of wells occurred, only the deeper reports were used. Most irrigation well reports were located, if possible, unless they were on small parcels with numerous adjacent wells. Well drillers' reports for wells located outside the Napa Valley Floor were also mostly not used for this study.

Because many drillers' reports are incorrectly located, or the report lacks a state-location identifier beyond the Section designator, a location identity was assigned to the 40 acre designator, followed by the year of the drillers' report. For example, a well report was designated as 20a-78 meaning location in Section 20, northeast-most 40 acre area, drilled in 1978. If several wells were drilled in 1978, a post script alphabetic designator was added, (i.e., -20A-78A; 20a-78b, etc.). The drillers' report is listed in the database with the report ID number listed. During the course of this study, about 1,300 water well drillers' reports were located and tabulated in the database.

5.1.3 Lithologic Logs

The second most important element on the water well drillers' report is the lithologic log, or description of the geologic material encountered in the borehole. Most drillers do not have geologic training, although they may have vast experience in drilling wells in their region. Most drillers can readily discern the differences between sand, gravel, and clay. However, mixtures of these materials are more difficult to describe. Generic terms such as 'rock' can describe many things such as boulders, hard sedimentary rock of any type, or volcanic rocks such as lava flows or tuffs. The driller is hindered by having to control the drilling operation and observe the nature of the material being drilled through and coming out of the borehole. Most drilling rigs use 20-foot long drill pipe sections, resulting in the 'rules of tens'. The driller observes the material coming out of the borehole (cuttings) at the bottom of the 20-foot drill pipe and describes what was drilled as either 10 or 20 feet thick.

Drilling through other geologic materials such as sedimentary rocks or volcanic rocks, the driller may describe the size of the fragments resulting from the drilling process, such as sand, gravel, or clay. Modifiers added to the description may help unravel the nature of the geologic material, such as 'hard', 'sticky', 'smooth', and colors.

Each lithologic log must be evaluated with recognition of the above limitations, and the log must also indicate the drilling method, the drilling date, the purpose of the well, the well location, and the drilling company. Review of numerous water well drillers' reports from the same drilling company generally shows evolving patterns in logging descriptions through time. If lithologic logs by other drilling companies are located nearby, comparison of the logs can lead to better evaluation of all of the logs. From such a review, a hierarchy of reliability of lithologic logs by different drillers can be defined based on the descriptions. In some instances, a lithologic log may be deemed unusable because of the lack of detail or incompatibility of the log with other nearby wells.

5.1.4 Geophysical/Electrical Logs

A complement to the driller's lithologic log is the geophysical (or electric) log, or survey of a borehole, which measures the resistivity of the geologic material to an induced electric current. Evaluation of such electric logs with the lithologic log can aid identification of the geologic material and bedding thickness. However, in Napa Valley only a dozen or so such electric logs have been found in the area. A small cluster of such electric logs just north of the Yountville Narrows show that correlation of geologic units is possible in that area. However, the remaining available electric logs are too widely scattered across the valley to allow correlation. Some additional water well drillers' reports indicate an electric log was made in the borehole, but these were not available for review. South of the Yountville Narrows no electric logs were found.

5.1.5 Well Construction Details

The third major element on the water well driller's report is the well construction details. These consist of the borehole size, size of the installed well pipe, and the location of intake sections (i.e., perforations or screened pipe). Also, the thickness and nature of any surface sanitary seal installed is noted.

Most wells in the Napa Valley constructed post 1970 tend to have long intake or screened intervals that extend from the near surface alluvium, if present, and across the underlying Sonoma Volcanics or Tertiary sedimentary rocks to the total depth drilled. The final well construction information is the estimated yield of the well in gallons per minute (gpm). This is determined by test pumping the well; this tends to be more accurate and give possible aquifer characteristics derived from lowering of the water level corresponding with pumping (drawdown). This method was used on a minority of wells, and these were mostly large diameter irrigation wells or public water supply wells.

The vast majority of wells were tested by air-lift methods where an air compressor is used to remove water from the well and the quantity of outflow is estimated by the driller. Most wells in the valley tested by this method are reported to have a yield of a few gpm, to several tens of gpm, to in a few occasions a couple of hundred gpm. When the resulting water level in the well is reported at the end of the test (usually 2 to 3 hours), and water levels are near the bottom of the well, this indicates the specific capacity (gpm/foot of water level lowering) of the well is low, i.e., fractions of a gallon per minute for each foot of drawdown. This indicates poor aquifer characteristics or low permeability, i.e., the limited ability of water to flow through the geologic material into the well. Alternatively, low well yields may be a result of well inefficiency due to the construction process. Because low well yields are generally widespread across the valley, and uniformly across the different well drilling companies, it is believed that poor aquifer characteristics are the cause. This is discussed in more detail in a later section.

5.2 Methodology

Geologic units described in Sections 5.2.1 Geologic Cross-Sections and 5.2.7 Structure Contours/Subcrop Map of Pre-Alluvium and depicted in **Figures 5-2 through 5-12**are compiled for reference in Appendix A.

5.2.1 Geologic Cross-Sections

As part of this study to update the hydrogeologic conceptualization and further evaluate the subsurface geology of the Napa Valley, a series of eight geologic cross-sections (**Figures 5-2 through 5-10**) have been prepared. The first step in cross-section construction was to review the water well drillers' reports along the general trend of the cross-sections. It was found that few reports were located on some initial cross section locations, so the locations were relocated to where more driller' reports occurred. This was particularly acute in the south, beneath the City of Napa to Suscol. Few drillers' reports in this area post-date 1960, exclusive of hazardous site monitoring wells.

The well locations from the drillers' reports were plotted on enlarged topographic base maps at a scale of 1 inch equals 1,000 feet with an overlay of parcel numbers. Wells which could be located were assigned a location number based on Township/Range/Section 40-acre subarea, and the date of construction, as described previously. The information for drillers' reports that could be located was tabulated into a database and the location was assigned digital coordinates.

Cross sections were constructed at a horizontal scale of 1 inch equals 500 feet, and a vertical scale of 1 inch equals 100 feet. The wells were located on the cross-section, and the lithologic log for each well was used to construct a profile of encountered geologic material. The initial cross-sections were made in the lower valley. It became apparent that the number and depths of well reports in this area were extremely limited. The location of cross-sections F and G were predicated on older deep wells drilled pre-1950. Beneath the City of Napa, deep well control was nearly non-existent. Cross-sections D and E were relocated from initially proposed locations due to a lack of drillers' reports for deep wells.

The following sections summarize the geologic observations on the cross sections by the various valley areas from south to north.

5.2.2 Lower Valley Cross Sections

In the lower valley, four geologic cross sections were constructed: Sections D; Section E; Section F; and Section G, from north to south (**Figures 5-6 through 5-9**). These cross sections show the general geologic patterns of the lower valley. Quaternary alluvium (Qa) grades southward into fine-grained Quaternary sedimentary basin deposits (Qsb). The alluvium overlies Tertiary sedimentary rocks (Tss/h) which declines southward and transitions into thick, fine-grained Tertiary and early Quaternary sedimentary basin deposits (TQsb). The sedimentary rocks and basin deposits overlie the lower member Sonoma Volcanics andesite flows with tuffs (Tsva, Tsvt), which descends to depths of 1,000 feet or more below the City of Napa. At the south end of the valley at the Suscol Narrows, faulting has brought the Sonoma Volcanics to shallower depths.

At the north end of the lower valley, Section D appears to show Quaternary alluvium of unconsolidated deposits, including lenses of thick sands and gravel beds, especially to the east, and more widespread fine-grained clays with thin beds of sand with gravels. The alluvium thins east and west towards the margins of the valley. Below the alluvium, a thin sequence of finer-grained deposits occurs with some thin sand and gravel beds and some volcanic ash beds. This unit was correlated to the Tertiary sedimentary rocks (Tss/h) exposed in the MST area.

Deeper boreholes encountered volcanic materials of the lower member Sonoma Volcanics, but these appeared to occur in bands or zones. To the east, andesite lava flows and breccias with tuffs (Tsva) occur. In this area, thin Tertiary sedimentary rocks occur overlying the andesite unit. In the center of Section D, between two possible faults, limited information indicates tuff beds (Tsct) occur, but whether these are of the lower or upper member is not clear. To the west, a mix of andesite lava flows or breccias (Tsvab?), and tuffs (Tsvt) occur; these are probably the lower member Sonoma Volcanics.

Cross-section E (**Figure 5-7**) shows a similar pattern for the Quaternary alluvium. The east side of Section E shows Tertiary sedimentary rocks above the Sonoma Volcanics in the MST area. Beneath the alluvium, the main valley area shows thick, fine-grained deposits with some sand and gravel beds. This unit is termed Tertiary Quaternary sedimentary basin deposits. Only one deep well (projected on to this section) encountered Sonoma Volcanics of uncertain correlation at great depth. On the west side of Section E, lower member Sonoma Volcanics (Tsva) are overlain by sedimentary deposits of uncertain correlation (TQsu) in a fault band block.

Cross-sections F and G (**Figures 5-8 and 5-9**) are located south of the City of Napa where little deep well control occurs. The locations of Sections F and G were predicated on the existence of a few deep old well logs from Kunkel and Upson (1960) along each cross section. These well logs date from the first half of the 1900s. A few more recent drillers' reports were also used to construct the cross sections.

Cross-section F (**Figure 5-8**) shows Quaternary sedimentary basin deposits (Qsb) up to about 300 feet thick and largely composed of clays with thin interbeds of sand. These are believed to be floodplain (?), marshland, and estuary origin. These deposits are underlain by thick clay with sands deposits of the Tertiary-Quaternary sedimentary basin deposits (TQsb). Some thick sand or sandstone beds occur interbedded with fine-grained units. The TQsb units are believed to be marshland, estuary, and lacustrine (?) deposits. The unit may be equivalent, in part, to the diatomaceous lake beds in the MST area, and the Tertiary sedimentary rocks of the MST and Carneros areas. As such, the age of the unit would range from the Pliocene and possibly into the Quaternary (early (?) Pleistocene). Below these units, the lower member of the Sonoma Volcanics of andesite flows and tuffs rise from great depth below the center of the valley to surface exposures, or near surface, by faulting.

Cross-section G (**Figure 5-9**) occurs at the south end of the lower valley near the Suscol Narrows. The south gravity low basin rises to the Suscol Narrows and the gravity high ridge. The high ridge separates the Napa Valley from the deep gravity low basin below the San Pablo Bay to the south. At the Suscol Narrows, the Napa Valley drains through a narrow (~2,000 feet) gap between exposed lower member Sonoma Volcanics (Tsva) to the east and low hills and exposes an older Tertiary marine rocks (Td) to the west. Cross-section G shows the complexity of this area as these older units are overlain by Tertiary-Quaternary sedimentary basin deposits and Quaternary alluvium. The cause of this complexity may be the intersection of the East Napa and West Napa Fault Zones. The merged (?) fault zone may continue southeasterly across the San Pablo Bay area towards Vallejo.

5.2.3 Carneros Area – Cross-Section H

To the west of the Napa Valley in the Carneros area, the review and locating of drillers' reports for the present study indicated that few wells occur until near Cuttings Wharf Road. West of that road, drillers' reports indicated that wells tend to be relatively shallow and low yielding. Near the marshlands of San Pablo Bay, drillers' reports were essentially non-existent. The drillers' reports in the Carneros area appear to show the geologic unit as mostly clays with thin sand and gravel beds with poor correlation (cross-section H; **Figure 5-10**). The entire unit encountered in the wells is believed to be the Huichica Formation as defined by Weaver (1949), or more recently as Tertiary-Quaternary Huichica Formation (TQh) by Graymer and others (2002).

5.2.4 Yountville Narrows Area – Cross-Section C

Northward in the Napa Valley, the review of water well driller's reports in the Yountville Narrows area indicated limited available well control, especially along the Napa River floodplain. Even away from the river, well control was limited. Cross-section C (**Figure 5-5**) was located near the north end of the area where well control was sufficient to extend the cross section across the valley. This cross section shows the complex structural features of the Yountville Narrows area. To the east, a possible East Napa Fault Zone separates the valley from the Howell Mountains. Beneath the valley floor, westward thickening Quaternary alluvium overlies the lower member Sonoma Volcanics andesite flow breccias mapped by the CGS. This unit appears to overlie a harder, more massive andesite flow and breccias (Tsvab) unit with some tuffs more typical of the Tsva in the mountains to the east. Deep well control is limited to one well, but the reported well yield (480 gpm) was much higher than nearby wells. Dips of bedding in the small hills and in the mountains to the east are somewhat lower (less than 30°) to nearly flat (less than 10°). This portion of the cross section overlies a flat shoulder of higher gravity which extends northward from the gravity ridge seen below the Yountville Narrows (Langenheim, 2006).

In the center of the Section C, the Quaternary alluvium, bound by faults, thickens and contains thick beds of fluvial sand and gravel. The underlying unit is termed Sonoma Volcanics conglomerate/breccias (Tca/b). The nature of the unit is unclear; it is uncertain whether it is a sedimentary conglomerate or volcanic flow breccias, or possibly a combination. Drillers' reports tend to log it as 'hard' gravel and boulders with some clay or volcanic ash, either as intermingled or separate beds. Two geophysical logs on the central two wells indicate high resistivity values and similar characteristic responses, but it could not be distinguished whether the deposits in these wells are sedimentary or volcanic. The four wells on the cross section were constructed for groundwater intake both in the thick coarse alluvium and this lower unit. Reported well yields were some of the highest in the valley, ranging from 770 to 2,000 gpm. Short duration test pumping of the two central wells indicated specific capacities of 17.9 and 33.9 gpm per foot of drawdown. This is higher than most wells in the valley which tend to be less than 1gpm per foot of drawdown. However, it is unclear if the extracted groundwater originated from the alluvium, which is most likely, and/or from the underlying conglomerate/breccias. The conglomerate/breccias unit was traced to north of Section A (see later section).

Further west on Section C occurs a fault-bound block of lower member Sonoma Volcanics andesite flows (Tsva). This is a continuation of the Yountville Hills just to the south.

The western remainder of Section C shows Mesozoic Great Valley Sequence rocks west of the main strand of the west Napa Fault Zone. The intervening area of the cross section shows a syncline-like or fault band block underlain by lower member Sonoma Volcanics andesite (Tsva), andesite and tuff (Tsva & t), and tuff (Tsvt). The actual configuration of these units is unclear due to limited information and possible complications of faulting. Overlying these units is a fine-grained sedimentary unit termed (Tertiary-Quaternary sedimentary basin deposits undivided (TQsbu), as it does not match with either the Tertiary sedimentary rocks or the Quaternary alluvium. The gravity map shows a small, low-gravity basin from just west of the northern Yountville Hills to about halfway to Section B. This may represent a small fault band block on which late Pliocene (?) and early (?) Quaternary fine-grained sediments are deposited in a marsh-like or lacustrine environment.

5.2.5 Middle Valley – Cross-Sections A and B

The northernmost cross section, Section A (**Figure 5-3**), shows a typical Quaternary alluvium configuration of thickest depths near the center of the valley. However, thick sand and gravel beds in the central area are largely lacking. Localized thick sand and gravel beds occur, but well yields are less than seen farther south. In general, the alluvium appears to be finer-grained than farther south in the middle valley and the Yountville Narrows.

Section A appears to show the disappearance of the lower member of the Sonoma Volcanics andesite units to depths not reached by boreholes. In the easternmost part of Section A, Tertiary sedimentary rocks (Tss/h) may overlie the lower member (Tsva?) in a fault block; farther west, they overlie Sonoma Volcanics of uncertain correlation (Tsv?), or do not reach the volcanics. A narrow, fault bound (?) block appears to contain the conglomerate/breccias (Tcg/b) overlying Sonoma Volcanics of uncertain correlation (Tsv?). However, well yields are only moderate (<150 gpm), and specific capacities are lower (less than 1 gpm per foot of drawdown). Overlying thick sand and gravel alluvium may not be either present or yielding little water. On the west side of Section A, upper member Sonoma Volcanics (Tsv?) and upper member (?) tuffs (Tst?) exhibit well yields across this entire western area that are low (a few tens of gpm) with specific capacities of much less than 1 gpm per foot of drawdown.

In the middle valley, the geologic units of the Sonoma Volcanics change in their surface exposure and in the subsurface. The lower member Sonoma Volcanics dominated by the andesite flows (Tsva) and flow breccias (Tsvab) with minor tuffs (Tsvt) seen in the Yountviille Narrows descend to depths northward, and they are replaced by upper member tuffs and Tertiary sedimentary rocks. This is the result of the northern low-gravity basin where the lower member and overlying upper member of the Sonoma Volcanics have been down-dropped in relation to the adjacent mountainous areas.

Section B (**Figure 5-4**) shows Quaternary alluvium overlying older units with the greatest thickness near the center of the valley. To the east on the Valley Floor, lower member Sonoma Volcanics andesite breccias (Tsvab) occur near the valley margin, which is overlain by the

Tertiary conglomerate/breccias (Tcg/b). Across the center of Section B, the conglomerate breccias occur similarly to what is seen on Section C to the south. The thickest part of the unit is overlain by thick Quaternary alluvium. The center area is bound by faults to the east and west. The four wells to the east in this area are similarly constructed with groundwater intake structures across both the alluvium and the conglomerate/breccias. Reported well yields by test pumping are high (between 1,000 to 2,400 gpm), and specific capacities are between 10.5 and 26.9 gpm per foot of drawdown (i.e., they are comparable to similar wells on Section C). It is unclear if the groundwater is sourced largely from the alluvium and/or from the conglomerate breccia.

Farther west on Section B, lower member andesite flows with tuffs (Tsva) are overlain by fine-grained beds of Tertiary sedimentary rocks, which may be in part tuff beds (Tss & t). This unit is believed to be possibly a portion of the upper member of the Sonoma Volcanics, although its exact correlation is unclear. To the west on the section, the lower member andesite appears to have been up-faulted by the west Napa Fault Zone.

5.2.6 Isopach/Facies Map of Alluvium

With the cross sections as a working conceptual model, the study involved locating water well drillers' reports which occurred outside of the cross-section areas. Besides the problems of locating wells, it became apparent that areas on the Napa Valley Floor were deficient in wells, especially south of cross-section E below the City of Napa.

In order to evaluate the Quaternary alluvium, each driller's report, was located and the thickness and nature of the alluvium were noted on base maps. Initially the net or total, thickness and number of the sand and gravel beds were annotated on the base maps. However, it became apparent that outside of a band of thick sand and gravel beds, representing previous Napa River channels, the remainder of the valley was characterized by thin bands outside the central band, These represent tributary stream channel beds found outside the central band, but they could not be traced due to lack of well control, or because the beds tend to thin away from the valley sides. For these reasons, the alluvium deposits are represented by the facies of the depositional environment which formed them. The thick sand and gravel bed areas were perceived as former Napa River stream channels, and these were termed the fluvial facies. The marginal areas towards the valley sides of thin sand and gravel beds were designated as the alluvial plain facies formed by alluvial fans of tributary channels. Near cross-section E, the alluvium was perceived to change in character. The deposits appear to be fine grained with some thicker sand and gravel beds interbedded. This area is believed to represent a broader flood plain to deltaic depositional environment grading further south into possible marshland or estuary environment. Well control south of cross-section E is very limited, so it is difficult to draw adequate conclusions. This finer-grained dominated area is termed the sedimentary basin facies. From the data collected on the alluvium, an isopach/facies map (**Figure 5-11**) was estimated to show equal thickness of alluvium and the distribution of the perceived facies.

5.2.7 Structure Contour/Subcrop Map of Pre-Alluvium

Concurrent with the process to locate wells and identify the alluvium thickness, the nature of the underlying older Sonoma Volcanics-aged deposits was examined. The initial step was to subtract the alluvium thickness from the surface elevation to yield the elevation of the older deposits at each well site; these elevations were plotted on base maps. These elevations were then contoured to produce the structure contour, or elevation map, on the top of the Sonoma Volcanics-aged geologic units.

Classification of the Sonoma Volcanics-aged units was problematic due to the varied drillers' descriptions of these units. Correlation between wells tended to be poor, and characterization of the rock types was interpretive. For each water well driller's report, it was necessary to recognize the age of the report and the driller, as patterns in drillers' terminology could be seen both between drillers and time. In most areas, it was necessary to examine all of the located wells to interpret the rock type encountered. It became advantageous to construct working cross sections in different areas to show to scale the various rock types in numerous wells. From these broader patterns, rock types and relationships became apparent.

The subcrop map (**Figure 5-12**) shows fine-grained sedimentary basin deposits near and south of Section E to Sections F and G. These deposits are believed to have formed in a subsiding basin banded by the marginal faults in marshland and estuary environments. These deposits are poorly known due to lack of deep well control except at the cross section locations and from wells mostly drilled almost 100 years ago. Some of the fine-grained deposits may represent tuffaceous deposits, but this is unclear. There appear to be few sand beds within these deposits. For groundwater production, volcanic rocks of the Sonoma Volcanics are found only along the margin of the valley bound by faults, or possibly at great depths of 1,000 feet or more. There sedimentary basin deposits are believed to be at least in part equivalent to the diatomaceous beds found in the MST and may range in age up to the early Quaternary.

Northward, toward Section D, a band of Tertiary Sonoma Volcanics sedimentary rocks (Tss/h) occurs of fine-grained beds with few sand and gravel beds. These overlie volcanic lower member Sonoma Volcanics andesites and a tuff of unknown correlation. Again, Sonoma Volcanics occur on the margin valleys bound by the faults. On the east side of the valley to just north of Section D, thin Tertiary sedimentary rocks overlie irregular topography of Sonoma Volcanics andesites as shown by the small knobs on the surficial geologic map.

Working cross-sections between Sections D and E indicate that the Sonoma Volcanics in Section D decline southward into the southern low-gravity basin. The overlying Tertiary sedimentary rocks appear to in part underlie, interbed, and interfinger with the Tertiary sedimentary basin deposits to the south.

In the Yountville Narrows area, the central Napa Valley Floor has poor and limited well control. Many wells appear to be completed solely in thick alluvial sand and gravel deposits. A few deeper wells either did not penetrate the alluvium, or the underlying rock type was not identifiable. The subcrop map in this area along the valley margins appears to reflect the surficial geologic units exposed in the various knobs and hills.

The subcrop map at Section C shows a more complex pattern. To the east, the lower member andesite breccias occur. In the central part of the valley, a sequence of reported conglomerate or flow breccias (Tcg/ab?) underlying thick sand and gravel of the alluvium is reported in a number of wells. This unit appeared distinct enough to map it separately, although the nature of this unit is unclear. It was traced laterally northward as shown, and it seems to be confined to a central narrow band. To the east, south of the Tertiary sedimentary surficial exposures near Conn Creek to the exposed flow breccias to the south, the conglomerate/breccias appear to grade southward into the flow breccias to the south. Both of these units appear to be overlain by Tertiary sedimentary rocks which extend northward.

The western side of the subcrop map north of Section C is more enigmatic in that rock types are more indistinct and dominated by tuffs and tuffaceous sedimentary rocks. Upper member tuffs of the Petrified Forest exposed north of the City of St. Helena appear to transition southward into interbedded tuffs and sedimentary rocks. Well control across this area from Section A to B and just south of these sections is limited by both the number and depth of wells. The areas are complicated by faulting, and the contours were drawn on local marker beds which do not match the top of Sonoma Volcanics-aged deposits. Beneath the Tss/h area, the contours are drawn on the underlying Tsva unit. The alluvium thickness across this area is thin, 50 feet or less. In the Tsvt areas near Section C, the structure contours are drawn on the top of the volcanic tuff unit. These are overlain by thick fine-grained sedimentary deposits which are undivided Tertiary and Quaternary (?) beds. The overlying alluvium is thin, about 50 feet thick or less. These two areas show the contours drawn on deep local marker beds to illustrate the complexity exhibited by certain beds in complex structural areas.

In the middle of the valley, the subcrop map of the Sonoma Volcanics units appears to reflect the declining of units into the narrow synclinal, fault bound northern gravity basin. The lower member andesitic Sonoma Volcanics (Tsva, Tsvt) descends northward to be overlain by tuffaceous sediments (Tst/s) and sedimentary rocks. These units appear to interfinger and interbed with the upper member tuffs of the Petrified Forest (Tst pf). The conglomerate/breccias unit appears to interbed with the tuffaceous sedimentary rocks. The subcrop map of the Sonoma Volcanics in the middle valley is complicated by structural deformation as shown by mapped perceived faults and the steeply dipping beds of the surficial geologic units. In addition, water well drillers' reports descriptions of thick tuffaceous deposits tend to be more difficult to interpret because of their fine-grained nature.

Cross-sections constructed in this study depict the interpreted subsurface shape and thickness of geologic units and movement of faults based on surface geologic mapping and subsurface lithology from well information. **Figure 5-13** illustrates how geologic interpretations from surface and subsurface geologic information can be visualized to understand the geologic setting and relate subsurface geologic features to surface geology and topography at a cross-section in the vicinity of the City of Napa. **Figure 5-14** provides a similar perspective, expanded to show the subsurface stratigraphic units mapped at each cross section throughout the Napa Valley study area.

6 HYDROGEOLOGY

Previously published hydrogeologic reports have largely focused on the Quaternary alluvium. This was probably a result of limited numbers of wells drilled into the underlying Sonoma Volcanics or sedimentary rocks. The Kunkel and Upson (1960) dataset consisted of wells drilled prior to the early 1950s. They mentioned only three areas where wells were completed in the Sonoma Volcanics: the MST area, the Suscol area, and the Calistoga area. The remainder of the valley was not mentioned; this was probably because few deep wells existed then. Faye (1973) also focused on the Quaternary alluvium from the City of Napa northward. His well dataset appeared to have been limited to pre-early 1970s. He mentions information for 140 wells tapping the Sonoma Volcanics, but their locations are unclear. Johnson (1977) and Farrar and Metzger (2003) examined the Sonoma Volcanics in the MST area, as Quaternary alluvium is largely absent in that area.

6.1 Alluvium

In this study, the Quaternary alluvium thickness was mapped, and three facies were defined: fluvial, alluvial plain, and sedimentary basin. The fluvial facies consists of a thin narrow band of stream channel sands and gravels deposited by the Napa River. The sand and gravel beds tend to be thicker and/or more numerous in the fluvial facies area. They are interbedded with finer-grained clay beds of probable floodplain origin. Wells constructed in the fluvial facies tend to be moderately high yielding (for the valley, roughly 50 to 200 gpm). Local areas where thicker sand and gravel beds are reported, the well yields are the highest in the valley, ranging from about 200 to 2,000 gpm.

These areas with thick sand and gravel beds occur in the Yountville Narrows area and extend northward. Local areas of relatively lower well yield values of 200 to 500 gpm occur to the north and south. Hydraulic properties of these deposits are recorded during airlift testing, and drawdown values are generally not reported. Only a few pump test results have been found, and these are in the high yielding area just north of the Yountville Narrows.

The alluvial plain facies of the Quaternary alluvium extends outward from the central fluvial facies and thins to zero at the edge of the valley sides. These deposits appear to have been deposited as tributary streams and alluvial fans. These deposits appear to consist of interbedded sandy clays with thin beds (less than 10 feet thick) of sand and gravel. Wells constructed in the alluvial plain facies tend to be low yielding, ranging from a few gpm to few tens of gpm. By at least 1970, most wells drilled on the alluvial plain facies were constructed to deeper depths into the underlying Sonoma Volcanics.

At the northern end of the lower valley, the sedimentary basin facies of the alluvium occurs. This facies is characterized by fine-grained silt, sand, and clays with thin to scattered thicker beds of sand and gravel. The sedimentary facies is believed to be floodplain deposits that extend to the southern marshland/estuary deposits. As noted, the extent of this facies is poorly known due to lack of well control farther south. Limited information indicates low to moderate well yields of a few gpm to possibly up to 100 gpm. Again, the lack of pump test information makes hydraulic properties of the deposits difficult to assess.

6.2 Sonoma Volcanics and Tertiary Sediments

In previous studies, the Sonoma Volcanics and sedimentary rocks have been undifferentiated in the subsurface below the Napa Valley. For this study, numerous water well drillers' reports from the last 40 years were used, and a subcrop map of the distribution of rock types has been developed. The subcrop pattern has been interpreted into the stratigraphic and structural features. Wells drilled into the Sonoma Volcanics and sedimentary rocks tend to be low yielding. Typically, wells yield less than 16 gpm to less than 50 gpm. A few wells are reported to yield over 100 gpm. Nearly all of this data is from airlifted well tests, where water levels decline drastically. This indicates that the hydraulic characteristic of these geologic units is poor, probably as a result of their origin, the degree of consolidation and/or fine-grained nature of the units. Essentially, this means the Sonoma Volcanics typically exhibit relatively low permeability, or limited ability to yield water to wells.

The subcrop units of tuffs (Tst and Tsvt) and sediments (Tsvt/s) have similar low water yielding characteristics. The Tertiary sedimentary rocks (Tss/h) seem to have slightly higher, but still low, well yielding characteristics. The conglomerate/breccias unit (Tcg/ab) appears to have somewhat higher water yielding characteristics, but most wells are screened across overlying thick alluvium deposits.

The andesite flows and flow breccias (Tsva and Tsvab) are possibly the most variable in well yielding characteristics ranging from low yields to as high as several hundred gpm. The final Sonoma Volcanics unit is the Tertiary sedimentary basin deposits (TQsb) in the lower valley, which may have low to moderate well yields depending on whether thin sand and gravel interbeds are encountered in the generally fine-grained sedimentary deposits.

The final part of the subcrop map is the small area of Mesozoic Great Valley unit (KJgv) in the Yountville Narrows which has possibly the lowest well yields of the units beneath the Napa Valley Floor.

6.3 Recharge Areas

The distribution and quantity of groundwater recharge occurring in Napa County is primarily a function of the geologic units which precipitation encounters, either as rainfall or runoff. Johnson (1977) performed a series of seepage experiments on the major creeks and tributaries in and around the MST Subarea to determine the primary mechanisms of groundwater recharge. A seepage experiment consists of several streamflow measurements taken along the length of a stream to quantify streamflow gains and losses. The stream is considered losing where streamflow decreases between measurements, and gaining where streamflow increases. He concluded that the infiltration rate from precipitation and runoff is greatest where tuffs are exposed or underlie shallow Quaternary deposits. Additionally, only a small percentage of groundwater recharge was found to come from direct precipitation, but instead it is greatest where streams and tributaries come in contact with tuffs. Farrar and Metzger (2003) similarly analyzed seepage gains/losses for various creeks and tributaries in the MST. They concluded that significant streambed infiltration also occurs where streamflow passes over unconsolidated, highly permeable, alluvial deposits. **Figure 6-1** is a conceptual illustration of the major surface and subsurface hydrologic processes occurring within a watershed and shows how the hydrogeology of the Napa Valley area relates to these processes. As illustrated in **Figure 6-1** and discussed in greater detail in Sections 7 and 8 of this report, precipitation falling within the watershed infiltrates the ground or becomes surface water outflow through surface runoff processes. Some fraction of infiltrated water is consumed through plant evapotranspiration and some water percolates deeper and into the aquifer system as recharge. The potential for water to recharge the groundwater system depends on many factors, including the nature of the geologic materials and topography.

Based on the findings of Johnson (1977) and Farrar and Metzger (2003), a map was created to locate areas of greatest recharge potential. This map shows the location of exposed tuffs throughout the county (**Figure 6-2**). Sonoma Volcanics sedimentary deposits and various alluvial units found countywide were also included in the map following findings by Farrar and Metzger (2003). Areas in which the slope of the land surface exceeds 30 degrees, beyond which recharge potential is significantly reduced, were also added to the map.

Two sizeable exposures of rhyolitic ash-flow tuff and related alluvium occur in the northern portion of the Eastern and Western Mountains near Calistoga. The eastern exposure covers roughly 30 square miles with tuff in the north and Sonoma Volcanics sedimentary deposits to the south. Following Johnson (1977), the greatest recharge would be expected along Bell Creek, which traverses much of the northern tuffs, and Conn Creek, which passes over large Sonoma Volcanic sedimentary deposits in Conn Valley, some of which are covered by younger alluvium. The Western Mountains exposure, which covers roughly 18 square miles, is almost entirely tuff, with a single Sonoma Volcanics sedimentary deposit in the north at Cyrus Creek. Again, following Johnson (1977), the greatest recharge potential would be expected along York, Mill, Richie, Nash, and Cyrus Creeks (Figure 6-2). Although concealed below the Napa Valley Floor, it is likely that the two exposures are connected at depth. It is expected that much of the water recharged through these two exposures eventually reaches the aquifer units of the Napa Valley Floor and flows to the south.

Another significant tuff exposure occurs to the east of the MST, which is discussed in depth in a later section. Other isolated exposures are found throughout the western portion of the county, including one in the Western Mountains along Redwood Creek, which may significantly influence local groundwater conditions. Additional local recharge occurs in the various alluvium filled valleys in the eastern portion of the county. The most significant area of groundwater recharge for the entire county occurs along the Napa Valley Floor in the Calistoga, St. Helena, Yountville, and Napa Subareas.

6.3.1 Napa Valley Floor

Groundwater recharge to the alluvium of the Napa Valley Floor (Calistoga, St. Helena, Yountville, and Napa Subareas) occurs by infiltration of precipitation, percolation from streams/rivers, and subsurface inflow from the surrounding subareas (**Figure 6-2**). The high permeability of the alluvial sediments permits precipitation and surface water to readily infiltrate and recharge groundwater throughout the majority of the valley. These high permeability soils combined with the large volume of water that flows through the Napa River create the potential for significant recharge to occur.

According to Faye (1973), this potential is restricted by high groundwater levels around the Napa River. According to the Napa Baseline Data Report (Jones and Stokes; and EDAW, 2005), recharge in the northern Napa Valley occurs primarily from direct infiltration of precipitation, and to a lesser extent, from irrigation and streambed percolation.

Data relating to groundwater inflow to the Napa Valley from surrounding subareas is limited to the MST. Johnson (1977) estimated that outflow from the MST into the Napa Valley was roughly 2,050 acre-feet per year (afy). Subsequently, Farrar and Metzger (2003) estimated that 600 acre-ft/yr of groundwater was entering the Napa Valley from the MST; they noted that the difference between their estimate and Johnson’s closely matches the increase in groundwater pumping in the MST between 1975 and 2000.

6.3.2 Milliken-Sarco-Tulucay

To the east of the MST Subarea a series of tuff exposures occur along Milliken, Sarco, Hagan, and Tulucay Creeks. Milliken, Sarco and Hagan Creeks flow into the MST Subarea where each crosses a large body of Sonoma Volcanics sedimentary deposits. Farrar and Metzger (2003) measured the greatest stream losses (16.5 acre-feet per day (afd)) along Milliken Creek where alluvial fan and Sonoma Volcanics sedimentary deposits overlie a thick tuff deposit. Streambed infiltration was significantly lower in the Sarco and Tulucay Creeks (0.1-1.1 afd), where low permeability diatomaceous deposits are either found in place of or covering tuff deposits.

6.3.3 Carneros

The Carneros Subarea is predominantly low permeability Huichica Formation with only minor tuff and alluvial deposits. The tuff deposits, located along the eastern and westernmost borders of the area are not expected to be significant sources of groundwater recharge, primarily due to their limited size and lack of proximity to surface water. Recharge within alluvial deposits along the Huichica and Carneros Creeks, as well as other nameless tributaries, is a significant source of recharge (Jones & Stokes et al., 2005), although this is most likely restricted by the underlying low permeability Huichica Formation and Sonoma Volcanics. Other sources of recharge may include inflow from the Western Mountains, Napa Valley or infiltration through local concentrations of coarse-grained materials within the Huichica Formations. More data would be necessary to determine where and to what extent recharge is occurring within the Carneros Subarea.

7 SURFACE WATER GROUNDWATER INTERACTIONS

7.1 Napa Valley Groundwater Levels

The nature of interactions between groundwater and surface water depend largely on the gradient for water flow between groundwater and surface water systems. Water flows from higher elevations to lower elevations. Groundwater elevation contours represent lines of equal groundwater elevation and are independent of ground surface topography. Contours of groundwater elevation provide a snapshot of the direction and relative magnitude of the groundwater flow gradient. If the groundwater system depicted on a contour map exists in an unconfined condition (i.e., at atmospheric pressure), as is expected in the widely distributed shallower alluvial deposits in Napa Valley, the groundwater elevation contours also represent the water table elevation. Characterizing the relationship between surface water elevations and groundwater elevations is important for understanding the nature of groundwater-surface water interaction. In an unconfined groundwater setting, groundwater and surface water will interact and exchange water according to the elevation gradient between these water bodies. To evaluate this relationship, elevations along surface waterways in the Napa Valley area were compared with groundwater elevations.

Previously published groundwater elevation contour maps provide a visual representation of historical conditions covering approximately 60 years between 1949 and 2008. These historical interpretations serve as a basis for comparing flow directions and gradients over different time periods. The 1949/1950 contours represent conditions during the early era of groundwater development in Napa Valley, while subsequent contour maps represent periods of increasing groundwater development and extraction. This report includes groundwater elevation contours for Napa Valley in Spring 2010, as an update to previous LSCE efforts (LSCE, 2011a) and as the basis for initial comparisons of groundwater-surface water interactions.

In addition to providing updated groundwater elevation contours, this report also evaluates available information about the construction of wells where groundwater level measurements were recorded in Spring 2010. This evaluation is important to ensure that groundwater elevations represent the conditions within a single unit of the aquifer system.

7.1.1 Groundwater Elevation Contours

Groundwater elevation contours are derived from available water level measurements made in wells. As a result, the accuracy of interpretations in groundwater elevation contours depends on the spatial distribution and accuracy of water level control data points. Spring 2010 groundwater level measurements were available from 30 monitored wells in Napa Valley, excluding the MST subarea. Sixteen of the measured wells are in the current Napa County groundwater monitoring network, which is monitored semi-annually while four additional wells are monitored monthly by DWR. Water level data for the remaining 10 wells are from regulated groundwater monitoring sites included in the SWRCB GeoTracker network. The total number of wells with available groundwater level data for Spring 2010 was down from 45 in 2008. **Figure 7-1** shows the locations of groundwater elevation data points used in generating the Spring 2010 groundwater elevation contours.

Groundwater elevation contours are developed from the available depth to water records from the 30 available wells. Prior to interpolating groundwater elevations across the valley, depth to water values were converted to groundwater elevation values by subtracting the measured depth to water from the reference point elevation at each monitored well. In this way the depth to water measurements were related to mean sea level as a standard point of reference. The resulting groundwater elevation values at each well were used to interpolate groundwater elevation contours throughout the Napa Valley Floor. Measured groundwater levels used in contouring generally represent conditions in the Napa Valley alluvium; therefore, mapped bedrock outcrop areas were excluded from the contouring process.

Interpreted groundwater elevation contours for Spring 2010 and Spring 2008 are shown in **Figures 7-1 and 7-2**, respectively. The direction of groundwater flow is perpendicular to the contour lines. Groundwater elevation contours for Spring 2010 appear similar to those developed by LSCE for Spring 2008. Contours during both time periods show a generally southeasterly to east-southeasterly groundwater gradient paralleling the valley axis from Calistoga to Yountville with similar groundwater elevation ranges. Groundwater elevations in Spring 2008 and 2010 ranged from above 300 feet near Calistoga to less than ten feet along the Napa River in southern areas of the City of Napa. In the southwestern quadrants of the St. Helena and Yountville Subareas and eastern portions of the Napa Subarea, Spring 2010 contours show a gradient for groundwater flow that is more perpendicular to the valley axis generally from the valley edges towards the Napa River. These areas have a greater density of groundwater elevation data, which improves the accuracy of interpreted groundwater elevation contours in the area. Both the accuracy and extent of the groundwater elevation contours could be improved with an expanded groundwater monitoring network of aquifer-specific wells, as previously recommended (LSCE, 2011a). Consistent with those recommendations, Napa County is embarking on activities to expand the countywide groundwater monitoring network (LSCE, 2013).

Some form of well construction information is available for 18 of the 19 non-regulated monitored wells used to create the Spring 2010 groundwater elevation contours. Of these wells, eight include sufficient information to determine the aquifer unit in which the well is completed. Of those eight, only three are completed in the Quaternary alluvium only. The other five monitored, non-regulated wells with a known well completion report all have well screen intervals extending into stratigraphic units below the alluvium, most often into underlying

Sonoma Volcanic units. The regulated monitoring wells used for the contour map are assumed to be completed only in the alluvium, since the purpose of such wells is generally to monitor shallow groundwater at soil and groundwater contamination sites.

7.1.2 Groundwater Elevations Northeastern Napa Subarea

Historical groundwater levels and trends through 2009 are comprehensively discussed in the report on Napa County Groundwater Conditions and groundwater Monitoring Recommendations (LSCE, 2011a). Historical groundwater level declines are described for the MST area and are also noted for the northeastern Napa Subarea, where there has been a 10 to 30 foot decline in water levels over the past 10 years. The geologic cross sections presented in this Report, along with the work described in Section 9, help to identify factors contributing to the observed groundwater level decline in the northeastern Napa Subarea. As shown in LSCE (2011a), there are four pumping depressions that have developed in the northern, central, southern, and northwestern parts of the MST subarea. The latter pumping depression (which is also shown on **Figure 7-1**) extends west of the Soda Creek fault. The currently monitored well located just east of the Napa River and west of Soda Creek fault (i.e., the well that shows a Spring 2010 groundwater elevation of – 7.6 msl) is constructed to a depth of 205 feet and is completed in the Sonoma Volcanics formation. The three nearest monitoring wells located west of the Napa River in the northeastern Napa Subarea constructed to depths of 120 feet or less and are completed in the alluvium. These well have shown stable groundwater level trends. The monitoring well in the alluvium that is closest to the well constructed in the Sonoma Volcanics has shown stable water levels since the 1960s.

As shown in Section 5, **Figure 5.7**, there is an offset of the Sonoma Volcanics in the west side of the Napa River where a possible fault is identified. It appears that the extent of the pumping depression beyond the MST subarea may be limited to the northeastern Napa Subarea east of the Napa River. However, there are no currently monitored wells west of the Napa River which are completed in the deeper Tertiary Quaternary sedimentary basin deposits. As described in Section 9 (and LSCE, 2013) additional monitoring locations are recommended in the Napa Subarea.

7.2 Stream Thalweg Mapping

Academic and resource management studies increasingly recognize the importance of groundwater-surface water interactions on the availability and quality of water resources (Winter et al., 1998; Alley et al., 1999; Sophocleous, 2002). As discussed above, water flows from high elevation potential to low elevation potential. The nature of interaction between groundwater and surface water depends largely on the hydraulic gradient between these water bodies. Previous hydrogeologic investigations of Napa Valley, beginning with Faye (1973), identified direct infiltration of precipitation and percolation of surface water as the primary mechanisms for groundwater recharge in the Napa Valley. Faye concluded that groundwater recharge from percolating surface water was greatest where tributaries overly alluvium along the valley margins. In 1972, Faye interpreted that groundwater was discharging to the Napa River and that the river was under net gaining conditions for the study area upstream of Oak Knoll Avenue, at least regionally and on an annual basis. Later, Farrar and Metzger (2003) noted that subsurface inflow to the southern Napa Valley had been significantly decreased by groundwater pumping within the MST.

These previous studies suggest that a strong relationship between groundwater and surface water systems exists in the Napa Valley. Consequently, characterizing the nature of these interactions and responses to hydrologic changes (including variations in annual precipitation and increasing surface water and groundwater use) warrant further attention. The hydrogeologic synthesis and groundwater elevation contours presented previously in this Report provide the foundation for better understanding this component of the Napa Valley hydrologic system.

The stream thalweg represents the path of lowest elevation along the length of a stream or other surface waterway. Determining stream thalweg elevations along waterways in the Napa Valley is an important element in understanding the relationship between surface water and groundwater resources in the area. Comparison of the elevations along the stream thalweg with groundwater elevations provides a general representation with which to evaluate the hydraulic gradient between the groundwater and surface water bodies. This analysis identifies approximate stream elevations based on available elevation data. These stream elevations are referred to as “estimated stream thalweg” throughout this Report.

Mapping of stream alignments and analyses of thalweg elevations were performed for the main stem of the Napa River and 28 tributaries using GIS analyses. Resulting estimated stream thalweg elevations and locations were checked against other readily available data and deemed adequate for characterizing the vertical relationship between groundwater and surface water bodies. However, the thalweg alignment and elevations are approximate and may not be accurate for all purposes. It is important to recognize the limitations of the approach and in the developed data. This approach was developed to estimate stream thalweg elevations across the entire Napa Valley area at reasonable expense. Conducting field surveys of stream thalweg elevation, which would verify the accuracy of this approach, were beyond the scope of this study.

Outputs from this mapping effort included GIS files containing polylines, with points and elevations representing the Napa River and its tributaries. The following description is provided as background on the development of these files and to explain and demonstrate the quality control and checks performed.

7.3 Elevation Data and Stream Alignments

GIS analyses relied on two primary pieces of data: ground surface elevation data for the Napa Valley area and stream alignments for the Napa River and tributaries. During the course of the analysis multiple elevation data sets were utilized and initial stream alignments were refined to produce a final set of stream alignment points with associated elevations.

Initial stream alignments for the Napa River Basin were extracted from an existing data set of stream alignments developed at the former Teague Data Center (TDC) based on USGS 1:100,000-scale topographic maps. TDC stream alignment data contain both named and unnamed streams in Napa County. Only named streams in the Napa Valley area were analyzed in this study. **Table 7-1** lists the named streams included in the estimated stream thalweg analysis. The locations of streams are shown in **Figure 7-3**.

Table 7-1: Napa River Tributaries Included in Estimated Stream Thalweg Analysis

Westside Tributary Streams	Eastside Tributary Streams
Blossom Creek	Garnett Creek
Cyrus Creek	Biter Creek
Ritchie Creek	Bell Canyon Creek
Mill Creek	Moore Creek
York Creek	Chiles Creek
Sulphur Creek	Sage Creek
Bale Slough	Conn Creek
Bear Canyon Creek	Rector Creek
Dry Creek	Soda Creek
Redwood Creek	Milliken Creek
Browns Creek	Sarco Creek
Napa Creek	Murphy Creek
Carneros Creek	Kreuse Creek
	Tulucay Creek
	Suscol Creek

TDC stream alignment data were acquired as geo-referenced polylines. Points were added to the polylines to develop discrete locations for sampling elevation data. A preliminary analysis was done using TDC stream alignments and 30-meter and then 10-meter resolution digital elevation model (DEM) data from the National Elevation Dataset (NED). Thalweg elevations derived from NED DEM data provided reasonable, but very coarse estimates. Comparison of these data with surveyed stream thalweg data for the Napa River obtained from the Napa County Resource Conservation District (RCD) showed reasonable results in some reaches and considerable differences in other reaches. Therefore, other sources of readily available elevation data were reviewed.

Light Detection and Ranging (LiDAR) elevation data collected on February 1, 2003 and available from the National Center for Airborne Laser Mapping (NCALM) were used to refine stream thalweg elevation estimates. These LiDAR data were processed to provide last return data representing bare ground elevation measurements. The resolution of LiDAR points was approximately 1.45 points per square meter, much finer than the 10-meter NED DEM data. The LiDAR survey was not identified as water penetrating and is therefore assumed to represent the water surface where water exits.

TDC stream alignments were used to sample point LiDAR elevation data at approximately 3-foot intervals along stream polylines. Review of resulting stream elevations showed considerable variation in elevation moving from upstream to downstream. Water surface elevation should generally decrease from upstream to downstream; however, initial results based on LiDAR data showed numerous sudden increases and decreases in elevation that were clearly in error. Further review of TDC stream alignments using aerial photographs showed that in many areas, stream alignments were outside stream corridors. Therefore, TDC stream alignments for the Napa River and tributaries were reviewed and redefined. The Napa River alignment was redrawn using a combination of shaded relief maps developed from LiDAR data and aerial photographs (Bing Maps Aerial imagery from www.esri.com). In this way, a polyline more closely following the current Napa River alignment was developed.

Tributaries of the Napa River were re-drawn by analysis of LiDAR data in GIS. This analysis processed the LiDAR data to automatically create a polyline along waterways based on the number of LiDAR data points that contribute to a drainage area. Computational limitations for processing the entire Napa River watershed with the high density LiDAR data prevented using this approach to re-draw the Napa River alignment.

All of the revised stream alignments were used to resample the LiDAR data at approximately 3-foot intervals along stream polylines to create final representations of the estimated thalweg elevation along the length of each stream thalweg.

7.4 Validation of Estimated Stream Thalweg Elevation

Final stream elevation points, based on revised stream alignments and LiDAR data, were reviewed for quality control and compared with surveyed stream thalweg data and other data sources. Direct comparisons of Napa River estimated thalweg elevations were made with surveyed stream thalweg data from the NCRCD. Stream thalweg surveys performed by the Napa County RCD were conducted with a rod and level in May and June of 2007. Survey data included thalweg distance and elevation and cover approximately 13.7 river miles of the Napa River between St. Helena and Napa, from just downstream of Zinfandel Lane Bridge and continuing downstream to Oak Knoll Avenue. Comparisons of surveyed data from Napa County RCD and estimated stream thalweg elevation points developed in this analysis are presented in **Figure 7-4**.

Figure 7-4 illustrates the generally similar trends in estimated stream thalweg elevations based on LiDAR data and digitized Napa River alignment and surveyed thalweg elevations from Napa County RCD. Differences between estimated stream thalweg elevation and survey data were quantified separately for the reach upstream of Oakville Cross Road and downstream of Oakville Cross Road. The average absolute difference upstream of Oakville Cross Road is 3.2 feet. Differences between estimated stream thalweg elevation and surveyed data are greatest at the upstream end of this reach, starting at approximately Zinfandel Lane. Differences in this section average approximately 6 feet. The estimated stream thalweg elevation is consistently higher than surveyed elevation upstream of Oakville Cross Road, perhaps due to LiDAR data measuring water surface instead of stream channel bottom. However, the estimated stream thalweg elevation is not consistently representing Napa River water surface as evidenced by frequent spikes and dips in elevation.

Average absolute difference between the estimated and surveyed stream thalweg elevations downstream of Oakville Cross Road is 2.3 feet. Estimated stream thalweg elevations are generally variable and are higher than surveyed elevations in some sections and lower than surveyed elevation in other parts of this reach. Estimated stream thalweg elevations are higher than surveyed data between Oakville Cross and Cook roads, approximately equal to surveyed data for several thousand feet downstream of Cook Road, and below surveyed data starting approximately 5,000 feet upstream of Oak Knoll Avenue

The variability in elevation of estimated stream thalweg elevations likely indicates LiDAR data are not always representative of water or ground surface. LiDAR data may include riparian canopy elevations, bridges, and other errors. An adjustment to estimated stream thalweg elevations was considered to partially account for these differences and potential errors. However, adjustments were not made because differences were not consistent and adjustments could potentially introduce additional error. Some component of these differences is likely caused by error in the stream alignment.

Estimated stream thalweg elevations for tributaries and other Napa River reaches were reviewed and spot checked with 1:24,000-scale USGS topographic maps to determine if estimated stream thalweg elevations are consistent with topography. The following figures are three examples of estimated stream thalweg elevation for tributaries throughout the Napa Valley area.

Figure 7-5 illustrates estimated stream thalweg elevations for Mill Creek, a small tributary on the west side and northern end of the Napa River. Mill Creek joins the Napa River at an elevation of approximately 250 feet and shows a steep section at approximately 16,000 feet of stream length upstream from the Napa River. The estimated stream thalweg elevations presented in **Figure 7-5** appear smooth compared to those presented above for the Napa River. However, this is a function of the large range of elevations illustrated (y-axis range). Closer review of data show that the same type of variability evident in estimated stream thalweg elevation data along the Napa River also exists in estimates for Mill Creek and other tributaries. This variability is likely caused by LiDAR data that represent canopy returns instead of ground surface or stream water surface.

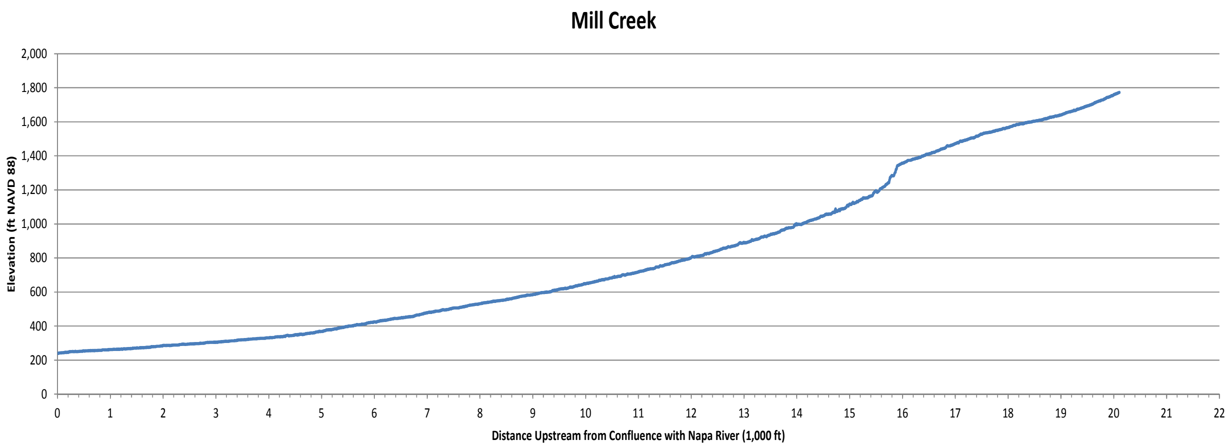


Figure 7-5. Estimated Stream Thalweg Elevations for Mill Creek

Figure 7-6 illustrates estimated stream thalweg elevations for Rector Creek, a tributary on the east side of the Napa River near Yountville. Rector Creek is dammed to create Rector Reservoir. Both the dam and reservoir water surface are clearly illustrated in the estimated stream thalweg elevations. The dam is located at approximately 9,500 feet of stream length and the reservoir water surface is shown from approximately 10,000 to 15,000 feet of stream length.

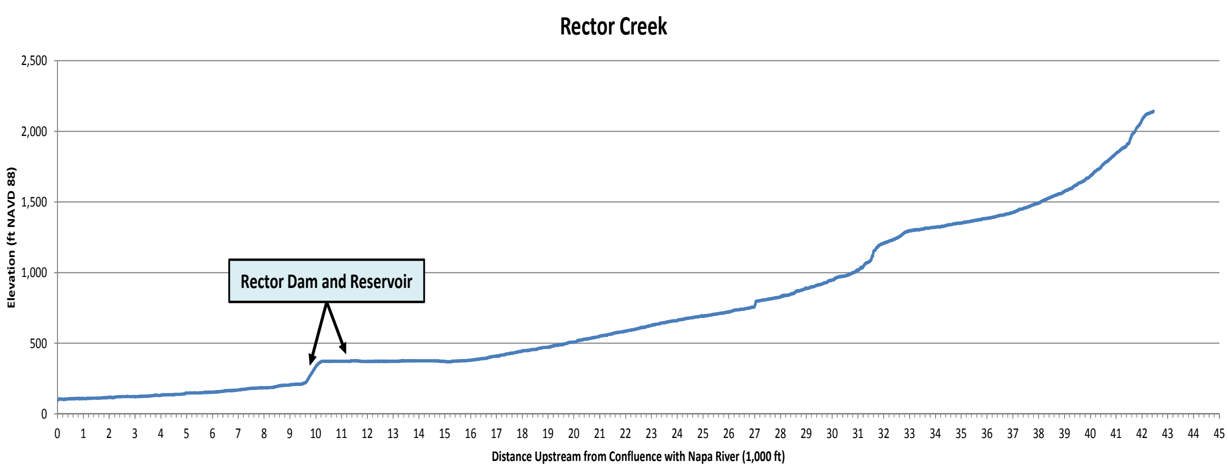


Figure 7-6. Estimated Stream Thalweg Elevations for Rector Creek

Figure 7-7 illustrates estimated stream thalweg elevations for Tulucay Creek, a tributary on the east side of the Napa River near Napa. This is the lower portion of Tulucay Creek only, with the upper portions represented as Murphy and Kreuse Creeks. The variability in estimated stream thalweg elevations evident along Tulucay Creek in **Figure 7-7** is representative of the variability for all tributaries; however, this pattern is more apparent in the profile for Tulucay Creek because of the narrower elevation range shown in the figure.

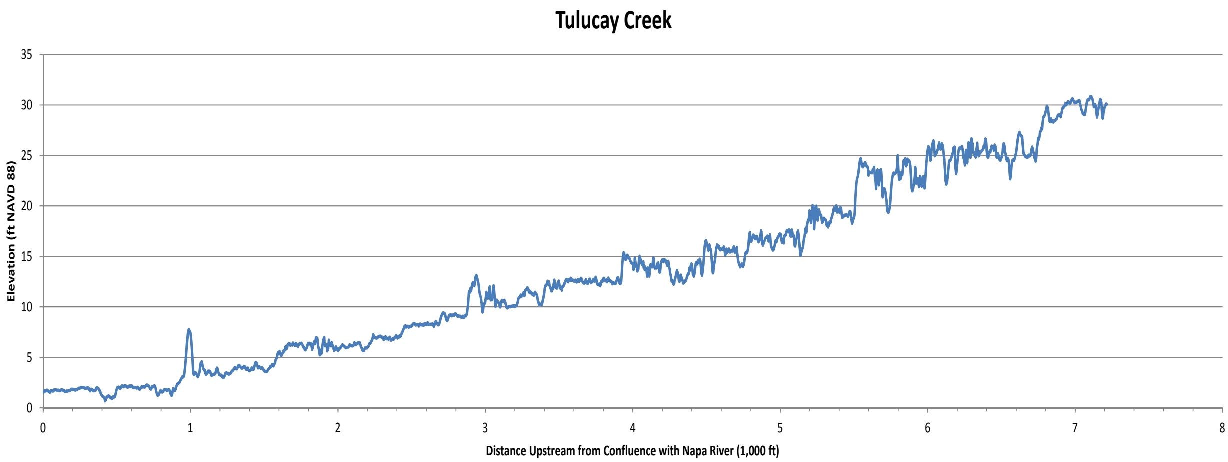


Figure 7-7. Estimated Stream Thalweg Elevations for Tulucay Creek

Based on review of all tributaries, checks against USGS topographic maps, and comparisons presented in **Figure 7-4**, estimated stream thalweg elevations are generally in agreement with surveyed data and topography and provide data useful for evaluating the vertical relationship between the groundwater surface and stream thalweg, which can be used to characterize groundwater-surface water interactions in the Napa Valley area. Estimated stream thalweg elevations show considerable variability over short distances, likely due to canopy returns in the LiDAR data used in the analysis or because of misalignment of the mapped stream with the actual channel.

7.5 Preliminary Evaluation of Groundwater-Surface Water Relationship

The groundwater surface elevation and the estimated stream thalweg elevation data are important components for characterizing the groundwater-surface water relationship in the Napa Valley area. The Spring 2010 groundwater elevation contours provide a snapshot representation of groundwater conditions with which to compare the vertical relationship between the groundwater and surface water. This spatial relationship will assist in developing an understanding of the nature of water exchange between the groundwater and surface water systems. When and where the groundwater surface is higher than the surface water elevation then groundwater is expected to discharge to the surface body. Conversely, when surface water elevation is higher than the groundwater elevation surface water is expected to flow into the groundwater system providing recharge. This analysis focuses specifically on the degree of connectivity between the Napa

River thalweg, as estimated above, and the elevation of the regional groundwater surface of the unconfined alluvial aquifer system of the Napa Valley in Spring 2010. Future expansion of this evaluation using more refined spatial representations of the groundwater surface and at different time periods will greatly improve the understanding of the dynamics in this relationship.

7.5.1 Methods and Limitations

This analysis is based on interpreted groundwater elevation contours for the alluvial aquifer system in Napa Valley for Spring 2010. As discussed above, the Spring 2010 groundwater elevation contour map was produced from 30 monitored wells in the Napa Valley area. The interpreted groundwater elevation has considerable uncertainty and limitations because of the sparse distribution of monitored sites over the mapped area. Furthermore, some of the monitored wells used to interpret the groundwater elevation contours may not be completed exclusively in the alluvial aquifer system.

The estimated Napa River thalweg alignment and elevations, described above, are used here to define the lowest point in the valley for evaluation of the vertical relationship between groundwater and surface water along the valley floor. Before performing this analysis, the estimated stream thalweg elevation data were filtered in order to minimize the variability in estimated stream thalweg elevation data and consistently represent the lowest estimated stream thalweg elevation. This was done by selecting the minimum stream thalweg elevation values within every approximately 60-foot segment of river. This process successfully provides a stream thalweg elevation representation that follows the elevation trends of the original data while consistently representing the lowest thalweg elevation along the river without the larger variability contained in the original data. This data filtering process was also conducted using smaller and larger sample intervals; however, the 60-foot sample interval appeared to best reduce the variability in the data without excessive generalization. The location of each minimum value was preserved along the thalweg alignment and assigned to a thalweg segment extending to the midpoint between each minimum value. The difference between the groundwater elevation and the estimated stream thalweg elevation was calculated for each stream thalweg segment to evaluate the vertical relationship between the groundwater surface and the thalweg bottom.

A similar depth to water value was calculated using valley-wide LiDAR data for 2003 from NCALM and the Spring 2010 groundwater elevation contours. In this case, the depth to groundwater below the ground surface was calculated throughout the extent of the interpreted groundwater elevation contours for the Napa Valley area.

7.5.2 Results and Interpretations

Figure 7-8 shows the calculated depth to groundwater below the estimated thalweg elevation along the Napa River as interpreted for Spring 2010. Only the calculated depth to groundwater values for portions of the Napa River thalweg located within one mile of a monitored well are symbolized on **Figure 7-8**. Confidence in the calculated depth to groundwater in these segments is greater because the groundwater elevation contours in these areas are more constrained by measured water levels at monitoring sites. The degree of confidence in the interpreted groundwater elevation is less in areas farther from monitoring locations.

Calculated depths to groundwater below the estimated thalweg alignment in **Figure 7-8** are commonly “negative” for Spring 2010 indicating that the interpreted groundwater elevation was above the bottom of the Napa River thalweg. These negative values suggest areas where a direct connection between the water table and the river may have existed in Spring 2010 and where groundwater has the potential to discharge into the stream channel. Positive values suggest areas where groundwater is below the bottom of the Napa River thalweg and where surface flows in the river have the potential to percolate and recharge the groundwater system. These results provide an insight into reaches where a direct connection between the Napa River and the alluvial aquifer are not likely under the conditions documented in Spring 2010. These areas include reaches along the northern boundary of the Napa and MST subareas at the Soda Creek Fault, adjacent to a previously documented area of lower groundwater elevations.

A definitive evaluation of the relationship between the river and groundwater would require accurate data for the river stage (i.e., elevation of water in the river) and more data about depth to groundwater in areas adjacent to the river at the time for which the depth to groundwater is represented. The product of such an evaluation depends greatly on the ability to accurately interpret groundwater levels throughout the valley. As discussed above, an expanded groundwater monitoring network would provide data for a more refined interpretation of the groundwater surface. Compiling and analyzing the necessary data for more detailed evaluations is beyond the scope of the current study but could be addressed in future water resource investigations in the Napa Valley.

Figure 7-9 shows the calculated depth of groundwater below the ground surface in the Napa Valley for Spring 2010. As with the calculated depth to groundwater values along the Napa River thalweg, the groundwater elevation contours in Spring 2010 were interpreted with limited well control (wells in the groundwater level monitoring program with known well construction information) and, therefore, calculated values in many areas of the valley have great uncertainty. Calculated depth to groundwater values are negative in parts of the valley (i.e., the computed groundwater depth is above the ground surface). Generally, these values occur in areas where the interpreted groundwater elevation contours are not constrained by actual water level measurements (no well control). Although negative depth to groundwater values are possible, such widespread shallow water table conditions (water table at or above the ground) have not been reported in the area. Because of the uncertainty of the interpreted groundwater elevation contours the negative depth to water values are not shown in **Figure 7-9**.

A review of depth to water values in the LiDAR-derived data set and the measured depth to water values in monitored wells shows consistent values between the two data sets. This suggests that these data represent actual conditions in areas where measured data exist; however, beyond these control points the data are more uncertain. Consequently, the calculated depth to groundwater values shown in **Figure 7-9** should be interpreted with consideration of the degree of confidence in the calculated values throughout the area. The degree of confidence in these calculated values is highest near monitoring well locations and decreases with distance away from such well control. Despite the great uncertainty in the data in parts of the valley, depths to groundwater (both measured and calculated) show generally shallow groundwater throughout much of the valley, particularly in the northern end of the valley. Areas where calculated depth to water is negative generally coincide with areas of the valley lacking sufficient monitoring site density. The calculated depths to groundwater appear to be reasonably represented in the Napa Subarea because this area has the greatest density of monitored sites, particularly along the lower elevation eastern edge.

8 GROUNDWATER RECHARGE

8.1 Estimating Groundwater Recharge (With Root-Zone Water Balance)

8.1.1 Overview

Updating the hydrogeologic conceptualization and characterization of conditions in Napa County involves refining understanding of the hydrologic processes for groundwater storage and movement, particularly in the aquifer system underlying the main Napa Valley Floor. These processes involve many complex pathways at many different time scales. A key County General Plan goal (Napa County, 2008) is to "Conserve, enhance and manage water resources on a sustainable basis to attempt to ensure that sufficient amounts of water will be available for the uses allowed by this General Plan, for the natural environment, and for future generations." Construction of a water budget, also known as a water balance, is a tool scientists can employ to assess the quantity of groundwater in storage. A conceptual illustration of the components of a water balance in a watershed is shown in **Figure 8-1** (figure from Healy et al., 2007).

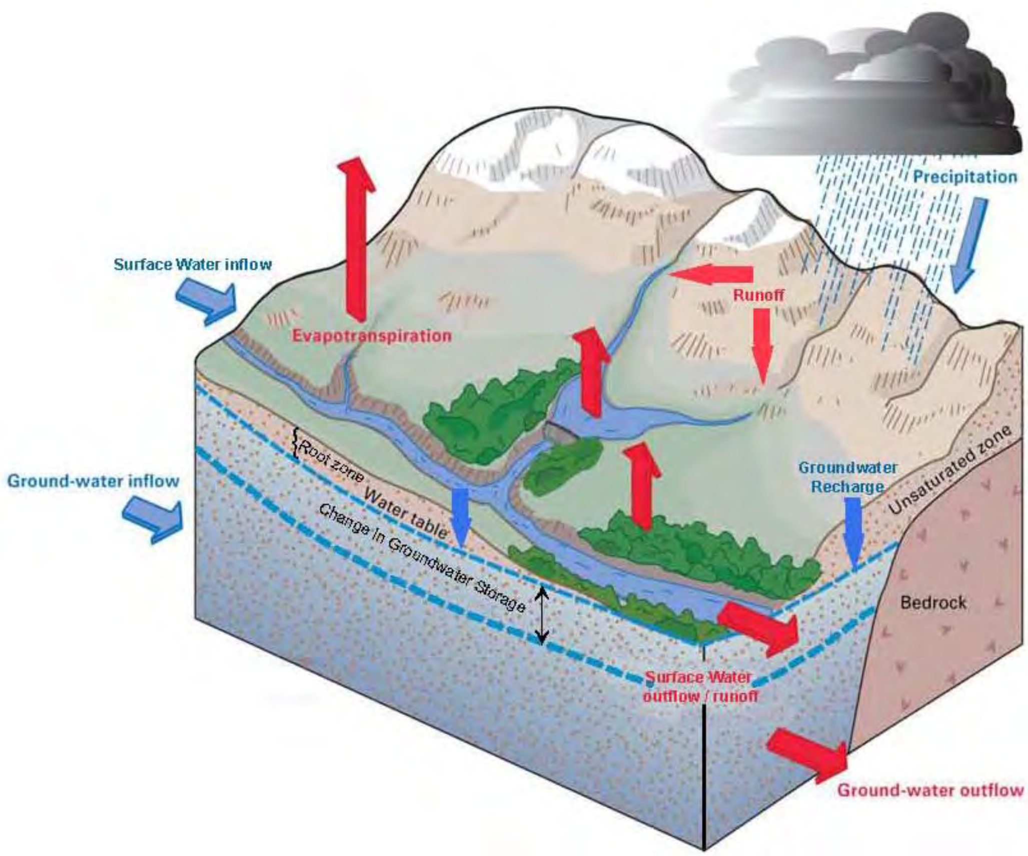


Figure 8-1. Conceptual Diagram of a Watershed Water Balance

A water balance can be used to observe how the quantity of groundwater in storage may vary over time. This tool relies upon a defined accounting unit of volume, for example a groundwater basin or other hydrologic unit of analysis. Measurements of water flowing into and out of the defined unit are used to determine the change in water storage. In the simplest form, the equation for this is:

Inflows – Outflows = Change in Storage

Typical Inflows and Outflows are summarized below (DWR, 2003):

Inflows

- Natural recharge from precipitation;
- Seepage from surface water channels;
- Intentional recharge via ponds, ditches, and injection wells;
- Net recharge of applied water for agricultural and other irrigation uses;
- Unintentional recharge from leaky conveyance pipelines; and
- Subsurface inflows from outside basin boundaries.

Outflows

- Groundwater extraction by wells;
- Groundwater discharge to surface water bodies and springs;
- Evapotranspiration; and
- Subsurface outflow across basin or subbasin boundaries.

Calculating change in storage using data for each inflow and outflow component provides the best approximation of the change in storage. A simple way of estimating the change in storage in a basin is through the determination of the average change in groundwater elevations over the groundwater basin for a period of time. This change in water levels is then multiplied by the area overlying the basin and the average specific yield (in the case of an unconfined aquifer system, or storativity in the case of a confined aquifer system). Change in groundwater levels is best determined over a specific study period that considers different water year types (wet, normal, dry, multiple dry years), but it is common for shorter time periods (e.g., one year's spring to spring groundwater elevations) to be used. This simplistic approach to calculating a change in storage does not provide an indication of the total volume of groundwater storage or the storage available for use. Rather, this computation provides a "snapshot" perspective of short-term trends. The quick calculation should only be considered as an indicator; a more complete groundwater balance evaluation is much preferred (e.g., groundwater flow model). For example, if stresses on the aquifer system induce additional surface water infiltration, the change in groundwater storage may not be apparent (DWR, 2003).

Groundwater recharge is a key component when assessing the water budget of a groundwater basin. Understanding recharge and other fluxes is important in evaluating groundwater conditions and understanding the effects of land development on groundwater resources. This study included characterizing groundwater recharge with an emphasis on the Napa Valley Floor. The groundwater recharge process begins in the shallow soil column when precipitation or applied water infiltrates below the ground surface. At shallow depths within the plant root zone water is consumed by plant evapotranspiration and can also be stored as soil moisture. When soil moisture exceeds its holding capacity, water percolates below the root zone as groundwater recharge. If plant consumptive needs are met and soil moisture storage is below its holding capacity, infiltrated water is stored within the root zone.

8.2 Root-Zone Water Balance

Groundwater recharge can be estimated based on a mass balance analysis of the root zone to estimate the amount of groundwater recharge occurring below the root zone. Flux terms for the root-zone water balance include precipitation (P), runoff (RO), evapotranspiration (ET), recharge (R), and change in soil moisture storage (ΔS). The root-zone water balance expression can be written as:

$$P - RO - ET - R = \Delta S \qquad [1]$$

Figure 8-2 illustrates the components of the root-zone water balance.

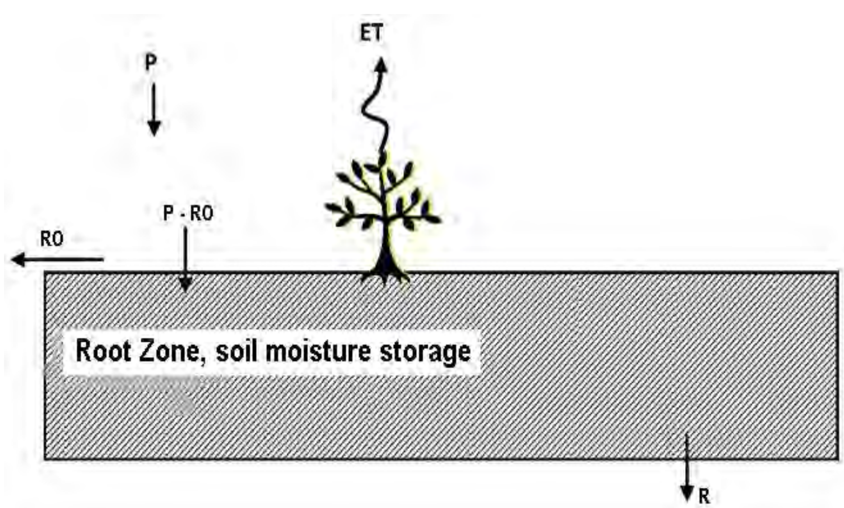


Figure 8-2. Conceptual Diagram of the Water Balance within the Root Zone

Infiltration is defined as precipitation minus runoff and is implicit in the root-zone water balance expression [1]. The root-zone water balance can also be expressed to solve for recharge as R = P – RO – ET – ΔS. Although this expression shows a solution for groundwater recharge with respect to the root-zone water balance, the estimations of groundwater recharge derived as part of this study are based on methods of calculating recharge from physical processes within the root zone. Instead, this analysis calculates groundwater recharge using three physical processes models as a function of ending soil moisture storage and soil texture parameters. Change in soil moisture storage (ΔS) becomes the closing term. A spreadsheet, hereinafter referred to as the root-zone water balance model, was developed on monthly time-steps to calculate this root-zone water balance in the Napa Valley area and is described in detail in the following sections.

8.3 Root-Zone Water Balance Model

The root-zone water balance model uses data from various sources described below to solve the water balance expression [1] within the root zone on a monthly time-step for each of nine gaged watersheds within the Napa Valley area. Land use is an important component in the model and is used to derive a number of the model parameters. Therefore, the root-zone water balance model performs most calculations by land use category within a watershed. However, infiltration is calculated as the difference between precipitation and runoff. Streamflow gage data are a valuable resource for quantifying runoff and were used in this analysis to represent the runoff component of the root-zone water balance. The limited availability of data from gaged streamflow locations precludes developing a more spatially distributed estimate of recharge using this method. Because streamflow as measured at a gage is an aggregate for the upstream drainage area, infiltration is assumed to be uniform throughout each gaged watershed and across all land use categories.

Water balance calculations in the model are made by land use category on a volumetric basis for the acreage of each land use. Calculations are made monthly in the following sequence:

1) Infiltration is added to the end of previous month soil moisture storage
2) ET is calculated based relationship between potential evapotranspiration (PET) and soil moisture storage from Step 1
3) ET is subtracted from soil moisture storage from Step 1
4) Recharge is calculated using soil moisture storage from Step 3
5) Recharge is subtracted from soil moisture storage from Step 3
6) End of month soil moisture storage is soil moisture storage from Step 3 minus recharge and becomes starting soil moisture storage for the next month.

Results in the root-zone water balance model are summed by land use category within a watershed to develop monthly values of groundwater recharge, ET, and change in soil moisture storage. This method estimates monthly groundwater recharge by accounting for changing hydrologic processes within the root zone as they occur at a monthly time step and root-zone soil moisture storage conditions are carried over from month to month. However, precipitation, runoff, and infiltration are calculated at the watershed level only. Because of this limitation in the spatially explicit nature of the model inputs, the resulting groundwater recharge estimates are aggregated at the watershed level.

Modeling groundwater recharge in the Napa Valley using a root-zone water balance method, where hydrologic processes are aggregated at a watershed level, provides a way to estimate groundwater recharge without as great a need to quantify other hydrologic components. The root-zone water balance model explicitly represents many of the physical processes occurring within a given watershed, including precipitation, runoff, evapotranspiration, storage in the root zone, and outflow. Implicit in the root-zone water balance model is a representation of surface water diversions for irrigation. Surface water diversions reduce watershed outflow at the outflow stream gage. Infiltration into the root zone is calculated as the difference between precipitation and outflow. Therefore, reductions in outflow tend to increase infiltration, producing the same effect as diversion and application of surface water for irrigation.

The root-zone water balance model does not correctly account for the location of the applied water in that it assumes infiltration is constant throughout the watershed. The root-zone water balance model likely overestimates infiltration in native vegetation areas in some months, resulting in increased ET from those areas, while underestimating infiltration in agricultural areas and decreasing ET. These errors help to offset each other at the watershed level, but are not expected to completely balance out.

Groundwater pumping and ET of applied groundwater are not represented in the root-zone water balance model. The root-zone water balance model was developed to estimate recharge at the watershed level and is not applicable for estimating demand for total applied water or groundwater pumping.

Although streamflow gage data were used to represent runoff in this study, it is important to recognize that streamflow gage data represent outflow from a watershed as a composite of surface runoff processes and subsurface flows discharging to the stream. Streamflow measured at watershed gages was not differentiated into surface runoff and subsurface discharge components in this analysis. Consequently, the groundwater recharge estimates developed in this study represent groundwater recharge values in excess of outflowing surface and subsurface discharges. In this study, runoff within a gaged watershed is represented by the total outflow past a streamflow gage located at the bottom of the watershed.

The root-zone water balance model applied in this study includes several assumptions. Two of the primary assumptions are that land use data used are representative of the time period being analyzed, and surface water used for irrigation is diverted and reapplied within the same gaged watershed.

8.4 Physical Processes

Time-series of flux terms identified in the water balance expression [1] are necessary to estimate recharge. Flux terms can be either observed data or calculated values based on mathematical representations of physical processes. Steps taken in the development of each model input term are discussed in sections that follow:

Precipitation (P)

Precipitation is a prepared input to the root-zone water balance model based on spatially distributed data from Parametric-elevation Regression on Independent Slopes Model (PRISM). The methods for preparing these data are further discussed in the Data Development section.

Runoff (RO)

The root-zone water balance expression represents fluxes within a defined area where inputs and outputs can be evaluated. For this analysis, the Napa County study area is divided into contributing areas or watersheds above measured streamflow gages within the County. In the water balance expression [1], runoff is the amount of precipitation that does not infiltrate below the ground surface and flows over the ground surface and out of the watershed. Streamflow gage data from the USGS were used in this analysis to represent watershed outflow which comprises the process of surface runoff and subsurface discharges to the stream.

Infiltration (I)

Infiltration is equal to the difference between precipitation and runoff (I = P - RO).

Evapotranspiration (ET)

Evapotranspiration is water loss through the combination of land surface evaporation and plant transpiration. Potential evapotranspiration (PET) represents the maximum volume loss when sufficient moisture is available in the soil column. PET is estimated in this analysis using a crop coefficient to relate PET to a reference evapotranspiration (ETo). Water stress reduces the PET for a given crop when plants are unable to extract enough moisture from the soil to fully meet PET. The water balance model incorporates water stress with the use of a water stress coefficient. A water stress coefficient is calculated each month as a function of available soil moisture. When the previous month's soil moisture storage plus infiltration exceeds 50% of field capacity (field capacity is the amount of water held in the soil that does not drain under gravitational forces), full land use PET is used in the root-zone water balance (DWR, 2012). Otherwise, a reduced PET is computed and used in the root-zone water balance.

Groundwater Recharge (R)

For comparison, three different physically based methods were used to estimate groundwater recharge: Van-Genuchten Mualem model (VGM), Campbell's model, and percent over field capacity. All three methods calculate groundwater recharge as a function of soil moisture storage and soil textural properties.

In terms of soil characteristics, the VGM model calculates groundwater recharge as a function of saturated hydraulic conductivity (ks), total soil porosity (η), soil moisture storage (θt), and pore-size distribution index (λ). Campbell's model calculates groundwater recharge as a function of saturated hydraulic conductivity (ks), total soil porosity (η), and residual water content. Details of the VGM and Campbell's model for calculating groundwater recharge are described in DWR's theoretical model documentation for the Integrated Water Flow Model (IWFM) demand calculator. This documentation is available on DWR's website at:

http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/IDC/IDCv4_0_226/downloadables/IDCv4.0_Documentation.pdf

The percent over field capacity method calculates groundwater recharge as a function of field capacity and soil moisture storage. Field capacity is defined as the amount of water held by capillary forces in the soil that does not drain under gravitational forces (Charbeneau, 2000). Field capacity is typically defined in units of length per unit of soil depth. Specifically, at any time-step when soil moisture storage exceeds field capacity, groundwater recharge equal to the difference between soil moisture storage and field capacity occurs.

8.5 Data Development

8.5.1 Precipitation

Daily precipitation gage records were collected from National Climatic Data Center (NCDC) CD-ROM product (NCDC, 2010). Daily records were aggregated into monthly depths and quality-control checked by comparison with other available sources such as DWR's California Data Exchange Center (CDEC) records. Available precipitation records and their period of record are summarized in **Table 8-1**. Values for "Data Completeness" quantify the percent of daily data available from NCDC for the period of record. Most missing data are during summer months when precipitation is likely zero. **Figure 8-3** identifies the locations of precipitation gages in Napa County with available NCDC data.

Table 8-1. Available Precipitation Gage Data

Gage Name	Elevation (feet)	Start Date	End Date	Number of Years	Data Completeness
Napa State Hospital	35	1-Feb-1917	31-Dec-2009	93	99.6%
St Helena	225	10-Feb-1931	31-Dec-2009	79	94.2%
Angwin Pacific Union	1715	1-Jul-1948	31-Dec-2009	61	97.2%
Calistoga	400	1-Jul-1948	31-Oct-2009	61	98.0%
Oakville 1 WNW	161	1-Jul-1948	30-Jun-1981	33	89.6%
Dutton's Landing	20	1-Nov-1955	30-Jun-1977	22	99.9%
Napa	20	1-Jul-1948	31-Dec-1965	17	98.7%
Napa Co Ap	14	1-Oct-2000	31-Dec-2009	9	100.0%
St Helena 4 WSW	1780	1-Jul-1948	16-Nov-1956	8	99.9%
Yountville	95	1-Nov-2002	31-Dec-2009	7	87.0%
Atlas Road	1742	1-Jul-1948	30-Sep-1951	3	97.8%
Oakville 4 SW	1470	1-Jul-1948	30-Sep-1951	3	97.2%
St Helena 6 NE	1001	3-Jul-1948	30-Sep-1951	3	98.3%

The root-zone water balance model requires precipitation data on a monthly basis distributed across the study area. The variability in the available period of record for precipitation gage data and limited spatial distribution of these data points present limitations for use in the model. Methods such as Thiessen Polygon or Isohyetal mapping can be used to create areal distribution and contour maps of precipitation depth. However, the relatively small number of discrete precipitation gages (13) combined with the limited overlap of precipitation records would produce spatially and temporally coarse precipitation contours of the basin. Additionally, these approaches do not capture, in great detail, orographic effects on precipitation. Therefore, an alternate method was used.

Spatially distributed precipitation data developed by the Oregon State PRISM Climate Group incorporates digital elevation models, point measurements of precipitation, and other climatic factors to map precipitation trends. PRISM monthly normal precipitation data for the period 1971 to 2000 at a cell size of 800 meters (30-arcsec) were acquired and used as the basis for developing the temporally distributed precipitation inputs to the water balance model. **Figure 8-4** illustrates the 800 meter (30-arcsec) grid system for the Napa County PRISM data. The

PRISM dataset contains only monthly precipitation depths for a normal year, whereas the water balance model requires a time-series of precipitation.

To accomplish this, the monthly normal precipitation depth for each cell in the PRISM dataset was translated into a time-series of precipitation for each grid cell. The Napa State Hospital precipitation gage contains records from 1917 to 2009 and the PRISM grid cell encompassing this gage was selected as a reference cell. A monthly multiplier was developed for each grid cell in the County by dividing the monthly normal precipitation for the reference cell by each grid cell. Using the precipitation data at the Napa State Hospital, these cell multipliers were used to estimate precipitation for all grid cells in the County. This approach will be referred to hereinafter as the PRISM scaling method. As described, the PRISM scaling method produced monthly time-series data for precipitation from 1917 through 2009 for the entire county at an 800 m (30-arcsecond) grid resolution. The PRISM scaling method is similar to producing monthly isohyetal maps for this period, but at a grid resolution of 800 meters.

8.5.2 PRISM Scaling Method Validation

The PRISM scaling method provided time-series of precipitation for grid cells across the county based on established relationships to the Napa State Hospital precipitation gage. Because of reliance on only one gage, measures were taken to assure the validity and applicability of this approach for other parts of the county.

The PRISM scaling method was validated by comparing NCDC records (observed data) with precipitation estimated using the PRISM scaling method at four different locations: Angwin Pacific Union, Calistoga, St. Helena, and Oakville for the periods of available data between 1971 and 2000. **Figures 8-5 and 8-6** illustrate comparisons of the observed and estimated data conducted for the Angwin Pacific Union and St. Helena precipitation gages. The Angwin Pacific Union gage is located in the northeastern portion of the Napa River Basin at an elevation of approximately 1,715 feet. The St. Helena gage is located in the northern portion of the Napa River Basin with an elevation of approximately 225 feet.

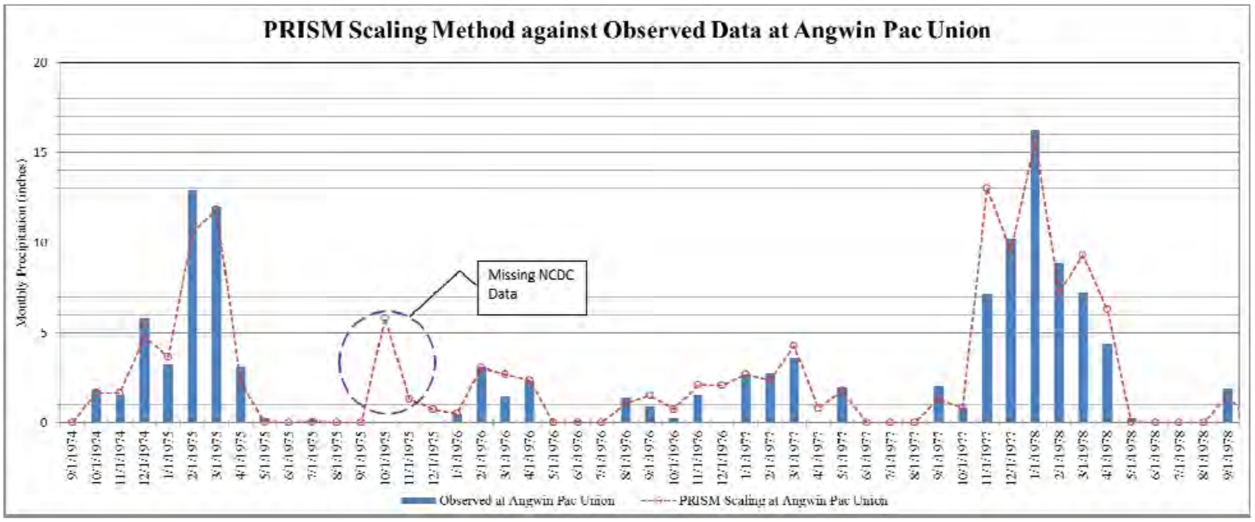


Figure 8-5. PRISM Validation (Angwin Pacific Union Gage - Higher Elevation)

Figure 8-5 illustrates PRISM scaled precipitation plotted against Angwin Pacific Union observed monthly precipitation during a four-year period that includes both wet (1975 and 1978) and dry (1976 and 1977) years. In general, the PRISM scaling method estimates precipitation time-series that are similar to observed data. At the Angwin Pacific Union gage, the PRISM scaled precipitation method tended to slightly overestimate precipitation. The average annual PRISM scaled precipitation at the Angwin Pacific Union gage was seven percent above the observed precipitation for all years with full precipitation data records.

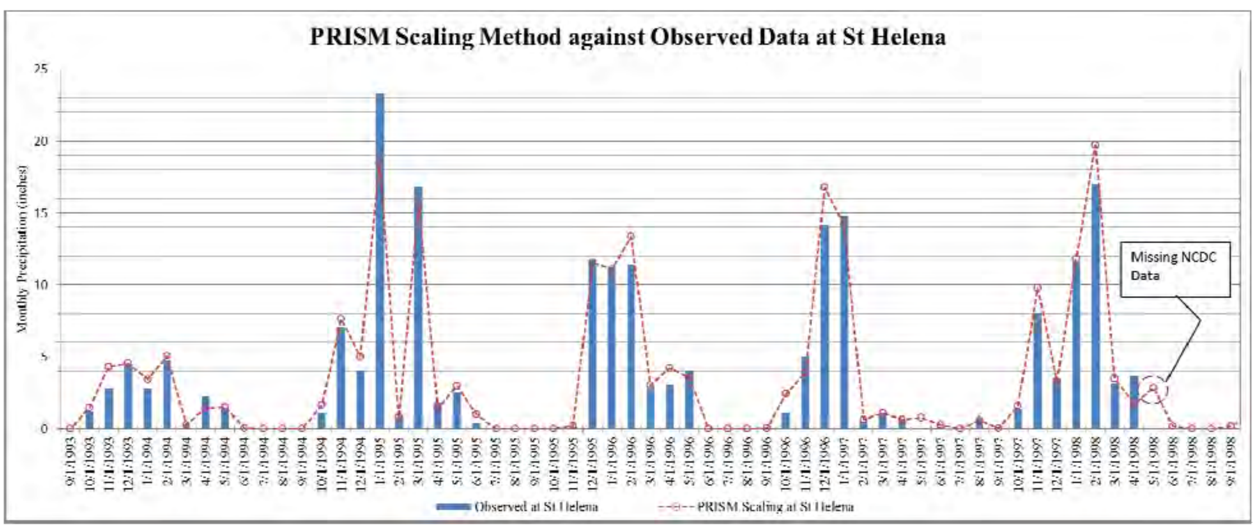


Figure 8-6: PRISM Validation (St. Helena - Valley Floor)

Figure 8-6 illustrates the PRISM scaling method precipitation compared with St. Helena observed monthly precipitation during a five-year period that includes both wet (1995 through

1998) and dry (1994) years. The PRISM scaled precipitation method tended to slightly underestimate precipitation. The average annual PRISM scaled precipitation was three percent below the observed precipitation for all years with full precipitation data records.

Comparisons between the PRISM scaling method and observed data at the other two locations were similar to those at Angwin Pacific Union and St. Helena. These comparisons indicate the PRISM scaled precipitation is a reasonable approximation for precipitation depths across the Napa River Basin.

8.5.3 Streamflow

Streamflow gage data are a valuable resource for quantifying runoff and were used in this analysis to represent the runoff component of the root-zone water balance. However, it is important to note that raw streamflow gage data represent outflow from a watershed as a composite of surface runoff processes and subsurface flows discharging to the stream. Measured streamflow data were not separated into surface runoff and subsurface discharge components in this analysis. Consequently, the runoff component in the water balance model may be overestimated. It is important to recognize this when interpreting the results of this analysis. There are nine streamflow gages identified in the Napa Valley area (**see Figure 8-4**). The upstream contributing areas for each streamflow gage define the watersheds for which the water balance model is applied. The periods of record for the nine streamflow gages are tabulated in **Table 8-2**. Several gaged watersheds are sub-watersheds of other larger, gaged watersheds. For example, the Napa River at Calistoga watershed is a part of both the Napa River near St Helena and the Napa River near Napa watersheds. Sub-watersheds are listed and indented below the encompassing watershed.

Table 8-2. Available Streamflow Gage Data

Stream-flow Gage Name	USGS #	Start	End	# of Years	Watershed Size (mi^2)
Napa River near Napa	11458000	1960	2011	52	218
- Conn Creek near Oakville	11456500	1930	1959	30	55.4
		1971	1975	5	
- Dry Creek near Napa	11457000	1952	1966	15	17.4
- Napa River Near St Helena	11456000	1940	1995	56	78.8
		2001	2011	11	
- Napa River at Calistoga	11455900	1976	1983	8	21.9
Milliken Creek Near Napa	11458100	1971	1983	13	17.3
Tulucay Creek at Napa	11458350	1972	1983	12	12.6
Redwood Creek Near Napa	11458200	1959	1973	15	9.79
Napa Creek at Napa	11458300	1971	1983	13	14.9

8.5.4 Land Use

Land use throughout each watershed where a water balance is calculated is important for several reasons. A primary reason is that different plants use water at different times and rates. Therefore, an estimation of the plant types growing throughout the county is necessary when performing a root-zone water budget. Land use data from DWR, representing surveyed conditions in 1999, were initially used to classify land uses by land cover and crop type (DWR 1999). However, the DWR land use survey data do not differentiate land cover in undeveloped areas, which represent much of the county. To address this limitation, additional land use data were incorporated from the Natural Resources Conservation Services (NRCS). The NRCS data were developed from analysis of satellite imagery and classifying undeveloped areas as forest, shrubland, grassland, and other native categories. Land use data used in the root-zone water balance model were an aggregation of both DWR and NRCS data.

Each of the nine gaged watersheds, outlined according to streamflow gage locations, is partitioned by land use type. A summary of land uses for each watershed is presented in **Table 8-3**. Native vegetation (NV) represents a majority of the land cover in Napa County and is categorized into three types: grasslands (NV Type 1), shrubland and brush (NV Type 2), and forests (NV Type 3). Vineyards are the predominant agricultural crop with typically less than 10 percent of agricultural areas planted in other crops as noted in **Table 8-3**. Therefore, agricultural land uses were categorized into two types for the root-zone water balance model analysis: vineyards and crops, which include all other agriculture.

Table 8-3. Land Use Acreages by Gaged Watershed

	Gaged Watershed								
Land Use	**Conn Creek (ac.)**	**Dry Creek (ac.)**	**Napa Creek at Napa (ac.)**	**Tulucay Creek (ac.)**	**Redwood Creek (ac.)**	**Milliken Creek (ac.)**	**Napa River at Calistog a (ac.)**	**Napa River at St. Helena (ac.)**	**Napa River near Napa (ac.)**
Evergreen Forest	10,700	6,365	2,505	492	2,351	426	4,529	19,390	42,568
Shrubland	11,445	2,345	1,311	1,597	1,055	6,935	3,775	11,820	34,718
Vineyard	3,392	303	1,106	449	826	332	1,376	7,217	27,064
Mixed Forest	4,059	1,056	1,606	1,771	1,114	948	1,195	4,284	12,101
Grassland Herbaceous	3,127	412	1,291	1,405	487	1,070	1,493	3,156	10,416
Developed or Open Space	993	313	375	782	165	434	667	2,378	4,359
Urban	268	62	1,138	1,042	50	639	667	1,904	4,353
Deciduous Forest	362	264	521	111	368	168	144	434	1,309
Open Water	753	0	3	11	2	51	12	121	1,016
Idle	171	24	6	206	6	14	22	124	1,162
Deciduous Fruits	9	7	14	13	4	0	44	87	157
Pasture	102	0	0	37	0	23	0	0	109
Grain and Hay Crops	25	0	1	20	0	4	0	17	180
Woody Wetlands	43	1	5	2	0	9	4	21	151
Herbaceous Wetlands	41	0	0	4	0	1	0	7	85
Almonds	1	0	0	77	0	37	0	0	1
Fallow/Idle Cropland	6	0	1	26	1	12	1	9	45
Citrus and Subtropical	5	0	0	5	0	9	0	5	10

8.5.5 Rooting Depth

Plant rooting depths are associated with the plant's potential to reach infiltrated water in the root zone. The water balance model in this analysis represents processes within the root zone, where water can be stored within soil pores, consumed by plant evapotranspiration, or become recharge to the groundwater system below. These rooting depth values are used to represent root-zone thickness or soil thickness. Soil thickness, in combination with other parameters such as field capacity, porosity, and pore-size distribution determines the soils' ability to hold water and the physical processes of drainage below the soil via groundwater recharge.

The rooting depth for plants is variable and these differences in rooting depth affect the water balance. Land use data were used to interpret rooting depth. Plant rooting depths range from 5 to 10 feet. Root-zone depths for different land uses were obtained from Chapter 11, of the NRCS National Engineering Handbook (NRCS, 1983) and are tabulated in **Table 8-4**.

Table 8-4. Root-Zone Depths

Land Use	Root-Zone Depth (ft)
Water	10
Wetlands	10
Vineyards	5
Idle Lands	5
Developed	5
Crops	5
NV Type 1	8
NV Type 2	8
NV Type 3	10

8.5.6 Soil Textural Parameters

Field capacities were selected for each land use based on values from the University of California's Drought Management website (UC, 2012). Assigned field capacities range from 1.5 to 2.5 inches of water holding capacity per foot of rooting depth and represent values for medium to fine textured soils. **Table 8-5** tabulates the field capacity with their corresponding land use.

Table 8-5. Field Capacities

Land Use	Field Capacity (ft/ft)
Water	0.2
Wetlands	0.2
Vineyards	0.15
Idle Lands	0.2
Developed	0.2
Crops	0.2
NV Type 1	0.2
NV Type 2	0.2
NV Type 3	0.25

An area-weighted approach was applied to soil parameters of porosity (η) and pore-size distribution index values (λ). Parameters were selected from Groundwater Hydraulics and Pollutant Transport (Charbeneau, 2000) and the NRCS SSURGO database (USDA, 2007). Four hydrologic soils groups (HSG) A, B, C, and D were identified in SSURGO. Bookend porosity and pore-size distribution index values from Charbeneau were selected and assigned to HSG A and D. The intermediate HSGs of B and C were assigned an equal increment between the bookend values selected for HSG A and D. The soil textural parameters for each HSG as used in the root-zone water balance model are shown in **Table 8-6**. Porosity and pore-size distribution indices were weighted with HSG percentages for each gaged watershed. The resulting area-weighted soil parameters are tabulated in **Table 8-7**.

Table 8-6. HSG Textural Parameters

HSG	Porosity (η)	Pore Size Distribution Index (λ)	Soil Texture Description
[1]A	0.43	1.68	Sand – Silty Clay Loam
B	0.41	1.15	Sandy Loam
C	0.39	0.62	Sandy Clay Loam
[1]D	0.37	0.09	Clay – Silty Clay

[1]Bookend Values

Table 8-7. Percentage Breakdown of Hydrologic Soils Groups

Gaged Watershed	Hydrologic Soils Group A	B	C	D	Weighted Porosity (η)	Weighted Pore Size Distribution Index (λ)
Tributaries						
Conn Creek	0%	11%	61%	28%	0.39	0.53
Dry Creek	0%	10%	52%	38%	0.38	0.48
Napa Creek at Napa	0%	15%	77%	8%	0.39	0.66
Tulucay Creek	0%	9%	46%	45%	0.38	0.43
Redwood Creek	0%	18%	73%	9%	0.39	0.67
Milliken Creek	0%	30%	21%	49%	0.39	0.52
Napa River						
Napa River at Calistoga	0%	33%	54%	13%	0.39	0.73
Napa River at St. Helena	2%	26%	56%	16%	0.39	0.69
Napa River near Napa	2%	19%	57%	23%	0.39	0.62

8.5.7 Evapotranspiration

Evapotranspiration is collectively the processes of evaporation from ground surfaces and transpiration from plants. The root-zone water balance represents ET as a flux out of the root zone. In this study ET is represented by monthly depth estimates for different land uses. Average monthly reference ET values (ETo) from the California Irrigation Management Information System (CIMIS) Oakville station were used as a basis for calculating PET for each land use. The ETo values from the CIMIS Oakville station appear similar to and representative of monthly and annual values for Zone 8 of the CIMIS reference ETo map for California. Zone 8 encompasses most of Lake and Napa Counties. Average monthly ETo values were multiplied by crop coefficient (kc) for various land uses to determine PET.

Vineyards represent the greatest non-native land use in the Napa Valley area. Deficit irrigation methods are commonly used in growing wine grapes, which are the dominant vineyard type in the Valley. This irrigation method reduces water application in specified periods to control the characteristics of grapes. As a result, the annual ET pattern for deficit-irrigated wine grapes does not follow typical patterns of table grape vineyards. SEBAL (2009) described the effects of deficit irrigation on the ET of wine grapes in the adjacent Russian River Basin. The PET pattern for vineyards used in this study was derived following crop coefficient patterns identified in the SEBAL. Additionally, the SEBAL report also provides estimates of ET for different native vegetation types in the area. These estimates were used to develop PET estimates for the three native vegetation land uses in the root-zone water balance model.

Agricultural land uses other than vineyards represent only a small part of the Napa Valley. Crop coefficients for non-vineyard agriculture and idle lands were obtained from the Irrigation Training and Research Center's (ITRC) Report 03-001 (ITRC, 2003). Crops including deciduous fruit trees, pasture, grain, hay, almonds, walnuts, citrus, and other subtropical trees were identified in the land use survey and were grouped as a single "crops" land use in the model.

The monthly and annual reference ET (ETo) and PET for land uses in the model are summarized in **Table 8-8**.

Table 8-8. Reference Evapotranspiration and Potential Evapotranspiration

Units:	Jan (in)	Feb (in)	Mar (in)	Apr (in)	May (in)	Jun (in)	Jul (in)	Aug (in)	Sep (in)	Oct (in)	Nov (in)	Dec (in)	Ann[1] (in)
ET_O	1.3	1.7	3.5	5.1	6.3	6.8	7.0	6.4	5.1	3.4	1.8	1.3	**49.8**
PET_{Water}	1.1	1.5	2.7	4.1	6.2	7.7	9.3	8.4	6.1	4.0	1.7	1.2	**53.9**
$PET_{Wetlands}$	1.1	1.5	2.7	4.1	6.2	7.7	9.3	8.4	6.1	4.0	1.7	1.2	**53.9**
$PET_{Vineyards}$	0.9	1.0	1.5	1.1	3.0	2.4	1.7	3.3	2.6	2.5	1.1	1.6	**22.5**
$PET_{Idle\ Lands}$	0.1	0.2	0.5	1.0	3.1	2.0	1.4	1.0	0.5	0.3	0.2	0.1	**10.6**
$PET_{Developed}$	0.3	0.4	0.9	1.3	1.6	1.7	1.8	1.6	1.3	0.9	0.5	0.3	**12.4**
PET_{Crops}	0.9	1.6	2.6	4.0	5.5	5.6	5.2	4.8	3.9	3.0	0.9	1.2	**39.2**
$PET_{NV\ Type\ 1}$	0.1	0.2	0.5	1.0	3.1	2.0	1.4	1.0	0.5	0.3	0.2	0.1	**10.6**
$PET_{NV\ Type\ 2}$	0.4	0.5	1.0	1.5	1.9	2.0	2.1	1.9	1.5	1.0	0.6	0.4	**14.9**
$PET_{NV\ Type\ 3}$	0.5	0.7	1.4	2.0	2.5	2.7	2.8	2.6	2.1	1.4	0.7	0.5	**19.9**

[1]Annual totals

8.6 Results and Summary for Root-Zone Water Balance

The following figures illustrate annual water year results for several watersheds for the period of available streamflow gage data. Because streamflow is a necessary input in the root-zone water balance model, the model was applied to each watershed for the period of record of available streamflow data. Most watersheds were analyzed for a period of approximately 10 to 15 years. Two sub-watersheds of the Napa River, upstream of gages near St. Helena and near Napa, were analyzed for 67 and 52 years, respectively.

Annual figures illustrate the values for root-zone water balance terms. Stacked bar charts illustrate how the root-zone water balance model allocates precipitation between all terms, i.e., precipitation = recharge + outflow + ET + change in soil moisture storage. Annual precipitation is illustrated as a line and provides an indication of the relative wetness for any given year. Outflow (surface runoff plus subsurface discharges to stream) is measured as the annual surface flow at the streamflow gage; infiltration is precipitation minus outflow. Fluxes out of the root zone include ET and groundwater recharge with soil moisture changing in response to the balance of water into and out of the root zone. Change in soil moisture storage can be positive or negative. Positive soil moisture storage values indicate that soil moisture storage was greater at the end of the water year than at the beginning because precipitation exceeded outflow, recharge, and ET. Conversely, negative values indicate soil moisture storage decreased during the water year because outflow, recharge, and ET exceeded precipitation. Such years are illustrated in the following figures when the total height of the stacked bars exceeds the precipitation line. This occurs most often during dry years following wet years because existing soil moisture storage is high following a wet year and is depleted over the course of a dry year. Conversely, larger increases in soil moisture storage occur most often during wet years that follow a dry year when soil moisture storage is low and is replenished by precipitation during a wet year. Annual figures illustrate the year-to-year variability in root-zone water balances, including considerable variability in groundwater recharge.

Annual root-zone water balance values represent the sum of monthly results from the root-zone water balance model for each water year (October through September). Results presented in this report are based on root-zone water balance model results using Campbell's method for calculating groundwater recharge, although the results were similar for the three methods of calculating recharge.

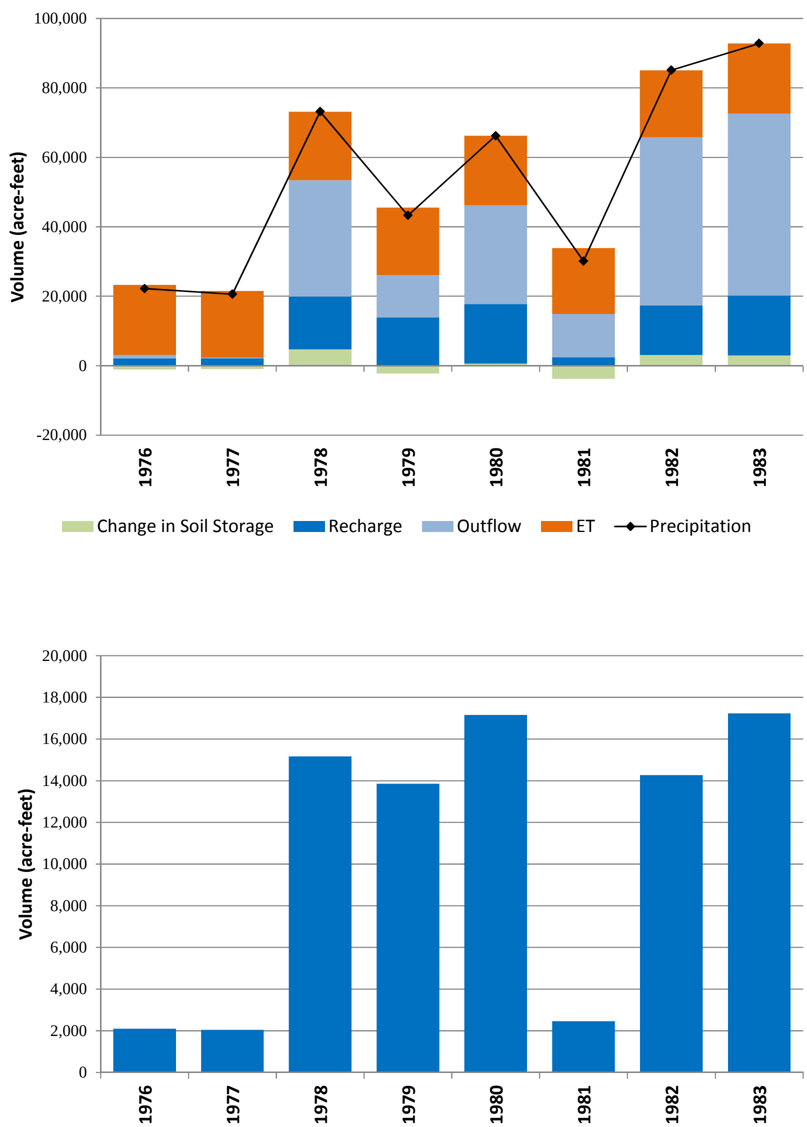


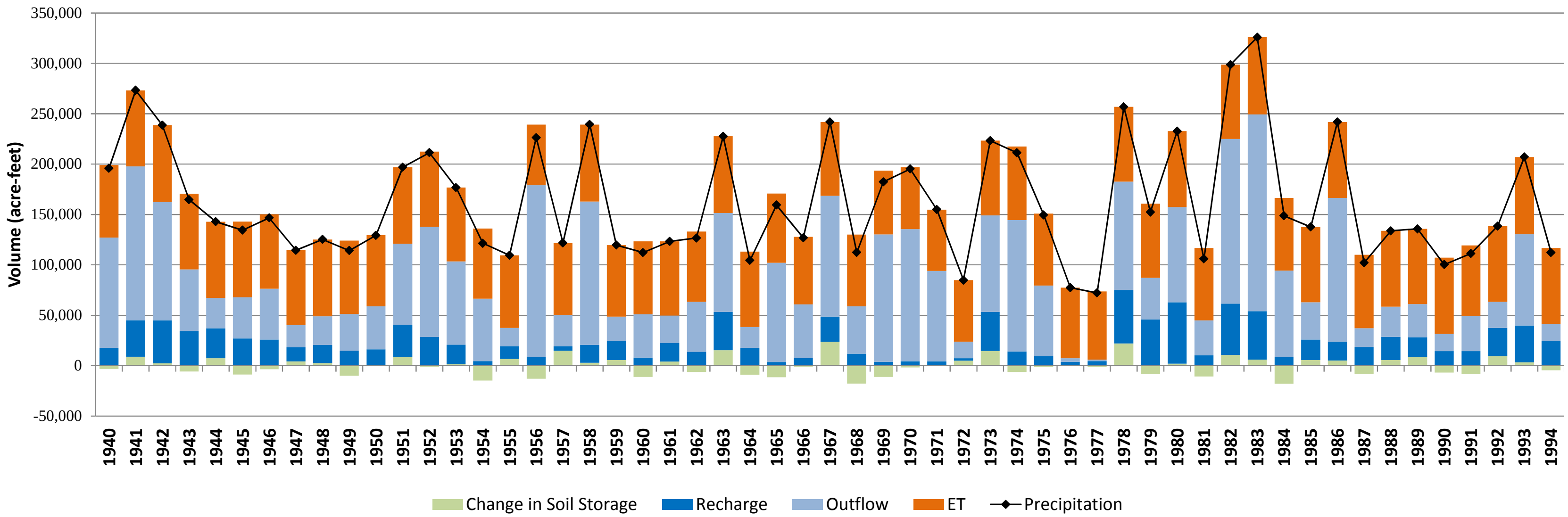
Figure 8-7. Annual Results for Napa River near Calistoga Watershed

Figure 8-7 illustrates annual root-zone water balance model results for the Napa River near Calistoga watershed. This watershed is located at the north end of the Napa Valley and includes developed and undeveloped lands. The streamflow gage near Calistoga was only in operation for eight years, but the period included considerable hydrologic variability, including a very wet year (1983) and very dry year (1977). This variability is evident in the root-zone water balance model results. Measured data and model results indicate large variations in precipitation, outflow, and recharge over this period. However, ET remains fairly constant because land use in the model does not change through time and PET represents typical year conditions. However, PET can be reduced due to water stress in years with low precipitation. In dry years such as 1976 and 1977, measured outflow from the watershed is low and estimated groundwater recharge is also low. In wetter years, groundwater recharge is estimated to be approximately 15,000 acre-feet.

Figure 8-8 illustrates annual root-zone water balance model results for the Napa River near St. Helena. This watershed is also in the northern portion of the Napa River Basin and includes the Napa River near Calistoga watershed. The streamflow gage near St Helena began operation in 1930. **Figure 8-8** illustrates the root-zone water balance for this watershed for the period from 1940 through 1994. **Figure 8-8** also illustrates the annual variability in root-zone water balance terms. During this period, the volume of precipitation varied greatly from less than 100,000 acre-feet to more than 300,000 acre-feet. Similarly, outflow and groundwater recharge vary considerably while ET again remains relatively constant at an annual average of approximately 70,000 acre-feet. Groundwater recharge generally increases and decreases with precipitation. However, although the highest annual precipitation occurred in 1983, the greatest annual groundwater recharge occurred in 1980. Interactions among the timing of precipitation, outflow, soil moisture conditions, and other factors affect the timing and magnitude of groundwater recharge.

Annual root-zone water balance model results for Dry Creek, a watershed located on the west side of the Napa Valley, are shown in **Figure 8-9**. The USGS streamflow gage on Dry Creek has a 15-year period of record and measures outflow from a mostly undeveloped watershed with an area of approximately 11,000 acres. Results from the root-zone water balance model for the Dry Creek watershed show the trends in the annual values for each water balance term and illustrate the dynamic relationship between the root-zone water balance components. For example, during each of the water years 1956, 1958, and 1963 the annual precipitation in the Dry Creek watershed was approximately 50,000 acre-feet; however, the timing and intensity of this precipitation varied. In 1956, approximately 35,000 acre-feet of precipitation were recorded in December and January and much of the precipitation left the watershed as outflow so estimated groundwater recharge for this period was relatively low. In contrast, during water year 1963 considerable early precipitation occurred in October with much less of the water leaving the watershed as outflow, presumably because soils were drier and able to absorb more precipitation during this time. This early precipitation replenished soil moisture storage, which resulted in greater groundwater recharge throughout the remainder of the winter season. The watershed experienced similar precipitation during water year 1958 and the estimated annual groundwater recharge was approximately twice that of 1956 and two-thirds that of 1963.

Figure 8-10 illustrates annual root-zone water balance model results for Tulucay Creek, a watershed encompassing approximately 8,000 acres in the southern end of the Napa Valley. Based on the land use data, Tulucay Creek watershed is the most developed of the watersheds analyzed. The USGS streamflow gage on Tulucay Creek was in operation for 12 years during a period of great hydrologic variability. Results from the root-zone water balance model for the Tulucay Creek watershed resemble trends in results for other watersheds. Recharge was highest in 1978, following two extremely dry years despite precipitation values below those for 1982 and 1983. In 1978, approximately 56 percent of precipitation was classified as infiltration and 44 percent was outflow from the watershed. By comparison, infiltration was calculated to be 32 and 36 percent of precipitation in 1982 and 1983, respectively. The higher infiltration in 1978 resulted in high groundwater recharge in this year.



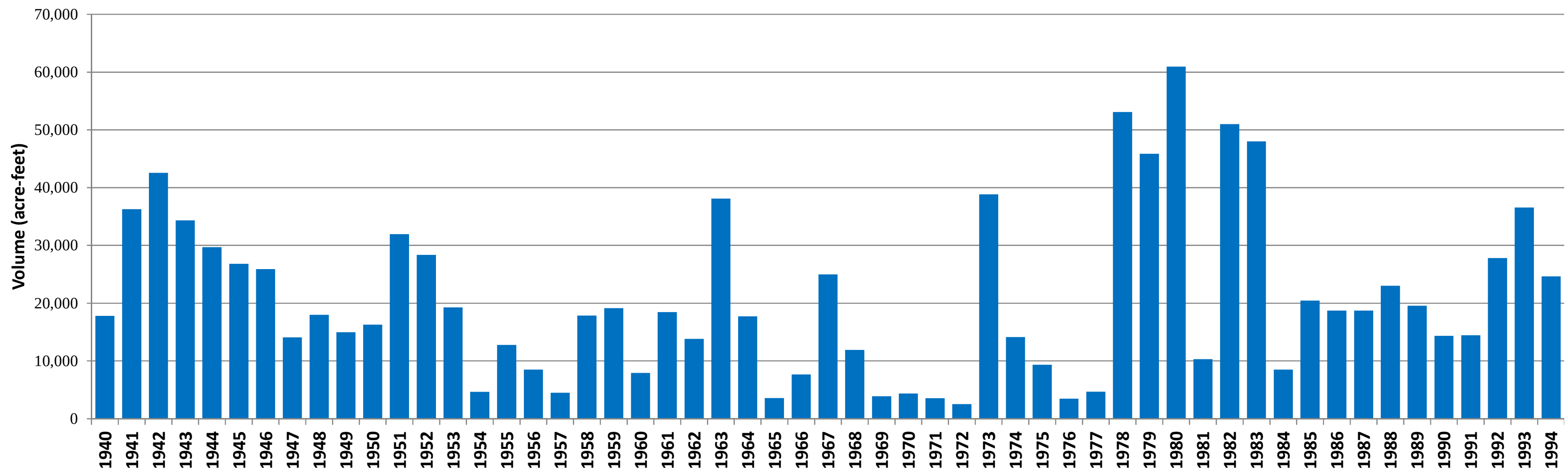


Figure 8-8. Annual Results for Napa River near St Helena Watershed

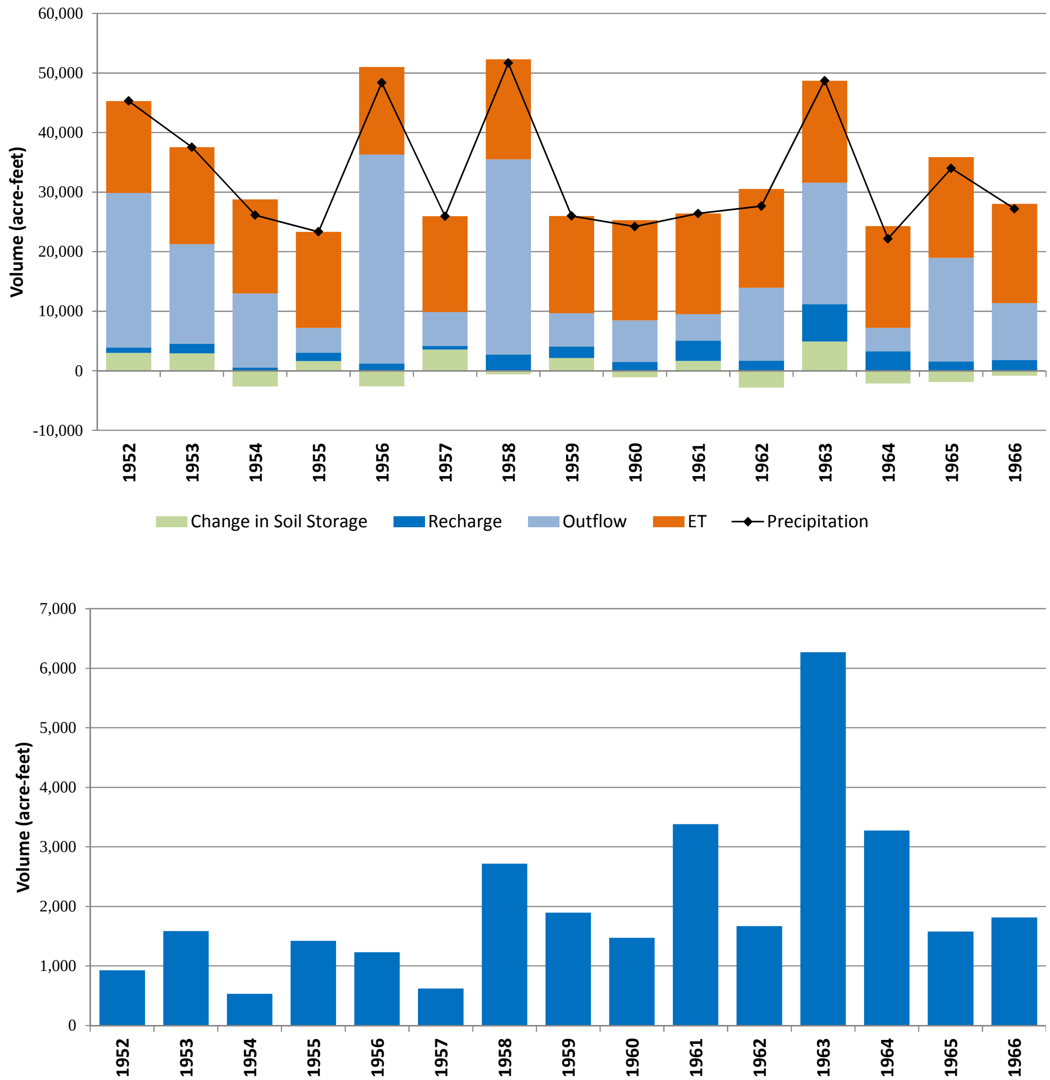


Figure 8-9. Annual Results for Dry Creek Watershed

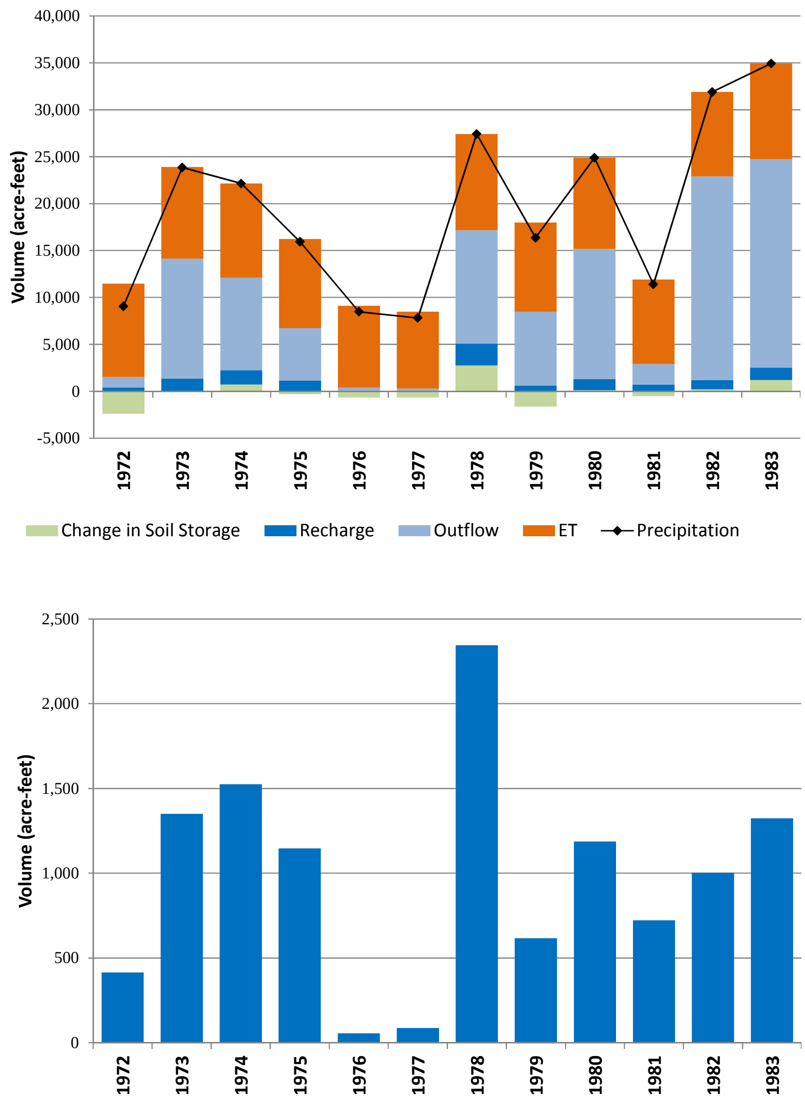
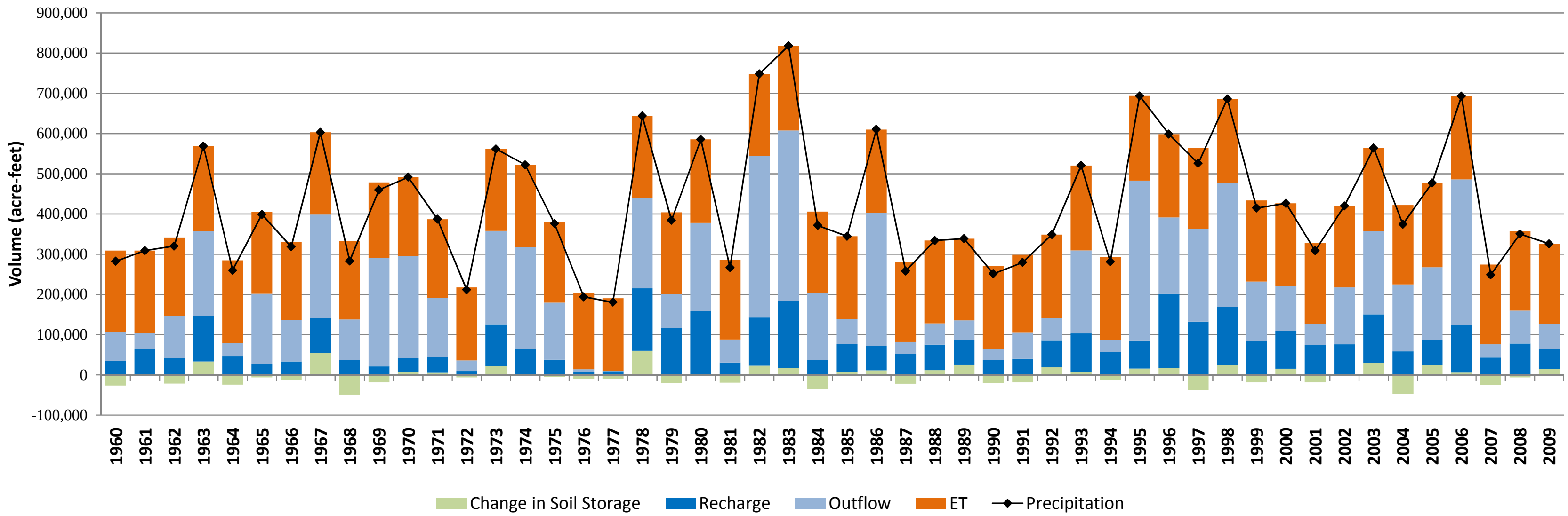


Figure 8-10. Annual Results for Tulucay Creek Watershed

Figure 8-11 illustrates annual root-zone water balance model results for the Napa River near Napa. This watershed is approximately 140,000 acres and includes the Dry Creek, Napa River at St. Helena, Napa River at Calistoga, and Conn Creek watersheds. The Napa River near Napa watershed accounts for approximately 60 percent of the entire Napa River drainage basin. Annual trends in soil moisture storage change and the relationship between years with high precipitation, high infiltration, and high recharge seen in other watersheds are also evident in this watershed.



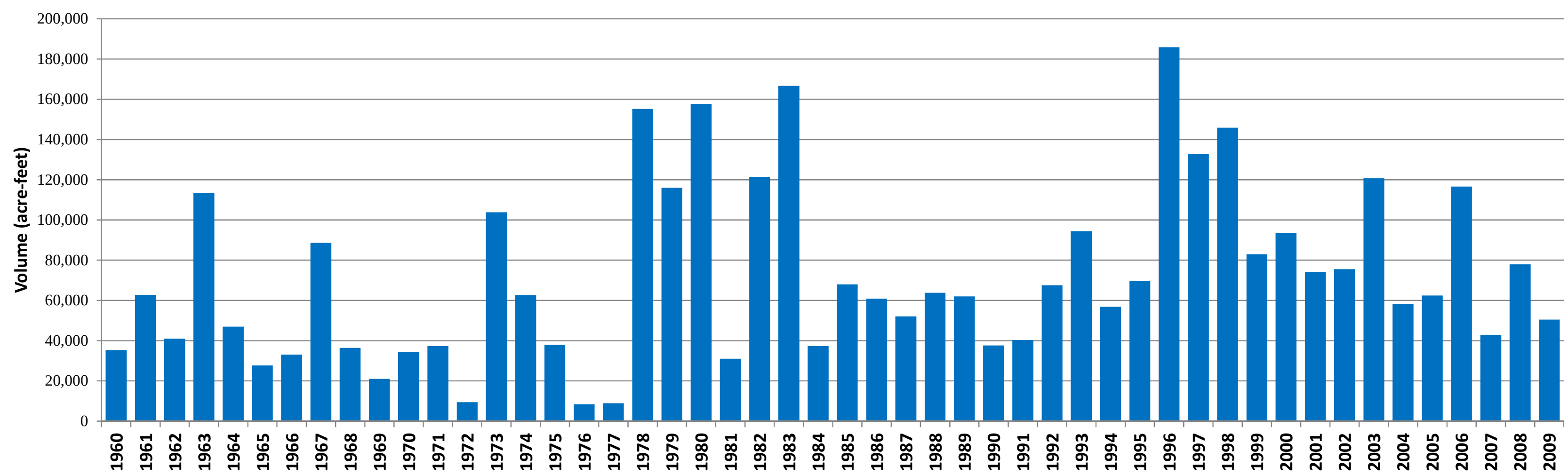


Figure 8-11. Annual Results for Napa River near Napa Watershed

In addition to annual results, monthly results from the water balance model indicate seasonal patterns including increased recharge from November through March when precipitation is higher, increased ET during the spring and summer months, increasing soil moisture storage from October through March and decreasing soil moisture storage from April through September. **Figure 8-12** illustrates the average monthly patterns for the Napa River near Napa watershed. This figure is provided as an example of monthly results of the water balance model to demonstrate that monthly results follow expected seasonal trends.

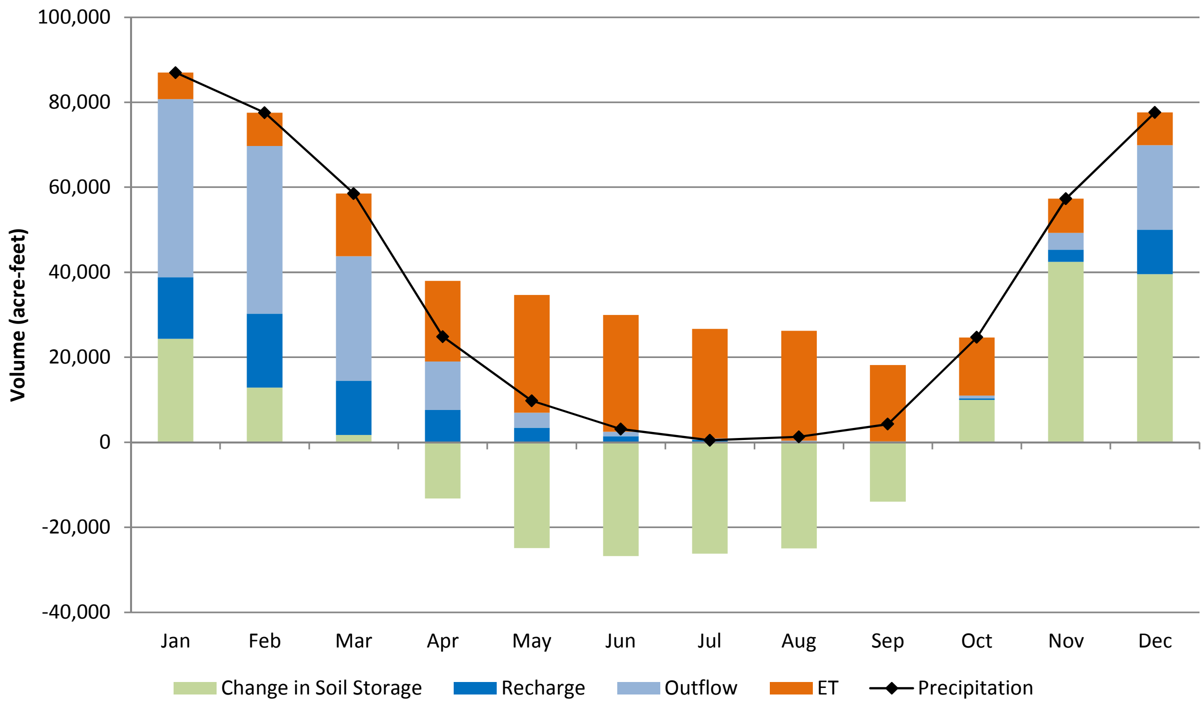


Figure 8-12. Example Average Monthly Root-Zone Water Balance Model Summary for Napa River near Napa Watershed

The average annual root-zone water balance for each watershed is summarized and tabulated in **Table 8-8**. **Table 8-8** is organized by watershed with each watershed listed and indented below encompassing watersheds. For example, Conn Creek, Dry Creek, and Napa River at St. Helena are all contributing watersheds contained within the Napa River near Napa watershed. As illustrated in the preceding figures, groundwater recharge estimates varied considerably from year-to-year and depended largely on timing and magnitude of precipitation. The variability in annual groundwater recharge estimates for the period of analysis are presented in **Table 8-8** as a range of minimum and maximum values. Annual groundwater recharge as a percent of annual precipitation is calculated for each watershed during the root-zone water balance analysis time period. Average annual groundwater recharge as a percent of average annual precipitation is included in **Table 8-8** to represent how recharge fits into the overall annual root-zone water balance for each watershed and provide a means to compare groundwater recharge between watersheds. Estimated groundwater recharge as a percent of precipitation ranges from 5 to 21% in the analyzed watersheds.

Average annual recharge values in **Table 8-9** reflect both the spatial variability of groundwater recharge within the Napa Valley area and the hydrologic variability of the period analyzed. Because of limitations in available streamflow gage data, each watershed was analyzed only for the time period for which streamflow records were available. Because of these unique aspects of each watershed analysis, direct comparisons of average annual recharge between watersheds in terms of absolute volumes are less meaningful. For example, the Napa River at Calistoga watershed analysis was based on eight years of available stream gage data. These eight years include two extreme dry years and four very wet years. Therefore, the average annual recharge for this watershed may appear higher when compared to other watersheds in the basin, but this is at least partially due to the wetter period of analysis. Comparisons of groundwater recharge as a percent of precipitation better account for hydrologic variability that occurs through time.

Note that several watersheds include dams and reservoirs on tributary streams. The largest reservoir is Lake Hennessey on Conn Creek. Results presented in **Table 8-9** for Conn Creek are for only the period prior to construction of Lake Hennessey in 1945. Regulation on other streams was considered insignificant due to the size of the reservoir and because the water budget was summarized on an annual time-step.

Table 8-9. Summary of Water Balance Model Results

	Average Annual (acre-feet)					Range (acre-feet)	Recharge (% of Precip.)
Watershed	**Precip.**	**Outflow**	**Infilt.**	**ET**	**Recharge**	**Recharge**	**Recharge**
Napa River near Napa	**418,500**	**146,800**	**271,700**	**201,900**	**70,600**	**8,300 - 185,900**	**17%**
- Conn Creek	98,200	24,600	73,600	52,200	21,100	4,300 - 40,700	21%
- Dry Creek	33,000	14,200	18,700	16,400	2,000	500 - 6,300	6%
- Napa River at St. Helena	161,400	67,000	94,400	72,500	22,000	2,500 - 60,900	14%
- Napa River at Calistoga	54,200	23,600	30,600	19,700	10,500	2,000 - 17,200	19%
Milliken Creek	**33,000**	**16,800**	**16,200**	**13,500**	**2,500**	**100 - 7,100**	**8%**
Tulucay Creek	**19,500**	**9,100**	**10,400**	**9,500**	**1,000**	**100 - 2,300**	**5%**
Redwood Creek	**19,300**	**7,800**	**11,500**	**9,500**	**1,900**	**400 - 5,000**	**10%**
Napa Creek at Napa	**32,100**	**14,800**	**17,300**	**13,700**	**3,600**	**600 - 6,900**	**11%**

Results presented in **Table 8-9** indicate that within the Napa River near Napa watershed groundwater recharge is higher in the Conn Creek watershed and in the northern portion of the watershed above Calistoga. Less recharge occurs in the Dry Creek watershed and the portion of the watershed between Calistoga and St. Helena. The Tulucay Creek watershed has the lowest estimated groundwater recharge equal to only 5% of precipitation.

A method for comparing absolute groundwater recharge between watersheds involves comparing groundwater recharge results as depth (normalized by area) for common hydrologic periods. Groundwater recharge can be expressed as depth by dividing average annual recharge volume by the watershed area. To facilitate such a comparison, three common hydrologic periods of eight years each were selected for comparisons of at least two different watersheds for each period. Common periods of record included water years 1952 through 1959, 1959 through 1966, and 1976 through 1983. Average annual groundwater recharge depths were calculated for each watershed during these periods. Average annual precipitation as depth over the watershed was also calculated to provide an indication of the relative wetness of the three common periods. These results are presented in **Figure 8-13**. The Conn Creek watershed was considered in this analysis for the period after construction of Lake Hennessey.

Results presented in **Figure 8-13** illustrate similar trends as seen in **Table 8-9**. The period from 1959 through 1966 was the driest of the three periods while the 1976 through 1983 period was the wettest. Based on absolute groundwater recharge depth, recharge was generally highest in the Conn Creek and Napa River at Calistoga watersheds. Precipitation also is higher in these areas, which may contribute to higher groundwater recharge amounts in this area. Estimates from the root-zone water balance model indicate that the Tulucay Creek watershed has the lowest amount of groundwater recharge. This may be because approximately 23 percent of the Tulucay Creek watershed is represented by urban land uses, the highest of all watersheds analyzed.

Potential explanations for the spatial variability of recharge presented in **Table 8-9** and **Figure 8-13** include differences in watershed soils and geology, slope, and land uses. Previous work by LSCE (2011a) analyzed geology and slope in Napa County and developed a map showing areas of highest recharge potential. This map is presented as **Figure 6-1** in this report and illustrates identified geologic units with the greatest recharge potential and areas where ground surface slopes exceed 30 degrees. **Table 8-10** summarizes the land area for the geologic units of greatest recharge potential by watershed.

The extent of high recharge potential geologic units as summarized in **Table 8-10** may explain some of the variability in groundwater recharge between different watersheds. The Dry Creek watershed has the lowest percent of area underlain by units of greatest potential recharge and the estimated groundwater recharge in this watershed is also low relative to other watersheds. Similarly, the areal extents of units of high recharge potential in Milliken, Redwood, and Napa Creeks are also relatively small and estimated groundwater recharge in these watersheds is relatively low. However, this relationship is not consistent throughout the Napa Valley area and extent of land covered by units of greatest potential recharge does not explain all the variability in the groundwater recharge estimates from the root-zone water balance model. Results presented in **Table 8-9** and **Figure 8-13** suggest that the Conn Creek watershed has the highest groundwater recharge of all watersheds analyzed, but the percent of this watershed underlain by geologic units of high recharge potential is relatively low. Likewise, the Napa River above Calistoga watershed has more groundwater recharge than the Napa River above St. Helena watershed, but the areal extent of geologic units of high recharge potential is relatively lower. These trends suggest that other factors such as topography, land use, and soils also affect recharge estimates.

Table 8-10. Areas of Greatest Potential Recharge by Watershed

	Area of Units of Greatest Potential Recharge (acres)										
Watershed	Alluvial Fan Deposits	Channel Deposits (Holocene)	Napa Valley Alluvium (Undiff.)	Quaternary Alluvium	Quaternary Alluvium (Holocene)	Sonoma Volcanic Sediment	Sonoma Volcanics Tuff	Total Recharge Area	Percent of Watershed	Total Watershed Area (acres)	Recharge (% of Precip.)
Napa River near Napa	**6,406**	**1,212**	**22,152**	**1,040**	**3,955**	**3,952**	**21,093**	**59,809**	**43%**	**139,819**	**17%**
- Conn Creek	1,223	125	950	487	402	1,997	3,154	8,338	23%	35,502	21%
- Dry Creek	0	78	7	112	0	0	91	288	3%	11,155	6%
- Napa River at St. Helena	834	455	6,135	148	2,772	827	17,150	28,321	56%	50,984	14%
-- Napa River at Calistoga	178	138	1,398	0	1,484	664	2,006	5,867	42%	13,937	19%
Milliken Creek	**170**	**23**	**46**	**105**	**216**	**640**	**1,747**	**2,947**	**27%**	**11,112**	**8%**
Tulucay Creek	**0**	**44**	**2,507**	**771**	**125**	**0**	**438**	**3,886**	**48%**	**8,052**	**5%**
Redwood Creek	**0**	**25**	**75**	**0**	**69**	**0**	**1,056**	**1,224**	**19%**	**6,434**	**10%**
Napa Creek at Napa	**622**	**110**	**571**	**7**	**302**	**0**	**1,190**	**2,802**	**28%**	**9,886**	**11%**

8.7 Comparisons with Other Studies

Several other studies conducted on watersheds within the Napa Valley area or on nearby watersheds such as Sonoma Creek have developed water budgets and estimated recharge. A groundwater resources investigation was conducted by the USGS in the lower Milliken, Sarco, and Tulucay Creeks (MST) area. As part of this investigation, the USGS estimated 6,000 acre-feet of groundwater recharge in this area. This value is derived using an estimated average annual precipitation of 69,000 acre-feet, runoff out of the watershed of 29,000 acre-feet, and ET of approximately 34,000 acre-feet (Farrar and Metzger, 2003). This estimate equates to an annual groundwater recharge of approximately 9 percent of precipitation, which is similar to results from the root-zone water balance model used in this study. Combined average annual recharge for Milliken and Tulucay Creek watersheds from the root-zone water balance model is approximately 3,500 acre-feet, or 7 percent of average annual precipitation. This is for an area of approximately 19,000 acres while the USGS study covered an area of approximately 10,000 acres. The rot-zone water balance model estimate is calculated from more detailed estimates of individual terms and from a monthly analysis that considers root-zone storage and physical processes. However, the hydrologic period used in the USGS study of the MST area is not provided so potential differences in hydrology during the periods of analysis should be considered when comparing results from this study.

Another USGS study was completed on Sonoma Creek in the Sonoma Valley, just west of the Napa River Basin. As part of this study the USGS calculated an annual recharge estimate using a water balance between precipitation, runoff, and ET (Farrar et al., 2006). USGS estimated between 28,000 and 48,000 acre-feet of groundwater recharge for the Sonoma Creek watershed based on precipitation of 269,000 acre-feet, runoff of 101,000 acre-feet, and 120,000 to 140,000 acre-feet of ET. A range of groundwater recharge was calculated because ET was calculated using two different methods. The USGS estimate for Sonoma Creek equates to annual groundwater recharge equal to between 10 and 18 percent of precipitation. These percentages are comparable to the root-zone water balance model results from this study presented in **Table 8-9**. Again, the hydrologic period used in the USGS study of Sonoma Creek is not provided so potential differences in hydrology during the periods of analysis should be considered when comparing results from this study.

The Baseline Data report (Napa County, 2005) and information on the Napa County Surface Water model and Napa County Groundwater model were reviewed for comparisons to estimated recharge. The Final Baseline Data Report Technical Appendix includes summaries of the annual water balance for both models as **Table 2-16** and **2-19**, respectively (DHI, 2006b). These tables summarize components of the water balance as expressed as average annual depths per year. However, these tables do not include a specific term for recharge, and it is unclear exactly what terms such as “infiltration” represent. Therefore, it is not possible to make a comparison between information from the Baseline Data Report or Napa County models and results from this analysis.

8.8 Sensitivity Analysis

The sensitivity of the root-zone water balance model to changes in select input parameters and processes was tested. This sensitivity analysis was performed to evaluate which parameters the model is most sensitive to and to understand how uncertainty in inputs creates uncertainty in recharge estimates. Input parameters with relatively larger uncertainties (i.e., soil parameters and evapotranspiration for native forests) were the main focus of the sensitivity analysis. These sensitivity analyses provide helpful guidance for considering approaches to improving recharge estimates in the Napa Valley area.

Results of sensitivity analyses are presented as the percent change in average annual recharge estimate for the Napa River near Napa watershed. This watershed was used for the sensitivity analyses because it is the largest watershed and most representative of the Napa Valley study area. Results for individual watersheds can be more or less sensitive to individual parameters, depending on the watershed. For example, watersheds with more native forests are more sensitive to changes in PET for native forests. Each sensitivity scenario was simulated for all three methods of calculating recharge: VGM, Campbell’s model, and percent over field capacity. Percent change is the average for all three methods, except as noted.

8.8.1 Scenarios and Results

Five sensitivity scenarios were evaluated in the root-zone water balance model. The sensitivity of the model results to changes in the following model components were evaluated: root-zone depth, soil field capacity, porosity and pore-size distribution index, ET of native forest vegetation, and the sequence of operations for groundwater recharge and ET demand processes. The following sections summarize the results of each sensitivity scenario.

1. Root-zone depth

   Root-zone depths for native vegetation plants are not well documented in the literature and can vary for agricultural crops. Root-zone depth affects recharge estimates because increased root-zone depth increases soil storage capacity. When more water is stored in root-zone soils it is available for plant evapotranspiration. Therefore, increases in root-zone depth are expected to increase evapotranspiration and decrease recharge estimates in the water balance model.

   Sensitivity analysis results presented in **Table 8-11** illustrate the inverse relationship between root-zone depth and estimated groundwater recharge. Reducing the root-zone depths used in the model (**Table 8-4**) results in increases in estimated recharge and increasing the root-zone depths decreases estimated groundwater recharge, but recharge is more sensitive to decreasing the root-zone depths. This is because greater root-zone depth equates to a greater soil moisture storage capacity makes it available to meet PET for the overlying land use. However, once PET is fully satisfied, water in the root zone will eventually drain. Increasing the root-zone depths in the model allows PET to be fully satisfied for some land use types, resulting in less reduction in estimated groundwater recharge.

Table 8-11. Sensitivity of Recharge Estimate to Change in Root-Zone Depth

Percent Change in Root-Zone Depth	Percent Change in Average Annual Recharge for Napa River near Napa
-20%	+12%
-10%	+5%
+10%	-3%
+20%	-6%

2. Field capacity

Field capacity, or water that remains in the soil and does not drain under gravitational forces, is not well known. Increases in field capacity increase soil moisture storage capacity and make more water available for plant evapotranspiration. Adjusting the model values for field capacity as shown in **Table 8-5** would be expected to reduce groundwater recharge estimates in the root-zone water balance model.

Sensitivity analysis results presented in **Table 8-12** show change in recharge estimates vary between different methods of calculating recharge for a change in field capacity. As expected, decreases in field capacity result in increases in calculated groundwater recharge using the percent over field capacity method. However, in the VGM and Campbell's model, decreases in field capacity tend to decrease recharge. Unlike percent over field capacity method, field capacity is not directly used to calculate recharge using VGM and Campbell methods. Recharge in VGM and Campbell methods are calculated as a fractional product of saturated hydraulic conductivity and corresponding land use area. That fractional product is a function of porosity and soil moisture storage, not field capacity. Field capacity indirectly affects recharge estimates in these two methods in the calculation of ET. Field capacity is used to determine the fraction of PET that becomes actual ET. As field capacity increases, evapotranspiration increases and moves closer to PET decreasing groundwater recharge.

Table 8-12. Sensitivity of Recharge Estimate to Change in Field Capacity

Percent Change in Field Capacity	Percent over Field Capacity Method	Average of VGM and Campbell's Method
	Percent Change in Average Annual Recharge for Napa River near Napa	
-20%	+10%	-3%
+20%	-7%	+4%

3. Porosity and pore-size distribution index

Soil porosity in the root-zone water balance model characterizes the amount of soil void space. Clayey soils tend to have higher porosities because of the many small pores, whereas sandy soils tend to have lower porosities. Increases in soil porosities from values used in the model (**Table 8-6**) would be expected to reduce recharge estimates from the root-zone water balance model because the capacity of the soil to store water decreases groundwater recharge below the root zone. Conversely, decreases in soil porosities would be expected to increase groundwater recharge estimates from the root-zone water balance model.

Pore-size distribution index "characterizes the range of pore sizes within the soil, with larger values corresponding to a narrow size range and small values corresponding to a wide distribution of pore sizes" (Charbeneau, 2000). The pore-size distribution index was varied to better understand its influence on the VGM and Campbell's recharge models.

Sensitivity analysis results presented in **Table 8-13** indicate that recharge estimates in the root-zone water balance model are relatively insensitive to changes in both porosity and pore size distribution index used in the model, but the results are more sensitive to porosity changes. Additionally, groundwater recharge estimates in the root-zone water balance model are more sensitive to decreasing soil porosity than increasing soil porosity.

Table 8-13: Sensitivity of Recharge Estimate to Change in Soil Porosity and Pore Size Distribution Index

Percent Change in Soil Parameter	Porosity (η)	Pore Size Distribution Index (λ)
	Percent Change in Average Annual Recharge for Napa River near Napa	
-10%	+5%	-1%
+10%	-3%	+1%

4. Evapotranspiration by native forests vegetation

Evapotranspiration by native forests is not well documented in the literature. While PET inputs to the water balance model were based on an energy budget calculation in the neighboring watershed, there is still considerable uncertainty in these inputs. As discussed in previous sections, native forests are the predominant land use in the Napa Valley area. Therefore, it is expected that changes in PET inputs for native forests from values used in the model (**Table 8-7**) will result in changes in recharge estimates. As PET increases, more water is consumed through ET and less water recharges to the groundwater.

Sensitivity analysis results presented in **Table 8-14** indicate that changes in PET values for native forests used in the root-zone water balance model inversely affect groundwater recharge estimates by roughly an equal percentage. In other words, increases to PET values for native forests result in approximately equal and opposite reductions in estimated groundwater recharge. However, these sensitivity results vary by watershed depending on the percentage of the watershed covered by native forest vegetation.

Table 8-14. Sensitivity of Recharge Estimate to Change in Potential Evapotranspiration of Native Forest

Percent Change in PET of Native Forests	Percent Change in Average Annual Recharge for Napa River near Napa
-20%	+27%
+20%	-17%

5. Prioritize recharge process before ET in root-zone water balance model calculations

The root-zone water balance model simulates the root-zone water balance on a monthly time-step. The sequence of operations within the model is as follows: 1) infiltration in the current month is added to the previous month's ending soil moisture storage, 2) evapotranspiration is subtracted from soil moisture storage, and 3) recharge is calculated and subtracted from soil moisture storage. This sensitivity scenario evaluates the change in groundwater recharge estimates if the recharge processes occurs prior to evapotranspiration during calculations within the root-zone water balance model. In reality, the ET and recharge processes occur simultaneously.

Prioritizing recharge before ET in the root-zone water balance model increases the average annual groundwater recharge estimate for the Napa River near Napa watershed by an average of 7%. This provides an upper estimate of groundwater recharge for comparison with root-zone water balance model results presented in **Table 8-9**.

Results of the sensitivity analysis indicate that groundwater recharge estimates are most sensitive to ET and rooting depths of forests. Rooting depths and ET data for California native forests are not well documented and root-zone water balance model ET values were determined using professional judgment and sources outside California such as an evapotranspiration study of Douglas Fir in British Columbia and the Pacific Northwest (Elsevier, 2009). Approximately 42% of the Napa Valley area is classified as native forests. Refining the estimate of ET for native forests would improve groundwater recharge estimates from the root-zone water balance model. Alternatively, a measurement study of ET for the Napa River Basin, including the foothills and undeveloped areas, could be performed. This study would improve estimates of actual ET for undeveloped areas that could improve PET inputs to the water balance model. An understanding of the root-zone soil moisture storage potentials of native forests could be gained by further studying their root depths and examining underlying soil textures.

Results of the sensitivity scenarios also indicate that groundwater recharge estimates calculated in the root-zone water balance model are subject to uncertainty of approximately +/-20%. Sensitivity scenarios attempted to bound uncertainty in input parameters within expected ranges. Ranges for parameters such as porosity and pore size distribution index exist in the literature and can be constrained based on published values. Parameters such as root-depth and PET are less well known and were tested over a wider range of potential values.

8.9 Extrapolation to Remaining Areas

An effort was made to extrapolate results from gaged watersheds within the Napa Valley area to other watersheds of Napa County outside the Valley. The root-zone water balance model was configured for the Napa Valley area only because this was the primary area of interest in this study and because of the lack of streamflow gages in watersheds outside the Napa Valley area. Because of these limitations, an alternate approach was required to estimate recharge in other parts of the county. Other major watersheds in the county are Putah Creek, Napa-Sonoma Marshes, and Suisun Creek with watershed areas listed in **Table 8-15**.

Table 8-15: Areas of Major Watersheds outside of Napa River Basin and the Napa River Basin

Watershed	Acreage
Putah Creek	231,357
Napa-Sonoma Marshes	11,530
Suisun Creek	30,386
Napa River Basin	232,193

Land use and precipitation data required for input to the water balance model were collected while processing data for the Napa Valley area. To supplement for the lack of measured streamflow gage data, an alternate approach involving using the streamflow record of a physically similar watershed and applying the unit discharge (streamflow discharge per unit of watershed area) to scale these data and produce stream flow time-series for watersheds outside of the Napa Valley area. Evaluating physical similarities in watersheds involve physical characteristics of precipitation, elevation, topography, land use, and other factors. None of the watersheds used in the root-zone water balance analysis for the Napa Valley area ideal for extrapolation to watersheds outside of the Valley. However, The Napa River near Napa watershed and was selected as the physically similar watershed to perform this extrapolation. The Napa River near Napa watershed was selected because it is similar in size to the Putah Creek watershed and has a long record of outflow gage data. Smaller gaged watersheds were considered to represent Napa-Sonoma Marshes and Suisun Creek, but none were similar. The areas of major watersheds outside of the Napa Valley area are tabulated in **Table 8-15**.

This approach to extrapolating results beyond the Napa Valley area produced groundwater recharge estimates of less than 10 percent of precipitation for Putah Creek, Napa-Sonoma Marshes, and Suisun Creek. For the Napa-Sonoma Marshes watershed, average annual calculated groundwater recharge was approximately zero for all three recharge methods. This may be because the Napa-Sonoma Marshes are low-elevation and flatter watersheds, and the Napa River watershed contains significant mountain areas that may generate more surface runoff and outflow. Scaling this outflow to a much smaller watershed that is physically different may produce overly high outflow estimates resulting in minimal infiltration and minimal recharge. These recharge estimates are low when compared to recharge estimates for watersheds in the Napa Valley area. This is not surprising because the hydrologic responses in these watersheds are likely to vary considerably as a result of the great differences in watershed land use and size between the Napa River near Napa watershed and the three watersheds listed in **Table 8-15**. Therefore, these results should be considered very rough approximations and are reported here to describe the nature of attempts that were made to estimate recharge outside of the Napa Valley area.

8.10 Future Considerations

Analyses conducted to estimate groundwater recharge in the Napa Valley area were based primarily on available data and were made at a coarse spatial scale. However, results appear reasonable and provide foundational building blocks to better understand groundwater resources in Napa County. Improvements in data used in the root-zone water balance model will reduce uncertainty in groundwater recharge estimates.

PRISM precipitation data are generally accepted as a good estimate of spatially disaggregated precipitation. Historical precipitation time-series at 30 arc-second (800 meter) grid cells are available for purchase from Oregon State University's PRISM Climate Group. Using historical PRISM calculated precipitation time-series, as opposed to the PRISM scaled time-series, would improve infiltration estimates.

Better understanding of ET of native vegetation would reduce the uncertainty in groundwater recharge estimates. The sensitivity analysis indicated that assumptions for ET of native forests can greatly affect recharge estimates. Techniques for quantifying actual ET across large areas using multispectral satellite imagery and modeling the energy balance are methods that could be used to improve estimates of ET throughout Napa County. It is possible that these types of methods have been employed for vineyards and other parts of the County.

One of the major limitations in this study is the spatial and temporal availability of streamflow gage data. In order to estimate streamflow from ungaged watersheds, a rainfall-runoff model could be developed and calibrated with records from gaged watersheds. A rainfall-runoff model may also help improve the spatial resolution of infiltration within gaged watersheds. Several different platforms are available for these types of models.

The Putah Creek watershed represents approximately 46 percent of Napa County and is an ungaged watershed; however, it may be possible to estimate runoff from this watershed by calculating inflow to Lake Berryessa. Reservoir inflow calculations require close quality control of inputs and may not be possible if flood control releases from Monticello Dam are not accurate. If it is possible to calculate inflow to Lake Berryessa, this time-series could be used as the outflow component in the water balance model to estimate groundwater recharge for this area of the county.

Lastly more detailed characterization and modeling of the root-zone hydrologic processes, including spatial variability in soil properties that might be developed from the NRCS SSURGO database, could considerably improve estimates of groundwater recharge throughout the county. Data and results from this study would aid in the development and calibration of a more detailed root-zone water balance model.

8.10.1 Considerations Related to Overall Water Balance

The root-zone water balance has resulted in recharge estimates for the Napa River Basin Watershed and sub-watersheds. As noted in the discussion of the root-zone water balance components, this model does not include groundwater pumping or subsurface groundwater outflow from the underlying aquifer system. One other component not quantified with the root-zone water balance method is direct streamflow infiltration (seepage). At this time, insufficient data are available to quantify the stream seepage rate and volume within the applicable watershed and sub-watershed root-zone water balance analyses. As discussed in Section 7, groundwater may be connected to surface water in locations along the main stem Napa River such that groundwater discharge occurs to the River and groundwater levels are high enough such that seepage may not occur. This may be a temporal condition, depending on location, climate, and other factors. As discussed in the next section, additional groundwater monitoring and interrelated surface water monitoring are recommended. This monitoring will improve the understanding of groundwater/surface water interrelationships and will help quantify: 1) seepage from and/or groundwater discharge to the River and 2) subsurface groundwater outflow.

The overall watershed water balance, which can be used to observe how the quantity of groundwater flowing into and out of the groundwater basin and the change in groundwater storage, can be estimated with the addition of the above components (e.g., stream seepage, groundwater pumping, and subsurface outflow). Previous studies have estimated groundwater pumpage for the main Napa-Sonoma Valley Groundwater Basin (WYA, 2005). It would be beneficial to update these pumpage estimates based on more recent land cover information. Such an effort would necessarily need to be accompanied by an analysis of the sources of water (surface water, groundwater, and/or recycled water) used to meet agricultural, rural residential, municipal, and other water requirements.

9 SUPPLEMENTAL GROUNDWATER MONITORING IN HIGH PRIORITY SUBAREAS

An important element in Napa County's Comprehensive Groundwater Monitoring Program is an evaluation of construction information for wells with water level monitoring data. Understanding the exposure of monitored wells to aquifers in their vicinity is critical to analyzing the data collected from those wells. The two most important pieces of construction information for monitored wells, in addition to accurate location information, are information about the geologic materials encountered when the well was drilled and a record of the depth of the well screens. These well construction details allow data collected from a well to be understood in a larger hydrogeologic context, enabling more accurate quantification of aquifer conditions. This section presents the results of an inventory of wells in Napa County with water level monitoring data. The goals of this inventory are to assess the extent of aquifer specific construction information for currently monitored wells and identify wells with historic data that may be suitable for inclusion into the Napa County monitoring network. Findings from the inventory are presented in light of results from the updated hydrogeologic characterization contained in this report.

Monitored wells records included in this inventory include those from federal, state, county, and municipal groundwater level monitoring networks. Federal, state, and county records have been reviewed and compiled from the California State Water Resources Control Board's GeoTracker Database, the DWR Water Data Library, and the Data Management System (DMS) previously constructed for Napa County (LSCE, 2010). Records for wells monitored by municipalities were collected for this inventory from direct outreach to Public Works Directors and staff in each of the four incorporated municipalities within Napa Valley as well as the City of American Canyon.

Due to the large proportion of wells lacking complete construction information, efforts to locate construction information for monitored wells focused on the high priority subareas in the Napa Valley Floor and the Carneros Subarea. Additional efforts were made to identify monitored wells adjacent to the Napa River to evaluate potential groundwater/surface water monitoring sites.

Currently monitored sites referred to in this report are sites where data have been collected through at least 2011. No restriction has been placed on the number of years of accumulated monitoring data. This definition is distinct from the definition for current monitoring wells applied for the Comprehensive Groundwater Management Program, where wells with periods of record extending to at least 2005 were designated as current (LSCE, 2011a). The more narrow definition used here enables a more precise evaluation of current monitoring activities, particularly in the context of wells monitored by entities other than Napa County that may be suitable candidates for inclusion in the Napa County monitoring network. The definition of currently monitored sites used here is also reflected in the Napa County Groundwater Monitoring Plan (LSCE, 2013).

9.1 Available Location and Construction Information for Groundwater Level Monitoring Sites

The DMS served as the initial source of reference for location and construction information about groundwater level monitoring sites. Wells with current and historic groundwater level data were initially selected from the DMS without regard to the availability of construction information. However, wells with records indicating that the well has been destroyed or abandoned were omitted. The distinction between wells with current and historic data was made based on communication with the monitoring entity, or, in the case of regulated monitoring sites in the GeoTracker database, an electronic search for all wells with monitoring data reported since 2011. The DMS was modified to incorporate the results of this review with a record for each well to indicate whether or not it is currently monitored.

Often, DMS records for monitored wells include only some form of location information and a value for total well depth, without specifying the depth of well screens or a Well Completion Report (also called a driller's report) with borehole lithology records that could enable a definitive linkage with the well's completion relative to aquifer units in the area. As part of this inventory of monitored wells, an effort was made to locate Well Completion Reports (or equivalent information) for all current and historic non-regulated monitoring sites in the study area for this report.

Well Completion Reports were linked with the selected wells by comparing the location information available in the "Well" table of the DMS with township/range/section, parcel number, and well address contained in the "WellMa" DMS table. In cases where more than one record was found in a given location, the range of data collected at each well relative to the recorded well completion date, type of well, and intended use were all used to determine the correct match. Separate searches for Well Completion Reports were also performed by individually reviewing available Well Completion Reports on a township/range/section basis with the available location information for wells of interest. For wells with a DMS record for completion date predating the DWR standardized Well Completion Report form, well construction records compiled by Kunkel and Upson (1960) were reviewed.

Table 9-1 provides a summary of the groundwater level monitoring well inventory in the county. As with all results reported here, the determination of whether or not aquifer specific information is available was made based on two independent criteria. First, well records were checked for a well completion report that included sufficient lithologic detail and information regarding well screen depth intervals. Separately, wells constructed within the hydrogeologic characterization study area considered for this report were reviewed for records of well screen intervals and total well depth in the DMS. In the latter case, where either well screen interval or total well depth information was available in the DMS, wells were reviewed with reference to their location relative to the mapped alluvium isopach contours and geologic subcrop units to make a determination, if possible, regarding the applicable aquifer unit(s) for each well.

Table 9-1 shows that a 54% of the currently monitored sites countywide are located in the Napa and MST subareas with in the Napa Valley Floor. The 87 currently monitored sites comprise only 15% of the total groundwater level monitoring sites that are not known to have been destroyed or abandoned. However, among wells for which aquifer specific construction information is available, currently monitored sites account for 61% of the total known sites.

Table 9-1
Summary of Sites[1,2] with Groundwater Level Data and Well Construction Information in Napa County

Napa County Subarea	Current and Historic Sites with WL Data[1,2]	Current and Historic Sites with WL Data and Any Construction Info	Current and Historic Sites w/ Aquifer Specific Construction Information	Current WL Sites	Current Sites w/ Aquifer Specific Construction Information
Napa Valley Floor-Calistoga	46	45	1	6	1
Napa Valley Floor-St. Helena	71	65	11	12	6
Napa Valley Floor-Yountville	51	50	13	9	7
Napa Valley Floor-Napa	79	75	13	18	9
Napa Valley Floor-MST	281	189	20	29	11
Carneros	18	17	4	5	4
Jameson/American Canyon	12	9	0	1	0
Napa River Marshes	2	2	0	1	0
Angwin	1	1	0	0	0
Berryessa	6	5	0	3	0
Central Interior Valleys	2	2	0	1	0
Eastern Mountains	8	4	0	0	0
Knoxville	1	0	0	1	0
Livermore Ranch	0	0	0	0	0
Pope Valley	2	2	0	1	0
Southern Interior Valleys	0	0	0	0	0
Western Mountains	0	0	0	0	0
Totals	**580**	**466**	**62**	**87**	**38**

[1] Regulated groundwater monitoring sites in the GeoTracker network with multiple monitoring wells are counted only once, while non-regulated monitoring wells with shared state well numbers are counted separately.

[2] Omits sites identified as abandoned or destroyed in Napa DMS water level records.

9.1.1 Voluntary and Non-Regulated Monitoring Sites

Napa County's existing groundwater monitoring program includes data currently collected at 47 non-regulated sites. The median and arithmetic mean periods of record for these sites are 13 years and 21.8 years, respectively, with the earliest record dated 2/14/1930.

Groundwater level monitoring data are also currently collected at twelve additional non-regulated sites in the county. These include monitoring at six sites by DWR, at four sites by the City of Napa, and at one site by the Town of Yountville.

Table 9-2 summarizes the construction and period of record information for all currently monitored non-regulated groundwater level monitoring sites with any available construction information. Of the 41 sites for which any construction information is available, 27 include sufficient information to determine the aquifer(s) in which the well is completed. Of these, 13 are completed in a single aquifer unit, with 9 wells completed solely in the Quaternary alluvium aquifer. The other 4 wells with a single aquifer completion are in a variety of Tertiary Sonoma Volcanic units, Tertiary sedimentary units.

Table 9-2
Current, Non-regulated Groundwater Level Sites with Any Construction Information

Napa County Subarea	Monitoring Network	Well ID	Construction Date (yyyymmdd)	Water Level Period of Record	Well Depth (feet, bgs)	Screened Interval[1] (feet bgs)	Aquifer Designation[2,3,4]
Napa Valley Floor-Calistoga	NapaCounty	NapaCounty-127	19580310	1962 - 2012	149	unk	unk
	NapaCounty	NapaCounty-129	19620719	1962 - 2012	253	unk	unk
	NapaCounty	NapaCounty-128	19620719	1962 - 2012	50	unk	Qa
	DWR	08N06W10Q001M		1949 - 2009	200	unk	unk
Napa Valley Floor-St. Helena	NapaCounty	NapaCounty-131	193907	1963 - 2012	221	7 - sections	Qa
	NapaCounty	NapaCounty-132		1962 - 2012	265	25 - 265	Qa, Tsvab?
	NapaCounty	NapaCounty-138		1949 - 2012	321	unk	Qa?, Tsv?
	DWR	07N05W09Q002M		1949 - 2009	232	unk	unk

Table 9-2
Current, Non-regulated Groundwater Level Sites with Any Construction Information

Napa County Subarea	Monitoring Network	Well ID	Construction Date (yyyymmdd)	Water Level Period of Record	Well Depth (feet, bgs)	Screened Interval[1] (feet bgs)	Aquifer Designation[2,3,4]
Napa Valley Floor-Yountville	NapaCounty	NapaCounty-133	19720415	1978 - 2012	120	20 - 120	Qa
	NapaCounty	NapaCounty-135	19620720	1979 - 2012	125	unk	Qa
	NapaCounty	NapaCounty-125	19710823	1979 - 2012	160	63 - 160	Tsva
	NapaCounty	NapaCounty-126	19711116	1984 - 2012	345	140 - 345	Tsva
	NapaCounty	NapaCounty-134	19550801	1963 - 2012	260	160 - 260	Qa
	NapaCounty	NapaCounty-139	19770125	1978 - 2012	120	40 - 120	Qa
	DWR	06N04W17A001M		1949 - 2008	250	unk	unk
	Townof Yountville	TownofYountville-MW1	20041103	unk	300	105 - 300	Qa
Napa Valley Floor-Napa	NapaCounty	NapaCounty-75	19710719	1978 - 2012	205	45 - 205	Qa, Tss/h
	NapaCounty	NapaCounty-136	19620720	1979 - 2012	120	unk	Qa
	DWR	06N04W27L002M	19660609	1966 - 2009	120	60 - 120	Qa
	DWR	05N04W15E001M		1949 - 1978	158	unk	unk
Napa Valley Floor-MST	NapaCounty	NapaCounty-18	19760714	2000 - 2012	189	unk	Tsv?
	NapaCounty	NapaCounty-22	19680416	2000 - 2012	135	unk	unk
	NapaCounty	NapaCounty-4	19890913	2000 - 2011	385	unk	unk
	NapaCounty	NapaCounty-72	19971007	2000 - 2012	245	unk	unk
	NapaCounty	NapaCounty-81	19880725	2000 - 2012	290	unk	unk
	NapaCounty	NapaCounty-10		1979 - 2012	320	unk	unk
	NapaCounty	NapaCounty-2		1979 - 2012	700	unk	unk
	NapaCounty	NapaCounty-20	19771208	1978 - 2012	208	130 - 207	Tsvt?
	NapaCounty	NapaCounty-56	19760828	1978 - 2012	210	30 - 210	Tss/h
	NapaCounty	NapaCounty-95	19770110	1979 - 2012	195	155 - 185	Tsv?
	NapaCounty	NapaCounty-137	19620716	1979 - 2012	364	unk	Qa?,Tsv?
	NapaCounty	NapaCounty-43		1978 - 2012	310	unk	Unk
	NapaCounty	NapaCounty-49		1989 - 2012	399	unk	Qa, Tsv
	NapaCounty	NapaCounty-74	19880818	1999 - 2012	300	unk	Qa?, Tsv?
	NapaCounty	NapaCounty-91	19860815	1992 - 2012	415	315 - 415	Tsvt?
	NapaCounty	NapaCounty-92		1999 - 2012	368	unk	Qa, Tsv?
Carneros	NapaCounty	NapaCounty-150		2011 - 2012	155	unk	Qa?
	NapaCounty	NapaCounty-153	19780508	2012 - 2012	200	60 - 200	QTh
	NapaCounty	NapaCounty-154	19900828	2012 - 2012	300	60 - 295	QTh?
	NapaCounty	NapaCounty-155	20030813	2012 - 2012	220	80 - 220	QTh?
	DWR	04N04W05D002M		1951 - 1978	60	unk	unk

[1] Screen intervals reported here are overall intervals for a given well and are not always representative of a continuous length of screen.

[2] Aquifer designations are made based on interpretation of driller's log and/or well location relative to the mapped alluvium isopach and subcrop geology.

[3] Aquifer Designations: Qa = Quaternary alluvium, Qsb = Quaternary sedimentary basin deposits, QTh = Quaternary and Tertiary Huichica formation, TQsb = Tertiary and early Quaternary sedimentary basin deposits, Tsv = Tertiary Sonoma Volcanic undifferentiated, Tsva = Tertiary Sonoma volcanic andesite flow, Tsvt = Tertiary Sonoma Volcanic tuff, Tsva&t = Tertiary Sonoma volcanic andesite and tuff, Tsvt/s = Tertiary Sonoma Volcanic tuff and sediments, Tsvab = Tertiary Sonoma Volcanic andesite flow or breccia, Tss/h = Tertiary sedimentary rock, Tcg/ab = Tertiary Sonoma Volcanic Conglomerate/breccia, Td = Tertiary marine rock

[4] "?" indicates uncertainty in aquifer designation due to the lithogic descriptions provided in driller's log, or, if driller's log is not available, uncertainty due to a well's location outside of mapped extents of subcrop alluvium isopach and subcrop geology.

Based on this inventory, opportunities do exist within the Napa Valley Floor subareas to incorporate previously monitored wells with aquifer specific construction data. **Table 9-3** summarizes the construction and period of record information for these wells.

It is possible that some of the wells listed in **Table 9-3** are actually duplicates representing cases where wells have been monitored by more than one entity. Although each well has unique location data, in some cases the location data vary only slightly and may be attributable one of several sources of variation, including differences in survey methods used by monitoring entities. Distinguishing between such duplicates should involve field visits to resolve the location data provided for the potentially duplicate wells.

Table 9-3
Historic, Non-regulated Groundwater Level Sites with Aquifer Specific Construction Information

Napa County Subarea	Monitoring Network	Well ID	Construction Date (yyyymmdd)	Water Level Period of Record	Well Depth (feet, bgs)	Screened Interval[1] (feet bgs)	Aquifer Designation[2,3,4]
Napa Valley Floor-St. Helena	NapaCounty	NapaCounty-130	19740309	1978 - 2001	207	50 - 207	Qa, Tss/h
	DWR	07N05W04E001M	19740309	1978 - 2001	207	50 - 207	Qa, Tss/h
	DWR	07N05W14B002M		1963 - 2008	265	25 - 265	Qa, Tsvab?
	DWR	08N06W26B004M	19720511	1979 - 1991	280	30 - 280	Qa, Tst
	USGS	383746122254001	19740309	1979 - 1983	207	50 - 207	Qa, Tss/h
Napa Valley Floor-Yountville	DWR	06N04W06L002M	19550801	1963 - 2008	260	160 - 260	Qa
	DWR	06N04W09Q001M	19710823	1984 - 2008	160	63 - 160	Tsva
	DWR	06N04W09Q002M	19711116	1984 - 2008	345	140 - 345	Tsva
	DWR	06N04W17R002M	19770125	1978 - 2008	120	40 - 120	Qa
	DWR	07N04W31M001M	19720415	1978 - 2008	120	20 - 120	Qa
	USGS	382442122210501	19720415	1978 - 1983	120	20 - 120	Qa
Napa Valley Floor-Napa	DWR	05N04W15C002M		1951 - 1978	66	20 - 66	Qa
	DWR	06N04W22R001M		1959 - 2008	205	45 - 205	Qa, Tss/h
	DWR	06N04W27N001M	19290729	1930 - 2008	125	32 - 125	Qa
	USGS	381953122175401	19290729	1962 - 2002	125	32 - 125	Qa
Napa Valley Floor-MST	DWR	05N03W06B002M	19860815	1992 - 2008	415	315 - 415	Tsvt?
	DWR	05N03W07C003M	19771208	1978 - 2008	208	130 - 207	Tsvt?
	DWR	06N04W26G001M	19760828	1978 - 2008	210	30 - 210	Tss/h
	DWR	06N04W36G001M	19770110	1978 - 2008	195	155 - 185	Tsv?
	USGS	381648122151501	19761030	2000 - 2002	210	105 - 126	Tsv?
	USGS	381710122162501b		1962 - 1983	220	30 - 220	Qa, TQsb?
	USGS	381831122140501	19860815	2001 - 2002	415	315 - 415	Tsvt?

[1] Screen intervals reported here are overall intervals for a given well and are not always representative of a continuous length of screen.

[2] Aquifer designations are made based on interpretation of driller's log and/or well location relative to the mapped alluvium isopach and subcrop geology.

[3] Aquifer Designations: Qa = Quaternary alluvium, Qsb = Quaternary sedimentary basin deposits, QTh = Quaternary and Tertiary Huichica formation, TQsb = Tertiary and early Quaternary sedimentary basin deposits Tsv = Tertiary Sonoma Volcanic undifferentiated, Tsva = Tertiary Sonoma volcanic andesite flow, Tsvt = Tertiary Sonoma Volcanic tuff, Tsva&t = Tertiary Sonoma volcanic andesite and tuff, Tsvt/s = Tertiary Sonoma Volcanic tuff and sediments, Tsvab = Tertiary Sonoma Volcanic andesite flow or breccia, Tss/h = Tertiary sedimentary rock, Tcg/ab = Tertiary Sonoma Volcanic Conglomerate/breccia, Td = Tertiary marine rock

[4] "?" indicates uncertainty in aquifer designation due to the lithogic descriptions provided in driller's log, or, if driller's log is not available, uncertainty due to a well's location outside of mapped extents of subcrop alluvium isopach and subcrop geology.

9.1.2 Regulated Monitoring Sites

Regulated groundwater monitoring sites provide data collected at regular intervals, often quarterly or semi-annually, from multiple wells in close proximity to the contamination source. Data from these regulated facilities usually consist of data from groundwater monitoring wells (typically shallow) and remediation wells. Although the wells constructed at these facilities should have a corresponding Well Completion Report on file with DWR, the most efficient means for determining the construction details associated with these wells is often by accessing the well construction data uploaded to the GeoTracker database and corresponding reports of well construction uploaded in PDF format to the GeoTracker database.

The well inventory results presented here are limited to currently monitored sites. Although over 500 monitoring wells have been constructed at regulated facilities in Napa County, official correspondence between regulators and site owners available in the GeoTracker database indicate that wells are frequently destroyed by the well owner once the requirement of monitoring is lifted. However, these destruction records are not represented with a record in the GeoTracker database that would enable efficient updating of the Napa DMS. Currently monitored wells, therefore, present the best opportunity for identifying wells for possible inclusion into the Napa County monitoring network.

The GeoTracker database contains 60 open, active sites in Napa County. Of those, 28 sites include water level monitoring data uploaded in the previous 12 months. **Table 9-4** shows the distribution of those currently monitored sites throughout the county. In addition to the GeoTracker sites, **Table 9-4** includes records for two regulated sites monitored by Napa County. Although some of the current GeoTracker sites do not have sufficient construction information available to determine the appropriate aquifer completion, such information should be available from the site owner or responsible authority should the County wish to pursue adding any of these sites to the current groundwater level monitoring network. However, since the status of monitored wells in the GeoTracker network tend to change more rapidly than those of wells in other monitoring networks, these correspondences should be reviewed prior to contacting a well owner regarding inclusion of a particular well in the Napa County monitoring network.

Table 9-4
Current, Regulated Groundwater Level Sites

Napa County Subarea	Monitoring Network	Well ID	Construction Date (yyyymmdd)	Water Level Period of Record	Well Depth (feet, bgs)	Screened Interval[1] (feet bgs)	Aquifer Designation [2,3,4]
Napa Valley Floor-Calistoga	Geotracker	T0605500250MW-1		2005 - 2009	24.83	10 - 25	Qa?
	Geotracker	T0605500272MW-1		2008 - 2009	0	unk	unk
Napa Valley Floor-St. Helena	Geotracker	T0605500061MW-8		2005 - 2009	20	6 - 20	Qa
	Geotracker	T0605500168MW-6		1998 - 2009	18	3 - 18	Qa
	Geotracker	T0605500190MW-1		2001 - 2009	22.5	7.5 - 22.5	Qa
Napa Valley Floor-Napa	Geotracker	SL0605536682MW-1		2005 - 2009	24	unk	Qa?
	Geotracker	T0605500008MW-3	20050721	2005 - 2009	15	3 - 15	Qa
	Geotracker	T0605500009MW1	19920301	2005 - 2009	14	3 - 14	Qa
	Geotracker	T0605500044C-4		2002 - 2009	12.63	10 - 30	Qa
	Geotracker	T0605500110KMW-1	19900815	2003 - 2006	19.65	9.5 - 24.5	Qa
	Geotracker	T0605500124MW-1		2002 - 2008	25	unk	Qa?
	Geotracker	T0605500164EX-1	2002112	2003 - 2009	37	10 - 35	Qa
	Geotracker	T0605500212MW-1		2003 - 2009	20	4 - 20	Qa
	Geotracker	T0605514064MW1		2005 - 2009	0	unk	unk
	Geotracker	T0605547200MW-1		2008 - 2009	0	unk	unk
	Geotracker	T0605575085MW-1		2009 - 2009	0	unk	unk
	Geotracker	T0605598080MW-1		2005 - 2009	0	unk	unk
Napa Valley Floor-MST	Geotracker	L10002804480DW-1		2005 - 2009	0	unk	unk
	Geotracker	T0605500138S-3	20030428	2003 - 2009	30	4 - 15	Qa
	Geotracker	T0605500140MW-1	19910119	2000 - 2009	24.86	11 - 26	Qa
Jameson/American Canyon	Geotracker	T0605500240MW-4		2007 - 2009	14.5	unk	Qa?
Napa River Marshes	Geotracker	L10002804480DW-2		2005 - 2009	0	unk	unk
Berryessa	NapaCounty	NBRID_MW2		2007 - 2009	0	unk	unk
	Geotracker	T0605500304MW-1		2002 - 2004	0	unk	unk
	Geotracker	T0605591908MW-1		2006 - 2009	34	unk	unk

Table 9-4
Current, Regulated Groundwater Level Sites

Napa County Subarea	Monitoring Network	Well ID	Construction Date (yyyymmdd)	Water Level Period of Record	Well Depth (feet, bgs)	Screened Interval[1] (feet bgs)	Aquifer Designation [2,3,4]
Central Interior Valleys	Geotracker	T0605500279MW1		2002 - 2009	0	unk	unk
Knoxville	NapaCounty	LBRID_MW1		2006 - 2009	0	unk	unk
Pope Valley	Geotracker	T0605593602MW-1		2002 - 2006	0	unk	unk

[1] Screen intervals reported here are overall intervals for a given well and are not always representative of a continuous length of screen.

[2] Aquifer designations are made based on interpretation of driller's log and/or well location relative to the mapped alluvium isopach and subcrop geology.

[3] Aquifer Designations: Qa = Quaternary alluvium, Qsb = Quaternary sedimentary basin deposits, QTh = Quaternary and Tertiary Huichica formation, TQsb = Tertiary and early Quaternary sedimentary basin deposits, Tsv = Tertiary Sonoma Volcanic undifferentiated, Tsva = Tertiary Sonoma volcanic andesite flow, Tsvt = Tertiary Sonoma Volcanic tuff, Tsva&t = Tertiary Sonoma volcanic andesite and tuff, Tsvt/s = Tertiary Sonoma Volcanic tuff and sediments, Tsvab = Tertiary Sonoma Volcanic andesite flow or breccia, Tss/h = Tertiary sedimentary rock, Tcg/ab = Tertiary Sonoma Volcanic Conglomerate/breccia, Td = Tertiary marine rock

[4] "?" indicates uncertainty in aquifer designation due to the lithogic descriptions provided in driller's log, or, if driller's log is not available, uncertainty due to a well's location outside of mapped extents of subcrop alluvium isopach and subcrop geology.

Construction information for the GeoTracker wells was extracted from the Napa County DMS where possible and through a review of data available in the GeoTracker database for wells not found in the DMS. However, even when directly referencing the GeoTracker database, not all monitored wells were found to have complete construction information uploaded to the GeoTracker database. In addition, the GeoTracker database does not include a record to indicate whether a given well has been abandoned or destroyed once a site becomes inactive or has closed. Official correspondence between the lead regulator and site owner or authorized representative is available on the GeoTracker website and can include correspondence relating to well abandonment. Because the status of monitored wells in the GeoTracker network change over time, these correspondences should be reviewed prior to contacting a well owner regarding inclusion of a particular well in the Napa County monitoring network.

9.2 Completion of Groundwater Level Monitoring Sites Relative to Aquifer System and Geologic Units

As the hydrogeologic characterization presented in Section 6 details, the aquifers underlying Napa Valley vary substantially in composition and productivity. Furthermore, most wells in the Napa Valley constructed post 1970 tend to have long intake or screened intervals, extending from the near surface alluvium, if present and across the underlying Sonoma Volcanics or Tertiary sedimentary rocks to the total depth drilled.

9.3 Recommendations for Napa County Groundwater Level Monitoring Network Expansion

The Napa County Groundwater Monitoring Plan (LSCE, 2013) includes a preliminary ranking and priorities for improving or expanding groundwater level monitoring for each county subarea. These rankings and priorities are presented in **Table 9-5** along with an updated count of current water level monitoring wells including five monitored by municipalities in Napa Valley. Six subareas are given a relatively higher priority for improving the groundwater level monitoring network based on factors of current population and groundwater utilization relative to other parts of the county, and/or the need to improve understanding of groundwater/surface water interactions. Some factors are given greater consideration in areas that currently use more groundwater than other areas. These areas include:

- NVF-Calistoga,
- NVF-St. Helena,
- NVF-Yountville,
- NVF- MST,
- NVF-Napa, and
- Carneros Subareas

Table 9-5
Groundwater Level Monitoring Sites, Napa County
(Current[1] and Future)

Subarea	No. Sites with Current Groundwater Level Data	Future Groundwater Level Monitoring		Monitoring Needs
		Relative Priority	Action (Expand/ Refine)	
Napa Valley Floor-Calistoga	**6**	**H**	E	**SP, SW**
Napa Valley Floor-MST	**29**	**H**	R	**SP, SW**
Napa Valley Floor-Napa	**18**	**H**	R	**SP, SW**
Napa Valley Floor-St. Helena	**12**	**H**	E	**SP, SW**
Napa Valley Floor-Yountville	**9**	**H**	E	**SP, SW**
Carneros	**5**	**H**	E	**B**
Jameson/American Canyon	1	M	E	B
Napa River Marshes	1	M	E	SP, SW
Angwin	0	M	E	B
Berryessa	3	L	E	B
Central Interior Valleys	1	L	E	B
Eastern Mountains	0	L	E	B
Knoxville	1	L	E	B
Livermore Ranch	0	L	E	B
Pope Valley[2]	1	L	E	B
Southern Interior Valleys	0	L	E	B
Western Mountains	0	L	E	B
Total	**87**			

[1] "Current" refers to monitored sites with wells measured for levels and/or any water quality parameter with a period of record extending to 2011 or later. “Future” refers to recommended monitoring locations.
[2] The relative priority for Pope Valley was changed from “high” in the Groundwater Report to “low” in the Plan based on input from the GRAC on the current population and groundwater use in this subarea.

L = Low Priority; add groundwater level monitoring based on areas of planned future groundwater development

M = Medium Priority; add groundwater level monitoring

H = High Priority; add groundwater level monitoring

E = Expand current monitoring network; possible alternatives for additional monitoring wells include 1) wells historically monitored by DWR/USGS/Others, preferably with well construction information; 2) existing water supply wells (e.g., private/commercial) with well construction information; 3) new dedicated monitoring wells coordinated with recent geologic investigations that are or will be conducted)

R = Refine current monitoring network (link well construction information to all monitored wells, as possible)

Monitoring Needs:
SP = Improve horizontal and/or vertical spatial distribution of data, including for the purpose of identifying such factors as climate change and to identify opportunities for enhanced groundwater recharge and storage;
SW =identify appropriate monitoring site to evaluate surface water -groundwater recharge/discharge mechanisms;
B = Basic data needed to accomplish groundwater level monitoring objectives

9.3.1 Areas of interest for groundwater water monitoring

Figure 9-1 depicts the distribution of currently monitored groundwater level sites throughout the county along with proposed areas of interest for additional monitoring wells. The areas of interest (AOI) are placed to fill spatial data gaps that exist within the various networks of currently monitored wells (**Table 9-6**). For each county subarea, **Table 9-6** shows the existing monitoring sites, provides recommendations for the number and location of additional monitoring areas, and describes the key groundwater level monitoring objectives to be addressed. Altogether, it is recommended that approximately six groundwater/surface water monitoring sites for purposes of evaluating groundwater/surface water interactions and about 18 other areas of interest (AOIs) be added to the network (**Figure 9-1**).

The areas of interest within the Napa Valley Floor and the data gaps that they fill are largely substantiated by the results of the LiDAR depth to water analysis for the Napa Valley Floor (**Figure 9-2**). In particular, the portion of the valley floor for which the implausible positive depth to water values were calculated also corresponds to the areas which lack sufficient representation in the existing monitoring network.

This inventory has found up to 13 wells with historical water level records and single aquifer completions in high priority subareas that may be suitable for inclusion in the current Napa County network, pending resolution of potential duplicate well records (see **Section 9.1.1**). An additional 20 currently monitored regulated groundwater level monitoring sites have been identified in high priority subareas.

Table 9-6
Proposed Monitoring Wells in Napa County

Subarea	Future GW Monitoring			AOI (number and GW or SW/GW)	Aquifer of Interest	Estimated alluvium depth at AOI (ft)
	Relative Priority	Needs	Objectives			
Napa Valley Floor-Calistoga	**H**	SP, SW	Conditions, Trends, Wtr Budget, SW	GW 14	Qa	unk
				GW 15	Qa	unk
Napa Valley Floor-St. Helena	**H**	SP, SW	Conditions, Trends, Wtr Budget, SW	GW 11	Qa	100 - 150
				GW 12	Qa	> 200
				GW 13	Qa	100 - 150
				SW E	Qa	100 - 150
				SW F	Qa, Tst	< 50
Napa Valley Floor-Yountville	**H**	SP, SW	Conditions, Trends, Wtr Budget, SW	GW 9	Qa	200 - 250
				GW 10	Qa, Tsvt	50 - 100
				SW D	Qa	100 - 200
				SW B	Qa	100 - 150
Napa Valley Floor-Napa	**H**	SP, SW	Conditions, Trends, Wtr Budget, SW	GW 5	Qa	> 200
				GW 6	Qa	unk
				GW 7	Qa	100 - 150
				GW 8	Qa	50
				SW A	Qa	unk
				SW C	Qa	50
Carneros	**H**	B	Conditions, Trends, Wtr Budget, Saltwater	GW 4	Qa	150 - 200
Jameson/American Canyon	M	B	Conditions, Trends, Wtr Budget, Saltwater	GW 1	Qa	unk
				GW 18	Qa	unk
Napa River Marshes	M	SP, SW	Conditions, Trends, Wtr Budget, Saltwater	GW 2	Qa	unk
				GW 3	Qa	unk
Angwin	M	B	Conditions, Trends, Wtr Budget	GW 16	Qa	unk
Pope Valley	L	B	Conditions, Trends (incl. CASGEM)	GW 17	Qa	unk

L = Low Priority; add groundwater level monitoring based on areas of planned future groundwater development

M = Medium Priority; add groundwater level monitoring

H = High Priority; add groundwater level monitoring

Monitoring Needs:
SP = Improve horizontal and/or vertical spatial distribution of data, including for the purpose of identifying such factors as climate change and to identify opportunities for enhanced groundwater recharge and storage;
SW =identify appropriate monitoring site to evaluate surface water -groundwater recharge/discharge mechanisms;
B = Basic data needed to accomplish groundwater level monitoring objectives

9.3.2 Areas of interest for additional groundwater monitoring

This review of monitored wells with current or historical data and aquifer-specific construction information did not find any such sites within a quarter mile of the mainstem Napa River that are screened exclusively in the shallow Quaternary alluvium aquifer. In response, six sites have been considered for the development of dedicated monitoring wells to provide data for groundwater/surface water monitoring.

The six proposed groundwater monitoring sites are located along the main Napa Valley Floor from the City of Napa north to St. Helena adjacent to the Napa River system (**Figure 9-1 and 9-2**). These facilities are planned to be located near to existing stream gauging stations and/or near areas where stream monitoring can also be conducted. **Table 9-7** provides a summary of the site locations and monitoring instrumentation. The proposed groundwater monitoring facilities are also being sited, where possible, adjacent to existing groundwater monitoring facilities (i.e., typically water supply wells constructed to greater depths in the aquifer system). The proposed monitoring wells will enable focused data collection regarding groundwater elevations and water quality to identify and characterize interactions with surface water.

The proposed groundwater monitoring sites described in **Table 9-7** would each include a dual casing installation with screen intervals located to provide for monitoring of the shallow and deeper portions of the alluvial aquifer at each location. In addition to the surface water monitoring equipment described in **Table 9-7**, the monitoring wells would also be equipped with automated water level recording equipment to measure changes in water levels that are more significant when studying groundwater surface water interactions than a semi-annual or even quarterly monitoring program would provide.

Table 9-7
Proposed Groundwater/Surface Water Monitoring Sites in the Napa Valley

Site	Location	Proposed MW property owner	Existing SW monitoring	Proposed additional SW monitoring	Proposed additional SW instrumentation location
F	Napa River at St. Helena	City of St. Helena	streamflow and stage (USGS)	temp, conductivity	USGS gauging station or Pope St Bridge
E	Napa River at Rutherford Rd	Napa County/State of California	none	stage, temp, conductivity	Napa River at Hoening/Round Pond property
D	Napa River at Yountville Cross Rd	Napa County	Stage (ultrasonic) at Yountville Cross Rd bridge (Napa RCD)	stage, temp, conductivity	Napa RCD gauging station
C	Napa River at Oak Knoll Ave	Napa County	streamflow and stage (USGS)	temp, conductivity	USGS gauging station or Oak Knoll Ave Bridge
B	Dry Creek at Washington St	Napa County	Stage (Napa RCD)	temp, conductivity	Napa RCD gauging station
A	Napa River at Napa	Napa County	Stage (ultrasonic) at Lincoln Ave bridge (Napa RCD)	stage, temp, conductivity	Lincoln Ave gauging station

Although no existing wells with water level records have been found to meet the needs for groundwater/surface water monitoring, four currently monitored sites with screened intervals in the shallow alluvial aquifer are located within one-half mile of the proposed groundwater/surface water monitoring locations. These sites would provide an opportunity to compare the groundwater level data collected in dedicated monitoring wells adjacent to the Napa River with data from sites somewhat farther away to assess groundwater gradients and water level trends relative to the river. These differences could be used to evaluate the interactions of groundwater and surface water seen near the Napa River with conditions farther removed from the river channel, both horizontally and vertically.

10 RECOMMENDATIONS

This study led to a broader awareness of the available geologic data, including drillers' reports, that were used to update the hydrogeologic conceptualization of Napa Valley Floor. This work also identified factors related to future assessment of groundwater availability. Spatial data coverage for stream gaging stations and groundwater level monitoring was good for some County subareas; however, for other subareas, additional stream gaging locations and monitoring network enhancements are needed. It was also learned better data are needed to develop aquifer characteristics that more accurately represent aquifers developed for groundwater utilization. Recommendations are presented to enhance and expand countywide monitoring to facilitate understanding of groundwater availability and integrated regional water management and planning efforts. Some of these recommendations, particularly recommendations related to the Carneros, Jameson/American Canyon, and Napa River Marshes Subareas, were previously discussed in reconnaissance work for the County's Comprehensive Groundwater Monitoring Program (LSCE, 2011a). The scope of the present study did not include the latter two subareas, so these recommendations still apply. The present study did attempt to develop a geologic cross-section in the Carneros Subarea and found geologic information to be lacking.

10.1 Carneros Subarea Hydrogeology

Limited data are available that describe the hydrogeologic setting of the Carneros Subarea. The available data suggest that groundwater resources are limited due to the generally low yielding nature of the formations in this area and poor groundwater quality at some locations (LSCE, 2011a). Future planning decisions require knowledge of current groundwater conditions and the possible impacts that may result from additional pumping. A complete analysis of the Carneros Subarea is recommended, including:

- Monitoring groundwater levels;
- Monitoring groundwater quality;
- Collection and interpretation of geologic data (primarily from well drillers' reports)
- Estimation of groundwater recharge using both mass balance;
- Determination of the extent and properties of aquifer materials; and
- Investigation of the influence of natural and induced hydrologic stresses occurring in neighboring subareas.

Since stream gaging information are lacking in the south part of the county, it is recommended that the focus be on enhancing the groundwater monitoring network (as discussed below) and development of additional geologic data, as feasible.

10.2 Hydrogeology and Saltwater Intrusion Potential for the Jameson/American Canyon and Napa River Marshes Subareas

Similar to the Carneros Subarea, limited data are available for the Jameson/American Canyons and Napa River Marshes Subareas which make up the southern County area. The two main issues facing this area are potential saltwater intrusion and the possibility that current water resources will not be sufficient to meet future demand. To establish current conditions and obtain information necessary for future development planning, further analysis is recommended that includes:

- Monitoring groundwater levels;
- Monitoring groundwater quality;
- Collection and interpretation of geologic data (primarily from well drillers' reports);
- Analysis of streamflow and precipitation;
- Estimation of recharge and discharge using both mass balance and streamflow infiltration methods; and
- Determination of the extent and properties of aquifer materials.

The current lack of groundwater data makes it difficult to determine the source and distribution of salinity in the southern County area with any certainty. A series of multi-level monitoring well clusters installed stepping south from the City of Napa toward San Pablo Bay would help in determining the geology of the Napa River Marsh Subarea and distribution of high salinity groundwater. This further subsurface exploration and characterization of the aquifer system, in conjunction with efforts to estimate subsurface outflow from the Napa Valley, would also help determine if freshwater within the Napa River Marshes Subarea could possibly be used to sustain increasing demand in the Jameson/American Canyon Subarea.

10.3 Aquifer Testing

As explained in this Report, the distribution of the hydraulic conductivities in the Napa Valley as presented by Faye (1973) was based on data recorded on historical drillers' reports. During the current study, it became evident, based on the approximately 1,300 reports reviewed, that most of the "test" data are insufficient to adequately determine or estimate aquifer characteristics, since most of these data were recorded during airlift operations rather than a pumping test. Currently, test methods accepted in the County's Well and Groundwater Ordinance allow bailing, airlifting, pumping, or any manner of testing generally acceptable within the well drilling industry to determine well yield. Recommendations for modifying the Napa County's Well and Groundwater Ordinance (Title 13, Chapter 13.04) have been proposed to improve the quality of data received by Environmental Management concerning reporting of well yield (LSCE, 2011c). These recommendations included removal of bailing and airlifting as acceptable methods; pumping is recommended to gather the appropriate data to reliably determine well yield, particularly in areas where such information along with aquifer characteristics is determined to be important to accomplish other County groundwater objectives. In 2013, County staff and the GRAC plan to review this recommendation and provide guidance for updating the County's Well and Groundwater Ordinance.

10.4 Stream Gaging Stations

One of the major limitations in this study is the spatial and temporal availability of streamflow gage data. The limited availability of data from gaged streamflow locations precludes developing a more spatially distributed estimate of recharge using this method. Because streamflow as measured at a gage is an aggregate for the upstream drainage area, infiltration is assumed to be uniform throughout each gaged watershed and across all land use categories.

In order to estimate streamflow from ungaged watersheds, a rainfall-runoff model could be developed and calibrated with records from gaged watersheds. A rainfall-runoff model may also help improve the spatial resolution of infiltration within gaged watersheds. Several different platforms are available for these types of models.

The Putah Creek watershed represents approximately 46 percent of Napa County and is an ungaged watershed; however, it may be possible to estimate runoff from this watershed by calculating inflow to Lake Berryessa. Reservoir inflow calculations require close quality control of inputs and may not be possible if flood control releases from Monticello Dam are not accurate. If it is possible to calculate inflow to Lake Berryessa, this time-series could be used as the outflow component in the water balance model to estimate groundwater recharge for this area of the county.

10.5 Groundwater Monitoring Network

This Report illustrates the distribution of current groundwater level monitoring locations, which is primarily located in the Napa Valley Floor-Napa and MST Subareas. Very little groundwater level monitoring is currently conducted elsewhere in Napa County outside these two subareas. Groundwater level measurements have been recorded at a total of 87 sites since 2011. Of these sites where groundwater levels are measured, some type of well construction information (depth and/or perforated interval(s)) is available for 67 sites (41 non-regulated sites and 26 regulated sites).

A preliminary ranking and priorities for improving or expanding groundwater level monitoring were prepared for each county subarea. Six subareas are given a relatively higher priority for improving the groundwater level monitoring network based on factors of current population and groundwater utilization relative to other parts of the county, and/or the need to improve understanding of groundwater/surface water interactions. These areas include:

- NVF-Calistoga,
- NVF-St. Helena,
- NVF-Yountville,
- NVF- MST,
- NVF-Napa, and
- Carneros Subareas

The monitoring network gaps in these six subareas might be addressed by:

1) Investigating the potential to restart monitoring where historical records are available but monitoring was discontinued;
2) Identifying existing wells of suitable construction that might be volunteered for inclusion through County and GRAC education and outreach efforts (this may include wells that are already being monitored for groundwater quality); and
3) Constructing new dedicated monitoring wells if suitable existing wells either do not exist in the area of interest or are otherwise not available.

Monitoring in other subareas with relatively medium to lower priorities is suggested to be addressed with volunteered wells. The Napa County CASGEM Network Plan submitted to DWR in September 2011 (LSCE, 2011b) also describes the County’s intent to include at least one additional monitoring well in the Pope Valley and Berryessa Valley Groundwater Basins.

The County plans to conduct additional public outreach to inform more private well owners of the value of understanding the groundwater resources in the County and to encourage their voluntary participation in the Comprehensive Groundwater Monitoring Program and/or CASGEM program (LSCE, 2013).

This Report describes the existing monitoring sites, provides recommendations for the number and location of additional monitoring areas, and describes the key groundwater level monitoring objectives to be addressed. Altogether, it is recommended that approximately six groundwater/surface water monitoring sites for purposes of evaluating groundwater/surface water interactions and about 18 other areas of interest be added to the network.

The six proposed groundwater/surface water monitoring sites are located along the main Napa Valley Floor from the City of Napa north to St. Helena adjacent to the Napa River system. These facilities are planned to be located near to existing stream gaging stations and/or near areas where stream monitoring can also be conducted. The proposed groundwater monitoring facilities are also being sited, where possible, adjacent to existing groundwater monitoring facilities (i.e., typically water supply wells constructed to greater depths in the aquifer system).

The proposed monitoring wells will enable focused data collection regarding groundwater elevations and water quality to identify and characterize interactions with surface water.

Although this Report focuses on the extent of groundwater level monitoring in Napa County, a summary review of current groundwater quality monitoring sites has been conducted for the Napa County Groundwater Monitoring Plan 2013. That review found 177 sites in Napa County, across all monitoring networks, with groundwater quality data collected since 2008 (LSCE, 2013). The current monitoring networks for groundwater levels and groundwater quality differ according to monitoring entity, data collection frequency, and monitoring goals. Given these differences, a similar inventory of the groundwater quality monitoring networks is advisable in light of the County's intention to increase its capacity to consider groundwater quality in future groundwater resources management decisions.

The proposed inventory should include an effort to locate construction information and identify aquifers encountered by sites monitored for groundwater quality. The updated hydrogeologic conceptualization presented here as well as previously published studies would guide the inventory. Goals of the proposed inventory include an evaluation of the extent and quality of data provided by currently monitored groundwater quality sites and historically monitored sites with the potential for reactivation. The proposed inventory should also consider Napa County's groundwater quality monitoring needs and develop proposals to meet those needs with data from currently monitored wells, where feasible, or wells added to the Napa County monitoring network.

10.6 Future Groundwater Modeling Efforts

As described earlier in this Report, a groundwater flow model was developed for the Napa River watershed which was generally conceptualized as a large basin of impermeable rock overlain in three distinct areas by more permeable units (DHI, 2006a). The three areas that were the focus of the groundwater model were the north Napa Valley area and the MST and Carneros Subareas. The groundwater model encompasses the Napa River watershed and consists of two layers. The upper layer was designated as being unconfined and the lower layer was designated as confined. Each of the three modeled areas was represented as a separate water-producing geologic unit. The geologic unit that was conceptualized as the primary source for groundwater in the north Napa Valley area was the alluvium. Aquifer parameters and their distribution were based on previous work presented in Faye (1973), and extrapolated to the rest of the Napa Valley Floor to the south.

A model is a tool that can help facilitate the examination of water resources management scenarios, including the effects of climate change and other stresses on surface and groundwater resources. Large regional models can be especially useful tools to examine complicated scenarios. As described in this Report, the geologic and hydrogeologic setting in Napa County and specifically the Napa Valley Floor, is extremely complex. The updated hydrogeologic conceptualization presented herein shows that the subsurface is so complex that the current two-layer model for the north Napa Valley area, which focuses on the alluvium with unconfined and semi-confined aquifer characteristics, needs significant refinement for future use and to improve the models' predicative utility. Such refinement includes, but is not limited to, incorporation of the updated physical hydrogeologic conceptualization in the model structure and consideration of revised aquifer parameters and/or sensitivity analyses of parameters until such parameters can be refined through proper testing.

11 REFERENCES

Alley, W.M., T.E. Reilly, O.L. Franke. 1999. Sustainability of ground-water resources. U.S. Geological Survey Circular 1186. Denver, CO.

Bezore, S., C.E. Randolph-Loar, and R.C. Witter. 2002. Geologic map of the Cuttings Wharf 7.5' Quadrangle, Napa and Solano Counties, California: A Digital Database. California Geological Survey available from CGS website at ftp://ftp.consrv.ca.gov/pub/dmg/rgmp/Prelim_geo_pdf

Bezore, S., C.E. Randolph-Loar, and R.C. Witter. 2004. Geologic map of the Mt. George 7.5' Quadrangle, Napa and Solano Counties, California: A Digital Database. California Geological Survey available from CGS website at ftp://ftp.consrv.ca.gov/pub/dmg/rgmp/Prelim_geo_pdf

Bezore, S.P., K.B. Clahan, J.M. Sowers, and R.C. Wittier. 2005. Geologic map of the Yountville 7.5' Quadrangle, Napa and Solano Counties, California: A Digital Database. California Geological Survey available from CGS website at ftp://ftp.consrv.ca.gov/pub/dmg/rgmp/Prelim_geo_pdf

California Department of Water Resources (DWR). 1962. Reconnaissance report on the Upper Putah Creek Basin investigation, Bulletin No. 99.

California Department of Water Resources (DWR). 1999. Land use survey, state of California, the Resources Agency Department of Water Resources, Land and Water Use Section, March 1999.

California Department of Water Resources (DWR). 2003. California's groundwater. DWR Bulletin 118.

California Department of Water Resources (DWR). 2012. IWFM demand calculator: IDC v4.0 theoretical documentation and user's manual, the Resources Agency Department of Water Resources, Bay-Delta Office, May 2012.

Center for Collaborative Policy at California State University Sacramento. 2010. Assessment of the feasibility of a collaborative groundwater data gathering effort in Napa County, California.

Charbeneau. 2000. Groundwater Hydraulics and Pollutant Transport, Prentice Hall.

Clahan, K.B., D.L. Wagner, G.L. Saucedo, C.E. Randolph-Loar, and J.M. Sowers. 2004. Geologic map of the Napa 7.5' Quadrangle, Napa County, California, California. California

Geological Survey available from CGS website at,
ftp://ftp.consrv.ca.gov/pub/dmg/rgmp/Prelim_geo_pdf/Napa_prelim.pdf

Clahan, K.B., D.L. Wagner, S.P. Bezore, J.M. Sowers, R.C. Witter. 2005. Geologic map of the Rutherford 7.5' Quadrangle, Sonoma and Napa County, California, California. California Geological Survey available from CGS website at,
ftp://ftp.consrv.ca.gov/pub/dmg/rgmp/Prelim_geo_pdf/Rutherford_prelim.pdf

DHI. 2006a. MIKE SHE an integrated hydrological modeling system – documentation and users guide. November 2006.

DHI. 2006b. Final baseline data report (BDR) technical appendix – water quantity and water quality report, Napa County, California. October 2006.

DHI. 2007. Modeling analysis in support of vineyard development scenarios evaluation, Napa County, California. February 2007.

Elsevier. 2009. Evapotranspiration and Water Use Efficiency in Different-Aged Pacific Northwest Douglas-fir Stands, Agricultural and Forest Meteorology Journal, February 2009.

ESRI. 2012. Bing maps aerial streaming aerial imagery. www.esri.com Accessed November 21, 2012.

Farrar, C.D. and L. F. Metzger. 2003. Ground-water resources in the Lower Milliken-Sarco-Tulucay Creeks area, southeastern Napa County, California, 2000-2002. USGS. Water-Resources Investigations Report 03-4229.

Farrar, C. D., K. Kockzot, L. Metzger, T. Nishikawa, E.G. Reichard. 2006. Geohydrologic characterization, water-chemistry, and ground-water flow simulation model of the Sonoma Valley area, Sonoma County, California, U.S. Geological Survey Scientific Investigations Report, 2006-5092.

Faye, R.E. 1973. Ground-water hydrology of northern Napa Valley California. Water Resources Investigations 13-73, US Geological Survey, Menlo Park, CA, 64 p.

Fox, K.F., Jr., J.D. Sims, J.A. Bartow, and E.J. Helley. 1973. Preliminary geologic map of eastern Sonoma County and western Napa County, California: U.S. Geological Survey Misc. Field Studies Map MF-483, 5 sheets, scale 1:62,500.

Fox, K.F., Jr., 1983. Tectonic setting of Late Miocene, Pliocene, and Pleistocene rocks in part of the Coast Ranges north of San Francisco, California, U.S. Geological Survey Professional Paper 1239. 33 pp.

Fox, K.F., Jr., R.J., Fleck, G.H., Curtis, and C.E. Meyer, 1985a. Potassium – Argon and Fission – track ages of the Sonoma Volcanics in an area north of San Pablo Bay, California. Geologic Society of America, Bulletin v 96, #5, p. 647-654.

Fox, K.F., Jr., R.J., Fleck, G.H., Curtis, and C.E. Meyer, 1985b. Implications of the northwestwardly age of the volcanic rocks of west - Central, California. USGS. Misc. Field Studies Map MF-1753.

Graymer, R.W., D.L. Jones, and E.E. Brabb. 2002. Geologic map and map database of northeastern San Francisco Bay region, California; most of Solano County and parts of Napa, Marin, Contra Costa, San Joaquin, Sacramento, Yolo, and Sonoma Counties: U.S Geological Survey Miscellaneous Field Studies Map MF-2403, 1 sheet, 1:100,000 scale, 28 p.

Graymer, R.W., B.C. Moring, G.J. Saucedo, C.M. Wentworth, E.E. Brabb, and K.L. Knudsen. 2006. Geologic Map of the San Francisco Bay Region. U.S. Geological Survey, Scientific Interpretations Map 2918, scale 1:275,000.

Graymer, R.W., E.E. Brabb, D.L. Jones, J. Barnes, R.S. Nicholson, and R.E. Stamski. 2007. Geologic map and map database of eastern Sonoma and western Napa Counties, California: U.S. Geological Survey Scientific Investigations Map 2956 http://pubs.usgs.gov/sim/2007/2956/.

Healy, R.W., T.C. Winter, J.W. LaBaugh, and O.L. Franke. 2007. Water Budgets: foundations for effective Water-resources and environmental management. U.S. Geological Survey Circular 1308.

Helley, E.J., K.R. Lajoie, W.E. Spangle, and M.L. Blair. 1979. Flatland deposits of the San Francisco Bay region, California; their geology and engineering properties, and their importance to comprehensive planning. U.S. Geological Survey Professional Paper 943. Scale 1:125,000.

ITRC. 2003. California Crop and Soil Evapotranspiration ITRC Report (03-001), January 2003, California State Polytechnic University, San Luis Obispo.

Johnson, M.J. 1977. Ground-water hydrology of the Lower Milliken-Sarco-Tulucay Creeks Area, Napa County, California. USGS Water-Resources Investigations 77-82.

Jones and Stokes & EDAW. 2005. Napa County baseline data report. November, 2005.

Koenig, J.B. 1963. Geologic map of California, Olaf P. Jenkins edition, Santa Rosa Sheet. California Division of Mines and Geology. Scale 1:250,000.

Kunkel, F. and J.E. Upson. 1960. Geology and groundwater in Napa and Sonoma Valleys Napa and Sonoma Counties California. U.S. Geological Survey Water Supply Paper 1495.

Langenheim, V.E., C.W. Roberts, C.A. McCabe, D.K. McPhee, J.E. Tilden, and R.C. Jachens. 2006. Preliminary isostatic gravity map of the Sonoma Volcanic Field and vicinity, Sonoma and Napa Counties. California. U.S. Geological Survey. Open-File Rpt. 2006-1056.

Lambert, G., J. Kashiwagi, B. Hansen, P. Gale, A. Endo. 1978. Soil survey of Napa County, California. US Department of Agriculture, Soil Conservation Service.

Luhdorff and Scalmanini, Consulting Engineers (LSCE). 2010. Task 1, Napa County data management system. Technical Memorandum prepared for Napa County.

Luhdorff and Scalmanini, Consulting Engineers (LSCE). 2011a. Napa County Conditions and Groundwater Monitoring Recommendations, prepared for Napa County Department of Public Works, February 2011.

Luhdorff and Scalmanini, Consulting Engineers (LSCE). 2011b. Napa County, California statewide groundwater elevation monitoring (CASGEM) network plan. September 2011.

Luhdorff and Scalmanini, Consulting Engineers (LSCE). 2011c. Groundwater planning considerations and review of Napa County groundwater ordinance and permit process. Technical Memorandum prepared for Napa County.

Luhdorff and Scalmanini, Consulting Engineers (LSCE). 2013. Napa County groundwater monitoring plan 2013. Prepared for Napa County.

Mankinen, E. A. 1972. Paleomagnetism and potassium-argon ages of the Sonoma Volcanics, California. Geological Society of America Bulletin, 83(7), 2063-2072.

Napa County. 2005. Napa County baseline data report (BDR). Prepared for the Napa County Conservation and Planning Department.

Napa County. 2008. Napa County general plan. (Amended June 23, 2009).

Napa County Website. 2013. http://www.countyofnapa.org/bos/grac/

NCDC. 2010. National Climatic Data Center, Hydrodata Volume 22.0 USGS Daily Values – West 1.

NRCS. 1983. National Engineering Handbook, Section 15 Sprinkle Irrigation.

PRISM. 2012. PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu.

SEBAL. 2009. Spatial mapping of ET in the Russian River Basin of California using SEBAL, SEBAL North America, Inc. June 2009.

Sims, J.D., K.F. Fox, Jr., J.A. Bartow, and E.J. Helley. 1973. Preliminary geologic map of Solano County and parts of Napa, Contra Costa, Marin, and Yolo Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-484, 5 sheets, scale 1:62,500.

Sophocleous. M. 2002. Interactions between groundwater and surface water: the state of the science. Hydrogeology Journal 10(1), p 52-67.

Sowers, J.M., J.S., Noller, and W.R. Lettis, 1998. Maps showing Quaternary geology and liquefaction susceptibility, Napa, California. 1:100,000 Quadrangle: A Digital Database. USGS. Open-file Report OF 98-460, 2 sheets.

Sweetkind, D.S. and E.M. Taylor. 2010. Digital tabulation of geologic and hydrologic data from water wells in the Northern San Francisco Bay Region, Northern California. U.S. Geological Survey Open - File Report 2010-1063.

University of California. 2012. University of California Drought Management website, Division of Agriculture and Natural Resources. http://ucanr.edu/sites/Drought/Agriculture/Irrigation_Scheduling/Evapotranspiration_Scheduling_ET/Frequency_of_Irrigation/Soil_Characteristics/ Access November 21, 2012.

USDA. 2007. Soil Survey Geographic (SSURGO) database for Napa County, California, U.S. Department of Agriculture, Natural Resources Conservation Service, December 10, 2007.

USDA/NRCS, NASS Cropland Data Layer. National Geospatial Management Center, Fort Worth, TX. Downloaded from datagateway.nrcs.usda.gov accessed June 2012.

USGS. 1996. United States Geologic Survey, National Hydrography Dataset, 1996.

Wagner, D.L and E.J. Bortugno. 1982. Geologic map of the Santa Rosa Quadrangle: California Division of Mines and Geology Regional Geologic Map Series, Map 2A, scale 1:250,000.

Weaver, C.E. 1949. Geology of the Coast Ranges immediately north of the San Francisco Bay region, California. California Department of Natural Resoures, Division of Mines. Bulletin 149. (Condensation of Geological Society of America. Memoir 35).

West Yost & Associates (WYA). 2005. 2005 Napa Valley water resources study, Napa County, California. Prepared for: Napa County Flood Control & Water Conservation District, City of Napa, City of American Canyon, Town of Yountville, City of St. Helena, and City of Calistoga.

Winter. T.C., J.W. Harvey, O.L. Franke, W.M. Alley. 1998. Ground water and surface water: a singular resource. U.S. Geological Survey Circular 1139. Denver, CO.

Figures

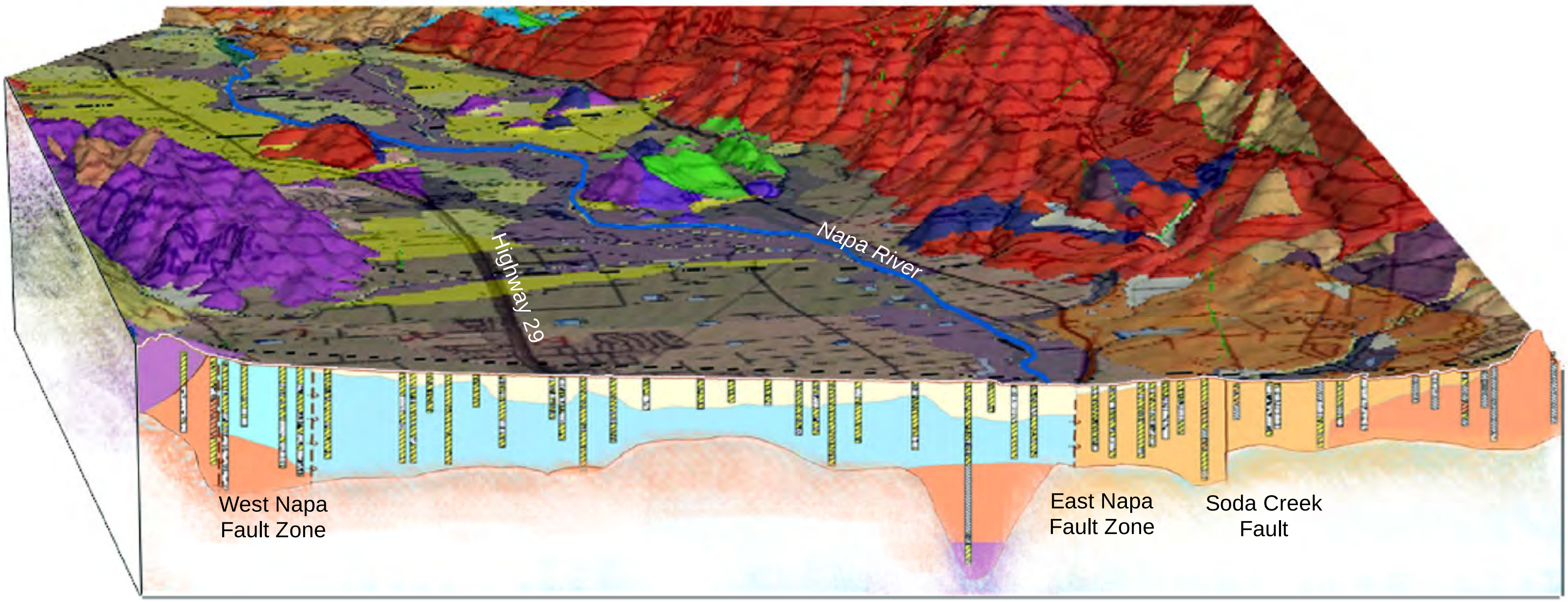


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Figure ES-1
Three-Dimensional Visualization of the Geology in the Napa Valley Area

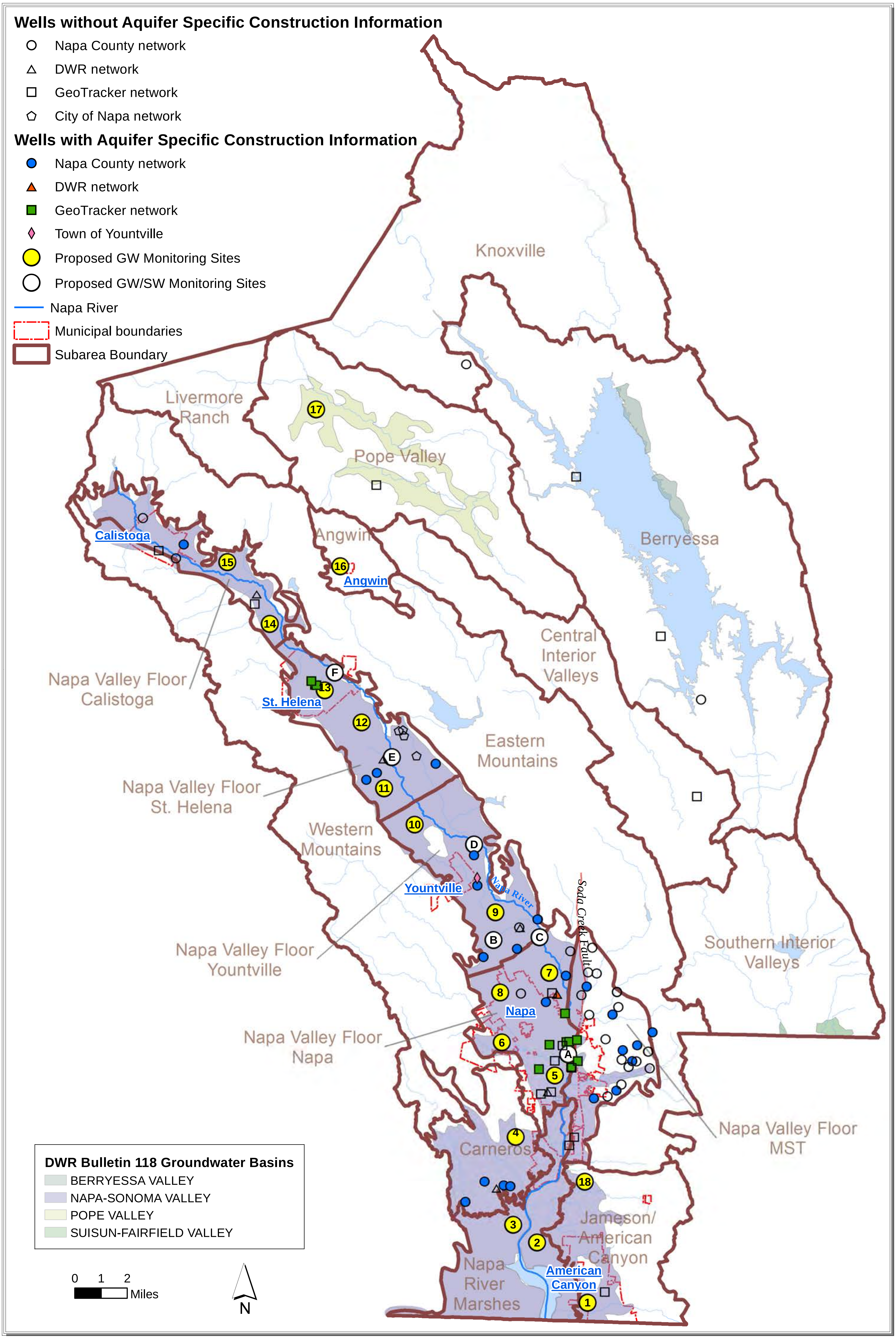

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Figure ES-4
Current and Proposed Groundwater Level Monitoring Sites in Napa County

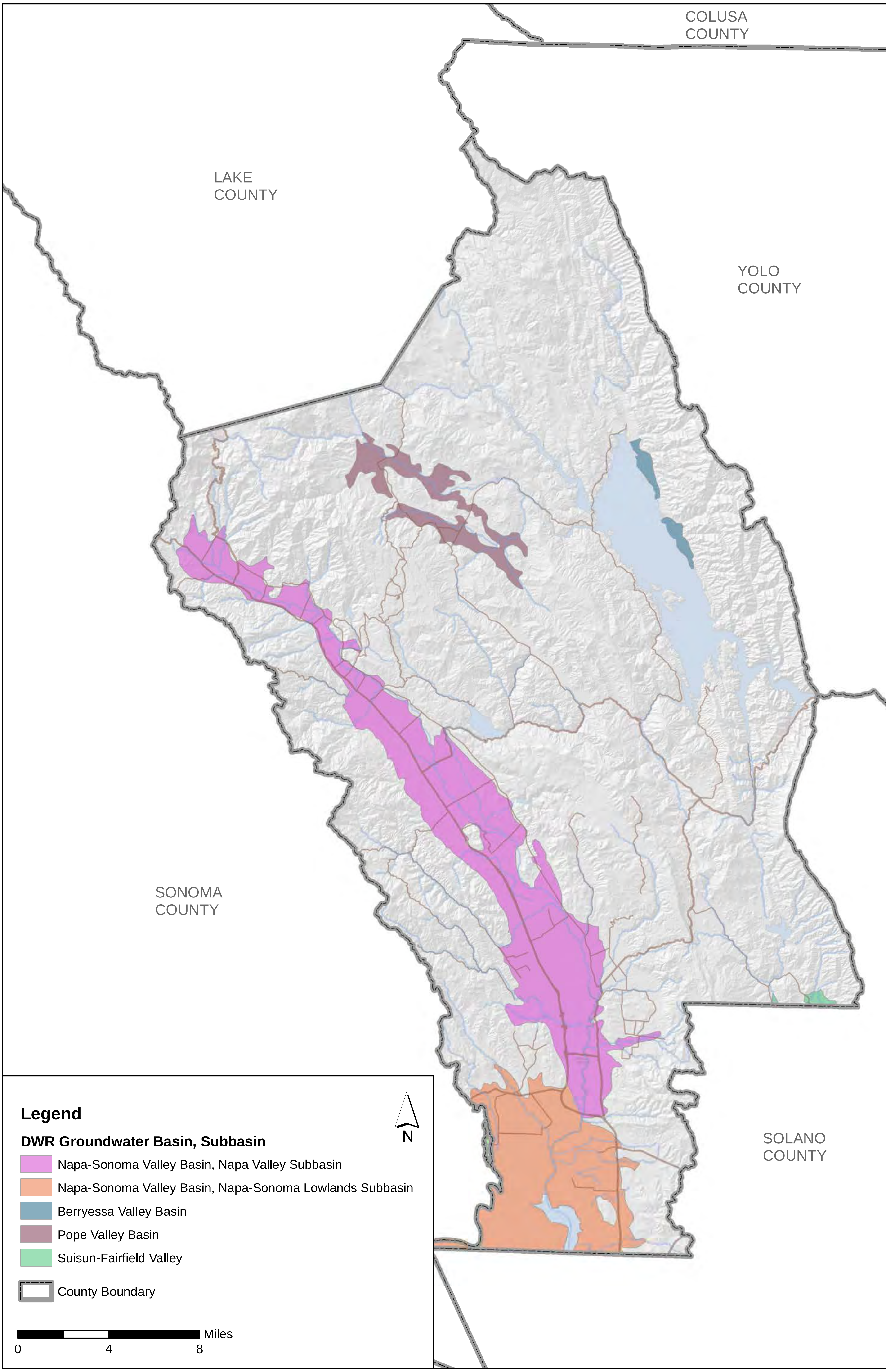

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Figure 2-1
Napa County Groundwater Basins
Napa County, CA

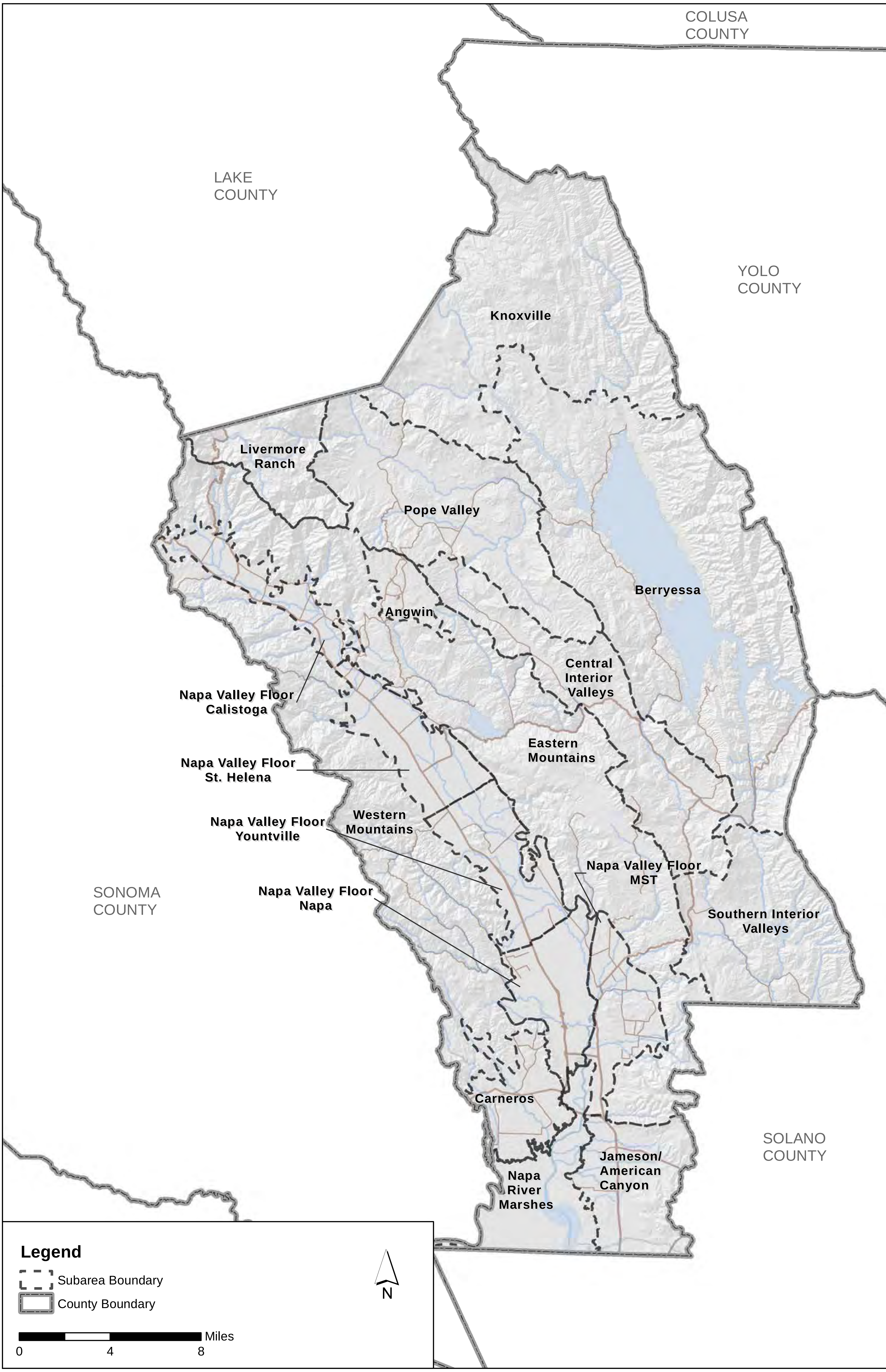

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Figure 2-2
Napa County Subareas
Napa County, CA

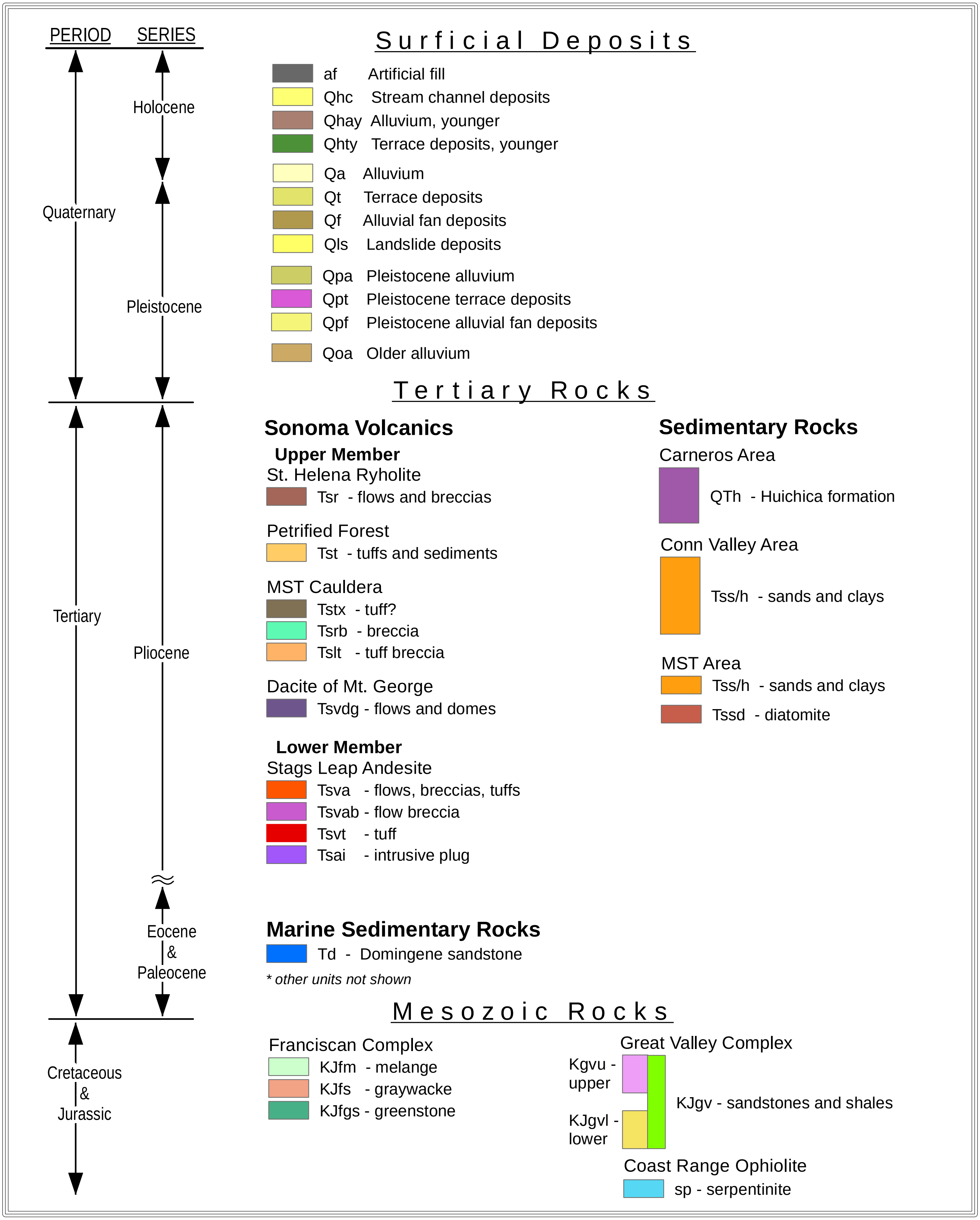

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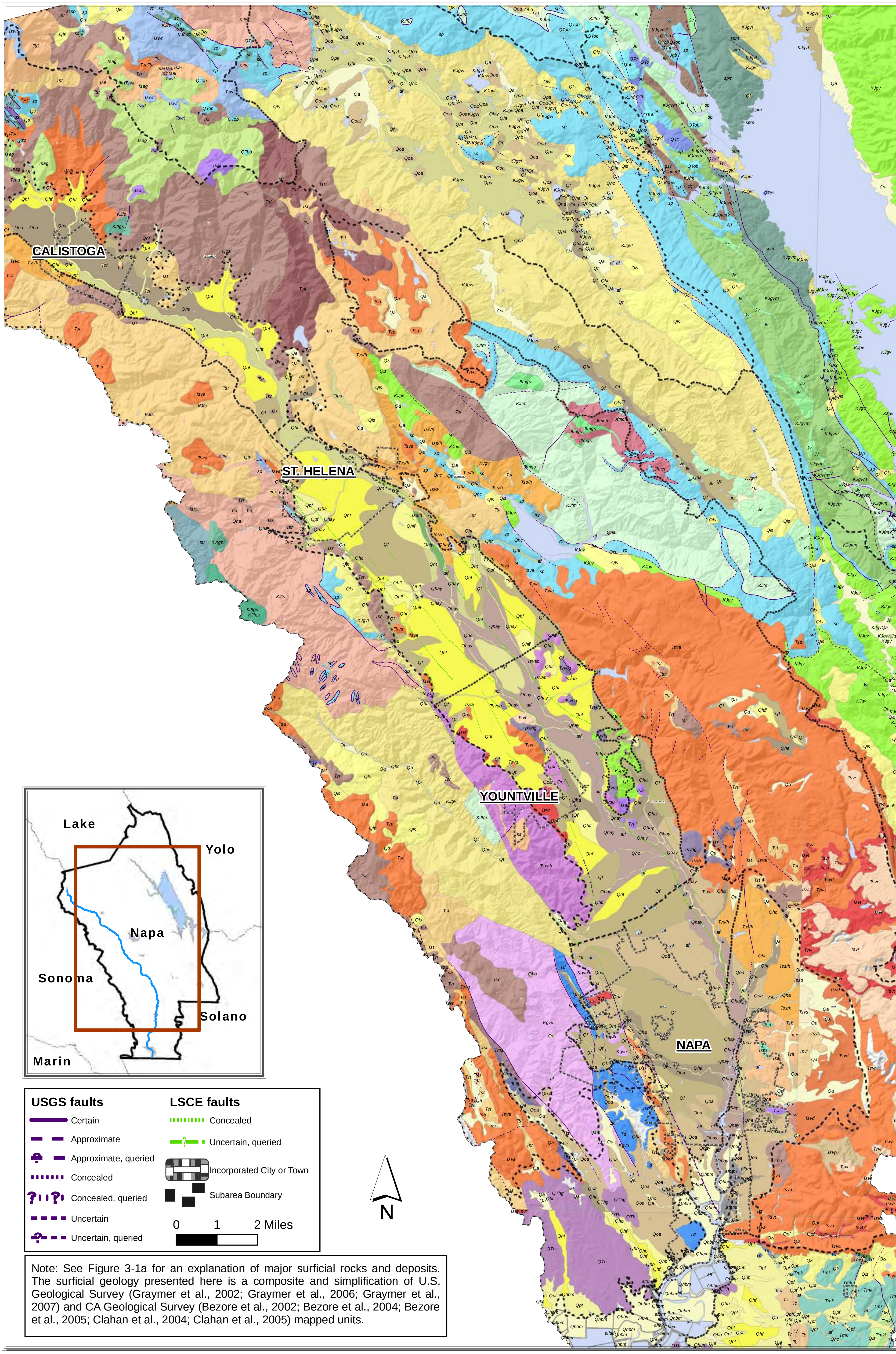
Figure 3-1a
Major Surficial Rocks and Deposits of Napa Valley



Note: See Figure 3-1a for an explanation of major surficial rocks and deposits. The surficial geology presented here is a composite and simplification of U.S. Geological Survey (Graymer et al., 2002; Graymer et al., 2006; Graymer et al., 2007) and CA Geological Survey (Bezore et al., 2002; Bezore et al., 2004; Bezore et al., 2005; Clahan et al., 2004; Clahan et al., 2005) mapped units.

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Figure 3-1b
Napa Valley Surficial Geology

Figure 5-1a Cross Section B-B' From Kunkel and Upson (1960)

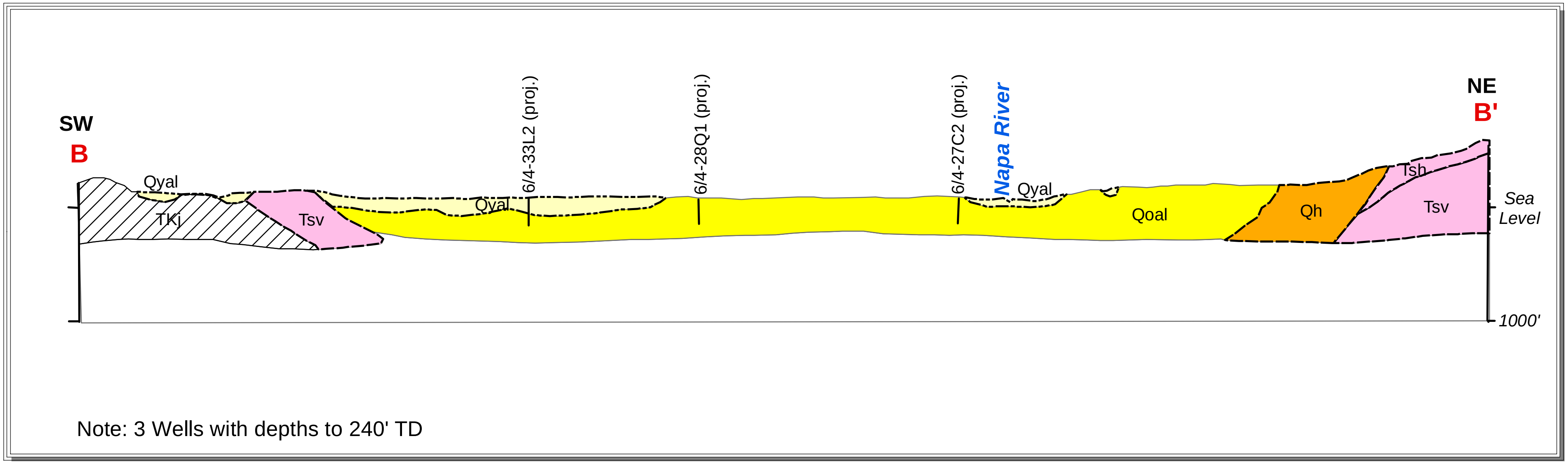

Figure 5-1b annotated Cross Section B-B', Schematic Geologic and Well Information From LSCE (2013)

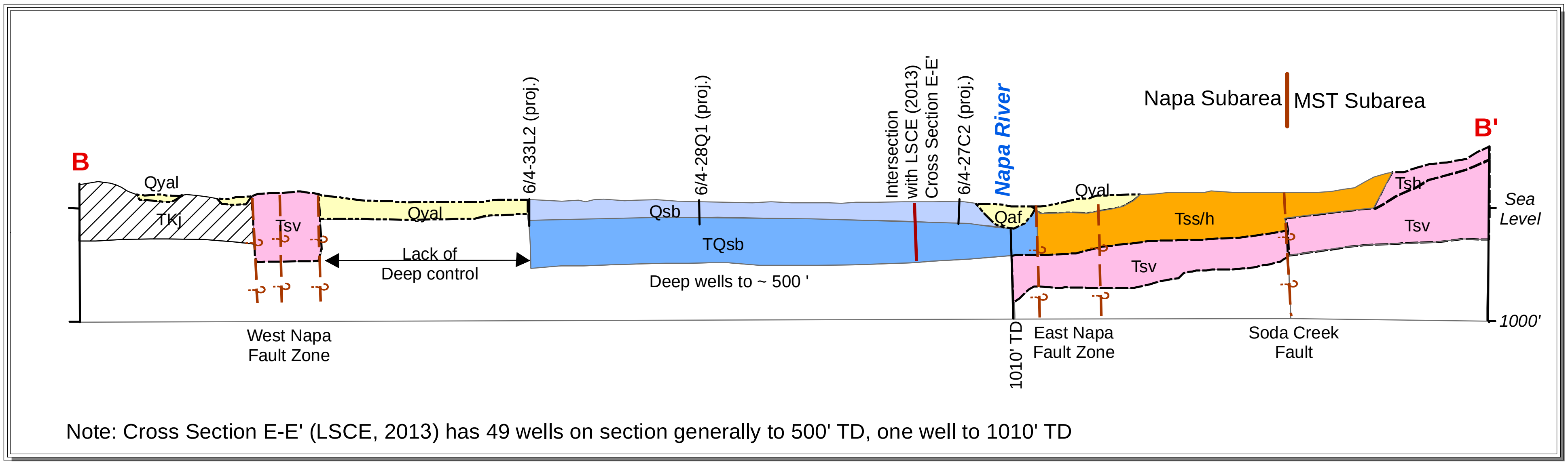

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Figure 5-1
Kunkel and Upson Geologic Cross Section

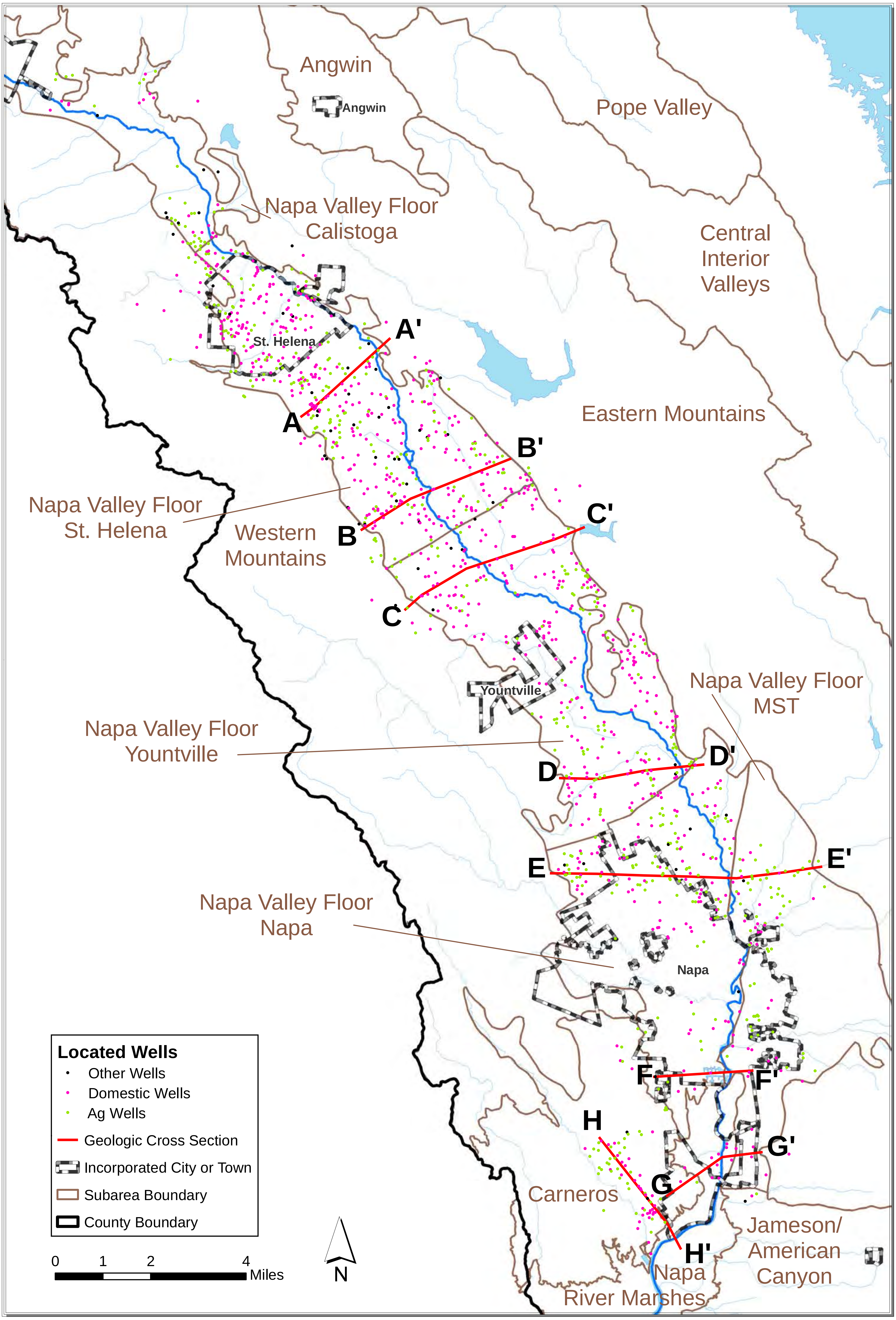

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Figure 5-2
Geologic Cross Section Location Map

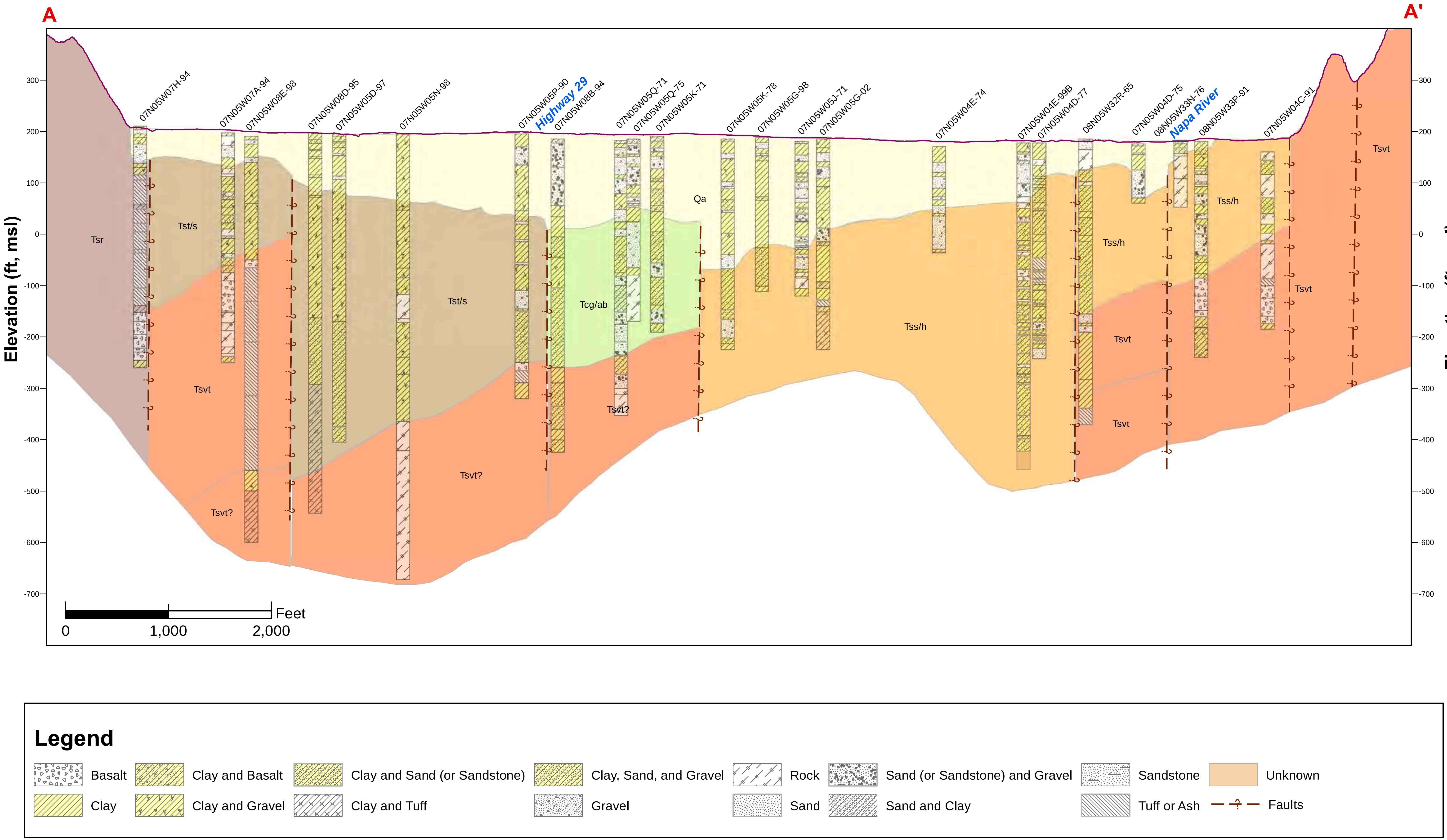

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Figure 5-3
Cross Section A – A'
Northern NVF-St. Helena Subarea, Napa County, CA

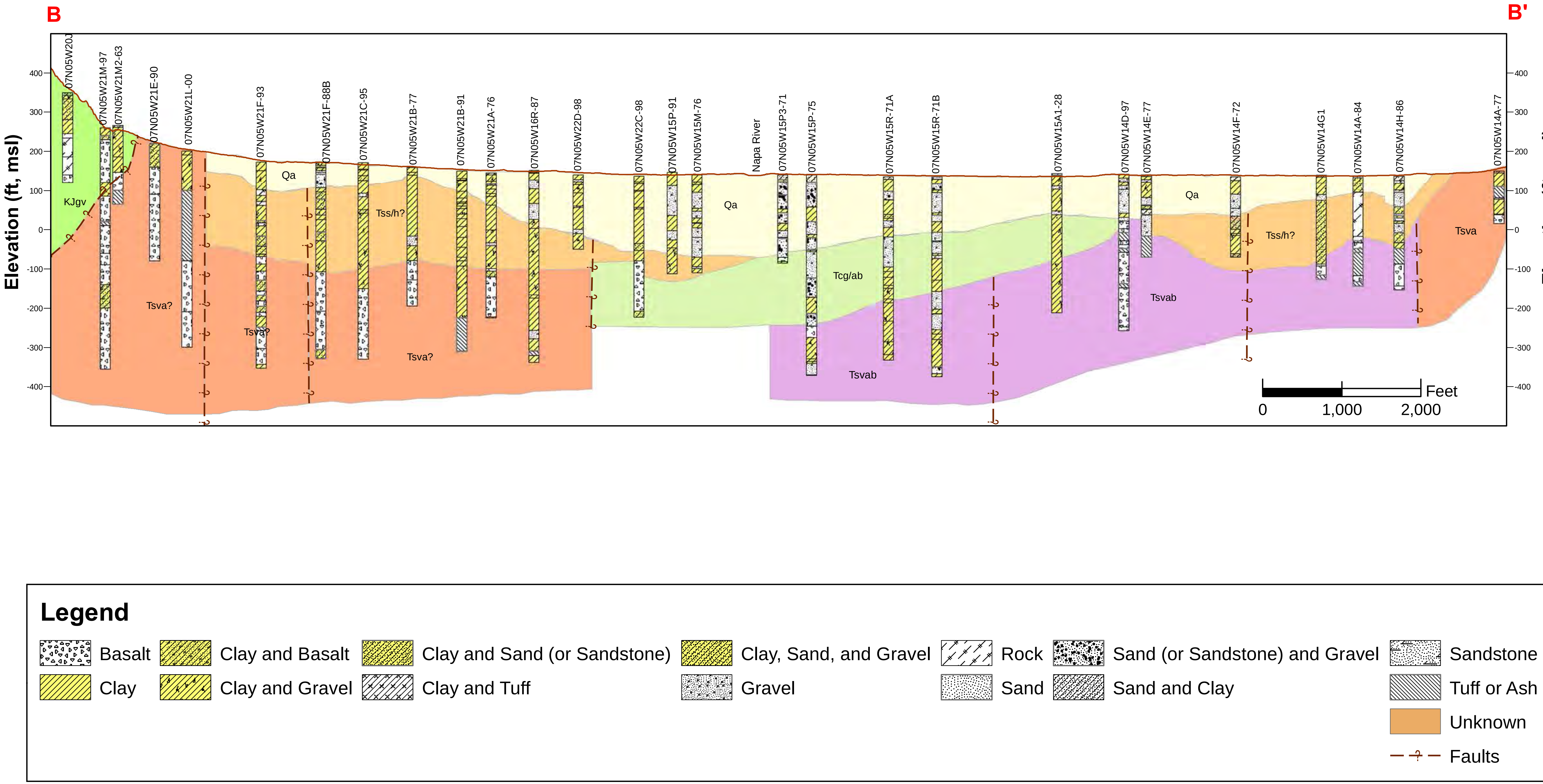

Figure 5-4
Cross Section B – B'
Southern NVF-St. Helena Subarea, Napa County, CA

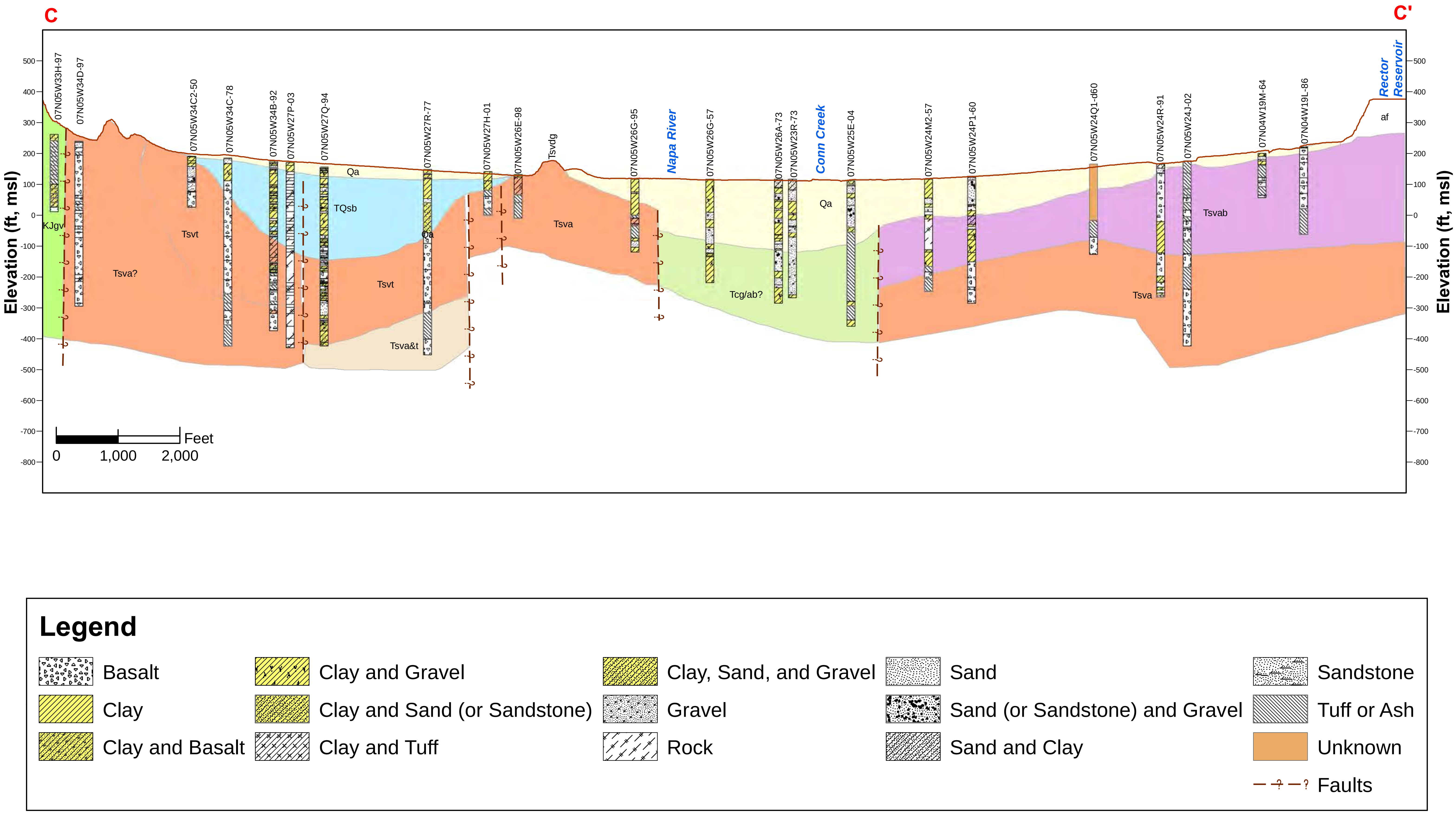

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Figure 5-5
Cross Section C – C'
Northern NVF-Yountville Subarea, Napa County, CA

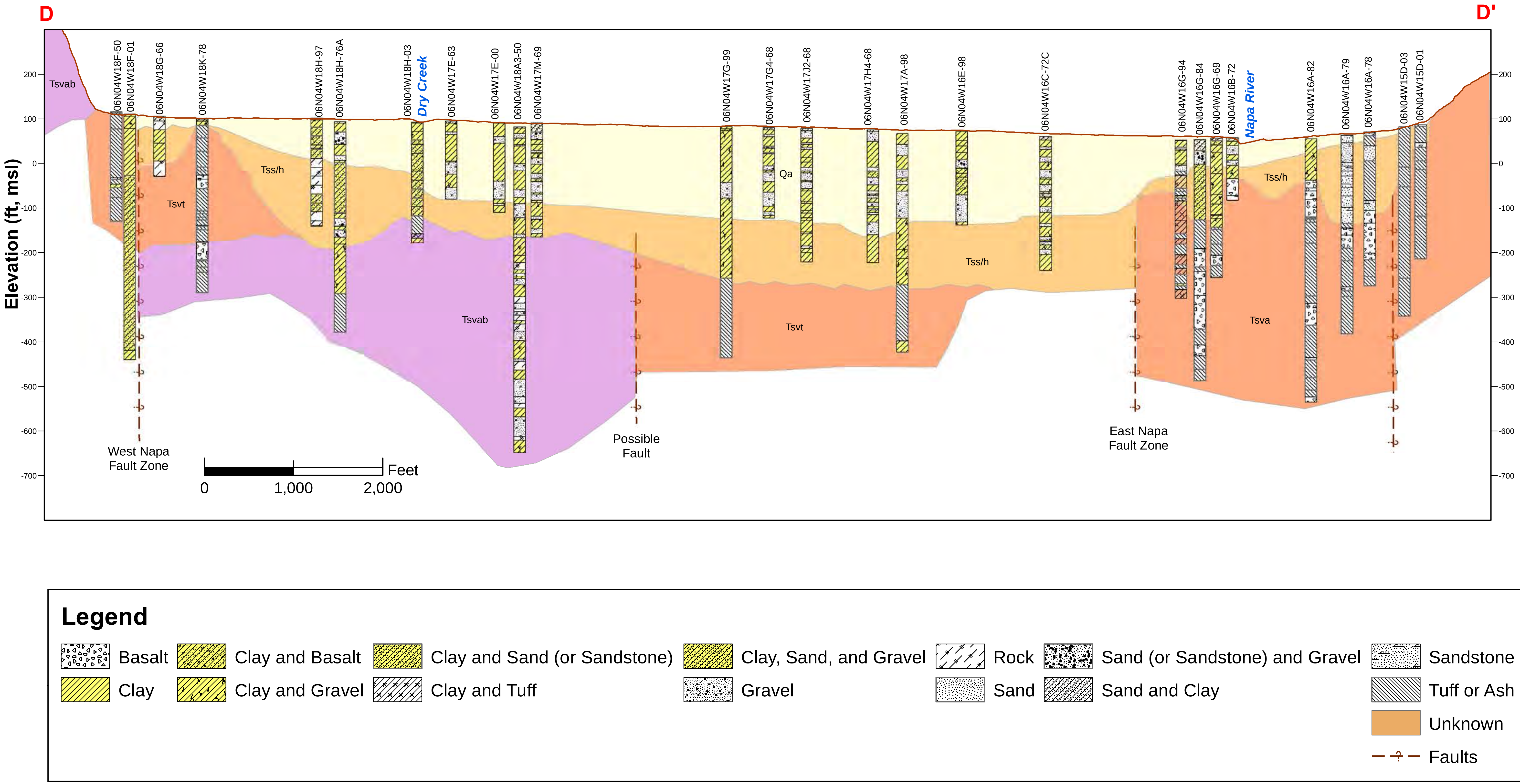

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Figure 5-6
Cross Section D – D'
Southern NVF-Yountville Subarea, Napa County, CA

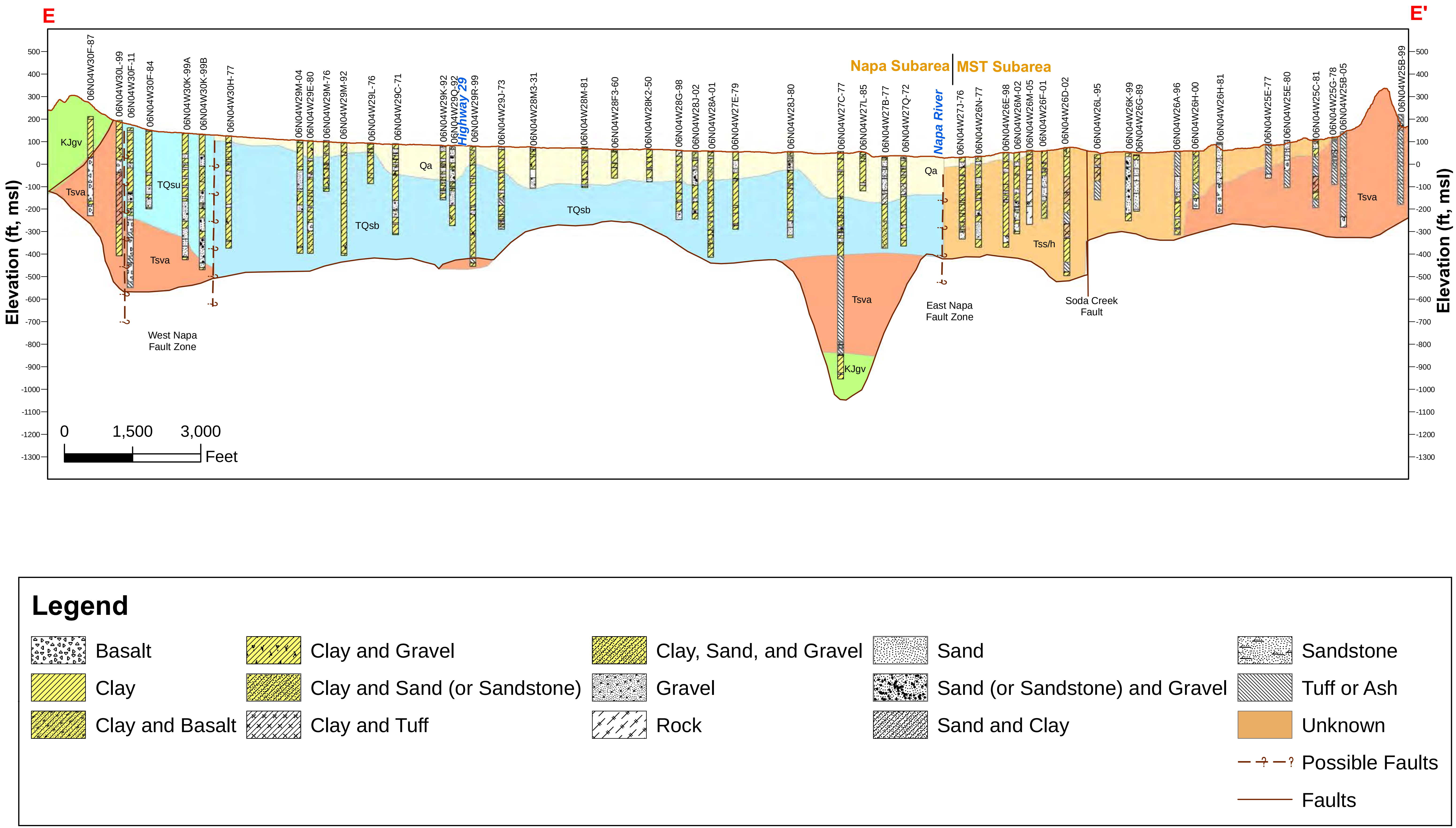

Figure 5-7
Cross Section E – E'
Northern NVF-Napa Subarea, Napa County, CA

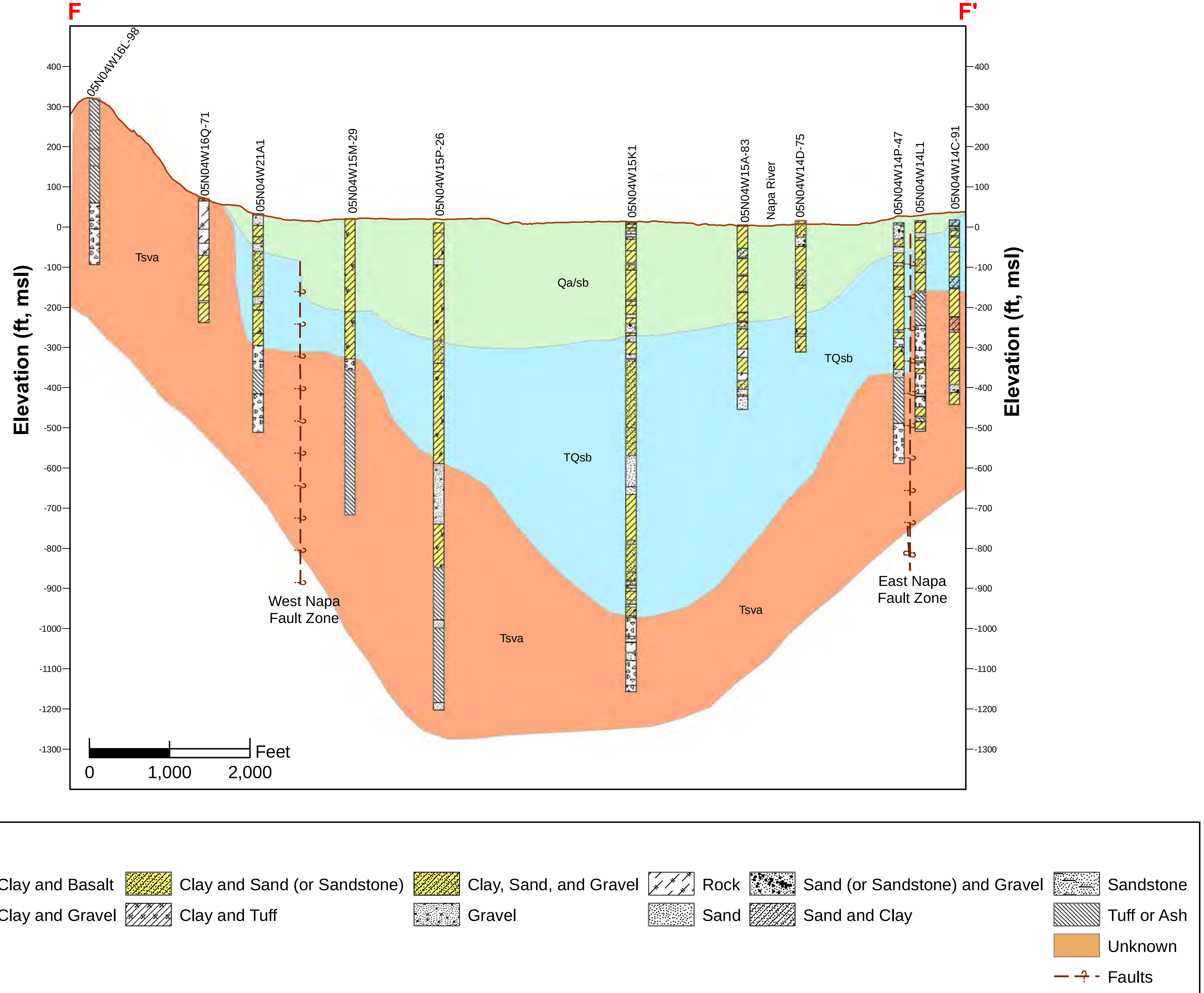

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Figure 5-8
Cross Section F – F'
Southern NVF-Napa Subarea, Napa County, CA

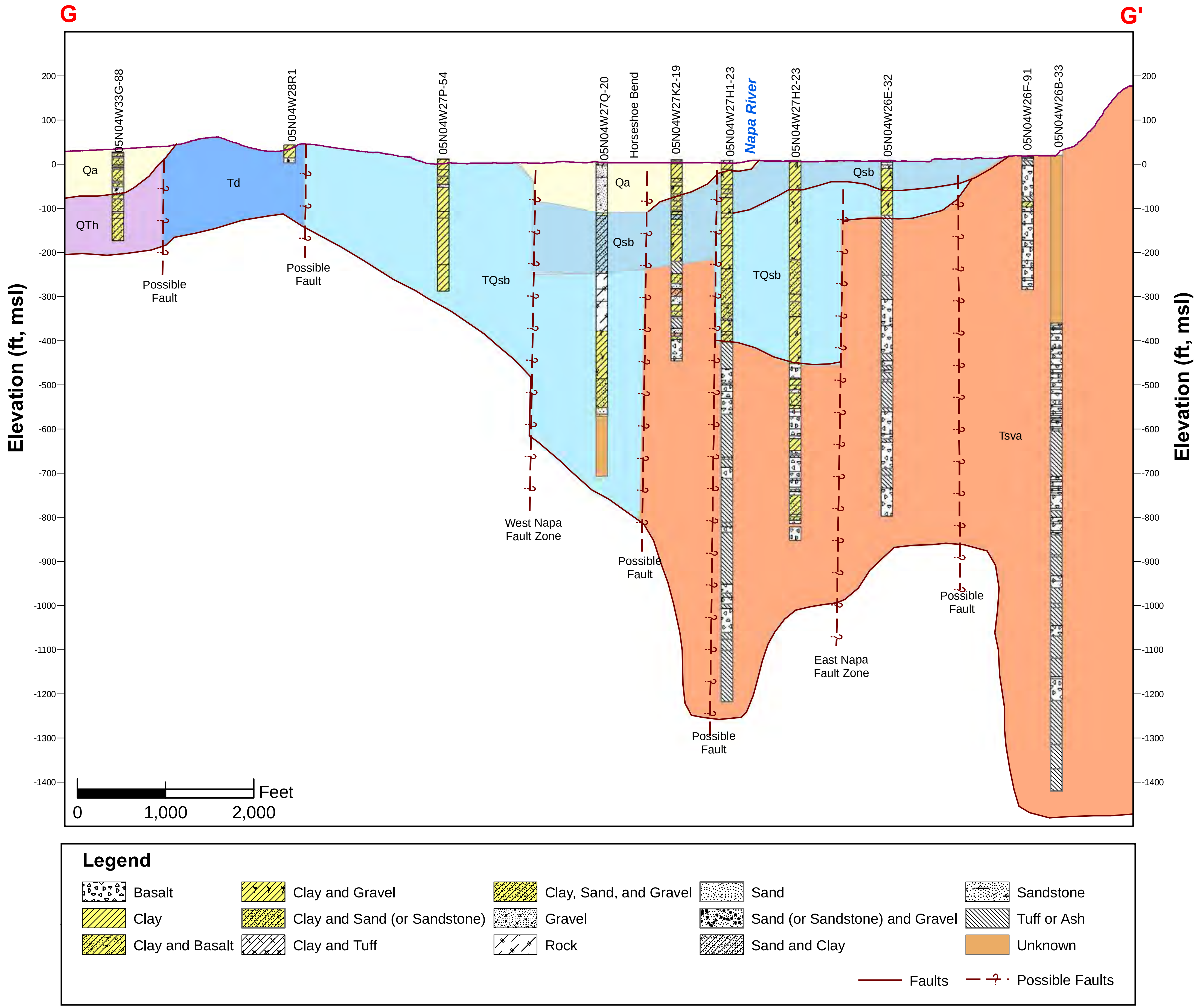

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Figure 5-9
Cross Section G – G'
Carneros/Napa River Marshes/NVF-MST Subareas, Napa County, CA

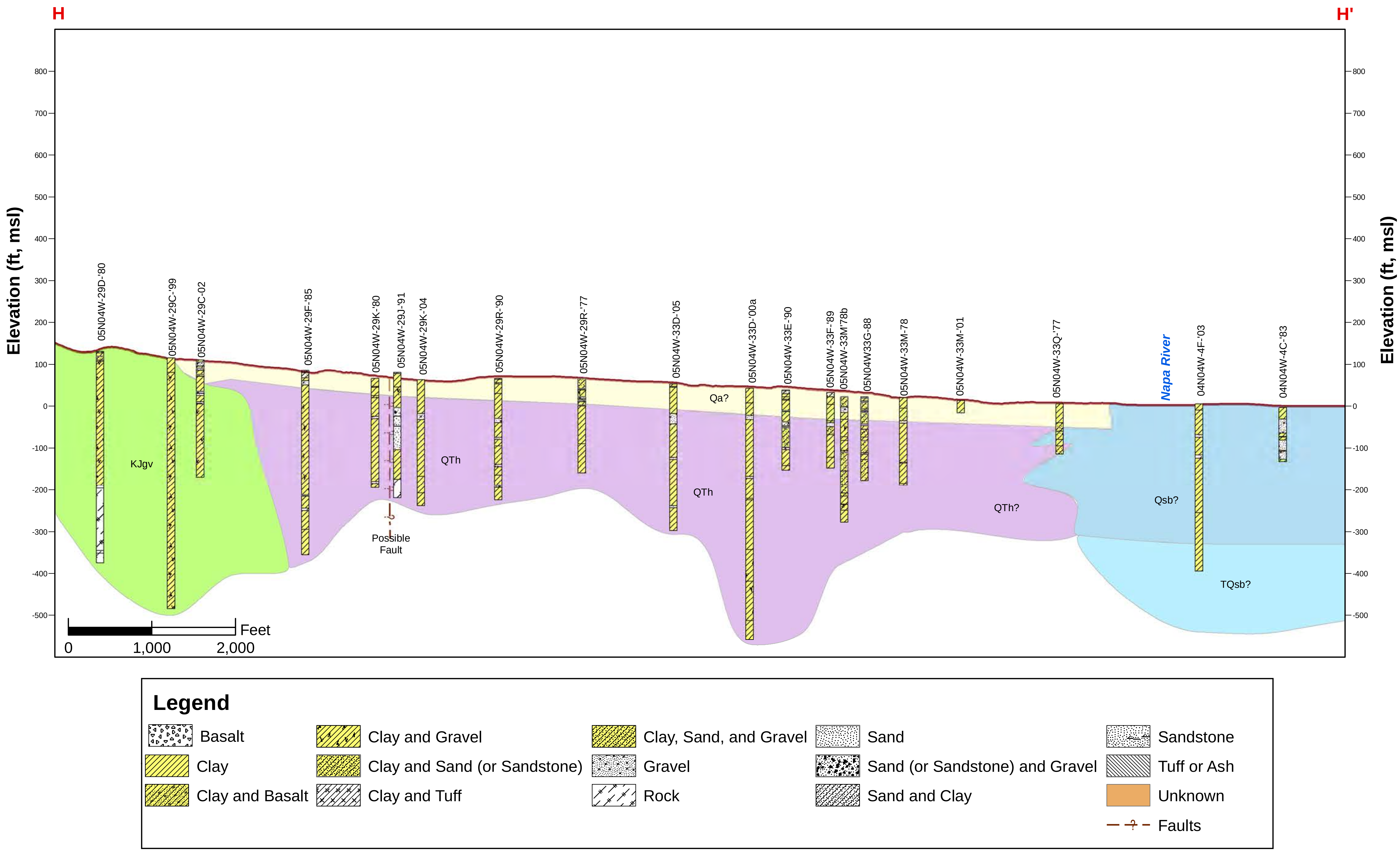

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Figure 5-10
Cross Section H-H'
Carneros Subarea, Napa County, CA

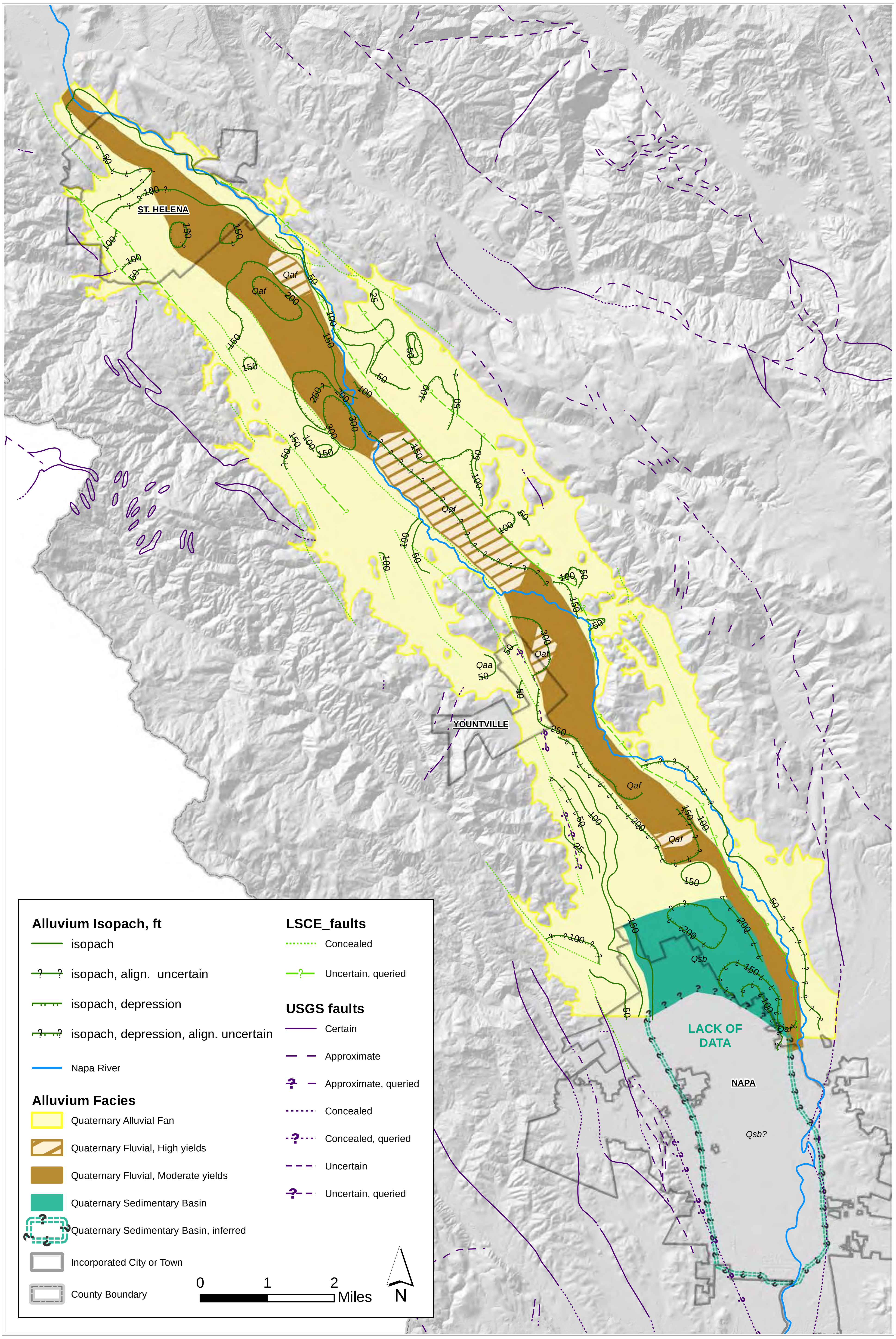

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Figure 5-11
Napa Valley Floor Isopach and Facies Map of Alluvium

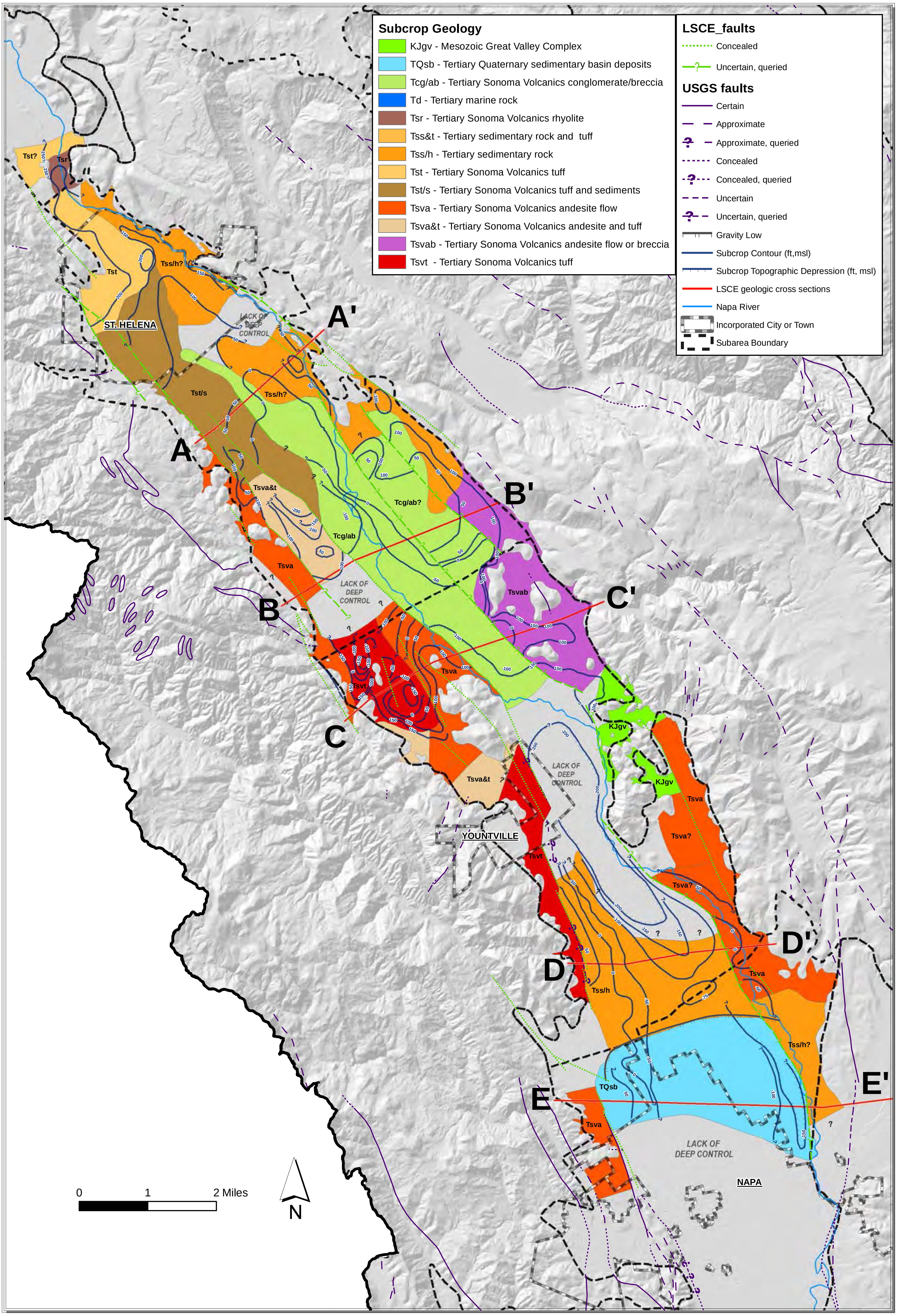

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Figure 5-12
Napa Valley Floor Structure Contours and Pre-Alluvium Subcrop Geology

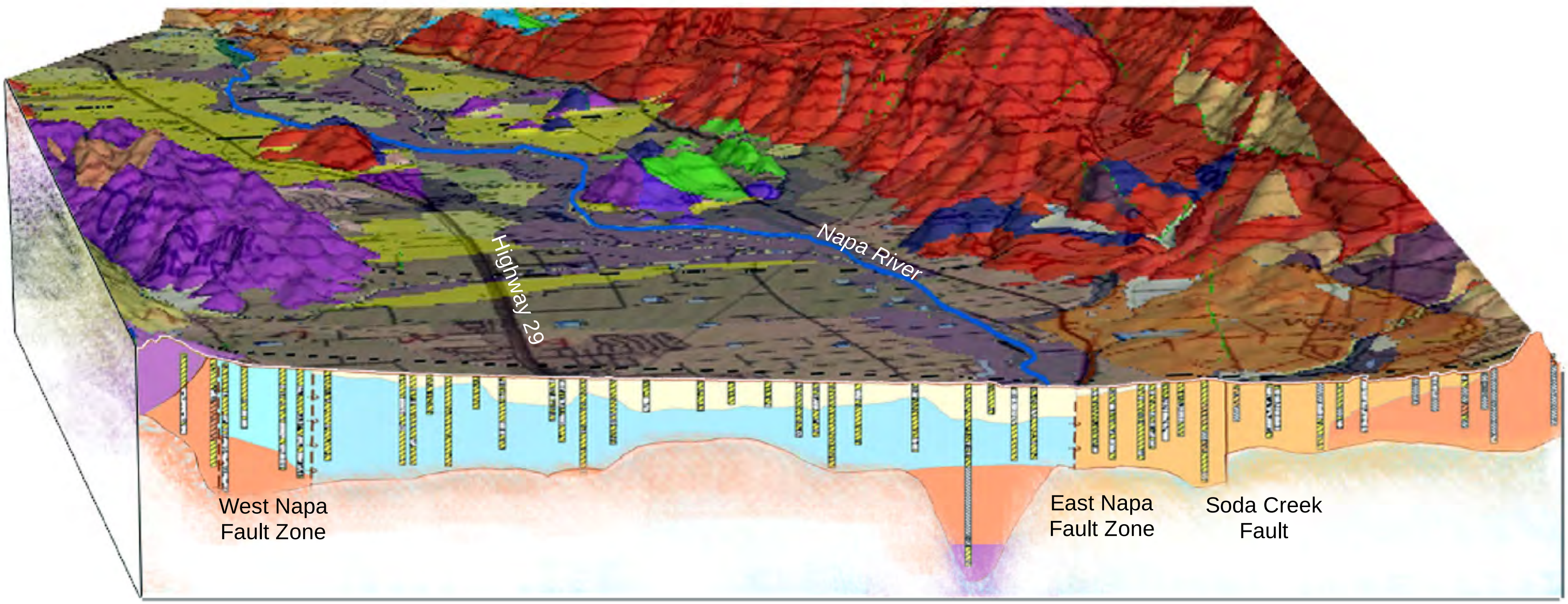

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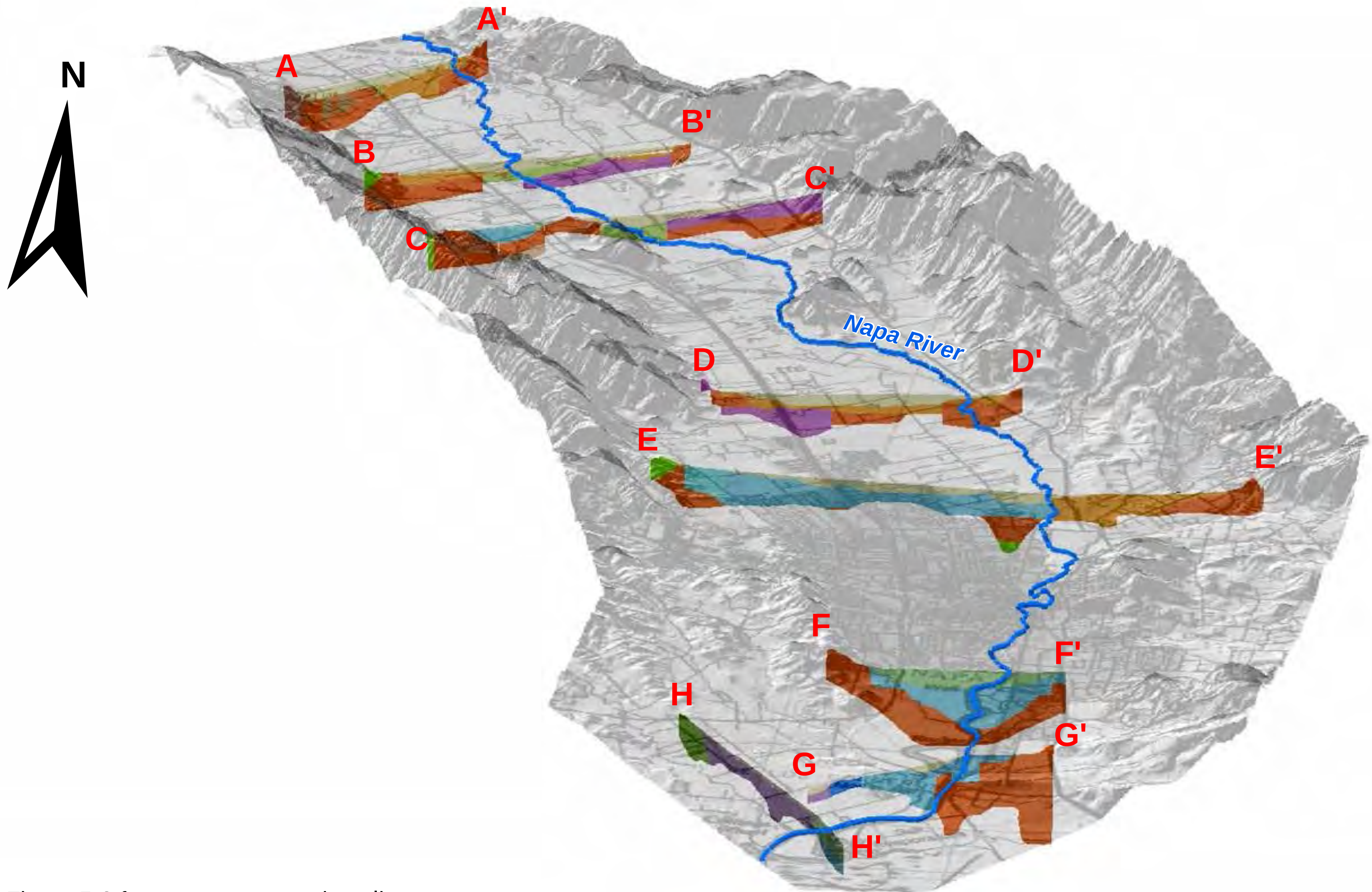
Figure 5-13
Three-Dimensional Visualization of the Geology in the Napa Valley Area



See Figure 5-2 for exact cross section alignments.
See Figures 5-3 through 5-10 for individual cross sections.
Vertical Exaggeration = 3x

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Figure 5-14
Napa Valley Geologic Cross Section Fence Diagram

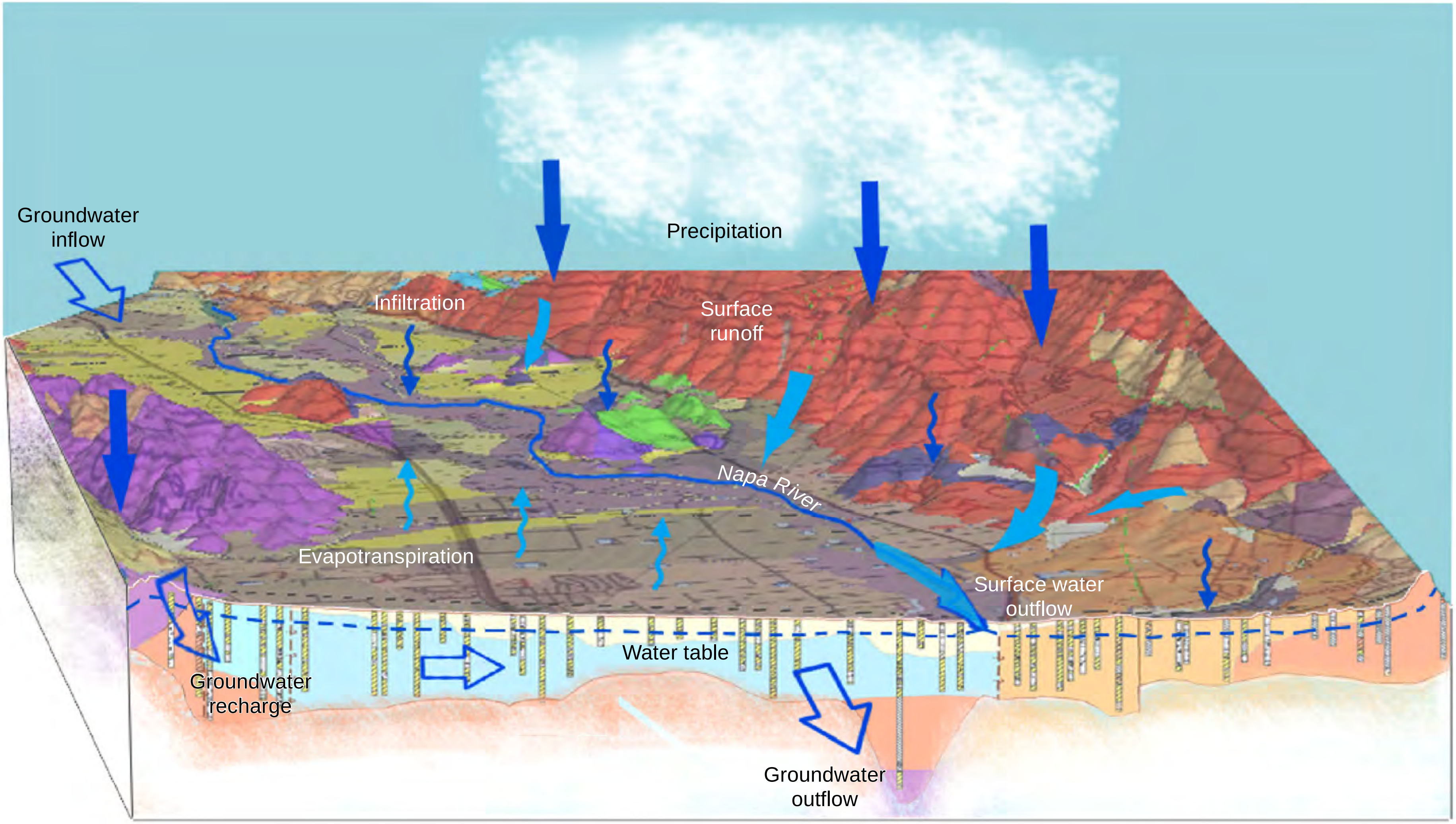

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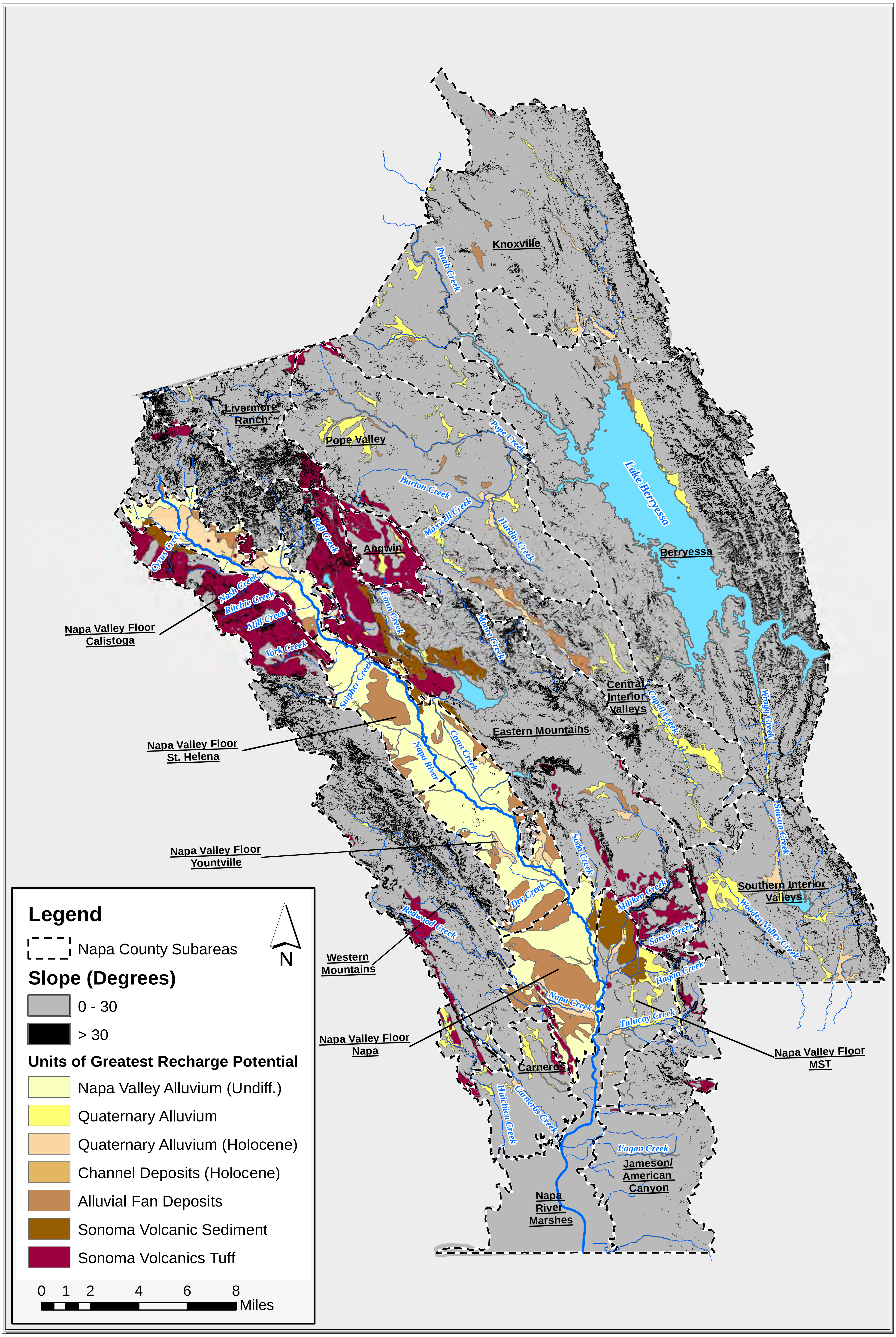
Figure 6-1
Conceptual Illustration of Major Hydrologic Processes in the Napa Valley Area



File: X:\2009 Job Files\09-012\Data\GIS\Recharge\Fig2.6.1-CountyRechargePotential.mxd Date: 1/11/2013

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Figure 6-2
Geologic Units of Greatest Recharge Potential
Napa County, CA

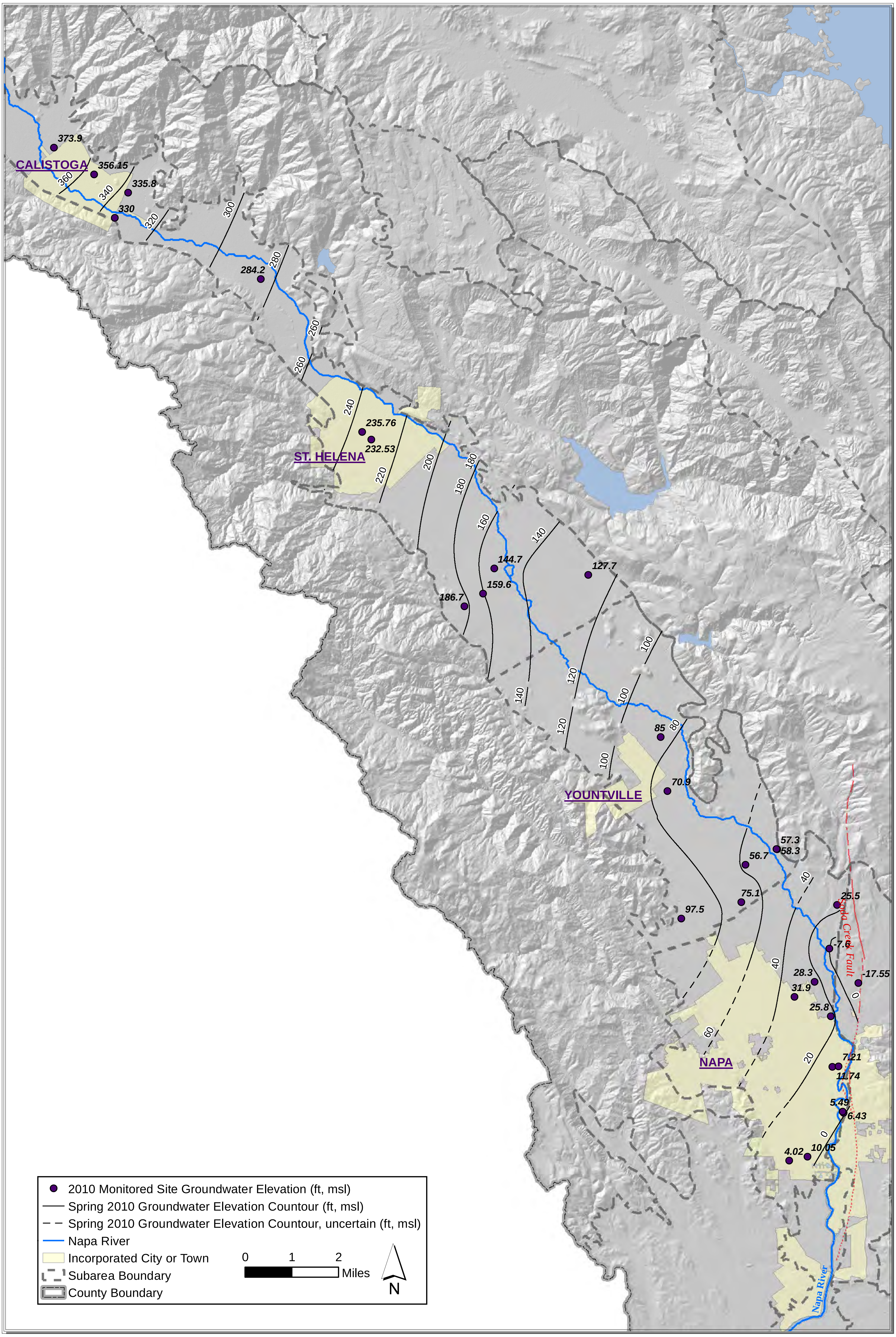

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Figure 7-1
Contours of Equal Groundwater Elevation
Napa Valley, Spring 2010

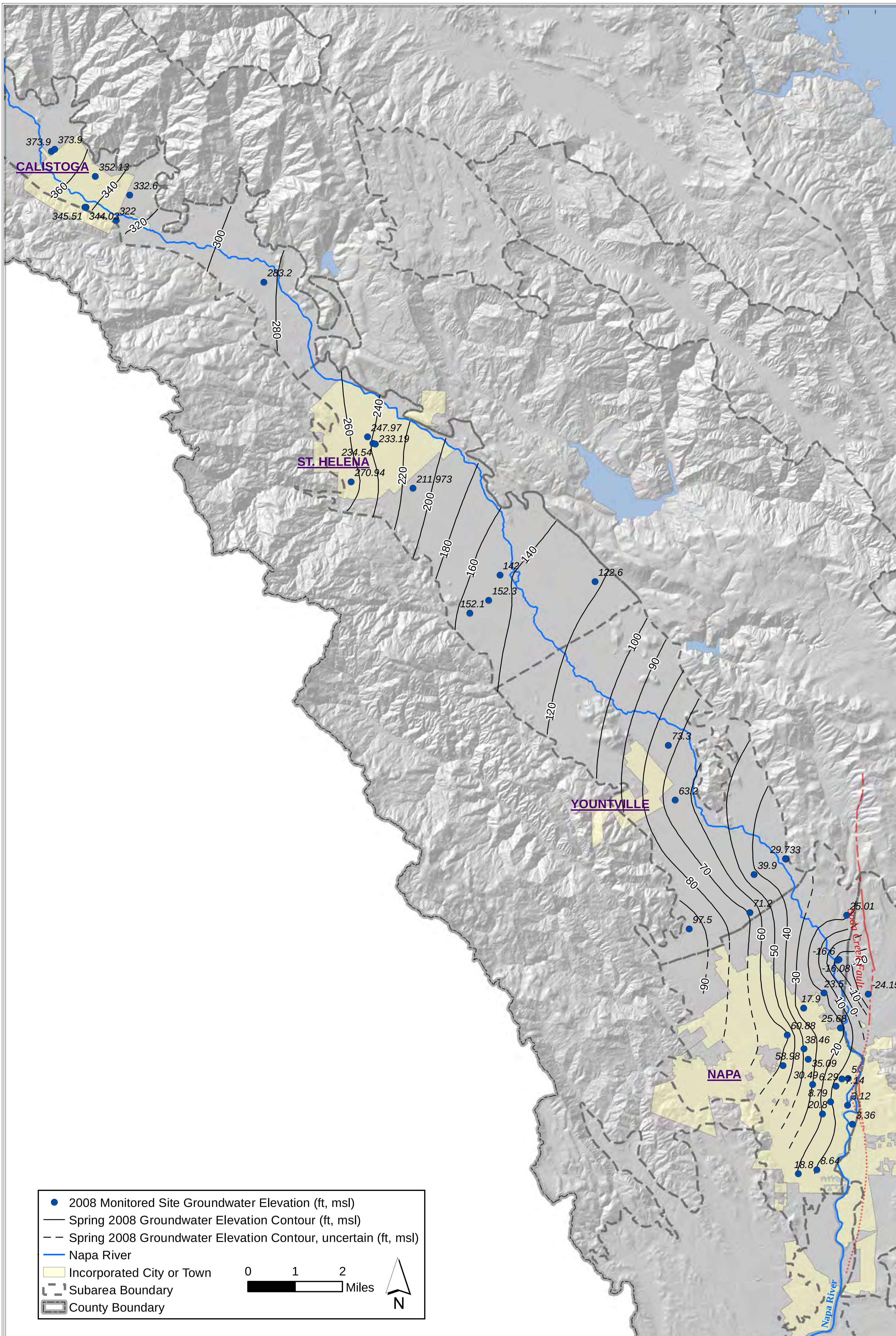

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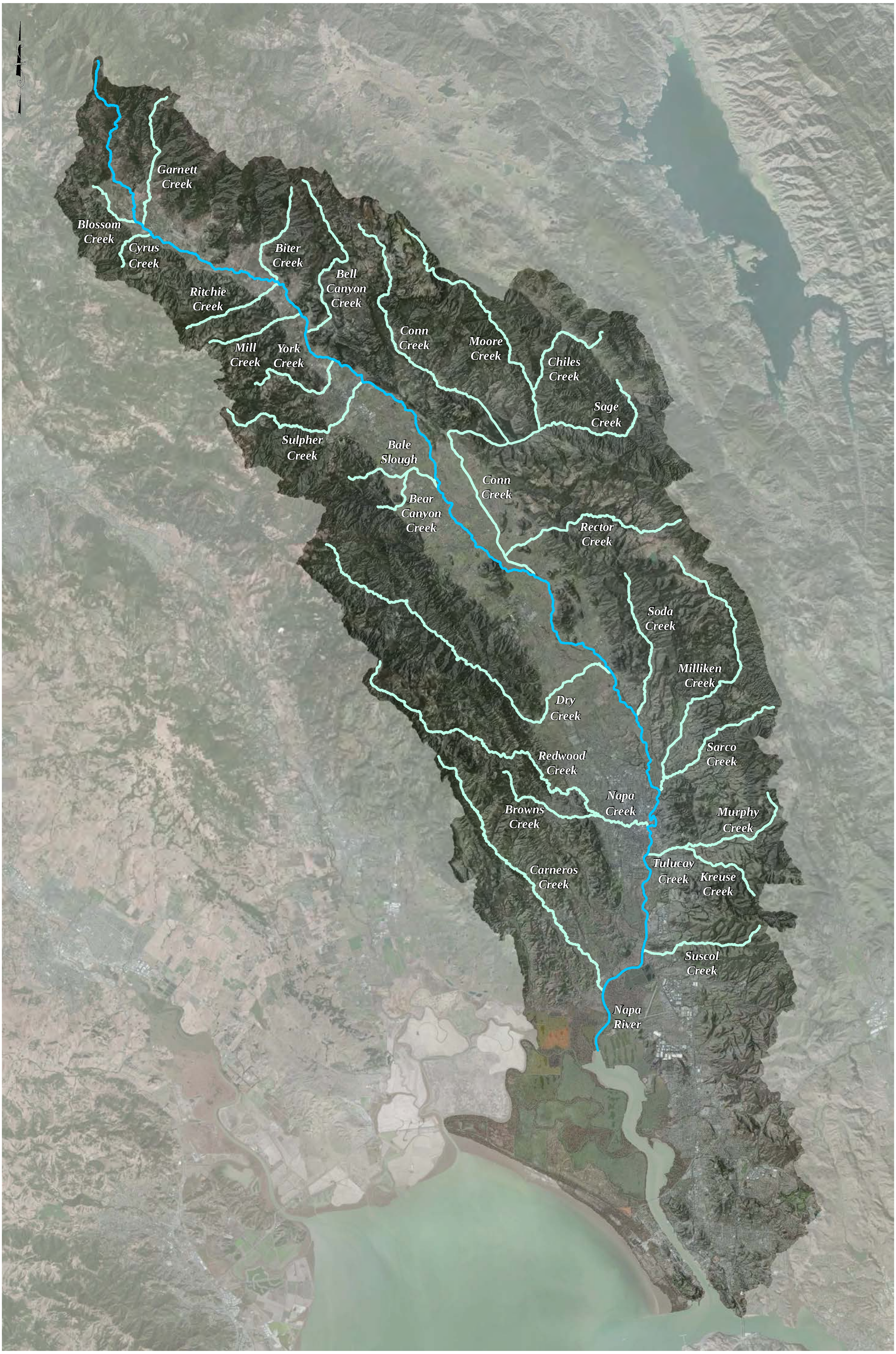
Figure 7-2
Contours of Equal Groundwater Elevation
Napa Valley, Spring 2008



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Sacramento, CA 95815
Phone: 916-456-4400 - Fax: 916-456-0253

Figure 7-3: Napa River and Tributaries in Estimated Stream Thalweg Mapping

NAPA RIVER BASIN

SCALE:	1" = 3 miles
JOB NUMBER:	3327
REQUESTED BY:	LB
DRAWN BY:	MB
DATE:	11/26/2012

Bar Length On Original Drawing Equals One Inch. Adjust Scale Accordingly

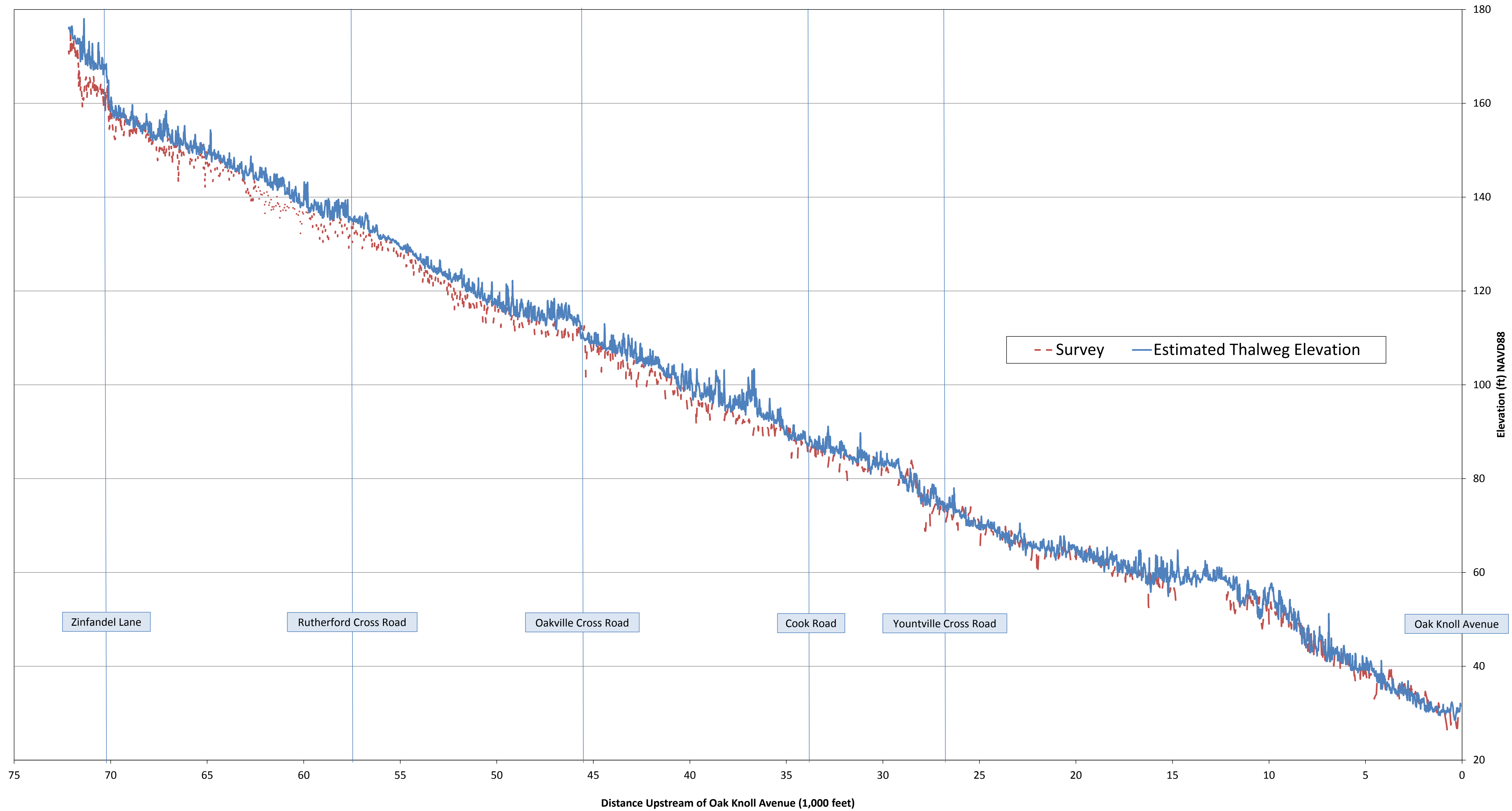

Figure 7-4: Comparison of Estimated Stream Thalweg Elevation with Surveyed Data

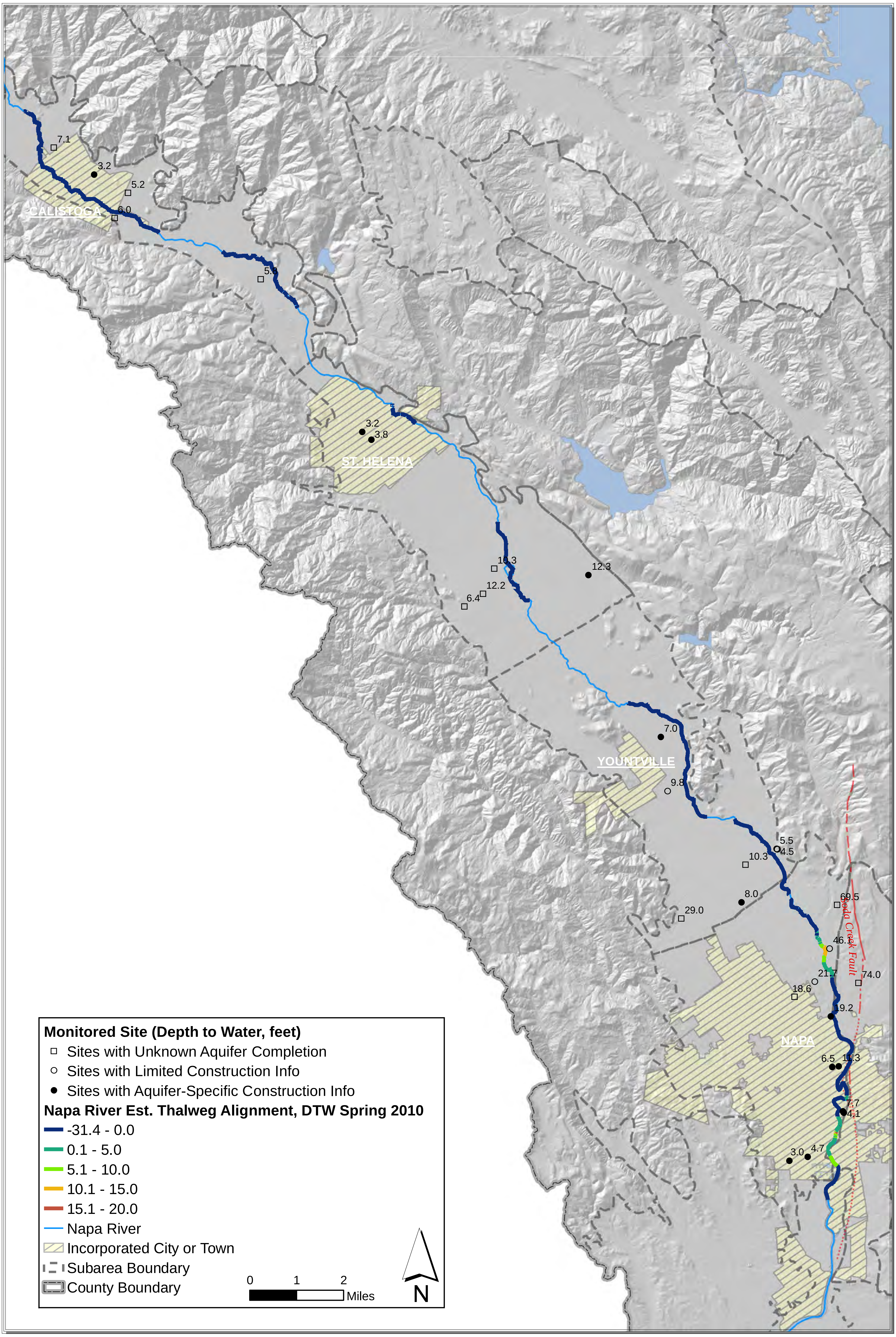

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Figure 7-8
Calculated Depth to Groundwater at Napa River Thalweg within One Mile of Monitored Wells, Spring 2010

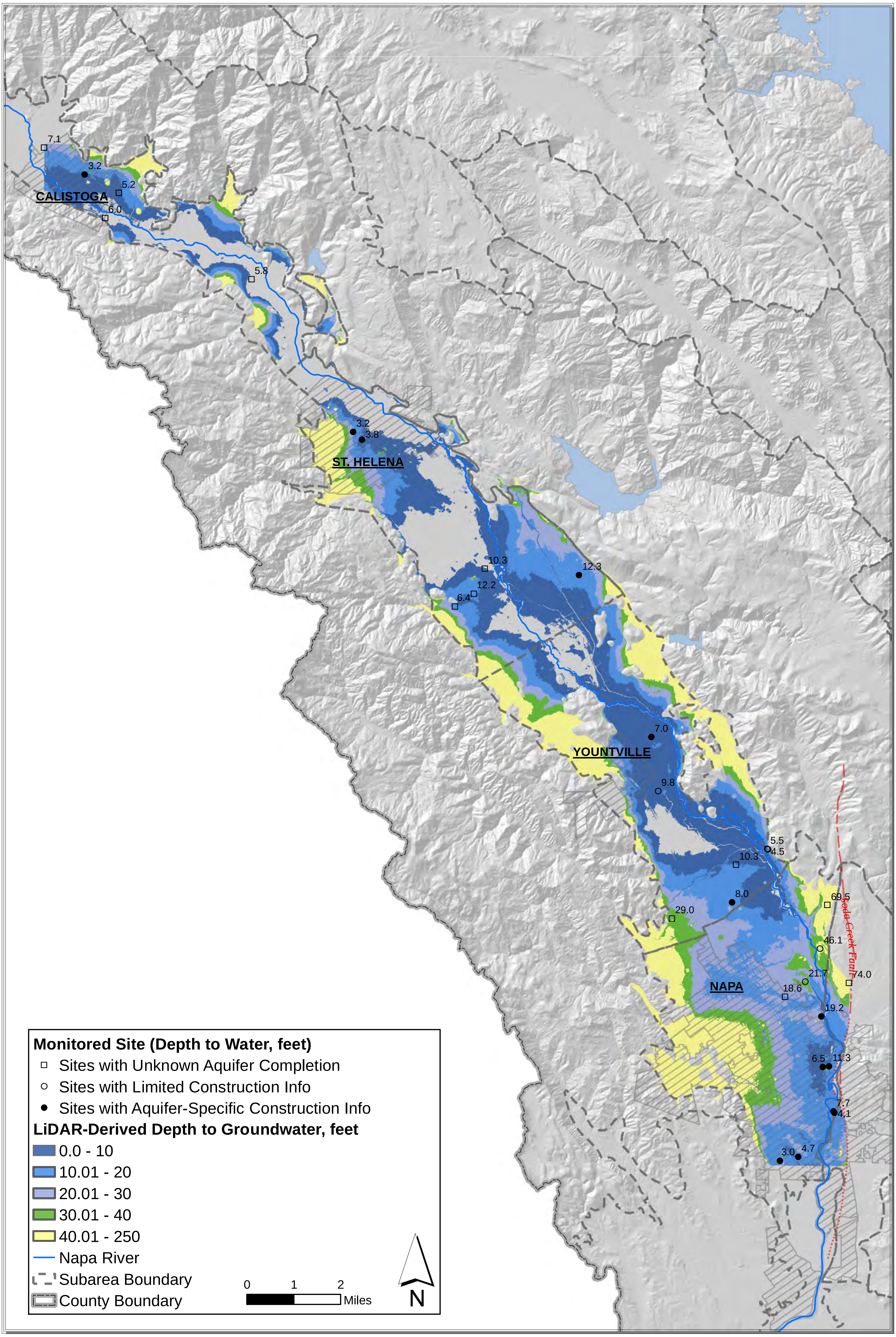

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Figure 7-9
Calculated Depth to Groundwater
Napa Valley Floor, Spring 2010

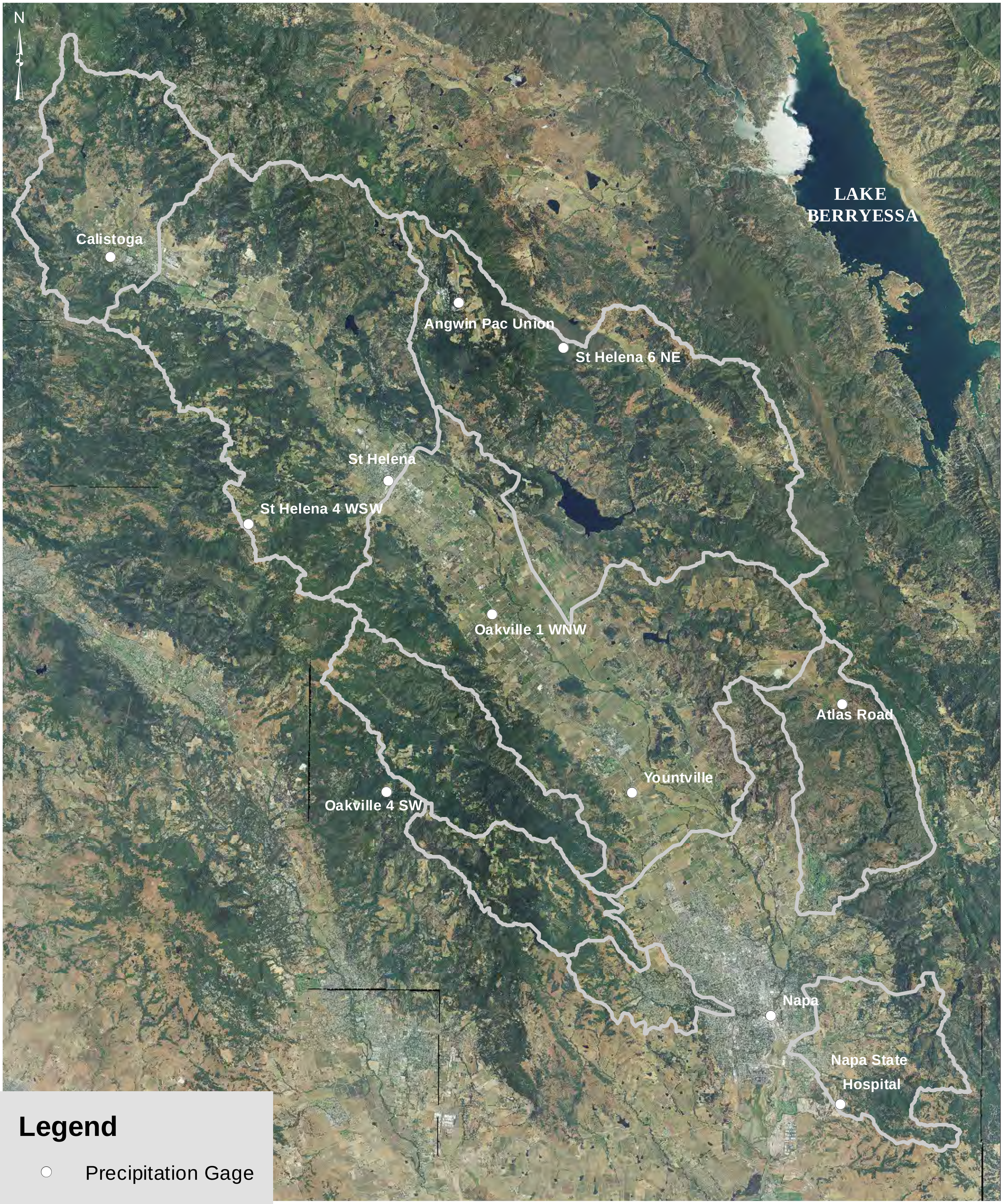

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Figure 8-3: Available NCDC Precipitation Gages in the Model Domain

NAPA RIVER BASIN

SCALE:	1" = 3.5 miles
JOB NUMBER:	3327
DRAWN BY:	P.Ho
DATE:	OCT 2012
	FIGURE 8-1

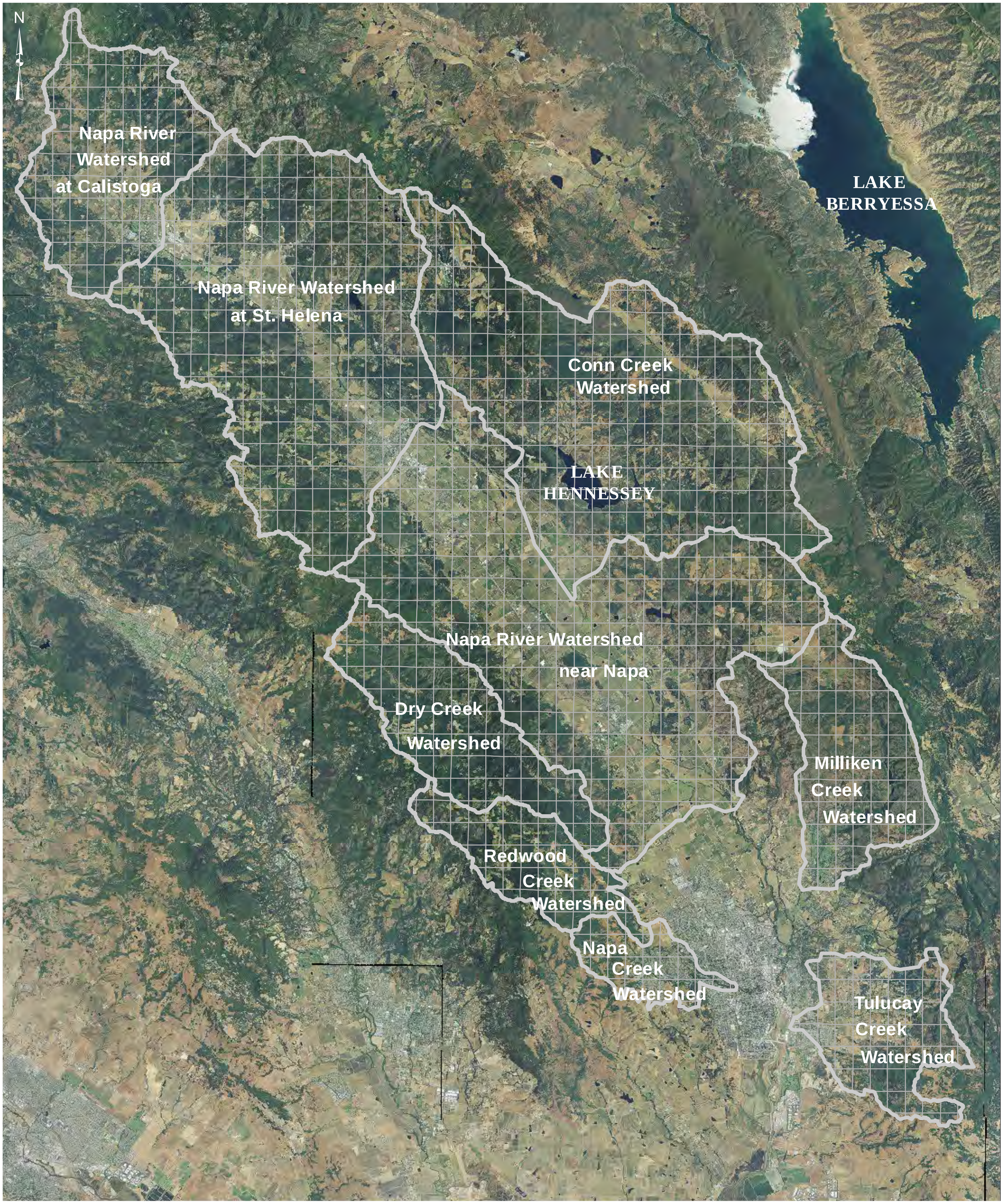

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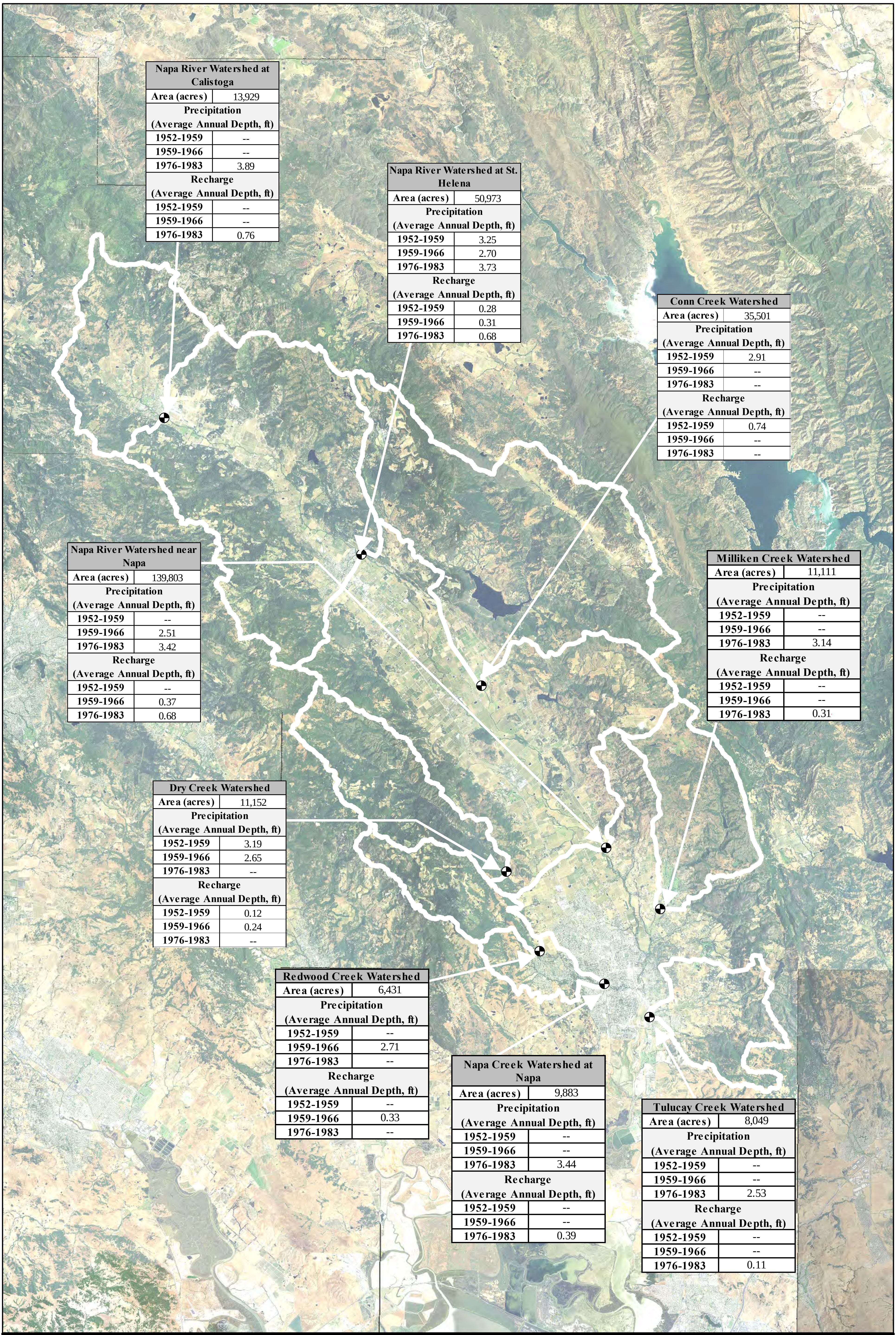
Figure 8-4: PRISM 800 Meter Precipitation Grid and Watersheds in the Model Domain

NAPA RIVER BASIN

SCALE:	1" = 3.5 miles
JOB NUMBER:	3327
DRAWN BY:	P.Ho
DATE:	OCT 2012
	FIGURE 8-2



Napa River Watershed at Calistoga	
Area (acres)	13,929
Precipitation (Average Annual Depth, ft)	
1952-1959	--
1959-1966	--
1976-1983	3.89
Recharge (Average Annual Depth, ft)	
1952-1959	--
1959-1966	--
1976-1983	0.76

Napa River Watershed at St. Helena	
Area (acres)	50,973
Precipitation (Average Annual Depth, ft)	
1952-1959	3.25
1959-1966	2.70
1976-1983	3.73
Recharge (Average Annual Depth, ft)	
1952-1959	0.28
1959-1966	0.31
1976-1983	0.68

Conn Creek Watershed	
Area (acres)	35,501
Precipitation (Average Annual Depth, ft)	
1952-1959	2.91
1959-1966	--
1976-1983	--
Recharge (Average Annual Depth, ft)	
1952-1959	0.74
1959-1966	--
1976-1983	--

Napa River Watershed near Napa	
Area (acres)	139,803
Precipitation (Average Annual Depth, ft)	
1952-1959	--
1959-1966	2.51
1976-1983	3.42
Recharge (Average Annual Depth, ft)	
1952-1959	--
1959-1966	0.37
1976-1983	0.68

Milliken Creek Watershed	
Area (acres)	11,111
Precipitation (Average Annual Depth, ft)	
1952-1959	--
1959-1966	--
1976-1983	3.14
Recharge (Average Annual Depth, ft)	
1952-1959	--
1959-1966	--
1976-1983	0.31

Dry Creek Watershed	
Area (acres)	11,152
Precipitation (Average Annual Depth, ft)	
1952-1959	3.19
1959-1966	2.65
1976-1983	--
Recharge (Average Annual Depth, ft)	
1952-1959	0.12
1959-1966	0.24
1976-1983	--

Redwood Creek Watershed	
Area (acres)	6,431
Precipitation (Average Annual Depth, ft)	
1952-1959	--
1959-1966	2.71
1976-1983	--
Recharge (Average Annual Depth, ft)	
1952-1959	--
1959-1966	0.33
1976-1983	--

Napa Creek Watershed at Napa	
Area (acres)	9,883
Precipitation (Average Annual Depth, ft)	
1952-1959	--
1959-1966	--
1976-1983	3.44
Recharge (Average Annual Depth, ft)	
1952-1959	--
1959-1966	--
1976-1983	0.39

Tulucay Creek Watershed	
Area (acres)	8,049
Precipitation (Average Annual Depth, ft)	
1952-1959	--
1959-1966	--
1976-1983	2.53
Recharge (Average Annual Depth, ft)	
1952-1959	--
1959-1966	--
1976-1983	0.11

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Figure 8-13: Napa Valley Area Recharge by Hydrologic Period

SCALE:	1" = 3.0 miles
JOB NUMBER:	3327
DRAWN BY:	P.Ho
DATE:	11-26-2012

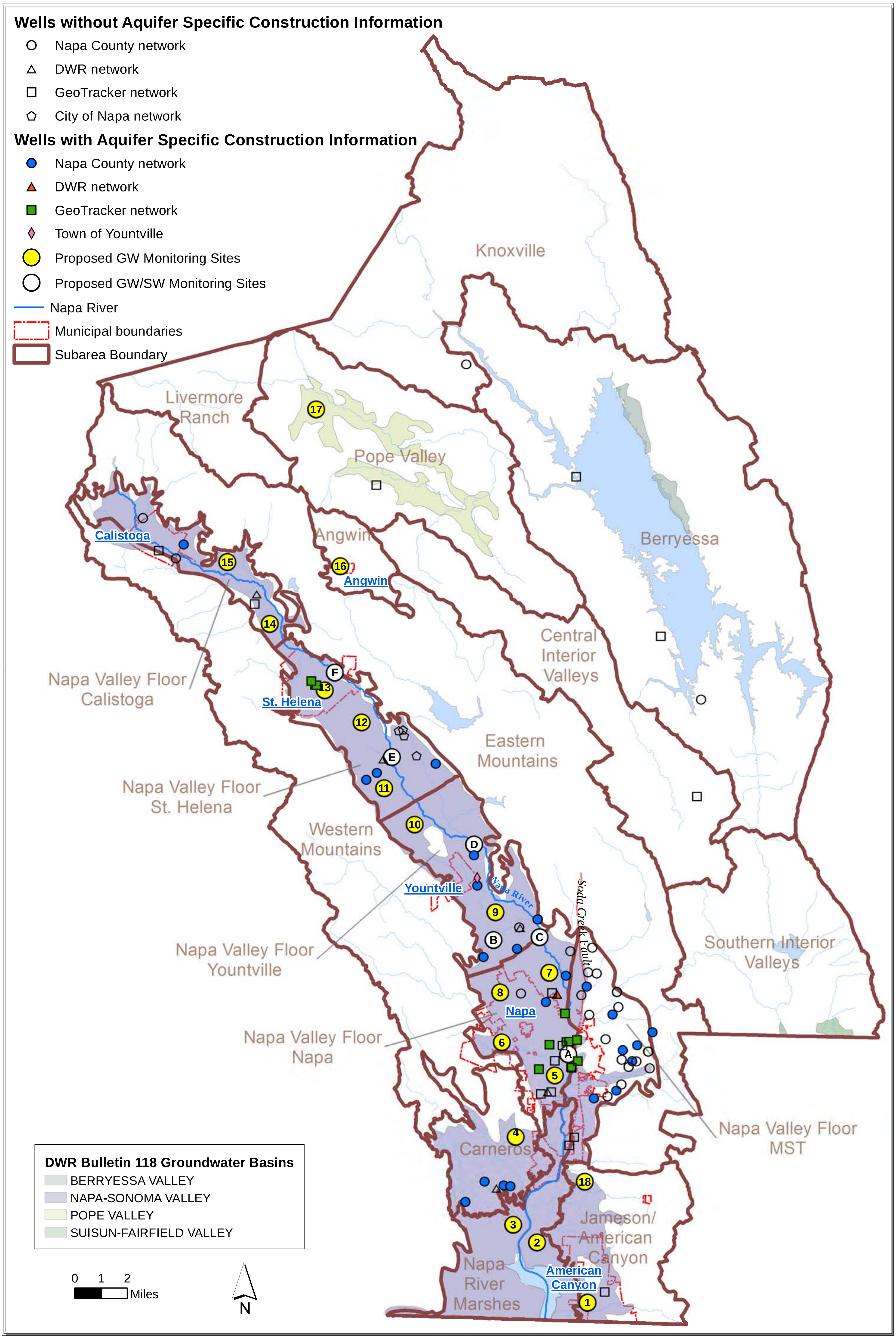

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Figure 9-1
Current and Proposed Groundwater Level Monitoring Sites in Napa County

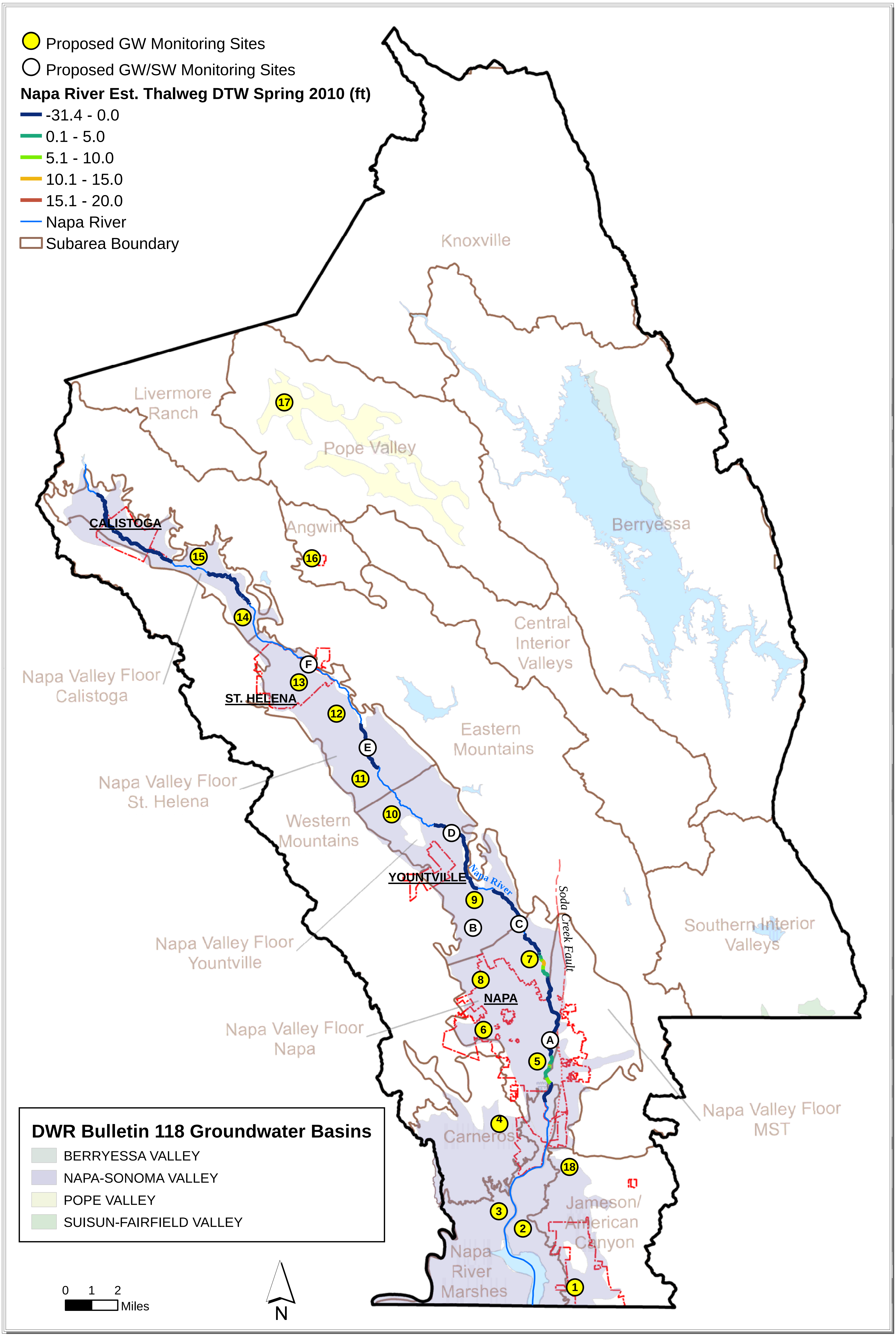

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Figure 9-2
Proposed Groundwater Level Monitoring Sites Related to Depth to Water at Napa River Thalweg

Appendix A

Cross Section Stratigraphy, Pre-Alluvium Subcrop Geology, and Well Lithology Legends

Appendix A - Cross-Section Stratigraphy, Pre-Alluvium Subcrop Geology, and Well Lithology Legends

Stratigraphy

- QTh: Quaternary Tertiary Huichica formation
- Qsb: Quaternary sedimentary basin deposits
- Tst/s: Tertiary Sonoma Volcanic tuff and sediments
- TQsu: Tertiary Quaternary sedimentary deposits, undifferentiated
- KJgv: Mesozoic Great Valley Complex
- Qa: Quaternary alluvium
- Qa/sb: Quaternary alluvium/sedimentary basin deposits
- TQsb: Tertiary Quaternary sedimentary basin deposits
- Tcg/ab: Tertiary Sonoma Volcanic conglomerate/breccia
- Tcg/ab?: Tertiary Sonoma Volcanic conglomerate/breccia
- Td: Tertiary marine rock
- Tsr: Tertiary Sonoma Volcanic rhyolite
- Tss/h: Tertiary sedimentary rock
- Tss/h?: Tertiary sedimentary rock
- Tst: Tertiary Sonoma Volcanic tuff
- Tsva: Tertiary Sonoma Volcanic andesite flow
- Tsvat: Tertiary Sonoma Volcanic andesite and tuff
- Tsva?: Tertiary Sonoma Volcanic andesite flow
- Tsvab: Tertiary Sonoma Volcanic andesite flow or breccia
- Tsvt: Tertiary Sonoma Volcanic tuff
- Tsvt?: Tertiary Sonoma Volcanic tuff
- Tst?: Tertiary Sonoma Volcanic tuff

Well Lithology

- Basalt
- Clay
- Clay and Basalt
- Clay and Gravel
- Clay and Sand (or Sandstone)
- Clay and Tuff
- Clay, Sand, and Gravel
- Gravel
- Rock
- Sand
- Sand (or Sandstone) and Gravel
- Sand and Clay
- Sandstone
- Tuff or Ash
- Unknown
- Faults
- Possible Faults

NAPA VALLEY GROUNDWATER SUSTAINABILITY:

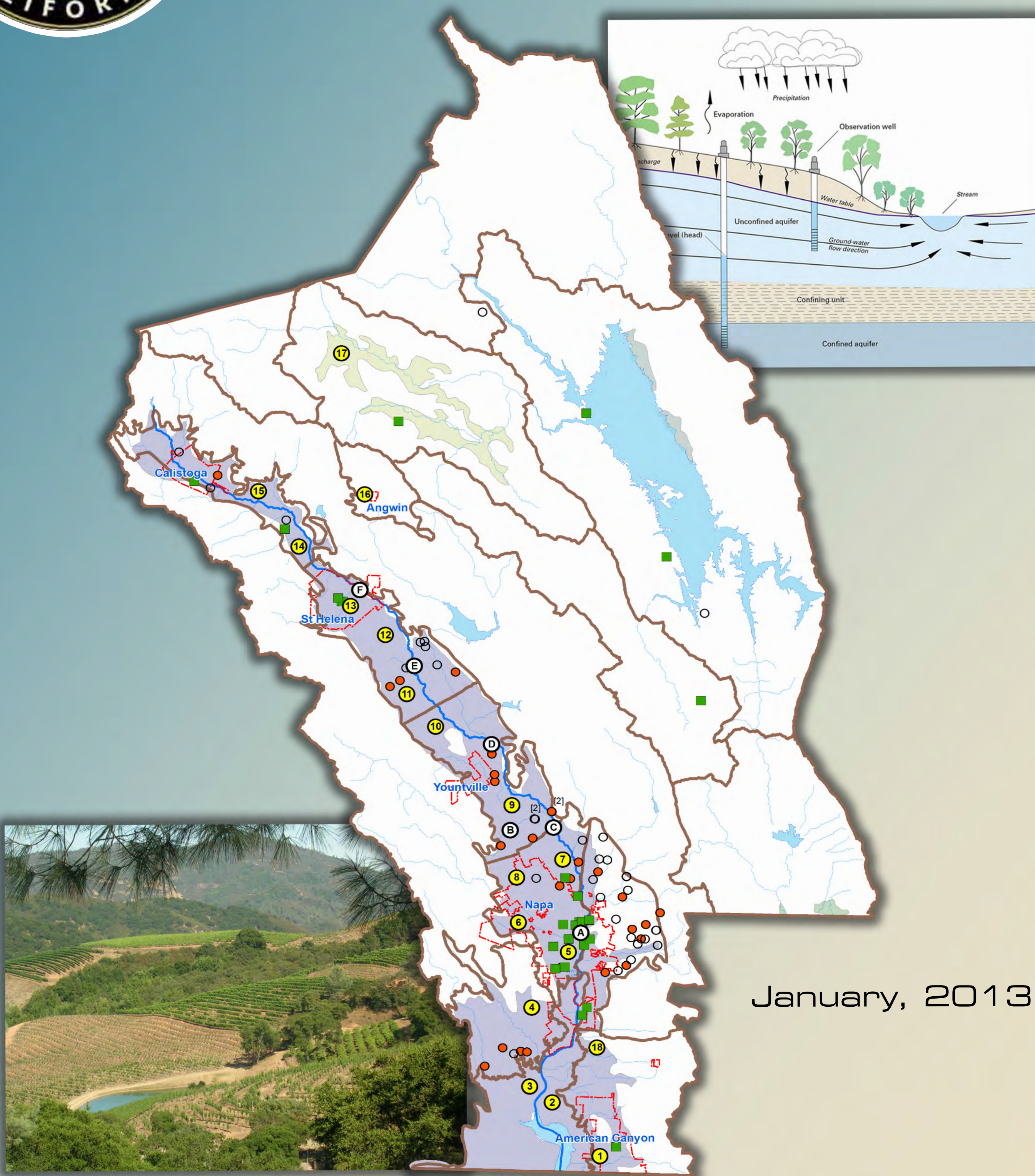
A BASIN ANALYSIS REPORT FOR THE NAPA VALLEY SUBBASIN

APPENDIX C:

Napa County

Groundwater Monitoring Plan 2013

Napa County Groundwater Monitoring Plan 2013



January, 2013

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CONSULTING ENGINEERS

Napa County

Groundwater Monitoring Plan 2013

January, 2013

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EXECUTIVE SUMMARY

Groundwater and surface water are highly important natural resources in Napa County. Long-term, systematic monitoring programs are essential to provide data that allow for improved evaluation of water resources conditions and to facilitate effective water resources planning. In 2009, Napa County embarked on a countywide project referred to as the "Comprehensive Groundwater Monitoring Program, Data Review, and Policy Recommendations for Napa County's Groundwater Resources" (Comprehensive Groundwater Monitoring Program), to meet identified action items in the 2008 General Plan update. The program emphasizes developing a sound understanding of groundwater conditions and implementing an expanded groundwater monitoring and data management program as a foundation for future coordinated, integrated water resources planning and dissemination of water resources information.

The purpose of this *Napa County Groundwater Monitoring Plan 2013* (Plan) is to formalize and augment current groundwater monitoring efforts [levels and quality] to better understand the groundwater resources of Napa County, aid in making the County eligible for public funds administered by the California Department of Water Resources (DWR), and regularly evaluate trends to identify changes in levels and /or quality and factors related to those changes that warrant further examination to ensure sustainable water resources. The Plan is considered a living document that will be updated based upon the data collected and County/community needs. It is envisioned that groundwater conditions and recommended modifications to the countywide groundwater monitoring program would be reported triennially or as needed.

Recent studies by Napa County have found that there are many areas in the county where further efforts to establish or refine groundwater monitoring, using existing or new monitoring facilities, will improve the understanding of groundwater resource conditions and availability. This Plan summarizes groundwater monitoring priorities and recommendations for addressing these priorities. This Plan also summarizes the overarching groundwater level and quality monitoring objectives defined by the County and the Groundwater Resources Advisory Committee (GRAC).

Existing groundwater level and quality monitoring sites are described and recommendations are made for additional monitoring locations of interest to fill data gaps. As additional monitoring sites are considered, or existing monitoring facilities are further evaluated, the groundwater level and quality monitoring objectives will be used to evaluate the suitability of the existing or proposed facilities to ensure that the data being (or planned to be) collected can address these objectives.

The recommended monitoring sites can be addressed in several ways, including:

1) Investigating the potential to restart monitoring where historical records are available but monitoring was discontinued;
2) identifying existing wells of suitable construction that might be volunteered for inclusion through County and GRAC education and outreach efforts (this may include wells that are already being monitored for groundwater quality); and
3) Constructing new dedicated monitoring wells if suitable existing wells either do not exist in the area of interest or are otherwise not available.

This Plan includes recommendations for 18 areas of interest for focused education and outreach efforts to identify existing wells suitable for meeting the monitoring objectives. Additionally, this Plan describes six groundwater monitoring sites located along the main Napa Valley Floor from the City of Napa north to St. Helena adjacent to the Napa River system. These recommended sites would provide the necessary information to further characterize in greater detail the interrelationship between groundwater and surface water resources.

1 INTRODUCTION

1.1 Purpose

Groundwater and surface water are highly important natural resources in Napa County. Collectively, the County and other municipalities, water districts, commercial and industrial operations, the agricultural community, and the general public, are stewards of the available water resources. Currently, municipal and private stakeholders are actively engaged in assessing the reliability of current and future demands and supplies. Important sources of water include both groundwater and surface water of good quality and quantity, to meet future urban, rural, and agricultural water demands. Similar to other areas in California, businesses and residents of Napa County face many water-related challenges including:

- Increased competition for current and future available supplies;
- Preserving the quality and availability of local and imported water supplies;
- Sustaining groundwater recharge capacity and supplies;
- Meeting challenges arising during drought conditions;
- Avoiding environmental effects due to water use; and
- Changes in long-term availability due to global warming and/or climate change.

To address these challenges, long-term, systematic monitoring programs are essential to provide data that allow for improved evaluation of water resources conditions and to facilitate effective water resources planning. Establishment of a groundwater and surface water monitoring network results in the collection of data necessary to distinguish long-term trends from short-term fluctuations, anticipate unintended consequences due to current and historical land uses, identify emerging issues, and design appropriate water resources planning and management strategies. In 2009, Napa County embarked on a countywide project referred to as the "Comprehensive Groundwater Monitoring Program, Data Review, and Policy Recommendations for Napa County's Groundwater Resources" (Comprehensive Groundwater Monitoring Program), to meet identified action items in the 2008 General Plan update. The program emphasizes developing a sound understanding of groundwater conditions and implementing an expanded groundwater monitoring and data management program as a foundation for future coordinated, integrated water resources planning and dissemination of water resources information.

The purpose of this *Napa County Groundwater Monitoring Plan 2013*(Plan) is to formalize and augment current groundwater monitoring efforts [levels and quality] to better understand the groundwater resources of Napa County, aid in making the County eligible for public funds administered by the California Department of Water Resources (DWR), and regularly evaluate trends to identify changes in levels and /or quality and factors related to those changes that warrant further examination to ensure sustainable water resources. The Plan is considered a living document that will be updated based upon the data collected and County/community needs. It is envisioned that groundwater conditions and recommended modifications to the countywide groundwater monitoring program would be reported triennially or as needed.

1.2 Organization of the Plan

This Plan formalizes recommendations provided in the County's Comprehensive Groundwater Monitoring Program by outlining steps to augment countywide groundwater level and quality monitoring. Recent studies by Napa County have found that there are many areas in the county where further efforts to establish or refine groundwater monitoring, using existing or new monitoring facilities, will improve the understanding of groundwater resource conditions and availability. This Plan summarizes groundwater monitoring priorities and recommendations for addressing these priorities. This Plan also summarizes the overarching groundwater level and quality monitoring objectives defined by the County and the GRAC. These objectives provide the framework necessary to ensure that the data collected from the countywide monitoring facilities can address these objectives.

On June 28, 2011, the County Board of Supervisors adopted a resolution establishing a Groundwater Resources Advisory Committee (GRAC). Two of the tasks assigned to the GRAC include: 1) assisting with the synthesis of the existing groundwater information and identifying critical data needs; and 2) providing input on the furtherance of the ongoing countywide groundwater monitoring program. During preparation of this Plan, input from this committee is being coordinated to optimize additional groundwater monitoring locations that serve to meet the objectives of the County's Comprehensive Groundwater Monitoring Program and the California Statewide Groundwater Elevation Monitoring (CASGEM) program. As explained in the next section, the CASGEM program is a subset of the countywide groundwater monitoring program.

This Plan includes the following sections:

Section 2: Hydrogeology of Napa County

- DWR Basins/Subbasins and County Subareas
- Summary of Geology and Groundwater Resources
- Overview of Recent Groundwater Studies and Programs
- Presentation of Groundwater Monitoring Priorities
    - Groundwater Level Monitoring
    - Groundwater Quality Monitoring
- Summary of Recommendations from Recent County Studies

Section 3: Groundwater Resources Goals and Monitoring Objectives

- Napa County Water Resources Goals and Policies
- Groundwater Level Monitoring Objectives
- Groundwater Quality Monitoring Objectives
- Funding and Collaboration for Groundwater Monitoring

Section 4: Groundwater Monitoring Network Design and Development

- **Groundwater Level Monitoring** - Monitoring Network (including existing groundwater level monitoring wells, recommendations to expand the monitoring well network, frequency of monitoring, and field methods)

- **Groundwater Quality Monitoring** - Monitoring Network (including existing groundwater quality monitoring wells, recommendations to expand the monitoring well network, frequency of monitoring, field methods, and parameters of interest)

Section 5: Groundwater Data Management

- Data Management Overview
- Data Management System (DMS)
- Data Use and Disclosure

Section 6: Reporting and Assessment

- Annual Update and Review of Monitoring Plan and Well Network
- Annual CASGEM Reporting
- Triennial Countywide Reporting

2 HYDROGEOLOGY OF NAPA COUNTY

This section summarizes the countywide geologic and hydrologic setting, and includes information about DWR groundwater basin/subbasin delineations and a description of the Napa County groundwater monitoring subareas. The studies that form the basis of the understanding of County hydrogeology are referenced, including the work for the *Updated Hydrogeologic Conceptualization and Characterization of Conditions* (LSCE and MBK Engineers, 2013).

2.1 DWR Basins/Subbasins and County Subareas

DWR has identified the major groundwater basins and subbasins in and around Napa County; these include the Napa-Sonoma Valley (which in Napa County includes the Napa Valley and Napa-Sonoma Lowlands Subbasins), Berryessa Valley, Pope Valley, and a small part of the Suisun-Fairfield Valley Groundwater Basins (**Figure 2-1**). These basins and subbasins are generally defined based on boundaries to groundwater flow and the presence of water-bearing geologic units. These groundwater basins defined by DWR are not confined within county boundaries, and DWR-designated "basin" or "subbasin" designations do not cover all of Napa County.

Groundwater conditions outside of the DWR-designated areas are also very important in Napa County. An example of such an area is the Milliken-Sarco-Tulucay (MST) area, a locally identified groundwater deficient area. For purposes of local planning, understanding, and studies, the County has been subdivided into a series of groundwater subareas (**Figure 2-2**). These subareas were delineated based on the main watersheds, groundwater basins, and the County's environmental resource planning areas. These subareas include the Knoxville, Livermore Ranch, Pope Valley, Berryessa, Angwin, Central Interior Valleys, Eastern Mountains, Southern Interior Valleys, Jameson/American Canyon, Napa River Marshes, Carneros, Western Mountains Subareas and five Napa Valley Floor Subareas (Calistoga, St. Helena, Yountville, Napa, and MST).

2.2 Summary of Geology and Groundwater Resources

2.2.1 Previous Studies

Previous hydrogeologic studies of Napa County and also mapping efforts are divisible into geologic studies and groundwater studies. The more significant studies and mapping efforts are mentioned in this section. **Table 2-1** shows the chronological sequence of these efforts that span more than six decades. Weaver (1949) presented geologic maps which covered the southern portion of the county and provided a listing of older geologic studies. Kunkel and Upson (1960) examined the groundwater and geology of the northern portion of the Napa Valley. DWR (Bulletin 99, 1962) presented a reconnaissance report on the geology and water resources of the eastern area of the County; Koenig (1963) compiled a regional geologic map which encompasses Napa County. Fox and others (1973) and Sims and others (1973) presented more detailed geologic mapping of Napa County. Faye (1973) reported on the groundwater of the northern Napa Valley. Johnson (1977) examined the groundwater hydrology of the MST area.

Table 2-1
Summary and Chronology of Hydrogeologic and Geologic Studies and Mapping Efforts in Napa County

Hydrogeologic and/or Geologic Studies and Mapping Efforts	Year of Report or Map Publication							
	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010-2019
Weaver, 1949	◆ (red)							
Kunkel and Upson,1960			◆ (red)					
DWR, 1962			◆ (blue)					
Koenig, 1963			◆ (orange)					
Fox et al., 1973				◆ (blue)				
Sims et al., 1973				◆ (orange)				
Faye, 1973				◆ (red)				
Johnson, 1977				◆ (blue)				
Helley et al., 1979				◆ (red)				
Wagner and Bortugno, 1982					◆ (orange)			
Fox, 1983					◆ (red)			
Graymer et al., 2002							◆ (orange)	
Farrar and Metzger, 2003							◆ (red)	
Graymer et al., 2007							◆ (orange)	
DHI, 2006 and 2007							◆ (blue)	
LSCE, 2011a								◆ (blue)
LSCE and MBK Eng., 2013								◆ (red)

◆ (red) = Report and Map produced

◆ (blue) = Report only

◆ (orange) = Map only

Helley and others (1979) summarized the flatland deposits of the San Francisco Bay Region, including those in Napa County. Fox (1983) examined the tectonic setting of Cenozoic rocks, including Napa County. Farrar and Metzger (2003) continued the study of groundwater conditions in the MST area.

Wagner and Bortugno (1982) compiled and revised the regional geologic map of Koenig (1963). Graymer and others (2002) presented detailed geologic mapping of the southern and portions of the eastern areas of the County, while Graymer and others (2007) compiled geologic mapping of the rest of Napa County.

In 2005 to 2007, DHI Water & Environment (DHI) contributed to the 2005 *Napa County Baseline Data Report* (DHI, 2006a and Jones & Stokes et al., 2005) which was part of the County's General Plan update (Napa County, 2008). A groundwater model was developed by DHI in conjunction with the Napa Valley and Lake Berryessa Surface Water models to simulate existing groundwater and surface water conditions on a regional basis primarily in the North Napa Valley and the MST and Carneros Subareas (DHI, 2006b). A 2007 technical memorandum, *Modeling Analysis in Support of Vineyard Development Scenarios Evaluation* (DHI, 2007), was prepared to document the groundwater model update which was used to evaluate various vineyard development scenarios.

Additional geologic maps, groundwater studies, and reports are listed in the references of the *Napa County Groundwater Conditions and Groundwater Monitoring Recommendations* (Groundwater Report) (LSCE, 2011a). As recommended in the Groundwater Report and described below, additional work has been conducted to update the conceptualization and characterization of hydrogeologic conditions particularly for the Napa Valley Floor (LSCE and MBK Engineers, 2013).

2.2.2 Summary of Geology and Water Resources

The geology of Napa County can be divided into three broad geologic units based on their ages and geologic nature. These units are: 1) Mesozoic Basement Rocks (pre-65 million years (my)), which underlie all of Napa County, but are primarily exposed in the Eastern County area and the Western Mountains Subarea, 2) Older Cenozoic Volcanic and Sedimentary Deposits (65 my to 2.5 my), including Tertiary Sonoma Volcanics (Miocene and Pliocene; 10 my to 2.5 my) which are found throughout the county, especially in the mountains surrounding Napa Valley, and 3) Younger Cenozoic Volcanic and Sedimentary Deposits (post 2.6 my to present), including the Quaternary alluvium of the Valley Floor. The two primary water-bearing units in the county are the tuffaceous member of the Sonoma Volcanics and the Quaternary alluvium.

Outside of the Napa Valley Floor, percolation of surface water appears to be the primary source of recharge. The rate of recharge within areas such as the MST Subarea has been shown to be significantly higher where streams and tributaries cross highly permeable outcrops (e.g., the tuffaceous member of the Sonoma Volcanics or shallow alluvium). Direct infiltration of precipitation is a major component of recharge in the main Napa Valley. Recharge throughout much of the county is generally limited by underlying shallow bedrock of low permeability. An additional component of groundwater recharge that is less understood is deep percolation through fractured rock and fault zones. This type of recharge can be very difficult to quantify due to the highly variable size and distribution of faults, fractures, and joints in a given area.

Groundwater Occurrence and Quality in the Sonoma Volcanics

Groundwater occurs in the Sonoma Volcanics in Napa County and yields water to wells. Well yields are highly variable from less than 10 to several hundred gallons per minute (gpm). The most common yields are between 10 to 100 gpm. Faye (1973) reported well-test information which showed an average yield of 32 gpm and an average specific capacity of 0.6 gallons per minute per foot of drawdown. From the available well log data, the Tertiary marine sedimentary rocks are poor groundwater producers either for a lack of water or poor water quality (high salinity). At great depths, groundwater quality in the Tertiary marine sedimentary rocks is generally poor due to elevated chloride concentrations.

According to Kunkel and Upson (1960), groundwater in the Sonoma Volcanics is generally of good quality except in three areas. The first area with poor groundwater quality, the Tulucay Creek drainage basin, east of the City of Napa, contains groundwater with elevated iron, sulfate, and boron. The Suscol area, south of the City of Napa, is the second area where some wells exhibit poor quality groundwater due to elevated chloride concentrations, possibly from leakage from salty water in the Napa River, alluvial material above, or the existence of zones of unusually saline connate water deep within the Sonoma Volcanics. The third area of poor groundwater quality, the Calistoga area in the northern end of the Napa Valley, contains isolated wells with elevated chloride, boron, and some trace metal concentrations.

Kunkel and Upson (1960) reported that the principal water yielding units of the Sonoma Volcanics are the tuffs, ash-type beds, and agglomerates. The lava flows were reported to be generally non-water bearing. However, it may be possible that fractured, fragmental, or weathered lava flows could yield water to wells. The hydrogeologic properties of the volcanic-sourced sedimentary deposits of the Sonoma Volcanics are complex and poorly understood.

Groundwater Occurrence in Other Units and in the Quaternary Sedimentary Deposits

Several hundred wells and test holes on record have been drilled into the exposed Huichica Formation. Well yields tend to be low to modest (< 10 gpm to tens of gpm). Only a few known wells on record are completed in the Clear Lake Volcanics near the northern County line. Three wells report high yields of 400 to 600 gpm. Much of the Clear Lake Volcanics to the south appear to be thinner, limited in extent, and in ridge-top locations where possible groundwater production appears to be less likely.

Groundwater production from Quaternary alluvium is variable, with yields ranging from <10 gpm in the East and West mountainous areas to a high of 3,000 gpm along the Napa Valley floor where the alluvium is thickest (>200 feet). According to Faye (1973), average yield of wells completed in the alluvium is 220 gpm. Many wells drilled in the alluvium within the last 30 years extend beyond the alluvium and into the underlying Cenozoic units. Kunkel and Upson (1960) report that groundwater in the alluvium is generally of good quality. The groundwater is somewhat hard and of the bicarbonate type, with small concentrations of sulfate, chloride, and total dissolved solids. A few isolated areas have increased chloride and boron concentrations.

2.3 Recent Groundwater Studies and Programs

This section summarizes the recently completed studies by Napa County and the recommendations relevant to groundwater monitoring that were developed.

2.3.1 Napa County's Comprehensive Groundwater Monitoring Program

In 2009, Napa County implemented a Comprehensive Groundwater Monitoring Program to meet identified action items in Napa County's 2008 General Plan update (Napa County, 2008). The program emphasizes developing a sound understanding of groundwater conditions and implementing an expanded groundwater monitoring and data management program as a foundation for future coordinated, integrated water resources planning and dissemination of water resources information. The program (and elements of this Plan) covers the continuation and refinement of countywide groundwater level and quality monitoring efforts (including many basins, subbasins and/or subareas throughout the county) for the purpose of understanding groundwater conditions (i.e., seasonal and long-term groundwater level trends and also quality trends) and availability. This information is critical to enable integrated water resources planning and the dissemination of water resources information to the public and state and local decision-makers. Napa County's combined efforts through the Comprehensive Groundwater Monitoring Program along with the related AB 303 Public Outreach Project on groundwater (CCP, 2010) and the efforts of the Watershed Information Center & Conservancy (WICC) of Napa County create a foundation for the County's continued efforts to increase public outreach and participation in water resources understanding, planning, and management. An informed and engaged public enables support of planned water resources projects and programs proposed by the County and others to meet the goals and objectives discussed in Section 3.

Napa County's Comprehensive Groundwater Monitoring Program involved many tasks that led to the preparation of five technical memorandums and a report on *Napa County Groundwater Conditions and Groundwater Monitoring Recommendations* (Groundwater Report) (LSCE, 2011a). This report and the other related documents can be found at: http://www.countyofnapa.org/bos/grac/. The report documents existing knowledge of countywide groundwater conditions and establishes a framework for the monitoring and reporting of groundwater levels and groundwater quality on a periodic basis. The report also summarizes priorities for groundwater level and quality monitoring for each of the county subareas.

2.3.2 Napa County Statewide Groundwater Elevation Monitoring (CASGEM)

This section describes the new DWR California Statewide Groundwater Elevation Monitoring (CASGEM) program. The wells included by the County in the CASGEM program are a *subset* of the overall network of wells monitored in Napa County.

In November 2009, Senate Bill SBX7 – 6 mandated that the groundwater elevations in all basins and subbasins in California be regularly and systematically monitored with the goal of demonstrating seasonal and long-term trends in groundwater elevations. In accordance with the mandate, DWR developed the CASGEM program. DWR is facilitating the statewide program which began with the opportunity for local entities to apply to DWR to assume the function of regularly and systematically collecting and reporting groundwater level data for the above purpose. These entities are referred to as Monitoring Entities. The legislature added a key aspect to SBX7 – 6 which was to make certain elements of the groundwater level information available to the public.

Wells designated for inclusion in the CASGEM program are for purposes of measuring groundwater levels on a semi-annual or more frequent basis that are representative of groundwater conditions in the state's groundwater basins and subbasins.

On December 29, 2010, the County applied to DWR to become the local countywide Monitoring Entity responsible for designating wells as appropriate for monitoring and reporting groundwater elevations for purposes of the CASGEM program.

The wells selected by the County for this program may be a *subset* of the overall wells monitored and need not be inclusive of the County's entire monitoring network. Thus, the County's participation in the CASGEM program complements other pre-existing groundwater monitoring that has been ongoing in Napa County for sometime (the overall historical monitoring record began in 1918). The end goals of the CASGEM program from the state's perspective is to support the understanding, managing, and sustaining of groundwater resources throughout California.

Following confirmation, the County, as the Monitoring Entity, proceeded to identify a *subset* of monitored wells to be included in the CASGEM network and to prepare a CASGEM Network Plan as required by DWR (LSCE, 2011b). At the time the County's CASGEM Network Plan was submitted to DWR, fourteen wells were included in the program. As of June 2012, the number of CASGEM wells had increased to nineteen.

2.3.3 Updated Conceptualization and Characterization of Hydrogeologic Conditions

In 2012, activities were implemented to update the characterization and conceptualization of hydrogeologic conditions (LSCE and MBK Engineers, 2013). Work to date is summarized below for three tasks, including: 1) the updated Napa Valley geologic conceptualization, 2) linking well construction information to groundwater level monitoring data, and 3) groundwater recharge characterization and estimates.

An important aspect of the work to update the hydrogeologic conceptualization is providing a refined understanding of the mechanisms through which water moves in response to the hydrologic cycle, particularly in the aquifer system underlying the main Napa Valley Floor. This involves many complex pathways and also considers many different time scales. As discussed further below, a key County General Plan goal (Napa County, 2008) is to "Conserve, enhance and manage water resources on a sustainable basis to attempt to ensure that sufficient amounts of water will be available for the uses allowed by this General Plan, for the natural environment, and for future generations." The groundwater monitoring program described in this Plan is instrumental to accomplishing this goal. The groundwater monitoring data (especially levels) are important for understanding the quantity of water flowing into and from a groundwater basin. Construction of a water budget, also known as a water balance, is a tool scientists can employ to assess the quantity of groundwater in storage. This tool is also used to observe how the quantity of groundwater in storage may vary over time. This tool relies upon a defined accounting unit of volume, for example a groundwater basin or other hydrologic unit of analysis. Measurements of water flowing into and out of the defined unit are used to determine the change in water storage. In the simplest form, the equation for this is:

Inflows – Outflows = Change in Storage

Typical Inflows and Outflows are summarized below (DWR, 2003):

Inflows

- Natural recharge from precipitation;
- Seepage from surface water channels;
- Intentional recharge via ponds, ditches, and injection wells;
- Net recharge of applied water for agricultural and other irrigation uses;
- Unintentional recharge from leaky conveyance pipelines; and
- Subsurface inflows from outside basin boundaries.

Outflows

- Groundwater extraction by wells;
- Groundwater discharge to surface water bodies and springs;
- Evapotranspiration; and
- Subsurface outflow across basin or subbasin boundaries.

Information relating to each of the above inflow and outflow data components provides the best approximation of the change in storage. A simple way of estimating the change in storage in a basin is through the determination of the average change in groundwater elevations over the groundwater basin for a period of time. This change in water levels is then multiplied by the area overlying the basin and also the average specific yield (in the case of an unconfined aquifer system, or storativity in the case of a confined aquifer system). The change in groundwater levels is best determined over a specific study period that considers different water year types (wet, normal, dry, multiple dry years), but it is common for shorter time periods (e.g., one year's spring to spring groundwater elevations) to be used. This simplistic approach to calculating a change in storage does not provide an indication of the total volume of groundwater storage or the storage available for use. Rather, this computation provides a "snapshot" perspective of short-term trends. The quick calculation should only be considered as an indicator; a more complete groundwater balance evaluation is much preferred (e.g., groundwater flow model). For example, if stresses on the aquifer system induce additional surface water infiltration, the change in groundwater storage may not be apparent (DWR, 2003).

Updated Napa Valley Geologic Conceptualization

Published hydrogeologic studies of Napa County have been largely based on pre-1970 water well drillers' reports and focused on the higher yielding Quaternary alluvium deposits of Napa Valley (Kunkel and Upson, 1960; Faye, 1973). Most previous hydrogeologic cross sections have been constructed in the southern portion of the valley near and to the east of the City of Napa (Kunkel and Upson, 1960; Sweetkind and Taylor, 2010; Farrar and Metzger 2003). The northern valley has been characterized by alluvium thickness maps (Faye, 1973) with little attention paid to the older deposits and Sonoma Volcanics.

As part of this investigation, a series of eight cross valley geologic sections were constructed utilizing water well drillers' reports extending up to 2011 (**Figure 2-3**). Cross-section locations were chosen based on perceived geologic relationships and the availability of sufficient well control. About 1,300 water well drillers' reports were reviewed and located on topographic base maps; 191 of these were selected for use in the cross sections. Geologic correlations seen on the cross-sections were then extended between sections by available well control and surficial geologic maps. From the geologic cross-sections and correlations of other water well drillers' reports, the Quaternary alluvium was separated from underlying units, and an isopach (contours of equal thickness) map was constructed.

The alluvium is divided into three facies on the map based on lithologic character. From the area just north of the City of Napa and southward, the alluvium is characterized as the basin fill facies consisting of thin sand and gravels with some thicker channel deposits interbedded with thicker beds of silt and clays of floodplain, marshland and possibly, estuary deposits in the Suscol area. This area is not well defined because of lack of well control. North of this area, the Napa Valley alluvium is subdivided into two facies: the fluvial facies and the alluvial plain facies. A narrow band of the fluvial facies consists of thick-bedded sand and gravel channels with interbedded floodplain silts and clays. The total thickness is up to 300 feet near Yountville and thins southward. The fluvial facies remains thick (up to 200 feet) northward to near Rutherford, and then thins to a thickness of 100 feet or less near the St. Helena area. The area between Rutherford and Oak Knoll Avenue is where the highest well yields are reported. Outside of the fluvial facies towards the valley sides occur the alluvial plain facies of thin sand and gravel beds of tributary streams interbedded with thicker, alluvial fan flood-flow sandy gravelly clays. These deposits appear to thin from a thickness of over 100 feet near the fluvial facies, with which they interfinger, to zero thickness near the valley sides. The alluvial plain facies deposits appear to be modest to low water yielding in pre-1970 wells, but more recently constructed wells extend into deeper units.

Beneath the alluvium is a complex sequence of Tertiary sedimentary deposits (Huichica Formation) and igneous deposits of the Sonoma Volcanics. These units are strongly deformed by folding and faulting and have complex stratigraphic relationships. From the geologic cross-sections, lateral correlations, and surficial map relationships, a structure contour map (elevations) of the top of these units and the subcrop[1] pattern were developed (LSCE and MBK Engineers, 2013). From north of the City of Napa and southward, these deposits are dominated by fine-grained basin fill with few sand and gravels of floodplain, estuary origin. North towards Yountville, sedimentary deposits of the Huichica Formation appear to overlie Sonoma Volcanics andesites and tuffs. Sonoma Volcanics and the older Mesozoic Great Valley sequence are exposed in a structural uplift area in the small hills in the Yountville area.

Further north, a Sonoma Volcanics andesite flow breccia appears to transition into a sedimentary conglomerate along the center of the valley. This unit is encountered in deep, high yielding wells also completed in the overlying alluvium fluvial facies, but it is not clear if this unit also is high yielding. Overlying the conglomerate/breccia on the east is the Tertiary sedimentary deposits sequence (Huichica Formation) of sandstones and mudstones. To the west of the unit occur older Sonoma Volcanics andesites, tuffs in the south, and possibly younger Sonoma Volcanics tuffs interbedded with Tertiary sedimentary deposits (Huichica Formation) of sand

[1] Occurrence of strata in contact with the undersurface of a stratigraphic unit, which in this case includes the strata beneath the alluvium.

and gravels and clays. All of the Tertiary units beneath the Napa Valley Floor appear to be low to moderately water yielding with poor aquifer characteristics (LSCE and MBK Engineers, 2013).

Linking Well Construction Information to Groundwater Monitoring Data

As part of the updated hydrogeologic characterization, existing monitoring well construction data from all available public sources were reviewed to determine the distribution of aquifer-specific monitoring data in Napa Valley. This effort addresses recommendations of the Comprehensive Groundwater Management Program to identify and fill data gaps that will allow for analysis of groundwater occurrence and flow as a more robust understanding of the extent of groundwater resources in the county is developed. A major component of this work has been to identify construction information for previously monitored wells in Napa Valley.

Groundwater level monitoring needs identified through the Comprehensive Groundwater Management Program include improved spatial distribution of groundwater level monitoring, additional characterization of subsurface geologic conditions in county subareas to identify aquifer characteristics, further examination of well construction information to define which portion of the aquifer system is represented by water levels measured in the currently monitored wells (and in many cases to link construction information to the monitored wells), and improve the understanding of surface water/groundwater interactions and relationships.

To address these needs, the Data Management System (DMS) created as part of the Comprehensive Groundwater Management Program was used along with a set of over 6,000 well drillers' reports for wells drilled in the county through 2011. Location and other data about wells where water level data have been collected within the Napa Valley Floor were extracted from the Napa DMS by a query that returned 938 wells. Four hundred sixty-eight of those are wells constructed for monitoring regulated soil and groundwater contamination sites. Of the remaining 470 wells, nine have a record of destruction or abandonment in the DMS. Many more of the 470 non-regulated monitoring wells are likely duplicate entries accumulated in the DMS as a result of records compiled from multiple monitoring entities.

Well construction information for these wells was identified by comparing data about the wells available in the Napa DMS with the actual drillers' reports that contain the well driller's record of subsurface lithology encountered during the drilling process. Information in the Napa DMS was compared in sequence for each well and included the township/range/section, parcel number, well address, type of well, intended use, and date of well completion. The range of data collected at each well relative to the recorded well completion date on the Well Completion Report was also referenced as a secondary indicator when more than one well was found with a given address or parcel. Records compiled by Kunkel and Upson (1960), who performed an extensive survey of wells drilled in Napa Valley through approximately 1952, were also referenced in cases where the earliest measurements or date of well completion were prior to 1960, which predates most drillers' reports from Napa County that were provided by DWR. Due to slight variations in location information recorded by various monitoring entities over time, multiple point locations have sometimes been assigned for a single well. The Napa DMS and direct communications with Napa County staff were used to identify duplicate well records. The DMS was used to compare metadata, including well depth, borehole depth, and construction date to avoid over representation of sites where water levels have been or are being recorded.

This process identified 42 duplicate well entries for sites where water levels have been or are currently monitored by Napa County, DWR, and USGS.

Monitored wells with at least 5 years of monitoring data and that are also relatively close to the mainstem Napa River were identified to address the need for improved monitoring of groundwater/surface water interactions in Napa Valley. That process identified 101 wells located within a one-quarter mile radius of the Napa River, with 38 wells which were not associated with regulated soil and groundwater contamination sites. A total of 180 wells were found within a one-half mile radius of the Napa River, with 89 of those not associated with regulated sites. Although the regulated sites most often have aquifer-specific shallow monitoring wells completed in the alluvial aquifer system, their spatial distribution is skewed to coincide with the developed population centers in the valley.

All monitored wells with at least 5 years of data were then compared by location with existing surface water gauges along the Napa River to evaluate the potential for pairing measurements of river stage with groundwater levels to assess surface water/groundwater interactions. Ultimately, six sites spanning from the City of Napa north to St. Helena were identified for future monitoring focus (see additional discussion of these sites in Section 4).

Groundwater Recharge Characterization and Estimates

Another important feature of the current hydrogeologic investigation is the development of improved characterization of groundwater recharge in the areas of greatest groundwater development, with an emphasis on Napa Valley. Understanding the volume of and mechanisms driving groundwater recharge in the county will be essential in determining where and how much groundwater can be produced without incurring negative impacts (LSCE, 2011a). Currently, evaluation of recharge mechanisms and volumes within Napa County has been limited to the Napa Valley (Faye, 1973) and the MST Subarea (Johnson, 1977; Farrar and Metzger, 2003).

The high permeability of the alluvial sediments in the Napa Valley permits precipitation and surface water to readily infiltrate and recharge groundwater throughout the majority of the valley. These high permeability soils combined with the large volume of water that flows through the Napa River create the potential for significant recharge to occur under the hydrologic circumstances and hydraulic gradient that allow for recharge from the river to groundwater to occur.

For the current project, mass balance and streamflow infiltration methods are being used to estimate regional and local recharge. Streamflow infiltration can be characterized by comparing the elevation of surface water to the shallowest adjacent groundwater. Detailed remotely sensed elevation data of the mainstem Napa River and several major tributaries have been obtained for this purpose. These LiDAR data provide sub-meter precision elevation data and have been sampled at 3 foot intervals along each watercourse. These data are paired with previously collected groundwater level data and estimates of areas of greatest recharge potential to estimate the potential for recharge to groundwater.

In addition, mass balance recharge estimates have been developed for the Napa River watershed and major tributary watersheds using a range of available data (LSCE and MBK Engineers, 2013). Available records for streamflow, precipitation, land use, and vegetative cover throughout these watersheds have been used to develop spatially-distributed estimates of annual hydrologic inputs and outputs in order to solve for the volume of groundwater recharge. Key components of this work include quantifying the distribution of precipitation across the land surface, quantifying the amount of water that returns to the atmosphere by evapotranspiration, and quantifying the hydraulic properties of soil and alluvial materials through which water must infiltrate to reach groundwater. Estimates developed through the mass balance approach have been evaluated using a sensitivity analysis to determine the degree to which any individual or set of inputs affects the recharge estimate.

2.3.4 Groundwater Monitoring Priorities

Priorities for addressing groundwater level and quality monitoring are presented below. These are based on the analysis of existing groundwater data and conditions described in the Groundwater Report (LSCE, 2011a). Preliminary prioritizations presented in the Groundwater Report are provided in Appendix A. The recommendations from the Groundwater Report have been slightly updated with input received from the GRAC.

Groundwater Level Monitoring

Currently, groundwater level measurements are recorded at a total of 87 sites (measurements began in 1920 for one Napa County monitoring well that is still being monitored). **Table 2-2** and **Figure 2-4** summarize the currently conducted monitoring in each subarea. Also shown in **Table 2-2** are the preliminary ranking and priorities for improving or expanding groundwater level monitoring in each of the designated subareas. Six subareas (including the NVF-Calistoga, NVF-MST, NVF-Napa, NVF-St. Helena, NVF-Yountville, and Carneros Subareas) are given a relatively higher priority. This relative prioritization is based on such factors as data scarcity, the need to improve the spatial distribution of the currently collected data, current population and groundwater utilization relative to other parts of the county, and /or the need to improve understanding of groundwater/surface water interactions. Some factors are given greater consideration in areas that currently use more groundwater than other areas. In mountainous areas where less groundwater development has occurred, where geologic conditions are complicated by basement rocks that are complexly deformed by folding and faulting and are well lithified, and overall there is considerable variability (LSCE, 2011a), future monitoring needs could be considered in coordination with potential or planned development in localized areas. Overall, groundwater level monitoring priorities are to identify seasonal and long-term trends and develop the data that facilitate better understanding of groundwater conditions, including response to such factors as climate change and to identify opportunities for enhanced groundwater recharge and storage.

Groundwater level monitoring needs include improved spatial distribution of groundwater level monitoring, additional characterization of subsurface geologic conditions in each subarea to identify aquifer characteristics, further examination of well construction information to define which portion of the aquifer system is represented by water levels measured in the currently monitored wells, and improve the understanding of surface water – groundwater relationships.

Table 2-2
Groundwater Level Monitoring Sites, Napa County
(Current[1] and Future)

Subarea	No. Sites with Current Groundwater Level Data	Future Groundwater Level Monitoring		Monitoring Needs
		Relative Priority	Action (Expand/ Refine)	
Napa Valley Floor-Calistoga	**6**	**H**	E	**SP, SW**
Napa Valley Floor-MST	**29**	**H**	R	**SP, SW**
Napa Valley Floor-Napa	**18**	**H**	R	**SP, SW**
Napa Valley Floor-St. Helena	**12**	**H**	E	**SP, SW**
Napa Valley Floor-Yountville	**9**	**H**	E	**SP, SW**
Carneros	**5**	**H**	E	**B**
Jameson/American Canyon	1	M	E	B
Napa River Marshes	1	M	E	SP, SW
Angwin	0	M	E	B
Berryessa	3	L	E	B
Central Interior Valleys	1	L	E	B
Eastern Mountains	0	L	E	B
Knoxville	1	L	E	B
Livermore Ranch	0	L	E	B
Pope Valley[2]	1	L	E	B
Southern Interior Valleys	0	L	E	B
Western Mountains	0	L	E	B
Total	**87**			

[1] "Current" refers to monitored sites with wells measured for levels and/or any water quality parameter with a period of record extending to 2011 or later. “Future” refers to recommended monitoring locations.
[2] The relative priority for Pope Valley was changed from “high” in the Groundwater Report to “low” in the Plan based on input from the GRAC on the current population and groundwater use in this subarea.

L = Low Priority; add groundwater level monitoring based on areas of planned future groundwater development

M = Medium Priority; add groundwater level monitoring

H = High Priority; add groundwater level monitoring

E = Expand current monitoring network; possible alternatives for additional monitoring wells include 1) wells historically monitored by DWR/USGS/Others, preferably with well construction information; 2) existing water supply wells (e.g., private/commercial) with well construction information; 3) new dedicated monitoring wells coordinated with recent geologic investigations that are or will be conducted)

R = Refine current monitoring network (link well construction information to all monitored wells, as possible)

Monitoring Needs:
SP = Improve horizontal and/or vertical spatial distribution of data, including for the purpose of identifying such factors as climate change and to identify opportunities for enhanced groundwater recharge and storage;
SW =identify appropriate monitoring site to evaluate surface water -groundwater recharge/discharge mechanisms;
B = Basic data needed to accomplish groundwater level monitoring objectives

Groundwater Quality Monitoring

The current groundwater quality monitoring network consists of 177 monitoring sites (**Table 2-3 and Figure 2-5**). Of these sites, some of the wells, but not all, have well construction information. Current groundwater quality monitoring sites are fairly well distributed throughout the Napa Valley Floor Subarea but are generally sparse elsewhere in the county. Recommended improvements to the groundwater quality monitoring program, and priority timelines for improvements, are summarized in **Table 2-3** and discussed further in the Groundwater Report (LSCE, 2011a).

Table 2-3 includes a ranking and prioritization for improving or expanding groundwater quality monitoring in each of the designated subareas. Three subareas (including NVF-MST, Carneros, and Jameson/American Canyon Subareas) are given a relatively higher priority. This relative prioritization is based on such factors as data scarcity, the need to improve the spatial distribution of the currently collected data, current population and groundwater utilization relative to other parts of the county, and/or the need to improve understanding of groundwater/surface water interactions. Some factors are given greater consideration in areas that currently use more groundwater than other areas. Seven subareas, including Berryessa, Central Interior Valleys, Knoxville, Livermore Ranch, Pope Valley, Southern Interior Valleys, and Western Mountains, are assigned lower priorities for groundwater quality monitoring due to the likely lower levels of projected land and groundwater use. The seven remaining subareas are designated as medium priorities for groundwater quality monitoring. Many of these areas have current monitoring programs, so the emphasis in these areas is to further examine land use with respect to monitoring locations and the units(s) of the aquifer system represented by this monitoring. For example, the Eastern Mountains Subarea appears to include 25 current groundwater quality monitoring sites. However, the source of this data is largely GeoTracker GAMA, which includes California Department of Public Health (DPH) data for community water supply wells. Consequently, these wells are assigned imprecise locations by DPH such that the well locations are accurate to plus or minus one mile. Most likely, these wells are actually located in the main Napa Valley Floor.

Table 2-3 also includes key factors related to monitoring needs. Many subareas outside the Napa Valley Floor have limited spatial distribution of the current groundwater quality monitoring wells/sites. Basic data are described as a key need to accomplish the Plan’s groundwater quality monitoring objectives. Importantly, expansion and/or refinement of groundwater quality monitoring conducted in all subareas should be coordinated with efforts to expand or refine groundwater level monitoring to be able to relate water quality trends to constituent transport within the aquifer system.

Table 2-3
Groundwater Quality Monitoring Sites, Napa County
(Current[1] and Future)

Subarea	No. Sites with Current Groundwater Quality Data	Future Groundwater Quality Monitoring		Monitoring Needs
		Relative Priority	Action (Expand/ Refine)	
Napa Valley Floor-Calistoga	20	M	R	SP,C
Napa Valley Floor-MST	**16**	**H**	R	**SP,C**
Napa Valley Floor-Napa	21	M	R	SP,C
Napa Valley Floor-St. Helena	31	M	R	SP,C
Napa Valley Floor-Yountville	14	M	R	SP,C
Carneros	**9**	**H**	R	**SP,C**
Jameson/American Canyon	**3**	**H**	E	**B,SP,C**
Napa River Marshes	6	M	E	B,SP,C
Angwin	4	M	E	B,C
Berryessa	6	L	E	B,C
Central Interior Valleys	6	L	R	B,SP,C
Eastern Mountains	25	M	E/R	B,C
Knoxville	0	L	E	B,C
Livermore Ranch	0	L	E	B,C
Pope Valley[2]	6	L	E	B,C
Southern Interior Valleys	1	L	E	B,C
Western Mountains	10	L	R	B,C
Total	**177**			

[1] "Current" refers to monitored sites with wells measured for levels and/or any water quality parameter with a period of record extending to 2008 or later. "Future" refers to recommended monitoring locations.
[2] The relative priority for Pope Valley was changed from "high" in the Groundwater Report to "low" in the Plan based on input from the GRAC on the current population and groundwater use in this subarea. Similarly, some subareas previously in a "medium" category were changed to a relatively low ranking.

L = Low Priority; add groundwater quality and also level monitoring based on areas of planned future groundwater development

M = Medium Priority; add groundwater quality and also level monitoring

H = High Priority; add groundwater quality and also level monitoring

E = Expand current monitoring network; possible alternatives for additional monitoring wells include 1) wells historically monitored by DWR/USGS/Others, preferably with well construction information and as the well may be available for monitoring; 2) existing water supply wells (e.g., private/commercial) with well construction information; 3) new dedicated monitoring wells (coordinate with potential geologic investigations that may be conducted in selected areas)

R = Refine current monitoring network (link well construction information to all monitored wells, as possible)

Monitoring Needs: SP = Improve horizontal and/or vertical spatial distribution of data; B = Basic data needed to accomplish groundwater level monitoring objectives; C = Coordinate with groundwater level monitoring

Note: Some sites with current groundwater quality data are approximately located and currently may not be counted in the correct subarea. Also, additional sites with current groundwater quality beyond this tabulation exist but the locations are currently unavailable and unable to be counted at this time.

2.3.5 Recommendations from Recent County Studies

Groundwater Level Monitoring Recommendations from the Groundwater Report

Below are recommendations from the 2011 Groundwater Report (LSCE, 2011a) in order to implement the expansion and improvement of countywide groundwater level monitoring activities by the County and others.

1. Replace water level monitoring wells that are completed in more than one aquifer with wells completed in (or representative of) a single aquifer (a phased approach is recommended for this effort that considers the historical record for existing wells in the network).
2. Continue groundwater level monitoring on at least a semi-annual basis; increase the spatial and vertical distribution of wells for monthly water level measurements (e.g., in key areas) to allow more comprehensive evaluation of groundwater conditions and stream-aquifer relationships.
3. Perform GPS surveys with higher accuracy instrumentation, as may be needed, to establish updated reference point elevation data.
4. Communicate County groundwater level monitoring objectives to private and commercial landowners and invite voluntary participation in the ongoing program (i.e., access to suitable wells with construction information located in areas of interest to meet subarea-specific monitoring objectives).

Groundwater Quality Monitoring Recommendations from the Groundwater Report

Below are recommendations from the 2011 Groundwater Report (LSCE, 2011a) in order to implement the expansion and improvement of countywide groundwater quality monitoring activities.

1. Implement efforts to expand and/or refine the groundwater quality monitoring program such that more wells can be "qualified" with well construction information.
2. Review the historically monitored wells to determine whether some of these may be suited to the objectives of gathering basic data and/or expanding groundwater quality monitoring in the various county subareas.
3. Coordinate expansion of the groundwater quality monitoring program with the expansion/refinement of subarea groundwater level monitoring.
4. Communicate County groundwater quality monitoring objectives to private and commercial landowners and invite voluntary participation in the ongoing program (i.e., access to suitable wells with construction information located in areas of interest to meet subarea-specific monitoring objectives).
5. As feasible, replace monitoring wells that are completed in more than one zone or aquifer with wells completed in a single unit that meets regional and subarea-specific groundwater quality monitoring objectives.

Summary of Overall Groundwater Monitoring Program Recommendations from the 2011 Groundwater Report

1. County establish its role as lead agency for ongoing groundwater monitoring program coordination and database oversight and management.
2. Establish plan for pertinent County departments to coordinate data collection, storage, and analysis efforts.
3. Identify potential collaborators (including local, federal, and state agency representatives) and interested stakeholders for the ongoing program.
4. Annually update the DMS (e.g., groundwater levels and quality and other water-related data), assess network and findings, and make changes to the program where necessary.
5. Discuss monitoring parameters of special interest with collaborators.
6. Review groundwater data annually and revise or make recommendations to revise data collection accordingly, pending changes to network wells and/or specific program objectives.
7. Identify locations for construction of dedicated monitoring wells for water level and/or quality monitoring (e.g., county subareas where more subsurface information is required to better quantify groundwater availability and quality, recharge areas where aquifer-specific monitoring is lacking, surface water-groundwater interaction, etc.).
8. Replace (over time) wells in the monitoring network that have no well construction information (or are perforated in more than one zone) to improve the understanding of aquifer-specific conditions.
9. Coordinate efforts being conducted for water supply investigation work (e.g., test hole construction) with opportunities for constructing zone-specific dedicated monitoring facilities for countywide water level and/or water quality monitoring.
10. Communicate program results to cooperating entities.
11. Provide an overview of program objectives, benefits and results to the general public via web information and other communication vehicles.
12. Seek funding to support program continuation, including DMS, data evaluation, and implementation of priority recommendations.
13. Explore the need to develop guidelines for testing private wells to evaluate potential water quality issues.

Napa County CASGEM Plan Recommendations

The County's 2011 CASGEM program (LSCE, 2011b) reported that the County plans to include at least one additional monitoring well in the Pope Valley and Berryessa Valley Groundwater Basins as well as additional wells in other subareas (including the NVF-Calistoga, NVF-MST, NVF-Napa, NVF-St. Helena, NVF-Yountville, and Carneros Subareas) over the coming years. Additional wells in these subareas are of interest for (LSCE, 2011a):

- Improving horizontal and/or vertical spatial distribution of data;
- Identifying appropriate monitoring sites to evaluate surface water-groundwater interaction; and

- Establishing additional basic data needed to accomplish groundwater level monitoring objectives.

Summary of Recommendations

Groundwater Level Monitoring

Per the priorities discussed in this section, additional groundwater level monitoring wells are recommended in the following subareas:

- NVF-MST
- NVF-Napa
- NVF-St. Helena
- NVF-Yountville
- NVF-Calistoga
- Carneros
- Pope Valley (CASGEM)
- Berryessa Valley (CASGEM)

Additional monitoring in the subareas in the Napa Valley Floor would be especially to improve the horizontal and spatial distribution of groundwater level data to better understand groundwater conditions, including response to such factors as climate change and to identify opportunities for enhanced groundwater recharge and storage.

Additional groundwater level monitoring is needed to further evaluate surface water-groundwater interaction and recharge/discharge mechanisms. It is especially recommended that dedicated shallow monitoring wells be constructed at appropriate locations, particularly along the main stem of the Napa River, for this purpose.

Groundwater Quality Monitoring

Per the priorities discussed in this section, additional groundwater quality monitoring wells are recommended in the following subareas:

- NVF-MST
- Carneros
- Jameson/American Canyon

Additional wells in these subareas are to improve horizontal and/or vertical spatial distribution of data and also to establish baseline groundwater quality conditions. Groundwater level monitoring would also occur at any wells added for groundwater quality monitoring in order to evaluate trends in and/or movement of the monitored constituents.

Further examination of the suitability of existing wells for groundwater monitoring (including their location and construction and relevance to meet County and/or CASGEM monitoring objectives) is necessary to determine if any existing wells would be suitable for ongoing evaluation of groundwater conditions. If existing private wells are considered, approval from the property owners to voluntarily participate in the County's groundwater monitoring program would be sought. Additional wells may be added to provide better spatial and/or vertical distribution of monitored locations within the subareas and to enhance the understanding of localized groundwater conditions and availability.

Section 4 outlines steps to optimize additional groundwater monitoring locations that serve to meet the objectives of the County's Comprehensive Groundwater Monitoring Program and the CASGEM monitoring program.

3 GROUNDWATER RESOURCES GOALS AND MONITORING OBJECTIVES

3.1 Napa County Water Resources Goals and Policies

The County's General Plan (2008, amended June 23, 2009) recognizes, "water is one of the most complex issues related to land use planning, development, and conservation; it is governed and affected by hundreds of federal, state, regional, and local mandates pertaining to pollution, land use, mineral resources, flood protection, soil erosion, reclamation, etc. Every year, the state legislature considers hundreds of bills relating to water issues, and in Napa County, more than two dozen agencies have some say in decisions and regulations affecting water quality and water use."

As part of the General Plan update in 2008, and within the Conservation Element, six goals are set forth relating to the County's water resources, including surface water and groundwater. Complementing these goals are twenty-eight policies and ten water resources action items (one of which is "reserved" for later description). The County's six water resources goals are included below (the entire group of water resources goals, policies, and action items is included in LSCE, 2011a).

> **Goal CON-8:** Reduce or eliminate groundwater and surface water contamination from known sources (e.g., underground tanks, chemical spills, landfills, livestock grazing, and other dispersed sources such as septic systems).
>
> **Goal CON-9:** Control urban and rural storm water runoff and related non-point source pollutants, reducing to acceptable levels pollutant discharges from land-based activities throughout the county.
>
> **Goal CON-10:** Conserve, enhance and manage water resources on a sustainable basis to attempt to ensure that sufficient amounts of water will be available for the uses allowed by this General Plan, for the natural environment, and for future generations.
>
> **Goal CON-11:** Prioritize the use of available groundwater for agricultural and rural residential uses rather than for urbanized areas and ensure that land use decisions recognize the long-term availability and value of water resources in Napa County.
>
> **Goal CON-12:** Proactively collect information about the status of the County's surface and groundwater resources to provide for improved forecasting of future supplies and effective management of the resources in each of the County's watersheds.
>
> **Goal CON-13:** Promote the development of additional water resources to improve water supply reliability and sustainability in Napa County, including imported water supplies and recycled water projects.

Addressing the six water resources goals above, the County has produced specific General Plan Action Items related to the focus and objective of this Plan. Those action items include:

Action Item CON WR-1: Develop basin-level watershed management plans for each of the three major watersheds in Napa County (Napa River, Putah Creek, and Suisun Creek). Support each basin-level plan with focused sub-basin (drainage-level) or evaluation area-level implementation strategies, specifically adapted and scaled to address identified water resource problems and restoration opportunities. Plan development and implementation shall utilize a flexible watershed approach to manage surface water and groundwater quality and quantity. The watershed planning process should be an iterative, holistic, and collaborative approach, identifying specific drainage areas or watersheds, eliciting stakeholder involvement, and developing management actions supported by sound science that can be effectively implemented. [Implements Policies 42 and 44]

Action Item CON WR-4: Implement a countywide watershed monitoring program to assess the health of the County's watersheds and track the effectiveness of management activities and related restoration efforts. Information from the monitoring program should be used to inform the development of basin-level watershed management plans as well as focused sub-basin (drainage-level) implementation strategies intended to address targeted water resource problems and facilitate restoration opportunities. Over time, the monitoring data will be used to develop overall watershed health indicators and as a basis of employing adaptive watershed management planning. [Implements Policies 42, 44, 47, 49, 63, and 64]

Action Item CON WR-6: Establish and disseminate standards for well pump testing and reporting and include as a condition of discretionary projects that well owners provide to the County upon request information regarding the locations, depths, yields, drilling and well construction logs, soil data, water levels and general mineral quality of any new wells. [Implements Policy 52 and 55]

Action Item CON WR-7: The County, in cooperation with local municipalities and districts, shall perform surface water and groundwater resources studies and analyses and work toward the development and implementation of an integrated water resources management plan (IRWMP) that covers the entirety of Napa County and addresses local and state water resource goals, including the identification of surface water protection and restoration projects, establishment of countywide groundwater management objectives and programs for the purpose of meeting those objectives, funding, and implementation. [Implements Policy 42, 44, 61 and 63]

Action Item CON WR-8: The County shall monitor groundwater and interrelated surface water resources, using County-owned monitoring wells and stream and precipitation gauges, data obtained from private property owners on a voluntary basis, data obtained via conditions of approval associated with discretionary projects, data from the State Department of Water Resources, other agencies and organizations. Monitoring data shall be used to determine baseline water quality conditions, track groundwater levels, and identify where problems may exist. Where there is a demonstrated need for additional management actions to address groundwater problems, the County shall work collaboratively with property owners and other stakeholders to prepare a plan for managing groundwater supplies pursuant to State Water Code Sections 10750-10755.4 or other applicable legal authorities. [Implements Policy 57, 63 and 64]

Action Item CON WR-9.5: The County shall work with the SWRCB, DWR, DPH, CalEPA, and applicable County and City agencies to seek and secure funding sources for the County to develop and expand its groundwater monitoring and assessment and undertake community-based planning efforts aimed at developing necessary management programs and enhancements.

3.2 Overarching Groundwater Monitoring Objectives

The following Plan subsections describe a number of water level and quality objectives to be accomplished with the current and refined countywide groundwater level and quality monitoring program. The overarching groundwater monitoring objectives are linked to the County's General Plan goals and action items presented above and also to hydrogeologic conditions and issues of interest, including (but not limited to):

- Monitoring trends in groundwater levels and storage (e.g., groundwater balance) to assess and ensure long-term groundwater availability and reliability;
- Monitoring of groundwater-surface water interactions to ensure sufficient amounts of water are available to the natural environment and for future generations;
- Monitoring in significant recharge areas to assess factors (natural and human-influenced) that may affect groundwater recharge (including climate change) and also aid the identification of opportunities to enhance groundwater recharge and storage;
- Monitoring to establish baseline conditions in areas of potential saline water intrusion;
- Monitoring of general water quality to establish baseline conditions, trends, and protect and preserve water quality.
- Identify where data gaps occur in the key subareas and provide infill, replacement, and/or project-specific monitoring (e.g., such as may occur for planned projects or expansion of existing projects) as needed; and
- Coordinate with other entities on the collection, utilization, and incorporation of groundwater level data in the countywide DMS.

3.2.1 Groundwater Level Monitoring Objectives

The focus of the countywide groundwater level monitoring program includes the following objectives:

- Expand groundwater level monitoring in priority County subareas to improve the understanding of the occurrence and movement of groundwater; monitor local and regional groundwater levels including seasonal and long-term trends; and identify vertical hydraulic head differences in the aquifer system and aquifer-specific groundwater conditions, especially in areas where short- and long-term development of groundwater resources are planned (this includes additional monitoring of the Tertiary formation aquifer in the area between the NVF-MST Subarea and the northeastern part of the NVF-Napa Subarea to determine whether groundwater water conditions in the NVF-MST are affecting other areas (see Section 9 in LSCE and MBK Engineers, 2013);

- Detect the occurrence of, and factors attributable to, natural (e.g., direct infiltration of precipitation, surface water seepage to groundwater, groundwater discharge to streams) or induced factors (e.g., pumping, purposeful recharge operations) that affect groundwater levels and trends;

- Identify appropriate monitoring sites to further evaluate surface water-groundwater interaction and recharge/discharge mechanisms, including whether groundwater utilization is affecting surface water flows;

- Establish a monitoring network to aid in the assessment of changes in groundwater storage; and

Generate data to better estimate groundwater basin conditions and assess local current and future water supply availability and reliability; update analyses as additional data become available.

Based on the analysis of existing groundwater data and conditions described in the Groundwater Report (LSCE, 2011a) and with input received from the GRAC, the key objectives for future groundwater level monitoring for each subarea are summarized in Appendix A.

3.2.2 Groundwater Quality Monitoring Objectives

The primary objectives of the countywide groundwater quality monitoring program include:

- Evaluate groundwater quality conditions in the various county subareas and identify differences in water quality spatially between areas and vertically in the aquifer system within a subarea;

- Detect the occurrence of and factors attributable to natural (e.g., general minerals and trace metals) or other constituents of concern;

- Establish baseline conditions in areas of potential saltwater intrusion, including the extent and natural occurrence and/or causes of saltwater beneath the Carneros, Jameson/American Canyon and Napa River Marshes Subareas;

- Assess the changes and trends in groundwater quality; and

- Identify the natural and human factors that affect changes in water quality.

Based on the analysis of existing groundwater data and conditions described in the Groundwater Report (LSCE, 2011a) and with input received from the GRAC, the key objectives for future groundwater quality monitoring for each subarea are summarized in Appendix A.

3.3 Collaboration and Funding for Groundwater Monitoring

As described above, the County wishes to promote interagency collaboration and coordination on the collection, utilization, and incorporation of groundwater monitoring data into the DMS and to achieve countywide groundwater resources goals and monitoring objectives. As also noted above, the County has an existing Action Item (CON WR-9.5) that sets forth its interest in working with the SWRCB, DWR, DPH, CalEPA, and applicable County and City agencies to seek and secure funding sources for the County to develop and expand its groundwater monitoring and assessment, and undertake community-based planning efforts aimed at developing necessary management programs and enhancements.

The Groundwater Management Act adopted in 2002 (SB 1938) amended and expanded AB 3030 groundwater management plans. As discussed in the technical memorandum prepared for the County on *Groundwater Planning Considerations and Review of Napa County Groundwater Ordinance and Permit Process* (LSCE, 2011c), the California Water Code requires public agencies seeking priority for state funds administered through DWR (e.g., Local Groundwater Assistance (LGA) grant program) for the construction of groundwater projects or groundwater quality projects to prepare and implement a groundwater management plan with certain required components (Water Code Section 10753.7). Previously, all plans were voluntary, and there were no required plan components. The requirements now include establishing basin management objectives, preparing a plan to involve other local agencies in the basin in a cooperative planning effort, and more comprehensive monitoring programs (including groundwater levels and quality; surface water flows and quality; and inelastic land surface subsidence for basins where it is identified as a potential concern) to assess changes in basin conditions and “generate information that promotes efficient and effective groundwater management” (Water Code Section 10753.7).

As described above, on November 6, 2009, SBx7-6 (e.g., the CASGEM program) was enacted. This revised Water Code Section 10920 et seq. and established a groundwater monitoring program designed to monitor and report groundwater elevations in all or part of a basin or subbasin. These new requirements also limit counties and various entities’ (Water Code Section 10927.(a)-(d), inclusive) ability to receive state grants or loans in the event that DWR is required to perform groundwater monitoring functions pursuant to Water Code 10933.7 (DWR, 2012). The goal of the LGA grant program is to improve groundwater resource management and the knowledge of various groundwater basins throughout the state by funding projects that will provide long-term benefit to the management of groundwater (DWR, 2012). A comprehensive groundwater monitoring program is an integral part of this goal. As such, this Plan would greatly improve the County’s ability to apply for state and possibly federal funds in the future.

4 GROUNDWATER MONITORING NETWORK DESIGN AND DEVELOPMENT

This section describes the existing well monitoring network and well qualification efforts concurrently being conducted to attempt to link well construction information to wells with historical groundwater level and/or groundwater quality monitoring records. This section will also discuss data gaps identified as a result of the well qualification efforts and the monitoring wells needed to achieve the groundwater monitoring objectives described in Section 3. The means by which the monitoring network gaps might be addressed include:

1) Investigating the potential to restart monitoring where historical records are available but monitoring was discontinued;
2) Identification of existing wells of suitable construction that might be volunteered for inclusion through County and GRAC education and outreach efforts; and
3) Construction of new dedicated monitoring wells if suitable existing wells either do not exist in the area of interest or are otherwise not available.

This section includes monitoring protocols to meet program objectives (i.e., including developing a program capable of tracking changes in groundwater level and quality conditions and groundwater/surface water interrelationships). In support of the County's General Plan Goal CON-12 and Action Item CON WR-7 (see Section 3), the monitoring protocols are designed to generate information that promotes efficient and effective groundwater management.

This section also includes recommendations for filling spatial/vertical groundwater monitoring data gaps. Finally, this section includes recommended monitoring frequencies for groundwater levels and quality and recommended groundwater quality monitoring parameters.

4.1 Groundwater Level Monitoring

This section describes existing groundwater level monitoring and recommended locations for wells for groundwater level monitoring to fill data gaps. As additional monitoring facilities are considered, or existing facilities are further evaluated, the objectives provided in **Section 3** will be used evaluate the suitability of the existing or proposed facilities to ensure that the data being (or planned to be) collected can address these objectives.

4.1.1 Monitoring Network

Existing Groundwater Level Monitoring Wells

Figure 4-1 illustrates the distribution of current groundwater level monitoring locations, which is primarily located in the Napa Valley Floor-Napa and MST Subareas. Very little groundwater level monitoring is currently conducted elsewhere in Napa County outside these two subareas. A few scattered locations of groundwater level monitoring occur in the Berryessa, Pope Valley, the southern portion of the Central Interior Valleys, Jameson/American Canyon, and in the NVF-Calistoga, NVF-St. Helena, and NVF-Yountville Subareas. Groundwater level monitoring is not currently conducted in the Carneros, Livermore Ranch, Angwin, Southern Interior Valleys, and Western Mountains Subareas. **Table 4-1** summarizes the number of wells in each subarea that are currently monitored for groundwater levels (a detailed list is included in **Appendix A)**.

Groundwater level measurements have been recorded at a total of 87 sites since 2011. Of these sites where groundwater levels are measured, some type of well construction information (depth and/or perforated interval(s)) is readily available for 67 sites (41 non-regulated sites and 26 regulated sites). Most current groundwater level monitoring occurs on a semi-annual frequency.

Recommendations to Expand Monitoring Well Network

As presented above in **Table 2-2**, and summarized in Section 2, a preliminary ranking and priorities for improving or expanding groundwater level monitoring were prepared for each county subarea. Six subareas are given a relatively higher priority for improving the groundwater level monitoring network based on factors of current population and groundwater utilization relative to other parts of the county, and/or the need to improve understanding of groundwater/surface water interactions. Some factors are given greater consideration in areas that currently use more groundwater than other areas. These areas include:

- NVF-Calistoga,
- NVF-St. Helena,
- NVF-Yountville,
- NVF- MST,
- NVF-Napa, and
- Carneros Subareas

The monitoring network gaps in these six subareas might be addressed by:

1) Investigating the potential to restart monitoring where historical records are available but monitoring was discontinued;
2) Identifying existing wells of suitable construction that might be volunteered for inclusion through County and GRAC education and outreach efforts (this may include wells that are already being monitored for groundwater quality); and
3) Constructing new dedicated monitoring wells if suitable existing wells either do not exist in the area of interest or are otherwise not available.

Monitoring in other subareas with relatively medium to lower priorities is suggested to be addressed with volunteered wells.

The Napa County CASGEM Network Plan submitted to DWR in September 2011 (LSCE, 2011b) also describes the County’s intent to include at least one additional monitoring well in the Pope Valley and Berryessa Valley Groundwater Basins, as noted above.

The County will conduct additional public outreach to inform more private well owners of the value of understanding the groundwater resources in the County and to encourage their voluntary participation in the Comprehensive Groundwater Monitoring Program and/or CASGEM program. The County anticipates additional wells to be included in the CASGEM program over the coming years. Wells will be included based upon input from the County’s GRAC and in concert with their work to meet the objectives of the County’s Comprehensive Groundwater Monitoring Program and the CASGEM program.

For each county subarea, **Table 4-1** shows the existing monitoring sites, provides recommendations for the number and location of additional monitoring areas, and describes the key groundwater level monitoring objectives to be addressed. Altogether, it is recommended that approximately six groundwater/surface water monitoring sites for purposes of evaluating groundwater/surface water interactions and about 18 other areas of interest (AOIs) be added to the network (**Figure 4-1**).

Table 4-1
Groundwater Level Monitoring Sites, Napa County
(Current[1] and Recommended Additional Sites)

Subarea	No. Sites with Current Ground-water Level Data	Future GW Level Monitoring (Relative Priority)		Monitoring Needs	Recommend Addn'l Sites[2] (Number of Areas of Interest; Additional Volunteered Sites)	Proposed Areas of Interest for Monitoring	Key Monitoring Objectives[3]
Napa Valley Floor-Calistoga	**6**	**H**	**E**	**SP, SW**	**2 AOIs; V**	**14, 15**	**Conditions, Trends, Wtr Budget, SW**
Napa Valley Floor-MST	**29**	**H**	**R**	**SP, SW**	**V**		**Conditions, Trends, Wtr Budget, SW**
Napa Valley Floor-Napa	**18**	**H**	**R**	**SP, SW**	**2 SW; 4 AOIs; V**	**5, 6, 7, 8**	**Conditions, Trends, Wtr Budget, SW**
Napa Valley Floor-St. Helena[4]	**12**	**H**	**E**	**SP, SW**	**2 SW; 3AOIs; V**	**11, 12, 13**	**Conditions, Trends, Wtr Budget, SW**
Napa Valley Floor-Yountville	**9**	**H**	**E**	**SP, SW**	**2 SW; 2 AOIs; V**	**9, 10**	**Conditions, Trends, Wtr Budget, SW**
Carneros	**5**	**H**	**E**	**B**	**1 AOI; V**	**4**	**Conditions, Trends, Wtr Budget, Saltwater**
Jameson/American Canyon	1	M	E	B	3 AOIs; V	1, 18	Conditions, Trends, Wtr Budget, Saltwater
Napa River Marshes	1	M	E	SP, SW	1 AOI; V	2, 3	Conditions, Trends, Wtr Budget, Saltwater
Angwin	0	M	E	B	1 AOI; V	16	Conditions, Trends, Wtr Budget
Berryessa	3	L	E	B	V		Conditions, Trends (includ. CASGEM)
Central Interior Valleys	1	L	E	B	V		Conditions, Trends
Eastern Mountains	0	L	E	B	V		Conditions, Trends
Knoxville	1	L	E	B	V		Conditions, Trends
Livermore Ranch	0	L	E	B	V		Conditions, Trends
Pope Valley	1	L	E	B	1 AOI; V	17	Conditions, Trends (includ. CASGEM)
Southern Interior Valleys	0	L	E	B	V		Conditions, Trends
Western Mountains	0	L	E	B	V		Conditions, Trends
Total	**87**				**6 SW; 18 AOIs; V**		

[1] "Current" refers to monitored sites with wells measured for levels and/or any water quality parameter with a period of record extending to 2011 or later. "Future" refers to recommended monitoring locations.
[2] The numbers shown in this column refer to the number of areas of interest for additional monitoring. SW in this column refers to recommended sites for groundwater/surface water monitoring. "V" refers to additional water

supply wells (private or other) that may be volunteered for participation in the County program. "AOI" refers to the Area of Interest for monitoring; see Figure 4-1 for AOI locations.
[3] The Groundwater Level Monitoring Objectives shown in this column are "shorthand" descriptors for the objectives explained in Section 3.
[4] The wells shown in the Recommended Additional Sites column include one or more of the City of St. Helena's wells.

L = Low Priority; add groundwater level monitoring based on areas of planned future groundwater development

M = Medium Priority; add groundwater level monitoring

H = High Priority; add groundwater level monitoring

E = Expand current monitoring network; possible alternatives for additional monitoring wells include 1) wells historically monitored by DWR/USGS/Others, preferably with well construction information and as the well may be available for monitoring; 2) existing water supply wells (e.g., private/commercial) with well construction information; 3) new dedicated monitoring wells (coordinate with potential geologic investigations that may be conducted in selected areas)

R = Refine current monitoring network (link well construction information to all monitored wells, as possible)

Monitoring Needs: SP = Improve horizontal and/or vertical spatial distribution of data; SW =identify appropriate monitoring site to evaluate surface water -groundwater interrelationships; B = Basic data needed to accomplish groundwater level monitoring objectives

The six proposed groundwater monitoring sites are located along the main Napa Valley Floor from the City of Napa north to St. Helena adjacent to the Napa River system (**Figure 4-1**). These facilities are planned to be located near to existing stream gauging stations and/or near areas where stream monitoring can also be conducted. The proposed groundwater monitoring facilities are also being sited, where possible, adjacent to existing groundwater monitoring facilities (i.e., typically water supply wells constructed to greater depths in the aquifer system). The proposed monitoring wells will enable focused data collection regarding groundwater elevations and water quality to identify and characterize interactions with surface water.

Frequency of Monitoring

Historically, the County has measured the newly designated CASGEM wells semi-annually in the spring (April) and fall (October) of each year. Historical hydrographs show that these measurement periods generally correspond to the seasonal high and low groundwater elevations observed in their respective county subareas. The County will continue to measure the CASGEM wells semi-annually during similar periods.

Monthly water level monitoring is limited and does not currently provide adequate data to evaluate the effects of hydrologic events or stresses on the aquifer system. In particular, 3 wells are monitored monthly by DWR. These wells are located in the NVF-Calistoga; NVF- St. Helena, and NVF-Napa Subareas, respectively, and are also located generally near the Napa River. It is recommended that selected additional wells (existing and new) be measured monthly to evaluate hydrologic effects and particularly the wells at the six sites recommended to assess surface water and groundwater interrelationships (Napa County, 2012).

Field Methods

Napa County has documented field procedures for the collection of groundwater level measurements which were updated as part of the County's Comprehensive Groundwater Monitoring Program (LSCE, 2010b). These procedures and an example form for recording water level measurements are included in **Appendix C**). The County uses these procedures for the CASGEM program as well as continued monitoring of wells where water level data are submitted to DWR semi-annually for inclusion in DWR's Water Data Library, and the monitoring of other wells measured for County information.

4.2 Groundwater Quality Monitoring

This section describes existing groundwater quality monitoring and recommended locations for wells for groundwater quality monitoring to fill data gaps. As additional monitoring facilities are considered, or existing facilities are further evaluated, the objectives provided in Section 3 will be used to evaluate the suitability of the existing or proposed facilities to ensure that the data being (or planned to be) collected can address these objectives.

4.2.1 Monitoring Network

Existing Groundwater Quality Monitoring Wells

The current groundwater quality monitoring network consists of 177 sites (**Table 4-2; see detailed list in Appendix B**). Current groundwater quality monitoring sites are fairly well distributed throughout the Napa Valley Floor Subarea (**Figure 4-2).** Recommended improvements to the groundwater quality monitoring program, and priority timelines for improvements are discussed below.

Recommendations

As presented above in **Table 2-2**, and summarized in Section 2, a preliminary ranking and priorities for improving or expanding groundwater quality monitoring were prepared for each of the county subareas. Three subareas are given a relatively higher priority for improving the groundwater quality monitoring network based on the lack of spatially distributed groundwater quality monitoring. Although other areas also lack baseline groundwater quality data, these areas are given a relatively higher priority due to interest in better understanding naturally occurring metals (MST) and naturally occurring elevated salinity levels (e.g., Jameson/American Canyon and Napa River Marshes).These areas include:

- NVF-MST;
- Carneros; and
- Jameson/American Canyon Subareas.

Seven subareas, including Berryessa, Central Interior Valleys, Knoxville, Livermore Ranch, Pope Valley, Southern Interior Valleys and Western Mountains, are assigned relatively lower priorities for groundwater quality monitoring due to lower levels of land and groundwater use and/or there appear to be additionally available groundwater quality data from DPH that can be further examined for completeness and ongoing evaluation. The seven remaining subareas are designated as medium priorities for groundwater quality monitoring. Many of these areas have current monitoring programs, so the emphasis is to periodically examine the groundwater quality data to assess changes in conditions, including any trends in constituent concentrations.

Many subareas outside the Napa Valley Floor have limited spatial distribution of the current groundwater monitoring wells (or monitoring locations). Basic data are described as a key monitoring need and expansion and/or refinement of groundwater monitoring conducted in all subareas should be coordinated with efforts to provide additional characterization of subsurface geologic conditions and well construction information. This effort was undertaken as part of the updated characterization and conceptualization of hydrogeologic conditions for linking groundwater levels to construction data. Over time, it is recommended a similar effort occur for water quality data. Initial efforts to link water quality data to representation of the aquifer system could focus on the MST, Carneros, and Jameson/American Canyon Subareas. This will allow for the evaluation of groundwater conditions specific to an aquifer rather than composite information which limits the ability to fully understand groundwater conditions in the County and in individual subareas.

The monitoring network gaps in the three subareas given a relatively higher priority might be addressed by:

1) Investigating the potential to restart monitoring where historical records are available but monitoring was discontinued;
2) Identifying existing wells of suitable construction that might be volunteered for inclusion through County and GRAC education and outreach efforts; and
3) Constructing new dedicated monitoring wells if suitable existing wells either do not exist in the area of interest or are otherwise not available (this is not likely to be necessary for groundwater quality monitoring purposes only; the six recommended sites with dedicated wells constructed for groundwater level monitoring to evaluate groundwater/surface water interactions could also be added to the groundwater quality monitoring network).

Groundwater quality monitoring is recommended in the 18 AOIs discussed above for groundwater level monitoring. This addresses specific groundwater quality monitoring needs for the relatively higher priority subareas, as well as broader assessment of groundwater quality conditions and trends in other subareas.

Monitoring in other subareas with relatively medium to lower priorities is suggested to be addressed with volunteered wells.

For each county subarea, **Table 4-2** shows the existing monitoring sites, provides recommendations for the number and location of additional monitoring sites, and describes the key groundwater quality monitoring objectives to be addressed.

Table 4-2
Groundwater Quality Monitoring Sites, Napa County
(Current[1] and Recommended Additional Monitoring Sites)

Subarea	No. Sites with Current GW Quality Data	Future GW Quality Monitoring (Relative Priority)		Monitoring Needs	Recommend Addn'l Sites[2] (Number of Areas of Interest; Additional Volunteered Sites)	Proposed Areas of Interest for Monitoring	Key Monitoring Objectives[3]
Napa Valley Floor-Calistoga	20	M	R	SP,C	2 AOIs; V	14, 15	Conditions, Trends, Nat'l Constituents
Napa Valley Floor-MST	**16**	**H**	**R**	**SP,C**	**V**		Conditions Trends, Nat'l Constituents
Napa Valley Floor-Napa	21	M	R	SP,C	2 SW; 4 AOIs; V	5, 6, 7, 8	Conditions, Trends, Nat'l Constituents
Napa Valley Floor-St. Helena	31	M	R	SP,C	2 SW; 3 AOIs; V	11, 12, 13	Conditions, Trends, Nat'l Constituents
Napa Valley Floor-Yountville	14	M	R	SP,C	2 SW; 2 AOIs; V	9, 10	Conditions, Trends, Nat'l Constituents
Carneros	**9**	**H**	**R**	**SP,C**	**1 AOI; V**	**4**	Conditions, Trends, Nat'l Constituents, Saltwater
Jameson/American Canyon	**3**	**H**	**E**	**B,SP,C**	**3 AOIs; V**	**1, 18**	Conditions, Trends, Nat'l Constituents, Saltwater
Napa River Marshes	6	M	E	B,SP,C	1 AOI; V	2, 3	Conditions, Trends, Nat'l Constituents. Saltwater
Angwin	4	M	E	B,C	1 AOI; V	16	Conditions, Trends, Nat'l Constituents
Berryessa	6	L	E	B,C	V		Conditions, Trends, Nat'l Constituents

Subarea	No. Sites with Current GW Quality Data	Future GW Quality Monitoring (Relative Priority)		Monitoring Needs	Recommend Addn'l Sites[2] (Number of Areas of Interest; Additional Volunteered Sites)	Proposed Areas of Interest for Monitoring	Key Monitoring Objectives[3]
Central Interior Valleys	6	L	R	B,SP,C	V		Conditions, Trends, Nat'l Constituents
Eastern Mountains	25	M	E	B,C	V		Conditions, Trends, Nat'l Constituents
Knoxville	0	L	E	B,C	V		Conditions, Trends, Nat'l Constituents
Livermore Ranch	0	L	E	B,C	V		Conditions, Trends, Nat'l Constituents
Pope Valley	6	L	E	B,C	1 AOI; V	17	Conditions, Trends, Nat'l Constituents
Southern Interior Valleys	0	L	E	B,C	V		Conditions, Trends, Nat'l Constituents
Western Mountains	10	L	R	B,C	V		Conditions, Trends, Nat'l Constituents
Total	**177**				**6 SW; 18 AOIs; V**		

[1] "Current" refers to monitored sites with wells measured for levels and/or any water quality parameter with a period of record extending to 2008 or later. "Future" refers to recommended monitoring locations.
[2]The numbers shown in this column refer to the number of areas of interest for additional monitoring. SW in this column refers to recommended sites for groundwater/surface water monitoring "V" refers to additional water supply wells (private or other) that may be volunteered for participation in the County program (these volunteered wells for groundwater quality monitoring would be coordinated with those volunteered for groundwater level monitoring). "AOI" refers to Areas of Interest for groundwater monitoring; see Figure 4-2 for AOI locations for groundwater quality monitoring.
[3] The Groundwater Level Monitoring Objectives shown in this column are "shorthand" descriptors for the objectives explained in Section 3.

L = Low Priority; add groundwater quality and also level monitoring based on areas of planned future groundwater development

M = Medium Priority; add groundwater quality and also level monitoring

H = High Priority; add groundwater quality and also level monitoring

E = Expand current monitoring network; possible alternatives for additional monitoring wells include 1) wells historically monitored by DWR/USGS/Others, preferably with well construction information and as the well may be available for monitoring; 2) existing water supply wells (e.g., private/commercial) with well construction information; 3) new dedicated monitoring wells (coordinate with potential geologic investigations that may be conducted in selected areas)

R = Refine current monitoring network (link well construction information to all monitored wells, as possible)

Monitoring Needs: SP = Improve horizontal and/or vertical spatial distribution of data; B = Basic data needed to accomplish groundwater level monitoring objectives; C = Coordinate with groundwater level monitoring

Note: Some sites with current groundwater quality data are approximately located and currently may not be counted in the correct subarea. Also, additional sites with current groundwater quality beyond this tabulation exist but the locations are currently unavailable and unable to be counted at this time.

Frequency of Monitoring

With the exception of GeoTracker regulated facility sites in the county, current groundwater quality monitoring for TDS and/or EC typically occurs on a less frequent than annual basis. Nitrate monitoring on an annual or more frequent basis has occurred more often than monitoring for TDS, EC, and chloride (LSCE, 2010a, 2010b, and 2011).

It is recommended that wells added to the monitoring network for groundwater quality monitoring are sampled initially for general minerals and drinking water metals. These wells would include the six sites recommended for the purpose of evaluating groundwater/surface water interactions and also about 18 other sites in AOIs for groundwater quality monitoring as shown in **Table 4-2** and described above. It is also recommended that groundwater quality samples for similar parameters be collected the following year to affirm baseline conditions. It is recommended that groundwater quality monitoring occur on a triennial basis for general minerals and drinking water metals at the six sites recommended for groundwater/surface water evaluation. Following the baseline sampling and the one-year confirmation sampling, a 5-year frequency is recommended for the other 18 AOIs and where wells are volunteered for inclusion for monitoring in other subareas. A subset of analytes is recommended in intervening years (see further discussion below).

Field Methods

The methods and procedures used by DWR (1994) and USGS (http://water.usgs.gov/owq/FieldManual/) are detailed and extensive and are often used by counties and consultants as guidelines for the collection of water level measurements and water quality samples.

Prior to sampling a monitoring well, the static water level is measured. An electric sounder is used to measure the depth to groundwater from a specified reference point (usually the top of the well casing). Wellhead reference points are typically marked to provide consistency between measurements. Measurements are recorded to the nearest 0.01 foot. The static water level in conjunction with well construction information is used to calculate the volume of water in the well. This information is used to determine the minimum volume of water to be purged prior to sample collection.

Dedicated monitoring wells are typically purged and sampled using a portable submersible sampling pump. A discharge hose is attached to the top of the pump assembly through which purge water is discharged. Smaller-diameter tubing for sample collection is also attached to the top of the pump assembly. Discharge and sample collection tubings are attached to a manifold and are isolated from each other by a check valve.

Private water wells (domestic or agricultural), and also municipal and industrial wells, most often can be sampled using installed pumping equipment. Often these wells are routinely used for their intended purpose so the purging duration may be adjusted accordingly. Samples collected from existing supply wells should be collected near the wellhead (i.e., prior to any type of water storage tank).

Monitoring wells are purged of at least three well casing volumes and until indicator parameters have stabilized prior to sample retrieval. Stabilization is defined as three consecutive readings at 5-minute intervals where parameters do not vary by more than 5 percent. Purged groundwater is disposed of by spreading it on the ground at a reasonable distance from the sampled well to avoid the potential for purge water to enter the well casing again during the purging process.

The following indicator parameters (or field parameters) are typically monitored during the well purging:

- temperature (°C)
- pH (standard pH-units)
- electrical conductivity (µS/cm)
- dissolved oxygen (percent saturation)
- oxygen reduction potential (mV)
- turbidity (NTU)

Visual (color, occurrence of solids), olfactory (odor) and other observations (e.g., wellhead conditions, well access, ground conditions, and weather) are noted as appropriate.

After completion of purging activities, groundwater quality samples are often filtered in the field to remove turbidity and collected in laboratory-supplied bottles with or without preservative (depending on analyses to be conducted) with or without headspace. Filtering may also be conducted by the laboratory, in which case preservatives are added at the laboratory. Bottles are labeled with laboratory-supplied labels, immediately placed on ice, and kept in a dark ice chest (at 4 °C) until delivered to the laboratory. Samples are delivered to a laboratory certified through the State of California (Department of Public Health Environmental Laboratory Accreditation Program) with the proper chain-of-custody documentation within the required holding time. A chain-of-custody form is used to record sample identification numbers, type of samples (matrix), date and time of sample collection, and analytical tests requested. In addition, times, dates, and individuals who had possession of the samples are documented to record sample custody.

A field sheet is used to document equipment calibration, water level measurements, well purging activities, and the measurement of indicator parameters; an example is provided in **Appendix D**.

Quality Assurance Procedures

Quality assurance (QA) is an overall management plan used to guarantee the integrity of data collected by the monitoring program. This includes the discussed guidelines for groundwater level measurements, purging protocol, and sample handling and recordation. Quality control (QC) is a component of QA that includes analytical measurements used to evaluate the quality of the data. A brief discussion of field QC is followed by a discussion of laboratory QC requirements.

Field Quality Control

"Blind" duplicate field samples are collected to monitor the precision of the field sampling process and to assess laboratory performance. Blind duplicates are collected from at least 5 percent (1 in 20) of the total number of sample locations. The true identity of the duplicate sample is not noted on the chain-of-custody form, rather a unique identifier is provided. The identities of the blind duplicate samples are recorded in the field sheet, but the sampling locations of the blind field duplicates will not be revealed to the laboratory. "Field blanks" may also be employed to assure that the field procedures are not introducing any bias or contamination to the samples. The sample water for these is usually provided by the laboratory.

Lab Quality Control

Quality assurance and quality control samples (e.g., spiked samples, blank samples, duplicates) are employed by the laboratory to document the laboratory performance. Results of this testing are provided with each laboratory report.

Review of Laboratory Data Reports

Data validation includes a data completeness check of each laboratory analytical report. Specifically, this review includes:

- Review of data package completeness (ensuring that required QC and analytical results are provided);
- Review of the required reporting summary forms to determine if the QC requirements were met and to determine the effect of exceeded QC requirements on the precision, accuracy, and sensitivity of the data;
- Review of the overall data package to determine if contractual requirements were met; and
- Review of additional QA/QC parameters to determine technical usability of the data.

In addition, the data validation includes a comprehensive review of the following QA/QC parameters:

- Holding times (to assess potential for degradation that will affect accuracy);
- Blanks (to assess potential laboratory contamination);
- Matrix spikes/matrix spike duplicates and laboratory control samples (to assess accuracy of the methods and precision of the method relative to the specific sample matrix);
- Internal standards (to assess method accuracy and sensitivity);
- Compound reporting limits and method detection limits; and
- Field duplicate relative percent differences.

Parameters of Interest

The recommended water quality monitoring parameters are described below.

Baseline

During the initial groundwater sampling campaign (i.e., when "new" wells are added to the groundwater quality monitoring network), samples will be laboratory analyzed for general minerals and drinking water metals.

- General Minerals: Specific conductance (or electrical conductivity, EC), total dissolved solids, pH, sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), chloride (Cl), sulfate (SO_4), nitrate (NO_3), fluoride (F), alkalinity series (total, carbonate (CO_3), bicarbonate (HCO_3), hydroxide (OH)), and hardness;
- Drinking Water Metals: silver (Ag), aluminum (Al), arsenic (As) (total and dissolved), boron (B), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr) (total and dissolved), Hexavalent Cr, copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), thallium (Tl), vanadium (V), and zinc (Zn).

Affirm Baseline

During the second year of a monitoring well's inclusion in the groundwater quality monitoring network, samples will again be collected and analyzed for general minerals and drinking water metals to affirm the findings of the baseline sampling event.

Annual

It is recommended that samples be collected annually for analysis of field parameters and laboratory analyses for at least TDS, nitrate, and chloride. Additional analyses may be appropriate in selected subareas. The groundwater quality sampling locations/AOIs listed in **Table 4-2** are also locations where groundwater levels would be measured at least semi-annually. Therefore, it is recommended that groundwater quality sampling be coordinated with the spring water level measurements.

Triennial and/or Every Five Years

It is recommended that samples be collected triennially from the wells in the groundwater quality monitoring network for the six sites recommended for groundwater/surface water evaluation. A 5-year frequency is recommended for the other 18 AOIs, including the main NVF, Carneros, Jameson/American Canyon, and Napa River Marshes Subareas and also where wells are volunteered for inclusion in other subareas, and analyzed for general minerals and drinking water metals.

Special Studies or Areas of Interest

Some county subareas may have naturally occurring compounds or human-influenced compounds that are of special interest. Special studies may be appropriate to determine the presence, concentration, persistence and potential effects of such compounds, particularly when site-specific factors may potentially affect groundwater quality (e.g., mining areas, wastewater disposal, recycled water use, etc.).

5 Groundwater Data Management

This section describes how groundwater data obtained by the County will be managed, used, and shared. Specifically, this section discusses the types of data to be collected, the County's Data Management System (DMS), and which data may be shared with the State (e.g., DWR or other entities) and/or reported to the public.

5.1 Data Management Overview

An overview of the County's data management approach is provided in **Figure 5-1.** Data will be collected from a variety of sources and programs. The groundwater monitoring program includes public and volunteered wells[2] and also permit-required monitoring. Therefore, it is important that guidelines are established to ensure that data are managed according to the well owner's permission and/or as it relates to applicable permit conditions.

5.2 Data Management System (DMS)

The Napa County DMS has been constructed to incorporate existing and new data about groundwater resources in Napa County (LSCE, 2010a). The data incorporated in the DMS will be used on an ongoing basis by the County to evaluate countywide groundwater supply and quality conditions and functions as a secure central data storage location.

In order to ensure security and user flexibility, the database was designed using Microsoft Access 2000 and the .mdb database format. Access has the capacity to store historical and future data, up to a total of 2 GB of data, and the DMS can be transitioned to an enterprise database software system as necessary.

5.3 Data Use and Disclosure

In this section, the County's use and disclosure of collected data are described. A tiered participation approach in the volunteer groundwater monitoring program will be followed which allows property owners to choose their level of participation, including what data can be shared versus what data are to be kept confidential as required by State law (Water Code §13751, §13752). Well owners that volunteer their well for inclusion in the County's program would receive the groundwater information collected from their well. This may be provided on an annual basis and/or in periodic reports produced by the County.

5.3.1 Protected Data

The DMS contains certain protected information that will not be made publicly available. For example, drillers' reports and the specific well construction information contained therein are confidential. This data will be held as confidential unless permission is received from the well owner.

[2] As described in Section 4, the County has identified areas of interest where additional groundwater level and/or quality monitoring will help address data gaps. The County will be seeking well owners interested in volunteering their wells for inclusion in this program. All groundwater level and/or quality monitoring will be done by the County or representatives on behalf of the County (i.e., the monitoring is at no cost to participants and participants will receive information about groundwater beneath their property.

5.3.2 Data Sharing and Disclosure

The County is planning to implement an education and outreach program that includes communication to the public about opportunities to volunteer to have their well monitored as part of the County's groundwater monitoring program. The County is providing a tiered participation program as described below.

Napa County Program

Property owners interested in participating in the County program but who wish to keep their information confidential may elect to not have their well data (e.g., groundwater levels) reported to DWR's Water Data Library or as part of the CASGEM program. This means the County would only use the collected groundwater data (levels and/or quality) for public education and information but would display the data in publically distributed reports which ensure the owner's privacy.

Water Data Library

DWR maintains groundwater information in a database called the Water Data Library (WDL). Napa County reports groundwater level elevation data to DWR for inclusion in the WDL. Although well location information is included in the WDL, well construction information is not reported. This level of participation will be offered to property owner's volunteering their well for the County groundwater monitoring program. This will authorize the County to release water level information, but State mandated protected information will continue to be held as confidential.

CASGEM Program

Property owners interested in participating in the County's groundwater monitoring program and who are willing to provide the information required by the CASGEM program could also become participants in that program . Particularly, owners would recognize that if the County elects to include their well in the CASGEM program, the construction information for their well would be available online on DWR's site.

5.3.3 Reporting of Data

The County has historically routinely reported groundwater level data to DWR for inclusion in the WDL. Beginning in 2012, the County is also now reporting a subset of the groundwater level data collected by the County to DWR as part of the CASGEM program.

Any maps prepared from data in the DMS should represent well locations with large symbols. Names and addresses of well owners would be kept confidential. Additional information related to reporting is contained in **Section 6**.

5.3.4 Data from Other Sources

In addition to the groundwater level and quality data directly collected by the County, other groundwater data are available for the County to download and include in the evaluation of countywide groundwater conditions. Several different public agencies collect and maintain groundwater data, including DWR, the USGS, the California Department of Public Health (DPH; GeoTracker-GAMA), and the State Water Resources Control Board (SWRCB; GeoTracker) (LSCE, 2010a). These sources can be accessed through the SWRCB website that summarizes the current data and databases available on the web at www.waterboards.ca.gov/resources/data_databases/. These programs and publicly available databases are continually evolving to expand and merge to create a more useful and powerful network of information. During the development of the County DMS, these data sources were combined with Napa County's own records in order to populate the Napa County DMS (LSCE, 2010a).

For gathering data that is collected by external agencies, a timeframe of about 2 to 3 years is a reasonable span between obtaining updates. This can be a sizeable effort to integrate multiple datasets, and planning should be done to avoid inconsistencies, gaps or duplications of data over a historical record.

6. REPORTING

To facilitate community understanding of Napa County groundwater and surface water systems, the reports prescribed in this section will be published in a manner that gives full and easy access to the public.

6.1 Annual Groundwater Monitoring Progress and Data Report

It is recommended that an Annual Groundwater Monitoring Progress and Data Report be prepared that includes a review of the groundwater monitoring program and network. Based on the data gathered from the current monitoring year, review of the historical record, water level and quality trend analyses, and consideration of issues of interest to the County and collaborating entities, the program may be adjusted as needed to accomplish the countywide groundwater resources goals and monitoring objectives. The Annual Progress Report will consider the stated goals and objectives of the groundwater monitoring program and include recommended modifications to the program and network, as needed.

It is recommended that the Progress Report also include a summary of the groundwater level and quality data collected by Napa County staff, including attachments containing tables that summarize the data and figures showing the measurement locations (this dataset and any accompanying discussion are not intended to be as comprehensive as the dataset and evaluation of groundwater level and quality conditions described below for Triennial Countywide Reporting).

6.2 Annual CASGEM Reporting

It is recommended that the County prepare an annual report summarizing the results and findings of the countywide CASGEM program. Each annual report will describe any changes to the current monitoring network and program, including recommended additions to the CASGEM program network.

6.3 Triennial Countywide Reporting on Groundwater Conditions

It is also recommended that the County prepare on a regular basis, approximately triennially, a report on countywide groundwater level and quality conditions and any other monitoring network modifications per the recommendations in this Plan which are for the purpose of meeting the County’s groundwater level and quality monitoring objectives.

It is recommended that the Triennial Groundwater Conditions Report be prepared that includes the following:

- A summary of the groundwater level and quality data collected in Napa County by Napa County staff and other entities, including attachments containing tables that summarize the data and provide a reference to applicable water quality standards; figures showing the measurement locations;
- Figures illustrating groundwater level trends at locations throughout the County, especially in high priority subareas;

- Figures showing contours of equal groundwater elevation for the 1) Napa Valley Floor subareas (including Calistoga, St. Helena, Yountville, and Napa Subareas); 2) MST Subarea; and 3) other subareas as the groundwater level monitoring program evolves;
- Figures illustrating groundwater quality trends at locations throughout the County, especially in high priority subareas (time series plots would include TDS, nitrate and chloride and other selected constituents, depending on specific interests in individual subareas;
- A summary of coordinated efforts with other local, state and federal agencies pertaining to County and Regional groundwater conditions and reporting. Examples include summaries pertaining to interagency collaboration on Integrated Regional Water Management Planning and Implementation, Urban Water Management Plan updates, and Basin Plan updates.

As for the Annual Progress Report, it is recommended that the groundwater monitoring program and network be regularly reviewed and modifications to the groundwater monitoring network and program also included in the Triennial Report.

Interagency coordination is important for the ongoing program. Specifically, the local participants will benefit from efforts made toward systematic data collection and analyses and maintaining the DMS in a standardized format. The Triennial Report will include recommendations relevant to interagency data coordination, as needed.

7. REFERENCES

California Department of Water Resources. 1962. Reconnaissance Report on the Upper Putah Creek Basin Investigation, Bulletin No. 99.

Center for Collaborative Policy at California State University Sacramento. 2010. Assessment of the feasibility of a collaborative groundwater data gathering effort in Napa County, California.

DHI. 2006a. Final baseline data report (BDR) technical appendix – water quantity and water quality report, Napa County, California. October 2006.

DHI. 2006b. MIKE SHE an integrated hydrological modeling system – documentation and users guide. November 2006.

DHI. 2007. Modeling analysis in support of vineyard development scenarios evaluation, Napa County, California. February 2007.

Farrar, C.D. and L. F. Metzger. 2003. Ground-water resources in the Lower Milliken-Sarco-Tulucay Creeks area, southeastern Napa County, California, 2000-2002. USGS. Water-Resources Investigations Report 03-4229.

Faye, R.E. 1973. Ground-water hydrology of northern Napa Valley California. Water Resources Investigations 13-73, US Geological Survey, Menlo Park, CA, 64 p.

Fox, K.F., Jr., J.D. Sims, J.A. Bartow, and E.J. Helley. 1973. Preliminary geologic map of eastern Sonoma County and western Napa County, California: U.S. Geological Survey Misc. Field Studies Map MF-483, 5 sheets, scale 1:62,500.

Fox, K. 1983. Tectonic setting of Late Miocene, Pliocene, and Pleistocene rocks in part of the Coast Ranges north of San Francisco, California, U.S. Geological Survey Professional Paper 1239. 33 pp.

Graymer, R.W., D.L. Jones, and E.E. Brabb. 2002, Geologic map and map database of northeastern San Francisco Bay region, California; most of Solano County and parts of Napa, Marin, Contra Costa, San Joaquin, Sacramento, Yolo, and Sonoma Counties: U.S Geological Survey Miscellaneous Field Studies Map MF-2403, 1 sheet, 1:100,000 scale, 28 p.

Graymer, R.W., B.C. Moring, G.J. Saucedo, C.M. Wentworth, E.E. Brabb, and K.L. Knudsen. 2006. Geologic Map of the San Francisco Bay Region. U.S. Geological Survey, Scientific Interpretations Map 2918, scale 1:275,000.

Graymer, R.W., E.E. Brabb, D.L. Jones, J. Barnes, R.S. Nicholson, and R.E. Stamski. Geologic map and map database of eastern Sonoma and western Napa Counties, California: U.S. Geological Survey Scientific Investigations Map 2956 [http://pubs.usgs.gov/sim/2007/2956/].

Helley, E.J., K.R. Lajoie, W.E. Spangle, and M.L. Blair. 1979. Flatland deposits of the San Francisco Bay region, California; their geology and engineering properties, and their importance to comprehensive planning. U.S. Geological Survey Professional Paper 943. Scale 1:125,000.

Johnson, M.J. 1977. Ground-water hydrology of the Lower Milliken-Sarco-Tulucay Creeks Area, Napa County, California. USGS Water-Resources Investigations 77-82.

Jones and Stokes & EDAW. 2005. Napa County baseline data report. November, 2005.

Koenig, J.B. 1963. Geologic map of California, Olaf P. Jenkins edition, Santa Rosa Sheet. California Division of Mines and Geology. Scale 1:250,000.

Kunkel, F. and J.E. Upson. 1960. Geology and groundwater in Napa and Sonoma Valleys Napa and Sonoma Counties California. U.S. Geological Survey Water Supply Paper 1495.

Luhdorff and Scalmanini, Consulting Engineers (LSCE). 2010a. Task 1, Napa County data management system. Technical Memorandum prepared for Napa County.

LSCE. 2010b. Task 2, Review and evaluation of data collection procedures and recommendations for improvement. Technical Memorandum prepared for Napa County.

LSCE. 2011a. Napa County groundwater conditions and groundwater monitoring recommendations. Task 4, Report.

LSCE. 2011b. Napa County, California statewide groundwater elevation monitoring (CASGEM) network plan. September 2011.

LSCE. 2011c. Groundwater planning considerations and review of Napa County groundwater ordinance and permit process. Technical Memorandum prepared for Napa County.

LSCE and MBK Engineers. 2013. Updated hydrogeologic conceptualization and characterization of conditions in Napa County.

Napa County. 2008. Napa County general plan. (Amended June 23, 2009.)

Napa County Department of Public Works. 2012. Napa County groundwater/surface water monitoring facilities to track resource interrelationships and sustainability. Local Groundwater Assistance Grant Proposal to California Department of Water Resources.

Napa County Web Site. 2011. http://www.countyofnapa.org/bos/grac /

Sims, J.D., K.F. Fox, Jr., J.A. Bartow, and E.J. Helley. 1973. Preliminary geologic map of Solano County and parts of Napa, Contra Costa, Marin, and Yolo Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-484, 5 sheets, scale 1:62,500.

Wagner, D.L., and E.J. Bortugno. 1982. Geologic map of the Santa Rosa quadrangle: California Division of Mines and Geology Regional Geologic Map Series, Map 2A, scale 1:250,000.

Weaver, C.E., 1949. Geology of the Coast Ranges immediately north of the San Francisco Bay region, California. California Department of Natural Resoures, Division of Mines. Bulletin 149

FIGURES

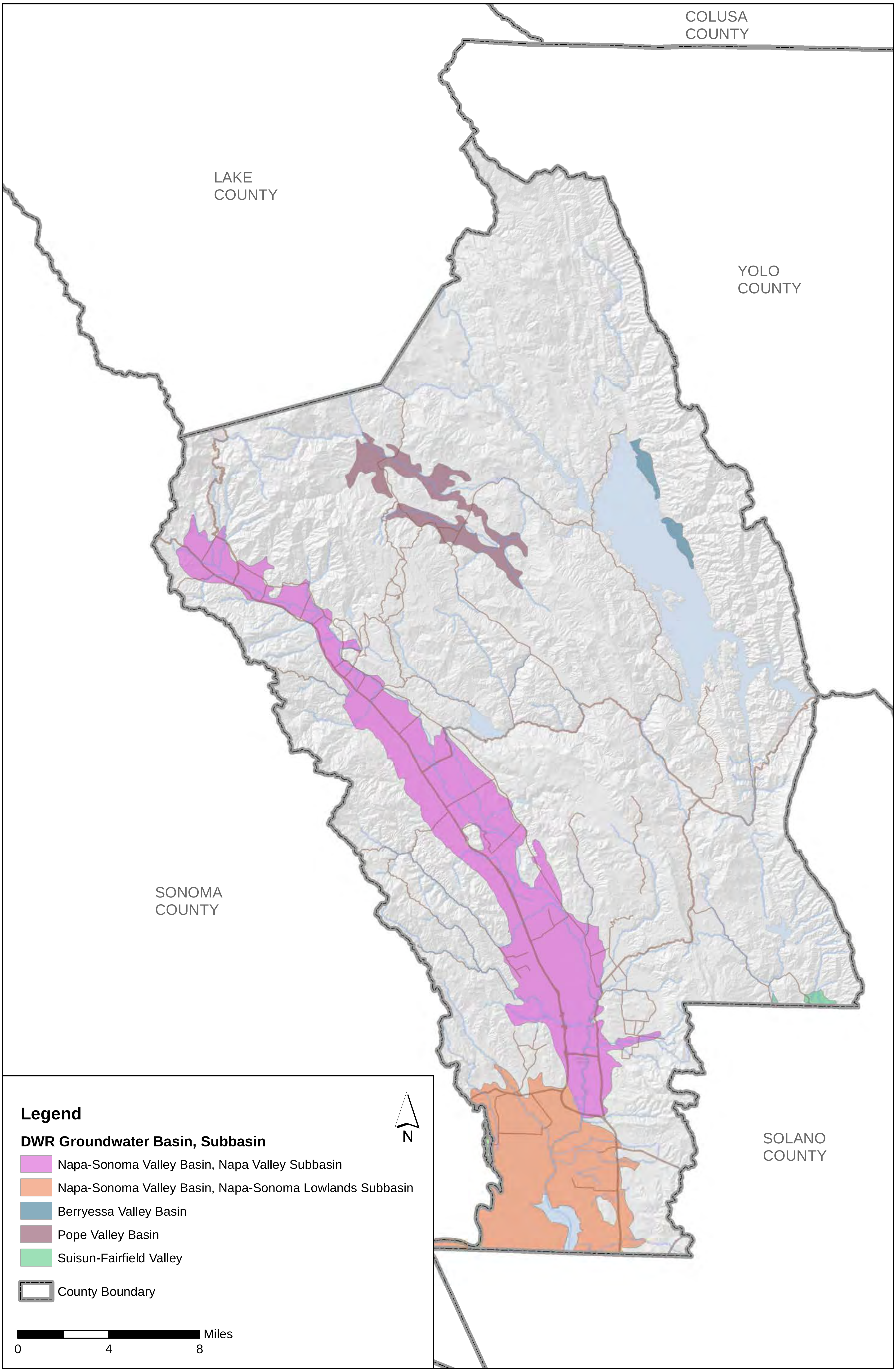

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Figure 2-1
Napa County Groundwater Basins
Napa County, CA

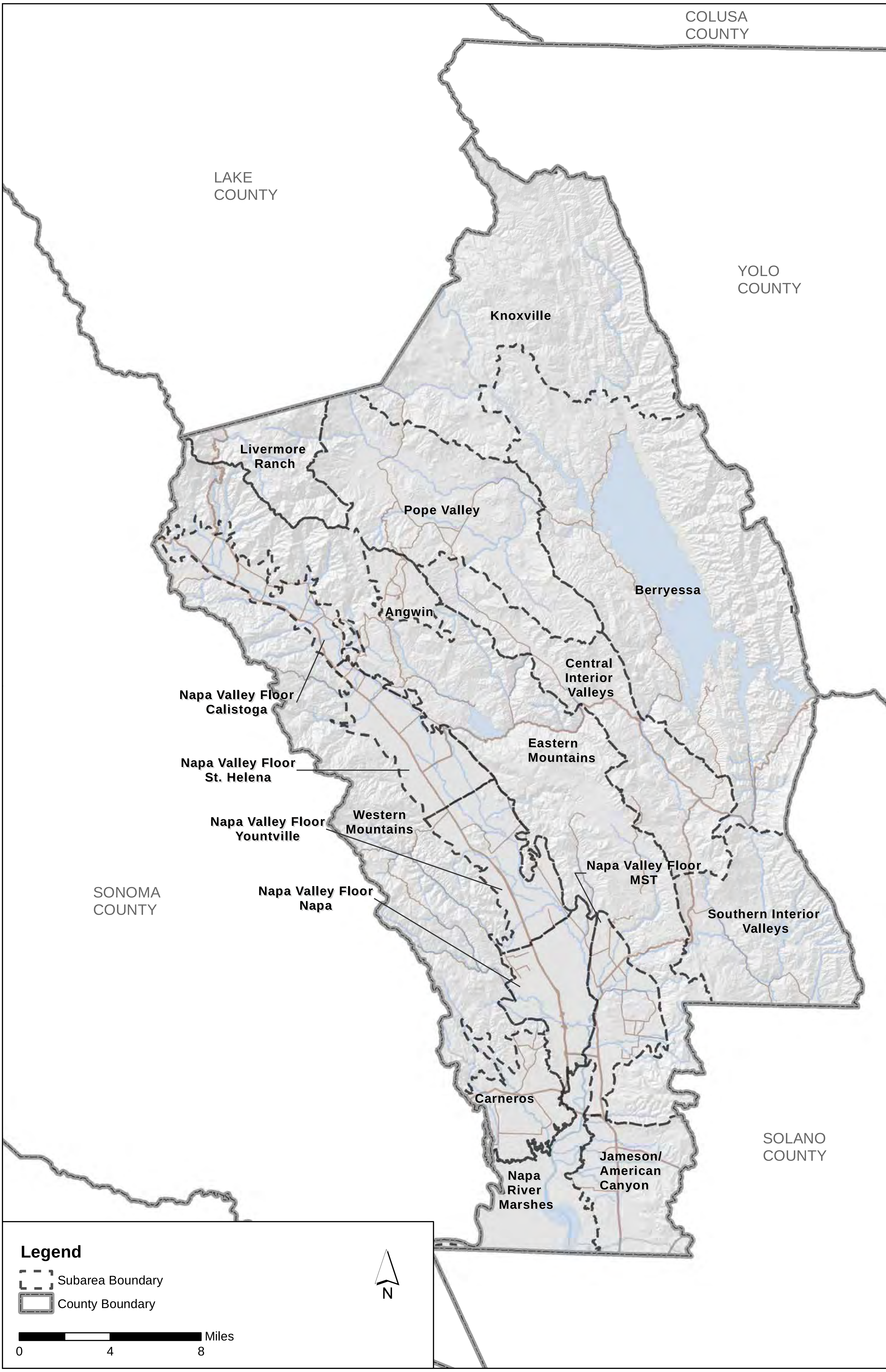

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Figure 2-2
Napa County Subareas
Napa County, CA

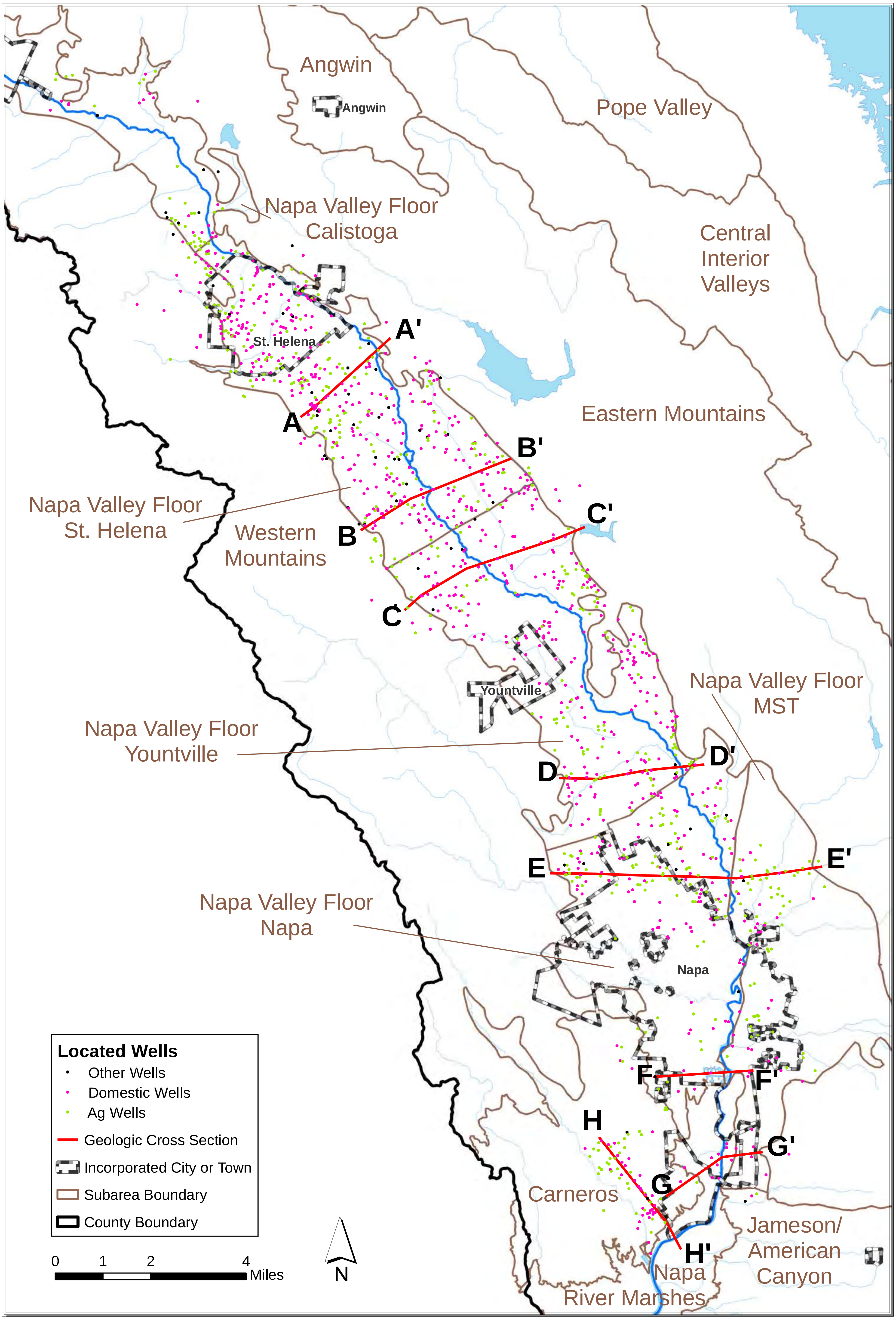

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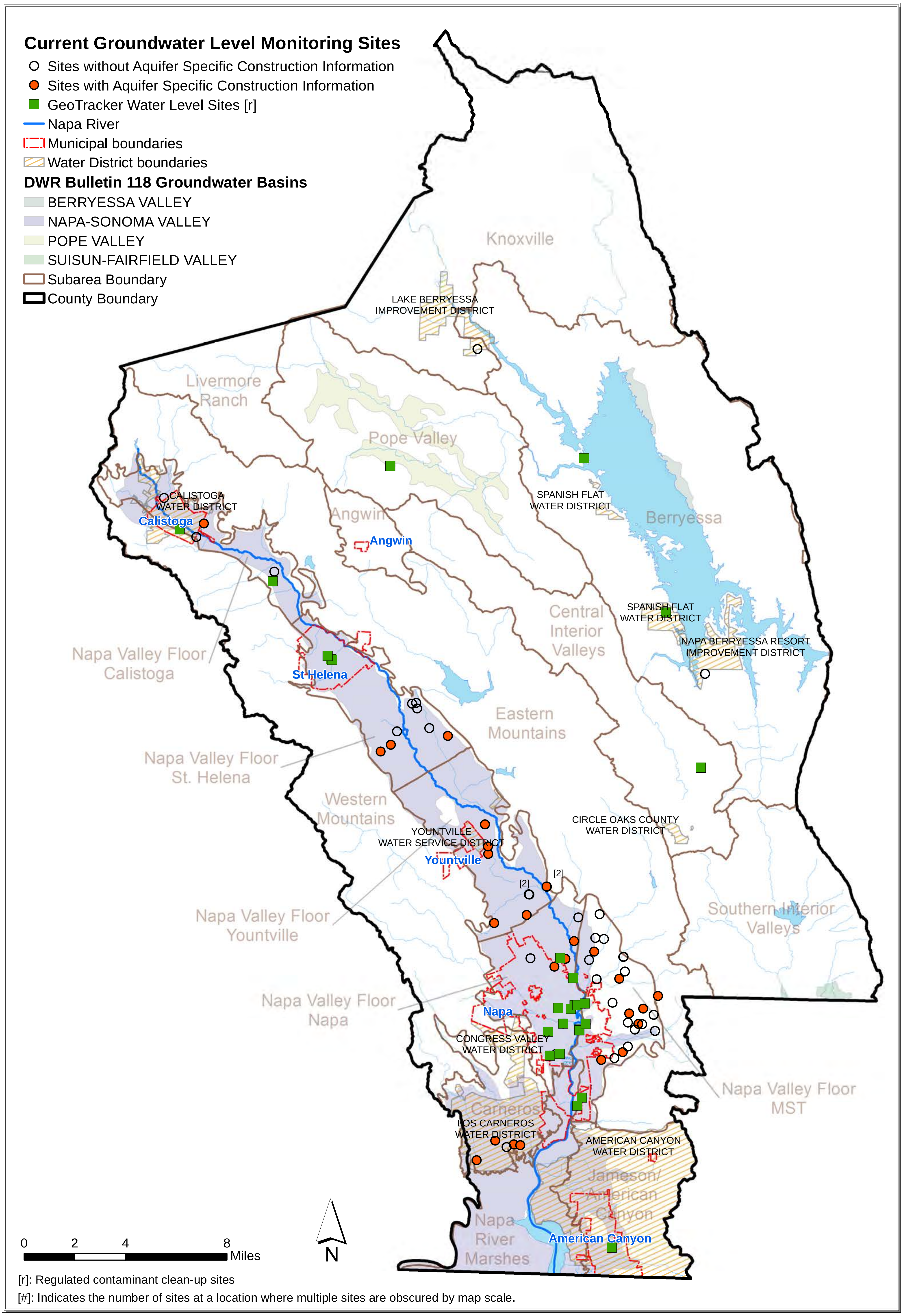
Figure 2-3
Geologic Cross Section Location Map



[r]: Regulated contaminant clean-up sites

[#]: Indicates the number of sites at a location where multiple sites are obscured by map scale.

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Figure 2-4
Current Groundwater Level Monitoring Sites in Napa County

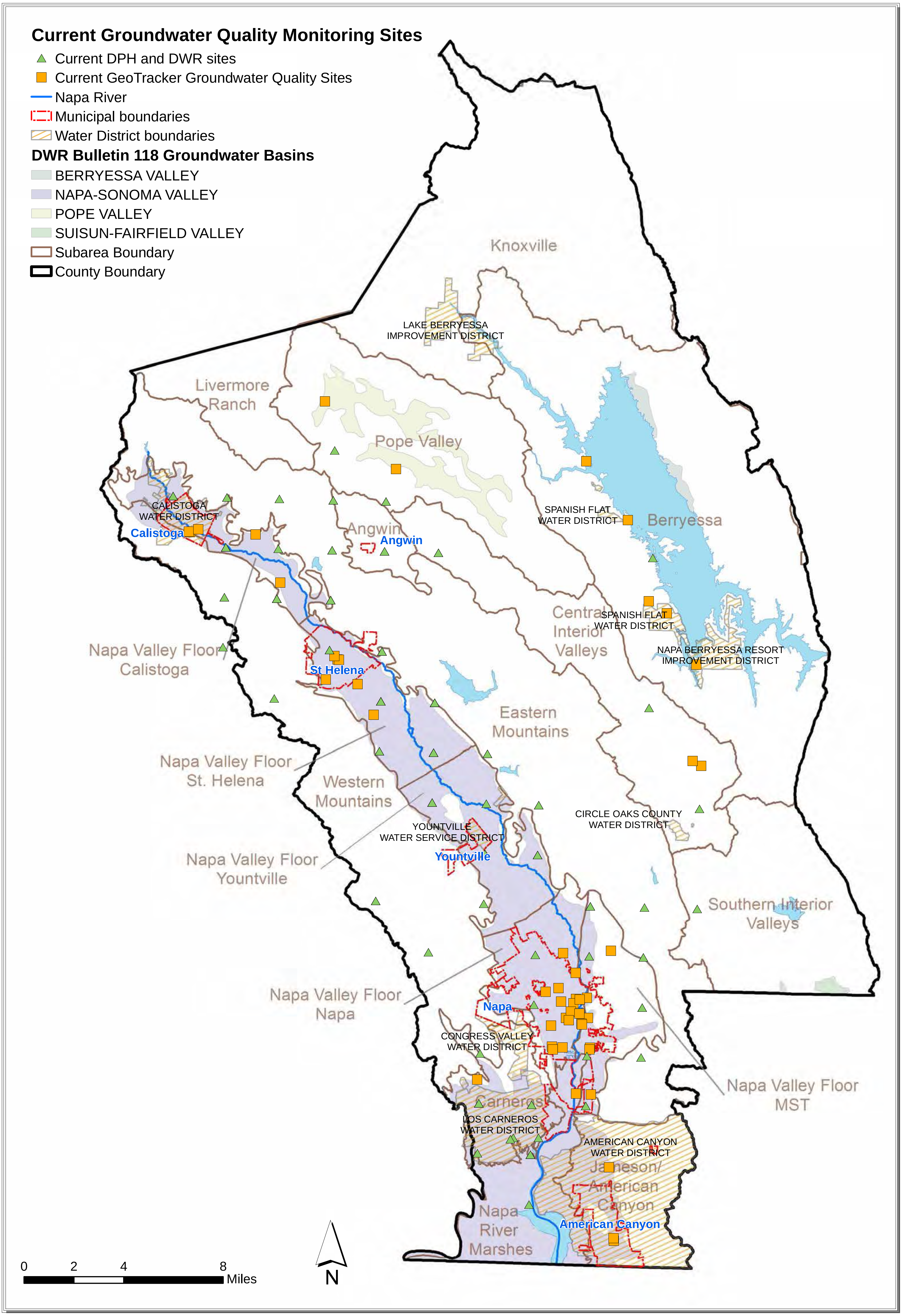

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Figure 2-5
Current Groundwater Quality Monitoring Sites in Napa County

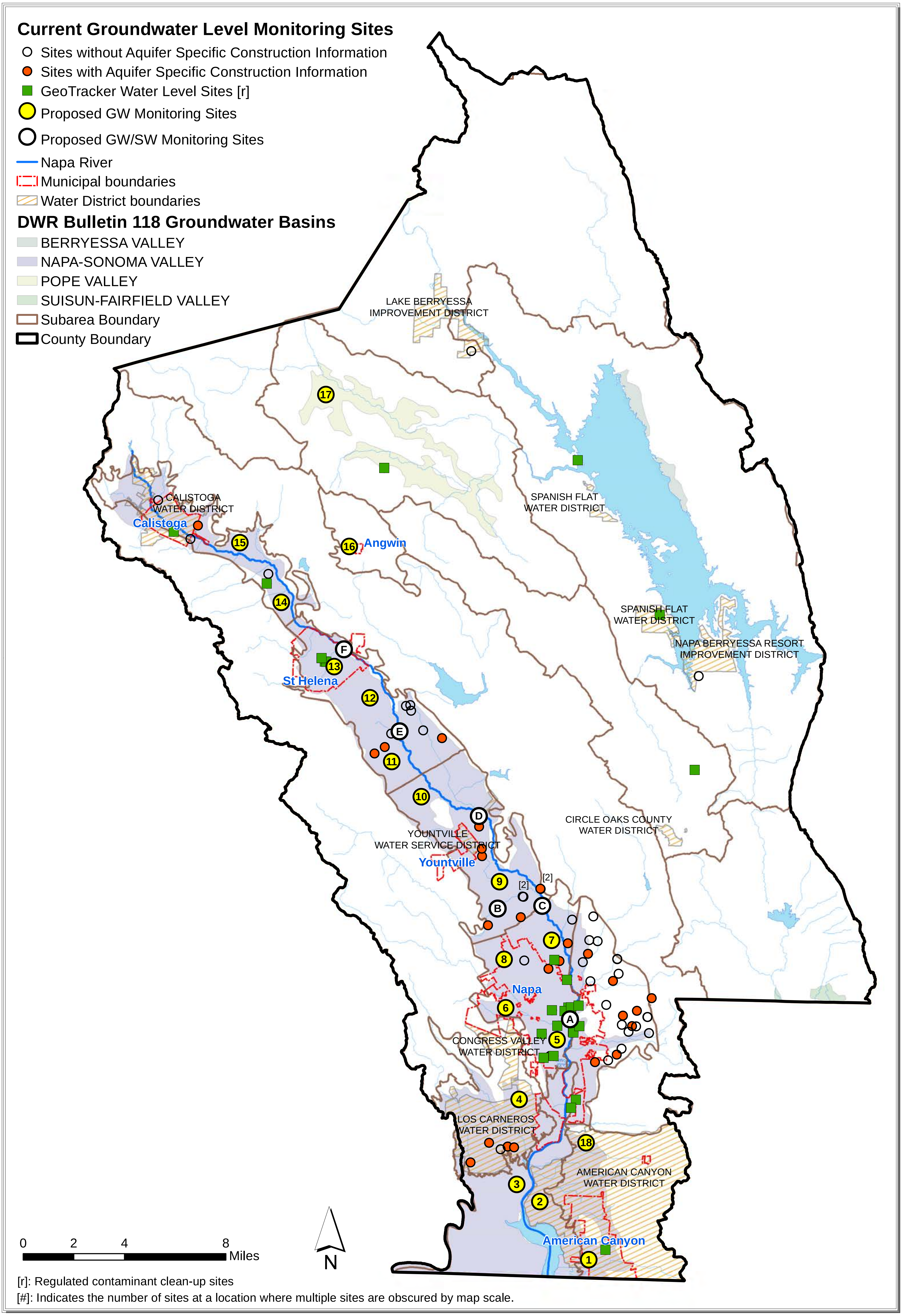

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Figure 4-1
Current and Proposed Groundwater Level Monitoring Sites in Napa County

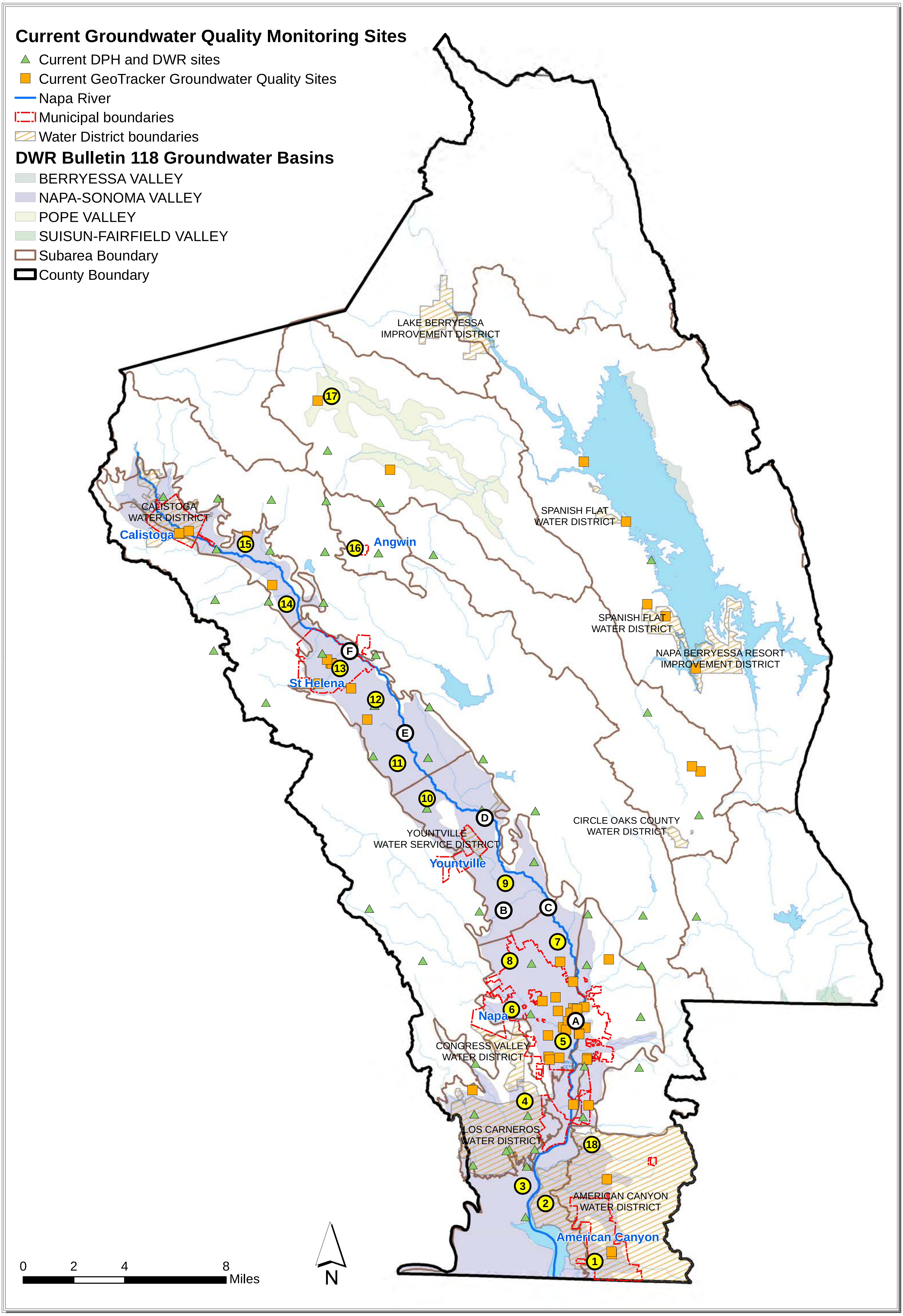

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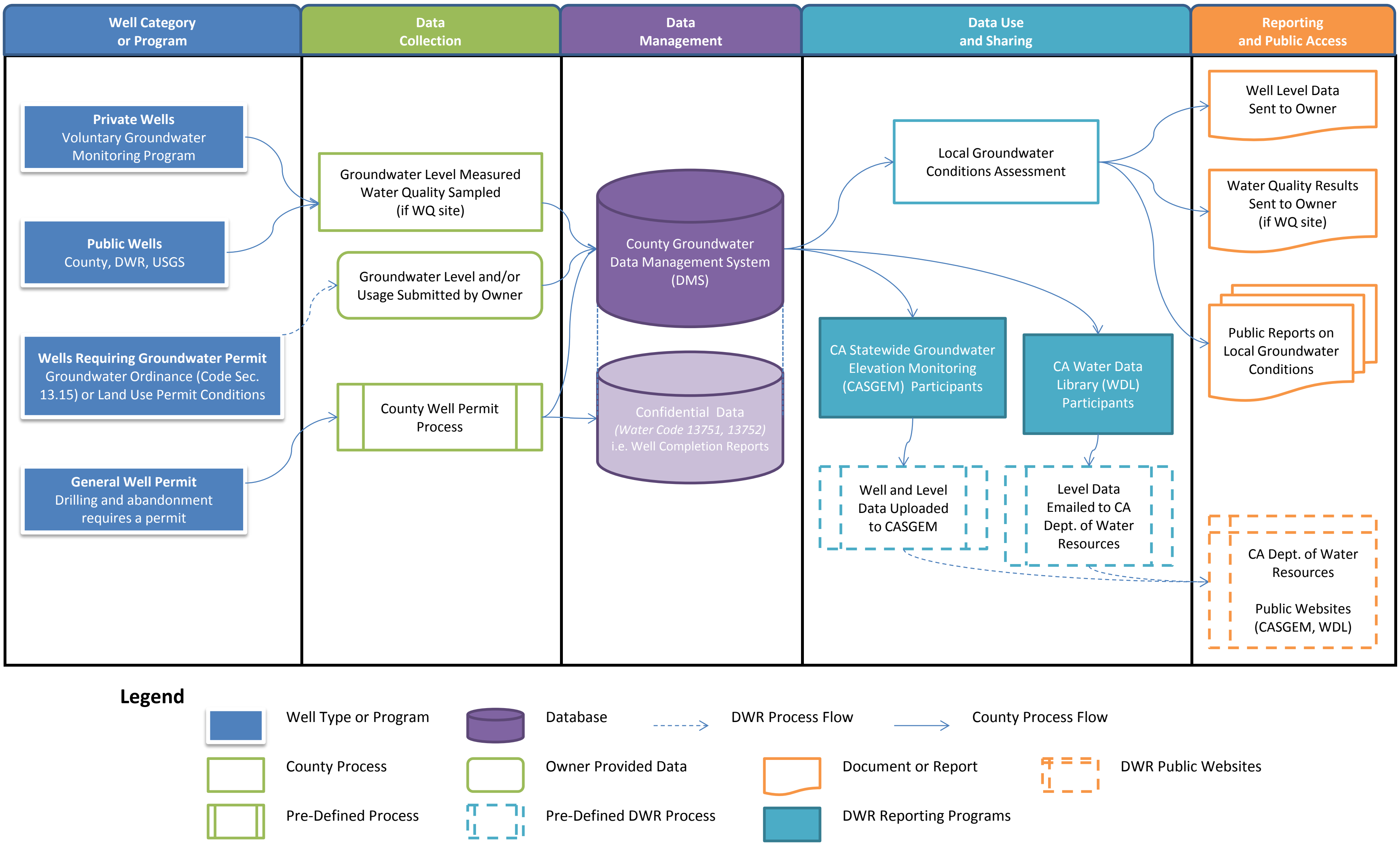
Figure 4-2
Current and Proposed Groundwater Quality Monitoring Sites in Napa County

Figure 5-1 Groundwater Data Collection, Management, Use, and Reporting



APPENDIX A

Summaries of 2011 and 2013 Groundwater Report Findings and Future Groundwater Level and Quality Monitoring Objectives

Summaries of 2011 Groundwater Report Findings and Objectives
Groundwater Level Monitoring Sites, Napa County

Subarea	No. Sites with Current GW Level Data[1]	Future Groundwater Level Monitoring[1]		Monitoring Needs	Findings on GW Level Conditions (LSCE, 2011a)	General Comments re Monitoring Needs	Improve understanding of occurrence and movement	Factors affecting levels & trends	Fill Data Gaps	Develop/refine GW budget (include recharge)	Further evaluate sw/gw potential exchange	Potential for saltwater intrusion
		Relative Priority (2011 Prelim)	Action (Expand/ Refine)									
Napa Valley Floor-Calistoga	**6**	**H**	E	**SP, SW**	*Water levels are generally stable and depths to gw are shallow; 156 wells provide data, about 3/4 of the wells have limited records.*	**Need to optimize current monitoring locations to ensure that the existing monitoring locations are adequately distributed throughout the subarea in aquifers of interest.**	**X**	**X**	**X**	**X**	**X**	
Napa Valley Floor-MST	**29**	**H**	R	**SP, SW**	*Wells with records show long term declining water levels; some have a repeating pattern of declining then stabilizing and never recovering, while others have a recent steady continuous decline; 286 wells provide data, half with limited records and more than half measured recently.*	**Need to optimize current monitoring locations to ensure the northern, central, and southern areas of MST have representative distribution of MWs in aquifers of interest. Would provide essential data to assess how existing gw development regulations are effective in managing gw resources in this area.**	**X**	**X**	**X**	**X**	**X**	
Napa Valley Floor-Napa	**18**	**H**	R	**SP, SW**	*Water levels are generally stable except toward the east where declines of 20 feet have been observed close to the northern MST; 273 wells provide data, most with limited records.*	**Need to optimize current monitoring locations to ensure that the existing monitoring locations are adequately distributed throughout the subarea in aquifers of interest.**	**X**	**X**	**X**	**X**	**X**	

Summaries of 2011 Groundwater Report Findings and Objectives
Groundwater Level Monitoring Sites, Napa County

Subarea	No. Sites with Current GW Level Data[1]	Future Groundwater Level Monitoring[1]		Monitoring Needs	Findings on GW Level Conditions (LSCE, 2011a)	General Comments re Monitoring Needs	Improve understanding of occurrence and movement	Factors affecting levels & trends	Fill Data Gaps	Develop/refine GW budget (include recharge)	Further evaluate sw/gw potential exchange	Potential for saltwater intrusion
		Relative Priority (2011 Prelim)	Action (Expand/ Refine)									
Napa Valley Floor-St. Helena	**12**	**H**	E	**SP, SW**	*Water levels are generally stable and depths to water are shallow; 70 wells provide data, most wells have good records.*	**Need to optimize current monitoring locations to ensure that the existing monitoring locations are adequately distributed throughout the subarea in aquifers of interest.**	**X**	**X**	**X**	**X**	**X**	
Napa Valley Floor-Yountville	**9**	**H**	E	**SP, SW**	*Water levels are generally stable with seasonal fluctuations; fewer wells have data (31 wells) compared to the rest of the Valley Floor, and fewer wells have good records or recent data.*	**Need to optimize current monitoring locations to ensure that the existing monitoring locations are adequately distributed throughout the subarea in aquifers of interest.**	**X**	**X**	**X**	**X**	**X**	
Carneros	**5**	**H**	E	**B**	*No current groundwater level data, but a good record exists for 7 wells with data between 1962 and 1978.*	**Very limited historical data and no current data. Additional data collection is recommended to investigate groundwater conditions under existing development conditions and for any planned additional use of groundwater resources.**	**X**	**X**	**X**	**X**		**X**
Jameson/American Canyon	1	M	E	B	*Limited groundwater level data; all recent data are from regulated facility monitoring wells.*	**Very limited data for the most part, however, short term development of groundwater resources are not anticipated on a significant scale.**	X	X	X	X		X

Summaries of 2011 Groundwater Report Findings and Objectives
Groundwater Level Monitoring Sites, Napa County

Subarea	No. Sites with Current GW Level Data[1]	Future Groundwater Level Monitoring[1]		Monitoring Needs	Findings on GW Level Conditions (LSCE, 2011a)	General Comments re Monitoring Needs	Improve understanding of occurrence and movement	Factors affecting levels & trends	Fill Data Gaps	Develop/refine GW budget (include recharge)	Further evaluate sw/gw potential exchange	Potential for saltwater intrusion
		Relative Priority (2011 Prelim)	Action (Expand/ Refine)									
Napa River Marshes	1	M	E	SP, SW	*Limited groundwater level data; all data are from regulated facility monitoring wells; no historical data pre-2000.*	Very limited data for the most part, however, short term development of groundwater resources are not anticipated on a significant scale.	X	X	X	X		X
Angwin	0	M	E	B	*No current groundwater level data; 10 wells are from one regulated facility site with data over three years; no historical data pre-2002.*	No data; short term development of gw resources are not anticipated on a significant scale.	X	X	X	X		
Berryessa	3	M	E	B	*Limited record and spatial distribution; most wells with data are monitoring wells on three different regulated facilities; no historic data pre-2002.*	Very limited data for the most part, however, short term development of groundwater resources are not anticipated on a significant scale.	X	X	X			
Central Interior Valleys	1	M	E	B	*Limited data; all data from three regulated facilities' monitoring wells; no historical data pre-2002.*	Very limited data for the most part, however, short term development of groundwater resources are not anticipated on a significant scale.	X	X	X			
Eastern Mountains	0	M	E	B	*Limited data and spatial distribution; one well near the MST shows recent declines similar to those found in the MST.*	No data; short term development of gw resources are not anticipated on a significant scale.	X	X	X			

Summaries of 2011 Groundwater Report Findings and Objectives
Groundwater Level Monitoring Sites, Napa County

Subarea	No. Sites with Current GW Level Data[1]	Future Groundwater Level Monitoring[1]		Monitoring Needs	Findings on GW Level Conditions (LSCE, 2011a)	General Comments re Monitoring Needs	Improve understanding of occurrence and movement	Factors affecting levels & trends	Fill Data Gaps	Develop/refine GW budget (include recharge)	Further evaluate sw/gw potential exchange	Potential for saltwater intrusion
		Relative Priority (2011 Prelim)	Action (Expand/ Refine)									
Knoxville	1	M	E	B	*Limited record and spatial distribution; no historic groundwater level data and a very short period of record.*	Very limited data for the most part, however, short term development of groundwater resources are not anticipated on a significant scale.	X	X	X			
Livermore Ranch	0	L	E	B	*No data.*	No data; short term development of gw resources are not anticipated on a significant scale.	X	X	X			
Pope Valley	1	H	E	B	*Limited groundwater level data; all data are from two regulated facilities' monitoring wells; no historical data pre-2002.*	Very limited existing data. Additional data collection is recommended to investigate groundwater conditions for planned use of groundwater resources.	X	X	X			
Southern Interior Valleys	0	L	E	B	*No data.*	No data; short term development of gw resources are not anticipated on a significant scale.	X	X	X			
Western Mountains	0	L	E	B	*No data.*	No data; short term development of gw resources are not anticipated on a significant scale.	X	X	X			
Total	**87**											

Groundwater Level Notes

[1] "Current" refers to monitored sites with wells measured for levels and/or any water quality parameter with a period of record extending to 2011 or later. "Current" groundwater level monitoring sites were identified as part of the *Updated hydrogeologic conceptualization and characterization of conditions in Napa County* (LSCE and MBK Engineers, 2013). "Future" refers to recommended monitoring locations.

L = Low Priority; add groundwater level monitoring based on areas of planned future groundwater development

M = Medium Priority; add groundwater level monitoring

H = High Priority; add groundwater level monitoring

E = Expand current monitoring network; possible alternatives for additional monitoring wells include 1) wells historically monitored by DWR/USGS/Others, preferably with well construction information; 2) existing water supply wells (e.g., private/commercial) with well construction information; 3) new dedicated monitoring wells coordinated with recent geologic investigations that are or will be conducted)

R = Refine current monitoring network (link well construction information to all monitored wells, as possible)

Monitoring Needs:
SP = Improve horizontal and/or vertical spatial distribution of data;
SW =identify appropriate monitoring site to evaluate surface water -groundwater recharge/discharge mechanisms;
B = Basic data needed to accomplish groundwater level monitoring objectives

Summaries of 2011 Groundwater Report Findings and Objectives for Groundwater Quality Monitoring Sites, Napa County

Subarea	No. Sites with Current GW Quality Data[1]	Future Groundwater Quality Monitoring[1]		Monitoring Needs	Findings GW Quality Conditions (LSCE, 2011a)	Constits. of Concern	Baseline conditions &spatial differences	Fill Data Gaps	Occurrence & factors related to natural or other constituents	Baseline conditions in areas of potential saltwater intrusion	Assess changes, trends, factors contrib. to change	Other
		Relative Priority (2011 Preilm)	Action (Expand/ Refine)									
Napa Valley Floor-Calistoga	20	M	R	SP,C	*Limited data record, minimal historical record*	*As, B*	X	X	X		X	
Napa Valley Floor-MST	**16**	**H**	R	**SP,C**	*Very limited long-term records*	*As, B, Fe, Mn, Na*	**X**	**X**	**X**		**X**	
Napa Valley Floor-Napa	21	M	R	SP,C	*Generally good water quality; most wells have limited data records and very little historical data*	*Na, As, NO3*	X	X	X		X	
Napa Valley Floor-St. Helena	31	M	R	SP,C	*Generally good water quality; most wells have limited data records and very little historical data*	*As, NO3*	X	X	X		X	
Napa Valley Floor-Yountville	14	M	R	SP,C	*Generally good water quality; most wells have limited data records and very little historical data*	*As, NO3*	X	X	X		X	
Carneros	**9**	**H**	R	**SP,C**	*Limited data record; minimal historic and recent records; poor water quality common; possible increasing recent trend seen in EC, chloride, and TDS*	*Cl, EC, TDS*	**X**	**X**	**X**	**X**	**X**	
Jameson/American Canyon	**3**	**H**	E	**B,SP,C**	*No recent data post-1998; generally poor water quality from a very limited data set; increasing chloride and EC levels*	*Cl, EC, Na, NO3, TDS*	**X**	**X**	**X**	**X**	**X**	

Summaries of 2011 Groundwater Report Findings and Objectives for Groundwater Quality Monitoring Sites, Napa County

Subarea	No. Sites with Current GW Quality Data[1]	Future Groundwater Quality Monitoring[1]		Monitoring Needs	Findings GW Quality Conditions (LSCE, 2011a)	Constits. of Concern	Baseline conditions &spatial differences	Fill Data Gaps	Occurrence & factors related to natural or other constituents	Baseline conditions in areas of potential saltwater intrusion	Assess changes, trends, factors contrib. to change	Other
		Relative Priority (2011 Preilm)	Action (Expand/ Refine)									
Napa River Marshes	6	M	E	B,SP,C	*Very limited long-term records; one well with historic data; generally poor water quality*	*Cl, EC, Na, NO3, TDS*	X	X	X	X	X	
Angwin	4	M	E	B,C	*No historic records; all measurements from two sites (ten wells total); generally good water quality*	*Fe, Mn*	X	X	X		X	
Berryessa	6	M	E	B,C	*Poor coverage for majority of constituents; no long-term records*	*EC, TDS*	X	X	X		X	
Central Interior Valleys	6	M	R	B,SP,C	*No historic records pre-2001; poor coverage for majority of constituents; no long-term data*	*TDS*	X	X	X		X	
Eastern Mountains	25	M	E	B,C	*Limited historic records; poor spatial distribution; generally good water quality*	*Fe, Mn*	X	X	X		X	
Knoxville	0	M	E	B,C	*Limited to one site with five monitoring wells; generally poor quality and no long-term records*	*B, Cl, EC, Na, TDS*	X	X	X		X	
Livermore Ranch	0	L	E	B,C	*No groundwater quality data available*	*unknown*	X	X	X		X	
Pope Valley	6	L	E	B,C	*No historic records; all measurements from two sites (seven wells total); generally good water quality from constituents with data*	*Fe, Mn*	X	X	X		X	

Summaries of 2011 Groundwater Report Findings and Objectives for Groundwater Quality Monitoring Sites, Napa County

Subarea	No. Sites with Current GW Quality Data[1]	Future Groundwater Quality Monitoring[1]		Monitoring Needs	Findings GW Quality Conditions (LSCE, 2011a)	Constits. of Concern	Baseline conditions &spatial differences	Fill Data Gaps	Occurrence & factors related to natural or other constituents	Baseline conditions in areas of potential saltwater intrusion	Assess changes, trends, factors contrib. to change	Other
		Relative Priority (2011 Preilm)	Action (Expand/ Refine)									
Southern Interior Valleys	0	L	E	B,C	*No historic records; poor spatial coverage (only three wells with data); generally good quality*	*As, Na*	X	X	X		X	
Western Mountains	10	L	R	B,C	*Very limited historic and current records (12 wells total); generally good quality*	*Fe, Mn*	X	X	X		X	
Total	**177**											

Groundwater Quality Notes

[1] "Current" refers to monitored sites with wells measured for levels and/or any water quality parameter with a period of record extending to 2008 or later. "Current" sites were tabulated for *the Napa County Groundwater Monitoring Plan 2013*. "Future" refers to recommended monitoring locations.

L = Low Priority; add groundwater quality and also level monitoring based on areas of planned future groundwater development

M = Medium Priority; add groundwater quality and also level monitoring

H = High Priority; add groundwater quality and also level monitoring

E = Expand current monitoring network; possible alternatives for additional monitoring wells include 1) wells historically monitored by DWR/USGS/Others, preferably with well construction information and as the well may be available for monitoring; 2) existing water supply wells (e.g., private/commercial) with well construction information; 3) new dedicated monitoring wells (coordinate with potential geologic investigations that may be conducted in selected areas)

R = Refine current monitoring network (link well construction information to all monitored wells, as possible)

Monitoring Needs: SP = Improve horizontal and/or vertical spatial distribution of data; B = Basic data needed to accomplish groundwater level monitoring objectives; C = Coordinate with groundwater level monitoring

Note: Some sites with current groundwater quality data are approximately located and currently may not be counted in the correct subarea. Also, additional sites with current groundwater quality beyond this tabulation exist but the locations are currently unavailable and unable to be counted at this time.

APPENDIX B

Summaries of Current Groundwater Level and Groundwater Quality Monitoring Locations

Summary of Current Groundwater Level Monitoring Locations

	WellID	State Well Number	Year Start	Construction Date (yyyymmdd)	Well Depth (ft)	Hole Depth (ft)	Screen Interval (ft)
Napa Valley Floor-Calistoga	NapaCounty-127	009N007W25N001M	1962	19580310	149	149	unk
	NapaCounty-129	008N006W06L004M	1962	19620719	253	253	unk
	NapaCounty-128	009N006W31Q001M	1962	19620719	50	50	unk
	08N06W10Q001M	008N006W10Q001M	1949		200		unk
	T0605500250MW-1		2005		24.83		10 - 25
	T0605500272MW-1		2008				unk
Napa Valley Floor-St. Helena	NapaCounty-131	007N005W16L001M	1963	193907	221	221	7 - sections
	NapaCounty-132	007N005W14B002M	1962		265	265	25 - 265
	NapaCounty-138	007N005W16N002M	1949		321	321	unk
	07N05W09Q002M	007N005W09Q002M	1949		232		unk
	T0605500061MW-8		2005		20		6 - 20
	T0605500168MW-6		1998		18		3 - 18
	T0605500190MW-1		2001		22.5		7.5 - 22.5
	T0605500190MW-1		2002		18.59		unk
	CityofNapa-BV		2002		unk		unk
	CityofNapa-C1		2002		unk		unk
	CityofNapa-Woods1		2002		unk		unk
	CityofNapa-Woods2		2002		unk		unk
	NapaCounty-133	007N004W31M001M	1978	19720415	120	120	20 - 120

	WellID	State Well Number	Year Start	Construction Date (yyyymmdd)	Well Depth (ft)	Hole Depth (ft)	Screen Interval (ft)
Napa Valley Floor-Yountville	NapaCounty-135	006N004W19B001M	1979	19620720	125	125	unk
	NapaCounty-125	006N004W09Q001M	1979	19710823	160	163	63 - 160
	NapaCounty-126	006N004W09Q002M	1984	19711116	345	345	140 - 345
	NapaCounty-134	006N004W06L002M	1963	19550801	260	264	160 - 260
	NapaCounty-139	006N004W17R002M	1978	19770125	120	120	40 - 120
	NapaCounty-151	006N004W17Ax	2012				unk
	06N04W17A001M	006N004W17A001M	1949		250		unk
	TownofYountville-MW1			20041103	300	320	105 - 300
Napa Valley Floor-Napa	NapaCounty-76	006N004W15R003M	2000				unk
	NapaCounty-75	006N004W22R001M	1978	19710719	205	208	45 - 205
	NapaCounty-136	006N004W27N001M	1979	19620720	120	120	unk
	NapaCounty-152	006N004W28Mx	2012				unk
	06N04W27L002M	006N004W27L002M	1966	19660609	120	122	60 - 120
	05N04W15E001M	005N004W15E001M	1949		158		unk
	SL0605536682MW-1		2005		24		unk
	T0605500008MW-3		2005	20050721	15		3 - 15
	T0605500009MW1		2005	19920301	14		3 - 14
	T0605500044C-4		2002		12.63		10 - 30
	T0605500110KMW-1		2003	19900815	19.65	26	9.5 - 24.5
	T0605500124MW-1		2002		25		unk
	T0605500164EX-1		2003	2002112	37	37	10 - 35

	WellID	State Well Number	Year Start	Construction Date (yyyymmdd)	Well Depth (ft)	Hole Depth (ft)	Screen Interval (ft)
	T0605500212MW-1		2003		20	21.5	4 - 20
	T0605514064MW1		2005				unk
	T0605547200MW-1		2008				unk
	T0605575085MW-1		2009				unk
	T0605598080MW-1		2005				unk
Napa Valley Floor-MST	NapaCounty-118	005N003W07B00_My	2001			0	unk
	NapaCounty-122	006N004W26L00_M	2001			0	unk
	NapaCounty-142	006N004W25G00_M	2001			0	unk
	NapaCounty-149	005N003W08E00_M	2010				unk
	NapaCounty-18	005N004W13G004M	2000	19760714	189	210	unk
	NapaCounty-22	005N003W08E001M	2000	19680416	135	140	unk
	NapaCounty-29	005N004W01F003M	2000			0	unk
	NapaCounty-35	005N003W18D001M	2000			0	unk
	NapaCounty-4	006N004W14Q001M	2000	19890913	385	390	unk
	NapaCounty-51	006N004W25G001M	2000			0	unk
	NapaCounty-69	006N004W35G005M	2000			0	unk
	NapaCounty-72	005N003W07D003M	2000	19971007	245	245	unk
	NapaCounty-81	005N003W07F003M	2000	19880725	290	290	unk
	NapaCounty-98	006N004W36A001M	2000			0	unk
	NapaCounty-10	005N003W05M001M	1979		320		unk
	NapaCounty-148	005N003W05M00_M	2009	20090805			unk

	WellID	State Well Number	Year Start	Construction Date (yyyymmdd)	Well Depth (ft)	Hole Depth (ft)	Screen Interval (ft)
	NapaCounty-2	006N004W23J001M	1979		700		unk
	NapaCounty-20	005N003W07C003M	1978	19771208	208	208	130 - 207
	NapaCounty-56	006N004W26G001M	1978	19760828	210	210	30 - 210
	NapaCounty-95	006N004W36G001M	1979	19770110	195	340	155 - 185
	NapaCounty-137	005N004W13H001M	1979	19620716	364	364	unk
	NapaCounty-43	006N004W23Q003M	1978		310		unk
	NapaCounty-49	005N004W14J003M	1989		399		unk
	NapaCounty-74	005N003W06M001M	1999	19880818	300	300	unk
	NapaCounty-91	005N003W06B002M	1992	19860815	415	415	315 - 415
	NapaCounty-92	005N003W06A001M	1999		368	0	unk
	L10002804480DW-1		2005				unk
	T0605500138S-3		2003	20030428	30	30	4 - 15
	T0605500140MW-1		2000	19910119	24.86	26	11 - 26
Carneros	NapaCounty-150	004N004W05C001M	2011		155		unk
Carneros	NapaCounty-153	004N004W05A001M	2012	19780508	200	210	60 - 200
Carneros	NapaCounty-154	005N004W31R001M	2012	19900828	300	320	60 - 295
Carneros	NapaCounty-155	004N004W06M001M	2012	20030813	220	220	80 - 220
Carneros	04N04W05D002M	004N004W05D002M	1951		60		unk
Jameson/ American Canyon	T0605500240MW-4		2007		14.5		unk
Napa River Marshes	L10002804480DW-2		2005				unk

	WellID	State Well Number	Year Start	Construction Date (yyyymmdd)	Well Depth (ft)	Hole Depth (ft)	Screen Interval (ft)
Berryessa	NBRID_MW2		2007				unk
	T0605500304MW-1		2002				unk
	T0605591908MW-1		2006		34		unk
Central Interior Valleys	T0605500279MW1		2002				unk
Knoxville	LBRID_MW1		2006				unk
Pope Valley	T0605593602MW-1		2002				unk

Summary of Current Groundwater Quality Monitoring Locations

	WellID	SRC	SYS_NO	SITE_TYPE
Napa Valley Floor - Calistoga	2800026	DPH	TRINCHERO WINERY	
	2800030	DPH	ENVY WINES	
	2800508	DPH	CUVAISON VINEYARD	
	2800516	DPH	TUCKER ACRES MUTUAL WATER CO.	
	2800555	DPH	TWOMEY CELLARS	
	2800587	DPH	DUFFY S MYRTLEDALE RESORT	
	2800648	DPH	WINE COUNTRY INN	
	2800741	DPH	ST. HELENA PREMIUM OUTLETS	
	2800742	DPH	GOLDEN HAVEN MOTEL	
	2801004	DPH	CHATEAU MONTELENA WINERY	
	2801007	DPH	CLOS PEGASE WINERY	
	2801015	DPH	FRANK FAMILY VINEYARDS	
	2802715	DPH	NORMAN ALUMBAUGH CO., INC.	
	2810002	DPH	CALISTOGA, CITY OF	
	2810300	DPH	CSP-BALE GRIST MILL STATE PARK	
	L10001344067B-11	Geotracker	L10001344067	
	T0605500196MW-1	Geotracker	T0605500196	
	T0605500250MW-1	Geotracker	T0605500250	
	T0605500259EB1	Geotracker	T0605500259	
	T0605500272EB	Geotracker	T0605500272	
Napa Valley Floor - St. Helena	2800027	DPH	NICKEL & NICKEL WINERY	
	2800035	DPH	RIVER RANCH FARM WORKER CENTER	
	2800536	DPH	GRGICH HILLS	
	2800556	DPH	BROKEN HILL 1 LLC	
	2800562	DPH	FRANCISCAN WINERY	

	WellID	SRC	SYS_NO	SITE_TYPE
	2800589	DPH	WHITEHALL LANE WINERY	
	2800609	DPH	PHELPS VINEYARDS	
	2800749	DPH	KENT RASMUSSEN WINERY	
	2801012	DPH	ALPHA AND OMEGA WINERY	
	2801022	DPH	MILAT WINERY	
	2801026	DPH	OPUS ONE WINERY	
	2801027	DPH	PEJU PROVINCE	
	2801031	DPH	RAYMOND VINEYARD & CELLAR	
	2801037	DPH	SEQUOIA GROVE VINEYARDS	
	2801038	DPH	SILVER OAKS WINE CELLARS	
	2801045	DPH	ST. CLEMENT VINEYARDS INC.	
	2801046	DPH	ST. SUPERY WINERY	
	2801049	DPH	THE RANCH WINERY	
	2801070	DPH	BERINGER VINEYARDS	
	2801073	DPH	PROVENANCE VINEYARDS	
	2801075	DPH	CAKEBREAD CELLAR	
	2801088	DPH	V. SATTUI WINERY	
	2803886	DPH	RUTHERFORD GROVE WINERY	
	2803912	DPH	BEAULIEU VINEYARD	
	2810004	DPH	ST. HELENA, CITY OF	
	L10003472156MW-1	Geotracker	L10003472156	
	SL0605506371MW-1	Geotracker	SL0605506371	
	T0605500061EW-1	Geotracker	T0605500061	
	T0605500143MW-1	Geotracker	T0605500143	
	T0605500168EW-1	Geotracker	T0605500168	
	T0605500190MW-1	Geotracker	T0605500190	
	2800299	DPH	FAR NIENTE WINERY	

	WellID	SRC	SYS_NO	SITE_TYPE
Napa Valley Floor - Yountville	2800302	DPH	HARTWELL WINERY	
	2800557	DPH	CASTLE TROVE, INC.	
	2800736	DPH	DOMAINE CHANDON	
	2801006	DPH	CLOS DU VAL WINE CO.	
	2801010	DPH	COSENTINO WINERY	
	2801028	DPH	CARDINALE ESTATE	
	2801029	DPH	PINE RIDGE WINERY	
	2801041	DPH	SILVERADO VINEYARDS	
	2801042	DPH	SINSKEY WINERY	
	2801047	DPH	STAG S LEAP WINE CELLARS	
	2801077	DPH	CHIMNEY ROCK WINERY	
	2803911	DPH	DOMINUS ESTATE WINERY	
	2810007	DPH	TOWN OF YOUNTVILLE	
Napa Valley Floor - Napa	2800635	DPH	STRACK W.D. WATER	
	2801020	DPH	ESPINOZA WATER SYSTEM	
	SL0605536682MW-1	Geotracker	SL0605536682	
	T0605500008BC-1	Geotracker	T0605500008	
	T0605500009EW-1	Geotracker	T0605500009	
	T0605500044C-4	Geotracker	T0605500044	
	T0605500110MW-1	Geotracker	T0605500110	
	T0605500124MW-1	Geotracker	T0605500124	
	T0605500164EFF	Geotracker	T0605500164	
	T0605500165EFF	Geotracker	T0605500165	
	T0605500212MW-1	Geotracker	T0605500212	
	T0605500256MW-1	Geotracker	T0605500256	
	T0605500261MW-2	Geotracker	T0605500261	
	T0605514064MW1	Geotracker	T0605514064	

	WellID	SRC	SYS_NO	SITE_TYPE
	T0605522317DP-1	Geotracker	T0605522317	
	T06055472002285DW	Geotracker	T0605547200	
	T0605575085B-1	Geotracker	T0605575085	
	T0605591205MW-1	Geotracker	T0605591205	
	T0605597251K-1	Geotracker	T0605597251	
	T0605598080MW-1	Geotracker	T0605598080	
	05N04W15E001M	DWR	005N004W15E001M	Dom_Irr
Napa Valley Floor - MST	2800025	DPH	HAGAFEN CELLARS	
	2800548	DPH	SILVERADO PINES MOBILE HOME	
	2800554	DPH	GENE NORRIS PLAZA	
	2800564	DPH	SODA CANYON STORE	
	2800580	DPH	SYAR INDUSTRIES	
	2800717	DPH	NAPA PIPE REDEVELOPMENT PARTNERS	
	2800848	DPH	NVUSD: MT. GEORGE SCHOOL	
	2801039	DPH	SILVERADO HILL CELLARS	
	2801055	DPH	WILLIAM HILL WINERY	
	2801081	DPH	MT. GEORGE ESTATES	
	T0605500007BC-10	Geotracker	T0605500007	
	T0605500135UST-GW	Geotracker	T0605500135	
	T0605500138DM-1	Geotracker	T0605500138	
	T0605500140MW-1	Geotracker	T0605500140	
	T0605500166DW-1019	Geotracker	T0605500166	
	T10000000413MW-1	Geotracker	T10000000413	
Carneros	2800538	DPH	CARNEROS INN	
	2800847	DPH	NVUSD: CARNEROS SCHOOL	
	2801002	DPH	ETUDE WINES	

	WellID	SRC	SYS_NO	SITE_TYPE
	2801011	DPH	DOMAINE CARNEROS	
	2801089	DPH	DI ROSA ART PRESERVE	
	T0605517802MW-1	Geotracker	T0605517802	
	04N04W05C001M	DWR	004N004W05C001M	Unk_GW
	04N04W05D002M	DWR	004N004W05D002M	Dom
	04N04W04C002M	DWR	004N004W04C002M	Unk_GW
Jameson/American Canyon	T0605500012MW 1	Geotracker	T0605500012	
	T0605500077MW-1	Geotracker	T0605500077	
	T0605500240MW-4	Geotracker	T0605500240	
Napa River Marshes	2800530	DPH	MEYERS WATER CO.	
	2800531	DPH	MOORE S RESORT	
	2800592	DPH	NAPA VALLEY MARINA	
	2800811	DPH	ACACIA WINERY	
	2801080	DPH	MILTON ROAD WATER COMPANY	
	L10002804480DUP-1	Geotracker	L10002804480	
Angwin	2800527	DPH	LINDA FALLS TERRACE MUTUAL	
	2800528	DPH	LINDA VISTA MUTUAL WATER CO	
	2801936	DPH	O SHAUGHNESSY WINERY	
	2810001	DPH	HOWELL MOUNTAIN MUTUAL WATER COMPANY	
Berryessa	2800129	DPH	STERLING VINEYARDS	
	T0605500257061808	Geotracker	T0605500257	
	T0605500298MW-1	Geotracker	T0605500298	
	T0605500304	Geotracker	T0605500304	
	T0605500312EFF	Geotracker	T0605500312	
	T0605591908B-10	Geotracker	T0605591908	

	WellID	SRC	SYS_NO	SITE_TYPE
Central Interior Valleys	2800297	DPH	CATACULA LAKE WINERY	
	2800521	DPH	CIRCLE WATER DISTRICT	
	2800584	DPH	LAS POSADAS 4-H CAMP	
	2800593	DPH	R RANCH AT THE LAKE	
	T0605500279MW1	Geotracker	T0605500279	
	T0605592744MW-1	Geotracker	T0605592744	
Eastern Mountains	2800023	DPH	RUTHERFORD HILL MUTUAL WATER	
	2800024	DPH	DUCKHORN VINEYARDS	
	2800029	DPH	AUGUST BRIGGS WINERY	
	2800298	DPH	DBA SILVER ROSE CELLARS	
	2800525	DPH	LA TIERRA HEIGHTS MUTUAL	
	2800532	DPH	VAILIMA ESTATES MUTUAL WATER	
	2800561	DPH	FREEMARK ABBEY PROPERTIES	
	2800575	DPH	CALISTOGA RANCH	
	2800583	DPH	WELCOME GRANGE HALL	
	2800588	DPH	NAPA VALLEY COUNTRY CLUB	
	2800625	DPH	ST. HELENA HOSPITAL	
	2800719	DPH	MUND S MOBILE HOME PARK	
	2801009	DPH	CONN CREEK WINERY	
	2801014	DPH	RUDD WINES, INC., DBA RUDD	
	2801024	DPH	MUMM OF NAPA VALLEY	
	2801033	DPH	ROMBAUER VINEYARDS	
	2801035	DPH	ROUND HILL WINERY	
	2801043	DPH	SKYLINE PARK	
	2801056	DPH	Z D WINES	
	2801076	DPH	CAYMUS VINEYARDS	
	2801084	DPH	RUTHERFORD HILL WINERY	

	WellID	SRC	SYS_NO	SITE_TYPE
	2801086	DPH	STAGS LEAP WINERY	
	2803697	DPH	STELTZNER WINERY	
	2803879	DPH	JARVIS VINEYARD	
	2803907	DPH	MINER FAMILY WINERY	
Pope Valley	2800569	DPH	AETNA SPRINGS GOLF COURSE	
	2800970	DPH	HOWELL MTN SCHOOL	
	2810012	DPH	PACIFIC UNION COLLEGE	
	T0605593602021909	Geotracker	T0605593602	
	T10000000436MW-1	Geotracker	T10000000436	
Southern Interior Valleys	2800845	DPH	NVUSD: WOODEN VALLEY SCHOOL	
Western Mountains	2800301	DPH	LAIRD FAMILY ESTATE	
	2800613	DPH	LOKOYA REDWOODS	
	2800621	DPH	MAYACAMAS VINEYARDS	
	2801008	DPH	ARTESA VINEYARDS & WINERY	
	2801016	DPH	HESS WINERY	
	2801036	DPH	SCHRAMSBERG WINERY	
	2801054	DPH	WHITE SULPHUR SPRINGS RESORT	
	2810301	DPH	CSP-BOTHE-NAPA STATE PARK	
	2800032	DPH	TERRA VALENTINE	

APPENDIX C

Napa County Procedure for Measuring Groundwater Levels

NAPA COUNTY PROCEDURE FOR MEASURING THE DEPTH TO WATER IN MONITORING AND PRODUCTION WELLS

Purpose

To obtain an accurate dated and timed measurement of the static depth to water in a well that can be converted into a water level elevation in reference to a commonly used reference datum (e.g., NAVD 1988). In this context, static means that the water level in the well is not influenced by pumping of the well. For comparability, measurements should be obtained according to an established schedule designed to capture times of both highest and lowest seasonal water level elevations. Also for comparability, measurements during a particular field campaign should be obtained consecutively and without delay within the shortest reasonable time.

Measurement Procedure

- If well is being pumped, do not measure (see below "Special Circumstances – Pumping Water Level on Arrival" for additional instructions).
- Turn on water level indicator signaling device and check battery by hitting the test button.
- Remove access plug or well cap from the well cover and lower probe (electric sounder) into the well.
- When probe hits water a loud "beep" will sound and signal light will turn red.
- Retract slightly until the tone stops.
- Slowly lower the probe until the tone sounds.
- Note depth measurement at rim (i.e., the surveyed reference point for water level readings) of well to the nearest 0.01 foot and rewind probe completely out of well.
- Remove excess water and lower probe once again into well and measure again.
- If difference is within ±0.02 foot of first measurement, record measurement.
- If difference is greater repeat the same procedure until three consecutive measurements are recorded within ± 0.02 foot.
- Rewind and remove probe from well and replace the access plug or well cap in the well cover.
- Clean and dry the measuring device/probe and continue to next well.

Special Circumstances

Oil Encountered in Well

If oil is detected in the well structure, the depth to the air-oil interface is measured. To obtain such a measurement, the electric sounder is used similar to the way chalked steel tapes were traditionally used for depth-to-water measurements.

1. Lower the cleaned probe well below the air-oil interface (e.g., 1 foot). Read and record the depth at the reference point (since this depth is chosen somewhat arbitrarily by the field technician, an even number can be chosen, e.g., 37.00 feet). This measurement is the length of cable lowered into the well and corresponds to a line that the oil leaves on the probe or cable (i.e., the oil inundation line). Above this line, smudges of oil may appear on the cable. Below this line, the cable/probe is completely covered with oil. If the probe is lowered too far, completely penetrates the oil, and is far submerged in the water below the oil, parts of the probe/cable below the oil inundation line may also appear smudgy.
2. Retrieve probe, identify and record the oil inundation line on the cable (e.g., 2.72 feet). This measurement does not reflect the thickness of the oil. It reflects the length of the cable below the air-oil interface.
3. Compute the depth to oil by subtracting the length of line below the air-oil interface from the corresponding measurement at the reference point: Depth to oil = 37.00 feet – 2.72 feet = 34.28 feet.

Since oil has a slightly smaller density than water, a depth-to-oil measurement will always be smaller than a corresponding depth-to-water measurement in the same well if oil were not present. Depth-to-oil measurements yield a reasonable approximation to depth-to-water measurements unless the oil thickness is great. For each foot of oil in the well casing, the depth-to-oil measurement will be approximately 0.12 foot smaller than a corresponding depth-to-water measurement if oil were not present.

Pumping Water Level on Arrival

If well is being pumped, do not measure. Return later when the water level has stabilized. Using past field notes, the field technician will use his/her experience to determine the appropriate duration necessary for static measurements. Upon returning to the well site (at a location where pumping was previously noted on the same day), the technician will measure the water level. The technician will have available historical water level data to determine whether the measurement is consistent with past measurements. If the initial measurement appears anomalous, the technician will measure water levels every 10 minutes over a period of 30 minutes. If measurements vary significantly from past measurements (taking into account seasonal variations), the technician will note the circumstances (i.e., the date and time when the well was first visited, total time it was pumping (if known), when it was shutoff, when the technician returned, and subsequent water level measurements [on the same day, or as the case may be based on experience, the day immediately following]). Subsequent consideration of pumping effects at a site-specific well location will be addressed as necessary.

Recordation

1. Name of field technician
2. Unique identification of well
3. Weather and site conditions (e.g., clear, sunny, strong north wind, intense dust blowing over wellhead from nearby plowed field; dry ground, easy access)
4. Condition of well structure (e.g., well cap cracked – replaced with new one; wasp hive between well casing and well housing; no action, discuss with project manager)
5. Time and date of depth-to-water reading
6. Any other pertinent comments (e.g., sounder hangs up at 33 feet, thus no measurement; or: fifth measurement of ~55.68 feet in a row…residual water in end cap?; or: oil in well…measurement is depth to oil; or: intense sulfur odor upon opening well cap; or: nearby (west ~100 feet) irrigation well pumping)

CALIFORNIA STATEWIDE GROUNDWATER ELEVATION MONITORING
(CASGEM)

STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES

GROUND WATER LEVEL MEASUREMENTS

Monitoring Entity: Napa County
Monitoring Period:____________________________
Measuring Agency Number: 3983
Measured By:________________________________

STATE WELL NUMBER	COUNTY WELL ID	MSRMNT DATE	R.P. ELEVATION (NAVD88 ft)	DIST. R.P. TO WATER	METHOD OF WATER DEPTH MSRMNT	MSRMNT QUALITY CODES[1]	MSRMNT TIME	COMMENTS

1 MEASUREMENT QUALITY CODES:

- If **no** measurement is taken, a specified "no measurement" code, must be recorded.
  0. Discontinued 1. Pumping 2. Pumphouse locked 3. Tape hung up 4. Can't get tape in casing 5. Unable to locate well 6. Well destroyed 7. Special 8. Casing leaking or wet 9. Temporarily inaccessible D. Dry well F. Flowing well
- If the quality of a measurement is **uncertain**, a "questionable measurement" code can be recorded.
  0. Caved or deepened 1. Pumping 2. Nearby pump operating 3. Casing leaking or wet 4. Pumped recently 5. Air or pressure gauge measurement 6. Other 7. Recharge operation at nearby well 8. Oil in casing 9. Acoustical sounder measurement

APPENDIX D

Example Field Sheet for Groundwater Quality Sampling

FIELD PURGE DATA
Monitoring Wells

Client: ______________________ Date: ______________________

Project: ______________________ Project No.: ______________________

Well ID: ______________________ Measured By: ______________________

TOTAL WELL DEPTH (ft)	CASING DIAMETER (in)	STICKUP (ft)	STATIC WATER LEVEL (ft)
	PVC / Steel		

STANDING WATER COLUMN (ft)				WET CASING VOLUME, Vc (gal)	3 Vc (gal)
	x	0.16 (for 2" casing); 0.37 (for 3" casing) 0.65 (for 4" casing); 1.0 (for 5" casing) 1.47 (for 6" casing); 2.61 (for 8" casing) 4.08 (for 10" casing); 5.88 (for 12" casing) 10.45 (for 16" casing); 16.32 (for 20" casing)	=		

Clock Time	Pumping Time (min)	Pump Rate (Hz)	Flow Rate (gpm)	Cumulative Flow (gals)	DTW (ft)	Temp (°F / °C)	pH	Sp. Cond. at 25°C (µs/cm)	Turbidity (NTU)	DO (mg/L)	ORP (milliVolt)	Observations (redox, color, odor, etc.)

Water Sample Collection (number of bottles and sample I.D.)

NAPA VALLEY GROUNDWATER SUSTAINABILITY:

A BASIN ANALYSIS REPORT FOR THE NAPA VALLEY SUBBASIN

APPENDIX D:

Napa Country Comprehensive Groundwater Monitoring Program, 2015 Annual Report and CASGEM Update

Napa County Comprehensive Groundwater Monitoring Program 2015 Annual Report and CASGEM Update

March 2016

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Napa County Comprehensive Groundwater Monitoring Program 2015 Annual Report and CASGEM Update

Prepared for
Napa County

Prepared by

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

March, 2016

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EXECUTIVE SUMMARY

ES 1 INTRODUCTION

Groundwater and surface water are highly important natural resources in Napa County. Together, the County and other municipalities, water districts, commercial and industrial operations, the agricultural community, and the general public, are stewards of the available water resources. Everyone living and working in Napa County has a stake in protecting the county's groundwater resources, including groundwater supplies, groundwater quality, and associated watersheds (GRAC, 2014).

Long-term, systematic monitoring programs are essential to provide data that allow for improved evaluation of water resources conditions and to facilitate effective water resources planning. For this reason, Napa County embarked on a countywide project referred to as the "Comprehensive Groundwater Monitoring Program, Data Review, and Policy Recommendations for Napa County's Groundwater Resources" (Comprehensive Groundwater Monitoring Program) in 2009, to meet action items identified in the 2008 General Plan update. The program emphasizes developing a sound understanding of groundwater conditions and implementing an expanded groundwater monitoring and data management program as a foundation for future coordinated, integrated water resources planning and dissemination of water resources information.

The *Napa County Groundwater Monitoring Plan 2013* (Plan) was prepared to formalize and augment groundwater monitoring efforts conducted as part of the Comprehensive Groundwater Monitoring Program. The Plan recommended annual reports on groundwater conditions and modifications to the countywide groundwater monitoring program as needed. Additionally, the Plan recommended a comprehensive triennial report. This report is the second Annual Report – *Napa County Comprehensive Groundwater Monitoring Program 2015 Annual Report and CASGEM*[1] *Update* (Report).

In addition to providing an update on groundwater level conditions and monitoring program modifications, this Report summarizes recent groundwater quality data.

ES 2 GROUNDWATER MONITORING GOALS AND OBJECTIVES

The California Department of Water Resources (DWR) has identified the major groundwater basins and subbasins in and around Napa County. The basins include the Napa-Sonoma Valley (which in Napa County includes the Napa Valley and Napa-Sonoma Lowlands Subbasins), Berryessa Valley, Pope Valley, and a small part of the Suisun-Fairfield Valley Groundwater Basins (**Figure 2-1**). For purposes of local planning, understanding, and studies, the County has been subdivided into a series of groundwater subareas (**Figure 2-2**). These subareas were delineated based on the main watersheds, groundwater basins, and the County's environmental resource planning areas.

Water level and quality objectives established for the countywide Comprehensive Groundwater Monitoring Program are linked to 1) the County's General Plan goals and action items presented in **Section 3.1** of this Report, and 2) hydrogeologic conditions and potential areas of concern (LSCE, 2013a).

[1] CASGEM is the California Statewide Groundwater Elevation Monitoring program implemented under Water Code Part 2.11 Groundwater Monitoring and administered by DWR.

The focus of the countywide groundwater level monitoring includes the following objectives:

- Expand groundwater level monitoring in priority County subareas to improve the understanding of the occurrence and movement of groundwater; monitor local and regional groundwater levels including seasonal and long-term trends; and identify hydraulic connections in aquifer systems and aquifer-specific groundwater conditions, especially in areas where short- and long-term development of groundwater resources are planned;
- Detect the occurrence of, and factors attributable to, natural (e.g., direct infiltration of precipitation, surface water seepage to groundwater, groundwater discharge to streams) or induced factors (e.g., pumping, purposeful recharge operations) that affect groundwater levels and trends;
- Identify appropriate monitoring sites to further evaluate groundwater-surface water interaction and recharge/discharge mechanisms, including whether groundwater utilization is affecting surface water flows;
- Establish a monitoring network to aid in the assessment of changes in groundwater storage; and
- Generate data to better estimate groundwater basin conditions and assess local current and future water supply availability and reliability; update analyses as additional data become available.

Based on the analysis of existing groundwater data and conditions described in the report *Napa County Groundwater Conditions and Groundwater Monitoring Recommendations* (LSCE, 2011a) and with input received from the Groundwater Resources Advisory Committee (GRAC), the key objectives for future groundwater level monitoring for each subarea are summarized in LSCE (2013a) and **Section 3** of this Report.

ES 3 SUSTAINABLE GROUNDWATER MANAGEMENT ACT

In September 2014, the California Legislature passed the Sustainable Groundwater Management Act (Act). SGMA changes how groundwater is managed in the state. SGMA defines “sustainable groundwater management” as the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results (Section 10721 (u)). Undesirable results, as defined by SGMA, means one or more effects caused by groundwater conditions occurring throughout the basin (Section 10721 (w)) (see **Section 6.2**).

As noted in **Section 2** of this Report, SGMA applies to basins or subbasins that DWR designates as medium- or high-priority basins. Previously under the California Statewide Groundwater Elevation Monitoring Program (CASGEM), DWR classified California’s groundwater basins and subbasins as either high, medium, low, or very low priority. The priority classifications are based on eight criteria that include the overlying population, the reliance on groundwater, and the number of wells in a basin or subbasin. In Napa County, the Napa Valley Subbasin was ranked medium priority. All other Napa County basins and subbasins were ranked as very low-priority (**Figure 2-1**).

For most basins designated by DWR as medium or high priority, SGMA requires the designation of groundwater sustainability agencies (GSA) and the adoption of groundwater sustainability plans (GSP); however, there is an alternative to a GSP, provided that the local entity (entities) can meet certain requirements. When required, GSPs must be developed to eliminate overdraft conditions in aquifers and to return them to a condition that assures their long-term sustainability within twenty years of GSP implementation. SGMA does not require the development of a GSP for basins that DWR ranks as low- or very low-priority basins; GSPs are voluntary for these basins.

As applicable, SGMA requires that a GSA be identified for medium- and high-priority groundwater basins by June 30, 2017. Counties are presumed to be the GSA for unmanaged areas of medium and high priority basins (Section 10724). However, counties are not required to assume this responsibility. When no entity steps forward, this can lead to state intervention (Section 10735 *et seq*.).

In addition to imposing a number of new requirements on local agencies related to groundwater management, SGMA also provides for state intervention – a "backstop" – when local agencies are unwilling or unable to manage their groundwater basin (Section 10735 *et seq*.).

Under SGMA, Section 10733.6, a local entity (or entities) can pursue an Alternative to a GSP provided that certain sustainability objectives are met. An Alternative to a GSP may include:

> (b) (3) "An analysis of basin conditions that demonstrates that the basin has operated within its sustainable yield over a period of at least 10 years. The submission of an alternative described by this paragraph shall include a report prepared by a registered professional engineer or geologist who is licensed by the state and submitted under that engineer's or geologist's seal."

The County would need to submit the alternative plan no later than January 1, 2017, and every five years thereafter.

(d)The assessment required by subdivision (a) shall include an assessment of whether the alternative is within a basin that is in compliance with Part 2.11 (commencing with Section 10920). If the alternative is within a basin that is not in compliance with Part 2.11 (commencing with Section 10920), the department shall find the alternative does not satisfy the objectives of this part.

On February 18, 2016 DWR published draft regulations for the development of GSPs and GSP-alternatives. Napa County staff have met with DWR staff to discuss a possible approach for a GSP-alternative for the Napa Valley Subbasin. County staff have also provided comments to DWR on the draft regulations, which are required under SGMA to be finalized and adopted by June 1, 2016. County staff are currently seeking input from the Napa County Board of Supervisors and preparing for multiple paths forward pending direction from the Supervisors and the content of the final regulations with respect to the requirements for GSP-alternatives.

ES 4 GROUNDWATER MONITORING NETWORK DESIGN AND DEVELOPMENT

Groundwater level monitoring was conducted at a total of 113 sites across Napa County in 2015 (**Table ES-1)**. The overall number and distribution of monitored sites remained consistent with the monitoring conducted in 2014 and was increased relative to the 87 sites reported in the 2011(LSCE, 2013a) (**Table ES-1**).

Out of the total 113 sites monitored in 2015, 100 were monitored by Napa County. Four sites were monitored by DWR. The remaining nine sites were regulated facilities with data reported as part of the State Water Resources Control Board (SWRCB) Geotracker Program.

Minor changes in the sites monitored by Napa County between 2014 and 2015 occurred due to a combination of well-owner requests and decisions by the Napa County Department of Public Works. In the latter case, three wells were discontinued by the County where other nearby monitored wells were determined to be sufficient to meet the monitoring objectives. Three additional wells were added to the County's monitoring networks during 2015 based on requests by well owners for monitoring by the County in areas where additional monitoring sites were needed. As recommended in the 2014 Annual Report, the County also began monthly monitoring of a subset of eight wells in order to provide greater temporal resolution in areas where semi-annual measurements may not accurately reflect the peak groundwater levels.

ES 4.1 Local Groundwater Assistance Grant Program Monitoring

Funding from the DWR 2012 Local Groundwater Assistance Grant Program enabled Napa County to construct ten monitoring wells at five sites in Napa Valley in September 2014. These wells comprise the groundwater monitoring facilities for the Napa County Surface Water-Groundwater Monitoring Project.

Table ES-1 Current Groundwater Level Monitoring Sites in Napa County by Groundwater Subarea

Groundwater Subarea	Number of Monitored Sites Through 2011	Number of Monitored Sites, Fall 2014	Number of Monitored Sites, Fall 2015
Napa Valley Floor-Calistoga	6	10	9
Napa Valley Floor-MST	29	27	27
Napa Valley Floor-Napa	18	21	20
Napa Valley Floor-St. Helena	12	14	14
Napa Valley Floor-Yountville	9	12	14
Carneros	5	12	12
Jameson/American Canyon	1	1	1
Napa River Marshes	1	1	-
Angwin	-	5	5
Berryessa	3	2	3
Central Interior Valleys	1	1	2
Eastern Mountains	-	3	4
Knoxville	1	-	-
Livermore Ranch	-	-	-
Pope Valley	1	1	1
Southern Interior Valleys	-	-	-
Western Mountains	-	2	1
Unknown[1]	-	3	-
Total Sites	**87**	**115**	**113**

[1] In 2014 three sites in the Geotracker regulated groundwater monitoring network were reporting groundwater level data, but had not yet reported location information for the monitored wells.

Water level data collected at the five sites are presented in **Section 5.5**. Data from Sites 1, 3, and 4 show that groundwater levels were above or very near the riverbed at these sites, indicating connectivity between groundwater and surface water. Data from Site 1 indicates that little to no flow occurred between groundwater and the river at that location. Data from Sites 3 and 4 showed variability in the nature of groundwater-surface water connection during 2015, ranging from groundwater flow into the river to the opposite. At both Site 2 and Site 5 the direction of groundwater flow was away from the streambed. At Site 5 water level data indicate that the river was hydraulically connected to groundwater during the first half of the year, until flows in the river ceased in July, and again in December 2015 as storms generated runoff leading to renewed flow in the river. At Site 2, located along Dry Creek, groundwater levels were consistently below the streambed elevation in 2015, indicating that groundwater was disconnected from the stream, although recharge to the groundwater system was likely occurring when water flowed in the creek.

ES 5 SUMMARY OF CONDITIONS AND RECOMMENDATIONS

Groundwater level monitoring was conducted at a total of 113 sites across Napa County in 2015 (**Table ES-1)**. The overall number and distribution of monitored sites remained consistent with the monitoring conducted in 2014 and was increased relative to the 87 sites reported in the 2011(LSCE, 2013a).

Groundwater level trends in the Napa Valley Subbasin of the Napa-Sonoma Valley Groundwater Basin are stable in the majority of wells with long-term groundwater level records. While many wells have shown at least some degree of response to recent drought conditions, the water levels observed in recent years are generally higher than groundwater levels in the same wells during the 1976 to 1977 drought. Elsewhere in the County long-term groundwater level records are limited, with the exception of the Milliken-Sarco-Tulucay (MST) Subarea.

Although designated as a groundwater subarea for local planning purposes, the majority of the MST is not part of a groundwater basin as mapped by DWR. Groundwater level declines observed in the MST Subarea as early as the 1960s and 1970s have stabilized since about 2008. Groundwater level responses differ within the MST Subarea and even within the north, central, and southern sections of this subarea, indicating that localized conditions, whether geologic or anthropogenic in nature, might be the primary influence on groundwater conditions in the subarea.

While the majority of wells with long-term groundwater level records exhibit stable trends, periods of year to year declines in groundwater levels have been observed in a few wells. These wells are located near the Napa Valley margin in the northeastern Napa Subarea (NapaCounty-75 and Napa County-76), southwestern Yountville Subarea (NapaCounty-135) and southeastern St. Helena Subarea (NapaCounty-132). These locations are characterized in part by relatively thin alluvial deposits, which may contribute to more groundwater being withdrawn from the underlying semi-consolidated deposits.

Water levels in northeastern Napa Subarea wells NapaCounty-75 and Napa County-76, east of the Napa River, have stabilized since 2009, though declines were observed over roughly the prior decade. Despite the recent stability, given the potential for a hydraulic connection between the aquifer units in the vicinity of these wells and the aquifer units of the MST Subarea and an apparent increase in the number of new well permits in the area over the past 10 years[2], further study in this area is recommended.

Water levels at NapaCounty-135 and NapaCounty-132 declined most distinctly between 2013 and 2014. The increased monitoring frequency at these wells through the end of 2015 has shown groundwater levels already recovering to levels comparable to or higher than those of spring 2013. Groundwater level

[2] In a Memorandum to David Morrison, Director of Planning, Building, and Environmental Services, dated December 7, 2015 regarding groundwater conditions in the northeastern corner of the Napa Subarea Steven Lederer, Director of Public Works, noted that "12 of the approximately 30 homes on Petra Drive have applied for new well permits in the past 10 years."

declines in these wells observed in 2014 could have one or more contributing factors, including variations in groundwater recharge due to changes in the timing and intensity of precipitation and changes in the level of pumping at the monitored well or in the vicinity of the monitored well. Continuation of the increased monitoring frequency through 2016 is recommended to assist with interpretation of conditions at these wells in the future.

Groundwater quality data show stable conditions between 2009 and 2015 compared to the conditions reported previously with data through 2008 (LSCE, 2011a). Water quality standard exceedances in the Napa Valley Floor subareas and Napa Valley Subbasin were limited to the naturally-occurring constituent arsenic, with 4 of 26 sites showing maximum concentrations above the MCL of 10 µg/L. Water quality standard exceedances in the Napa-Sonoma Lowlands Subbasin, including portions of the Carneros and Jameson/American Canyon Subareas, occurred for arsenic (three wells), nitrate (one well), TDS (five wells).

Wells with long-term water quality data show stable TDS and Nitrate concentrations, with the exception of one well (06N04W27L002M) which had a peak of 7.7 mg/L NO3-N (nitrate as nitrogen) in 2007 compared to initial concentrations of 3.4 mg/L NO3-N and 4.0 mg/L NO3-N in 1982 and 1972, respectively. In the Napa-Sonoma Lowlands Subbasin, nitrate concentrations have been stable to decreasing in all five wells with long-term records in the Napa-Sonoma Lowlands Subbasin. Two wells have shown increasing TDS trends, though all four wells with long-term trends were initially at or above the secondary MCL.

The following recommendations have been developed based on the findings presented in this report.

ES 5.1 Northeast Napa Subarea Special Study

Previously observed groundwater level declines in the northeast Napa Subarea, east of the Napa River in the vicinity of NapaCounty-75 and NapaCounty-76, along with reports of increased well replacement activity along Petra Drive have raised questions about the cumulative impacts of existing and potential future groundwater use in this area. In addition to completing the standard project-level planning review of the proposed projects, a focused study of hydrogeologic conditions affecting groundwater availability is advisable for this area. The investigation should be designed to address existing and future water use in the area, sources of groundwater recharge, and the geologic setting in order to address the potential for cumulative impacts of future development. The investigation would also seek to address the influence of previously documented groundwater cones of depression in the MST subarea on both the study area east of the Napa River and the Napa Subarea west of the Napa River.

ES 5.2 Data Gap Refinement

Groundwater levels in two monitored wells located near to the Napa Valley margin showed year to year declines in groundwater levels. Additional information is needed in order to consider the full range of possible causes for these declines and more accurately determine if the present emerging trends. Recommended actions include a review of land use data in these areas and continuation of the increased frequency of data collection at a subset of wells. More frequent data collection could be accomplished, pending agreement with the well owner, by monthly manual groundwater level measurements.

For wells added to the County's monitoring networks in recent years without a record of key well construction details, continued efforts to locate construction information and link those data with aquifer units is recommended. In cases where a well owner does not have a record of the construction, a review of Well Completion Reports is recommended.

Once final Groundwater Sustainability Plan regulations are published by DWR later in 2016, there may be a need to add one or more wells to the CASGEM network near the southern boundary of the Napa Valley Subbasin. A well or wells in this area would be used to monitor groundwater gradients at the basin boundary where subsurface outflow occurs into the Napa-Sonoma Lowlands Subbasin. This data will be a component of the subbasin water budget that will be a key feature of the quantitative approach to groundwater management described in SGMA. For similar reasons, the County may benefit from updating reference point elevation data for some monitored wells with surveyed values in order more accurately monitor groundwater level gradients and any potential future seawater intrusion.

ES 5.3 Baseline Water Quality Sampling

The groundwater quality monitoring objectives contained in the *Napa County Groundwater Monitoring Plan 2013* (Plan) included the investigating of variations in water quality at different points within the groundwater subareas and at different aquifer units within a given subarea (LSCE, 2013a). The Plan recommended baseline sampling in wells at each of 18 Areas of Interest for additional monitoring and at the then proposed dedicated surface water-groundwater monitoring wells. It is recommended that wells added to the County monitoring networks in these areas be reviewed for suitability in light of the groundwater quality monitoring objectives, with baseline sampling conducted for those wells with sufficient well construction records to enable interpretation of the results for specific aquifer units.

A second round of baseline water quality sampling is also recommended for the five dual-completion monitoring wells constructed in 2014 at surface water-groundwater monitoring sites, as described in the Plan. An initial round of sampling and analysis was completed in June 2015 with a combination of County matching funds, DWR grant funds, and DWR in-kind support. Sampling these wells again in 2016 will provide a more robust baseline dataset that would be used to characterize any inter-annual variability at each well and provide a basis for interpreting future groundwater quality data.

ES 5.4 Coordination with Other Monitoring Efforts

Coordination with other county departments and other agencies that monitor groundwater data or receive groundwater data could provide an additional source of data in places where data are limited. Several local agencies, including Town of Yountville, City of St. Helena, City of Napa, already monitor groundwater levels at locations around the County.

1 INTRODUCTION

1.1 Purpose

Groundwater and surface water are highly important natural resources in Napa County. Together, the County and other municipalities, water districts, commercial and industrial operations, the agricultural community, and the general public, are stewards of the available water resources. Everyone living and working in Napa County has a stake in protecting the county's groundwater resources; including groundwater supplies, quality, and associated watersheds (GRAC, 2014). Without sustainable groundwater resources, the character of the County would be significantly different in terms of its economy, communities, rural character, ecology, housing, and lifestyles.

Similar to other areas in California, businesses and residents of Napa County face many water-related challenges including:

- Sustaining the quality, availability and reliability of local and imported water supplies;
- Meeting challenges arising during drought conditions;
- Avoiding environmental effects due to water use; and
- Changes in long-term availability due to global warming and/or climate change.

To address these challenges, long-term, systematic monitoring programs are essential to provide data that allow for improved evaluation of water resources conditions and to facilitate effective water resources planning. In 2009, Napa County embarked on a countywide project referred to as the "Comprehensive Groundwater Monitoring Program, Data Review, and Policy Recommendations for Napa County's Groundwater Resources" (Comprehensive Groundwater Monitoring Program), to meet identified action items in the 2008 General Plan update. The program emphasizes developing a sound understanding of groundwater conditions and implementing an expanded groundwater monitoring and data management program as a foundation for future coordinated, integrated water resources planning and dissemination of water resources information.

On June 28, 2011, the Napa County Board of Supervisors adopted a resolution to establish a Groundwater Resources Advisory Committee (GRAC), and an outreach effort for applicants began. On September 20, 2011, the Board of Supervisors appointed 15 residents to the GRAC, and the GRAC held its first organizational meeting on October 27, 2011. The members represented diverse interests, including environmental, agricultural, development, and community interests.

The GRAC was created to assist County staff and technical consultants with recommendations regarding:

- Synthesis of existing information and identification of critical data needs;
- Development and implementation of an ongoing non-regulatory groundwater monitoring program;
- Development of revised well pump test protocols and related revisions to the County's groundwater ordinance;
- Conceptualization of hydrogeologic conditions in various areas of the County and an assessment of groundwater resources as data become available;
- Development of groundwater sustainability objectives that can be achieved through voluntary means and incentives; and
- Building community support for these activities and next steps.

From January 2012 until January 2013, the GRAC reviewed and provided feedback on the development of the *Napa County Groundwater Monitoring Plan 2013* (Plan) (LSCE, 2013a). The Plan was prepared to formalize and augment groundwater monitoring efforts [levels and quality] to better understand the groundwater resources of Napa County, aid in making the County eligible for public funds administered by the California Department of Water Resources (DWR), and regularly evaluate trends to identify changes in levels and/or quality and factors related to those changes that warrant further examination to ensure sustainable water resources. The Plan included refinement of criteria used to identify priority monitoring areas and a proposed expanded monitoring network.

The Napa County groundwater monitoring program relies on both publicly-owned and volunteered private wells. To fulfill its mission and garner community interest and support, the GRAC developed a Communication and Education Plan, designed to implement the Plan through voluntary participation. This effort included the development of an outreach brochure and a series of fact sheets on specific topics.

Some of the many activities accomplished by the GRAC over a two and a half year period included:

- Provided updates to agriculture industry groups, environmental organizations and others;
- Led and supported outreach efforts to well owners for volunteer monitoring wells which has been very successful in adding new wells to the Napa County groundwater monitoring program;
- Held a joint public outreach meeting of the GRAC and Watershed Information and Conservation Council (WICC) Board (July 25, 2013);
- Reviewed and recommended modifications to the Napa County Water Availability Analysis and Groundwater Ordinance; and
- Developed and approved Groundwater Sustainability Objectives (GRAC, 2014).

The Plan recommended annual reports on groundwater conditions and modifications to the countywide groundwater monitoring program as needed. Additionally, the Plan recommended a comprehensive triennial report. This report is the second Annual Report – *Napa County Comprehensive Groundwater Monitoring Program 2015 Annual Report and CASGEM[3] Update* (Report).

1.2 Organization of Report

This Report summarizes activities implemented as part of the County’s Comprehensive Groundwater Monitoring Program to improve the understanding of groundwater resource conditions and availability. This Report summarizes groundwater monitoring needed to fill the data gaps (i.e., relatively higher monitoring priorities) that were established in the Plan, recommendations made to address these priorities, and activities implemented since 2014. This Report also summarizes the overarching groundwater level and quality monitoring objectives defined by the County and the GRAC. These objectives provide the framework necessary to ensure that the data collected from the countywide monitoring facilities can address these objectives.

This Report includes the following sections:

[3] CASGEM is the California Statewide Groundwater Elevation Monitoring program implemented under Water Code Part 2.11 Groundwater Monitoring and administered by DWR.

Section 2: Hydrogeology of Napa County

- DWR Basins/Subbasins and County Subareas
- Summary of Geology and Groundwater Resources
- Overview of Recent Groundwater Studies and Programs

Section 3: Groundwater Resources Goals and Monitoring Objectives

- Napa County Water Resources Goals and Policies
- Groundwater Level Monitoring Objectives
- Groundwater Quality Monitoring Objectives

Section 4: Groundwater Monitoring Network Design and Development

- Groundwater Level Monitoring
- Surface Water-Groundwater Monitoring

Section 5: Groundwater Level Trends and Flow Directions

- Napa Valley Floor Subareas
- Subareas South of the Napa Valley Floor
- Subareas East and West of the Napa Valley Floor
- Angwin and Pope Valley Subareas
- Napa Valley Surface Water-Groundwater Monitoring

Section 6: Groundwater Quality Conditions and Trends

- Napa Valley Floor Subareas
- Subareas South of the Napa Valley Floor
- Subareas East and West of the Napa Valley Floor
- Angwin and Pope Valley Subareas

Section 7: Coordination and Collaboration

- Integrated Regional Water Management Plans
- Groundwater Sustainability
- Napa County Watershed Information and Conservation Council

Section 8: Summary and Recommendations

- Ongoing Vetting and Review of Potential Monitoring Sites
- Data Gap Refinement
- Baseline Water Quality Sampling
- Coordination with Other Monitoring Efforts
- Existing Activities in the MST Subarea

2 HYDROGEOLOGY OF NAPA COUNTY

This section summarizes the countywide geologic and hydrologic setting, and includes information about DWR groundwater basin/subbasin delineations and a description of the Napa County groundwater monitoring subareas. The studies that form the basis of the understanding of County hydrogeology are referenced, including the work for the *Updated Hydrogeologic Conceptualization and Characterization of Conditions* (LSCE and MBK, 2013).

2.1 DWR Basins/ Subbasins and County Subareas

DWR has identified the major groundwater basins and subbasins in and around Napa County. The basins include the Napa-Sonoma Valley (which in Napa County includes the Napa Valley and Napa-Sonoma Lowlands Subbasins), Berryessa Valley, Pope Valley, and a small part of the Suisun-Fairfield Valley Groundwater Basins (**Figure 2-1**). These basins and subbasins are generally defined based on boundaries to groundwater flow and the presence of water-bearing geologic units. These groundwater basins defined by DWR are not confined within county boundaries, and DWR-designated “basin” or “subbasin” designations do not cover all of Napa County.

Groundwater conditions outside of the DWR-designated basins and subbasins are also very important in Napa County. An example of such an area is the Milliken-Sarco-Tulucay (MST) area, a locally identified groundwater deficient area. For purposes of local planning, understanding, and studies, the County has been subdivided into a series of groundwater subareas (**Figure 2-2**). These subareas were delineated based on the main watersheds, groundwater basins, and the County’s environmental resource planning areas. These subareas include the Knoxville, Livermore Ranch, Pope Valley, Berryessa, Angwin, Central Interior Valleys, Eastern Mountains, Southern Interior Valleys, Jameson/American Canyon, Napa River Marshes, Carneros, Western Mountains Subareas and five Napa Valley Floor Subareas (Calistoga, St. Helena, Yountville, Napa, and MST).

DWR has given the Napa Valley Subbasin a “medium priority”[4] ranking according to the criteria specified in California Water Code Part 2.11 Groundwater Monitoring (i.e., this relates to the CASGEM program).

2.2 Summary of Geology and Groundwater Resources

2.2.1 Previous Studies

Previous hydrogeologic studies of Napa County and also mapping efforts are divisible into geologic studies and groundwater studies. The more significant studies and mapping efforts are mentioned in this section. **Table 2-1** shows the chronological sequence of these efforts that span more than six decades. Weaver (1949) presented geologic maps which covered the southern portion of the county and provided a listing of older geologic studies. Kunkel and Upson (1960) examined the groundwater and geology of the northern portion of the Napa Valley. DWR (Bulletin 99, 1962) presented a reconnaissance report on the geology and water resources of the eastern area of the County; Koenig (1963) compiled a regional geologic map which encompasses Napa County. Fox and others (1973) and Sims and others (1973) presented more detailed geologic mapping of Napa County. Faye (1973) reported on the

[4] As part of the CASGEM Program, DWR has developed the Basin Prioritization process. The California Water Code (§10933 and §12924) requires DWR to prioritize California’s groundwater basins and subbasins statewide. As such, DWR developed the CASGEM Groundwater Basin Prioritization Process. Details are available at http://www.water.ca.gov/groundwater/casgem/basin_prioritization.cfm.

groundwater of the northern Napa Valley. Johnson (1977) examined the groundwater hydrology of the MST area.

Helley and others (1979) summarized the flatland deposits of the San Francisco Bay Region, including those in Napa County. Fox (1983) examined the tectonic setting of Cenozoic rocks, including Napa County. Farrar and Metzger (2003) continued the study of groundwater conditions in the MST area.

Wagner and Bortugno (1982) compiled and revised the regional geologic map of Koenig (1963). Graymer and others (2002) presented detailed geologic mapping of the southern and portions of the eastern areas of the County, while Graymer and others (2007) compiled geologic mapping of the rest of Napa County.

In 2005 to 2007, DHI Water & Environment (DHI) contributed to the 2005 *Napa County Baseline Data Report* (DHI, 2006a and Jones & Stokes et al., 2005) which was part of the County's General Plan update (Napa County, 2008). A groundwater model was developed by DHI in conjunction with the Napa Valley and Lake Berryessa Surface Water models to simulate existing groundwater and surface water conditions on a regional basis primarily in the North Napa Valley and the MST and Carneros Subareas (DHI, 2006b). A 2007 technical memorandum, *Modeling Analysis in Support of Vineyard Development Scenarios Evaluation* (DHI, 2007), was prepared to document the groundwater model update which was used to evaluate various vineyard development scenarios.

Additional geologic maps, groundwater studies, and reports are listed in the references of the *Napa County Groundwater Conditions and Groundwater Monitoring Recommendations* (LSCE, 2011a). Additional work has been conducted to update the conceptualization and characterization of hydrogeologic conditions particularly for the Napa Valley Floor (LSCE and MBK, 2013 and LSCE, 2013b).

A new project, "Napa County Groundwater/Surface Water Monitoring Facilities to Track Resource Interrelationships and Sustainability", is currently underway (LSCE, in progress). This project, which is supported through grant funding from DWR, involves the installation of shallow dual-completion groundwater monitoring facilities at five sites adjacent to the Napa River system. The goals of the project are to implement groundwater and surface water monitoring to characterize the interrelationship between these water resources in Napa Valley. The project includes gathering data to:

1. Assess the response to surface water and groundwater use and the potential effect of future climate changes, and
2. Ensure water resources sustainability for the natural environment and future generations. The facilities will enable the collection of new data to augment existing monitoring activities and datasets and will fill groundwater data gaps previously identified by Napa County.

Table 2-1 Summary and Chronology of Hydrogeologic and Geologic Studies and Mapping Efforts in Napa County

Hydrogeologic and/or Geologic Studies and Mapping Efforts	Year of Report or Map Publication							
	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010-2019
Weaver, 1949	◆ (Report and Map produced)							
Kunkel and Upson,1960			◆ (Report and Map produced)					
DWR, 1962			◆ (Report only)					
Koenig, 1963			◆ (Map only)					
Fox et al., 1973				◆ (Report only)				
Sims et al., 1973				◆ (Map only)				
Faye, 1973				◆ (Report and Map produced)				
Johnson, 1977				◆ (Report only)				
Helley et al., 1979				◆ (Report and Map produced)				
Wagner and Bortugno, 1982					◆ (Map only)			
Fox, 1983					◆ (Report and Map produced)			
Graymer et al., 2002							◆ (Map only)	
Farrar and Metzger, 2003							◆ (Report and Map produced)	
Graymer et al., 2007							◆ (Map only)	
DHI, 2006 and 2007							◆ (Report only)	
LSCE, 2011a								◆ (Report only)
LSCE and MBK, 2013								◆ (Report and Map produced)
LSCE, 2013a								◆ (Report only)
LSCE, 2013b								◆ (Report only)
LSCE, 2014								◆ (Report only)
LSCE, 2015								◆ (Report and Map produced)

◆ = Report and Map produced

◆ = Report only

◆ = Map only

2.2.2 Precipitation Monitoring and Water Year Classifications

Infiltration of precipitation has been shown to provide significant groundwater recharge in Napa County, particularly in unconsolidated geologic settings (Kunkel and Upson 1960, LSCE and MBK 2013).

Precipitation records in Napa County date to 1906 at the longest continually operating gauge at the Napa State Hospital (GHCND: USC00046074). In a separate analysis precipitation data from the Napa State Hospital gauge in Napa (elevation 35 feet) have been shown to have strong linear correlations (i.e., $R^2 \geq 0.90$) with monthly and annual precipitation totals from two other gauges in Saint Helena (elevation 1,780 feet) and Angwin (elevation 1,815 feet) (2NDNature, 2014). Based on the strength of those correlations, the Napa State Hospital gauge has been recommended for use as an index gauge for the Napa River Watershed.

The water year classification presented in **Table 2-2** is revised from the version developed by 2NDNature (2014) and presented in the 2014 Annual Report (LSCE, 2015). The classification presented here accounts for gaps in the daily precipitation record at the Napa State Hospital gauge. Specifically, missing daily precipitation data in the Napa State Hospital gauge record from water years 1920 through 2015 were estimated based on daily data from the Saint Helena precipitation gauge (GHCND: USC0004764) and Oakville precipitation gauge (elevation: 190 feet, CIMIS Station No. 77). These gauges show very strong linear correlations (i.e., $R^2 > 0.99$) for cumulative daily data from the Napa State hospital gauge. Estimated daily precipitation values were calculated to fill gaps in the Napa State Hospital gauge record using observed values form either the Oakville or Saint Helena gauges and the linear regression for cumulative daily precipitation between those gauges and the Napa State Hospital gauge.

A frequency analysis was used to define very dry, dry, normal, wet, and very wet water year types according to exceedance probabilities calculated from the 96-year period of record for precipitation at the Napa State Hospital gauge from water years 1920 through 2015. Data from water years prior to 1920 were excluded from the frequency analysis due to large gaps in the Napa State Hospital gauge record prior to that year that were not able to be estimated using data from other gauges.

Table 2-2 Napa River Watershed Water Year Classification

Year Type	Water Year Precipitation Total		Annual Precipitation Exceedance Probability (%)	Number of Years in Period of Record
	Lower Bound (inches)	Upper Bound (inches)		
Very Dry		15.19	≥ 91	9
Dry	15.20	19.67	≥ 67	23
Normal	19.68	26.99	≥ 33	33
Wet	27.00	36.75	≥ 10	22
Very Wet	36.76		< 10	9
Napa State Hospital (NSH) Average Annual Water Year Precipitation (1920 – 2015) = 24.86 inches Period of record used for frequency analysis: 1920 – 2015				

2.2.3 Summary of Geology and Groundwater Resources

The geology of Napa County can be divided into three broad geologic units based on their ages and geologic nature. These units are: 1) Mesozoic Basement Rocks (pre-65 million years (my)), which underlie all of Napa County, but are primarily exposed in the Eastern County area and the Western Mountains Subarea, 2) Older Cenozoic Volcanic and Sedimentary Deposits (65 my to 2.5 my), including Tertiary Sonoma Volcanics (Miocene and Pliocene; 10 my to 2.5 my) which are found throughout the county, especially in the mountains surrounding Napa Valley, and 3) Younger Cenozoic Volcanic and Sedimentary Deposits (post 2.6 my to present), including the Quaternary alluvium of the Valley Floor. The two primary water-bearing units in the county are the tuffaceous member of the Sonoma Volcanics and the Quaternary alluvium.

Outside of the Napa Valley Floor, percolation of surface water appears to be the primary source of recharge. The rate of recharge within areas such as the MST Subarea has been shown to be significantly higher where streams and tributaries cross highly permeable outcrops (e.g., the tuffaceous member of the Sonoma Volcanics or shallow alluvium). Direct infiltration of precipitation is a major component of recharge in the main Napa Valley. Recharge throughout much of the county is generally limited by underlying shallow bedrock of low permeability. An additional component of groundwater recharge that is less understood is deep percolation through fractured rock and fault zones. This type of recharge can be very difficult to quantify due to the highly variable size and distribution of faults, fractures, and joints in a given area.

Groundwater Occurrence and Quality in the Sonoma Volcanics

Groundwater occurs in the Sonoma Volcanics in Napa County and yields water to wells. Well yields are highly variable from less than 10 to several hundred gallons per minute (gpm). The most common yields are between 10 to 100 gpm. Faye (1973) reported well-test information which showed an average yield of 32 gpm and an average specific capacity of 0.6 gallons per minute per foot of drawdown. From the available well log data, the Tertiary marine sedimentary rocks are poor groundwater producers either for a lack of water or poor water quality (high salinity). At great depths, groundwater quality in the Tertiary marine sedimentary rocks is generally poor due to elevated chloride concentrations.

According to Kunkel and Upson (1960), groundwater in the Sonoma Volcanics is generally of good quality except in three areas. The first area with poor groundwater quality, the Tulucay Creek drainage basin, east of the City of Napa, contains groundwater with elevated iron, sulfate, and boron. The Suscol area, south of the City of Napa, is the second area where some wells exhibit poor quality groundwater due to elevated chloride concentrations, possibly from leakage from salty water in the Napa River, alluvial material above, or the existence of zones of unusually saline connate water deep within the Sonoma Volcanics. The third area of poor groundwater quality, the Calistoga area in the northern end of the Napa Valley, contains isolated wells with naturally occurring elevated chloride, boron, and some trace metal concentrations.

Kunkel and Upson (1960) reported that the principal water yielding units of the Sonoma Volcanics are the tuffs, ash-type beds, and agglomerates. The lava flows were reported to be generally non-water bearing. However, it may be possible that fractured, fragmental, or weathered lava flows could yield water to wells. The hydrogeologic properties of the volcanic-sourced sedimentary deposits of the Sonoma Volcanics are complex and poorly understood.

Groundwater Occurrence in Other Units and in the Quaternary Sedimentary Deposits

Several hundred wells and test holes on record have been drilled into the exposed Huichica Formation. Well yields tend to be low to modest (< 10 gpm to tens of gpm). Only a few known wells on record are completed in the Clear Lake Volcanics near the northern County line. Three wells report high yields of 400 to 600 gpm. Much of the Clear Lake Volcanics to the south appear to be thinner, limited in extent, and in ridge-top locations where possible groundwater production appears to be less likely.

Groundwater production from Quaternary alluvium is variable, with yields ranging from <10 gpm in the East and West mountainous areas to a high of 3,000 gpm along the Napa Valley Floor where the alluvium is thickest (>200 feet). According to Faye (1973), average yield of wells completed in the alluvium is 220 gpm. Many wells drilled in the alluvium within the last 30 years extend beyond the alluvium and into the underlying Cenozoic units. Kunkel and Upson (1960) report that groundwater in the alluvium is generally of good quality. The groundwater is somewhat hard and of the bicarbonate type, with small concentrations of sulfate, chloride, and total dissolved solids. A few isolated areas have increased chloride and boron concentrations.

2.3 Recent Groundwater Studies and Programs

This section summarizes the recently completed studies by Napa County and the recommendations relevant to ongoing groundwater monitoring that were developed.

2.3.1 Napa County's Comprehensive Groundwater Monitoring Program

In 2009, Napa County implemented a Comprehensive Groundwater Monitoring Program to meet action items identified in Napa County's 2008 General Plan update (Napa County, 2008). The program emphasizes developing a sound understanding of groundwater conditions and implementing an expanded groundwater monitoring and data management program as a foundation for future coordinated, integrated water resources planning and dissemination of water resources information. The program (and the Plan (LSCE, 2013a)) covers the continuation and refinement of countywide groundwater level and quality monitoring efforts (including many basins, subbasins and/or subareas throughout the county) for the purpose of understanding groundwater conditions (i.e., seasonal and long-term groundwater level trends and also quality trends) and availability. This information is critical to enable integrated water resources planning and the dissemination of water resources information to the public and state and local decision-makers. Napa County's combined efforts through the Comprehensive Groundwater Monitoring Program along with the related AB 303 Public Outreach Project on groundwater (CCP, 2010) and the efforts of the WICC of Napa County create a foundation for the County's continued efforts to increase public outreach and participation in water resources understanding, planning, and management.

Napa County's Comprehensive Groundwater Monitoring Program involved many tasks that led to the preparation of five technical memorandums and a report on *Napa County Groundwater Conditions and Groundwater Monitoring Recommendations* (LSCE, 2011a). This report and the other related documents can be found at: http://www.napawatersheds.org/. The report documents existing knowledge of countywide groundwater conditions and establishes a framework for the monitoring and reporting of groundwater levels and groundwater quality on a periodic basis. The report also summarizes priorities for groundwater level and quality monitoring for each of the county subareas.

As described above, the *Napa County Groundwater Monitoring Plan 2013* (LSCE, 2013a) was prepared to formalize and augment groundwater monitoring efforts [levels and quality] to better understand the groundwater resources of Napa County, aid in making the County eligible for public funds administered by the California Department of Water Resources (DWR), and regularly evaluate trends to identify changes in levels and/or quality and factors related to those changes that warrant further examination to ensure sustainable water resources. The Plan included refinement of criteria used to identify priority monitoring areas and a proposed expanded monitoring network. During Plan implementation, the GRAC led and supported outreach efforts to well owners for volunteer monitoring wells; the GRAC efforts were very successful in adding new wells to the Napa County groundwater monitoring program.

2.3.2 Napa County Statewide Groundwater Elevation Monitoring (CASGEM)

This section describes the DWR California Statewide Groundwater Elevation Monitoring (CASGEM) program. The wells included by the County in the CASGEM program are a *subset* of the overall network of wells monitored in Napa County.

In November 2009, Senate Bill SBX7 – 6 mandated that the groundwater elevations in all basins and subbasins in California be regularly and systematically monitored with the goal of demonstrating seasonal and long-term trends in groundwater elevations. In accordance with the mandate, DWR developed the CASGEM program. DWR is facilitating the statewide program which began with the opportunity for local entities to apply to DWR to assume the function of regularly and systematically collecting and reporting groundwater level data for the above purpose. These entities are referred to as Monitoring Entities.

Wells designated for inclusion in the CASGEM program are for purposes of measuring groundwater levels on a semi-annual or more frequent basis that are representative of groundwater conditions in the state's groundwater basins and subbasins. A key aspect of the program is to make certain elements of the groundwater level information available to the public.

On December 29, 2010, the County applied to DWR to become the local countywide Monitoring Entity responsible for designating wells as appropriate for monitoring and reporting groundwater elevations for purposes of the CASGEM program.

The wells selected by the County for this program are a *subset* of the overall wells monitored, i.e., the County has a much larger overall monitoring network. The County's participation in the CASGEM program complements other pre-existing groundwater monitoring that has been ongoing in Napa County for some time (the overall historical monitoring record began in 1920).

Following confirmation, the County, as the Monitoring Entity, proceeded to identify a *subset* of monitored wells to be included in the CASGEM network and to prepare a CASGEM Network Plan as required by DWR (LSCE, 2011b and LSCE, 2014). At the time the County's CASGEM Network Plan was initially submitted to DWR, fourteen wells were included in the program. DWR formally designated Napa County as the Monitoring Entity for two basins in August 2014, specifically:

- Napa County was designated as the Monitoring Entity for the 2-2.01 Napa Valley Subbasin (medium priority basin)
- Napa County was designated as the Monitoring Entity for the 2-2.03 Napa-Sonoma Lowlands Subbasin in Napa County (very low priority basin)

During the initial CASGEM monitoring year (beginning 2011), the County continued to monitor 14 wells that had already been part of the group of wells where groundwater levels are measured by the County and reported to DWR semi-annually, or are measured directly by DWR. The current 2014 CASGEM network wells are located primarily on the Napa Valley Floor, Carneros Subarea, and in the MST Subarea. Some of these wells do not have sufficient construction details to define which portion of the aquifer system is represented by measured water levels. Additional data gathering and surveying will be performed, and such information will be provided in future annual reports as it becomes available. Depending on the results of the County’s evaluation, future actions may include removal and replacement of CASGEM wells with wells that are more representative of local groundwater conditions to better meet the objectives of the CASGEM program and also overall objectives of the County’s Comprehensive Groundwater Monitoring Program.

In addition to the CASGEM well network described herein, the County is currently exploring the availability of additional monitoring wells in the Pope Valley Groundwater Basin[5]. Public outreach is underway through community organizations and other contacts. The Berryessa Valley Groundwater Basin has a very low DWR priority and extremely small utilization of groundwater[6]. Per discussions with DWR, outreach will continue but no monitoring is planned in this groundwater basin at this time. The County has submitted detailed information to DWR to support consideration of the removal of this basin through a Bulletin 118 update or other appropriate process (LSCE, 2014).

The Suisun-Fairfield Valley Basin and the Napa-Sonoma Lowlands Subbasin are two examples of basins that do not conform to county boundaries, and they are also basins with a very low-priority designation from DWR. While these two basins have low groundwater utilization and less extensive monitoring than other basins, they are situated adjacent to the bay and delta water ways and are important areas to monitor for protection against saltwater intrusion. The Suisun-Fairfield Valley Basin, which is mostly in Solano County and has only a very small area (less than 0.3% of the total basin area) in Napa County, is being monitored in its entirety by Solano County Water Agency as the CASGEM Monitoring Entity for Solano County. The monitoring of Napa-Sonoma Lowlands Subbasin, whose area is shared with Solano County in more equitable portions (63% in Napa County, 37% in Solano County), is anticipated to have monitoring that is coordinated between the two respective Monitoring Entities in the future. Currently, all monitoring is within the Napa County portion of the subbasin; in the future, monitoring in this subbasin will expand as necessary to ensure representative coverage and as coordinated between the two Monitoring Entities.

2.3.3 Updated Conceptualization and Characterization of Hydrogeologic Conditions

In 2012, activities were implemented to update the characterization and conceptualization of hydrogeologic conditions (LSCE and MBK, 2013). This work included: 1) an updated Napa Valley hydrogeologic conceptualization, 2) linking well construction information to groundwater level monitoring data, 3) groundwater recharge characterization and estimates, and 4) surface water/groundwater interrelationships.

Updated Napa Valley Geologic Conceptualization

As part of the updated hydrogeologic conceptualization (LSCE and MBK, 2013), eight cross- valley geologic sections were constructed (**Figure 2-3**). About 1,300 water well drillers’ reports were reviewed and located on topographic base maps; 191 of these were selected for use in the cross sections.

[5] DWR Overall Basin Ranking Score is “0.0”; the very low priority basin ranking range is 0-5.4. http://www.water.ca.gov/groundwater/casgem/pdfs/basin_prioritization/NCRO%2074.pdf

[6] DWR Overall Basin Ranking Score is “0.0”; the very low priority basin ranking range is 0-5.4. http://www.water.ca.gov/groundwater/casgem/pdfs/basin_prioritization/NCRO%2062.pdf

Geologic correlations seen on the cross sections were extended between sections by available well control and surficial geologic maps. From the geologic cross-sections and correlations of other water well drillers' reports, the Quaternary alluvium was separated from underlying units, and an isopach (contours of equal thickness) map was constructed.

The alluvium was divided into three facies according to patterns detected in the lithologic record and used to delineate the depositional environment which formed them: fluvial, alluvial fan, and sedimentary basin (LSCE and MBK, 2013 and LSCE, 2013b). The fluvial facies consists of a thin narrow band of stream channel sands and gravels deposited by the Napa River. The sand and gravel beds tend to be thicker and/or more numerous in the fluvial facies area. They are interbedded with finer-grained clay beds of probable floodplain origin. Wells constructed in the fluvial facies tend to be moderately high yielding (for the valley, roughly 50 to 200 gpm). Local areas where thicker sand and gravel beds are reported, the well yields are the highest in the valley, ranging from about 200 to 2,000 gpm.

These areas with thick sand and gravel beds occur in the Yountville Narrows area, which extends about five miles from Oakville south to Ragatz Lane. Local areas of relatively lower well yield values of 200 to 500 gpm occur to the north and south. Hydraulic properties of these deposits are recorded during airlift testing, and drawdown values are generally not reported. Only a few pump test results have been found, and these are in the high yielding area just north of the Yountville Narrows.

The alluvial plain facies of the Quaternary alluvium extends outward from the central fluvial facies and thins to zero thickness at the edge of the valley sides. These deposits appear to have been deposited as tributary streams and alluvial fans. These deposits appear to consist of interbedded sandy clays with thin beds (less than 10 feet thick) of sand and gravel. Wells constructed in the alluvial plain facies tend to be low yielding, ranging from a few gpm to a few tens of gpm. By at least 1970, most wells drilled on the alluvial plain facies were constructed to deeper depths into the underlying Sonoma Volcanics.

The alluvial facies shows some overlap with the shallowest depths to groundwater, as measured in spring 2010 (**Figures 2-4, 2-5, and 2-6**). These areas of overlap occur generally to the west of the Napa River and adjacent to mapped perennial streams, including Hopper Creek, Sulpher Creek, York Creek, Bale Slough (west of Highway 29), and possibly Dry Creek. These areas represent somewhat likely areas of connection between surface waters (including the Napa River and perennial streams described above) and groundwater.

At the northern end of the lower valley, the sedimentary basin facies of the alluvium occurs. This facies is characterized by fine-grained silt, sand, and clays with thin to scattered thicker beds of sand and gravel. The sedimentary facies is believed to be floodplain deposits that extend to the southern marshland/estuary deposits. As noted, the extent of this facies is poorly known due to lack of well control farther south. Limited information indicates low to moderate well yields of a few gpm to possibly up to 100 gpm. Again, the lack of pump test information makes hydraulic properties of the deposits difficult to assess.

Napa Creek and the Napa River east of Highway 29 in the vicinity of downtown Napa show a connection with groundwater in this portion of the Napa Valley (**Figure 2-6**).

Portions of Napa Valley north of Deer Park Road were not characterized according to their Quaternary alluvial facies by LSCE and MBK (2013). However, depths to groundwater in the vicinity of monitored wells indicate the potential for connection between surface water and groundwater in the vicinity of Garnett Creek and Cyrus Creek in and near Calistoga (**Figure 2-6**).

Beneath the alluvium is a complex sequence of Tertiary sedimentary deposits (Huichica Formation) and igneous deposits of the Sonoma Volcanics. These units are strongly deformed by folding and faulting and have complex stratigraphic relationships. From the geologic cross-sections, lateral correlations, and surficial map relationships, a structure contour map (elevations) of the top of these units and the subcrop[7] pattern were developed (LSCE and MBK, 2013). From north of the City of Napa and southward, these deposits are dominated by fine-grained basin fill with few sand and gravels of floodplain, estuary origin. North towards Yountville, sedimentary deposits of the Huichica Formation appear to overlie Sonoma Volcanics andesites and tuffs. Sonoma Volcanics and the older Mesozoic Great Valley sequence are exposed in a structural uplift area in the small hills in the Yountville area.

Further north, a Sonoma Volcanics andesite flow breccia appears to transition into a sedimentary conglomerate along the center of the valley. This unit is encountered in deep, high yielding wells also completed in the overlying alluvium fluvial facies, but it is not clear if this unit also is high yielding. Overlying the conglomerate/breccia on the east is the Tertiary sedimentary deposits sequence (Huichica Formation) of sandstones and mudstones. To the west of the unit occur older Sonoma Volcanics andesites, tuffs in the south, and possibly younger Sonoma Volcanics tuffs interbedded with Tertiary sedimentary deposits (Huichica Formation) of sand and gravels and clays. All of the Tertiary units beneath the Napa Valley Floor appear to be low to moderately water yielding with poor aquifer characteristics (LSCE and MBK, 2013).

Linking Well Construction Information to Groundwater Monitoring Data

As part of the updated hydrogeologic characterization, existing monitoring well construction data from all available public sources were reviewed to determine the distribution of aquifer-specific monitoring data in Napa Valley. This effort addresses recommendations of the Comprehensive Groundwater Monitoring Program to identify and fill data gaps that will allow for analysis of groundwater occurrence and flow as a more robust understanding of the extent of groundwater resources in the county is developed. A major component of this work has been to identify construction information for previously monitored wells in Napa Valley.

Groundwater level monitoring needs identified through the Comprehensive Groundwater Management Program include improved spatial distribution of groundwater level monitoring, additional characterization of subsurface geologic conditions in county subareas to identify aquifer characteristics, further examination of well construction information to define which portion of the aquifer system is represented by water levels measured in the currently monitored wells (and in many cases to link construction information to the monitored wells), and improve the understanding of surface water/groundwater interactions and relationships.

Groundwater Recharge Characterization and Estimates

Another important feature of the updated hydrogeologic investigation was the development of improved characterization of groundwater recharge in the areas of greatest groundwater development, with an emphasis on Napa Valley. Understanding the volume of and mechanisms driving groundwater recharge in the county are essential in determining where and how much groundwater can be produced without incurring negative impacts (LSCE, 2011a). The high permeability of the alluvial sediments in the Napa Valley permits precipitation and surface water to readily infiltrate and recharge groundwater throughout the majority of the valley. These high permeability soils combined with the large volume of

[7] Occurrence of strata in contact with the undersurface of a stratigraphic unit, which in this case includes the strata beneath the alluvium.

water that flows through the Napa River create the potential for significant recharge to occur under the hydrologic circumstances and hydraulic gradient that allow for recharge from the river to groundwater to occur.

Mass balance and streamflow infiltration methods were used to estimate regional and local recharge. Streamflow infiltration can be characterized by comparing the elevation of surface water to the shallowest adjacent groundwater. Detailed remotely sensed elevation data of the mainstem Napa River and several major tributaries were obtained for this purpose. LiDAR data were paired with previously collected groundwater level data and estimates of areas of greatest recharge potential to estimate the potential for recharge to groundwater.

In addition, mass balance recharge estimates have been developed for the Napa River watershed and major tributary watersheds using a range of available data (LSCE and MBK, 2013). Available records for streamflow, precipitation, land use, and vegetative cover throughout these watersheds have been used to develop spatially-distributed estimates of annual hydrologic inputs and outputs in order to solve for the volume of groundwater recharge at the watershed scale. Key components of this work included quantifying the distribution of precipitation across the land surface, quantifying the amount of water that returns to the atmosphere by evapotranspiration, and quantifying the hydraulic properties of soil and alluvial materials through which water must infiltrate to reach groundwater. Estimates developed through the mass balance approach have been evaluated using a sensitivity analysis to determine the degree to which any individual or set of inputs affects the recharge estimate.

Groundwater-Surface Water Interrelationships

Depth to Groundwater Relative to Stream Thalweg

The groundwater surface elevation and the estimated stream thalweg elevation data are important components for characterizing the groundwater-surface water relationship in the Napa Valley area. The spring 2010 contours of equal groundwater elevation were used to provide a snapshot representation of groundwater conditions with which to compare the vertical relationship between groundwater and surface water (LSCE and MBK, 2013 and LSCE, 2013b). This spatial relationship assisted in developing an understanding of the nature of water exchange between the groundwater and surface water systems. This analysis focused specifically on the degree of connectivity between the Napa River thalweg and the elevation of the regional groundwater surface in the Napa Valley in spring 2010.

Calculated depths to groundwater equal to or above the estimated thalweg alignment indicate that for spring 2010 the interpreted groundwater elevation was above the bottom of the Napa River thalweg. The data suggest areas where a direct connection between the water table and the river may have existed in spring 2010 and where groundwater has the potential to discharge into the stream channel. In other areas, the depth to groundwater is below the bottom of the Napa River thalweg such that surface flows in the river have the potential to percolate and recharge the groundwater system.

Despite the uncertainty in the data in parts of the valley, depths to groundwater (both measured and calculated) show generally shallow groundwater throughout much of the valley, particularly in the northern end of the valley. The calculated depths to groundwater appear to be reasonably represented in the Napa Subarea east of the Napa River because this area has the greatest density of monitored sites. **Figure 2-6** presents the depths to groundwater for Napa Valley based on water level measurement for wells constructed in the alluvial aquifer system (LSCE, 2013b). This figure reflects the generally shallow groundwater levels measured particularly along the axis of the valley.

Other Areas of County

Potential connections between surface water and groundwater in other areas of the county are less well known. Perennial water courses have been mapped by Napa County in other portions of the county with state-designated groundwater basins. In the Pope Valley Groundwater Basin, these include Pope Creek, Burton Creek, and Maxwell Creek. In the small portion of the Suisun-Fairfield Valley Groundwater Basin that extends into Napa County, in the Southern Interior Valley Subarea, Wooden Valley Creek is mapped as a probable perennial stream.

Blueline Stream Locations

Napa County's Planning, Building, and Environmental Services Department maintains a GIS dataset of perennial streams throughout the county, included as a part of the larger "bluelines" shapefile (LSCE, 2013b). The dataset includes both unnamed and 48 named streams, creeks, rivers, and other surface water courses classified as known perennial or probable perennial (**Figure 2-7**). The known and probable classifications are a subset of all water courses originally digitized from U.S. Geological Survey (USGS) topographic maps of Napa County. Metadata for the dataset describe the known perennial water courses as those determined by "stream reports or other known data sources", while probable perennial water courses are defined as having been determined by "computer analysis of probable streams". As shown in **Figure 2-7**, known or probable perennial water courses are present in all Napa County subareas except for the Livermore Ranch, Knoxville, Berryessa, and Jameson/American Canyon Subareas.

3 GROUNDWATER RESOURCES GOALS AND MONITORING OBJECTIVES

3.1 Napa County Water Resources Goals and Policies

The County's General Plan (2008, amended June 23, 2009) recognizes, "water is one of the most complex issues related to land use planning, development, and conservation; it is governed and affected by hundreds of federal, state, regional, and local mandates pertaining to pollution, land use, mineral resources, flood protection, soil erosion, reclamation, etc. Every year, the state legislature considers hundreds of bills relating to water issues, and in Napa County, more than two dozen agencies have some say in decisions and regulations affecting water quality and water use."

As part of the General Plan update in 2008, and within the Conservation Element, six goals are set forth relating to the county's water resources, including surface water and groundwater. Complementing these goals are twenty-eight policies and ten water resources action items (one of which is "reserved" for later description). Napa County's six water resources goals are included below (the entire group of water resources goals, policies, and action items is included in LSCE, 2011a).

Goal CON-8: Reduce or eliminate groundwater and surface water contamination from known sources (e.g., underground tanks, chemical spills, landfills, livestock grazing, and other dispersed sources such as septic systems).

Goal CON-9: Control urban and rural storm water runoff and related non-point source pollutants, reducing to acceptable levels pollutant discharges from land-based activities throughout the county.

Goal CON-10: Conserve, enhance and manage water resources on a sustainable basis to attempt to ensure that sufficient amounts of water will be available for the uses allowed by this General Plan, for the natural environment, and for future generations.

Goal CON-11: Prioritize the use of available groundwater for agricultural and rural residential uses rather than for urbanized areas and ensure that land use decisions recognize the long-term availability and value of water resources in Napa County.

Goal CON-12: Proactively collect information about the status of the County's surface and groundwater resources to provide for improved forecasting of future supplies and effective management of the resources in each of the County's watersheds.

Goal CON-13: Promote the development of additional water resources to improve water supply reliability and sustainability in Napa County, including imported water supplies and recycled water projects.

Addressing the six water resources goals above, Napa County has produced specific General Plan Action Items related to the focus and objective of this Plan. Those action items include:

Action Item CON WR-1: Develop basin-level watershed management plans for each of the three major watersheds in Napa County (Napa River, Putah Creek, and Suisun Creek). Support each basin-level plan with focused sub-basin (drainage-level) or evaluation area-level implementation strategies, specifically adapted and scaled to address identified water resource problems and restoration opportunities. Plan development and implementation shall utilize a flexible watershed approach to manage surface water and groundwater quality and quantity. The watershed planning process should be an iterative, holistic, and collaborative approach, identifying specific drainage areas or watersheds, eliciting stakeholder involvement, and developing management actions supported by sound science that can be effectively implemented. [Implements Policies 42 and 44]

Action Item CON WR-4: Implement a countywide watershed monitoring program to assess the health of the County's watersheds and track the effectiveness of management activities and related restoration efforts. Information from the monitoring program should be used to inform the development of basin-level watershed management plans as well as focused sub-basin (drainage-level) implementation strategies intended to address targeted water resource problems and facilitate restoration opportunities. Over time, the monitoring data will be used to develop overall watershed health indicators and as a basis of employing adaptive watershed management planning. [Implements Policies 42, 44, 47, 49, 63, and 64]

Action Item CON WR-6: Establish and disseminate standards for well pump testing and reporting and include as a condition of discretionary projects that well owners provide to the County upon request information regarding the locations, depths, yields, drilling and well construction logs, soil data, water levels and general mineral quality of any new wells. [Implements Policy 52 and 55]

Action Item CON WR-7: The County, in cooperation with local municipalities and districts, shall perform surface water and groundwater resources studies and analyses and work toward the development and implementation of an integrated water resources management plan (IRWMP) that covers the entirety of Napa County and addresses local and state water resource goals, including the identification of surface water protection and restoration projects, establishment of countywide groundwater management objectives and programs for the purpose of meeting those objectives, funding, and implementation. [Implements Policy 42, 44, 61 and 63]

Action Item CON WR-8: The County shall monitor groundwater and interrelated surface water resources, using County-owned monitoring wells and stream and precipitation gauges, data obtained from private property owners on a voluntary basis, data obtained via conditions of approval associated with discretionary projects, data from the State Department of Water Resources, other agencies and organizations. Monitoring data shall be used to determine baseline water quality conditions, track groundwater levels, and identify where problems may exist. Where there is a demonstrated need for additional management actions to address groundwater problems, the County shall work collaboratively with property owners and other stakeholders to prepare a plan for managing groundwater supplies pursuant to State Water Code Sections 10750-10755.4 or other applicable legal authorities. [Implements Policy 57, 63 and 64]

Action Item CON WR-9.5: The County shall work with the SWRCB[8], DWR, DPH, CalEPA, and applicable County and City agencies to seek and secure funding sources for the County to develop and expand its groundwater monitoring and assessment and undertake community-based planning efforts aimed at developing necessary management programs and enhancements.

[8] SWRCB is the California State Water Resources Control Board. DPH is the California Department of Public Health.

The County continues to address the General Plan goals and actions. Additionally, through the efforts embarked upon through the implementation of the County's Comprehensive Groundwater Monitoring Program, those persons whose livelihoods depend upon the county's natural resources can help ensure the sustainability of groundwater resources for future generations and the environment.

Based on the GRAC's charge from the Napa County Board of Supervisors and a review of many definitions in published literature, the GRAC (2014) defined "groundwater sustainability[9]" as:

> *Groundwater sustainability depends on the development and use of groundwater in a manner that can be maintained indefinitely without causing unacceptable economic, environmental, or social consequences, while protecting economic, environmental, and social benefits.*

The GRAC concluded that groundwater sustainability is both a goal and a process; most importantly, it is a shared responsibility. Everyone living and working in the county has a stake in protecting groundwater resources; including groundwater supplies, quality, and associated watersheds (GRAC, 2014). The GRAC further found that healthy communities, healthy agriculture and healthy environments exist together and not in isolation. Without sustainable groundwater resources, the character of the county would be significantly different in terms of its economy, communities, rural character, ecology, housing, and lifestyles.

The GRAC also developed a set of groundwater sustainability objectives (GRAC, 2014):

1. Initiate and carry out outreach and education efforts.
    a. Develop public outreach programs and materials to make everyone who lives and works in the County aware that the protection of water supplies is a shared responsibility and everyone needs to participate.
    b. Through education, enable people to take action.
2. Optimize existing water supplies and systems.
    a. Support landowners in implementing best sustainable practices.
    b. Enhance the water supply system and infrastructure – including but not limited to system efficiencies, reservoir dredging, recycled water, groundwater storage and recharge, conjunctive use – to improve water supply reliability.
3. Continue long-term monitoring and evaluation.
    a. Collect groundwater and surface water data and maintain a usable database that can provide information about the status of the county's groundwater and surface water resources and help forecast future supplies.
    b. Evaluate data using best analytical methods in order to better understand characteristics of the county's groundwater and water resources systems.
    c. Share data and results of related analytical efforts while following appropriate confidentiality standards.
4. Improve our scientific understanding of groundwater recharge and groundwater-surface water interactions.

[9] The definition for Groundwater Sustainability developed by the GRAC is separate from the definition of Sustainable Groundwater Management applied in the 2014 Sustainable Groundwater Management Act, see Section 7.2 of this Report for additional information.

5. Improve preparedness to address groundwater issues that might emerge.
    a. Improve preparedness for responding to long-term trends and evolving issues, such as adverse groundwater trends (including levels and quality), changes in precipitation and temperature patterns, and saltwater intrusion.
    b. Improve preparedness for responding to acute crises, such as water supply disruptions and multiyear drought conditions.

3.2 Overarching Groundwater Monitoring Objectives

This section describes the water level and quality objectives established for the countywide Comprehensive Groundwater Monitoring Program[10] (LSCE, 2013a). The overarching groundwater monitoring objectives are linked to 1) the County's General Plan goals and action items presented above, and 2) hydrogeologic conditions and potential areas of concern, including (but not limited to):

- Monitoring trends in groundwater levels and storage (e.g., groundwater balance) to assess and ensure long-term groundwater availability and reliability;
- Monitoring of groundwater-surface water interactions to ensure sufficient amounts of water are available to the natural environment and for future generations;
- Monitoring in significant recharge areas to assess factors (natural and human-influenced) that may affect groundwater recharge (including climate change) and also aid the identification of opportunities to enhance groundwater recharge and storage;
- Monitoring to establish baseline conditions in areas of potential saline water intrusion;
- Monitoring of general water quality to establish baseline conditions, trends, and protect and preserve water quality.
- Identify where data gaps occur in the key subareas and provide infill, replacement, and/or project-specific monitoring (e.g., such as may occur for planned projects or expansion of existing projects) as needed; and
- Coordinate with other entities on the collection, utilization, and incorporation of groundwater level data in the countywide Data Management System (DMS).

Although this Report focuses on an update of the groundwater monitoring network and groundwater level trends and conditions, groundwater quality objectives are also included for completeness.

[10] These objectives were developed by the Napa County GRAC prior to passage of the 2014 Sustainable Groundwater Management Act. SGMA defines Measurable Objectives as quantitative means of evaluating the efficacy of groundwater basin management, which is different from the approach applied by the GRAC.

3.2.1 Groundwater Level Monitoring Objectives

The focus of the countywide groundwater level monitoring program includes the following objectives:

- Expand groundwater level monitoring in priority County subareas to improve the understanding of the occurrence and movement of groundwater; monitor local and regional groundwater levels including seasonal and long-term trends; and identify vertical hydraulic head differences in the aquifer system and aquifer-specific groundwater conditions, especially in areas where short- and long-term development of groundwater resources are planned (this includes additional monitoring of the Tertiary formation aquifer in the area between the NVF-MST Subarea and the northeastern part of the NVF-Napa Subarea to determine whether groundwater water conditions in the NVF-MST are affecting other areas (LSCE and MBK, 2013);
- Detect the occurrence of, and factors attributable to, natural (e.g., direct infiltration of precipitation, surface water seepage to groundwater, groundwater discharge to streams) or induced factors (e.g., pumping, purposeful recharge operations) that affect groundwater levels and trends;
- Identify appropriate monitoring sites to further evaluate groundwater-surface water interaction and recharge/discharge mechanisms, including whether groundwater utilization is affecting surface water flows;
- Establish a monitoring network to aid in the assessment of changes in groundwater storage; and
- Generate data to better estimate groundwater basin conditions and assess local current and future water supply availability and reliability; update analyses as additional data become available.

Based on the analysis of existing groundwater data and conditions described in the report *Napa County Groundwater Conditions and Groundwater Monitoring Recommendations* (LSCE, 2011a) and with input received from the GRAC, the key objectives for future groundwater level monitoring for each subarea are summarized in the Plan (LSCE, 2013a).

3.2.2 Groundwater Quality Monitoring Objectives

The primary objectives of the countywide groundwater quality monitoring program include (LSCE, 2013a):

- Evaluate groundwater quality conditions in the various county subareas and identify differences in water quality spatially between areas and vertically in the aquifer system within a subarea;
- Detect the occurrence of and factors attributable to natural (e.g., general minerals and trace metals) or other constituents of concern;
- Establish baseline conditions in areas of potential saltwater intrusion, including the extent and natural occurrence and/or causes of saltwater beneath the Carneros, Jameson/American Canyon and Napa River Marshes Subareas;
- Assess the changes and trends in groundwater quality; and
- Identify the natural and human factors that affect changes in water quality.

Based on the analysis of existing groundwater data and conditions described in the report *Napa County Groundwater Conditions and Groundwater Monitoring Recommendations* (LSCE, 2011a) and with input received from the GRAC, the key objectives for future groundwater quality monitoring for each subarea are summarized in the Plan (LSCE, 2013a).

4 GROUNDWATER MONITORING NETWORK

4.1 Groundwater Level Monitoring

Groundwater level monitoring was conducted at a total of 113 sites across Napa County in 2015 (**Table 4-1)**. The overall number and distribution of monitored sites remained consistent with the monitoring conducted in 2014 and was increased relative to the 87 sites reported in the 2011(LSCE, 2013a). **Figure 4-1** shows the distribution of sites monitored in 2015 according to the monitoring entity.

Table 4-1 Current Groundwater Level Monitoring Sites in Napa County by Reporting Entity

Entity	Reporting Program	Number of Monitored Sites, Fall 2015
Napa County	CASGEM	28
	State Water Data Library	19
	County Volunteer Groundwater Monitoring Program	48
	Surface Water-Groundwater Monitoring	10
California Department of Water Resources	Volunteered Sites	4
State Water Resources Control Board	Geotracker	9
	Total Sites	**113**

Out of the total 113 sites monitored in 2015, 100 were monitored by Napa County. Four sites were monitored by DWR. The remaining nine sites were regulated facilities with data reported as part of the State Water Resources Control Board (SWRCB) Geotracker Program (**Table 4-1**).

Minor reductions in the number of sites monitored by Napa County between 2014 and 2015 occurred due to a combination of well-owner requests and decisions by the Napa County Department of Public Works. In the latter case, three wells were discontinued by the County where other nearby monitored wells were determined to be sufficient to meet the monitoring objectives. Three additional wells were added to the County's monitoring networks during 2015 based on requests by well owners for monitoring by the County in areas where additional monitoring sites were needed.

Additional summary information for currently monitored sites is provided in **Appendix A**.

Table 4-2 Current Groundwater Level Monitoring Sites in Napa County by Groundwater Subarea

Groundwater Subarea	Number of Monitored Sites Through 2011	Number of Monitored Sites, Fall 2014	Number of Monitored Sites, Fall 2015
Napa Valley Floor-Calistoga	6	10	9
Napa Valley Floor-MST	29	27	27
Napa Valley Floor-Napa	18	21	20
Napa Valley Floor-St. Helena	12	14	14
Napa Valley Floor-Yountville	9	12	14
Carneros	5	12	12
Jameson/American Canyon	1	1	1
Napa River Marshes	1	1	-
Angwin	-	5	5
Berryessa	3	2	3
Central Interior Valleys	1	1	2
Eastern Mountains	-	3	4
Knoxville	1	-	-
Livermore Ranch	-	-	-
Pope Valley	1	1	1
Southern Interior Valleys	-	-	-
Western Mountains	-	2	1
Unknown[1]	-	3	-
Total Sites	**87**	**115**	**113**

[1] In 2014 three sites in the Geotracker regulated groundwater monitoring network were reporting groundwater level data, but had not yet reported location information for the monitored wells.

4.1.1 Napa County Monitoring Network

In 2015, Napa County conducted semi-annual groundwater level monitoring at 82 sites across the county, with the majority of sites located within the Napa Valley Floor Subareas. Eight sites were monitored by Napa County on a monthly interval, to begin to address temporal data gaps identified in the 2014 Annual Monitoring Report (LSCE, 2015). Five sites were monitored using continuously recording instrumentation at dedicated monitoring wells constructed as part of the County's Surface Water–Groundwater Monitoring Project.

4.1.2 CASGEM Monitoring Network

As of fall 2015 the Napa County CASGEM Monitoring Network included 23 privately-owned wells monitored by Napa County and the five dual-completion dedicated monitoring wells from the Surface Water-Groundwater Monitoring Project (**Figure 4-3**). Wells in the CASGEM monitoring network are distributed across all five Napa Valley Floor Subareas (Calistoga, St. Helena, Yountville, Napa, and MST) as well as the Carneros, Angwin, Eastern Mountains, and Western Mountains Subareas (**Table 4-3**). Half of the CASGEM Network wells in Napa County, 14, are located in the medium priority Napa Valley

Subbasin of the Napa-Sonoma Valley Groundwater Basin (**Table 4-4**). In addition, six CASGEM Network wells are located in the very low priority Napa-Sonoma Lowlands Subbasin of the Napa-Sonoma Valley, while eight are not located in any groundwater basin or subbasin.

Table 4-3 Current CASGEM Network Sites in Napa County by Groundwater Subarea

Groundwater Subarea	Number of Monitored Sites, Fall 2015
Napa Valley Floor-Calistoga	1
Napa Valley Floor-MST	4
Napa Valley Floor-Napa	6
Napa Valley Floor-St. Helena	4
Napa Valley Floor-Yountville	4
Carneros	6
Jameson/American Canyon	-
Napa River Marshes	-
Angwin	1
Berryessa	-
Central Interior Valleys	-
Eastern Mountains	1
Knoxville	-
Livermore Ranch	-
Pope Valley	-
Southern Interior Valleys	-
Western Mountains	1
Total Sites	**28**

4.1.3 DWR Monitoring Network

The DWR currently monitors four wells in Napa County as part of its voluntary groundwater monitoring efforts (**Table 4-1**). Three of these sites are monitored at monthly intervals, while one is monitored semi-annually. These wells are located in each of the Napa Valley Floor subareas, excluding the MST Subarea.

Table 4-4 Current CASGEM Network Sites in Napa County by Groundwater Basin

Basin Name	Subbasin Name	Number of Monitored Sites, Fall 2015
Napa-Sonoma Valley	Napa Valley	14
Napa-Sonoma Valley	Napa-Sonoma Lowlands	6
Berryessa Valley	-	-
Pope Valley	-	-
Suisun-Fairfield Valley	-	-
Non-basin Areas	-	8
	Total Sites	**28**

4.1.4 State Water Resources Control Board Geotracker Network

The State Water Resources Control Board (SWRCB) stores environmental data for regulated facilities in California in their Geotracker database, including groundwater levels and groundwater quality. Data from these regulated facilities usually includes manual measurements and samples from groundwater monitoring wells (typically shallow) at each site. Groundwater level data are available for 9 Geotracker sites located throughout Napa County in 2015 (**Table 4-1**). The groundwater level monitoring frequency is typically semi-annual or quarterly, although more frequent measurements are sometimes recorded. Geotracker sites with data reported in 2015 were located in the Napa Valley Floor-Napa, Berryessa, and Central Interior Valleys subareas (**Figure 4-1**).

4.2 Surface Water-Groundwater Monitoring

Funding from the DWR 2012 Local Groundwater Assistance Grant Program enabled Napa County to construct ten monitoring wells at five sites in Napa Valley in September 2014. These wells comprise the groundwater monitoring facilities for the Napa County Surface Water-Groundwater Monitoring Project. In addition to grant funding from DWR, Napa County is providing matching funds to cover a portion of the monitoring well construction and instrumentation costs.

4.2.1 Monitoring Network

Figure 4-4 shows the location of the five project sites, with four sites along the Napa River and one adjacent to Dry Creek. The five sites selected for the project are within the Napa, Yountville, and St. Helena Subareas of the Napa Valley Floor. These are three of the six subareas where paired surface water-groundwater monitoring was recommended in the 2013 Plan (**Table 2-3**).

Each of the five sites includes a dual-completion monitoring well to enable monitoring of groundwater conditions at specific depth intervals. These dual-completion wells consist of two separate casings in a single borehole. Each casing is independent of the other with distinct total depths and screen intervals.

The construction details for each casing were developed based on sites specific hydrogeologic and surface water channel considerations.

In general, groundwater monitoring facilities at each site consist of one shallow casing constructed to represent groundwater conditions at the water table surface and at elevations similar to the adjacent surface water channel. The second casing at each site is constructed to a deeper depth with screen intervals coinciding with aquifer materials and depths likely to be accessed by production wells in the vicinity. Paired casings are separated within the borehole by intermediate seals designed to provide a physical separation such that groundwater conditions reflected by each casing are not influenced by conditions in other portions of the groundwater system.

5 GROUNDWATER LEVEL TRENDS AND FLOW DIRECTIONS

Groundwater data availability in Napa County varies widely among the subareas. The bulk of the historical and current groundwater level and quality data is located in the Napa Valley Floor Subarea with limited to no data in the other Napa County subareas. This section presents discussions of groundwater levels, with a focus on groundwater level characteristics by subarea.

Napa County received below average precipitation at the Napa State Hospital gauge during water years[11] 2012, 2013, 2014, and 2015. Water year 2013 registered as a Dry year on the five stage rating system of Very Dry, Dry, Normal, Wet and Very Wet water year types (**Table 5-1**). Since 1949 when most long-term groundwater monitoring records begin, comparable multi-year periods with below average precipitation occurred in 1990 – 1991 (both Dry), 1976 – 1977 (both Very Dry), and 1959 – 1962 (all Dry), 1954 – 1955 (both Dry), and 1947-1949 (all Dry).

Successive years of below average precipitation in water years 2012 through 2015 provide an important context for the review of recent groundwater level trends. **Figure 5-1** depicts both the annual water year precipitation recorded at the Napa State Hospital gauge along with the cumulative departure from the mean water year precipitation value for water years 1970 through 2015 The cumulative departure values calculated for **Figure 5-1** provide a tally of precipitation received relative to the mean value over time.

Notably, the eight-year span from 1987 through 1994, with only one year of above average precipitation, resulted in a net cumulative departure deficit of 38.55 inches (**Figure 5-1**). This protracted period contrasts with the Very Dry years of 1976 and 1977, which although more acute, produced a less severe net cumulative departure deficit of 26.13 inches. Groundwater level records from the Napa Valley Groundwater Subbasin that include both of these time periods generally show the lowest spring groundwater levels in 1977, as compared to the 1987 to 1994 period. This indicates that the subbasin experienced sufficient recharge to maintain relatively stable spring groundwater levels over an eight-year period when precipitation totals were below average on the whole.

The four year span from 2012 through 2015 produced a net cumulative departure deficit of 17.04 inches.

[11] A water year is defined as the period from October 1 through the following September 30 and is numbered according to the calendar year on its final day. In this way, water years maintain continuity between the times when water supplies typically increase and the following dry season when water demand is greatest.

Table 5-1 Recent Napa State Hospital Annual Precipitation Totals and Napa River Watershed Water Year Types

Water Year	Annual Precipitation (in) (updated values from LSCE)	Water Year Type
2009	21.31	Normal (below average)
2010	28.85	Wet
2011	36.62	Wet
2012	21.75	Normal (below average)
2013	20.26	Normal (below average)
2014	19.67	Dry
2015	20.72	Normal (below average)
Napa State Hospital (NSH) Average Annual Water Year Precipitation (1920 – 2015) = 24.86 inches		

Geologic setting and differences in aquifer zones within a subarea or groundwater subbasin are additional considerations relevant to the interpretation of groundwater levels, particularly for wells constructed entirely or partially within the alluvium in Napa Valley. **Figure 5-2** depicts two wells located relatively near each other at the land surface which exhibit distinct groundwater levels due in part to having been constructed within different aquifer zones. Well 07N05W09Q2 is located near the center of Napa Valley, where the alluvium extends to approximately 200 feet below ground surface (LSCE and MBK, 2013). NapaCounty-138 has a total depth of 321 feet and is located closer to the western edge of Napa Valley in an area where the alluvium extends only about 50 feet below ground surface. The lower static water levels measured in the fall at NapaCounty-138 indicate that the well draws water from a geologic formation below the alluvium. Knowledge of the geologic setting and construction details for a given well are important considerations when interpreting groundwater level data.

Figure 5-3 depicts another example of the influence that aquifer zones can have on water levels in wells located in the same area. In this case, the well located east of the Napa River is constructed in the Sonoma Volcanics, while the wells west of the Napa River are constructed within alluvial sediments. Additional discussion of these wells is provided in **Section 5.1.2**.

The groundwater elevation contours described below are derived from available depth to water measurements made in wells. Prior to interpolating groundwater elevations across the valley, depth to water values were converted to groundwater elevation values by subtracting the measured depth to water from the reference point elevation at each monitored well. In this way the depth to water measurements were related to the North American Vertical Datum 1988 (NAVD88) as a standard point of reference. The resulting groundwater elevation values at each well were used to interpolate groundwater elevation contours throughout the Napa Valley Floor and in the MST area. A contour line represents a line of equal elevation of the water surface similar to the way a topographic map contour line shows a line of equal elevation of ground surface. The direction of groundwater flow is perpendicular to the contour lines.

5.1 Napa Valley Floor Subareas

The Napa Valley Floor Subarea is subdivided into five smaller subareas. From north to south these areas are Calistoga, St. Helena, Yountville, Napa, and the MST. The groundwater level conditions in each of these areas are described below.

Over the length of the Napa Valley, groundwater is contained in and moves primarily through the older and younger alluvium from Calistoga to San Pablo Bay, and is assumed for purposes of contouring groundwater data on a regional basis, to represent a single aquifer. Groundwater levels that were determined to represent a non-alluvial part of the aquifer system were excluded from the contouring dataset.

Interpreted groundwater elevation contours for spring and fall 2015 are shown in **Figures 5-4** and **5-5,** respectively. Groundwater elevation contours for Napa Valley spring 2015 appear similar to those developed for spring 2014 and spring 2010 (LSCE, 2013b and 2015). Contours across these time periods show a generally southeasterly to east-southeasterly groundwater gradient paralleling the valley axis from Calistoga to Yountville with similar groundwater elevation ranges. In the southern portion of the valley, near the City of Napa, contours indicate a more eastward flow direction consistent with the spring 2014 contours. Through the valley, groundwater elevations in spring 2015 ranged from 378 feet near Calistoga to 5 feet along the Napa River near First Street in Napa.

5.1.1 Napa Valley Floor – Calistoga and St. Helena Subareas

The hydrographs for the representative wells illustrated on **Figure 5-6** show groundwater elevations and corresponding depth to groundwater from 1970 to present, as available. Groundwater levels have been generally stable over time in the Calistoga Subarea and northern portion of the St. Helena Subarea. Groundwater levels in the representative wells are frequently very shallow at less than ten feet below the ground surface in the spring. Minor seasonal groundwater level variations of about 10 feet occur between spring and fall in the Calistoga Subarea. Groundwater levels in well 8N6W10Q1 have been lower in the late September to December timeframe in seven years since 2001. However, in every year since 1970, including 2015 groundwater levels returned to within 10 feet of the ground surface the following spring.

Elsewhere in the St. Helena Subarea, groundwater levels exhibit greater seasonal declines of about 20 feet. Groundwater levels at well 7N5W09Q2 have remained relatively stable although somewhat susceptible to dry years. An example of this occurred in 1976 and 1977, two Very Dry years in the Napa River Watershed. In 1976, the spring groundwater level measurement was 19.3 feet below ground surface, lower by more than 10 feet from the prior spring. In 1977, the spring groundwater level measurement was 27.2 feet below ground surface, down almost 8 feet from the spring 1976 measurement. Spring water levels in the same well in 2014 and 2015 were 18.6 feet and 13.2 feet below ground surface, respectively; the spring 2014 and 2015 levels are above the levels measured in 1976 and 1977.

NapaCounty-132 was noted in the 2014 Annual Monitoring Report for possible signs of declining water levels. This well is recorded as having a total depth of 265 feet, screened from 25 feet to 265 feet, in an area where the thickness of alluvial deposits is likely less than 100 feet. The Driller's Log for the well indicates extensive clay (or fine grained, low permeability) layers were encountered, particularly in the upper 100 feet of the boring. In spring 2015 a depth to groundwater of 16.1 feet was measured at this well, which is more comparable to levels seen prior to 2014. A site visit to this well conducted in 2015 showed that much of the surrounding acreage is planted in young vines. A subsequent review of aerial photography showed that a large scale vineyard replanting took place in 2007. Given these observations it is possible that changing irrigation demands have been a factor in this area since 2007.

5.1.2 Napa Valley Floor – Yountville and Napa Subareas

The representative hydrographs shown in **Figure 5-7** show groundwater elevations and corresponding depths to water in the Yountville and Napa Subareas. Long-term groundwater elevations have remained for the most part stable in the Yountville Subarea. In the Yountville Subarea, the depth to groundwater in the spring is generally less than ten feet, similar in nature to the Calistoga and St. Helena Subareas to the north. Seasonal fluctuations vary by proximity to the center of the valley. Along the western and eastern edges of the subarea, levels are more subject to larger seasonal fluctuations. Groundwater elevations in the center of the valley fluctuate seasonally approximately 10 to 25 feet, and near the edge of the valley fluctuate approximately 25 to 35 feet.

In the Napa Subarea, depth to water ranges from about 20 to 50 feet below ground surface during the spring. Seasonal groundwater elevations in this subarea generally fluctuate from 10 to 40 feet. Long-term trends have been generally stable with the exception of the northeastern area at NapaCounty-75 and Napa County-76 where groundwater levels have locally declined by about 20 feet to 30 feet over the past 15 years[12]. Reasons for the declines in water levels at these wells are not yet fully understood. One possible factor is that lowered groundwater elevations in the northern MST Subarea could be drawing water from the northeast corner of the Napa Subarea towards the MST Subarea. Another possible factor is that the northeast corner of the Napa Subarea experiences limited groundwater recharge compared to the rest of the Napa Subarea as a result of being bounded by the East Napa Fault and Soda Creek Fault (**Figure 5-8**).

NapaCounty-75 and NapaCounty-76 are located east of the Napa River and East Napa Fault and west of Soda Creek Fault. Both wells are completed below the alluvium in the Sonoma Volcanics formation. The Sonoma Volcanics formation is also present in the MST Subarea to the east, where previous monitoring has shown several pumping depressions (LSCE, 2011a). The two nearest monitoring wells located west of the Napa River in the northeastern Napa Subarea constructed to depths of 120 feet or less and are completed in the alluvium. These wells have shown stable groundwater level trends. The monitoring well in the alluvium that is closest to the well constructed in the Sonoma Volcanics has shown stable water levels since the 1960s. It appears that the extent of the pumping depression beyond the MST subarea is limited to the northeastern Napa Subarea east of the Napa River.

Although NapaCounty-75 is no longer actively monitored by Napa County, two additional wells have been added to the County's monitoring networks in this area in the last two years, NapaCounty-182 and NapaCounty-228. In addition to adding new monitoring wells in the northeast portion of the Napa Subarea, the County is considering a focused investigation of groundwater conditions and hydrogeologic constraints in the area east of the Napa River and west of the Soda Creek Fault to address concerns regarding groundwater conditions in this area.

In the southwestern part of the Yountville Subarea and at the Napa Valley margin, groundwater levels in well NapaCounty-135 have also declined by about 30 feet since the first measurements were recorded in the late 1970s and early 1980s, with a particularly low spring groundwater level measurement recorded in 2014. In response to these observations Napa County began monitoring this well at monthly intervals in summer 2015. The increased frequency of data collection is intended to fill temporal data

[12] NapaCounty-75 is among the wells that left the monitoring network in 2015. The latest available measurement from this well was recorded in October 2014.

gaps in the record for this well to understand whether groundwater levels are recovering at different times relative to other wells.

Very little construction information is available for NapaCounty-135. All that is known is that it has a total depth of 125 feet. It is located in an area where the total thickness of the alluvium is likely less than 50 feet, based on contours of alluvium thickness developed as part of the Updated Hydrogeologic Conceptualization and Characterization of Conditions Report (LSCE and MBK Engineers, 2013).

In March 2015, the water level at NapaCounty-135 rebounded to a depth of 40.9 feet, comparable to the value recorded in 2013. The dedicated monitoring wells for Site 2 of the Surface Water Groundwater Monitoring Project are less than a mile from NapaCounty-135. Data from those wells will also be used in the future to differentiate between observations at that well and water level trends in the alluvial aquifer system at Site 2.

5.1.3 Napa Valley Floor – Milliken-Sarco-Tulucay (MST) Subarea

Although designated as a groundwater subarea for local planning purposes, the majority of the MST is not part of a groundwater basin as mapped by DWR. In the MST, the aquifer system is composed primarily of the Sonoma Volcanics and associated Tertiary sedimentary deposits. These aquifer materials have different hydraulic properties than the Napa Valley alluvial deposits and the level of communication and connectivity between the two areas is believed to be limited. Groundwater levels used for contour mapping in the MST Subarea generally represent conditions of a composite aquifer system as previously described by Farrar and Metzger (2003).

Historically, groundwater flow directions in the MST Subarea were generally from the Howell Mountains in the east toward the Napa River to the west. Beginning in the 1970s, investigators have identified pumping depressions in the northern, central, and southern parts of the MST (Johnson 1975, Farrar and Metzger 2003). The current coverage of wells does not extend to the former location of the central (and deepest) pumping depression and therefore flow directions cannot be visualized and evaluated; however, the coverage does extend to the former locations of the northern and southern depressions, and they are shown in the spring and fall 2015 groundwater level contour maps (**Figure 5-8** and **5-9**).

In the northern MST, groundwater flow directions in 2015 were more varied than in 2014. The highest groundwater elevations occurred between Monticello Road and Hagen Road along the lower one mile of Sarco Creek. Groundwater flow directions were to the east and north of this area. Flows to the east were towards an area of -40 feet groundwater elevations. Flows to the north were toward Milliken Creek where two monitored wells recorded spring groundwater elevations of -14 feet and -18 feet, respectively. A positive groundwater elevation value of 3 feet recorded at a well along Hardman Avenue indicates a southward flow direction in that vicinity.

In the southern MST, groundwater flow continues to be generally northwest (unchanged direction since 2008) in the spring and fall 2015with a minimum spring groundwater elevation of about -45 feet (NAVD88) in the southern MST; however, the western portion of this area has no coverage of wells with water levels which would be necessary to define the extent of the pumping depression.

Representative hydrographs for the MST illustrated on **Figures 5-10 and 5-11** show groundwater elevations and corresponding depth to groundwater since 1970 in the northern (**Figure 5-10**) and central/southern parts of the MST (**Figure 5-11**). In the northern MST, groundwater levels were stable throughout the late seventies until the mid-1980s (1986), at which time a decline of about 10 to 40 feet occurred. Following this decline, groundwater levels stabilized until the late 1990s to early 2000s. After that time, groundwater levels experienced a gradual decline of about 10 to 30 feet until approximately 2008. After 2008 groundwater levels have shown signs of stabilizing in three of four currently monitored wells in the northern MST (NapaCounty-2, NapaCounty-43, and NapaCounty-122), while NapaCounty-56 has shown continued declines, possibly resulting from recent dry years. Depth to groundwater in the northern part of the MST Subarea currently ranges from about 60 to 200 feet.

An important feature within the northern part of the MST is the Soda Creek Fault that several previous investigators have described as an occasional barrier to groundwater flow. It is described by Weaver (1949) as a normal fault with more than 700 feet vertical displacement downward on the western side. Johnson (1977) and Farrar and Metzger (2003) describe groundwater elevations were about 10 feet higher on the eastern side of the fault during their respective study periods. Recent measurements (post-2000) indicate that groundwater levels are about 20 to 30 feet higher on the eastern side of the fault.

In **Figure 5-11**, groundwater elevations in the central and southern portion of the MST have stabilized since about 2008. The groundwater elevations in the central portion of the MST began to decline in the 1950s and currently have declined up to 250 feet in some locations. The central portion of the MST also corresponds to an area in which the primary aquifer of the Sonoma Volcanics, the tuffaceous member of that unit, is not present. Based on the groundwater level trends and local geologic conditions, some of these trends may be the result of variations in geologic conditions or increasing levels of development relative to conditions 40 to 50 years ago. However, the stability of water levels over the past seven years indicates that rate of groundwater extraction is being balanced by rates of groundwater recharge.

5.2 Subareas South of the Napa Valley Floor

South of the Napa Valley Floor the only subareas with current groundwater level monitoring sites in 2015 were the Carneros and Jameson/American Canyon Subareas.

In 2015, the Carneros Subarea had 12 current groundwater level monitoring sites. The longest period of record among them extended back to October 2011. All four monitored wells are located in the southern half of the subarea at land surface elevations between 100 feet to 25 feet (NAVD88). Patterns of groundwater level fluctuations in these wells have shown annual variations of approximately 5 feet from spring to fall, with groundwater elevations ranging from about 20 feet, relative to mean sea level, to -5 feet, relative to mean sea level. Depths to groundwater below ground surface have varied more widely from 10 feet to 100 feet.

Groundwater elevation contours for spring and fall 2015 (**Figures 5-12** and **5-13**) show flow directions were generally southeast to eastward, with very little seasonal variation.

In the Jameson/American Canyon Subarea the only current groundwater level data are from one well recently volunteered for monitoring. Spring and fall measurements recorded in that well in 2014 and 2015 found depths to groundwater ranging from 5 feet in the spring to 14 feet in the fall.

5.3 Subareas East and West of the Napa Valley Floor

The Eastern Mountains and Western Mountains Subareas flank the Napa Valley Floor Subareas and comprise the uplands of the Napa River Watershed. The geology of these large subareas is complex and highly variable. Recent efforts to expand the Napa County monitoring network have identified five new volunteered monitoring wells between the two subareas (**Table 4-2**).

Groundwater level monitoring data for these wells are limited to no more than two years of semi-annual measurements. The depths to groundwater in these wells ranged from 44 feet to 240 feet from ground surface elevations ranging from 390 feet to 1660 feet, mean sea level.

5.4 Angwin and Pope Valley Subareas

In 2015, groundwater level monitoring in the Angwin and Pope Valley Subareas was performed by Napa County at recently volunteered wells. In the Angwin Subarea five wells were monitored, while one well was monitored in the Pope Valley Subarea (**Table 4-2**).

Groundwater level monitoring data for the Angwin Subarea wells are only available for 2014 and 2015. Depths to groundwater in these wells ranged from 95 feet to 207 feet from ground surface elevations ranging from 1678 feet to 1860 feet, mean sea level.

The only groundwater level monitoring data point for the single volunteered well in Pope Valley is from 2014 and 2015, when the depth to groundwater was measured to 16 feet below ground surface.

5.5 Napa Valley Surface Water-Groundwater Monitoring

Data from Sites 1 (**Figure 5-12**), 3 (**Figure 5-14**), and 4 (**Figure 5-15**) show that groundwater levels were above or very near the riverbed at these sites, indicating connectivity between groundwater and surface water in 2015.

Site 1 is located within the City of Napa and is currently the farthest downstream of the four project monitoring sites along the Napa River (**Figure 4-4**). The river is perennially wetted and tidally-influenced at this site with a 5 to 7 foot tidal range observed during the period of record. Data collected at this site have shown very similar water level elevations at all three monitoring locations including a similar, though dampened, response to the tidal cycles in the two piezometers. Data from Site 1 show that groundwater levels were above the elevation of the riverbed and near to or slightly above the elevation of water in the river channel, indicating a connection between groundwater and surface water.

Data from Sites 3 and 4 along the Napa River showed variability in the nature of groundwater-surface water connection during 2015, ranging from groundwater flow into the river to the opposite. Data from these two sites suggest groundwater flowed into the river channel from January through at least the end of July. Through the late summer and fall of 2015 the data indicate no significant flow of water between groundwater and surface water. Then in December 2015, as storms generated runoff in the watershed and flow in the river channel, the direction of flow was away from the riverbed.

At both Site 2 (**Figure 5-13**) and Site 5 (**Figure 5-16**) the direction of groundwater flow was away from the streambed in 2015.

At Site 5 water level data indicate that the river was hydraulically connected to groundwater during the first half of the year, until flows in the river ceased in July, and again in December 2015 as storms generated runoff leading to renewed flow in the river. At Site 2, located along Dry Creek, groundwater levels were consistently below the streambed elevation in 2015, indicating that groundwater was disconnected from the stream, although recharge to the groundwater system was likely occurring when water flowed in the creek.

Sites 2 and 5 also showed groundwater level differences between the shallow and deep casings of at least 5 feet for most or all of 2015. Given that most groundwater withdrawals in Napa Valley occur from depths greater than 50 feet, these water level differences show how the groundwater system's response to pumping from deeper aquifer units does not necessarily lead to an equivalent reduction in shallow groundwater levels.

Although the period of record at these sites is short compared to many wells monitored by Napa County, **Figure 5-17** demonstrates how the range of groundwater elevations monitored at a Surface Water –Groundwater Network site are comparable to a well constructed in a similar part of the aquifer system nearby. NapaCounty-133 is located approximately 0.5 miles from Site 4 and a similar distance from the Napa River. Data from NapaCounty-133 from 1978 through 2015 show a similar range and stable trend in groundwater elevations from spring to fall across the full period of record, including 2015.

6 GROUNDWATER QUALITY CONDITIONS AND TRENDS

Groundwater quality data in Napa County are collected primarily at sites regulated by the SWRCB through the Division of Drinking Water and Geotracker program, although data are available from other public agencies as well.

For this Report groundwater quality data reported between 2009 and 2015 were reviewed in order to provide an updated understanding of conditions and trends relative to the most recent County-wide review of groundwater quality data published as part of the Napa County Groundwater Conditions and Groundwater Monitoring Recommendations Report (LSCE, 2011a). Between 2009 and 2015, groundwater quality data were available from a total of 81 sites (**Table 6-1 and Figure 6-1**).

In addition to the regulated sites overseen by the SWRCB, data were available from voluntary data collection efforts conducted by Napa County at the ten Surface Water-Groundwater Project monitoring wells and by the U.S. Geological Survey and DWR at privately-owned wells. Water quality data from the ten Napa County Surface Water-Groundwater Project monitoring wells consists of a single round of baseline sampling conducted in June 2015. Results from the monitoring well and surface water samples are included in **Appendix D**.

Table 6-1 Recent Groundwater Quality Monitoring Sites in Napa County by Entity and Monitoring Program

Entity	Reporting Program	Number of Monitored Sites, 2009 - 2015
Napa County	Napa Berryessa Resort Improvement District	2
	Lake Berryessa Resort Improvement District	5
	Surface Water-Groundwater Monitoring Sites	10
California Department of Water Resources	Volunteered Sites	8
State Water Resources Control Board	Division of Drinking Water	35
	Geotracker	3
U.S. Geological Survey	-	18
	Total Sites	**81**

Figures 6-2 through **6-8** summarize the available water quality results reported between 2009 and 2015 for a range of constituents. These figures are intended to provide an indication of recent water quality conditions. **Figures 6-9** through **6-12** present time series plots for wells with the longest records of

nitrate and total dissolved solids data (TDS). These figures provide a perspective on the trends in groundwater quality over time at a given well and location.

6.1 Napa Valley Floor Subareas

Groundwater quality data show generally good water quality with stable conditions in the Napa Valley Floor Subareas between 2009 and 2015 compared to the conditions reported previously based on data reported through 2008 (LSCE, 2011a). Water quality standard exceedances in the Napa Valley Floor subareas and Napa Valley Subbasin included arsenic, with 4 of 26 sites showing maximum concentrations above the Maximum Contaminant Level (MCL) of 10 µg/L (**Figure 6-2**). With a Total Dissolved Solids[13] (TDS) concentration of 683 mg/L the deep monitoring well at Site 1 of the Surface Water-Groundwater Project, in Napa Subarea within the Napa Valley Subbasin, exceeded the secondary MCL of 500 mg/L. The same well and the deep well at Site 3 of the Surface Water-Groundwater Project, located near the Napa River at the boundary of the Napa and Yountville Subareas, had boron concentrations of 1,400 µg/L and 9,100 µg/L, respectively, well above the 1,000 µg/L Notification Level. The results from these dedicated monitoring wells may indicate the dominant influence of a geologic source on water quality in these wells.

Wells with long-term water quality data show stable TDS and nitrate concentrations, with one exception (**Figures 6-9** and **6-11)**. Well (06N04W27L002M) in the Napa Subarea which had a peak of 7.7 mg/L NO3-N (nitrate as nitrogen) in 2011 compared to initial concentrations of 3.4 mg/L NO3-N and 4.0 mg/L NO3-N in 1982 and 1972, respectively.

6.2 Subareas South of the Napa Valley Floor

Subareas south of the Napa Valley Floor may be susceptible to seawater intrusion originating from San Pablo Bay. As documented previously, groundwater in the Carneros and Jameson/American Canyon Subareas show elevated concentrations of several constituents, including TDS, chloride, and Electrical Conductivity (EC) (LSCE, 2011a). Water quality standard exceedances in the Napa-Sonoma Lowlands Subbasin, including portions of the Carneros and Jameson/American Canyon Subareas, occurred for arsenic (three wells), nitrate (one well), TDS (five wells) (**Figures 6-2**, **6-5**, and **6-8**). Sodium concentrations were above the agricultural water quality limit of 69 mg/L at all seven sites (**Figure 6-6**).

In the Napa-Sonoma Lowlands Subbasin and Carneros Subarea, available data show that nitrate concentrations have been stable to decreasing in all five wells with long-term records in the Napa-Sonoma Lowlands Subbasin (**Figures 6-10**). Two wells have shown increasing TDS trends, though all four wells with long-term trends were initially at or above the secondary MCL (**Figure 6-12**).

Construction data for monitored wells in the three subarea south of the Napa Valley Floor are very limited, making it difficult to conclusively determine the source and distribution of observed salinity. For example, it is not clear whether high salinity groundwater in the Carneros Subarea is a result of saltwater intrusion or interaction of groundwater with the geologic units present in and around the subarea.

[13] Total Dissolved Solids is a measure of “all solid material in solution, whether ionized or not. It does not include suspended sediment, colloids, or dissolved gases” (Davis and DeWiest, 1966).

6.3 Subareas East and West of the Napa Valley Floor

Recent groundwater quality data from the Eastern and Western Subareas are limited. The available data show a wide range in water quality. TDS values ranged from 120 mg/L to 941 mg/L across eight sites with data, with three sites above the 500 mg/L secondary MCL (**Figure 6-8**). Boron concentrations ranged from 13 µg/L to 3,560 µg/L, with two exceedances of the 1,000 µg/L Notification Level (Figure 6-3). Sodium concentrations ranged from 7.6 mg/L to 384 mg/L, with two exceedances of the agricultural water quality limit of 69 mg/L at all seven sites (**Figure 6-6**). The pattern of the water quality standard exceedances appears to coincide with areas in the Western Mountains characterized by Great Valley Sequence sedimentary rocks.

6.4 Berryessa and Pope Valley Subareas

Recent groundwater quality data in Berryessa and Pope Valley Subareas are limited to three sites. TDS concentrations at all but one well at one site in the Berryessa Subarea exceeded the 500 mg/L secondary MCL. TDS concentrations ranged from 92 mg/L to 5,600 mg/L (**Figure 6-8**). Boron concentrations were also above the Notification Level at all but one well (**Figure 6-3**). The values ranged from non-detect to 15,000 µg/L (**Figure 6-3**). Nitrate concentrations were elevated, though below the 10 mg/L MCL, at two wells (**Figure 6-5**). Sodium concentrations ranged from non-detect to 1,300 mg/L, with three wells above the agricultural water quality limit of 69 mg/L. Spatial and temporal trends in the data from these Subareas are not evident due to the limited available data.

7 COORDINATION AND COLLABORATION

7.1 Integrated Regional Water Management Plans

Integrated Regional Water Management (IRWM) is defined by DWR as "a collaborative effort to identify and implement water management solutions on a regional scale that increase self-reliance, reduce conflict, and manage water to concurrently achieve social, environmental, and economic objectives" (DWR, 2015a).

7.1.1 Napa County's Participation in San Francisco Bay Area and Westside IRWMPs

In 2005, the County formed the Napa County regional water management group (RWMG), a working group of local water agencies, where the Napa County Flood Control and Water Conservation District served as the lead agency. The County RWMG worked together to draft the Napa-Berryessa Integrated Regional Water Management Plan (IRWMP) Functional Equivalent (Napa-Berryessa Regional Water Management Group, 2005).

In 2009, DWR established IRWM regions that have been accepted through the Regional Acceptance Process (DWR, 2009). Currently, there are two formally accepted regions that include Napa County; these regions are: 1) the San Francisco Bay Area Region (which covers the generally southern part of Napa County and focuses on the Napa River and Suisun Creek watersheds), and 2) the Westside Sacramento Region (which covers the generally northern part of Napa County and focuses on the Putah Creek/Lake Berryessa watershed; the Westside Region also covers parts of Yolo, Solano, Lake, and Colusa Counties).

The County has contributed to two larger regional IRWMPs. The County actively collaborated with the San Francisco Bay and Westside RWMGs to update the IRWMP for the San Francisco Bay (Kennedy Jenks et al., 2013) and to develop a new IRWMP for the Westside Sacramento Region (Kennedy Jenks, 2013). The County's representation and participation in the San Francisco Bay and Westside IRWMPs enables further coordination and sharing of information on water resources management planning programs and projects (particularly those that are a high priority for the County) and other information for IRWMP grant funding and implementation.

7.2 Groundwater Sustainability

In September 2014, the California Legislature passed the Sustainable Groundwater Management Act (Act) (DWR, 2015b). SGMA changes how groundwater is managed in the state. SGMA defines "sustainable groundwater management" as the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results (Section 10721 (u)). Undesirable results, as defined by SGMA, means one or more of the following effects caused by groundwater conditions occurring throughout the basin (Section 10721 (w)):

(1) 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 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.

(2) Significant and unreasonable reduction of groundwater storage.

(3) Significant and unreasonable seawater intrusion.

(4) Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.

(5) Significant and unreasonable land subsidence that substantially interferes with surface land uses.

(6) Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

7.2.1 DWR Prioritization of Groundwater Basins

As noted in **Section 2** of this Report, DWR has prioritized groundwater basins and subbasins in accordance with the requirements of Water Code Section 10933. SGMA applies to basins or subbasins that DWR designates as medium- or high-priority basins. Previously under CASGEM, DWR ranked California's basins and subbasins. In Napa County, the Napa Valley Subbasin was ranked medium-priority. All other Napa County basins or subbasins were ranked as very low-priority basins.

Under SGMA, DWR must review and update the ranking of each of the basins or subbasins as a very low-, low-, medium-, or high-priority basin based on requirements contained in Section 10933. DWR was required to complete its initial ranking by January 31, 2015. Because of the expediency of this requirement, DWR's CASGEM basin rankings were used to meet this requirement.

Under SGMA, DWR must also consider adverse impacts on local habitat and local streamflows. The factors for basin ranking and prioritization include:

- Overlying population;
- Projected growth of overlying population;
- Public supply wells;
- Total wells;
- Overlying irrigated acreage;
- Reliance on groundwater as the primary source of water;
- Impacts on the groundwater, including overdraft, subsidence, saline intrusion, and other water quality degradation; and
- Any other information determined to be relevant, including adverse impacts on local habitat and local streamflows.

For most basins designated by DWR as medium or high priority, SGMA requires the designation of groundwater sustainability agencies (GSA) and the adoption of groundwater sustainability plans (GSP); however, there is an alternative to a GSP, pending the local entity (entities) can meet the requirements. When required, GSPs must be developed to eliminate overdraft conditions in aquifers and to return them to a condition that assures their long-term sustainability within twenty years of GSP implementation.

SGMA does not require the development of a GSP for basins that DWR ranks as low- or very low-priority basins; GSPs are voluntary for these basins. SGMA planning requirements also do not apply to adjudicated groundwater basins that are managed by the courts. As discussed below, under certain groundwater basin conditions, local entities can pursue an Alternative Report (i.e., a document other than a GSP).

As applicable, SGMA requires that a GSA be identified for medium- and high-priority groundwater basins by June 30, 2017. Counties are presumed to be the GSA for unmanaged areas of medium- and high priority basins (Section 10724). However, counties are not required to assume this responsibility. When no entity steps forward, this can lead to state intervention (Section 10735 *et seq*.).

SGMA requires GSAs for medium- and high-priority basins to adopt a GSP by January 31, 2022 (Section 10720.7). For basins subject to critical overdraft conditions, the GSP must be adopted by January 31, 2020.

Upon adoption of a GSP, the designated GSA must submit the GSP to DWR for review. SGMA requires that DWR develop regulations for evaluating GSPs by June 1, 2016. On February 18, 2016 DWR released draft GSP regulations. The draft regulations discuss alternatives to a GSP only briefly and appear to require a level of analysis equivalent to that of a GSP. The public comment period for the draft GSP regulations is set to close on April 1, 2016.

Upon completion of its review of a GSP, DWR has the power to request changes to the GSP to address deficiencies. DWR is required to re-evaluate GSPs every five years to ensure continued compliance and sufficiency. After adoption of a GSP, the GSA must submit to DWR an annual compliance report containing basin groundwater data, including groundwater elevation data, annual aggregated extraction data, surface water supply for or available for use for groundwater recharge or in-lieu use, total water use, and any changes in groundwater storage (Section 10728).

In addition to imposing a number of new requirements on local agencies related to groundwater management, SGMA also provides for state intervention – a “backstop” – when local agencies are unwilling or unable to manage their groundwater basin (Section 10735 *et seq*.).

7.2.2 Alternatives to GSPs

Under SGMA, Section 10733.6, a local entity (or entities) can pursue an Alternative to a GSP under the following circumstances:

(a) If a local agency believes that an alternative described in subdivision (b) satisfies the objectives of this part, the local agency may submit the alternative to the department for evaluation and assessment of whether the alternative satisfies the objectives of this part for the basin.

(b) An alternative is any of the following:

(1) A plan developed pursuant to Part 2.75 (commencing with Section 10750) or other law authorizing groundwater management.

(2) Management pursuant to an adjudication action.

(3) An analysis of basin conditions that demonstrates that the basin has operated within its sustainable yield over a period of at least 10 years. The submission of an alternative described by this paragraph shall include a report prepared by a registered professional engineer or geologist who is licensed by the state and submitted under that engineer’s or geologist’s seal.

(c) A local agency shall submit an alternative pursuant to this section no later than January 1, 2017, and every five years thereafter.

(d) The assessment required by subdivision (a) shall include an assessment of whether the alternative is within a basin that is in compliance with Part 2.11 (commencing with Section 10920). If the alternative is within a basin that is not in compliance with Part 2.11 (commencing with Section 10920), the department shall find the alternative does not satisfy the objectives of this part.

On February 18, 2016 DWR published draft regulations for the development of GSPs and GSP-alternatives. Napa County staff have met with DWR staff to discuss an approach for a GSP-alternative for the Napa Valley Subbasin. County staff have also provided comments to DWR on the draft regulations, which are required under SGMA to be finalized and adopted by June 1, 2016. County staff are currently seeking input from the Napa County Board of Supervisors and preparing for multiple paths forward pending direction from the Supervisors and the content of the final regulations with respect to the requirements for GSP-alternatives.

More details about SGMA are available at http://www.water.ca.gov/groundwater/sgm/index.cfm.

7.3 Napa County Watershed Information and Conservation Council

The Watershed Information and Conservation Council[14] (WICC) Board was established in 2002 to serve as an advisory committee to Napa County Board of Supervisors – assisting with the Board's decision making and serving as a conduit for citizen input by gathering, analyzing, and recommending options related to the management of watershed resources (WICC, 2015). The WICC has achieved significant accomplishments in its 12-year history – both alone and in partnership with nonprofits, public agencies, and private landowners.

The WICC Mission is: improving the health of Napa County's watersheds by informing, engaging and fostering partnerships within the community.

The 2015 WICC Strategic Plan outlines five goals, including (WICC, 2015):

- Goal 1: Coordinate and facilitate watershed planning, research, and monitoring efforts among Napa County organizations, agencies, landowners and citizens.
- Goal 2: Strengthen and expand community understanding, connections and involvement to improve the health of Napa County's watersheds.
- Goal 3: Support informed decision-making on topics that affect the health of Napa County's watersheds.
- Goal 4: Improve WICC Board efficiency and effectiveness.
- Goal 5: Explore additional funding opportunities to support the goals of the WICC.

[14] Prior to 2015 this organization was named the Watershed Information Center and Conservancy.

Additionally, Subgoal 1B to Goal 1 includes the WICC serving as the local clearinghouse for groundwater resource data, mapping, and monitoring (Implements: Napa County General Plan Action Item CON WR-4). As part of developing education and outreach for the community regarding groundwater conditions, the WICC is expanding groundwater information on the WICC website at www.napawatersheds.org. This new initiative has involved adding groundwater summary data and graphs for the County's groundwater basins and/or subareas that are already delineated on the website's maps. Specifically, the WICC has established a portion of the WICC website dedicated to groundwater. Data and information are at a watershed scale and not be project or parcel specific scale. Information includes:

- Updates on groundwater resource issues locally and throughout California.
- Articles explaining key technical issues related to groundwater.
- Updates on groundwater mapping and monitoring in Napa County.
- Educational materials and resources on groundwater recharge areas and ways to improve these areas.
- Report on the Napa County Voluntary Groundwater Level Monitoring Program.

8 SUMMARY AND RECOMMENDATIONS

Groundwater level monitoring was conducted at a total of 113 sites across Napa County in 2015 (**Table 4-1)**. The overall number and distribution of monitored sites remained consistent with the monitoring conducted in 2014 and was increased relative to the 87 sites reported in the 2011(LSCE, 2013a).

Groundwater level trends in the Napa Valley Subbasin of the Napa-Sonoma Valley Groundwater Basin are stable in the majority of wells with long-term groundwater level records. While many wells have shown at least some degree of response to recent drought conditions, the water levels observed in recent years are generally higher than groundwater levels in the same wells during the 1976 to 1977 drought. Elsewhere in the County long-term groundwater level records are limited, with the exception of the Milliken-Sarco-Tulucay (MST) Subarea.

Although designated as a groundwater subarea for local planning purposes, the majority of the MST is not part of a groundwater basin as mapped by DWR. Groundwater level declines observed in the MST Subarea as early as the 1960s and 1970s have stabilized since about 2008. Groundwater level responses differ within the MST Subarea and even within the north, central, and southern sections of this subarea, indicating that localized conditions, whether geologic or anthropogenic in nature, might be the primary influence on groundwater conditions in the subarea.

While the majority of wells with long-term groundwater level records exhibit stable trends, periods of year to year declines in groundwater levels have been observed in a few wells. These wells are located near the Napa Valley margin in the northeastern Napa Subarea (NapaCounty-75 and Napa County-76), southwestern Yountville Subarea (NapaCounty-135) and southeastern St. Helena Subarea (NapaCounty-132). These locations are characterized in part by relatively thin alluvial deposits, which may contribute to more groundwater being withdrawn from the underlying semi-consolidated deposits.

Water levels in northeastern Napa Subarea wells NapaCounty-75 and Napa County-76, east of the Napa River, have stabilized since 2009, though declines were observed over roughly the prior decade (**Figure 5-7**). Despite the recent stability, given the potential for a hydraulic connection between the aquifer units in the vicinity of these wells and the aquifer units of the MST Subarea and an apparent increase in the number of new well permits in the area over the past 10 years[15], further study in this area is recommended.

Water levels at NapaCounty-135 and NapaCounty-132 declined most distinctly between 2013 and 2014 (**Figures 5-6 and 5-7**). The increased monitoring frequency at these wells through the end of 2015 has shown groundwater levels already recovering to levels comparable to or higher than those of spring 2013. Groundwater level declines in these wells observed in 2014 could have one or more contributing factors, including variations in groundwater recharge due to changes in the timing and intensity of precipitation and changes in the level of pumping at the monitored well or in the vicinity of the monitored well. Continuation of the increased monitoring frequency is recommended to assist with interpretation of conditions at these wells in the future.

[15] In a Memorandum to David Morrison, Director of Planning, Building, and Environmental Services, dated December 7, 2015 regarding groundwater conditions in the northeastern corner of the Napa Subarea Steven Lederer, Director of Public Works, noted that “12 of the approximately 30 homes on Petra Drive have applied for new well permits in the past 10 years.”

Groundwater quality data show stable conditions between 2009 and 2015 compared to the conditions reported previously with data through 2008 (LSCE, 2011a). Water quality standard exceedances in the Napa Valley Floor subareas and Napa Valley Subbasin were limited to the naturally-occurring constituent arsenic, with 4 of 26 sites showing maximum concentrations above the MCL of 10 µg /L (**Figure 6-2**). Water quality standard exceedances in the Napa-Sonoma Lowlands Subbasin, including portions of the Carneros and Jameson/American Canyon Subareas, occurred for arsenic (three wells), nitrate (one well), TDS (five wells) (**Figures 6-2**, **6-5**, and **6-8**). Construction information for monitored wells those three subarea are very limited, making it difficult to conclusively determine the source and distribution of observed salinity. For example, it is not clear whether high salinity groundwater in the Carneros Subarea is a result of saltwater intrusion or interaction of groundwater with the geologic units present in and around the subarea.

Wells with long-term water quality data in the Napa Valley Subbasin show stable TDS and nitrate concentrations, with one exception (**Figures 6-9** and **6-11)**. Well (06N04W27L002M) in the Napa Subarea which had a peak of 7.7 mg/L NO3-N (nitrate as nitrogen) in 2011 compared to initial concentrations of 3.4 mg/L NO3-N and 4.0 mg/L NO3-N in 1982 and 1972, respectively. In the Napa-Sonoma Lowlands Subbasin, nitrate concentrations have been stable to decreasing in all five wells with long-term records in the Napa-Sonoma Lowlands Subbasin (**Figures 6-10**). Two wells have shown increasing TDS trends, though all four wells with long-term trends were initially at or above the secondary MCL (**Figure 6-12**).

The following recommendations have been developed based on the findings presented in this report.

8.1 Northeast Napa Subarea Hydrogeologic Investigation

Previously observed groundwater level declines in the northeast Napa Subarea, east of the Napa River in the vicinity of NapaCounty-75 and NapaCounty-76, along with reports of increased well replacement activity along Petra Drive have raised questions about the cumulative impacts of existing and potential future groundwater use in this area. In addition to completing the standard project-level planning review of the proposed projects, a focused study of hydrogeologic conditions affecting groundwater availability is advisable for this area. The investigation should be designed to address existing and future water use in the area, sources of groundwater recharge, and the geologic setting in order to address the potential for cumulative impacts of future development. The investigation would also seek to address the influence of previously documented groundwater cones of depression in the MST subarea on both the study area east of the Napa River and the Napa Subarea west of the Napa River.

8.2 Data Gap Refinement

Groundwater levels in two monitored wells located near to the Napa Valley margin showed year to year declines in groundwater levels. Additional information is needed in order to consider the full range of possible causes for these declines and more accurately determine if the present emerging trends. Recommended actions include a review of land use data in these areas and continuation of the increased frequency of data collection at a subset of wells. More frequent data collection could be accomplished, pending agreement with the well owner, by monthly manual groundwater level measurements.

For wells added to the County’s monitoring networks in recent years without a record of key well construction details, continued efforts to locate construction information and link those data with aquifer units is recommended. In cases where a well owner does not have a record of the construction, a review of Well Completion Reports is recommended.

Once final Groundwater Sustainability Plan regulations are published by DWR later in 2016, there may be a need to add one or more wells to the CASGEM network near the southern boundary of the Napa Valley Subbasin. A well or wells in this area would be used to monitor groundwater gradients at the basin boundary where subsurface outflow occurs into the Napa-Sonoma Lowlands Subbasin. This data will be a component of the subbasin water budget that will be a key feature of the quantitative approach to groundwater management described in SGMA. For similar reasons, the County may benefit from updating reference point elevation data for some monitored wells with surveyed values in order more accurately monitor groundwater level gradients and any potential future seawater intrusion.

8.3 Baseline Water Quality Sampling

The groundwater quality monitoring objectives contained in the *Napa County Groundwater Monitoring Plan 2013* (Plan) included the investigating of variations in water quality at different points within the groundwater Subareas and at different aquifer units within a given subarea (LSCE, 2013a). The Plan recommended baseline sampling in wells at each of 18 Areas of Interest for additional monitoring and at the then proposed dedicated surface water-groundwater monitoring wells. It is recommended that wells added to the County monitoring networks in these areas be reviewed for suitability in light of the groundwater quality monitoring objectives, with baseline sampling conducted for those wells with sufficient well construction records to enable interpretation of the results for specific aquifer units.

A second round of baseline water quality sampling is also recommended for the five dual-completion monitoring wells constructed in 2014 at surface water-groundwater monitoring sites, as described in the Plan. An initial round of sampling and analysis was completed in June 2015 with a combination of County matching funds, DWR grant funds, and DWR in-kind support. Sampling these wells again in 2016 will provide a more robust baseline dataset that would be used to characterize any inter-annual variability at each well and provide a basis for interpreting future groundwater quality data.

8.4 Coordination with Other Monitoring Efforts

Coordination with other county departments and other agencies that collect or utilize groundwater data could provide an additional source of data in places where data are limited. Several local agencies, including the Town of Yountville, City of St. Helena, and City of Napa, already monitor groundwater levels at locations around the county. Another potential source of coordination would be a continuation of the in-kind support for laboratory analysis of water quality samples, as occurred in 2015.

8.5 Existing Activities in the MST Subarea

In 1999 the County passed a Groundwater Ordinance which, among other things, limited approval of discretionary permits in the MST Subarea to those projects that could meet the “Fair Share” requirement of 0.3 acre-foot/per acre of land. In 2004, discretionary approvals were further limited to those projects that could meet a “no net increase” standard. These actions were intended to slow the decline of water levels in the MST Subarea while a more permanent solution could be found.

It was recognized at the time that these actions by themselves would not “fix” the problem, but were a good step given the constraints of land use and groundwater law. It is reasonable to assume that these actions restricting increased use of groundwater have had beneficial impacts. However, ministerial projects (such as a single family home on a parcel without any other development, or Track II replants) were not so regulated, nor were existing (pre-1999) water users regulated.

In 2014 construction commenced on a pipeline that will deliver tertiary treated recycled waste water to the MST Subarea. It is expected that customers for approximately 400 acre-feet of recycled water will commence receiving deliveries upon completion of the pipeline in 2016. The pipeline capacity allows for delivery of up to 2,000 acre-feet of water. If customer demand for the recycled water increases, as anticipated, this new source of supply may further offset demand for groundwater in the subarea. Continued monitoring of groundwater levels will improve the understanding of groundwater trends related to any reduced demand for groundwater in the area.

9 REFERENCES

2NDNature. 2014. Napa Watershed water year classification methodology. Technical Memorandum prepared for Napa County.

Barlow, P.M., and S. A. Leake. 2012. Streamflow depletion by wells – Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological Survey Circular 1376.

California Department of Water Resources (DWR). 1962. Reconnaissance Report on the Upper Putah Creek Basin Investigation, Bulletin No. 99.

California Department of Water Resources (DWR). 2015a. Integrated Regional Water Management. http://www.water.ca.gov/irwm/ (accessed February 2015).

California Department of Water Resources (DWR). 2015b. Groundwater Information Center. Key Legislation. http://www.water.ca.gov/groundwater/groundwater_management/legislation.cfm (accessed January 2015).

Center for Collaborative Policy at California State University Sacramento. 2010. Assessment of the feasibility of a collaborative groundwater data gathering effort in Napa County, California.

Davis, S.N., DeWiest, R.J.M. 1966. Hydrogeology. John Wiley & Sons, Inc.

DHI. 2006a. Final baseline data report (BDR) technical appendix – water quantity and water quality report, Napa County, California. October 2006.

DHI. 2006b. MIKE SHE an integrated hydrological modeling system – documentation and users guide. November 2006.

DHI. 2007. Modeling analysis in support of vineyard development scenarios evaluation, Napa County, California. February 2007.

Farrar, C.D. and L. F. Metzger. 2003. Ground-water resources in the Lower Milliken-Sarco-Tulucay Creeks area, southeastern Napa County, California, 2000-2002. USGS. Water-Resources Investigations Report 03-4229.

Faye, R.E. 1973. Ground-water hydrology of northern Napa Valley California. Water Resources Investigations 13-73, US Geological Survey, Menlo Park, CA, 64 p.

Fox, K.F., Jr., J.D. Sims, J.A. Bartow, and E.J. Helley. 1973. Preliminary geologic map of eastern Sonoma County and western Napa County, California: U.S. Geological Survey Misc. Field Studies Map MF-483, 5 sheets, scale 1:62,500.

Fox, K. 1983. Tectonic setting of Late Miocene, Pliocene, and Pleistocene rocks in part of the Coast Ranges north of San Francisco, California, U.S. Geological Survey Professional Paper 1239. 33 pp.

Graymer, R.W., D.L. Jones, and E.E. Brabb. 2002, Geologic map and map database of northeastern San Francisco Bay region, California; most of Solano County and parts of Napa, Marin, Contra Costa, San

Joaquin, Sacramento, Yolo, and Sonoma Counties: U.S Geological Survey Miscellaneous Field Studies Map MF-2403, 1 sheet, 1:100,000 scale, 28 p.

Graymer, R.W., B.C. Moring, G.J. Saucedo, C.M. Wentworth, E.E. Brabb, and K.L. Knudsen. 2006. Geologic Map of the San Francisco Bay Region. U.S. Geological Survey, Scientific Interpretations Map 2918, scale 1:275,000.

Graymer, R.W., E.E. Brabb, D.L. Jones, J. Barnes, R.S. Nicholson, and R.E. Stamski. Geologic map and map database of eastern Sonoma and western Napa Counties, California: U.S. Geological Survey Scientific Investigations Map 2956 [http://pubs.usgs.gov/sim/2007/2956/].

Goundwater Resources Advisory Committee. 2014. Groundwater Sustainability Objectives, February 27, 2014. Included in Final Report to the Napa County Board of Supervisors.

Helley, E.J., K.R. Lajoie, W.E. Spangle, and M.L. Blair. 1979. Flatland deposits of the San Francisco Bay region, California; their geology and engineering properties, and their importance to comprehensive planning. U.S. Geological Survey Professional Paper 943. Scale 1:125,000.

Johnson, M.J. 1977. Ground-water hydrology of the Lower Milliken-Sarco-Tulucay Creeks Area, Napa County, California. USGS Water-Resources Investigations 77-82.

Jones and Stokes & EDAW. 2005. Napa County baseline data report. November, 2005.

Kennedy Jenks. 2013. Westside Sacramento integrated regional water management plan.

Kennedy Jenks, ESA, Kearns & West, and Zentraal. 2013. San Francisco Bay Area integrated regional water management plan.

Koenig, J.B. 1963. Geologic map of California, Olaf P. Jenkins edition, Santa Rosa Sheet. California Division of Mines and Geology. Scale 1:250,000.

Kunkel, F. and J.E. Upson. 1960. Geology and groundwater in Napa and Sonoma Valleys Napa and Sonoma Counties California. U.S. Geological Survey Water Supply Paper 1495.

Lederer, S.L. 2015. Groundwater Concerns in the Northeastern Corner of the Napa Subarea. Memorandum to David Morrison, Director of Planning, Building, and Environmental Services. December 7, 2015

Luhdorff and Scalmanini, Consulting Engineers (LSCE). 2010a. Task 1, Napa County data management system. Technical Memorandum prepared for Napa County.

LSCE. 2010b. Task 2, Review and evaluation of data collection procedures and recommendations for improvement. Technical Memorandum prepared for Napa County.

LSCE. 2011a. Napa County groundwater conditions and groundwater monitoring recommendations. Task 4, Report.

LSCE. 2011b. Napa County, California statewide groundwater elevation monitoring (CASGEM) network plan. September 2011.

LSCE. 2011c. Groundwater planning considerations and review of Napa County groundwater ordinance and permit process. Technical Memorandum prepared for Napa County.

LSCE. 2013a. Napa County groundwater monitoring plan 2013. January 2013.

LSCE. 2013b. Approach for evaluating the potential effects of groundwater pumping in surface water flows and recommended well siting and construction criteria. Technical Memorandum prepared for Napa County. October 2013.

LSCE and MBK Engineers. 2013. Updated hydrogeologic conceptualization and characterization of conditions in Napa County.

LSCE. 2014. Napa County California Statewide groundwater elevation monitoring (CASGEM) network plan. Originally prepared September 2011. Updated August 2014.

LSCE. 2015. Napa County comprehensive groundwater monitoring program 2014 annual report and CASGEM update.

Napa County. 2008. Napa County general plan. (Amended June 23, 2009.)

Napa County Department of Public Works. 2012. Napa County groundwater/surface water monitoring facilities to track resource interrelationships and sustainability. Local Groundwater Assistance Grant Proposal to California Department of Water Resources.

Napa County. 2011. Napa County Board of Supervisors Groundwater Resources Advisory Committee. http://www.countyofnapa.org/bos/grac/ (accessed January 2015).

Napa County Groundwater Resources Advisory Committee (GRAC). Groundwater sustainability objectives. February 2014.

Sims, J.D., K.F. Fox, Jr., J.A. Bartow, and E.J. Helley. 1973. Preliminary geologic map of Solano County and parts of Napa, Contra Costa, Marin, and Yolo Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-484, 5 sheets, scale 1:62,500.

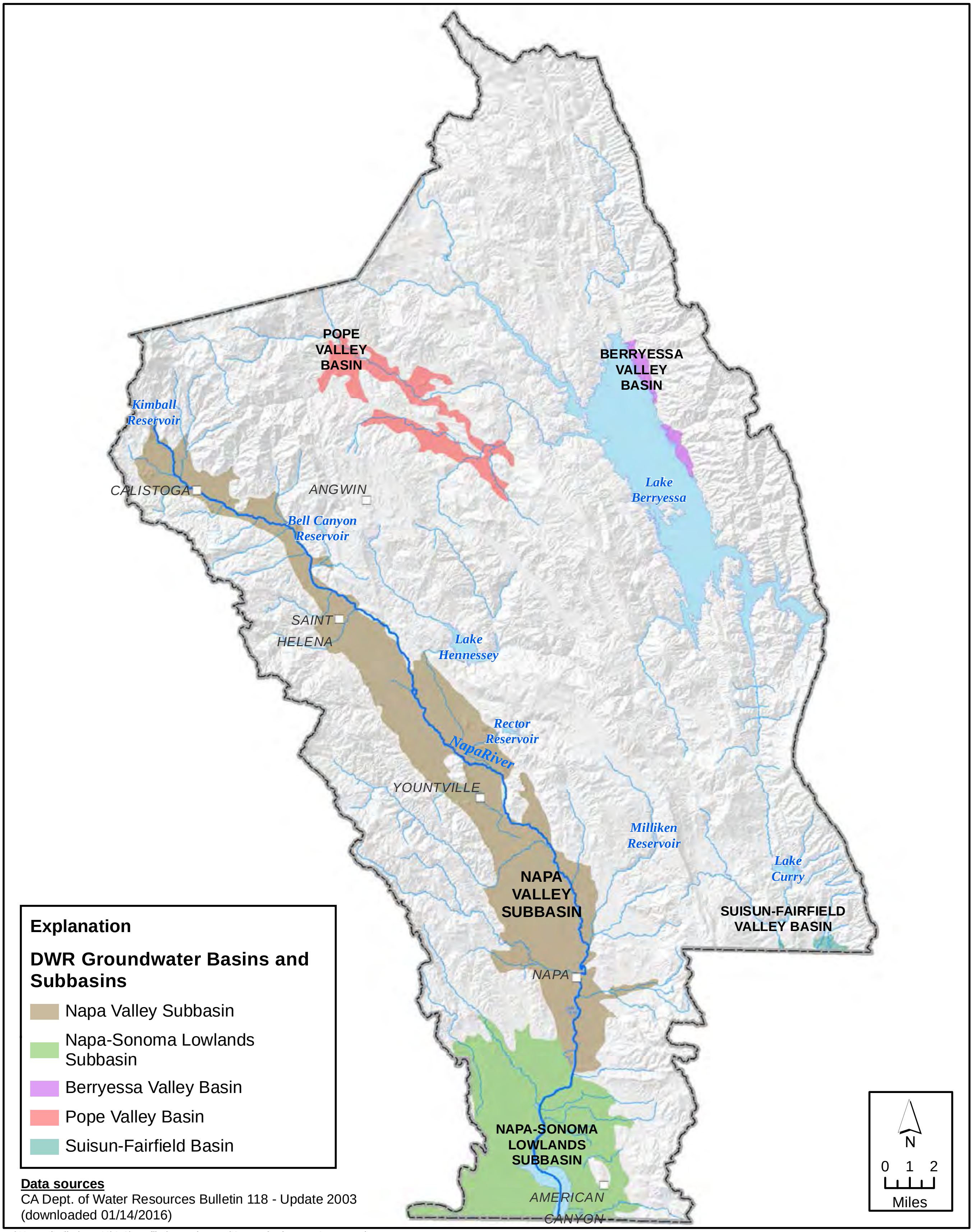
Taylor, C. and W.M. Alley.2001. Ground-water-level monitoring and the importance of long-term water-level data. U.S. Geological Survey Circular 1217.

Watershed Information and Conservation Council (WICC). 2015. 2015 strategic plan. January 2015. Prepared for the Napa County WICC Board.

Wagner, D.L., and E.J. Bortugno. 1982. Geologic map of the Santa Rosa quadrangle: California Division of Mines and Geology Regional Geologic Map Series, Map 2A, scale 1:250,000.

Weaver, C.E., 1949. Geology of the Coast Ranges immediately north of the San Francisco Bay region, California. California Department of Natural Resources, Division of Mines. Bulletin 149

FIGURES



Data sources
CA Dept. of Water Resources Bulletin 118 - Update 2003
(downloaded 01/14/2016)

X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\GW Basins in Napa County.mxd

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FIGURE 2-1
Groundwater Basins and Subbasins in Napa County, CA

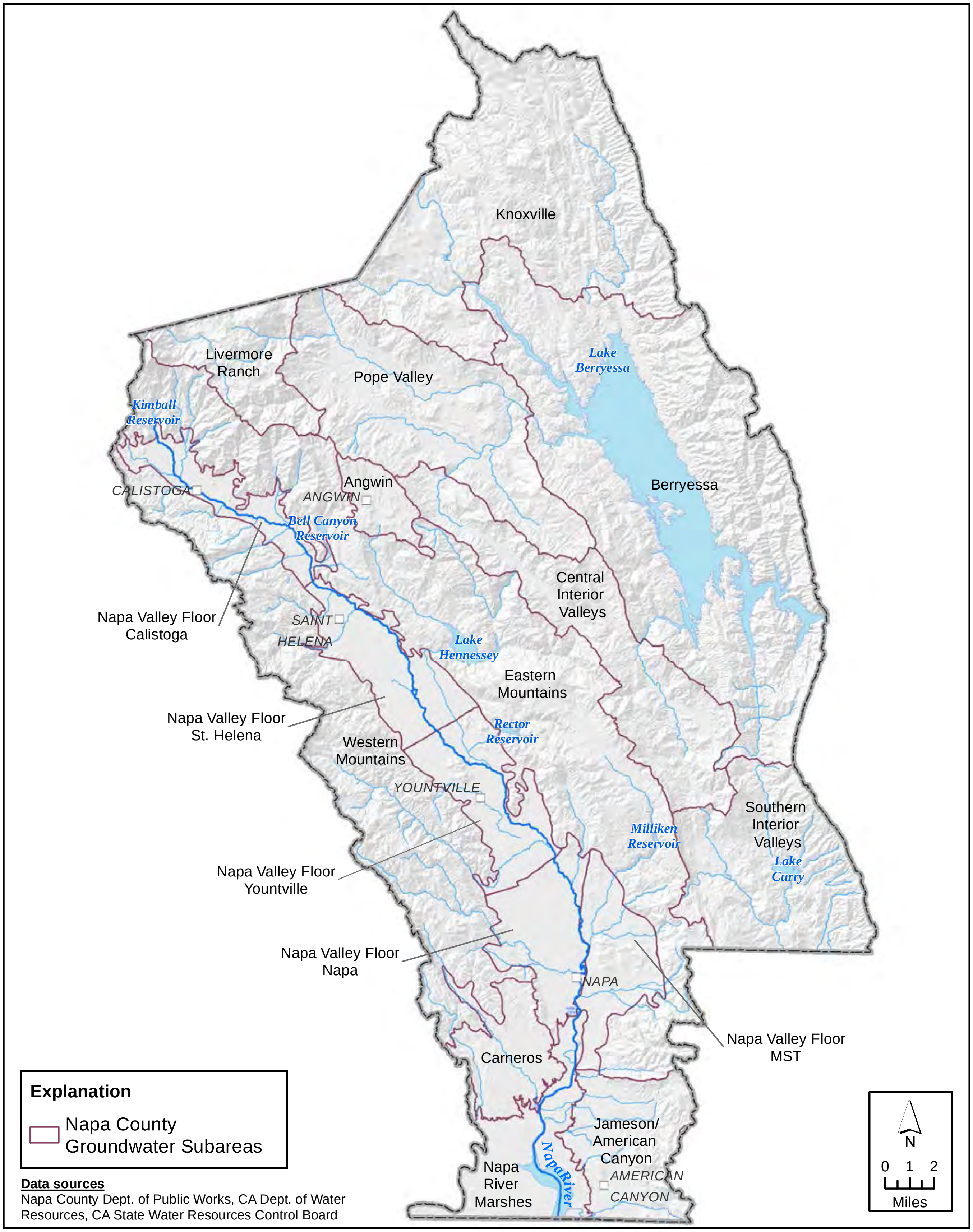

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FIGURE 2-2
Napa County Groundwater Subareas

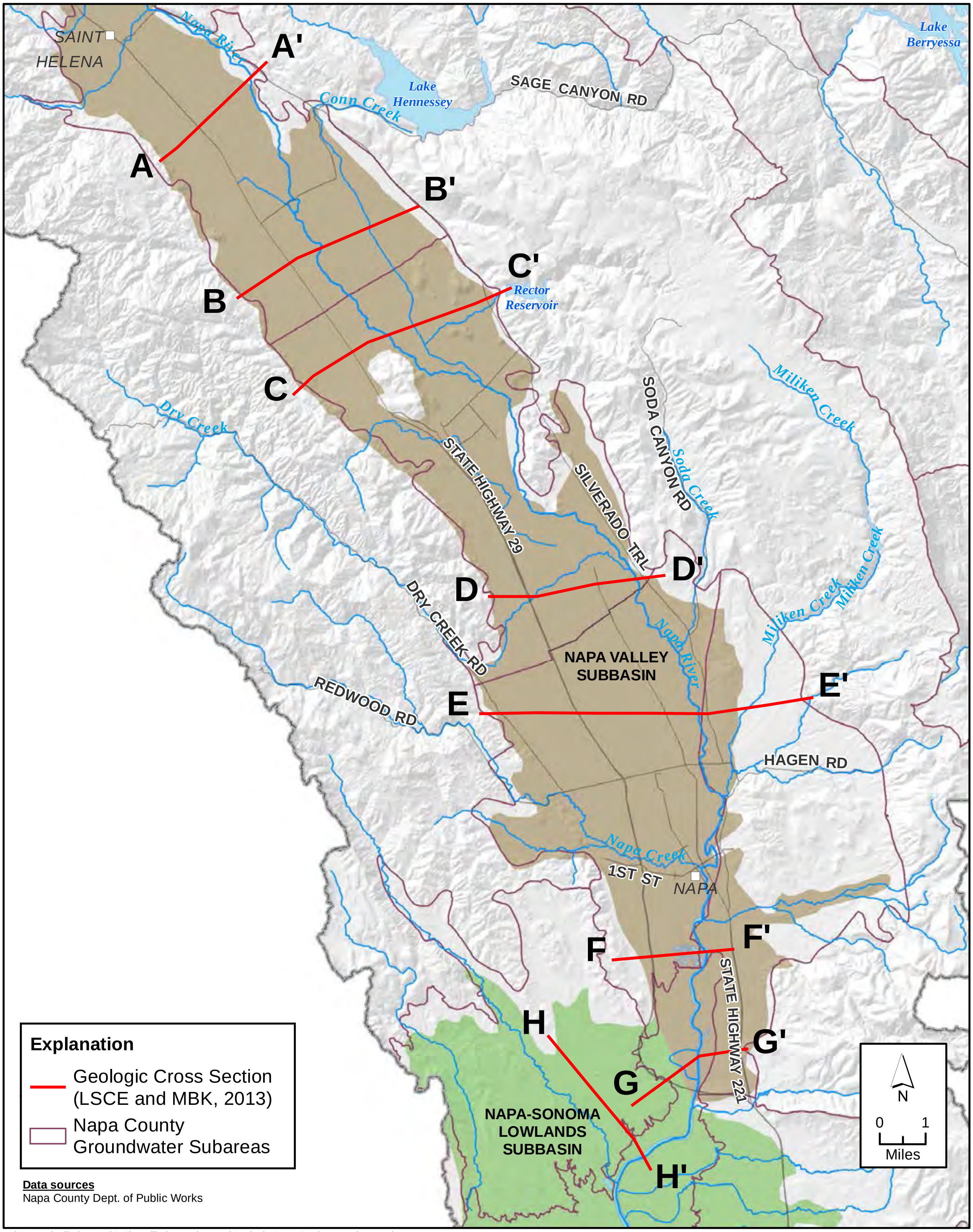

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FIGURE 2-3
Updated Hydrogeologic Conceptualization
Geologic Cross Section Locations

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update

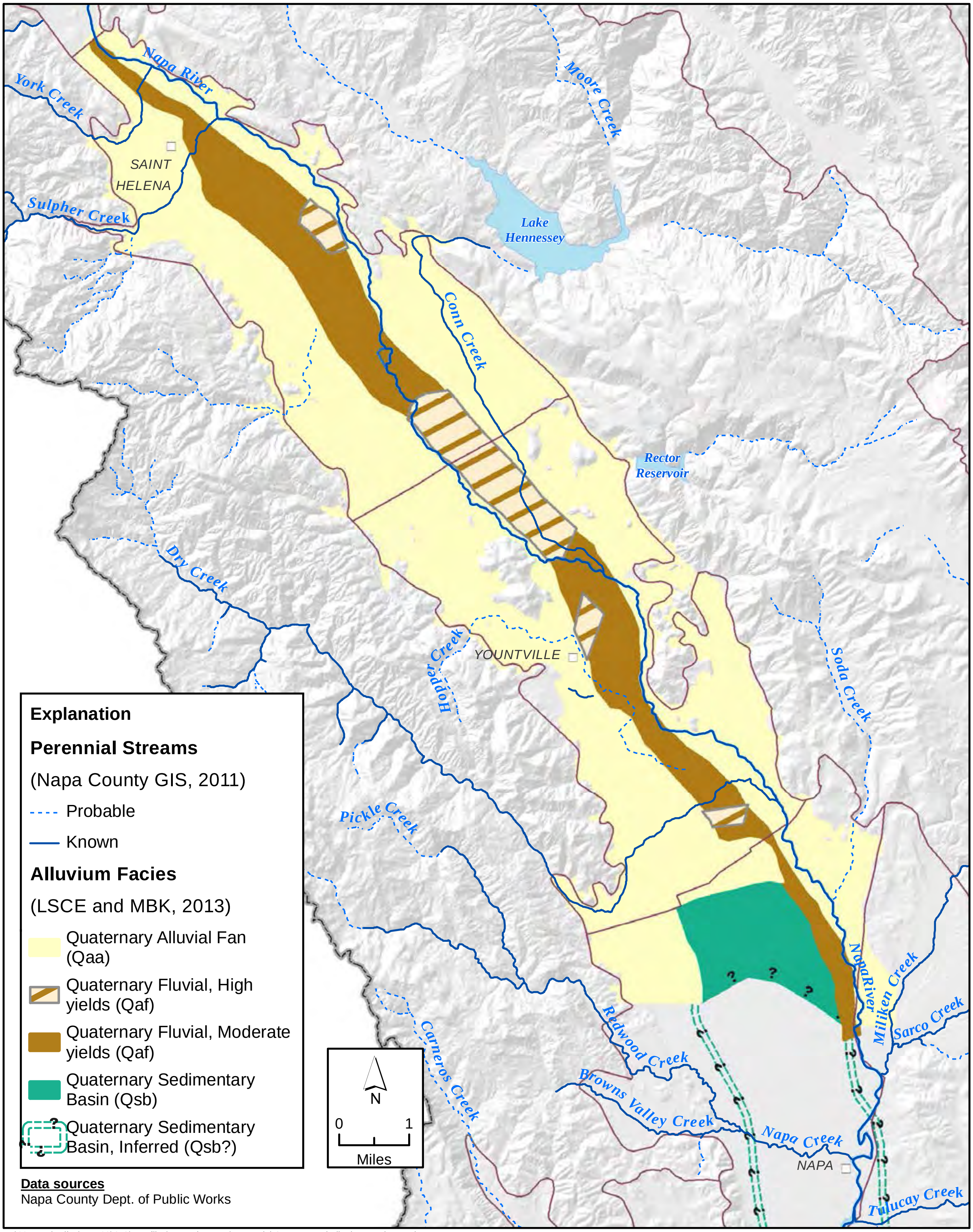

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FIGURE 2-4
Perennial Streams and Alluvium Facies
Napa Valley Floor, Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update

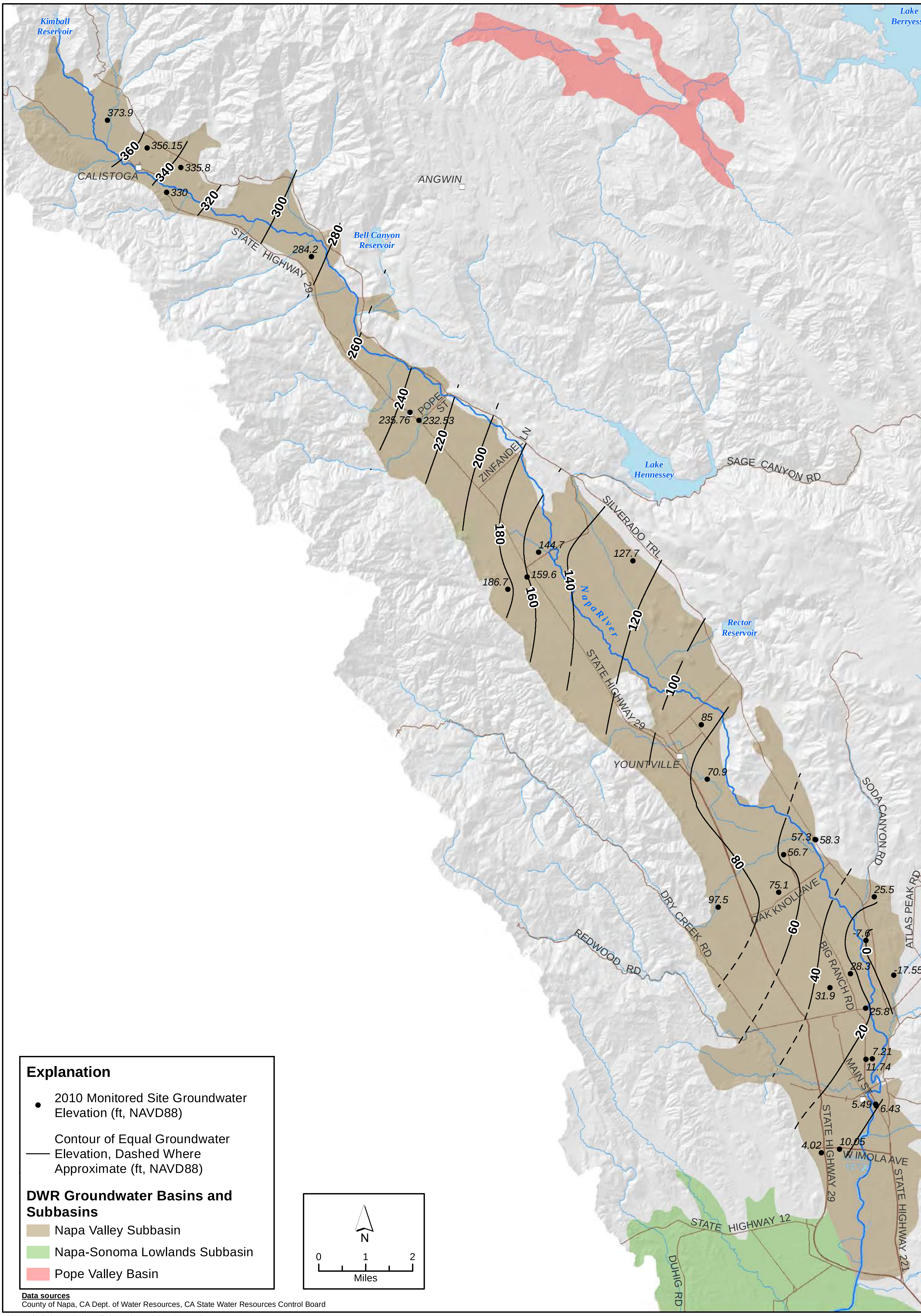

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FIGURE 2-5
Contours of Equal Groundwater Elevation, Spring 2010
Napa Valley Floor, Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update

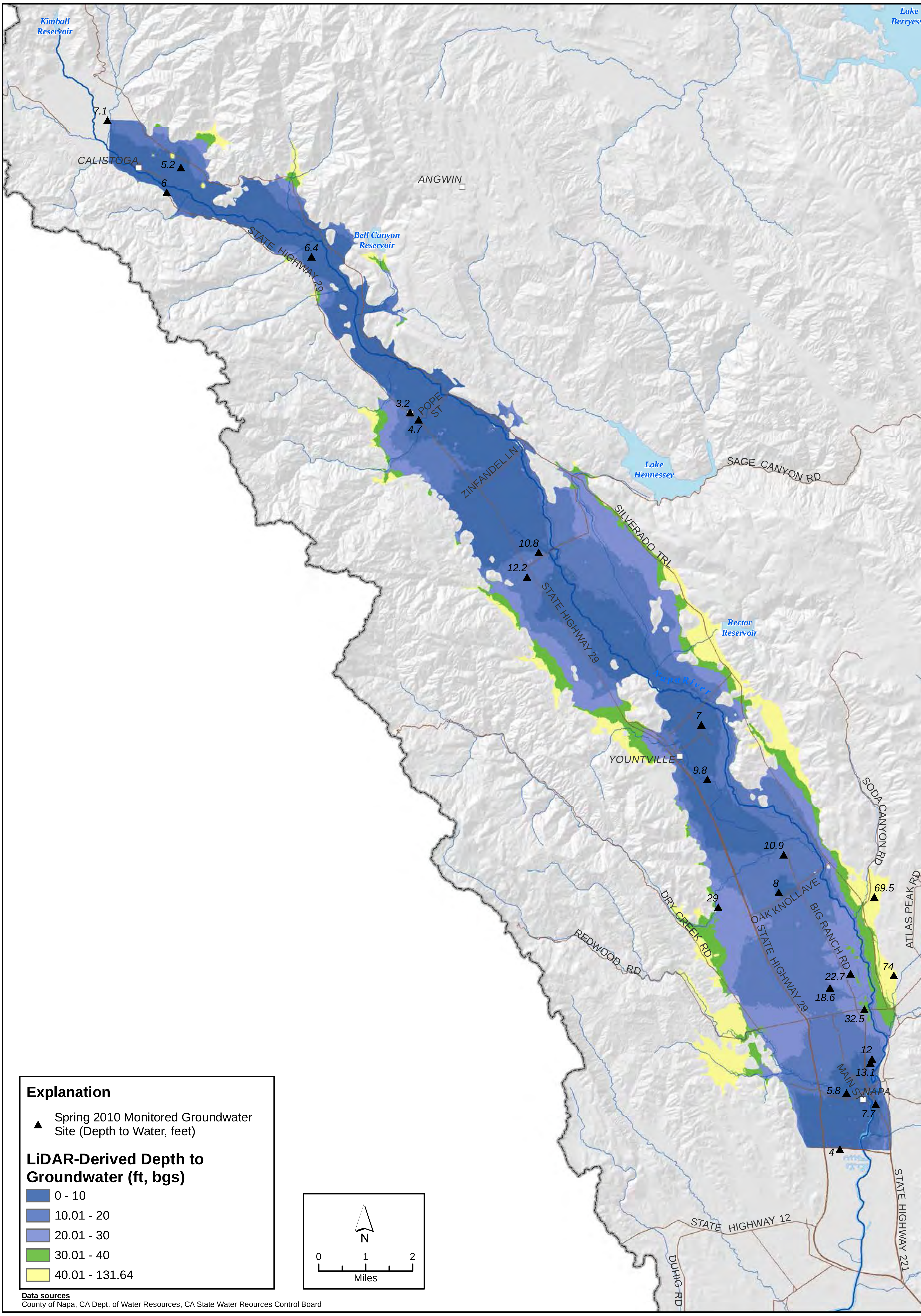

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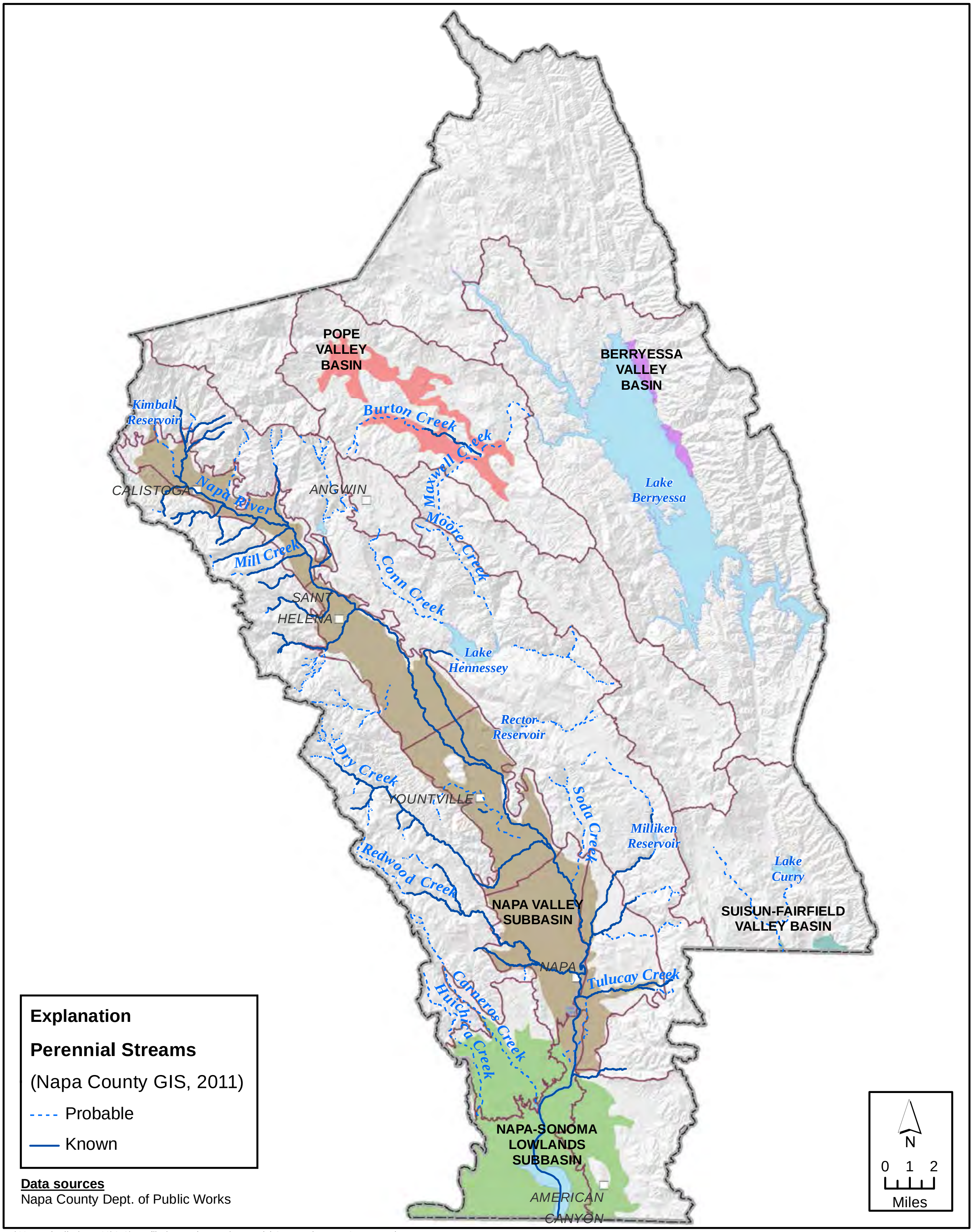
FIGURE 2-6
Spring 2010 Calculated Depth to Groundwater, Napa Valley Floor, Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



Data sources
Napa County Dept. of Public Works

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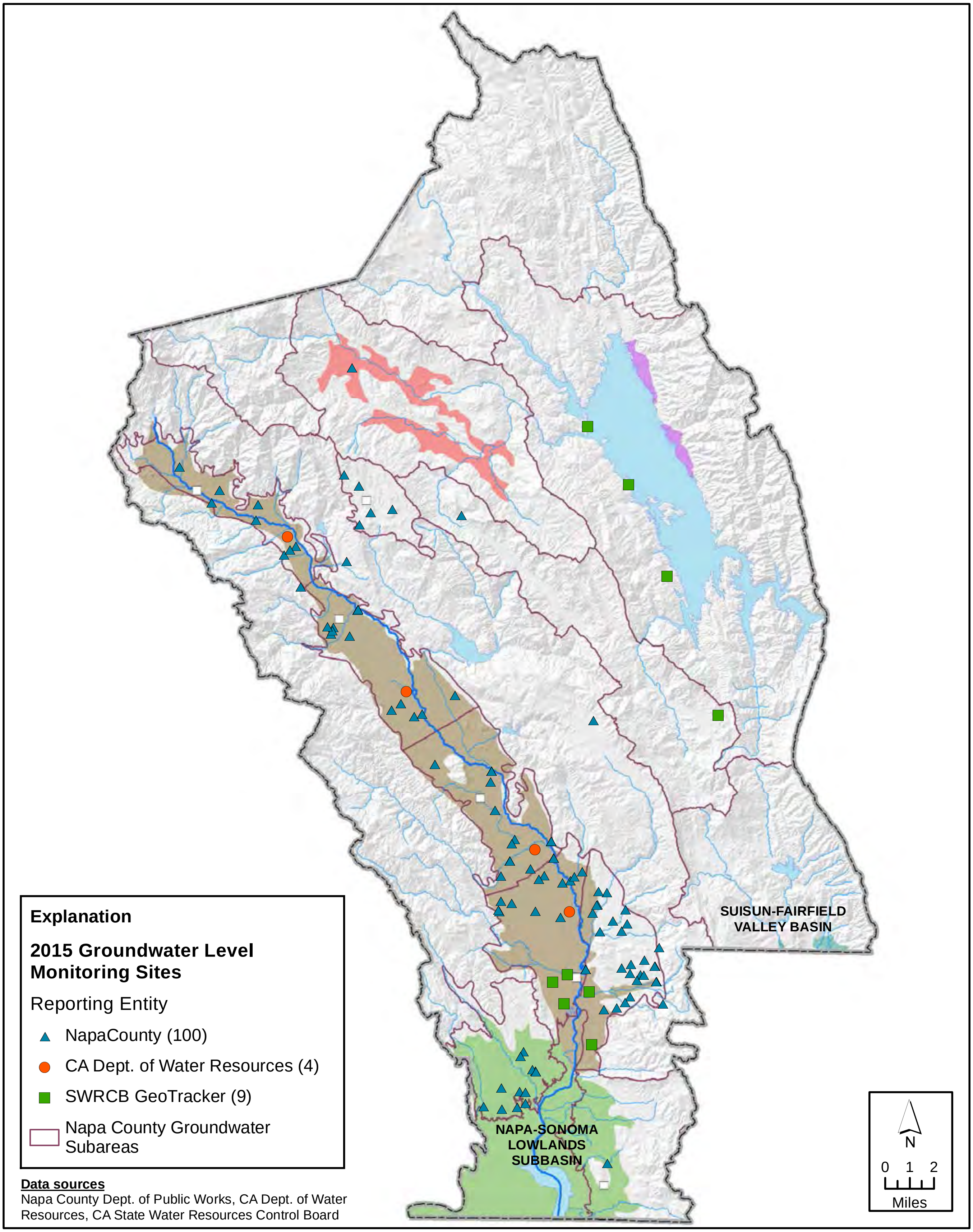
FIGURE 2-7
Perennial Streams in Napa County



X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\2015 Current GWL Monitoring Sites by Entity.mxd

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FIGURE 4-1
Current Groundwater Level Monitoring Sites by Reporting Entity

Napa County Comprehensive Groundwater Monitoring Program 2015 Annual Report and CASGEM Update

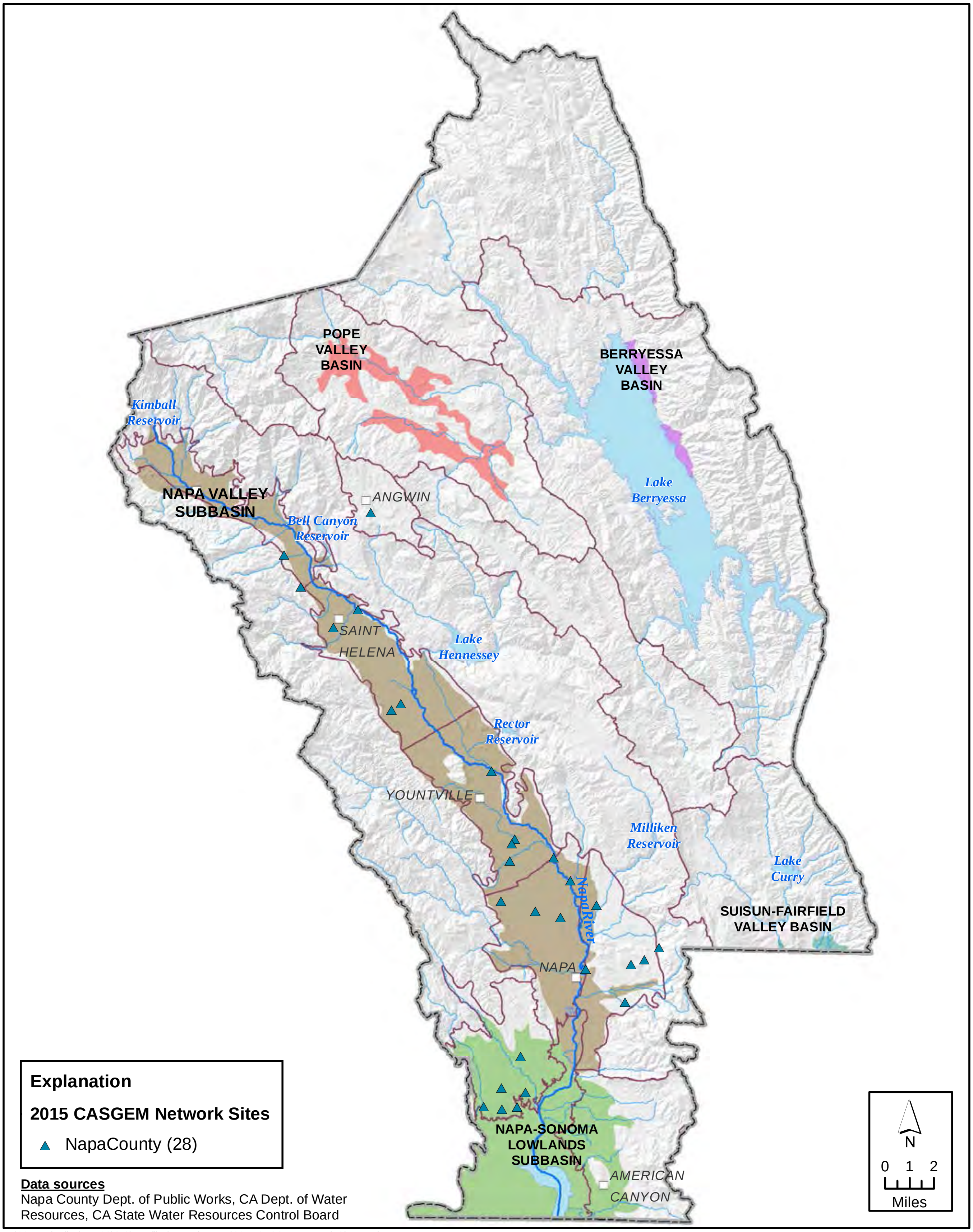

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FIGURE 4-2
2015 CASGEM Network Sites
Napa County, CA

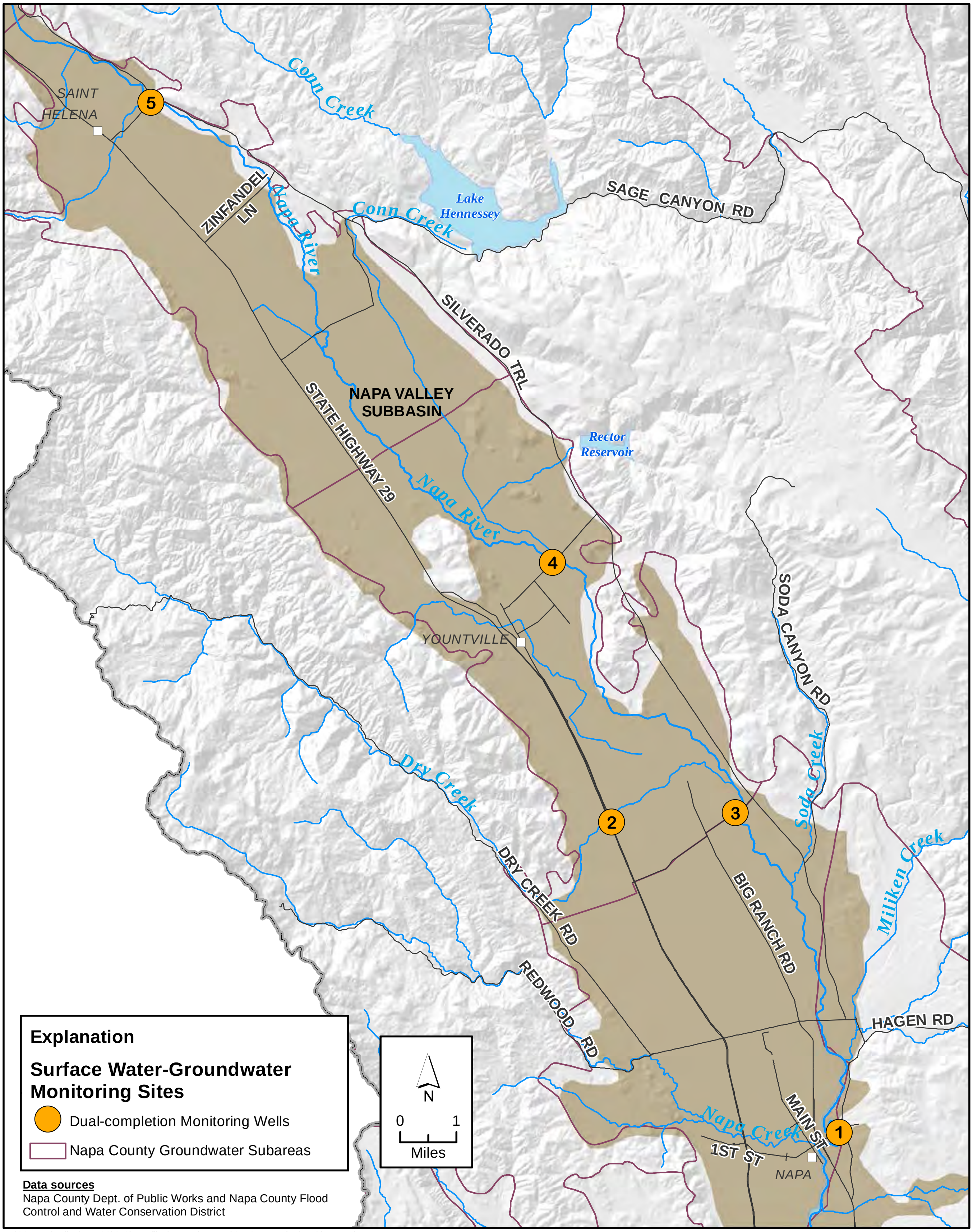

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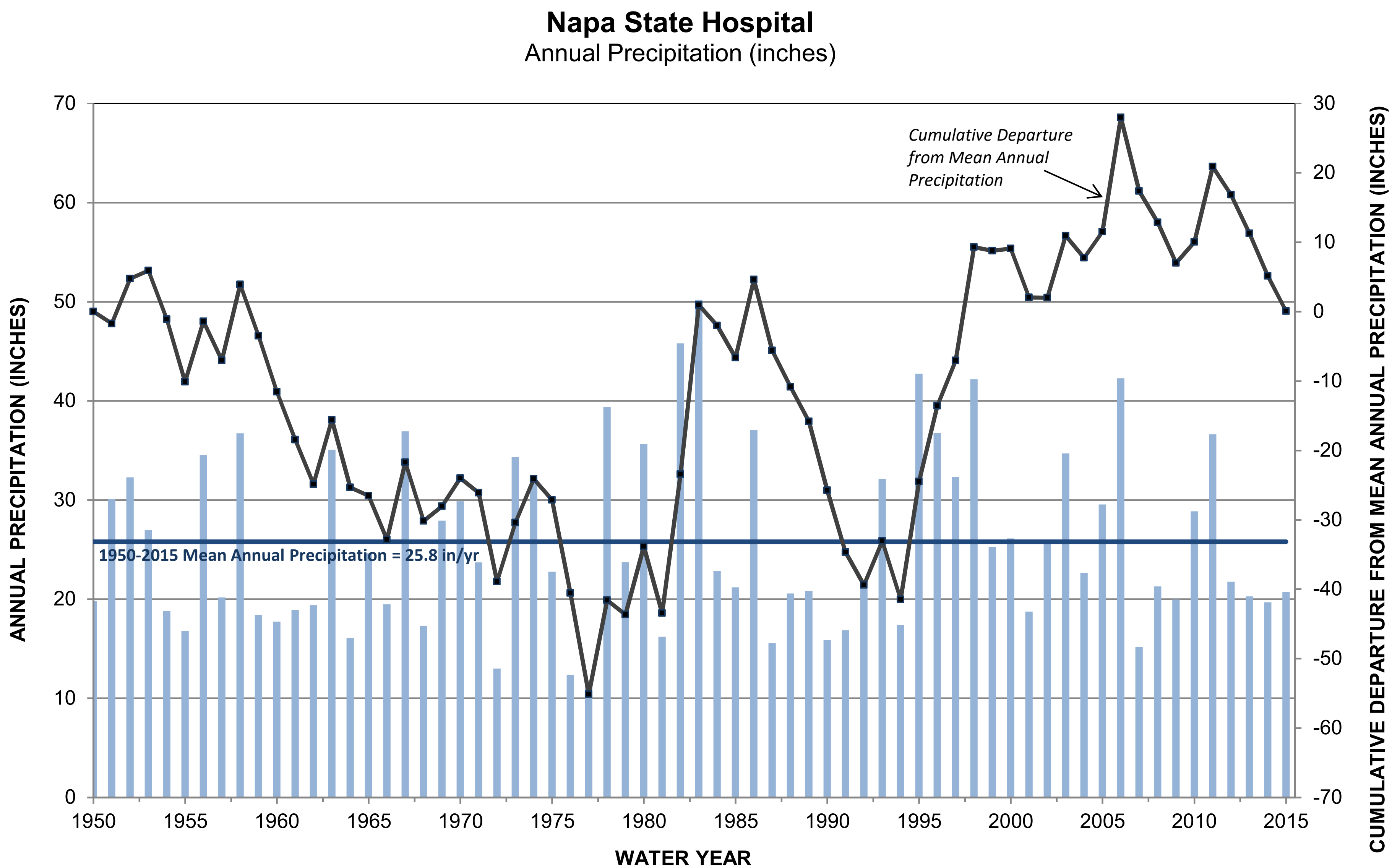
FIGURE 4-3
Napa County Surface Water-Groundwater Monitoring Sites

Napa County Comprehensive Groundwater Monitoring Program 2015 Annual Report and CASGEM Update



NOTE: Gaps in this data record have been reconstructed using data from the Oakville CIMIS station (77) and NOAA Saint Helena, CA US station (GHCND:USC0004764).

X:\2014 Job Files\14-054\Data\Precip\NCDC Data Summary UPDATED Feb2016.xlsx\NSH_CD_50-15plot Annual Rep (2

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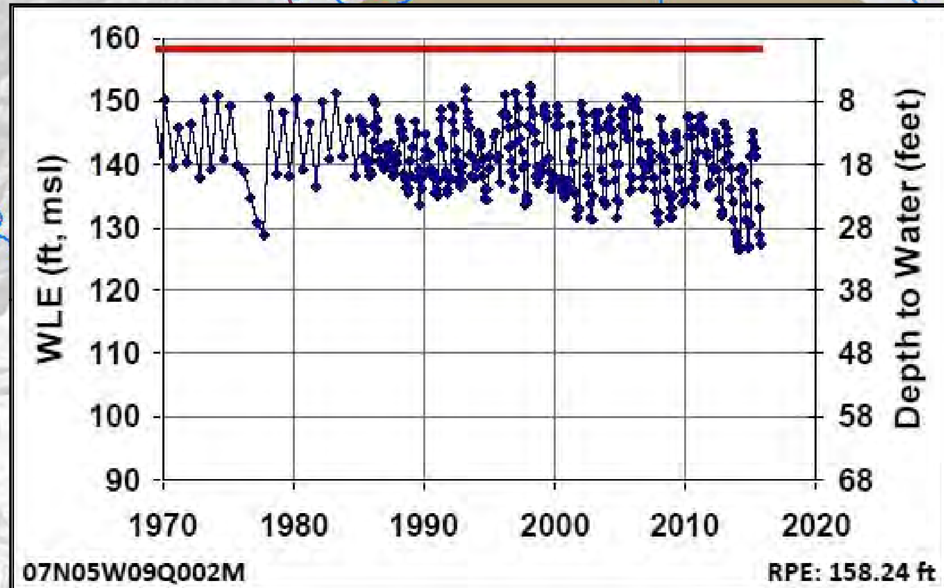
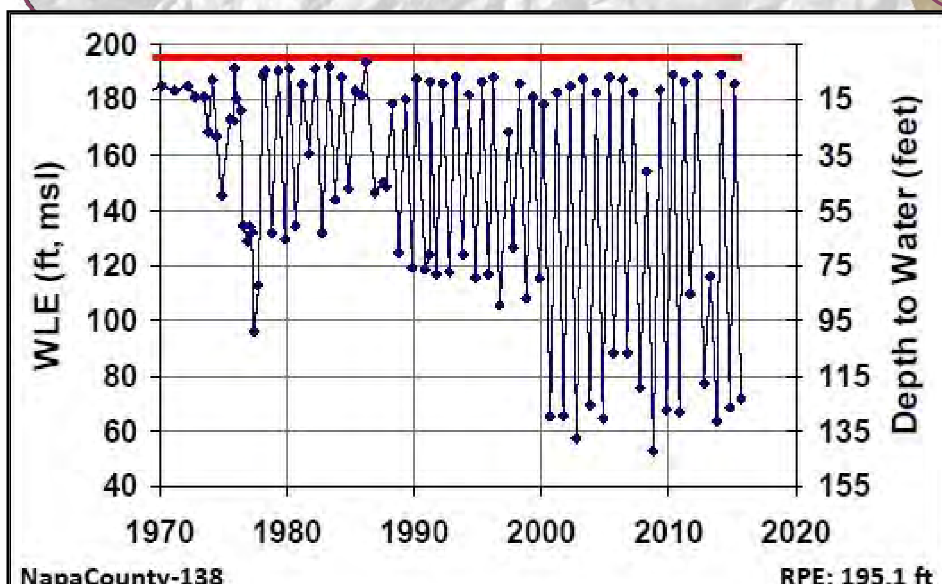
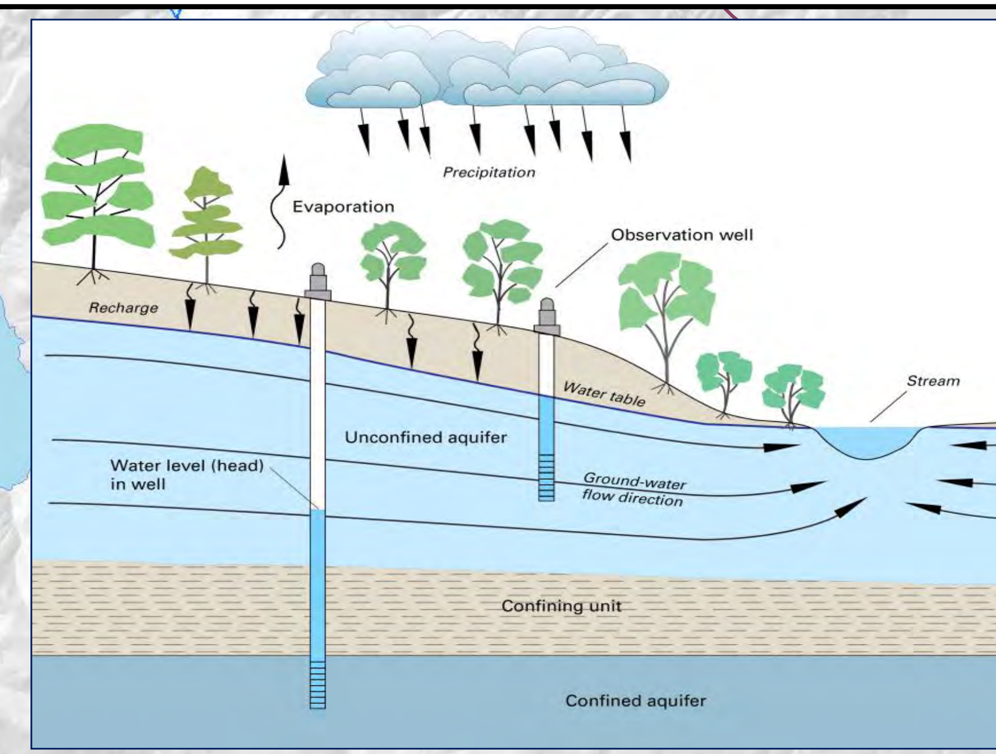
Figure 5-1
Napa State Hospital Water Year Precipitation and Cumulative Departure , Water Years 1950 - 2015



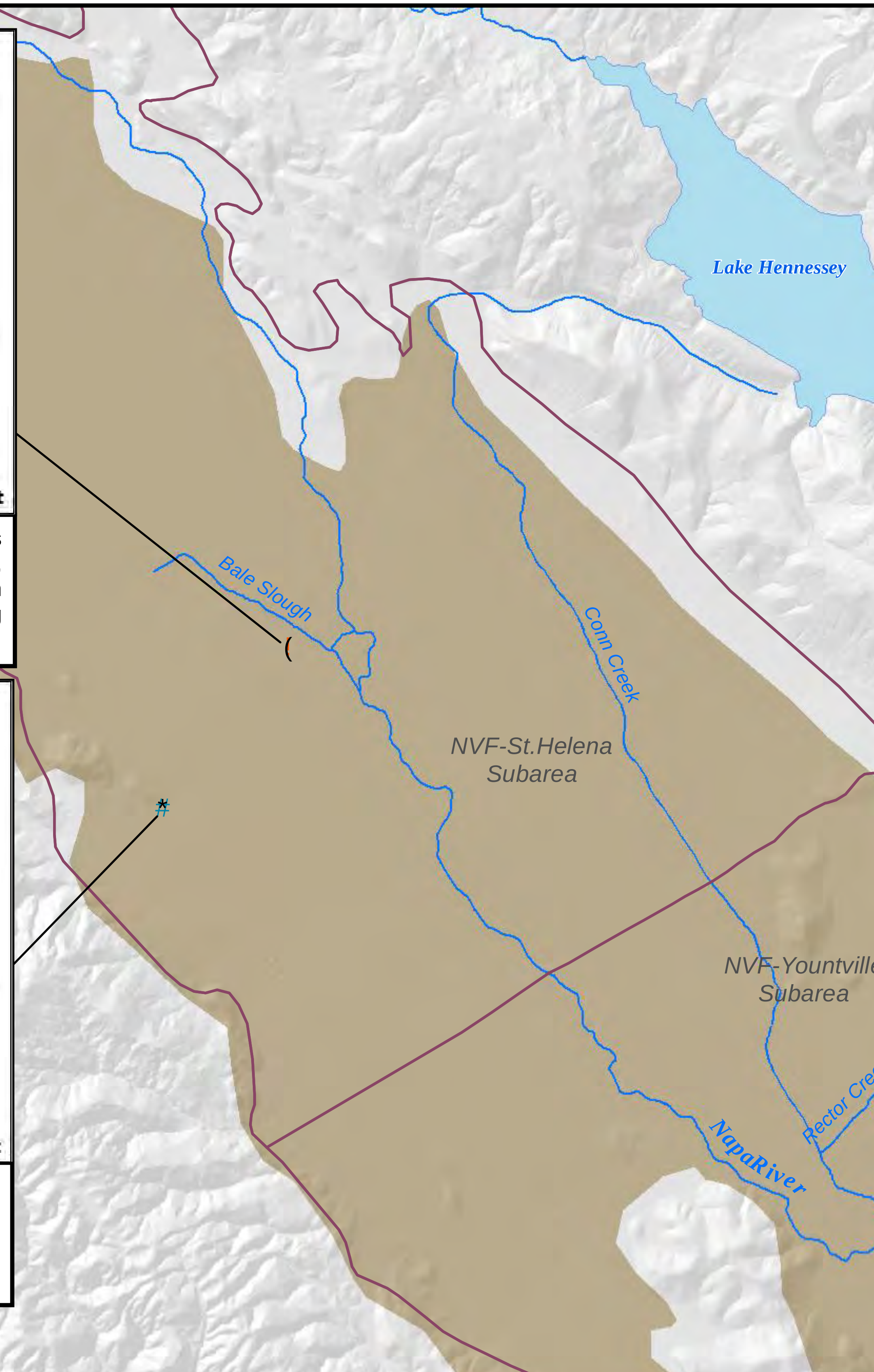
Well 07N05W09Q2 is constructed in an area where alluvial sediments extend to approximately 200 feet below ground surface (LSCE and MBK, 2013). Static groundwater levels in this well typically vary by about 20 ft from spring to fall and have remained well above the bottom of alluvium, indicating significant contributions from the alluvial aquifer system.



Well NapaCounty-138 has a total depth of 321 ft and is located in nearer to the Napa Valley margin in an area where alluvial sediments extend only approximately 50 feet below ground surface (LSCE and MBK, 2013). Static groundwater levels in this well indicate increasing contributions from geologic formations below the alluvium, although spring season groundwater levels have remained stable.



USGS (Taylor and Alley, 2001) schematic showing a relatively shallower well completed in (i.e., with screened intervals intersecting) an unconfined upper aquifer zone and a relatively deeper well completed below a confining unit in a deeper aquifer zone. The groundwater levels in these wells are illustrated as being different due to the influence of the distinct aquifer zones.



Explanation

2015 Groundwater Level Monitoring Sites

- NapaCounty
- CA Dept. of Water Resources

DWR Groundwater Basins and Subbasins

- Napa Valley Subbasin

Data sources

Napa County Comprehensive Groundwater Monitoring Program, California Department of Water Resources Water Data Library, Taylor and Alley, 2001

Path: X:\2014 Job Files\14-108\GIS\Mapfiles\Figure 5-2_Aq_zone_schematic 11_17_20160315.mxd

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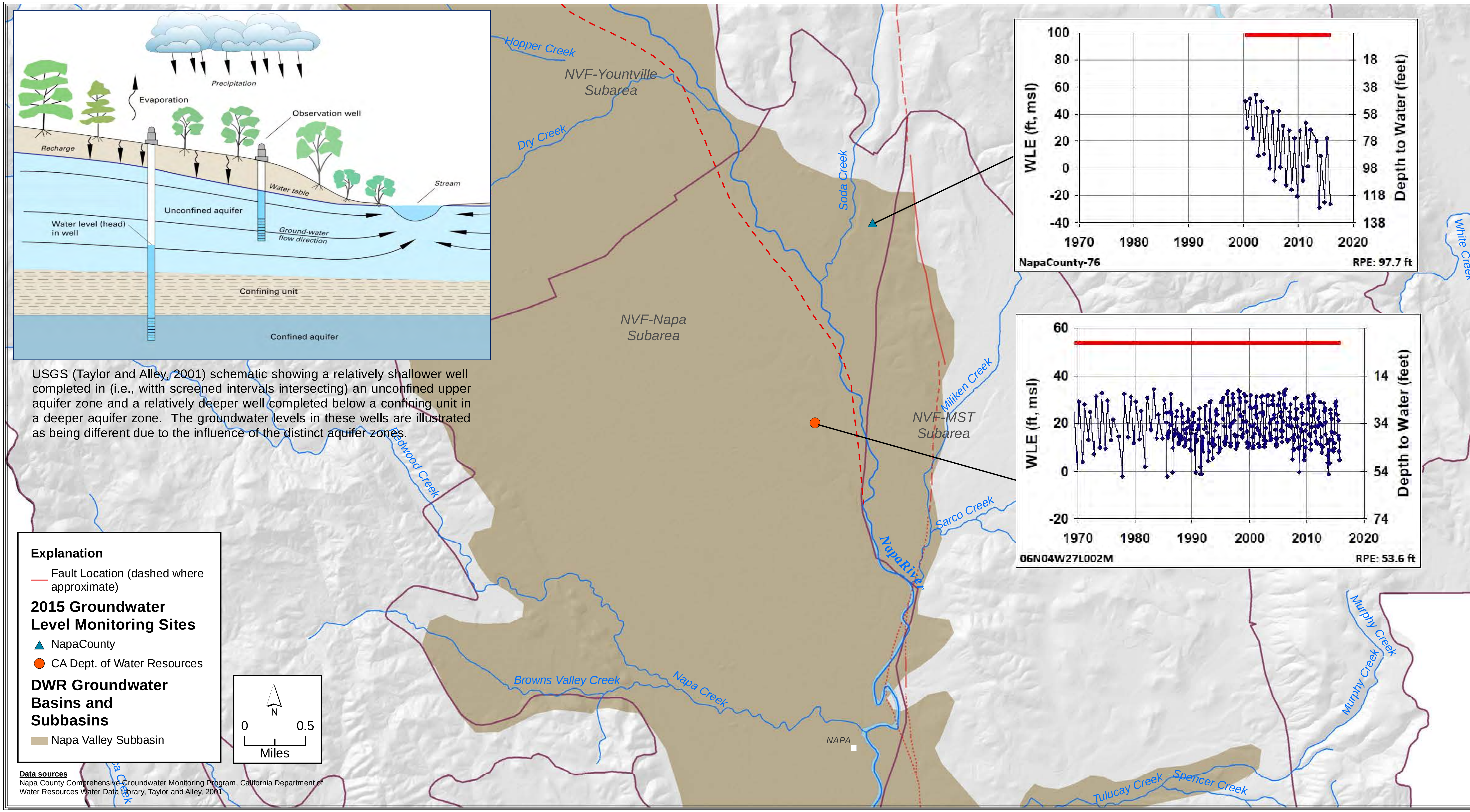
FIGURE 5-2

Southern St. Helena Subarea Aquifer Zone Schematic and Representative Hydrographs



USGS (Taylor and Alley, 2001) schematic showing a relatively shallower well completed in (i.e., witth screened intervals intersecting) an unconfined upper aquifer zone and a relatively deeper well completed below a confining unit in a deeper aquifer zone. The groundwater levels in these wells are illustrated as being different due to the influence of the distinct aquifer zones.

Path: X:\2014 Job Files\14-108\GIS\Mapfiles\Figure 5-3_Aq_zone_schematic 11_17_NVF_Napa20160315.mxd

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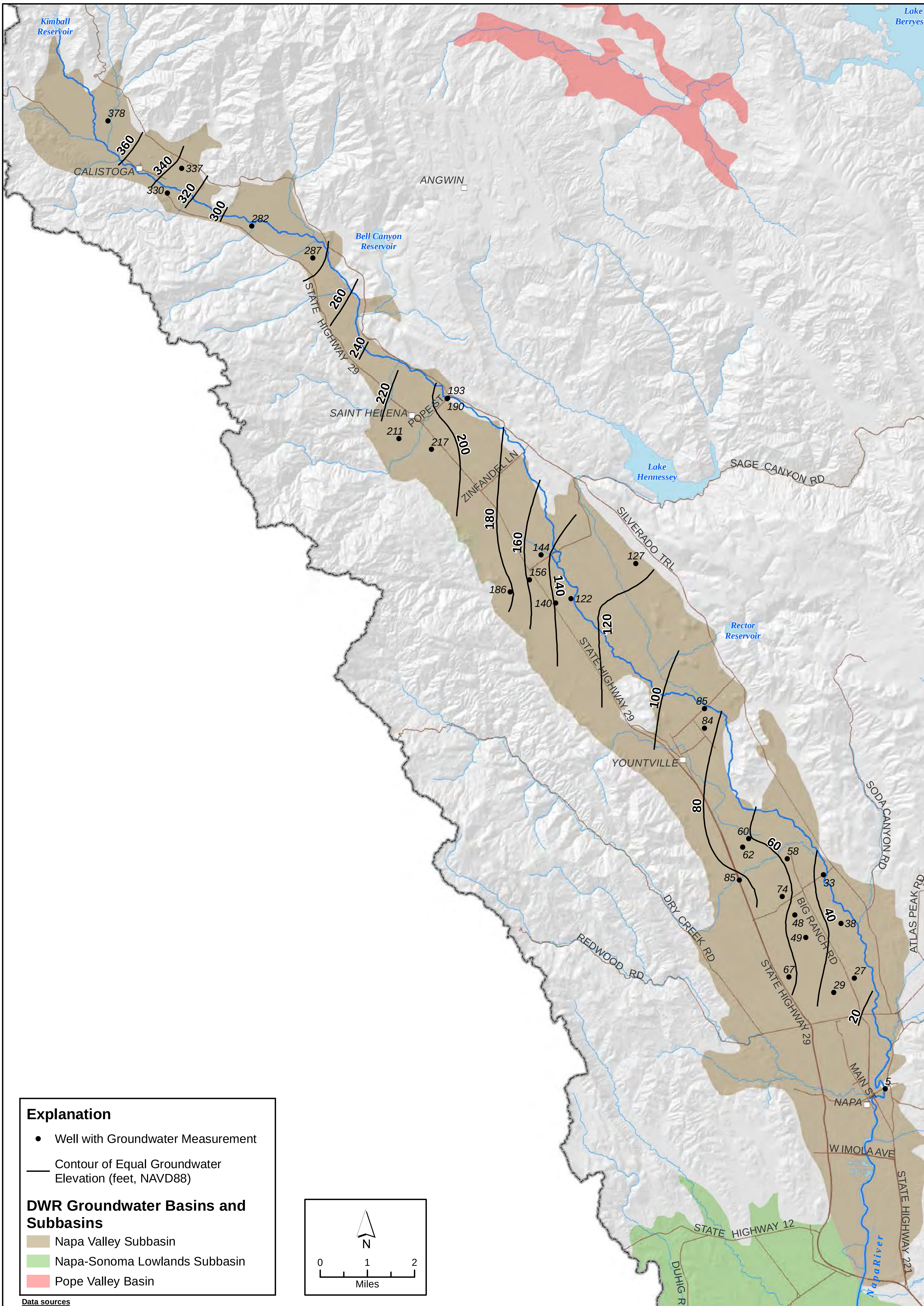
FIGURE 5-3

Northeast Napa Subarea Aquifer Zone Schematic and Representative Hydrographs

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



X:\2014 Job Files\14-108\GIS\Mapfiles\Spring 2015 NVF WL Contour Map.mxd

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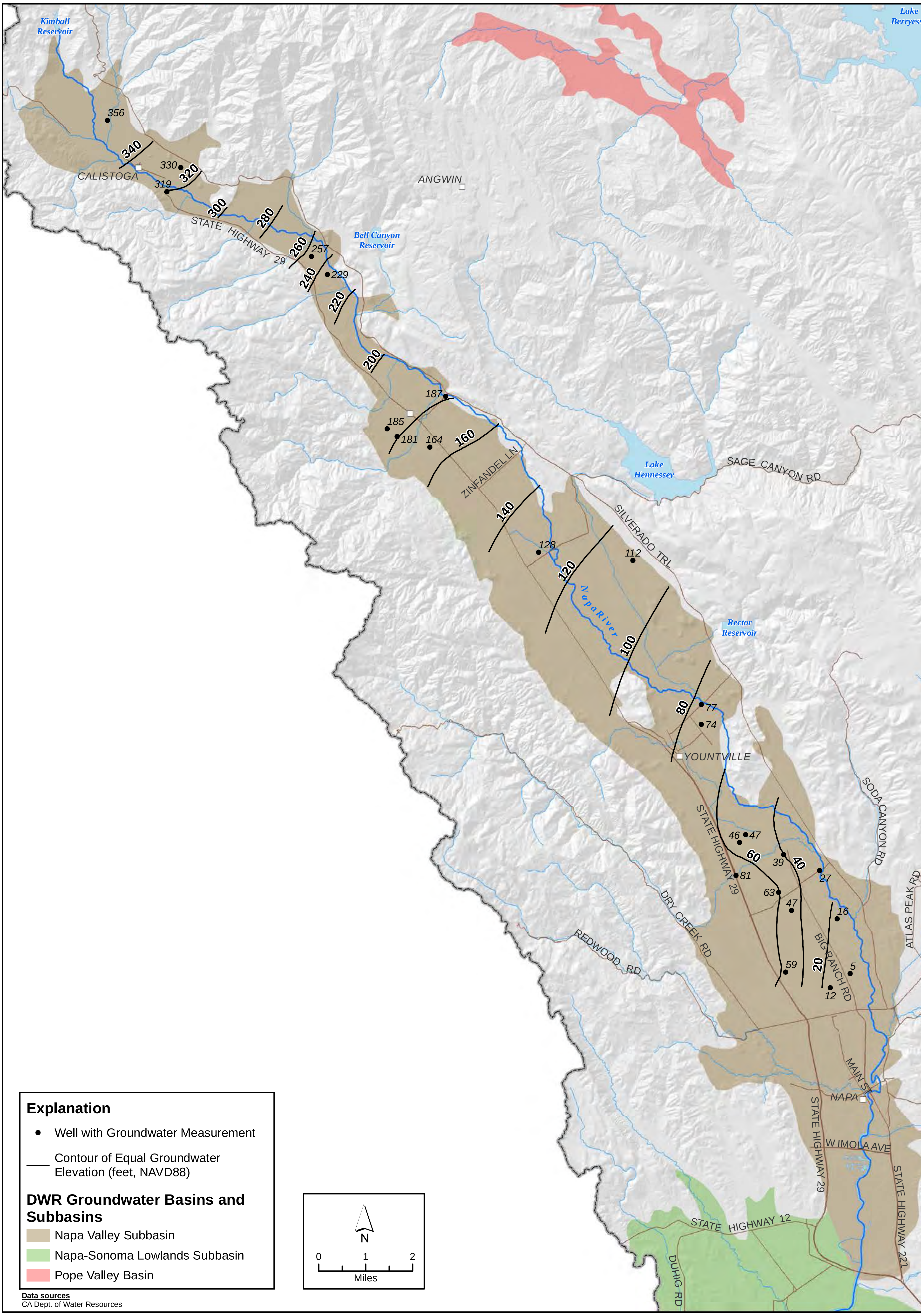
FIGURE 5-4
Contours of Equal Groundwater Elevation, Spring 2015
Napa Valley Subbasin, Napa County, CA



X:\2014 Job Files\14-108\GIS\Mapfiles\Fall 2015 NVF WL Contour Map.mxd

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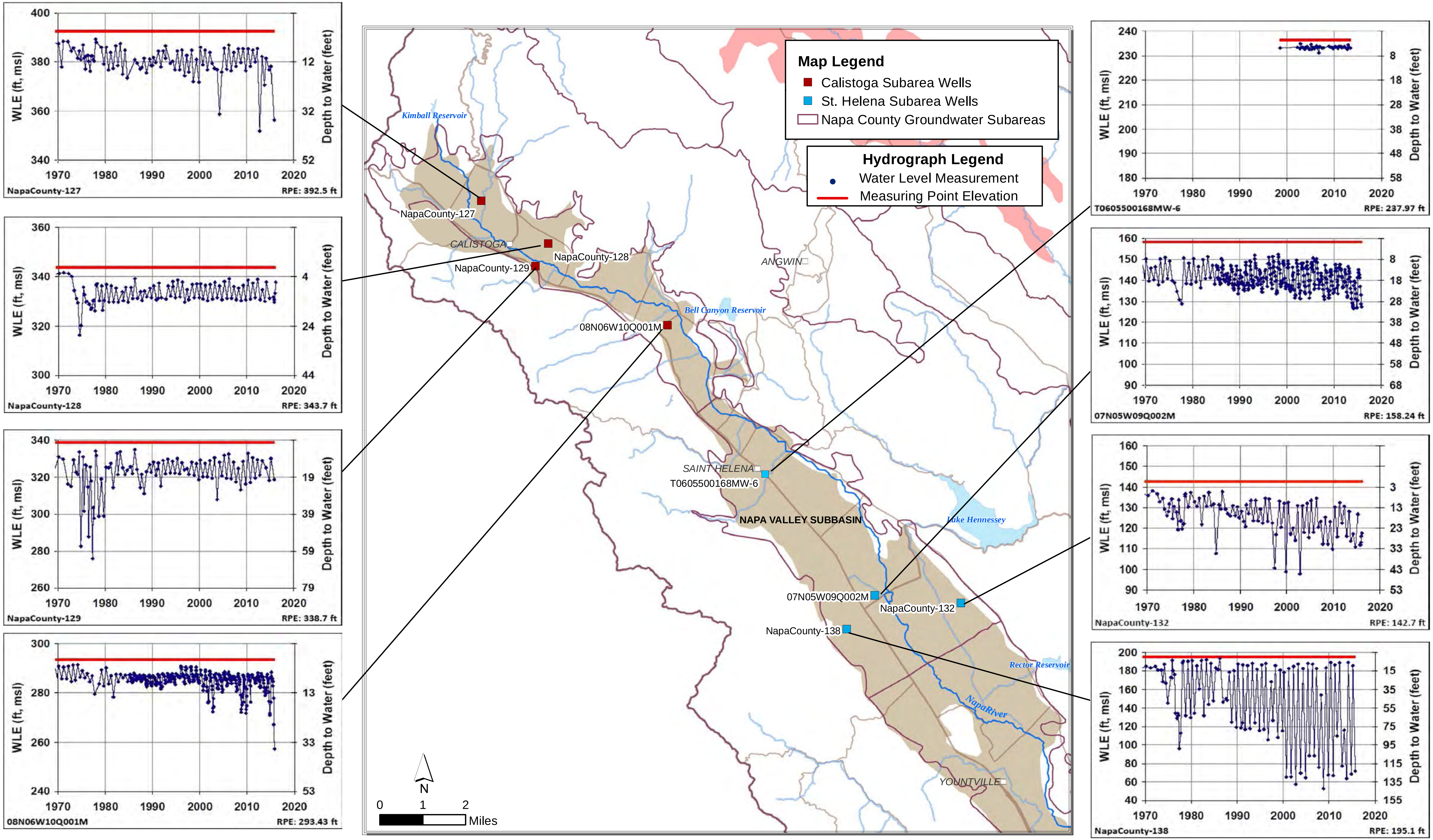
FIGURE 5-5
Contours of Equal Groundwater Elevation, Fall 2015
Napa Valley Floor, Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



Path: X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\HydrographNorthernNapaValley_thru2015.mxd

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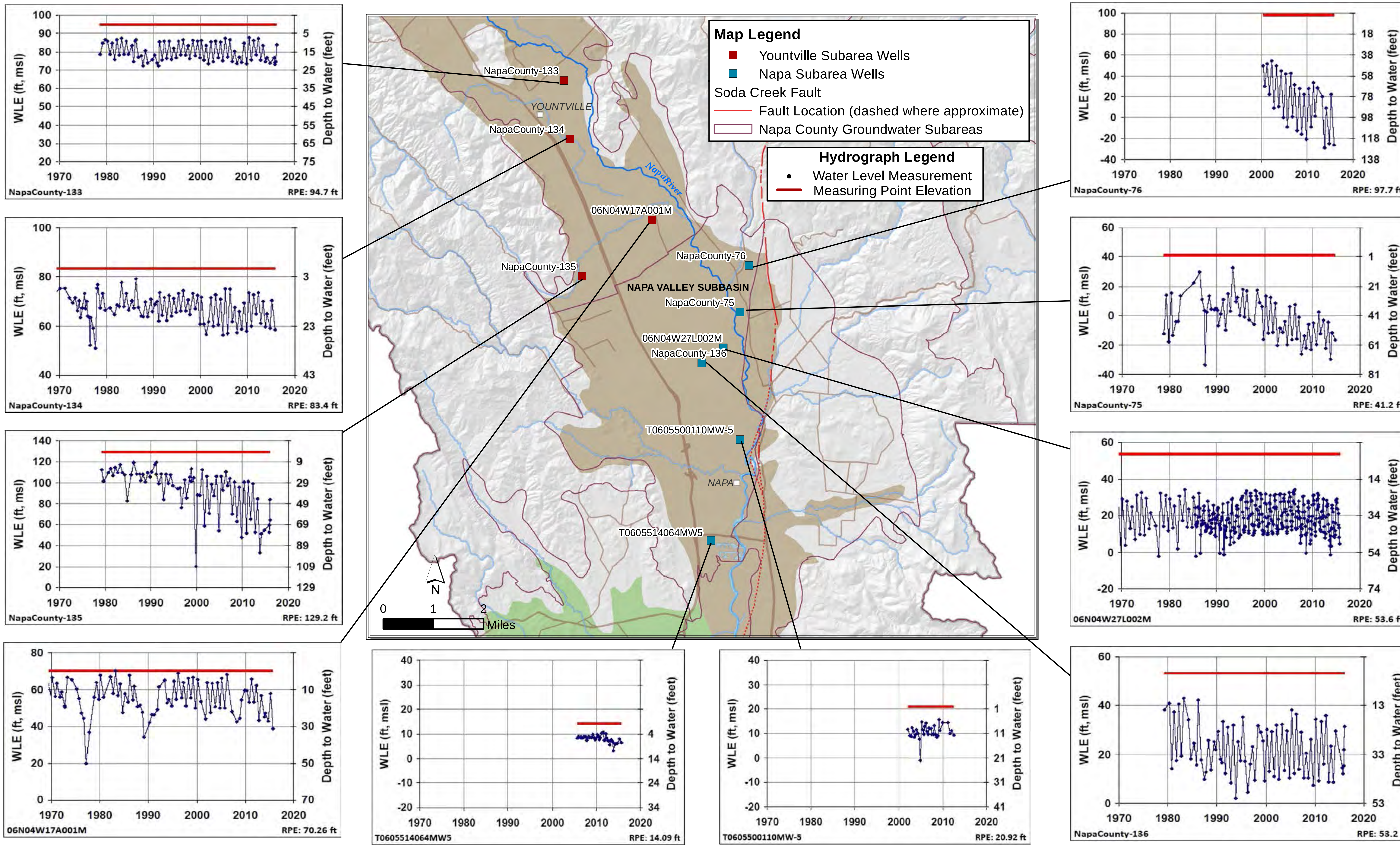
FIGURE 5-6
Representative Groundwater Hydrographs Northern Napa Valley

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



Path: X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\Hydrograph_SouthernNapaValley.mxd

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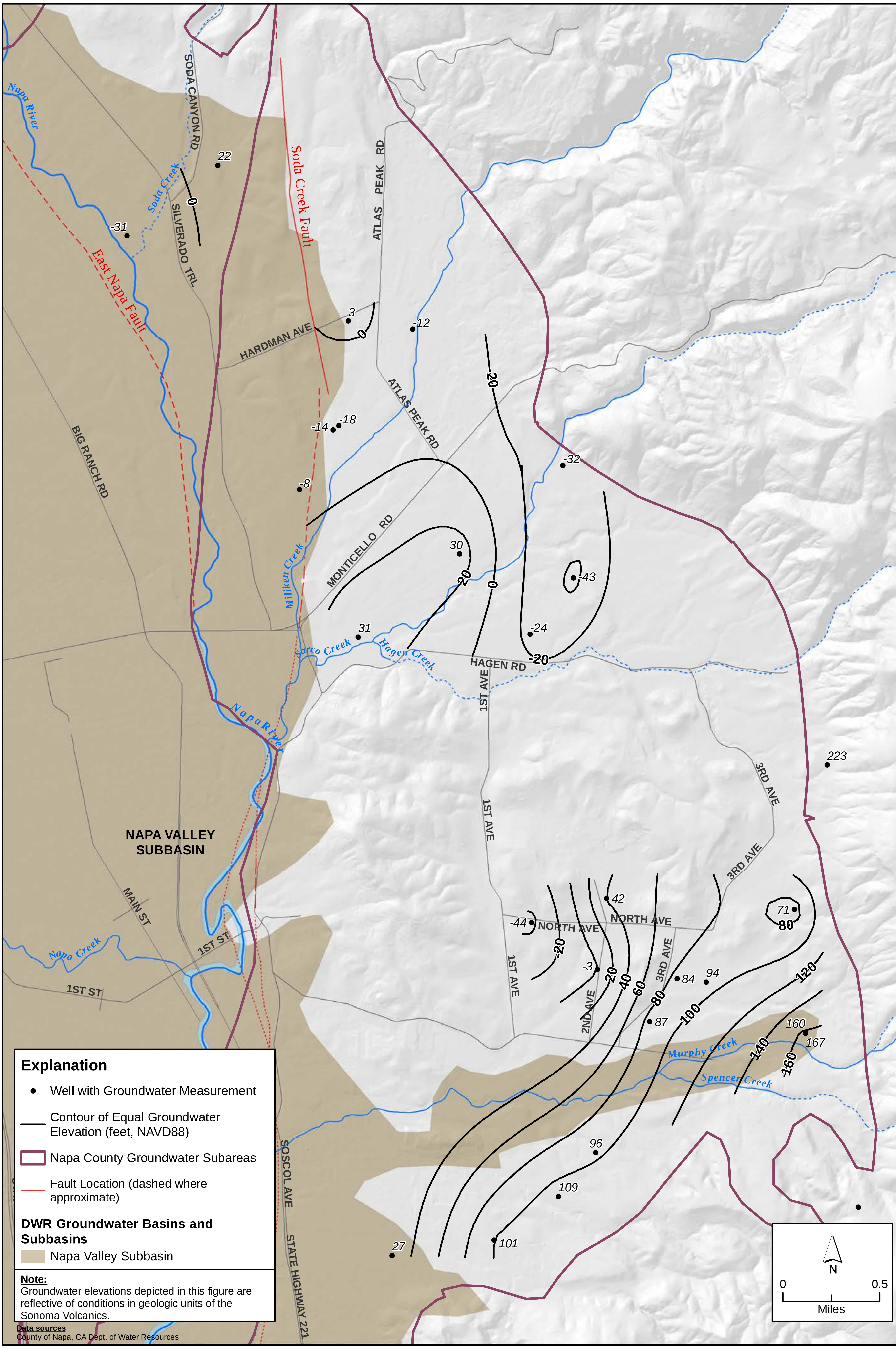
FIGURE 5-7
Representative Groundwater Hydrographs Southern Napa Valley

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



X:\2014 Job Files\14-108\GIS\Mapfiles\Spring 2015 MST WL Contour Map.mxd

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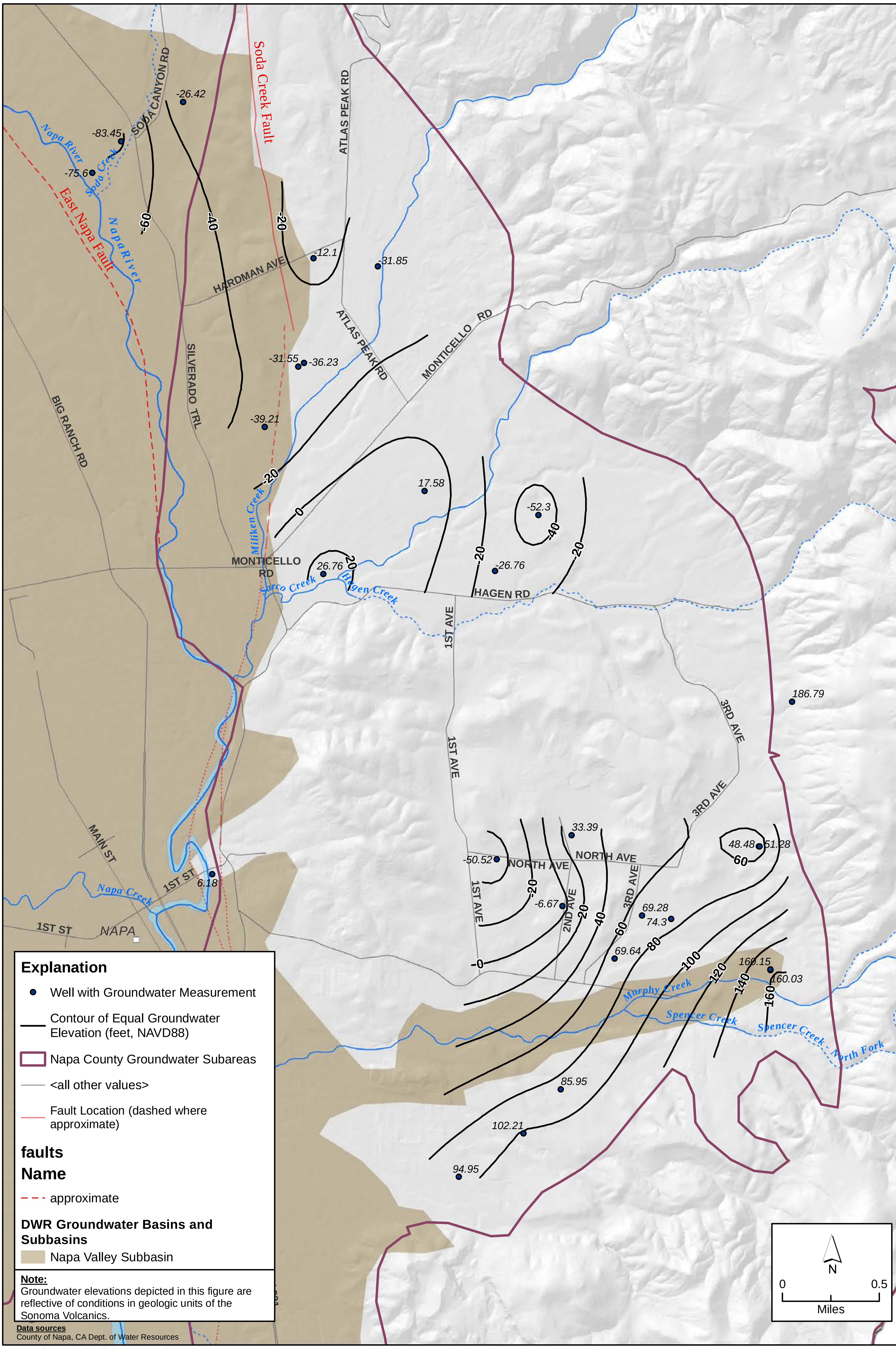
FIGURE 5-8

Contours of Equal Groundwater Elevation, Spring 2015
MST Subarea, Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\Fall 2015 MST WL Contour Map.mxd

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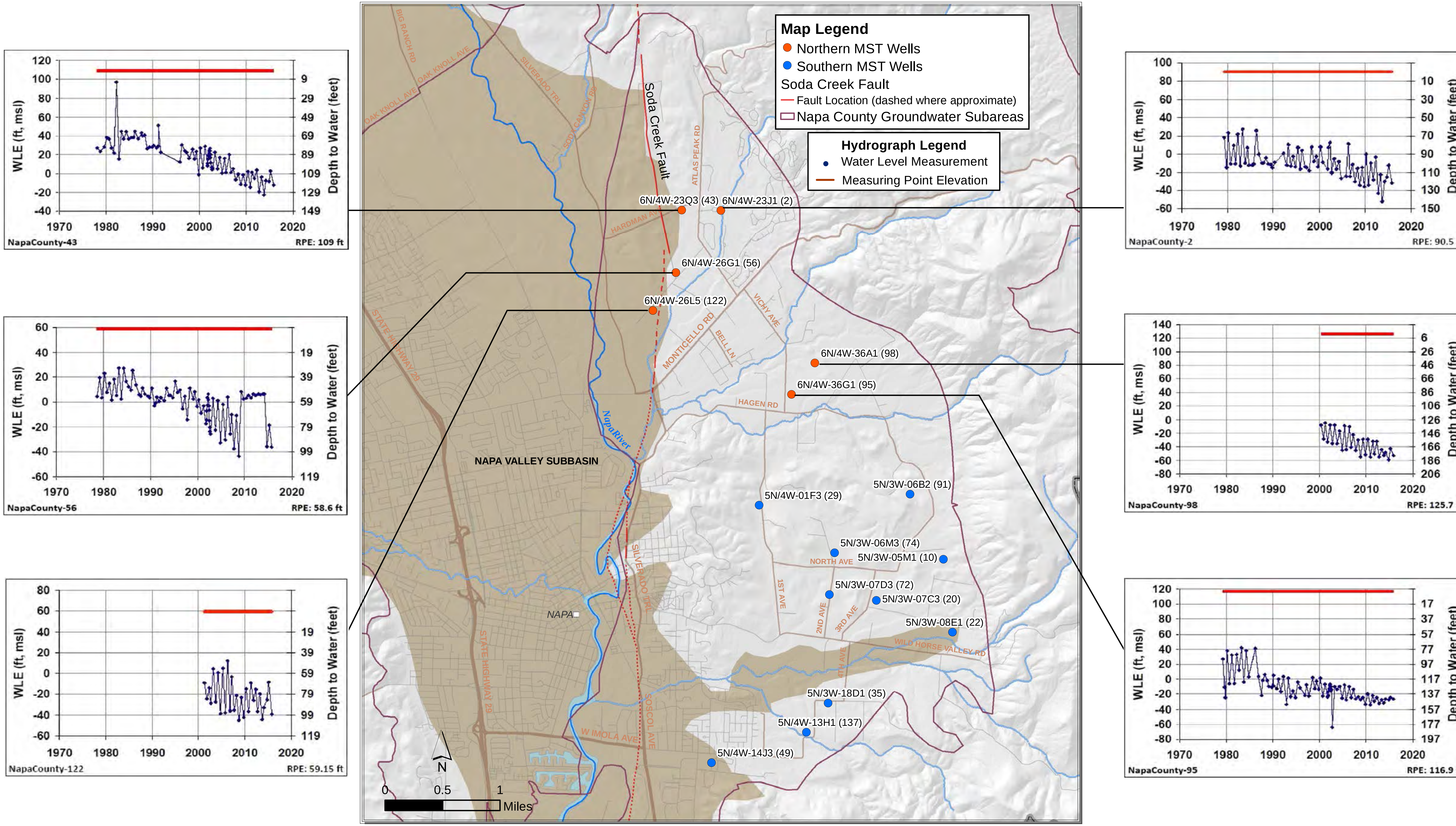
FIGURE 5-9

Contours of Equal Groundwater Elevation, Fall 2015
MST Subarea, Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



Path: X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\HydrographNorthernMST_thru2015.mxd

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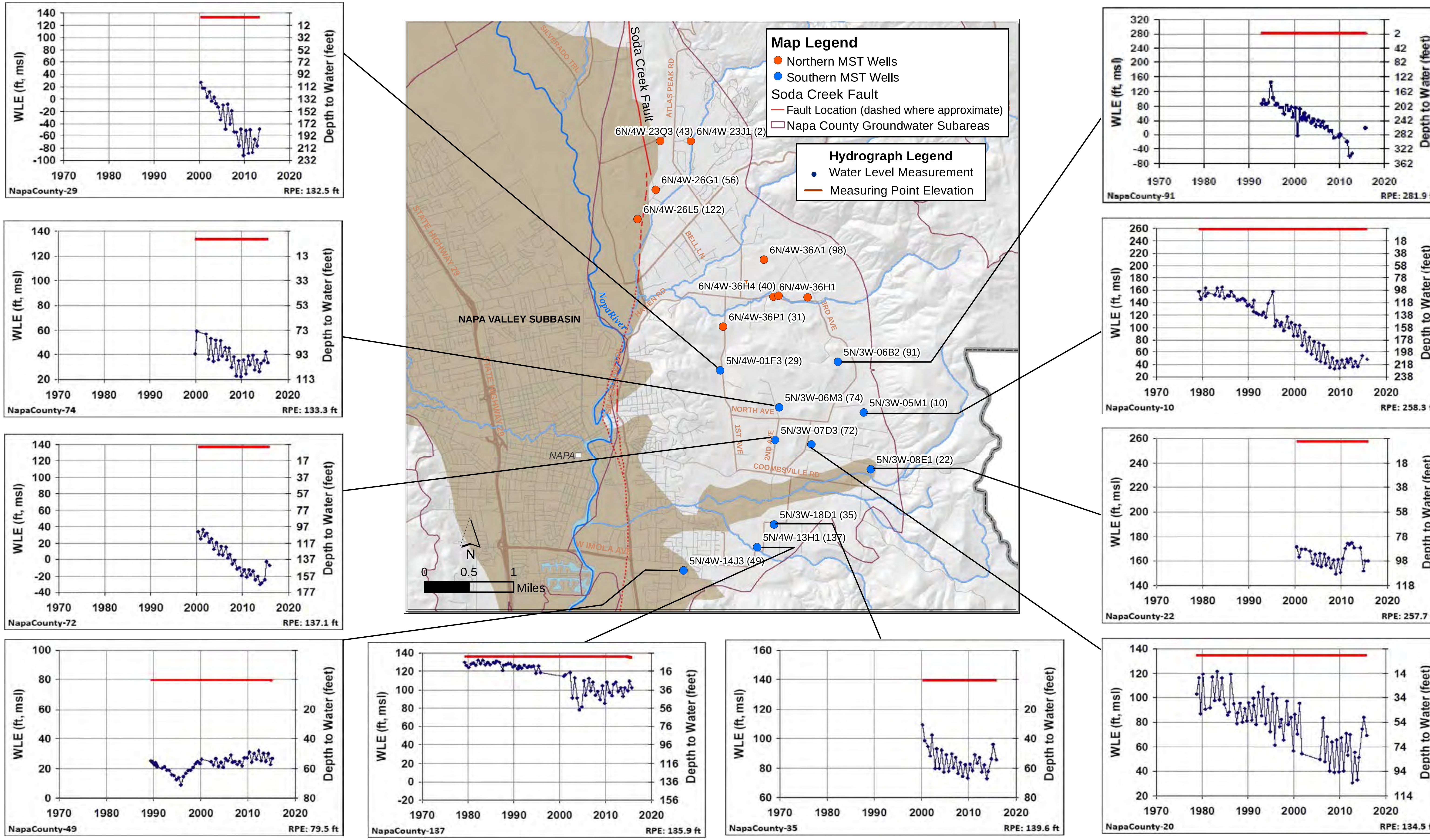
FIGURE 5-10

Representative Groundwater Hydrographs Northern MST Subarea

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



Path: X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\HydrographsSouthernMST_thru2015.mxd

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FIGURE 5-11
Representative Groundwater Hydrographs Southern MST Subarea

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update

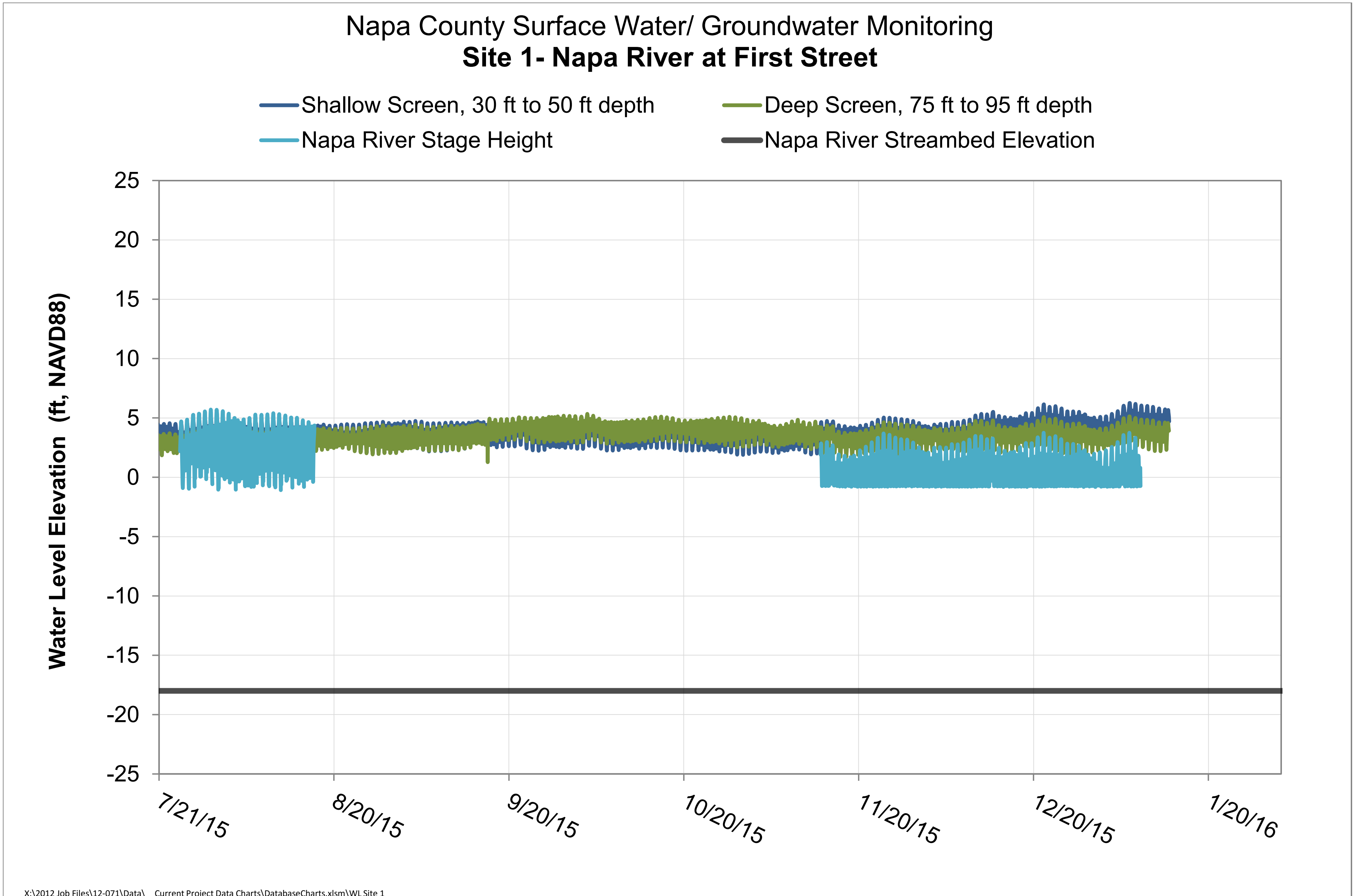

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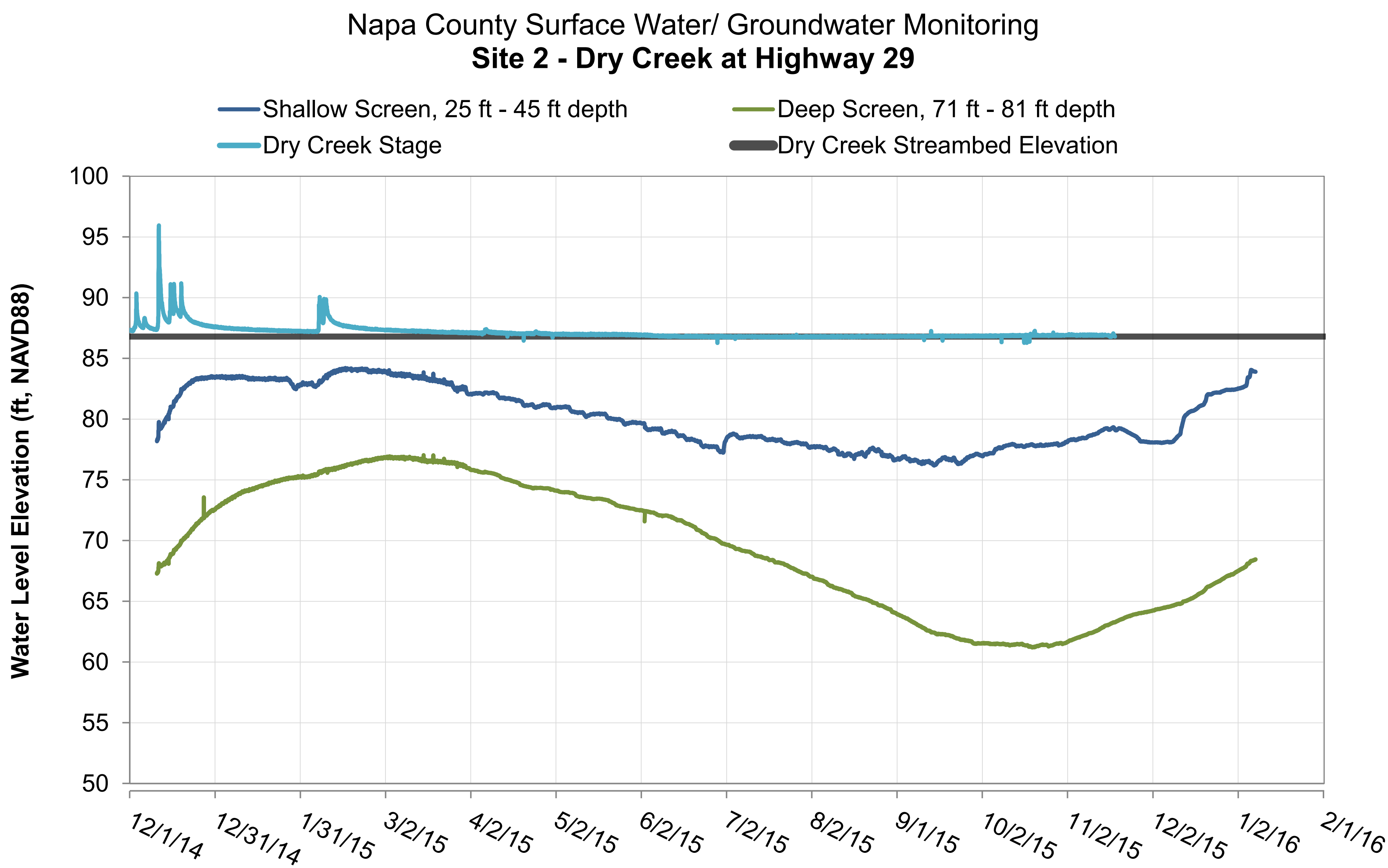
Figure 5-12
Surface Water-Groundwater Hydrograph
Site 1: Napa River at First Street



X:\2012 Job Files\12-071\Data__Current Project Data Charts\DatabaseCharts.xlsm\WL Site 2

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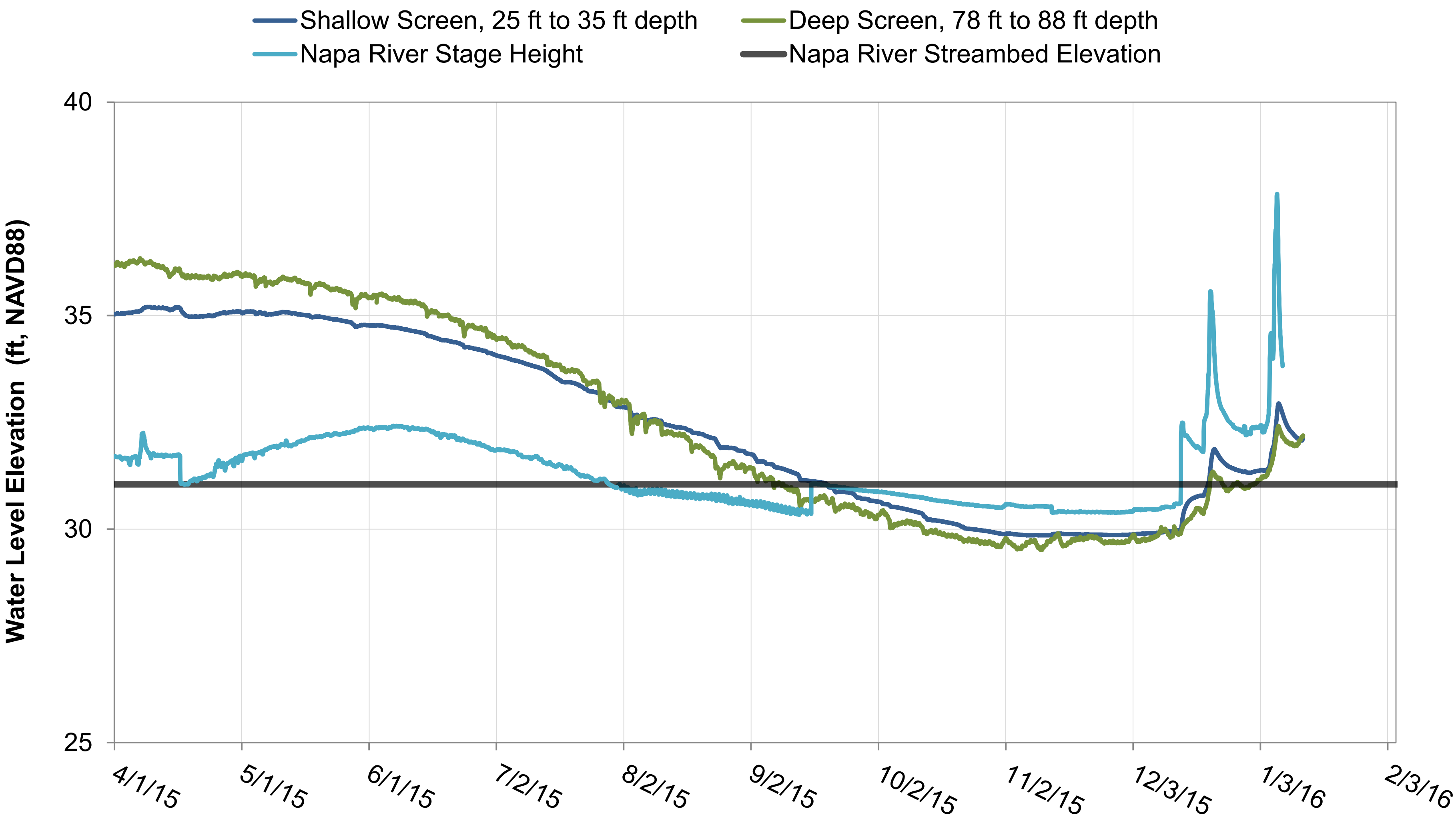
Figure 5-13
Surface Water-Groundwater Hydrograph
Site 2: Dry Creek at Highway 29

Napa County Surface Water/ Groundwater Monitoring

Site 3 - Napa River at Oak Knoll Boulevard



X:\2012 Job Files\12-071\Data__Current Project Data Charts\DatabaseCharts.xlsm\WL Site 3

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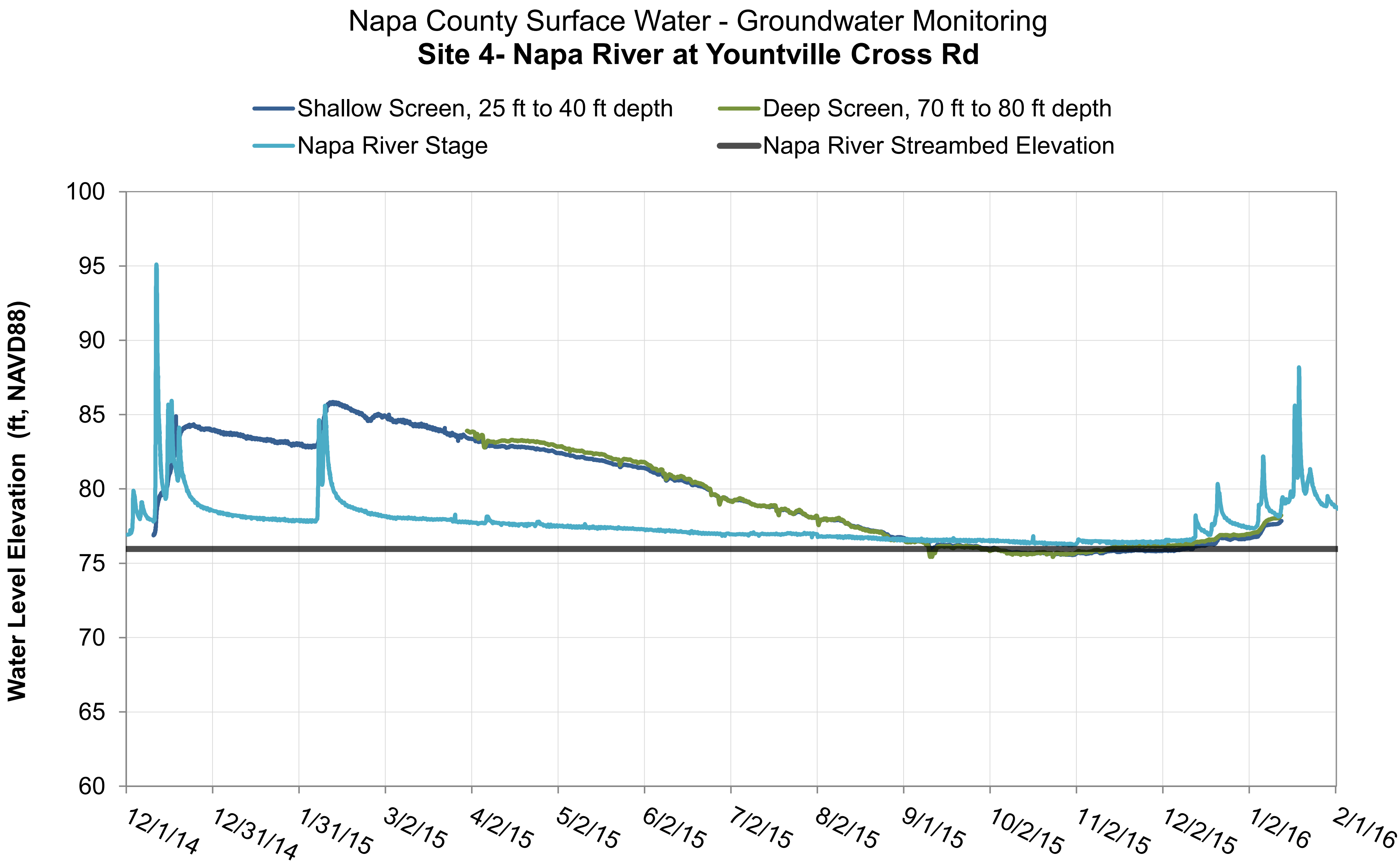
Figure 5-14
Surface Water-Groundwater Hydrograph
Site 3: Napa River at Oak Knoll Avenue



X:\2012 Job Files\12-071\Data__Current Project Data Charts\DatabaseCharts.xlsm\WL Site 4

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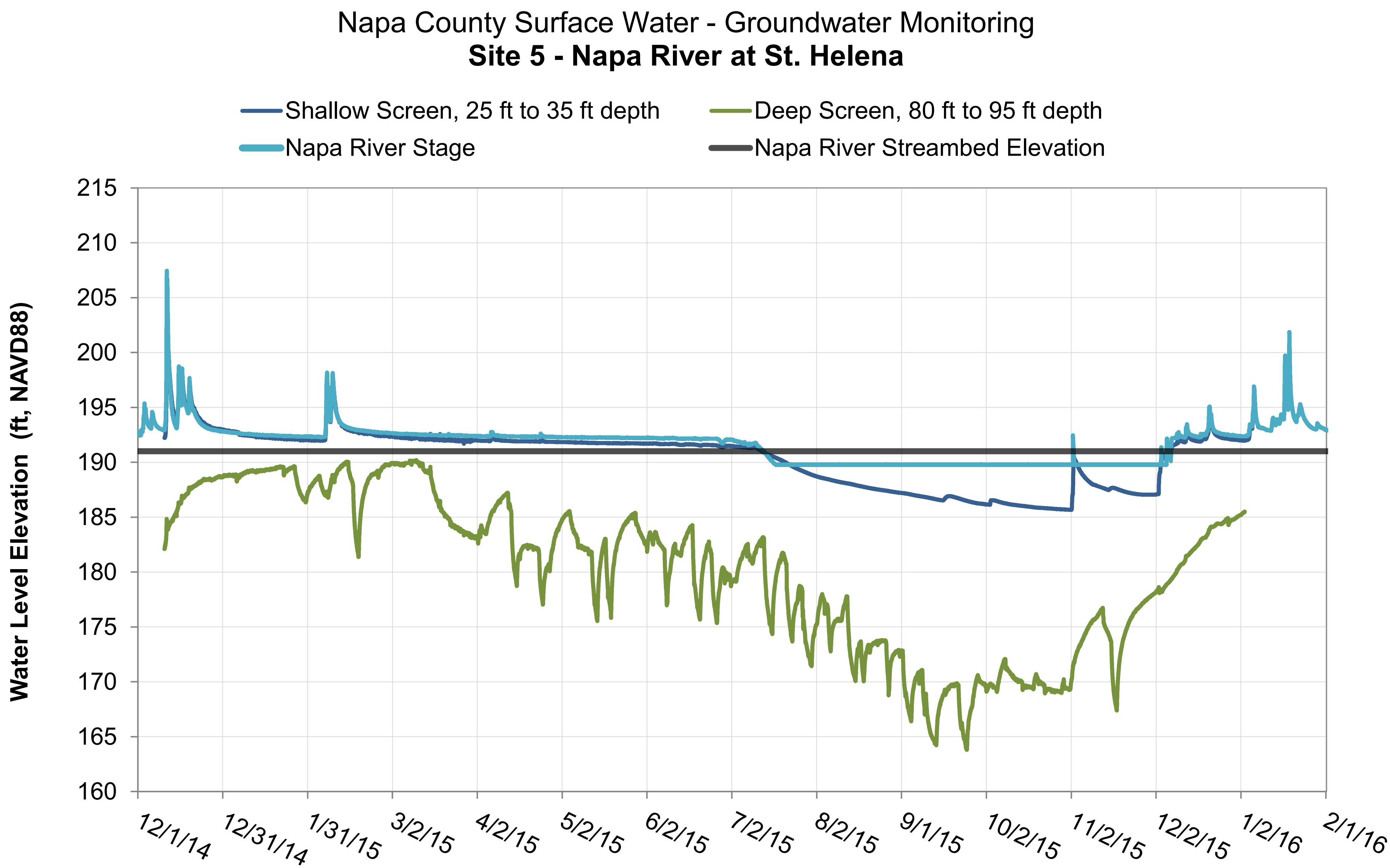
Figure 5-15
Surface Water-Groundwater Hydrograph
Site 4: Napa River at Yountville Cross Road



X:\2012 Job Files\12-071\Data__Current Project Data Charts\DatabaseCharts.xlsm\WL Site5

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Figure 5-16
Surface Water-Groundwater Hydrograph
Site 5: Napa River at Pope Street

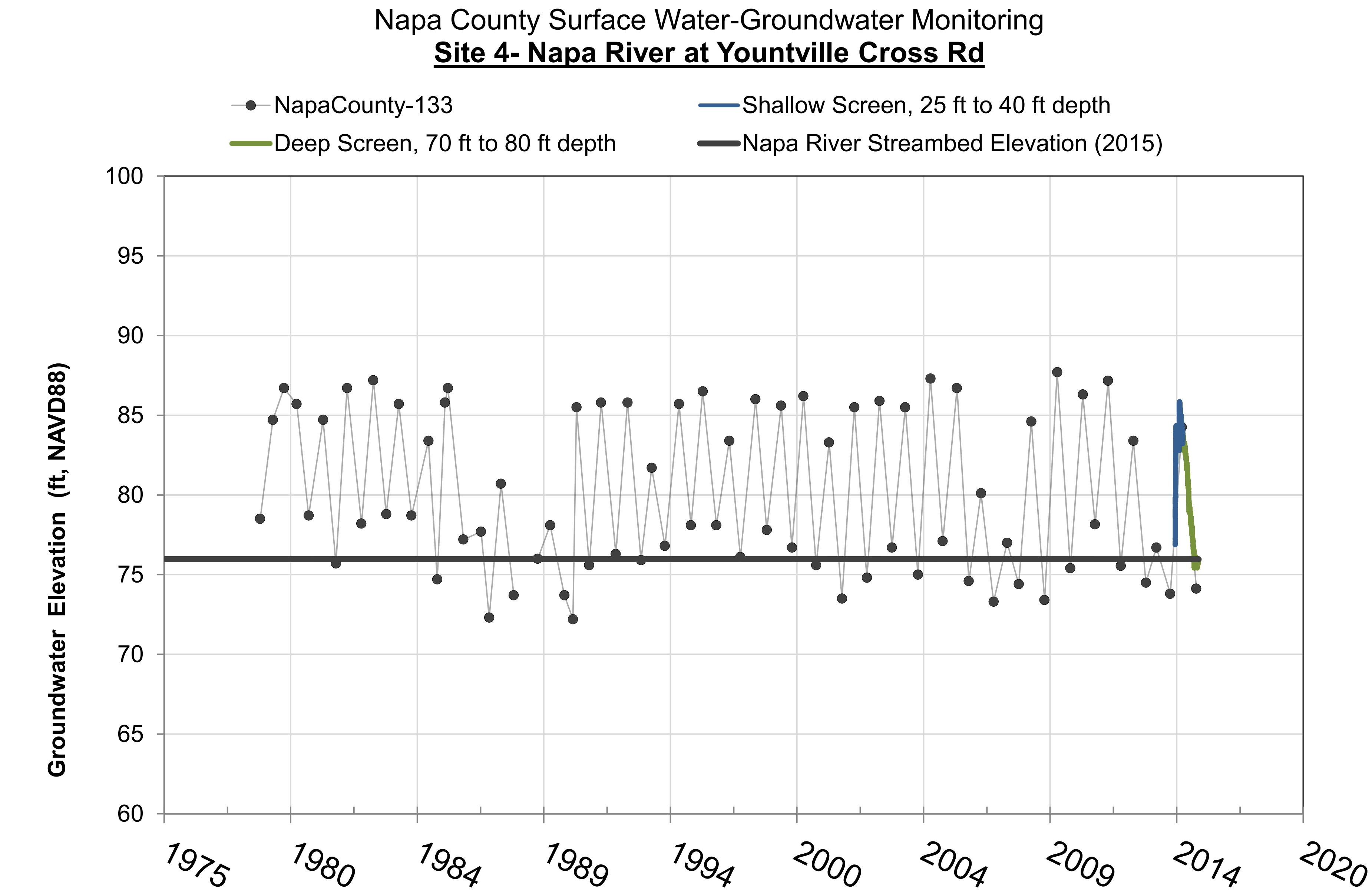

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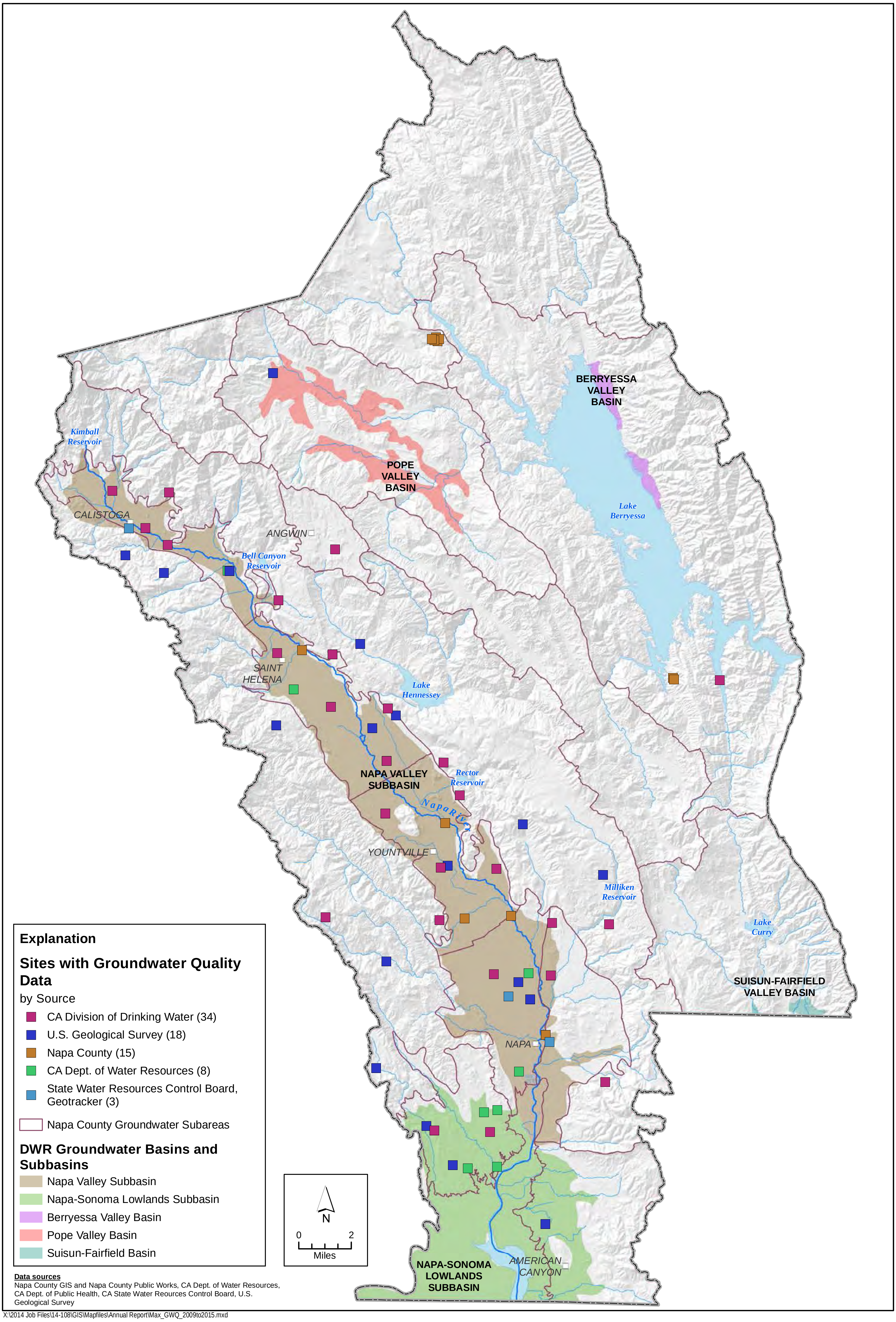
Figure 5-17
Surface Water-Groundwater Network Site Historical Comparison
Site 4: Napa River at Yountville Cross Road



Data sources
Napa County GIS and Napa County Public Works, CA Dept. of Water Resources, CA Dept. of Public Health, CA State Water Reources Control Board, U.S. Geological Survey

X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\Max_GWQ_2009to2015.mxd

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FIGURE 6-1
Groundwater Quality Sites, 2009 - 2015
Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update

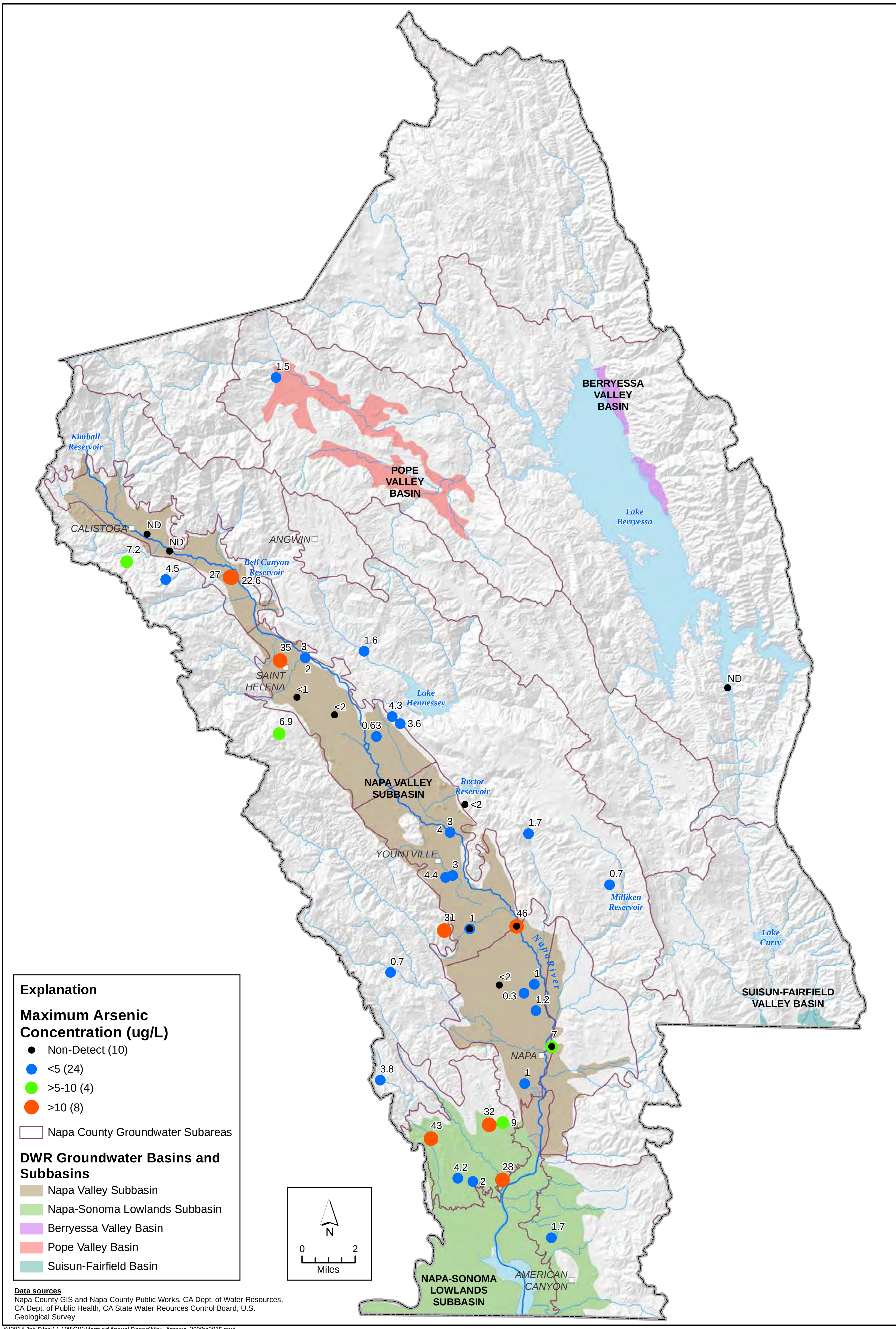

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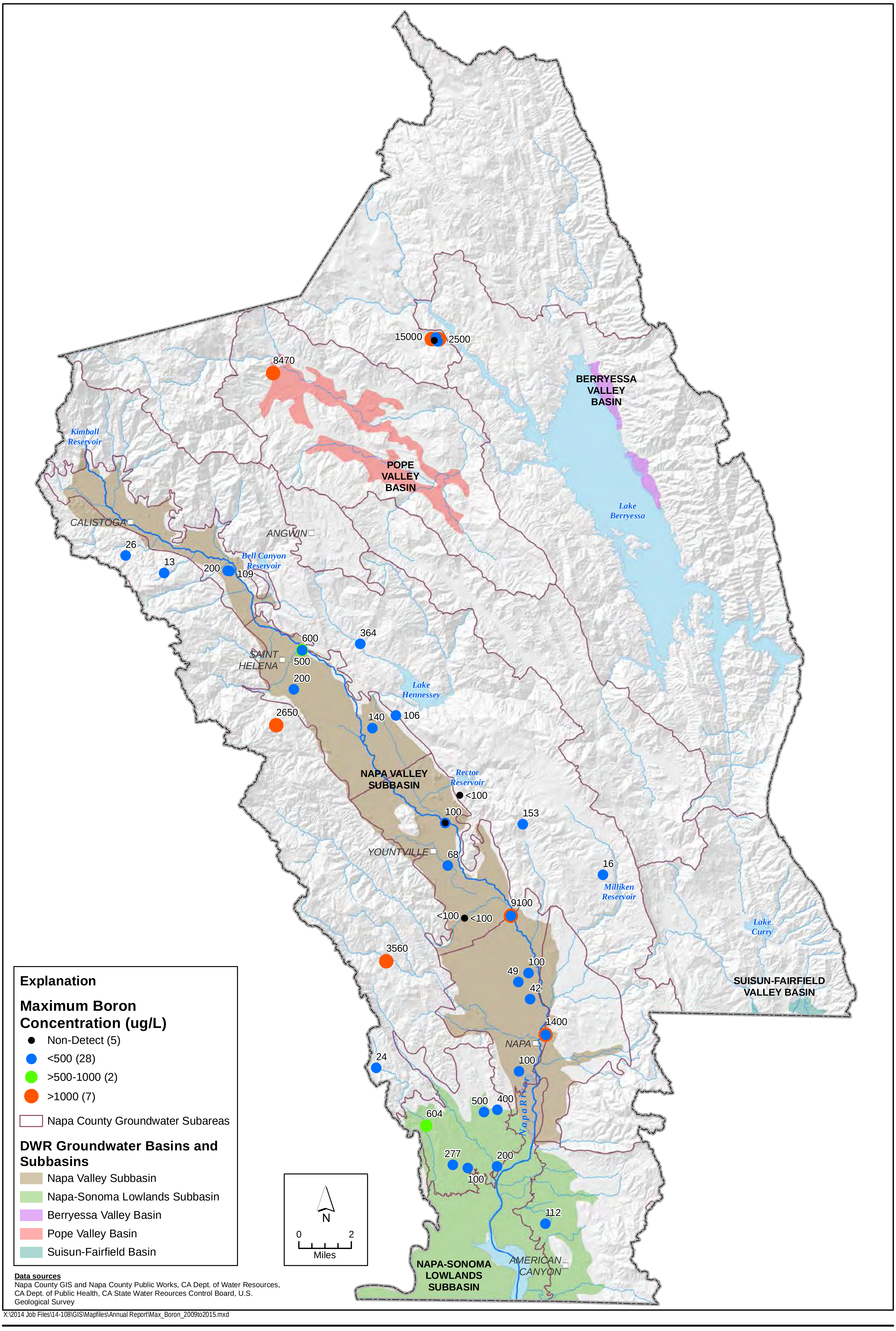
FIGURE 6-2
Maximum Arsenic Concentrations in Groundwater, 2009 - 2015
Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\Max_Boron_2009to2015.mxd

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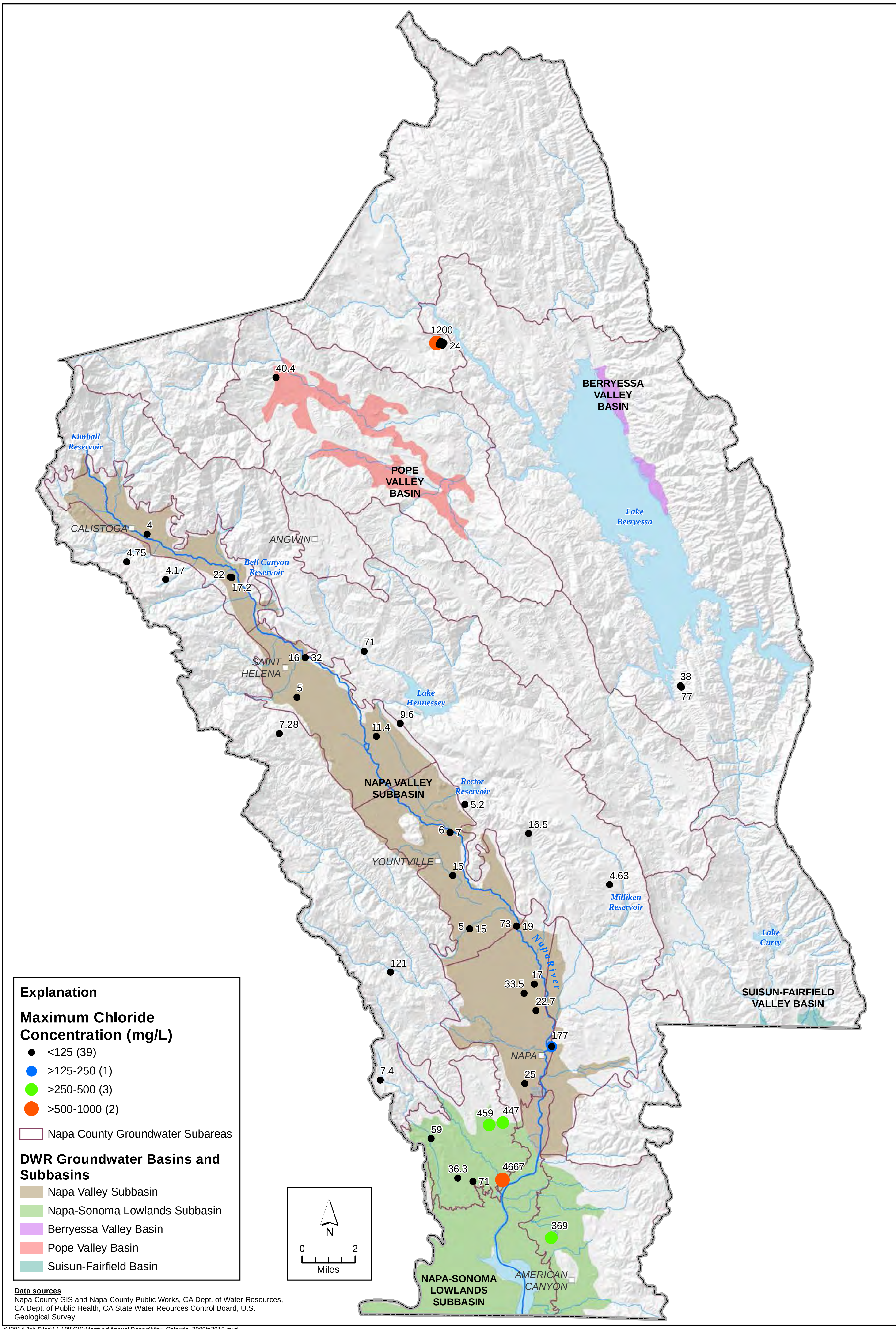
FIGURE 6-3
Maximum Boron Concentrations in Groundwater, 2009 - 2015
Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\Max_Chloride_2009to2015.mxd

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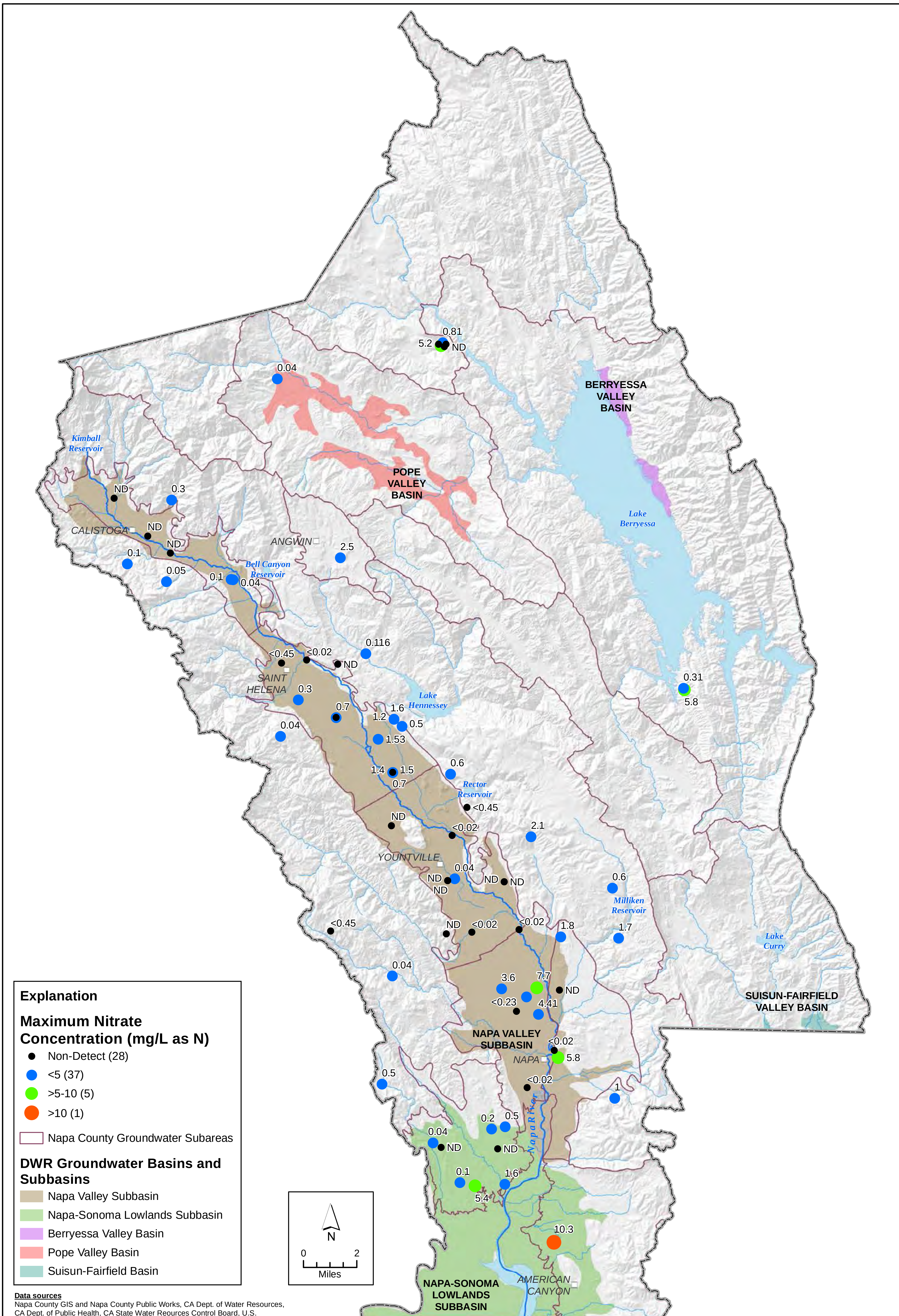
FIGURE 6-4
Maximum Chloride Concentrations in Groundwater, 2009 - 2015
Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



Data sources
Napa County GIS and Napa County Public Works, CA Dept. of Water Resources, CA Dept. of Public Health, CA State Water Reources Control Board, U.S. Geological Survey

X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\Max_Nitrate_2009to2015.mxd

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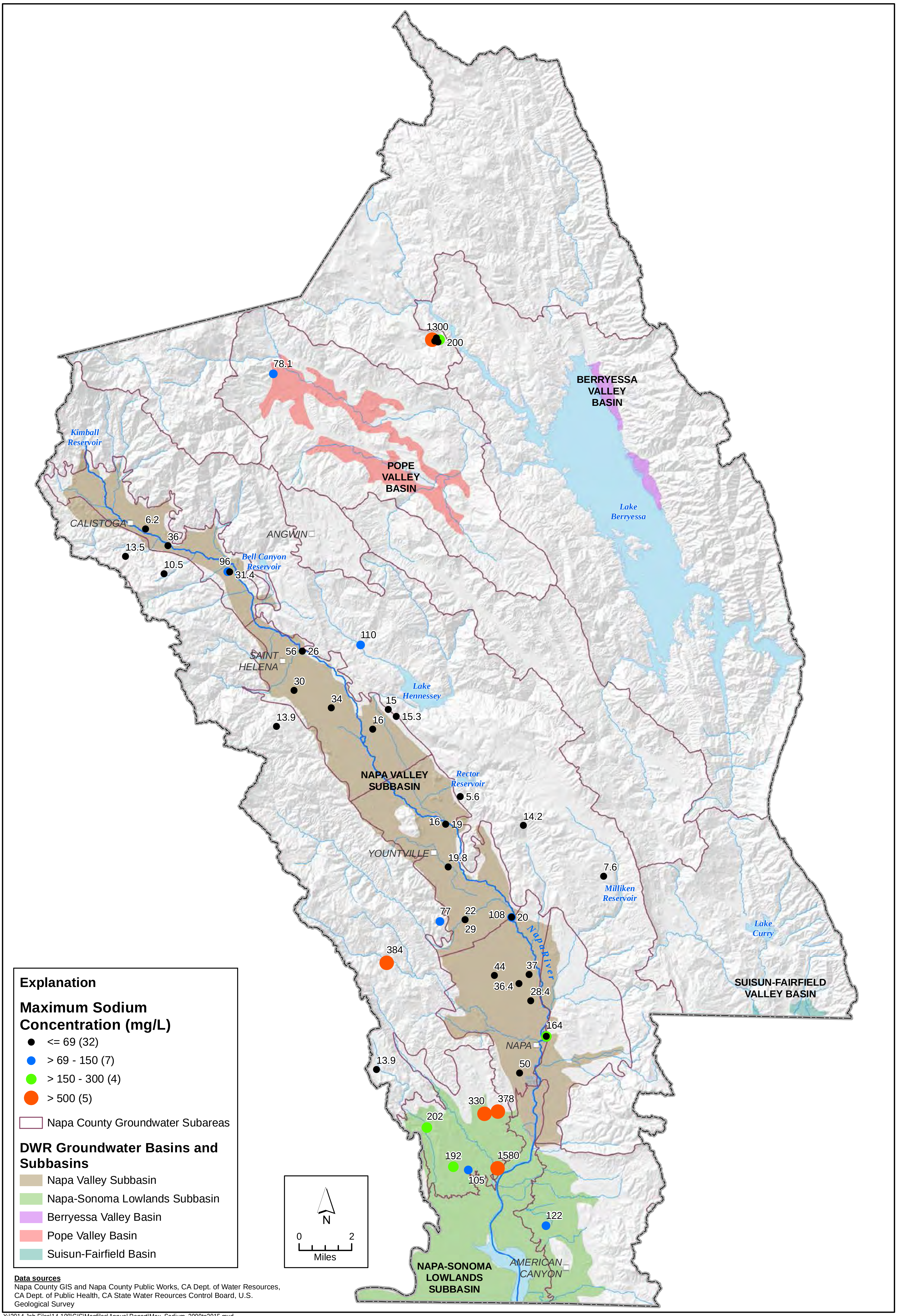
FIGURE 6-5
Maximum Nitrate Concentrations in Groundwater, 2009 - 2015
Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\Max_Sodium_2009to2015.mxd

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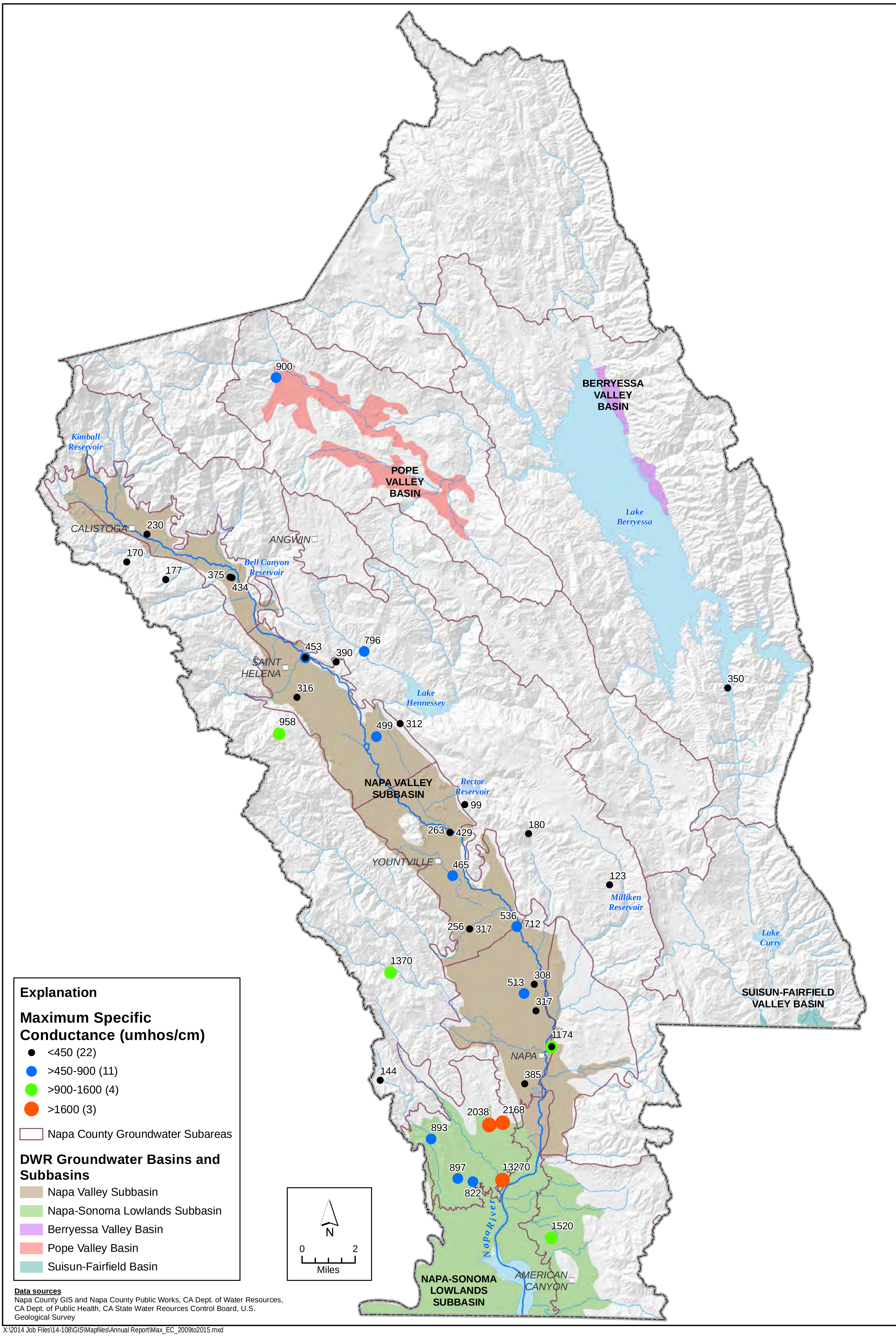
FIGURE 6-6
Maximum Sodium Concentrations in Groundwater, 2009 - 2015
Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



Data sources
Napa County GIS and Napa County Public Works, CA Dept. of Water Resources, CA Dept. of Public Health, CA State Water Reources Control Board, U.S. Geological Survey

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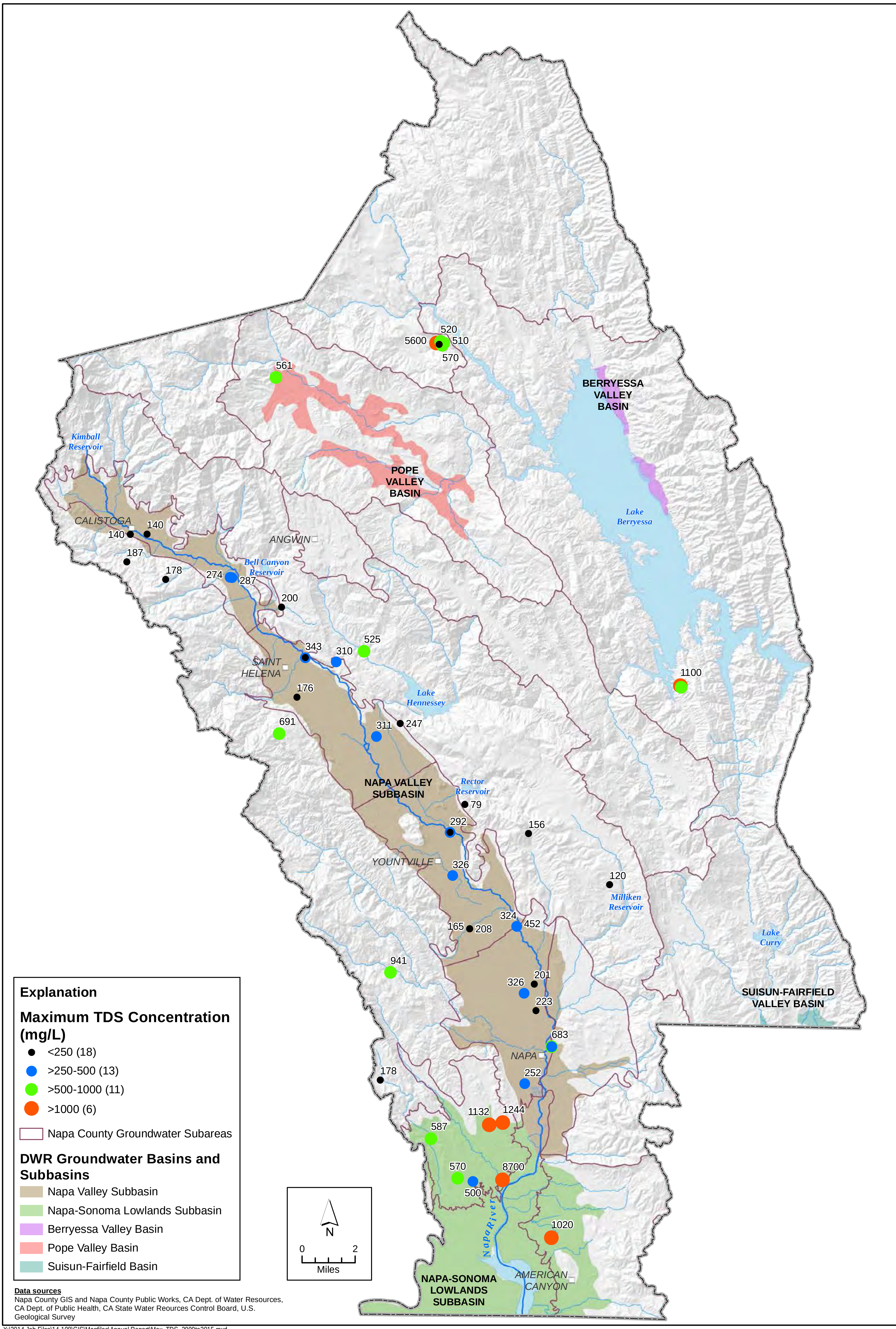
FIGURE 6-7
Maximum Specific Conductance Concentrations in Groundwater, 2009 - 2015
Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update



Data sources
Napa County GIS and Napa County Public Works, CA Dept. of Water Resources, CA Dept. of Public Health, CA State Water Reources Control Board, U.S. Geological Survey

X:\2014 Job Files\14-108\GIS\Mapfiles\Annual Report\Max_TDS_2009to2015.mxd

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FIGURE 6-8
Maximum TDS Concentrations in Groundwater, 2009 - 2015
Napa County, CA

Napa County Comprehensive Groundwater Monitoring Program
2015 Annual Report and CASGEM Update

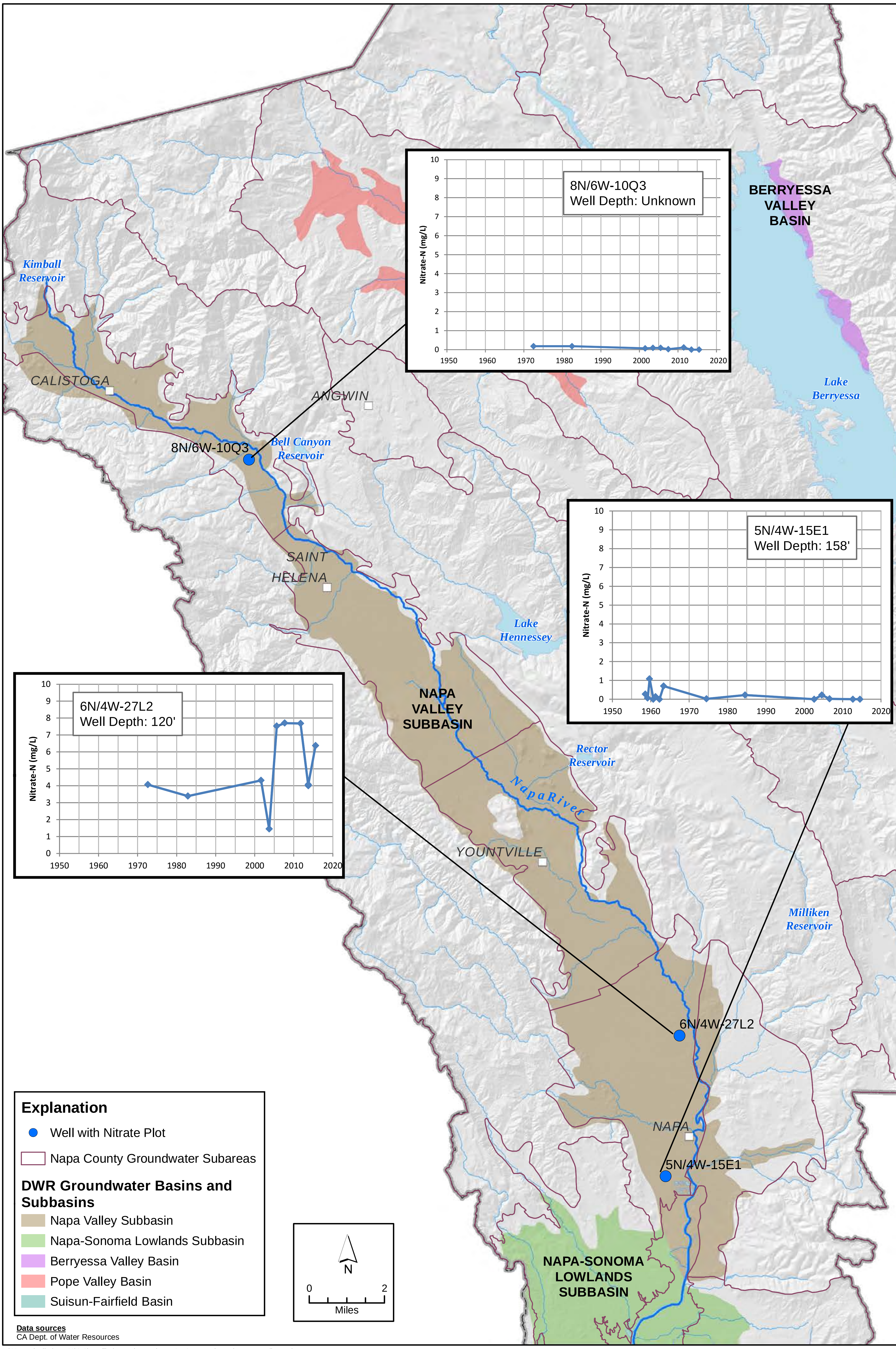

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FIGURE 6-9
Nitrate Concentrations Time-Series Plots
Napa Valley Groundwater Subbasin, Napa County, CA

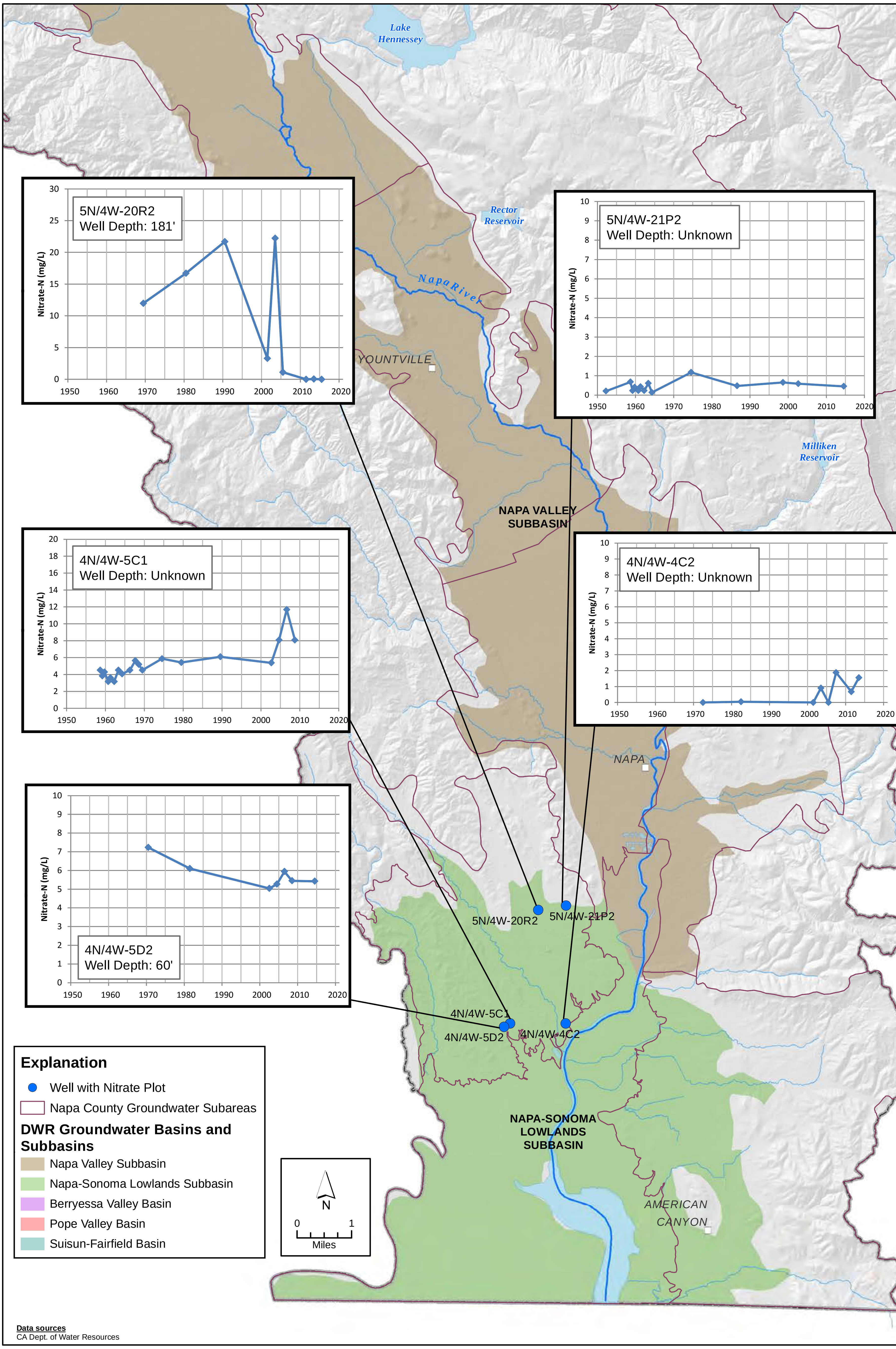

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FIGURE 6-10
Nitrate Concentrations Time-Series Plots
Napa-Sonoma Lowlands Groundwater Subbasin, Napa County, CA

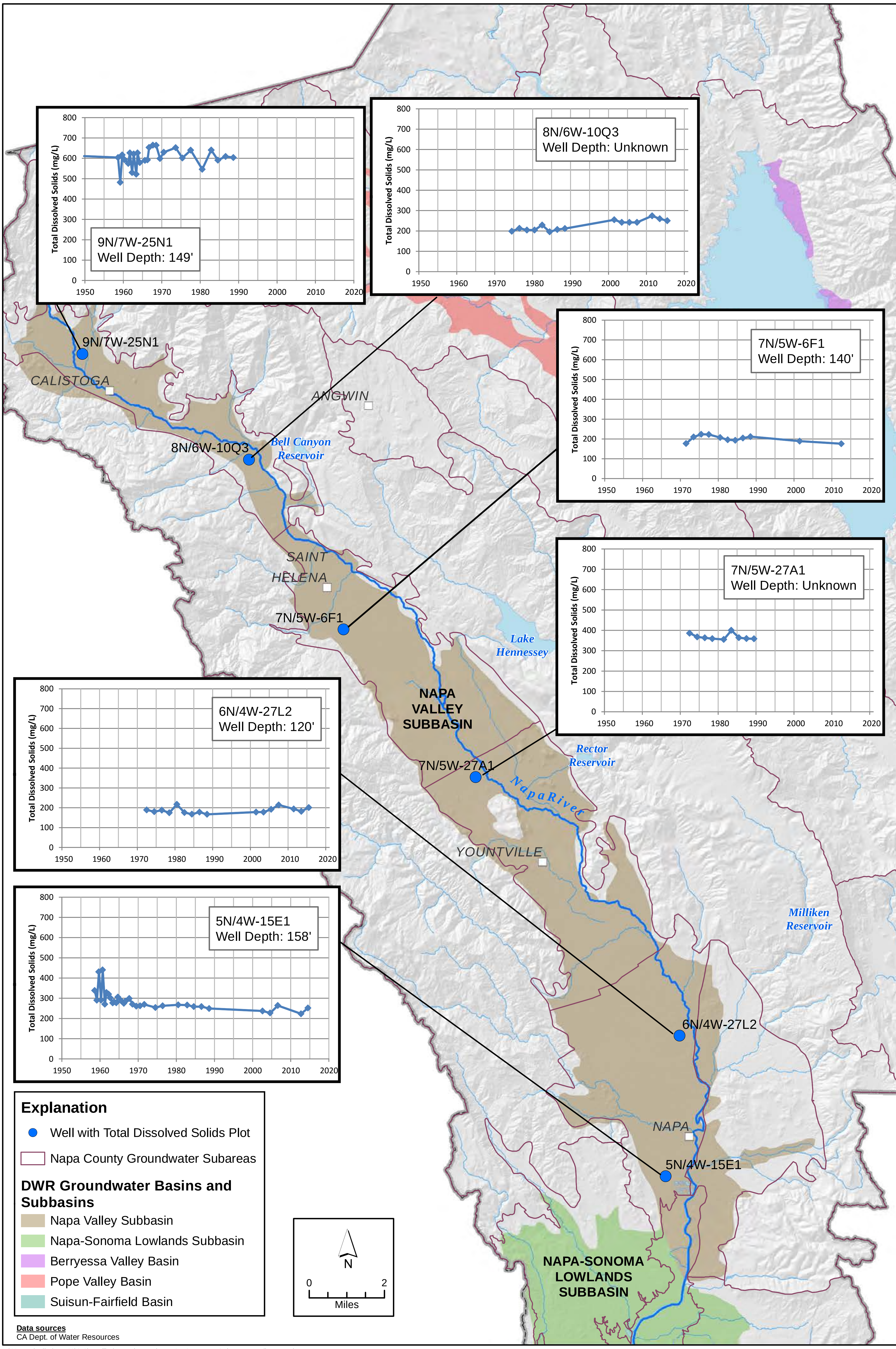

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FIGURE 6-11
TDS Concentrations Time-Series Plots
Napa Valley Groundwater Subbasin, Napa County, CA

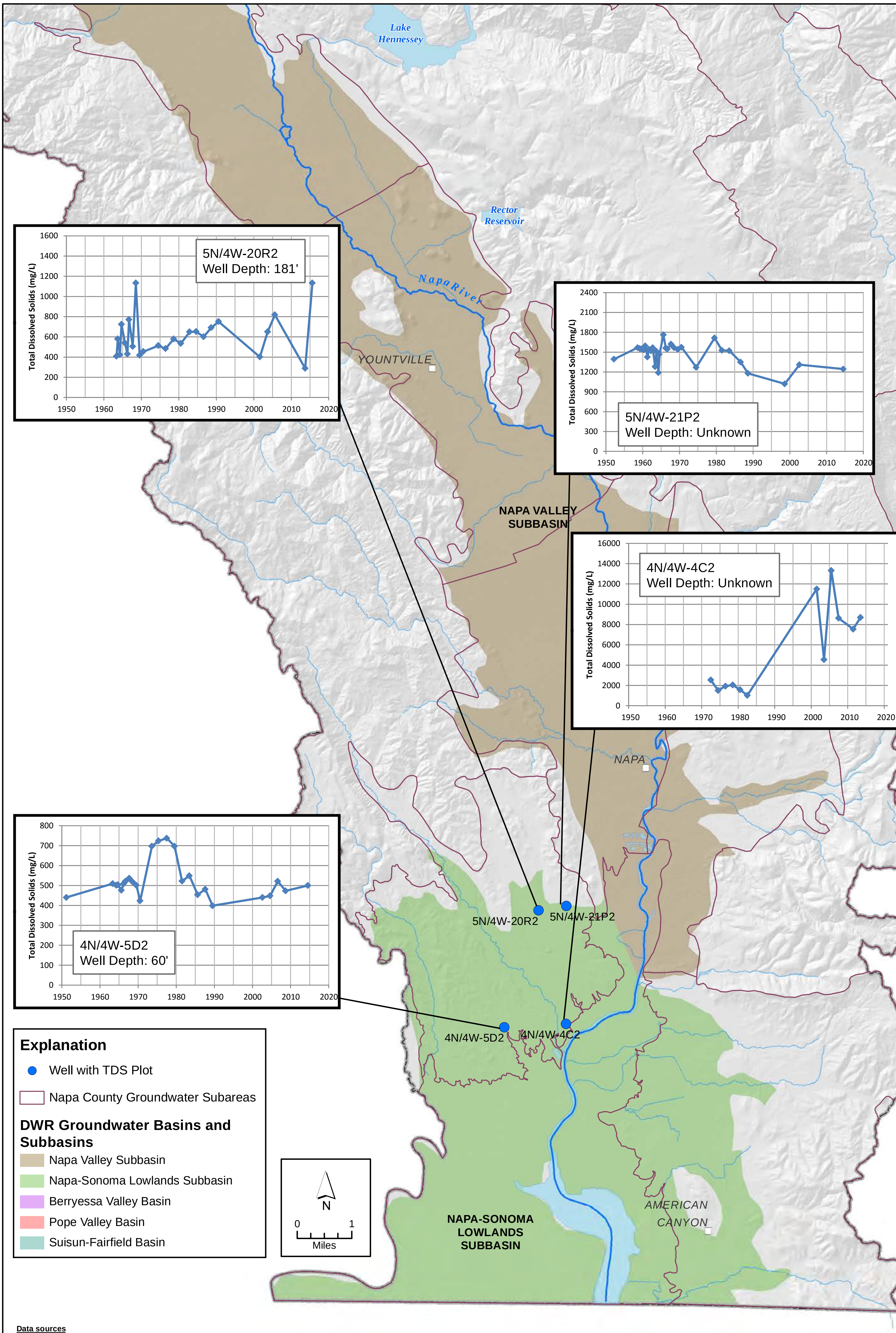

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FIGURE 6-12
TDS Concentrations Time-Series Plots
Napa-Sonoma Lowlands Groundwater Subbasin, Napa County, CA

APPENDIX A
Summary of Current Groundwater Level Monitoring Locations

Subarea	SWN	Well ID	Network as of 2015	Period of Record
Angwin		NapaCounty-165	No Reporting County Only	2014 - 2015
Angwin		NapaCounty-166	No Reporting County Only	2014 - 2015
Angwin		NapaCounty-167	No Reporting County Only	2014 - 2015
Angwin		NapaCounty-168	No Reporting County Only	2014 - 2015
Angwin		NapaCounty-202	CASGEM	2014 - 2015
Berryessa		T0605500298	Geotracker	2004 - 2015
Berryessa		T0605500304	Geotracker	2002 - 2015
Berryessa		T0605591908	Geotracker	2006 - 2015
Carneros	004N004W05C001M	NapaCounty-150	CASGEM	2011 - 2015
Carneros	004N004W05A001M	NapaCounty-153	CASGEM	2012 - 2015
Carneros	005N004W31R001M	NapaCounty-154	CASGEM	2012 - 2015
Carneros	004N004W06M001M	NapaCounty-155	CASGEM	2012 - 2015
Carneros		NapaCounty-176	No Reporting County Only	2014 - 2015
Carneros		NapaCounty-194	No Reporting County Only	2014 - 2015
Carneros		NapaCounty-195	CASGEM	2014 - 2015
Carneros		NapaCounty-200	CASGEM	2014 - 2015
Carneros		NapaCounty-201	CASGEM	2014 - 2015
Carneros		NapaCounty-205	No Reporting County Only	2014 - 2015
Carneros		NapaCounty-206	No Reporting County Only	2014 - 2015
Carneros		NapaCounty-207	No Reporting County Only	2014 - 2015
Central Interior Valleys		L10003756160	Geotracker	1990 - 2015
Central Interior Valleys		NapaCounty-209	No Reporting County Only	2014 - 2015
Eastern Mountains		NapaCounty-175	No Reporting County Only	2014 - 2015
Eastern Mountains		NapaCounty-193	No Reporting County Only	2014 - 2015
Eastern Mountains		NapaCounty-210	No Reporting County Only	2014 - 2015
Jameson American Canyon		NapaCounty-196	No Reporting County Only	2014 - 2015
NVF-Calistoga	008N006W10Q001M	08N06W10Q001M	Monthly DWR	1949 - 2015
NVF-Calistoga	009N007W25N001M	NapaCounty-127	Voluntary Reporting	1962 - 2015
NVF-Calistoga	009N006W31Q001M	NapaCounty-128	CASGEM	1962 - 2016
NVF-Calistoga	008N006W06L004M	NapaCounty-129	Voluntary Reporting	1962 - 2015
NVF-Calistoga		NapaCounty-178	No Reporting County Only	2014 - 2015
NVF-Calistoga		NapaCounty-203	No Reporting County Only	2014 - 2015
NVF-Calistoga		NapaCounty-224	No Reporting County Only	2014 - 2015

Subarea	SWN	Well ID	Network as of 2015	Period of Record
NVF-Calistoga		NapaCounty-225	No Reporting County Only	2014 - 2015
NVF-MST	005N003W05M001M	NapaCounty-10	Voluntary Reporting	1979 - 2015
NVF-MST	005N003W07B00_My	NapaCounty-118	No Reporting County Only	2001 - 2015
NVF-MST	006N004W26L00_M	NapaCounty-122	No Reporting County Only	2001 - 2015
NVF-MST	005N004W13H001M	NapaCounty-137	CASGEM	1979 - 2015
NVF-MST	006N004W25G00_M	NapaCounty-142	No Reporting County Only	2001 - 2015
NVF-MST	005N003W05M00_M	NapaCounty-148	Voluntary Reporting	2009 - 2015
NVF-MST	005N003W08E00_M	NapaCounty-149	No Reporting County Only	2010 - 2015
NVF-MST	005N004W13G004M	NapaCounty-18	No Reporting County Only	2000 - 2015
NVF-MST		NapaCounty-191	CASGEM	2014 - 2015
NVF-MST		NapaCounty-192	No Reporting County Only	2014 - 2015
NVF-MST	006N004W23J001M	NapaCounty-2	Voluntary Reporting	1979 - 2015
NVF-MST	005N003W07C003M	NapaCounty-20	Voluntary Reporting	1978 - 2015
NVF-MST	005N003W08E001M	NapaCounty-22	No Reporting County Only	2000 - 2015
NVF-MST		NapaCounty-226	No Reporting County Only	2015 - 2015
NVF-MST	005N003W18D001M	NapaCounty-35	No Reporting County Only	2000 - 2015
NVF-MST	006N004W23Q003M	NapaCounty-43	CASGEM	1978 - 2015
NVF-MST	005N004W14J003M	NapaCounty-49	CASGEM	1899 - 2015
NVF-MST	006N004W26G001M	NapaCounty-56	Voluntary Reporting	1978 - 2015
NVF-MST	006N004W35G005M	NapaCounty-69	No Reporting County Only	2000 - 2015
NVF-MST	005N003W07D003M	NapaCounty-72	No Reporting County Only	2000 - 2015
NVF-MST	005N003W06M001M	NapaCounty-74	CASGEM	1999 - 2015
NVF-MST	005N003W07F003M	NapaCounty-81	No Reporting County Only	2000 - 2015
NVF-MST	005N003W06B002M	NapaCounty-91	CASGEM	1992 - 2014
NVF-MST	005N003W06A001M	NapaCounty-92	CASGEM	1999 - 2015
NVF-MST	006N004W36G001M	NapaCounty-95	Voluntary Reporting	1979 - 2015
NVF-MST	006N004W36A001M	NapaCounty-98	No Reporting County Only	2000 - 2015
NVF-MST		T0605500200	Geotracker	2014 - 2015
NVF-MST		T10000005248	Geotracker	2013 - 2015
NVF-Napa	006N004W27L002M	06N04W27L002M	Monthly DWR	1966 - 2015
NVF-Napa	006N004W27N001M	NapaCounty-136	CASGEM	1979 - 2016
NVF-Napa	006N004W28Mx	NapaCounty-152	No Reporting County Only	2012 - 2015
NVF-Napa		NapaCounty-182	CASGEM	2014 - 2016

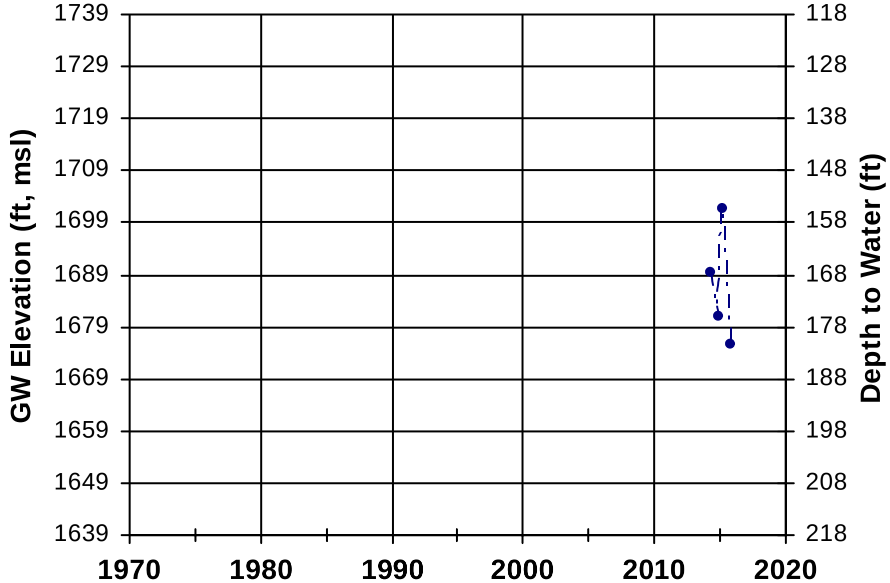
Subarea	SWN	Well ID	Network as of 2015	Period of Record
NVF-Napa		NapaCounty-183	No Reporting County Only	2014 - 2015
NVF-Napa		NapaCounty-184	No Reporting County Only	2014 - 2015
NVF-Napa		NapaCounty-185	No Reporting County Only	2014 - 2016
NVF-Napa		NapaCounty-187	No Reporting County Only	2014 - 2015
NVF-Napa		NapaCounty-188	No Reporting County Only	2014 - 2015
NVF-Napa		NapaCounty-189	No Reporting County Only	2014 - 2015
NVF-Napa		NapaCounty-227	CASGEM	2015 - 2015
NVF-Napa		NapaCounty-228	No Reporting County Only	2015 - 2015
NVF-Napa	006N004W15R003M	NapaCounty-76	No Reporting County Only	2000 - 2015
NVF-Napa		NapaCounty-swgw1	CASGEM	2014 - 2015
NVF-Napa		NapaCounty-swgw3	CASGEM	2014 - 2015
NVF-Napa		SL0605536682	Geotracker	2005 - 2015
NVF-Napa		T0605500009	Geotracker	2005 - 2015
NVF-Napa		T0605514064	Geotracker	2005 - 2015
NVF-Saint Helena	007N005W09Q002M	07N05W09Q002M	Monthly DWR	1949 - 2015
NVF-Saint Helena	007N005W16L001M	NapaCounty-131	CASGEM	1963 - 2015
NVF-Saint Helena	007N005W14B002M	NapaCounty-132	CASGEM	1962 - 2016
NVF-Saint Helena	007N005W16N002M	NapaCounty-138	CASGEM	1949 - 2015
NVF-Saint Helena		NapaCounty-169	CASGEM	2014 - 2015
NVF-Saint Helena		NapaCounty-171	No Reporting County Only	2014 - 2016
NVF-Saint Helena		NapaCounty-172	No Reporting County Only	2014 - 2015
NVF-Saint Helena		NapaCounty-173	No Reporting County Only	2014 - 2015
NVF-Saint Helena		NapaCounty-174	No Reporting County Only	2014 - 2015
NVF-Saint Helena		NapaCounty-177	No Reporting County Only	2014 - 2015
NVF-Saint Helena		NapaCounty-204	No Reporting County Only	2014 - 2015
NVF-Saint Helena		NapaCounty-212	No Reporting County Only	2015 - 2015
NVF-Saint Helena		NapaCounty-swgw5	CASGEM	2014 - 2015
NVF-Yountville	006N004W17A001M	06N04W17A001M	Semi-annual DWR	1949 - 2015
NVF-Yountville	006N004W09Q001M	NapaCounty-125	CASGEM	1979 - 2015
NVF-Yountville	006N004W09Q002M	NapaCounty-126	CASGEM	1984 - 2015
NVF-Yountville	007N004W31M001M	NapaCounty-133	Voluntary Reporting	1978 - 2016
NVF-Yountville	006N004W06L002M	NapaCounty-134	CASGEM	1963 - 2015
NVF-Yountville	006N004W19B001M	NapaCounty-135	Voluntary Reporting	1979 - 2016

Subarea	SWN	Well ID	Network as of 2015	Period of Record
NVF-Yountville	006N004W17R002M	NapaCounty-139	CASGEM	1978 - 2015
NVF-Yountville		NapaCounty-179	CASGEM	2014 - 2015
NVF-Yountville		NapaCounty-180	CASGEM	2014 - 2015
NVF-Yountville		NapaCounty-181	No Reporting County Only	2014 - 2015
NVF-Yountville		NapaCounty-swgw2	CASGEM	2014 - 2015
NVF-Yountville		NapaCounty-swgw4	CASGEM	2014 - 2015
Pope Valley		NapaCounty-211	No Reporting County Only	2014 - 2015
Western Mountains		NapaCounty-208	CASGEM	2014 - 2015
Western Mountains		NapaCounty-213	CASGEM	2014 - 2015

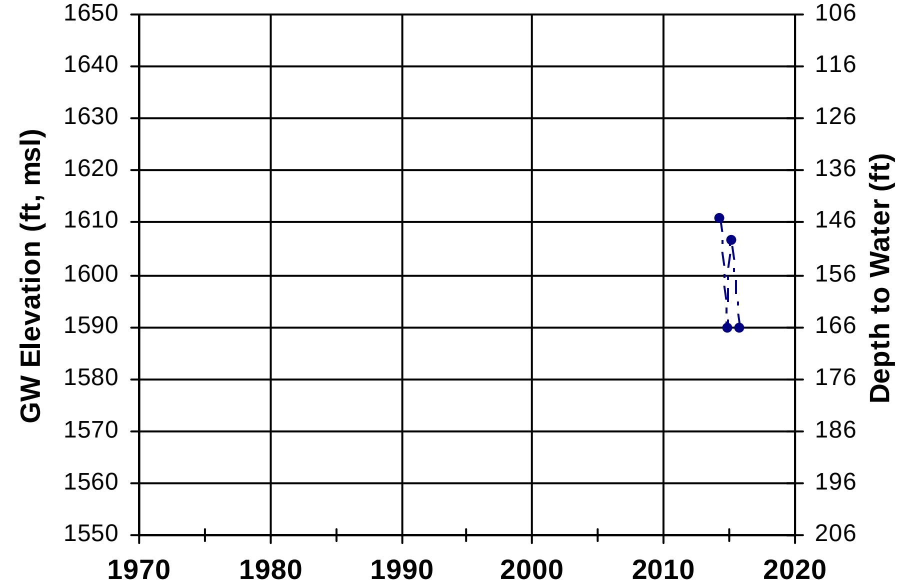
APPENDIX B

Groundwater Level Hydrographs for Current Monitoring Locations

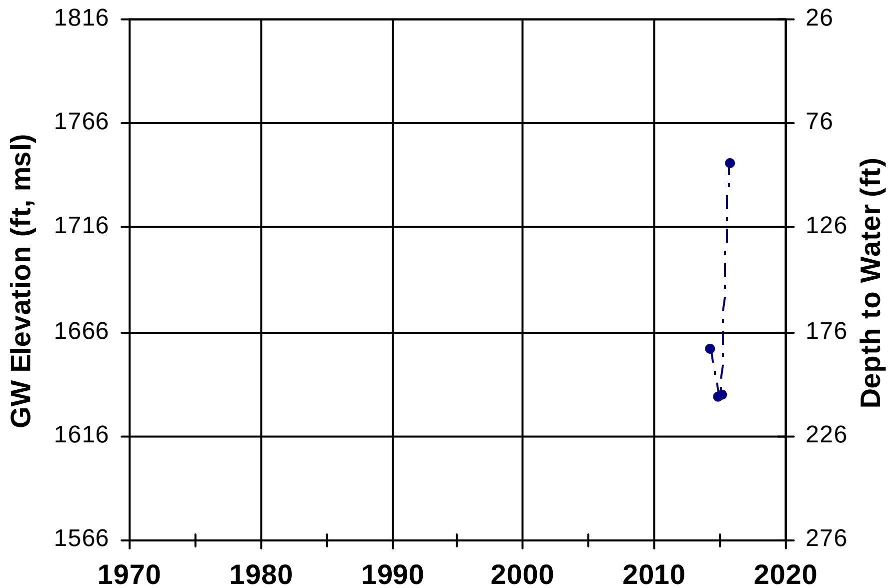
WellID: **NapaCounty-165** RPE: 1857 ft, msl Subarea: Ang
SWN: Unknown Source: NapaCounty



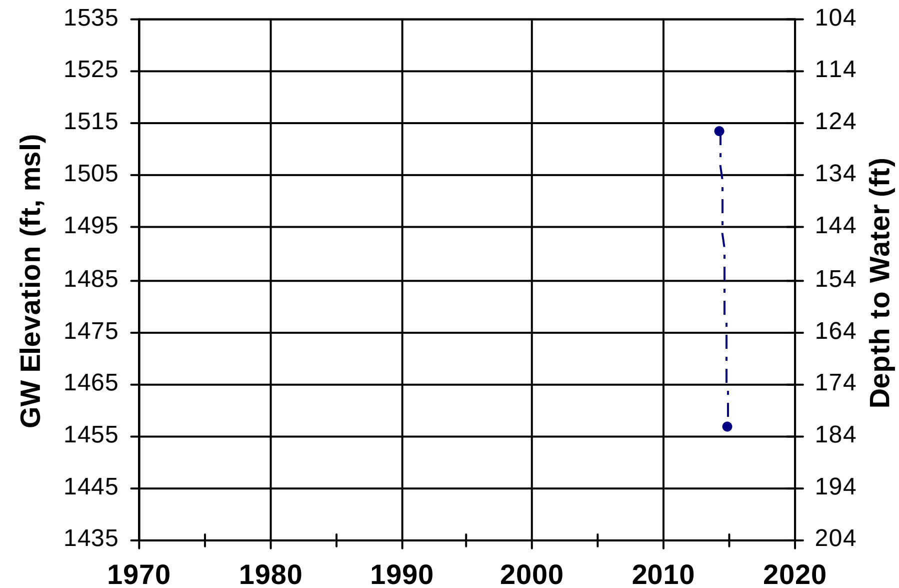
WellID: **NapaCounty-166** RPE: 1755.8 ft, msl Subarea: Ang
SWN: Unknown Source: NapaCounty



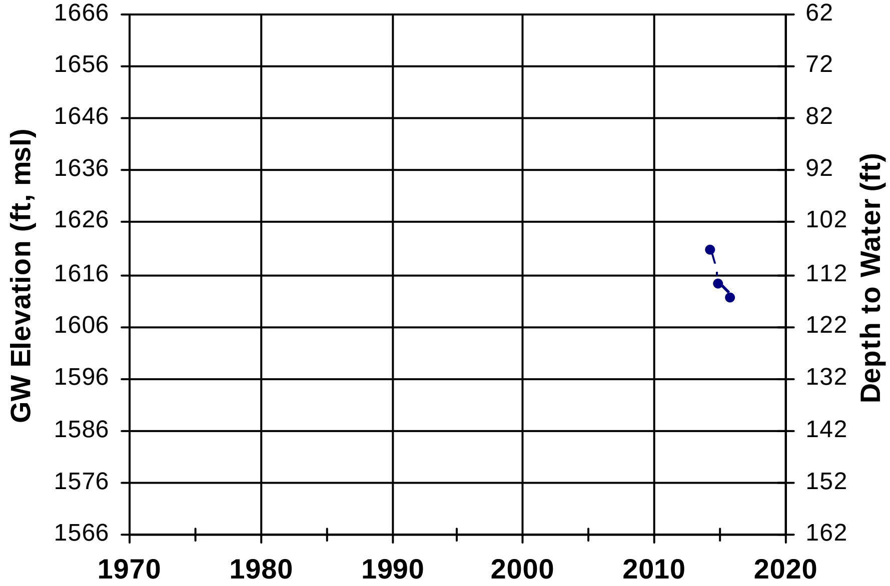
WellID: **NapaCounty-167** RPE: 1842.3 ft, msl Subarea: Ang
SWN: Unknown Source: NapaCounty



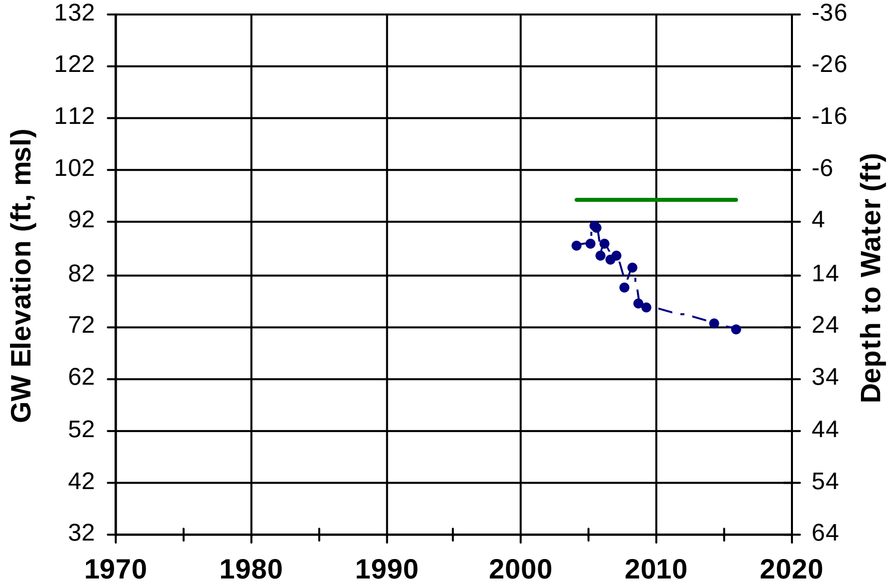
WellID: **NapaCounty-168** RPE: 1639 ft, msl Subarea: Ang
SWN: Unknown Source: NapaCounty



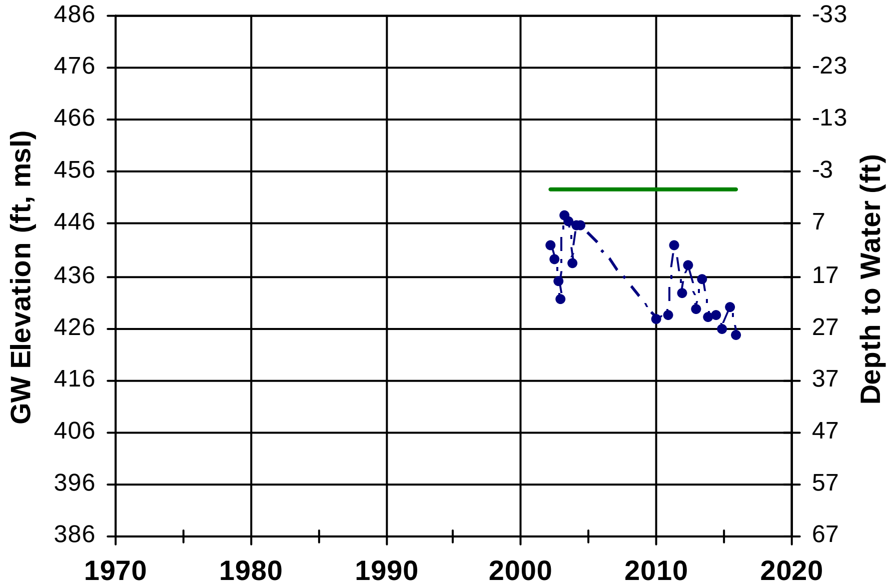
WellID: **NapaCounty-202** RPE: 1728.2 ft, msl Subarea: Ang
SWN: Unknown Source: NapaCounty



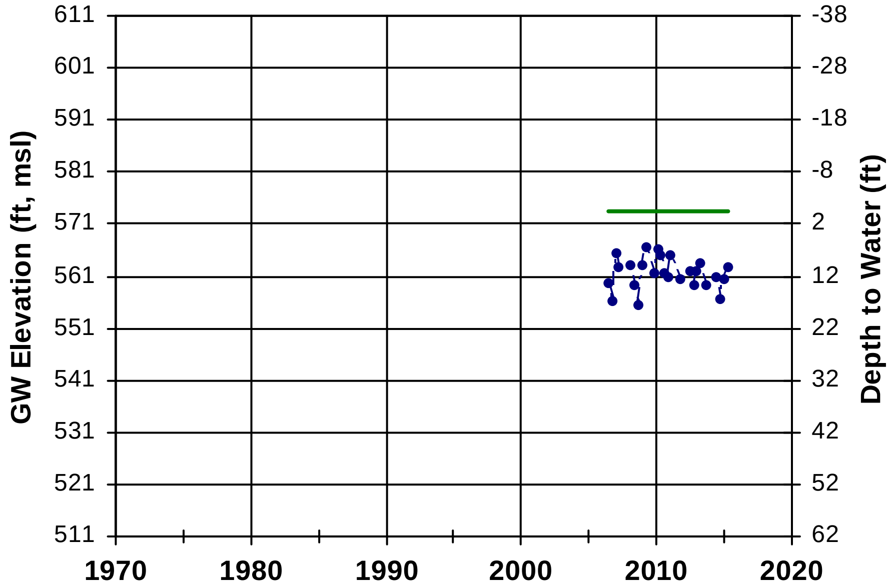
WellID: **T0605500298MW-1** RPE: 96.47 ft, msl Subarea: Berryessa
SWN: Unknown Source: Geotracker



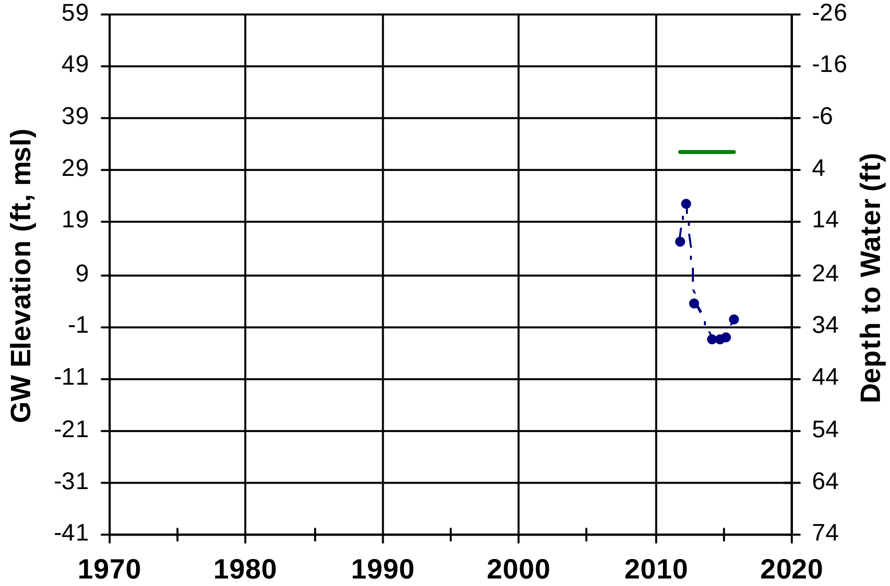
WellID: **T0605500304MW-1** RPE: 452.82 ft, msl Subarea: Berryessa
SWN: Unknown Source: Geotracker



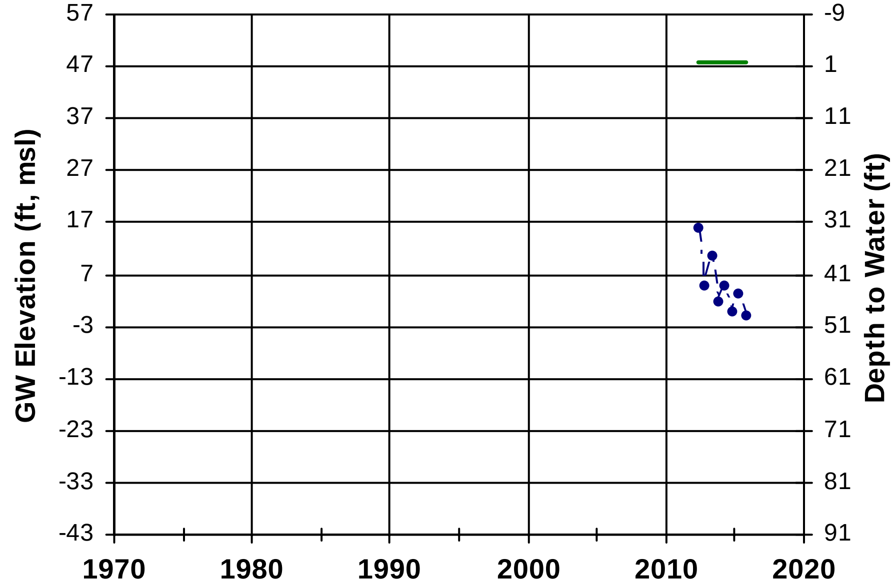
WellID: **T0605591908MW-1** RPE: 573.28 ft, msl Subarea: Berryessa
SWN: Unknown Source: Geotracker



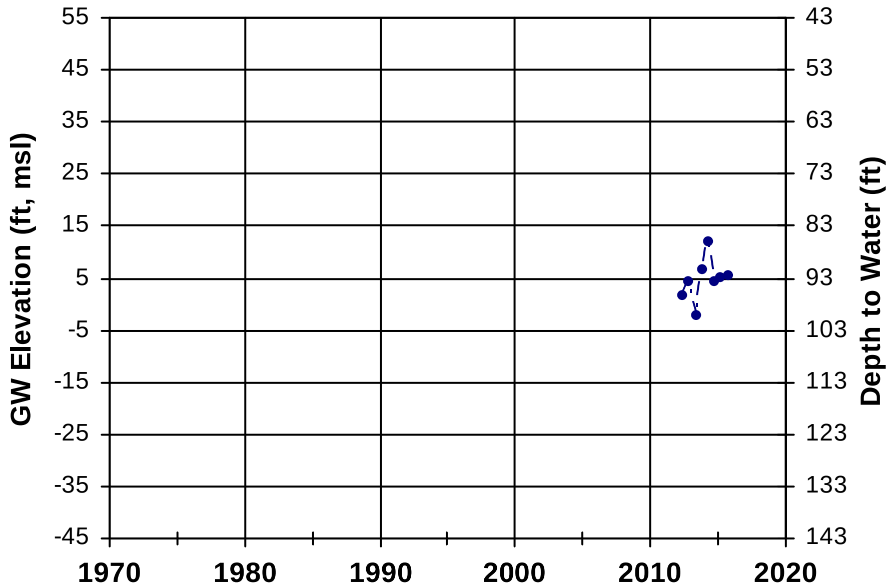
WellID: **NapaCounty-150** RPE: 32.7 ft, msl Subarea: Carn
SWN: 004N004W05C001M Source: NapaCounty



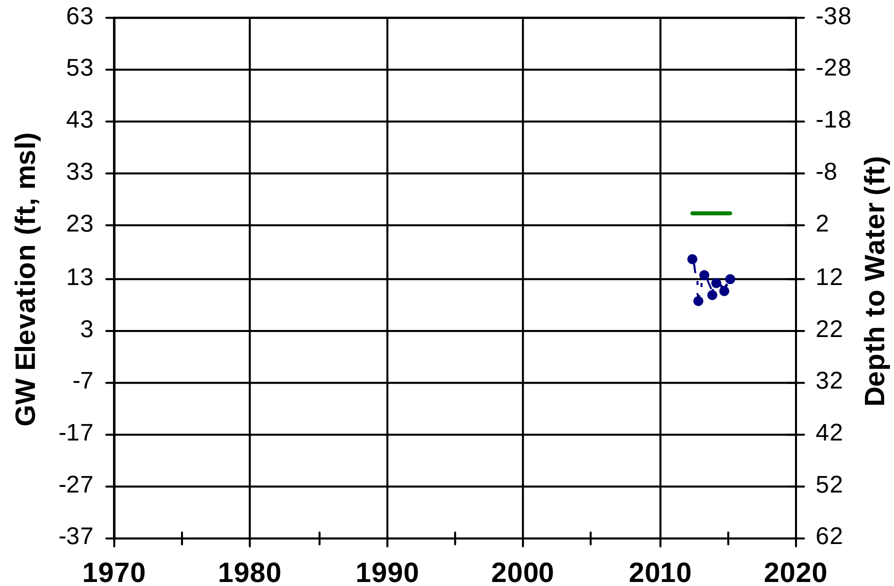
WellID: **NapaCounty-153** RPE: 47.65 ft, msl Subarea: Carn
SWN: 004N004W05A001M Source: NapaCounty



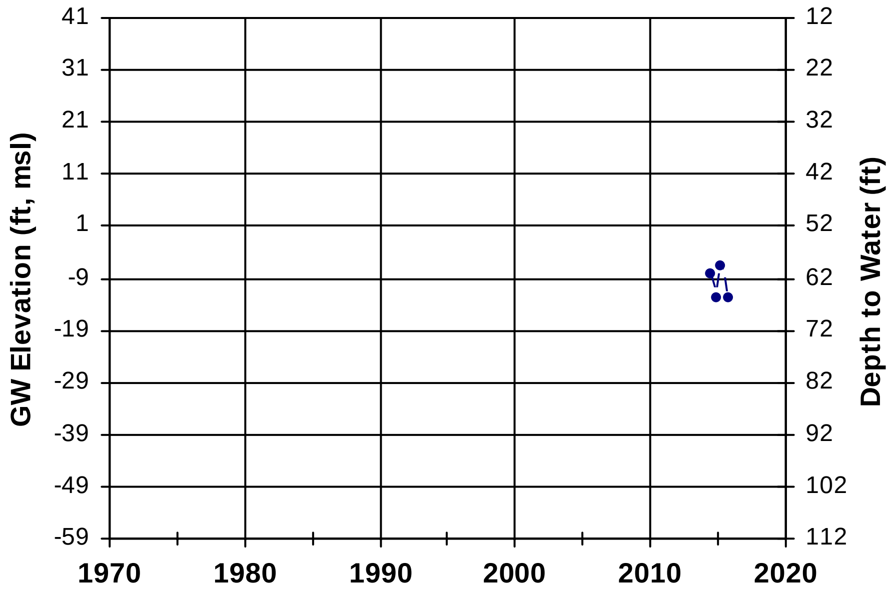
WellID: **NapaCounty-154** RPE: 98.3 ft, msl Subarea: Carn
SWN: 005N004W31R001M Source: NapaCounty



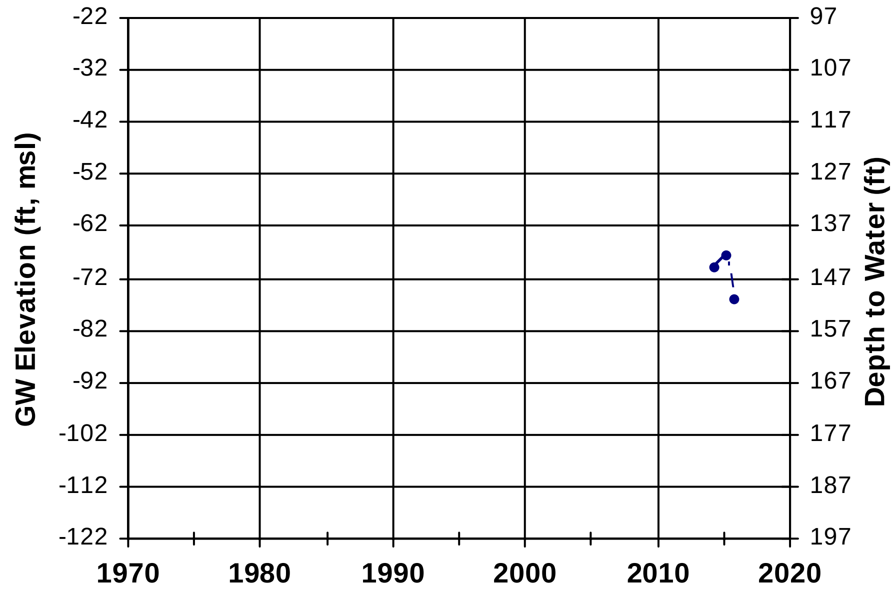
WellID: **NapaCounty-155** RPE: 25.3 ft, msl Subarea: Carn
SWN: 004N004W06M001M Source: NapaCounty



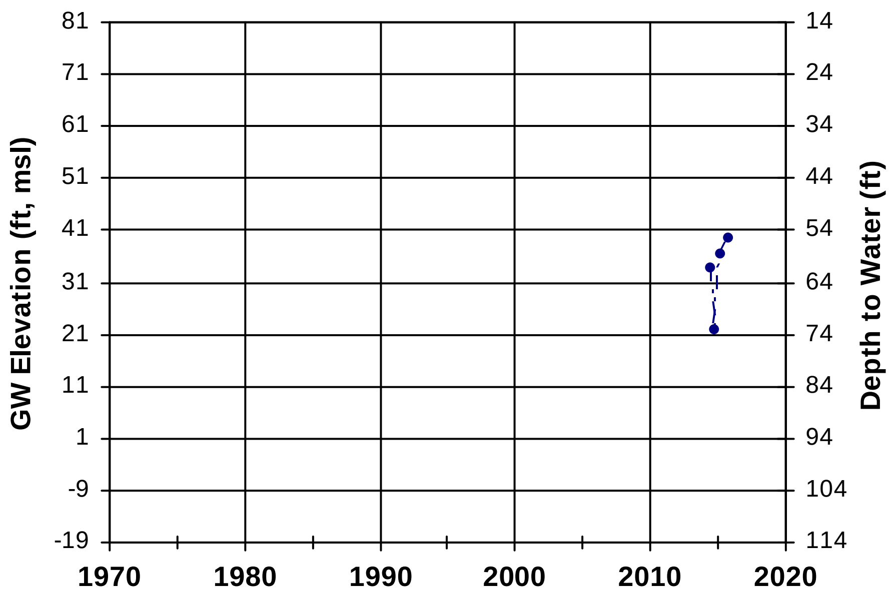
WellID: **NapaCounty-176** RPE: 53.4 ft, msl Subarea: Carn
SWN: Unknown Source: NapaCounty



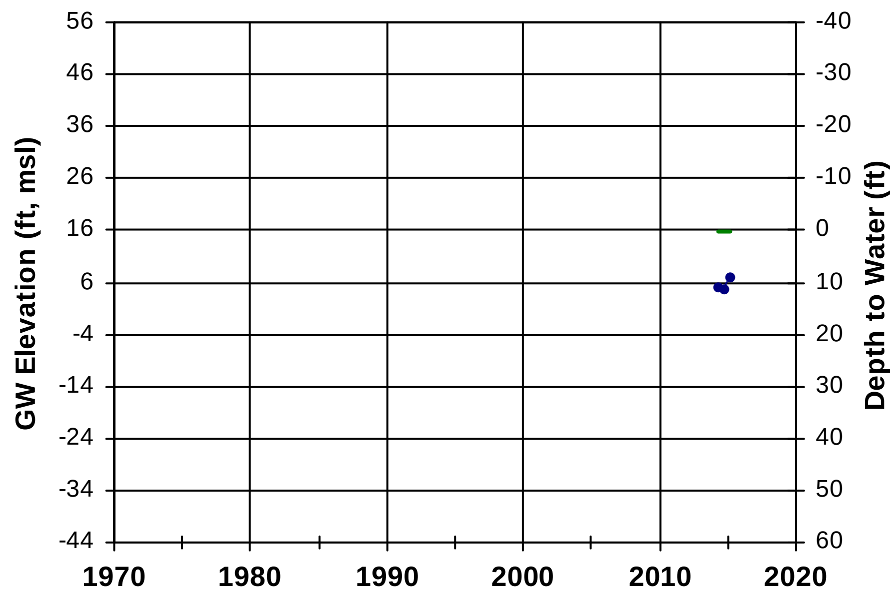
WellID: **NapaCounty-194** RPE: 75.1 ft, msl Subarea: Carn
SWN: Unknown Source: NapaCounty



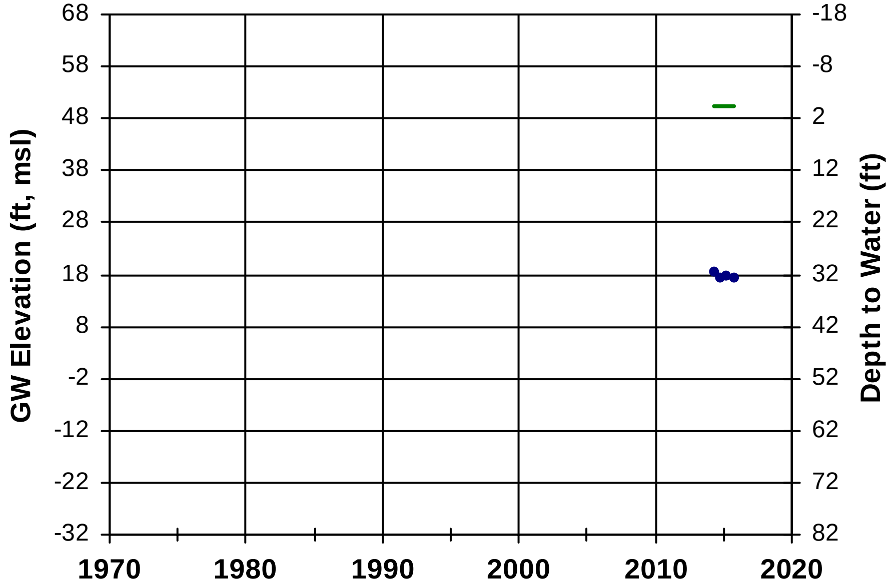
WellID: **NapaCounty-195** RPE: 94.8 ft, msl Subarea: Carn
SWN: Unknown Source: NapaCounty



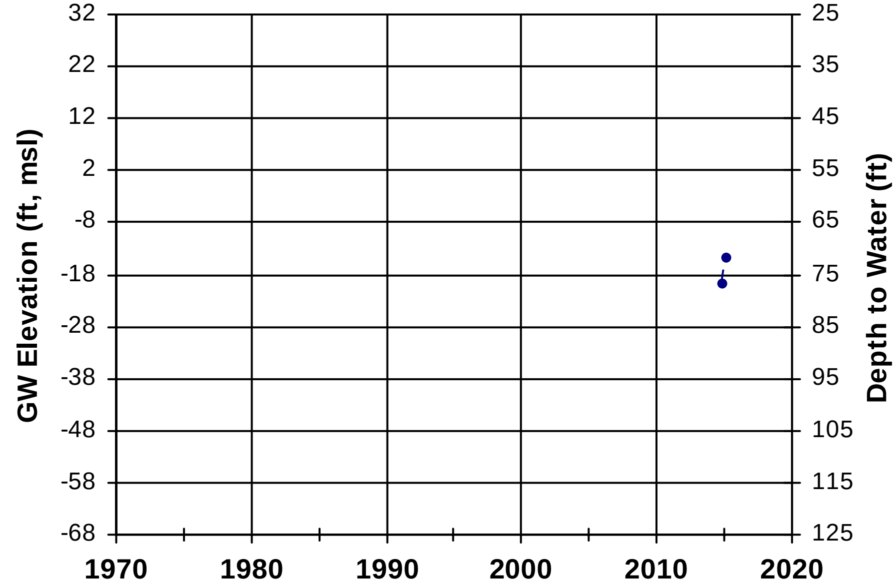
WellID: **NapaCounty-200** RPE: 15.7 ft, msl Subarea: Carn
SWN: Unknown Source: NapaCounty



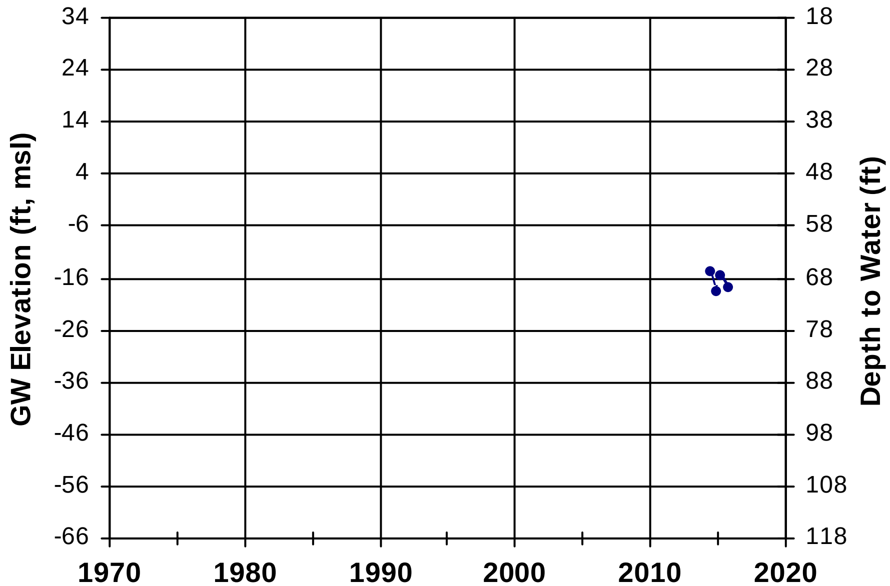
WellID: **NapaCounty-201** RPE: 50.4 ft, msl Subarea: Carn
SWN: Unknown Source: NapaCounty



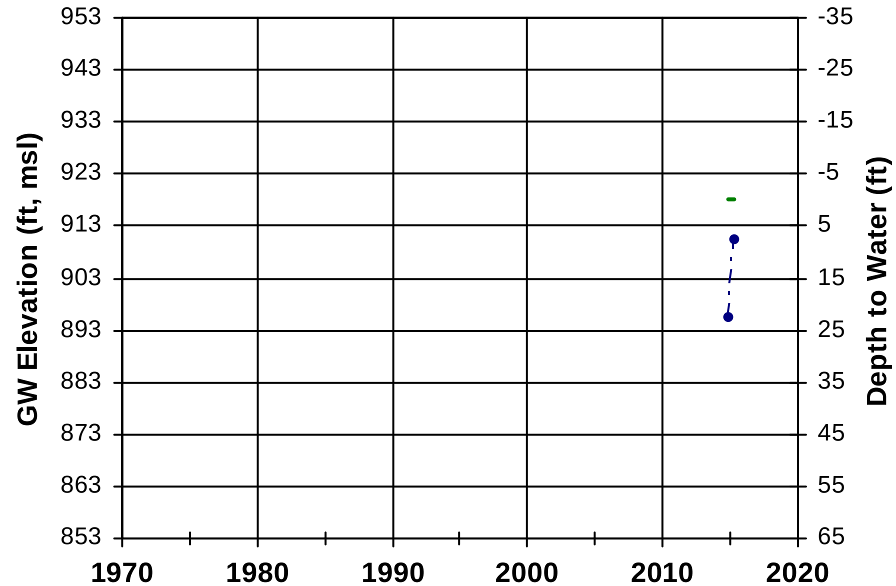
WellID: **NapaCounty-205** RPE: 56.8 ft, msl Subarea: Carn
SWN: Unknown Source: NapaCounty



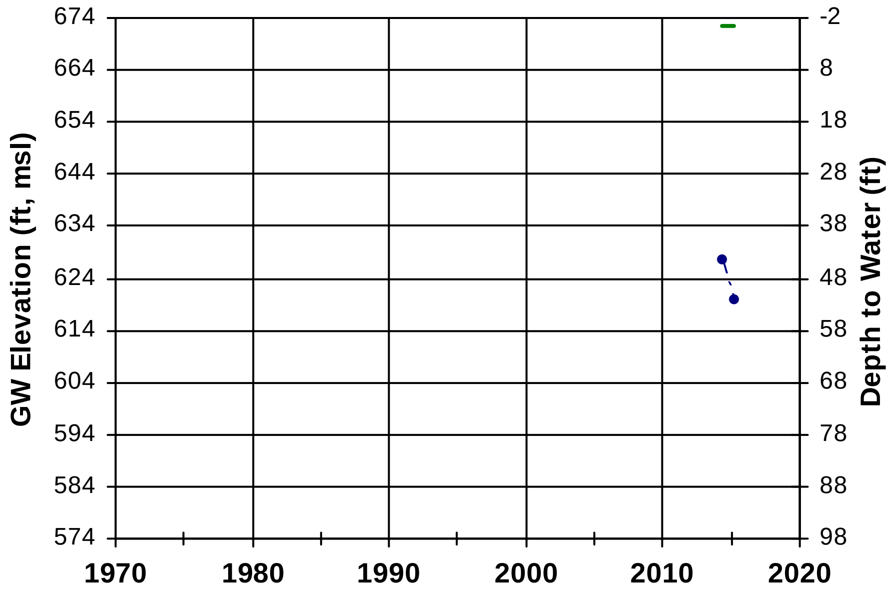
WellID: **NapaCounty-206** RPE: 52.4 ft, msl Subarea: Carn
SWN: Unknown Source: NapaCounty



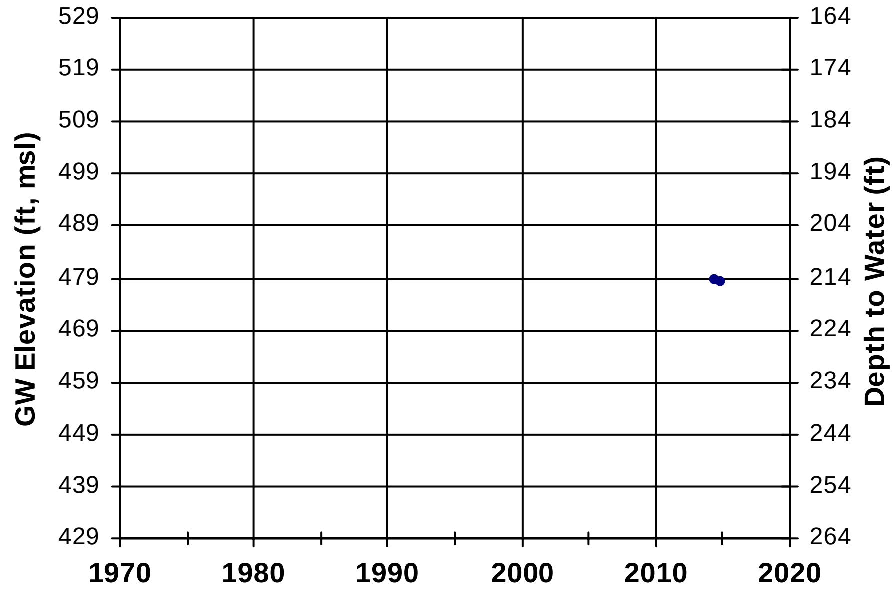
WellID: **NapaCounty-209** RPE: 918 ft, msl Subarea: Cent_Int_Val
SWN: Unknown Source: NapaCounty



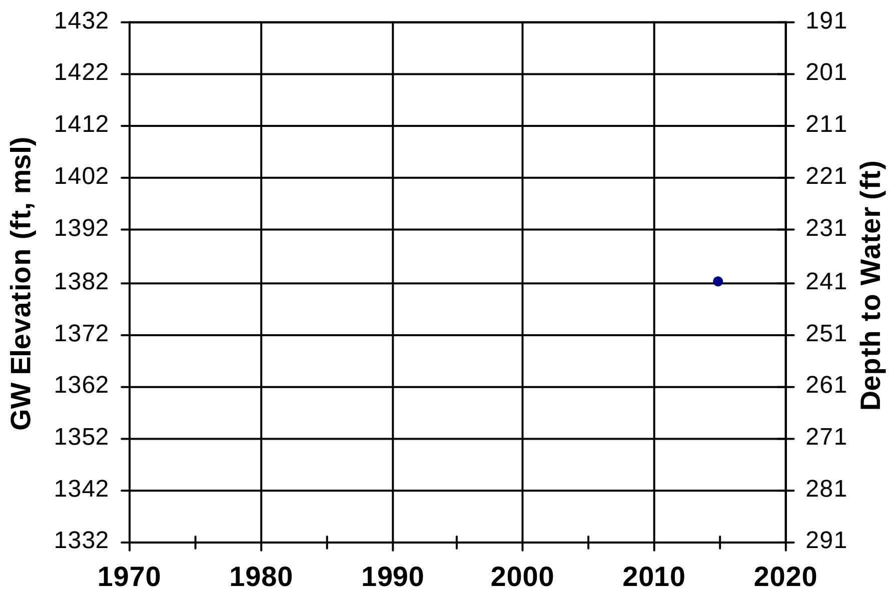
WellID: **NapaCounty-175** RPE: 672.3 ft, msl Subarea: East_Mnts
SWN: Unknown Source: NapaCounty



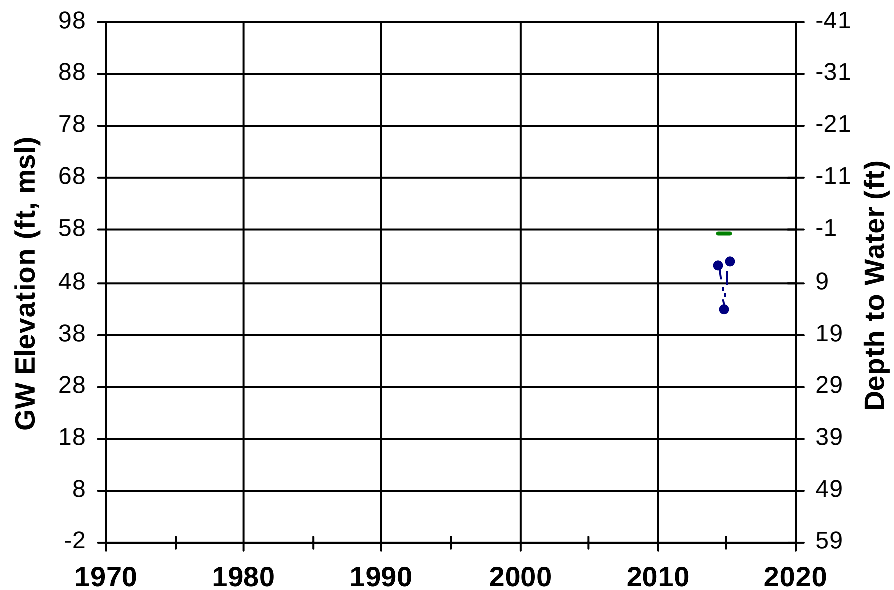
WellID: **NapaCounty-193** RPE: 693.1 ft, msl Subarea: East_Mnts
SWN: Unknown Source: NapaCounty

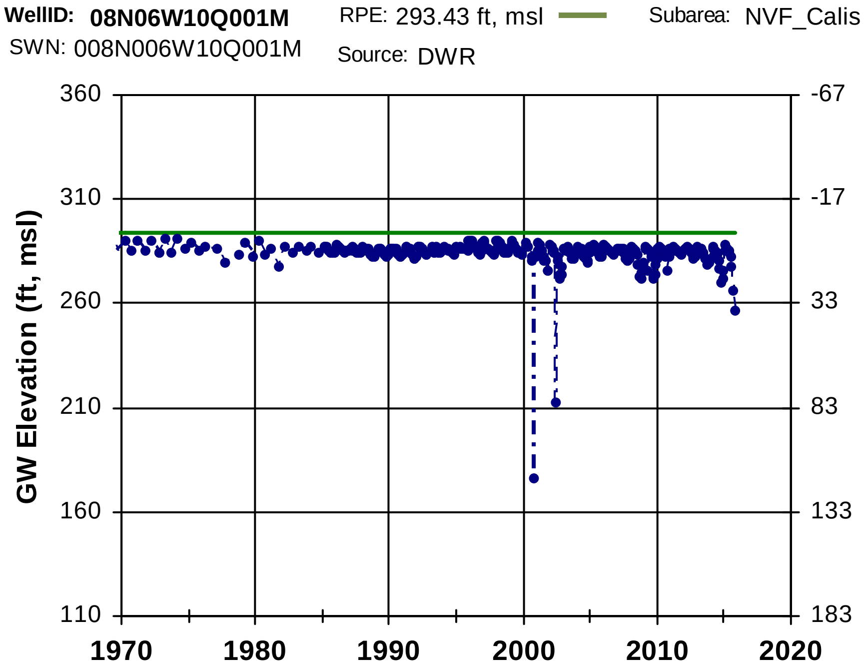


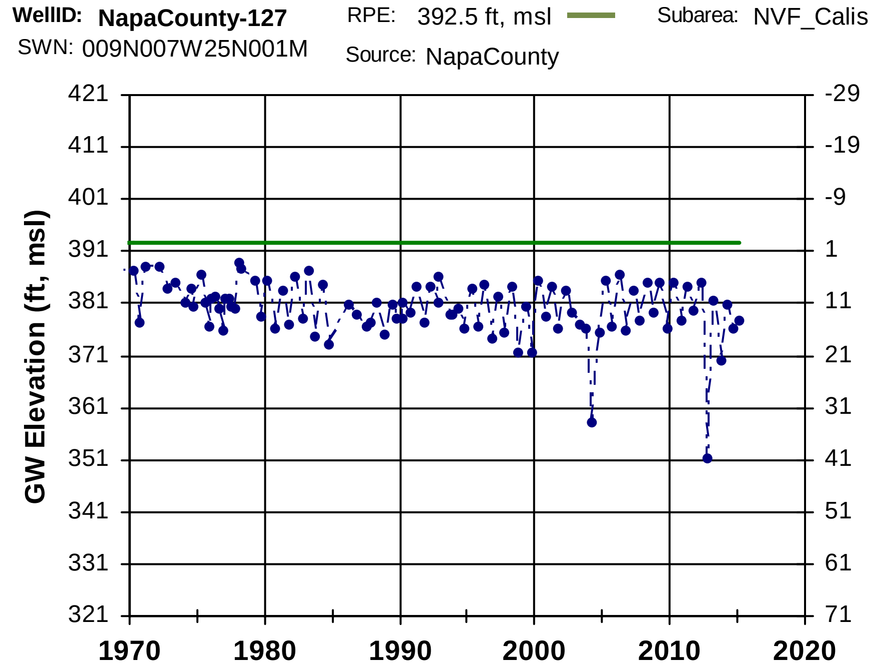
WellID: **NapaCounty-210** RPE: 1622.9 ft, msl Subarea: East_Mnts
SWN: Unknown Source: NapaCounty

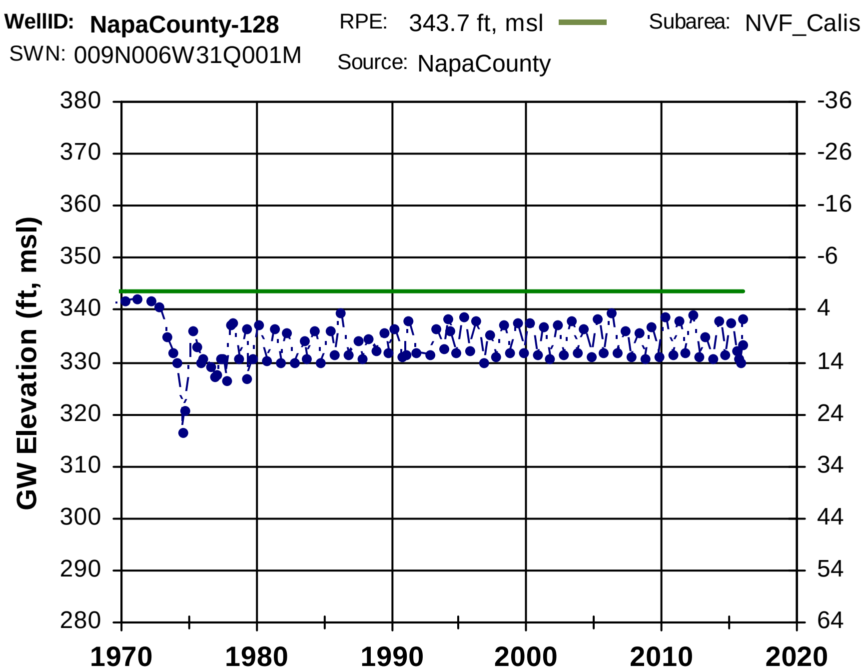


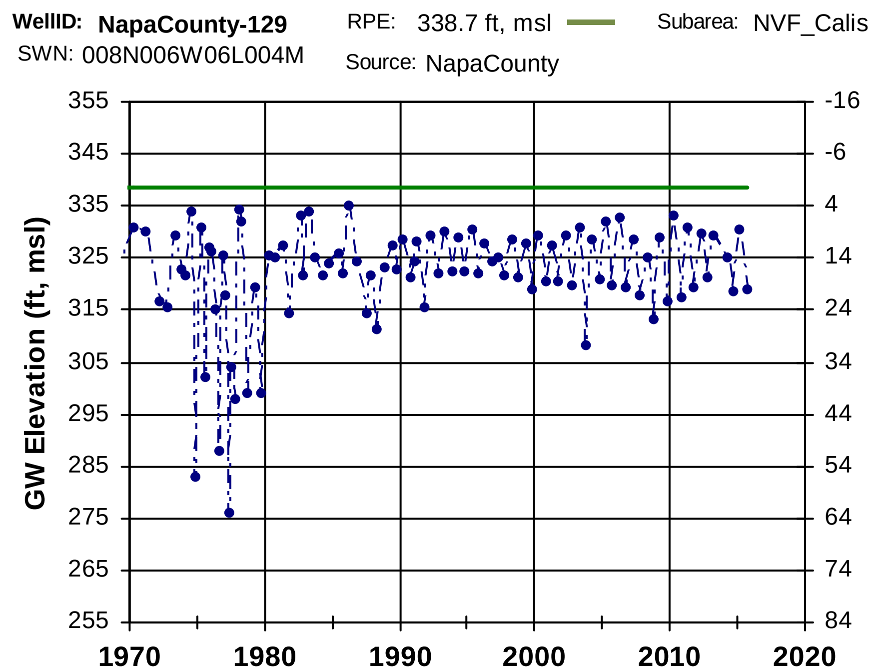
WellID: **NapaCounty-196** RPE: 57.4 ft, msl Subarea: Jam_AmerCan
SWN: Unknown Source: NapaCounty

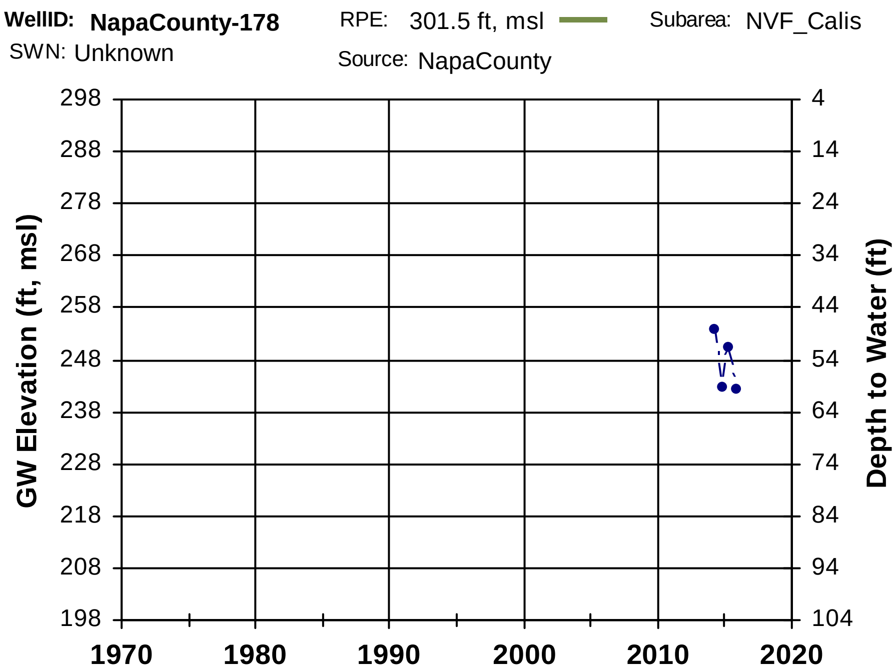


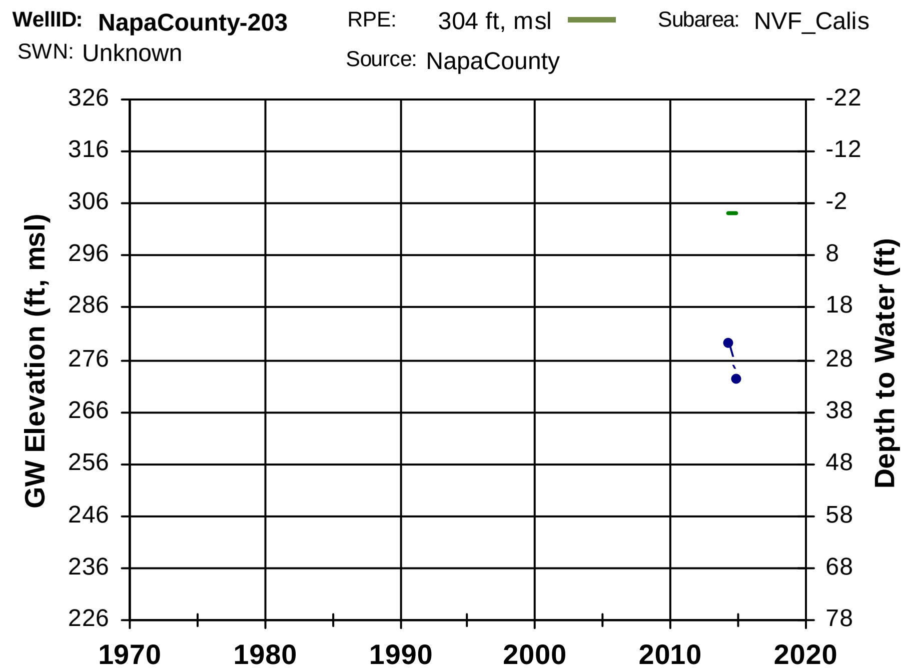

WellID: 08N06W10Q001M
SWN: 008N006W10Q001M
RPE: 293.43 ft, msl
Source: DWR
Subarea: NVF_Calis
GW Elevation (ft, msl)
Depth to Water (ft)
360 310 260 210 160 110
-67 -17 33 83 133 183
1970 1980 1990 2000 2010 2020

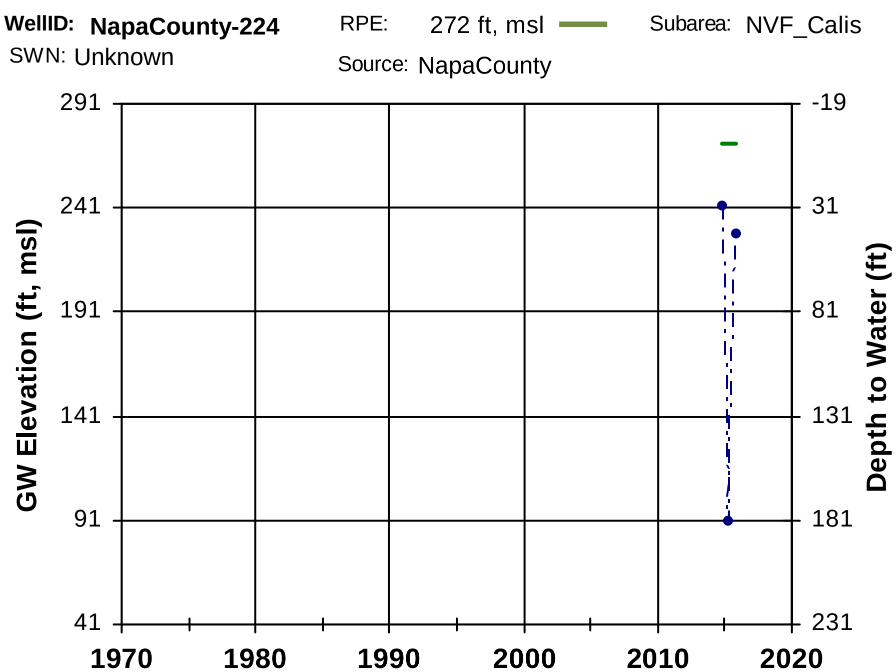

WellID: NapaCounty-127
SWN: 009N007W25N001M
RPE: 392.5 ft, msl
Source: NapaCounty
Subarea: NVF_Calis
GW Elevation (ft, msl)
Depth to Water (ft)
421 411 401 391 381 371 361 351 341 331 321
-29 -19 -9 1 11 21 31 41 51 61 71
1970 1980 1990 2000 2010 2020

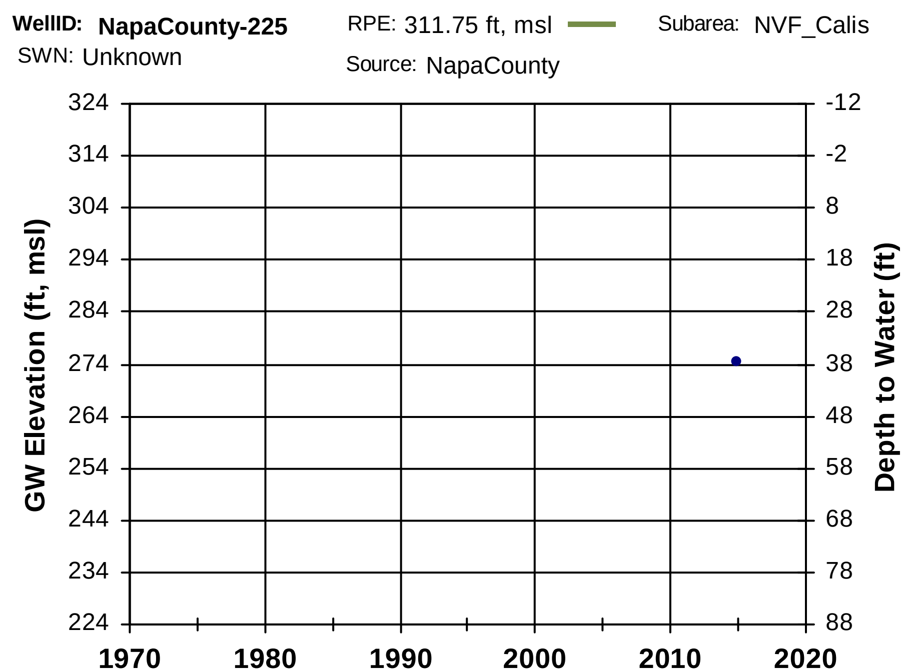

WellID: NapaCounty-128
SWN: 009N006W31Q001M
RPE: 343.7 ft, msl
Source: NapaCounty
Subarea: NVF_Calis
GW Elevation (ft, msl)
Depth to Water (ft)
380 370 360 350 340 330 320 310 300 290 280
-36 -26 -16 -6 4 14 24 34 44 54 64
1970 1980 1990 2000 2010 2020


WellID: NapaCounty-129
SWN: 008N006W06L004M
RPE: 338.7 ft, msl
Source: NapaCounty
Subarea: NVF_Calis
GW Elevation (ft, msl)
Depth to Water (ft)
355 345 335 325 315 305 295 285 275 265 255
-16 -6 4 14 24 34 44 54 64 74 84
1970 1980 1990 2000 2010 2020

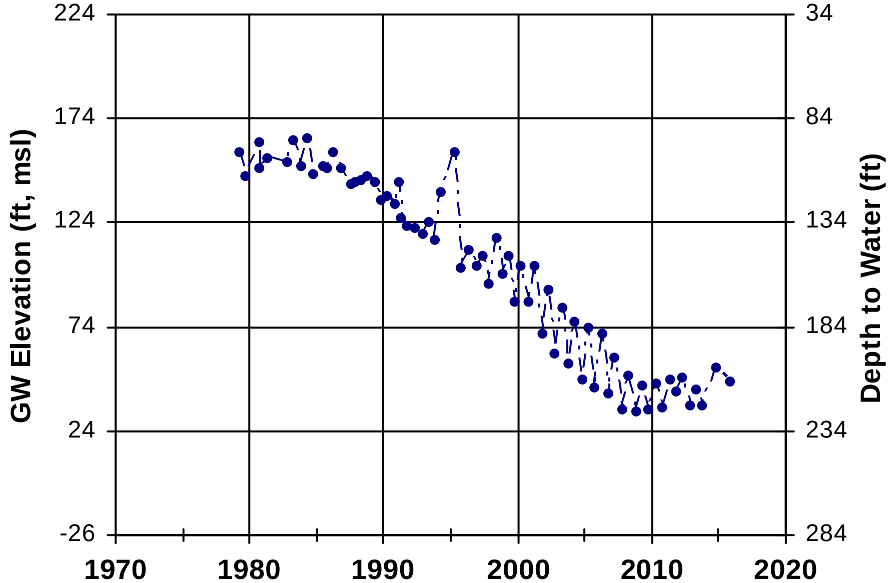

WellID: NapaCounty-178
SWN: Unknown
RPE: 301.5 ft, msl
Source: NapaCounty
Subarea: NVF_Calis
GW Elevation (ft, msl)
298
288
278
268
258
248
238
228
218
208
198
Depth to Water (ft)
4
14
24
34
44
54
64
74
84
94
104
1970
1980
1990
2000
2010
2020


WellID: NapaCounty-203
SWN: Unknown
RPE: 304 ft, msl
Source: NapaCounty
Subarea: NVF_Calis
GW Elevation (ft, msl)
326
316
306
296
286
276
266
256
246
236
226
Depth to Water (ft)
-22
-12
-2
8
18
28
38
48
58
68
78
1970
1980
1990
2000
2010
2020

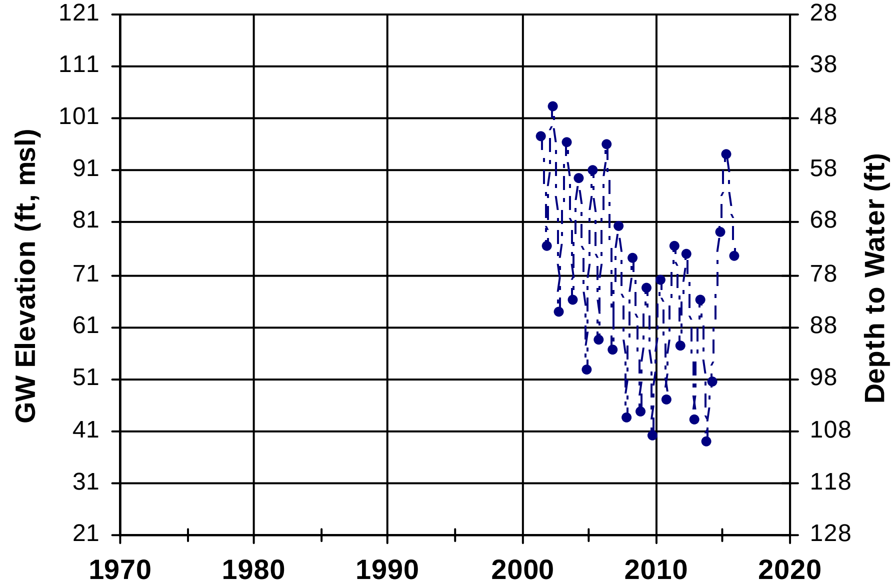

WellID: NapaCounty-224
SWN: Unknown
RPE: 272 ft, msl
Source: NapaCounty
Subarea: NVF_Calis
GW Elevation (ft, msl)
291
241
191
141
91
41
Depth to Water (ft)
-19
31
81
131
181
231
1970
1980
1990
2000
2010
2020


WellID: NapaCounty-225
SWN: Unknown
RPE: 311.75 ft, msl
Source: NapaCounty
Subarea: NVF_Calis
GW Elevation (ft, msl)
324
314
304
294
284
274
264
254
244
234
224
Depth to Water (ft)
-12
-2
8
18
28
38
48
58
68
78
88
1970
1980
1990
2000
2010
2020

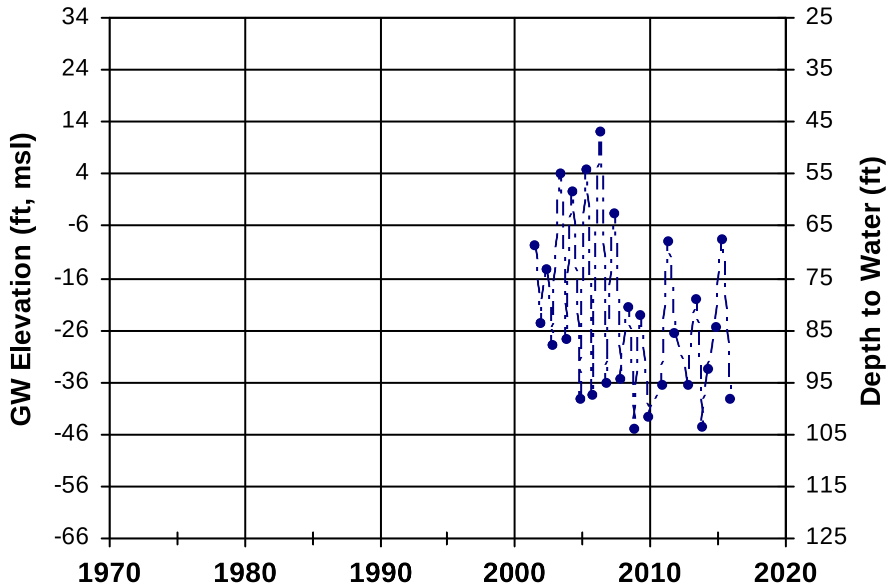
WellID: **NapaCounty-10** RPE: 258.3 ft, msl Subarea: NVF_MST
SWN: 005N003W05M001M Source: NapaCounty



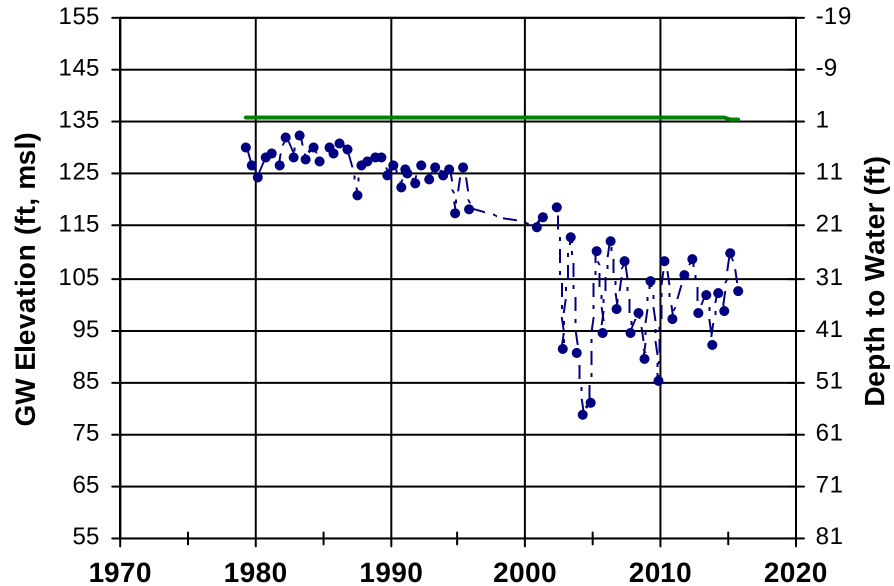
WellID: **NapaCounty-118** RPE: 148.65 ft, msl Subarea: NVF_MST
SWN: 005N003W07B00_My Source: NapaCounty



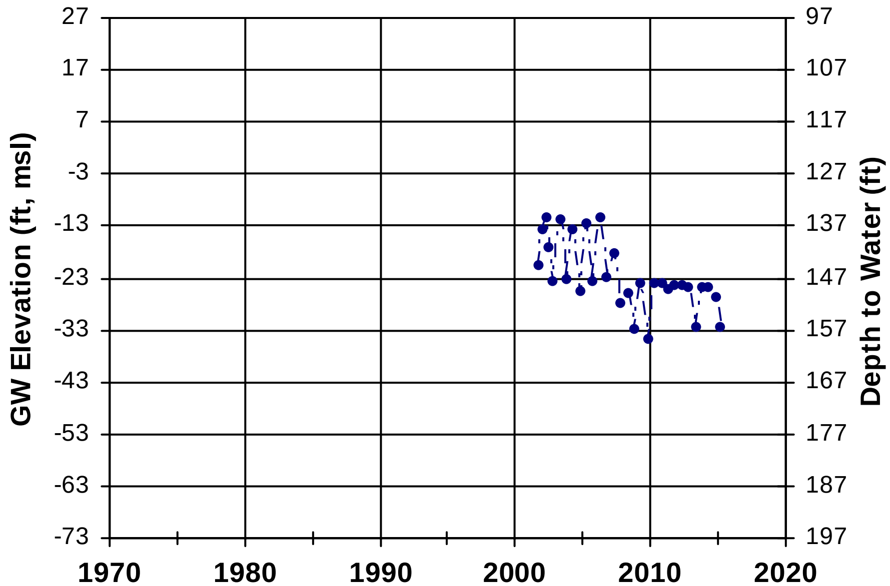
WellID: **NapaCounty-122** RPE: 59.15 ft, msl Subarea: NVF_MST
SWN: 006N004W26L00_M Source: NapaCounty



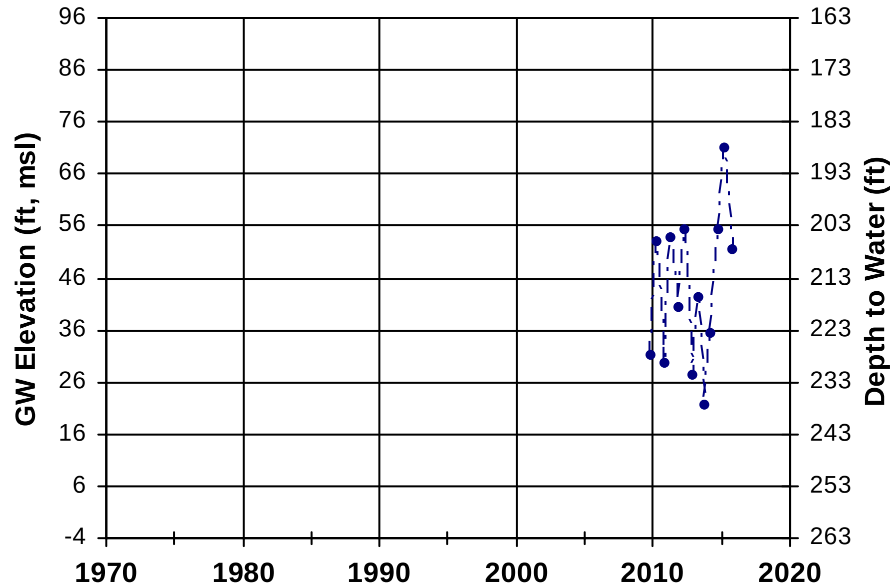
WellID: **NapaCounty-137** RPE: 135.6 ft, msl Subarea: NVF_MST
SWN: 005N004W13H001M Source: NapaCounty



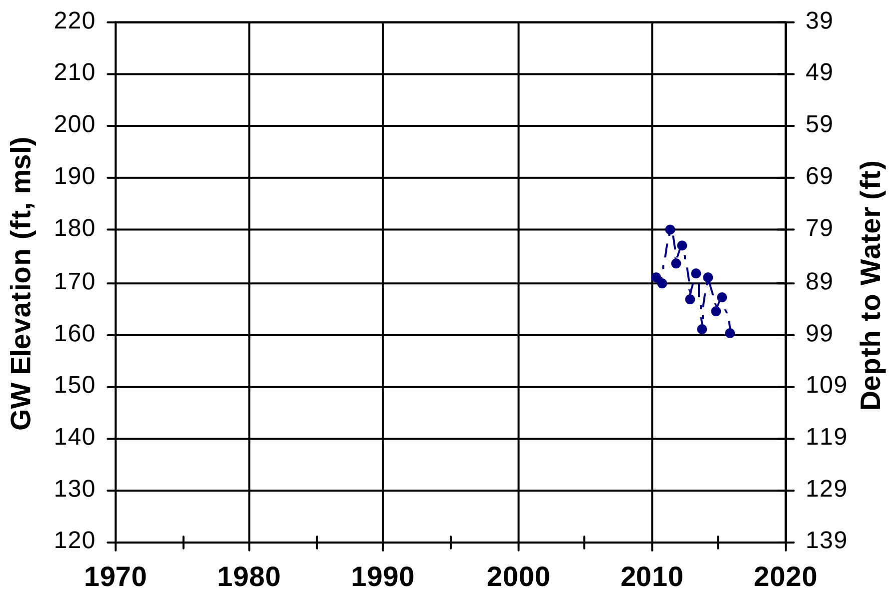
WellID: **NapaCounty-142** RPE: 124.2 ft, msl Subarea: NVF_MST
SWN: 006N004W25G00_M Source: NapaCounty



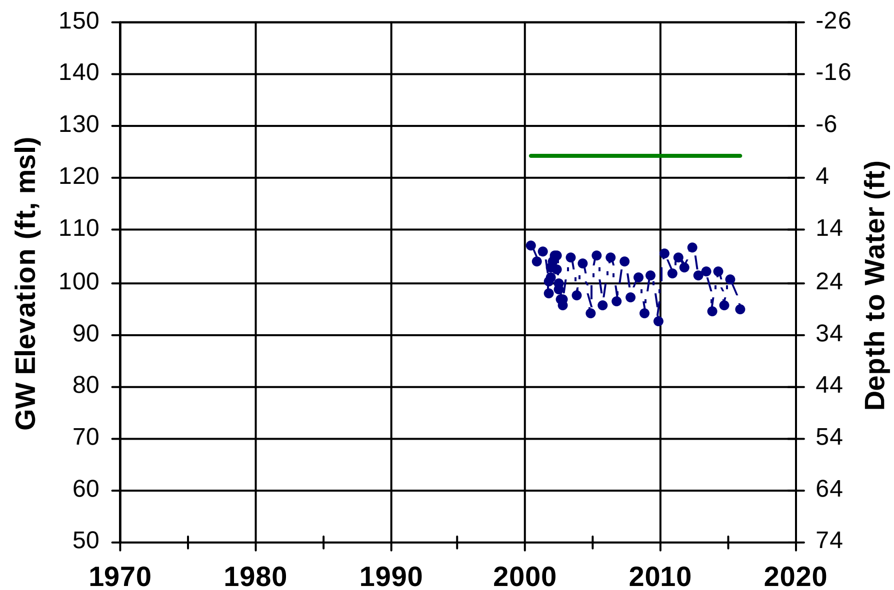
WellID: **NapaCounty-148** RPE: 258.6 ft, msl Subarea: NVF_MST
SWN: 005N003W05M00_M Source: NapaCounty



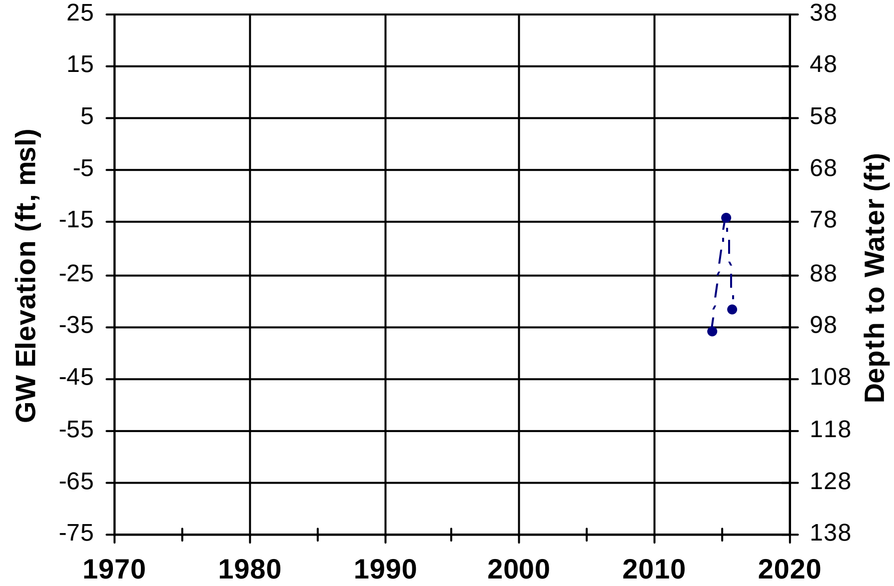
WellID: **NapaCounty-149** RPE: 258.9 ft, msl Subarea: NVF_MST
SWN: 005N003W08E00_M Source: NapaCounty



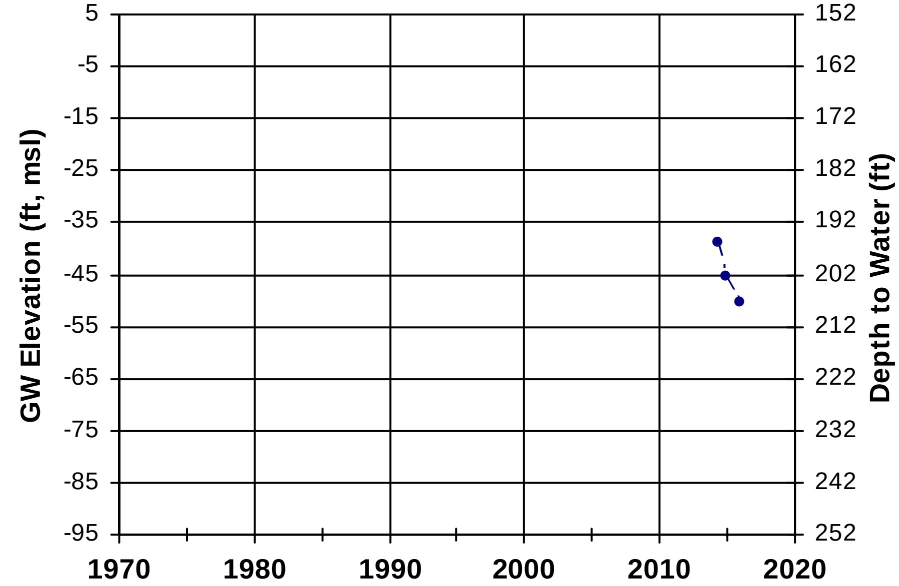
WellID: **NapaCounty-18** RPE: 124.3 ft, msl Subarea: NVF_MST
SWN: 005N004W13G004M Source: NapaCounty



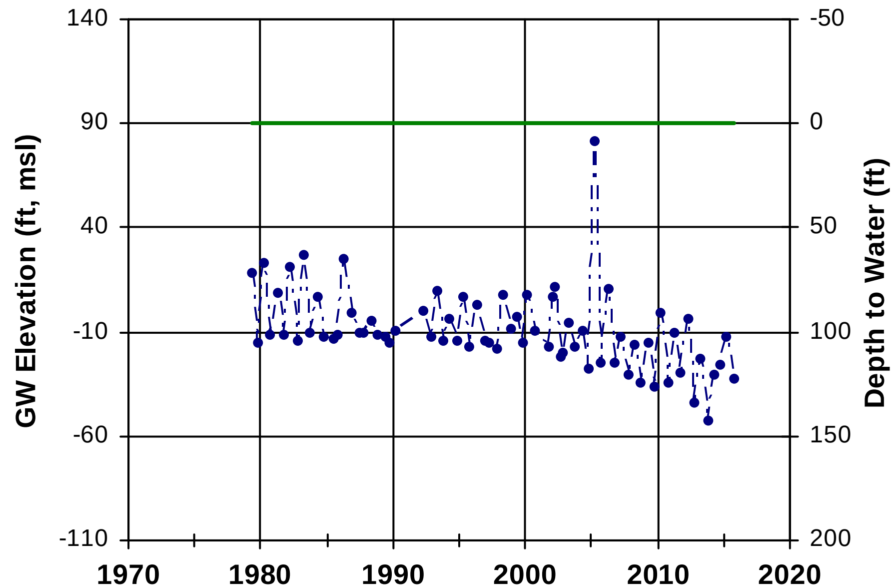
WellID: **NapaCounty-191** RPE: 63.1 ft, msl Subarea: NVF_MST
SWN: Unknown Source: NapaCounty



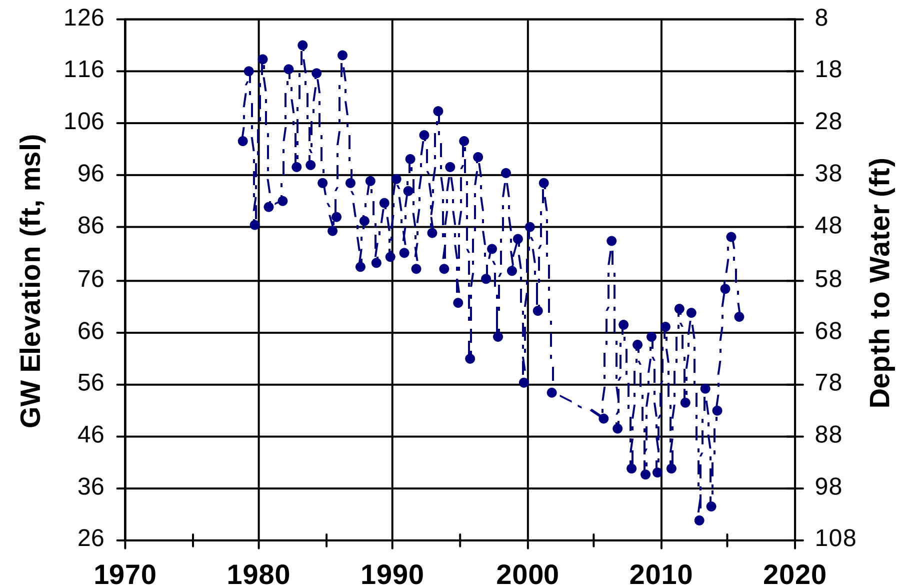
WellID: **NapaCounty-192** RPE: 156.8 ft, msl Subarea: NVF_MST
SWN: Unknown Source: NapaCounty



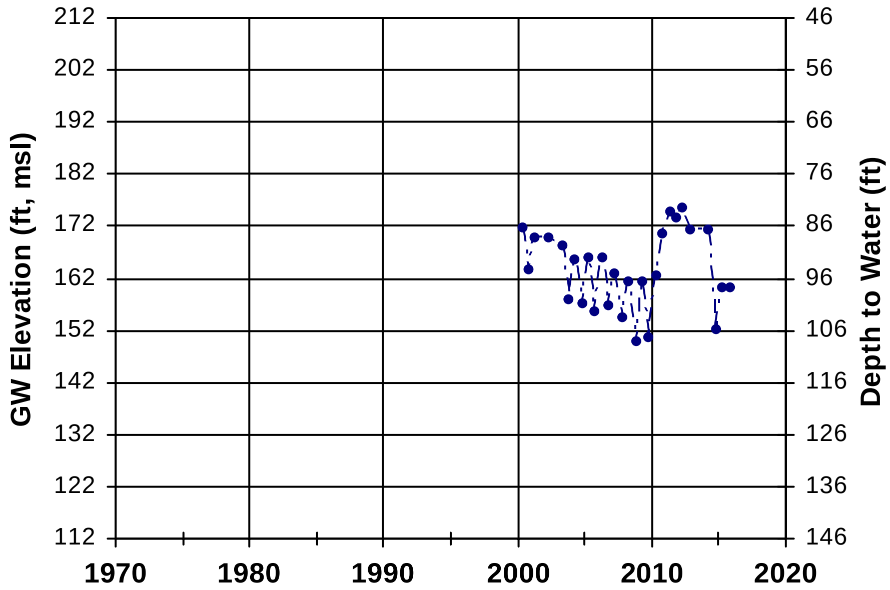
WellID: **NapaCounty-2** RPE: 90.5 ft, msl Subarea: NVF_MST
SWN: 006N004W23J001M Source: NapaCounty



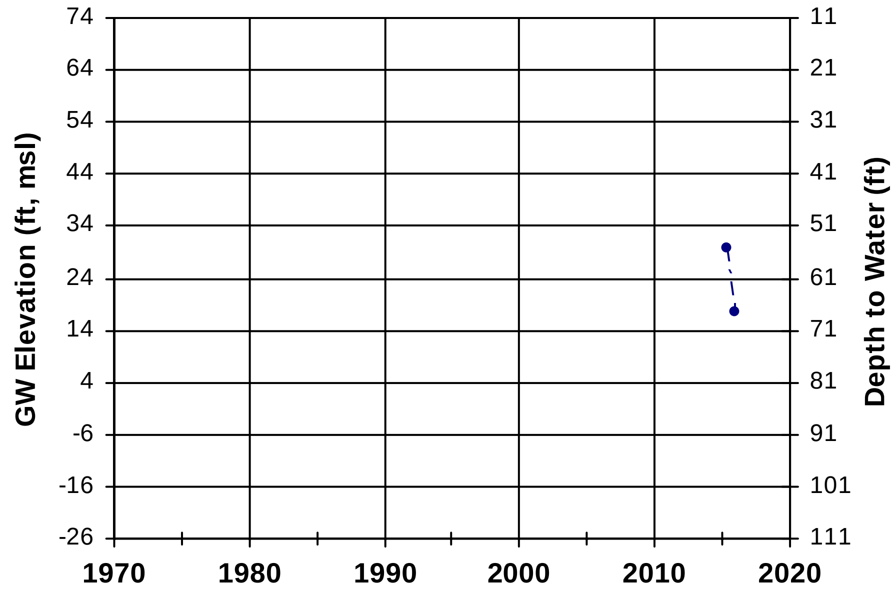
WellID: **NapaCounty-20** RPE: 134.5 ft, msl Subarea: NVF_MST
SWN: 005N003W07C003M Source: NapaCounty



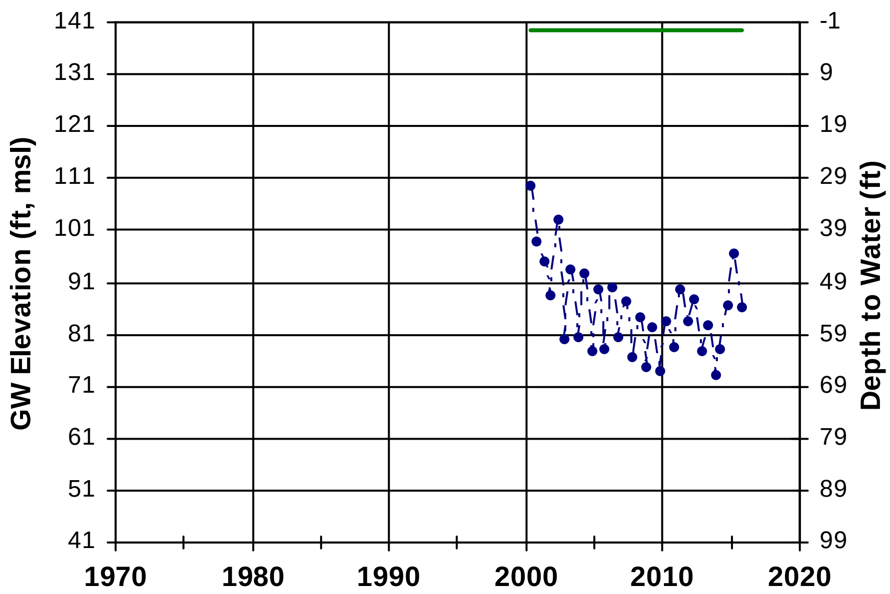
WellID: NapaCounty-22 RPE: 257.7 ft, msl Subarea: NVF_MST
SWN: 005N003W08E001M Source: NapaCounty



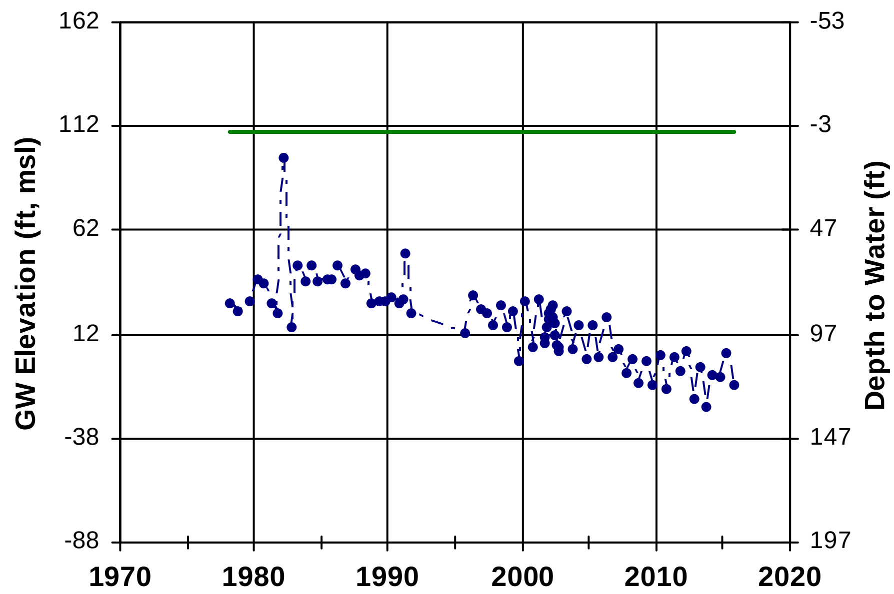
WellID: NapaCounty-226 RPE: 84.9 ft, msl Subarea: NVF_MST
SWN: Unknown Source: NapaCounty

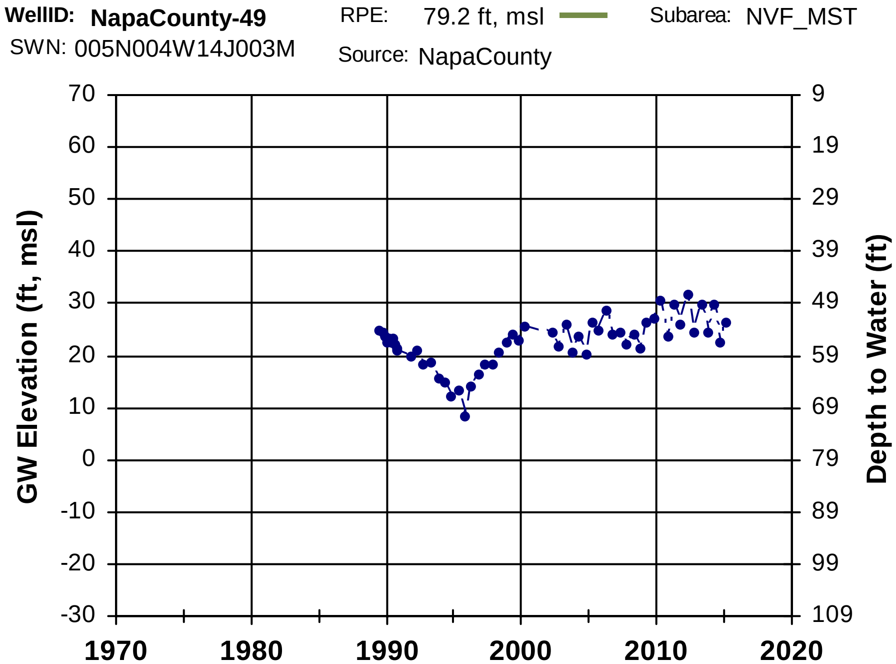


WellID: NapaCounty-35 RPE: 139.6 ft, msl Subarea: NVF_MST
SWN: 005N003W18D001M Source: NapaCounty

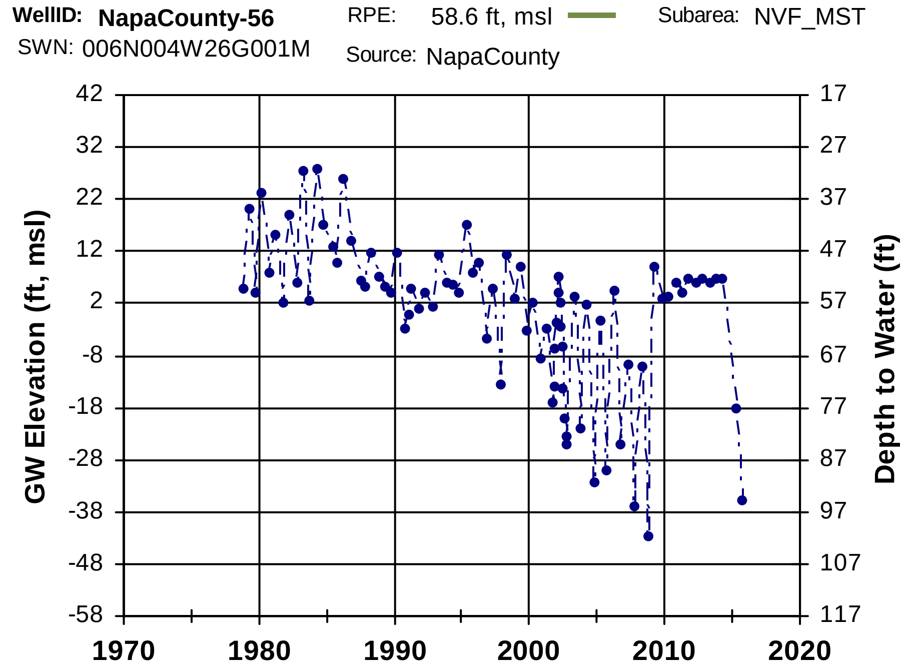


WellID: NapaCounty-43 RPE: 109 ft, msl Subarea: NVF_MST
SWN: 006N004W23Q003M Source: NapaCounty

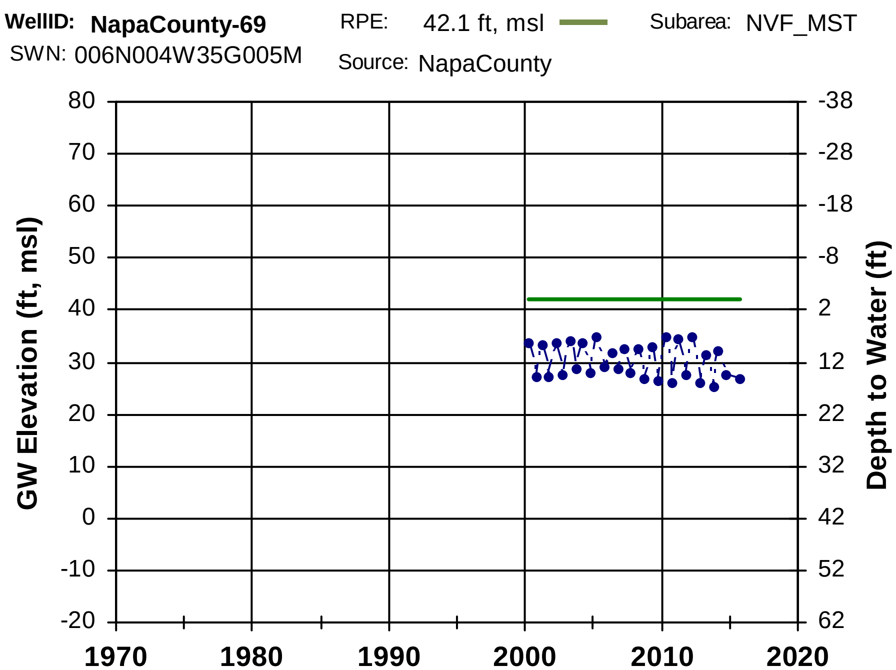




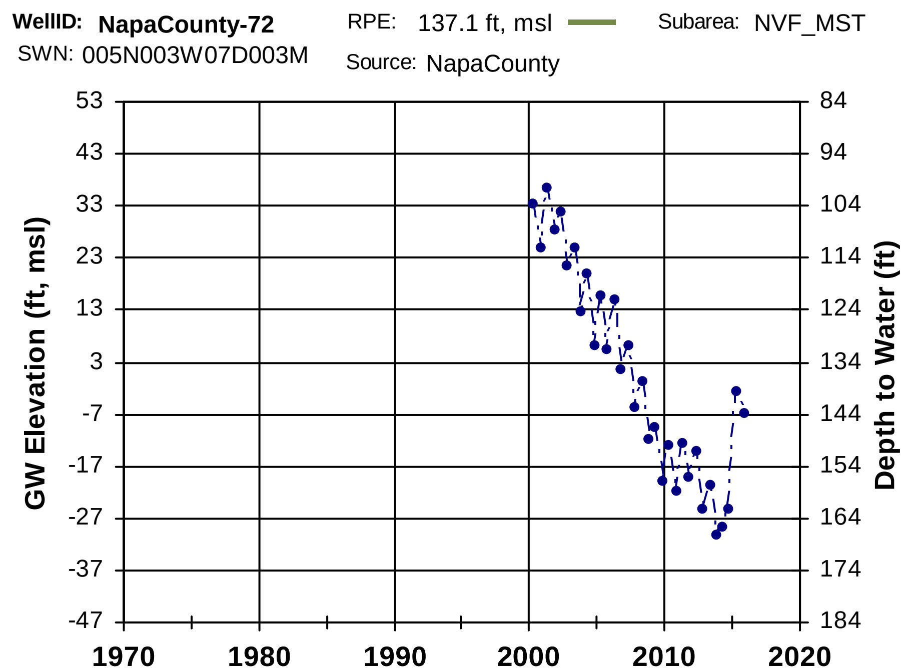
WellID: NapaCounty-49
SWN: 005N004W14J003M
RPE: 79.2 ft, msl
Source: NapaCounty
Subarea: NVF_MST
GW Elevation (ft, msl)
Depth to Water (ft)
70
60
50
40
30
20
10
0
-10
-20
-30
9
19
29
39
49
59
69
79
89
99
109
1970
1980
1990
2000
2010
2020



WellID: NapaCounty-56
SWN: 006N004W26G001M
RPE: 58.6 ft, msl
Source: NapaCounty
Subarea: NVF_MST
GW Elevation (ft, msl)
Depth to Water (ft)
42
32
22
12
2
-8
-18
-28
-38
-48
-58
17
27
37
47
57
67
77
87
97
107
117
1970
1980
1990
2000
2010
2020

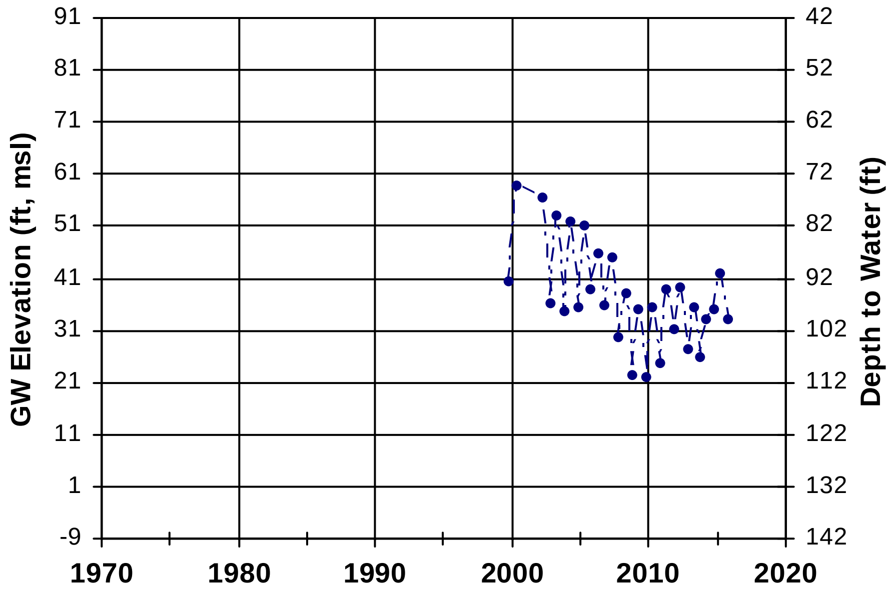


WellID: NapaCounty-69
SWN: 006N004W35G005M
RPE: 42.1 ft, msl
Source: NapaCounty
Subarea: NVF_MST
GW Elevation (ft, msl)
Depth to Water (ft)
80
70
60
50
40
30
20
10
0
-10
-20
-38
-28
-18
-8
2
12
22
32
42
52
62
1970
1980
1990
2000
2010
2020

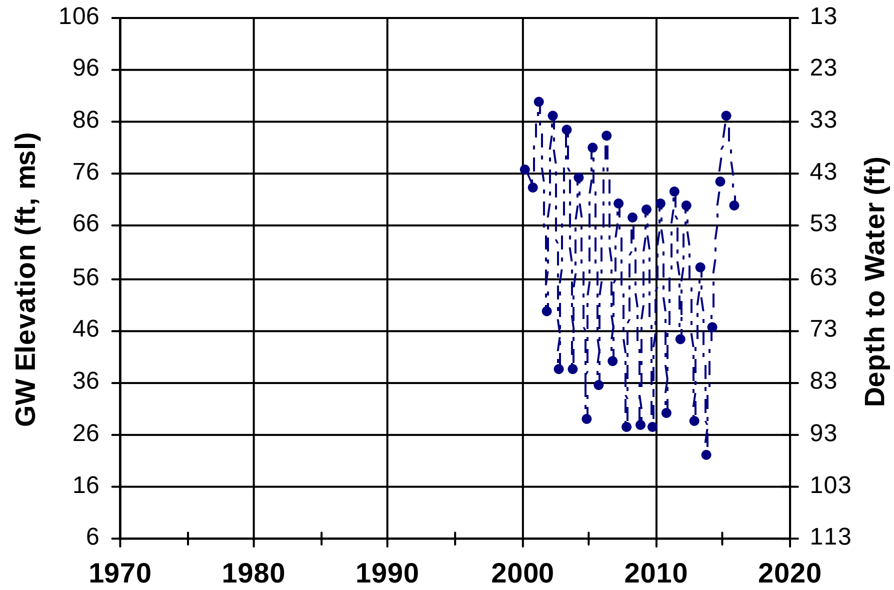


WellID: NapaCounty-72
SWN: 005N003W07D003M
RPE: 137.1 ft, msl
Source: NapaCounty
Subarea: NVF_MST
GW Elevation (ft, msl)
Depth to Water (ft)
53
43
33
23
13
3
-7
-17
-27
-37
-47
84
94
104
114
124
134
144
154
164
174
184
1970
1980
1990
2000
2010
2020

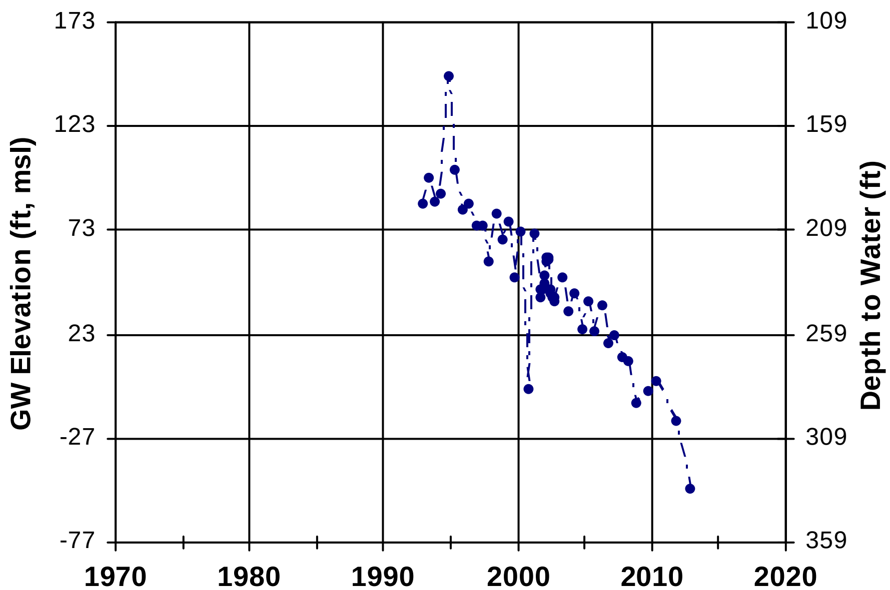
WellID: **NapaCounty-74** RPE: 133.3 ft, msl Subarea: NVF_MST
SWN: 005N003W06M001M Source: NapaCounty



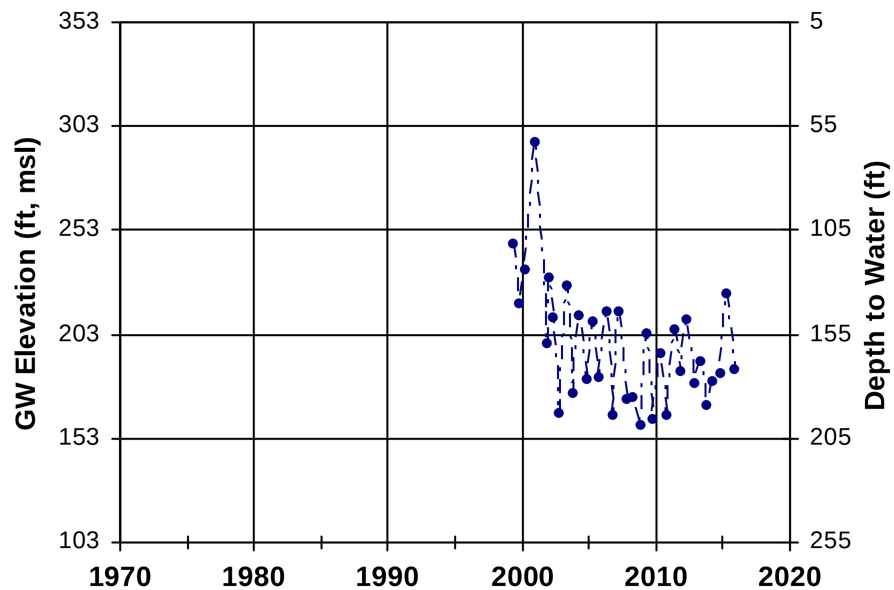
WellID: **NapaCounty-81** RPE: 118.6 ft, msl Subarea: NVF_MST
SWN: 005N003W07F003M Source: NapaCounty



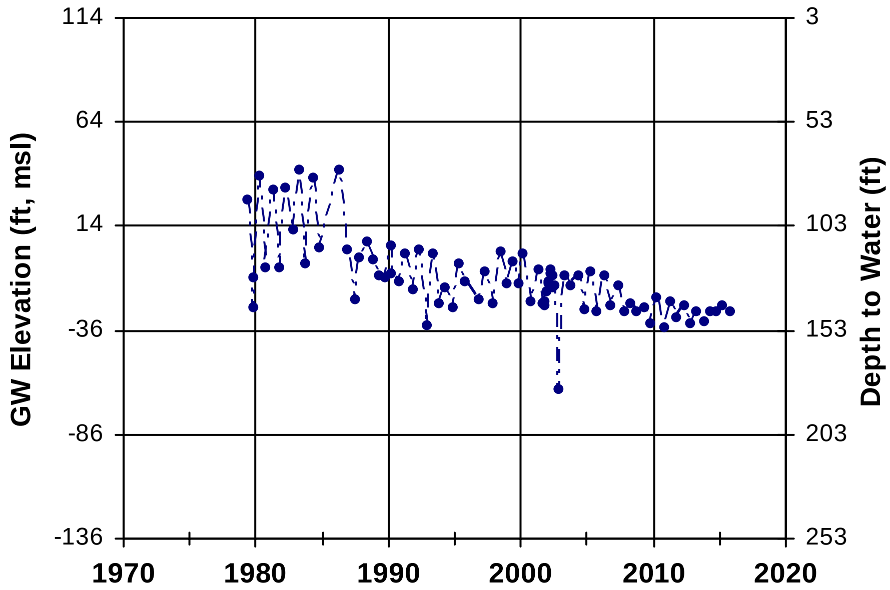
WellID: **NapaCounty-91** RPE: 281.9 ft, msl Subarea: NVF_MST
SWN: 005N003W06B002M Source: NapaCounty



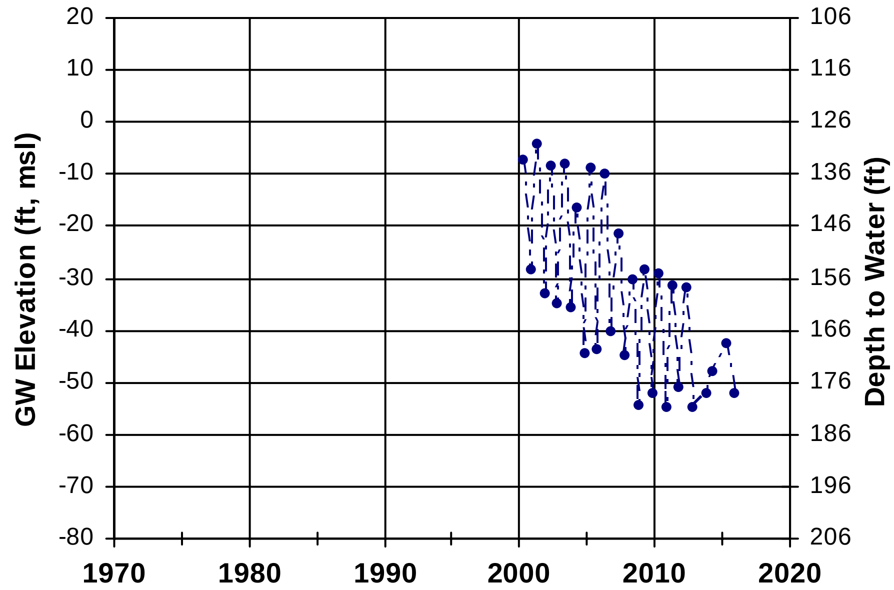
WellID: **NapaCounty-92** RPE: 358.2 ft, msl Subarea: NVF_MST
SWN: 005N003W06A001M Source: NapaCounty



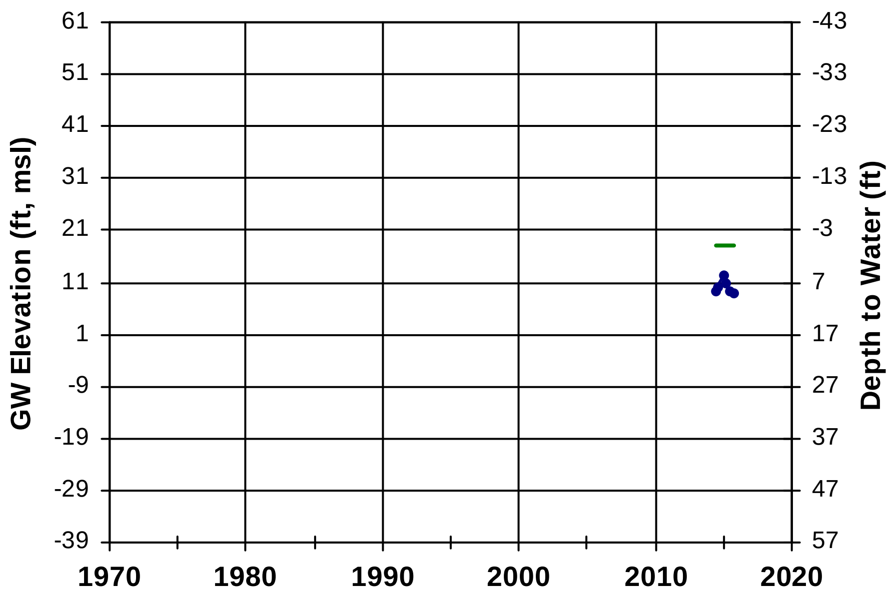
WellID: **NapaCounty-95** RPE: 116.9 ft, msl Subarea: NVF_MST
SWN: 006N004W36G001M Source: NapaCounty



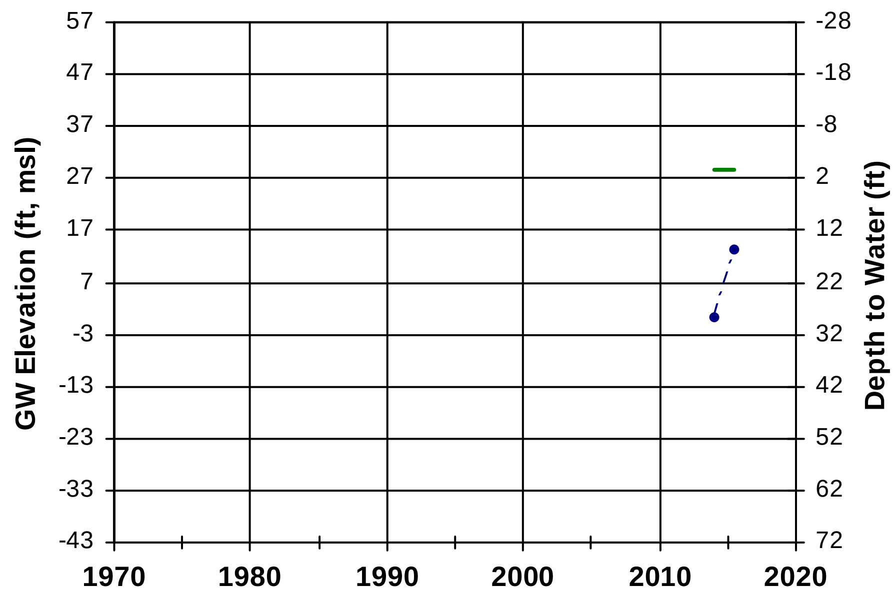
WellID: **NapaCounty-98** RPE: 125.7 ft, msl Subarea: NVF_MST
SWN: 006N004W36A001M Source: NapaCounty

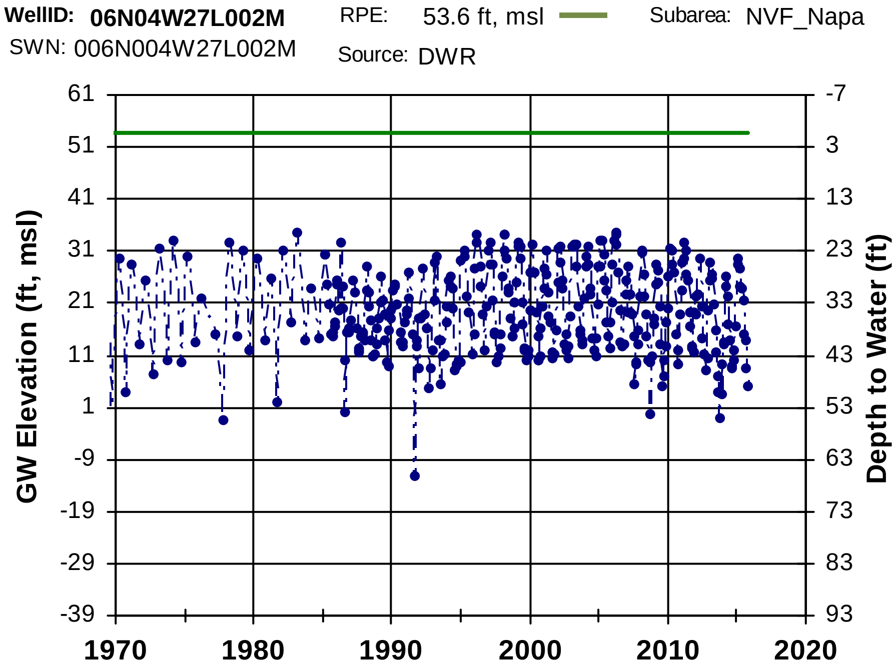


WellID: **T0605500200MW-1** RPE: 18.16 ft, msl Subarea: NVF_MST
SWN: Unknown Source: Geotracker

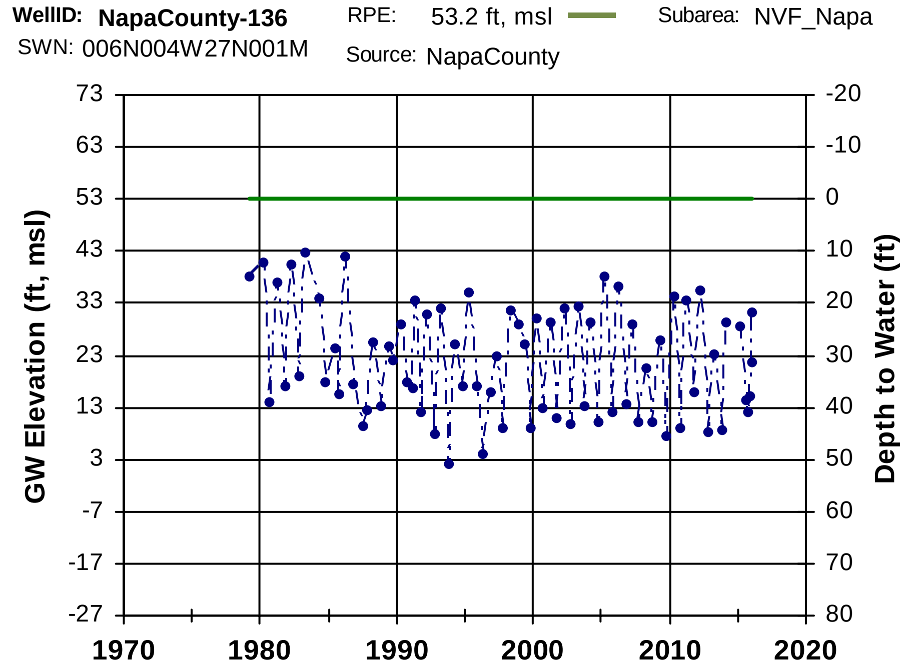


WellID: **T10000005248MW-** RPE: 28.81 ft, msl Subarea: NVF_MST
SWN: Unknown Source: Geotracker

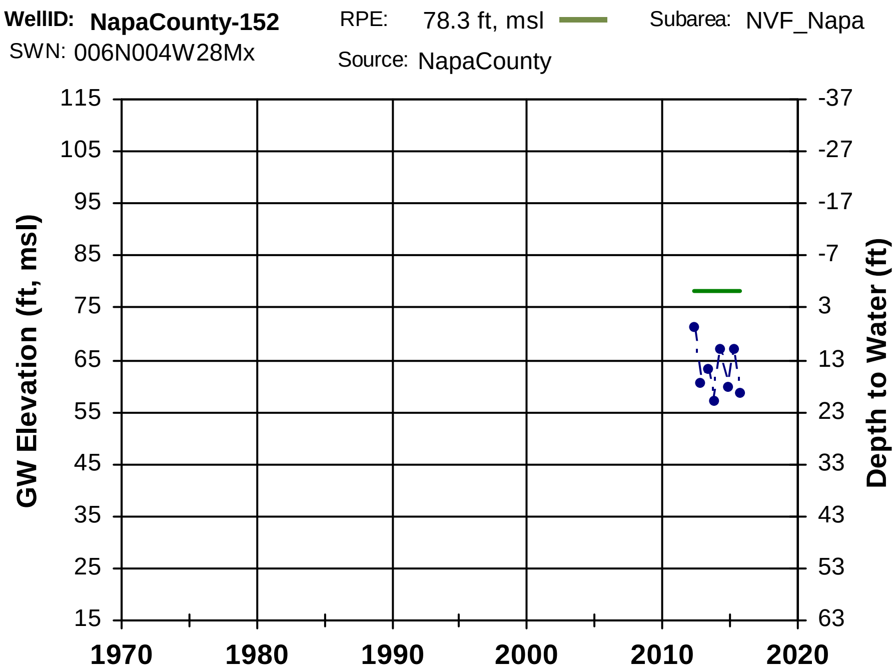




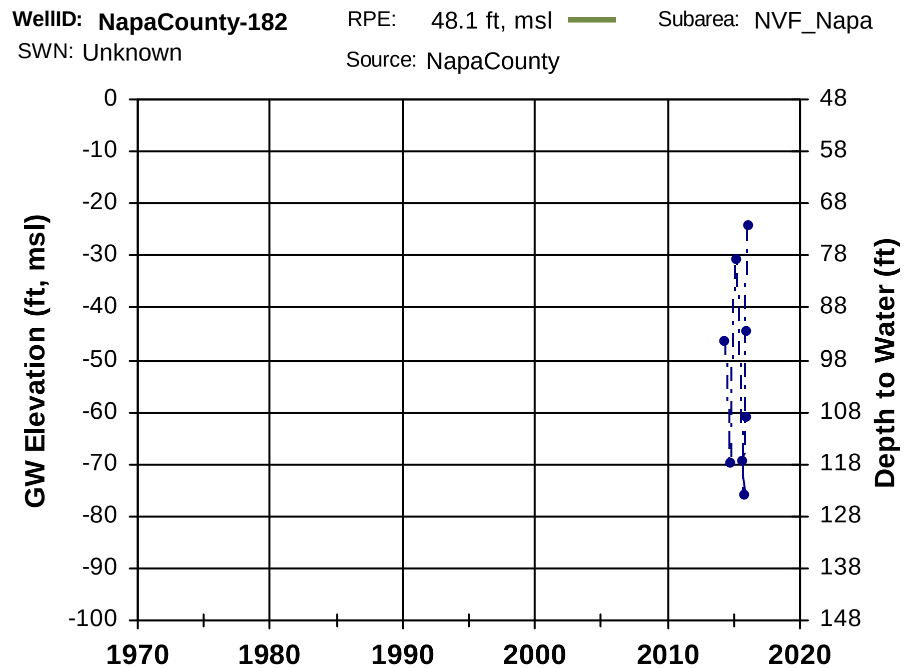
WellID: 06N04W27L002M
RPE: 53.6 ft, msl
Subarea: NVF_Napa
SWN: 006N004W27L002M
Source: DWR
GW Elevation (ft, msl)
Depth to Water (ft)
61
51
41
31
21
11
1
-9
-19
-29
-39
-7
3
13
23
33
43
53
63
73
83
93
1970
1980
1990
2000
2010
2020



WellID: NapaCounty-136
RPE: 53.2 ft, msl
Subarea: NVF_Napa
SWN: 006N004W27N001M
Source: NapaCounty
GW Elevation (ft, msl)
Depth to Water (ft)
73
63
53
43
33
23
13
3
-7
-17
-27
-20
-10
0
10
20
30
40
50
60
70
80
1970
1980
1990
2000
2010
2020

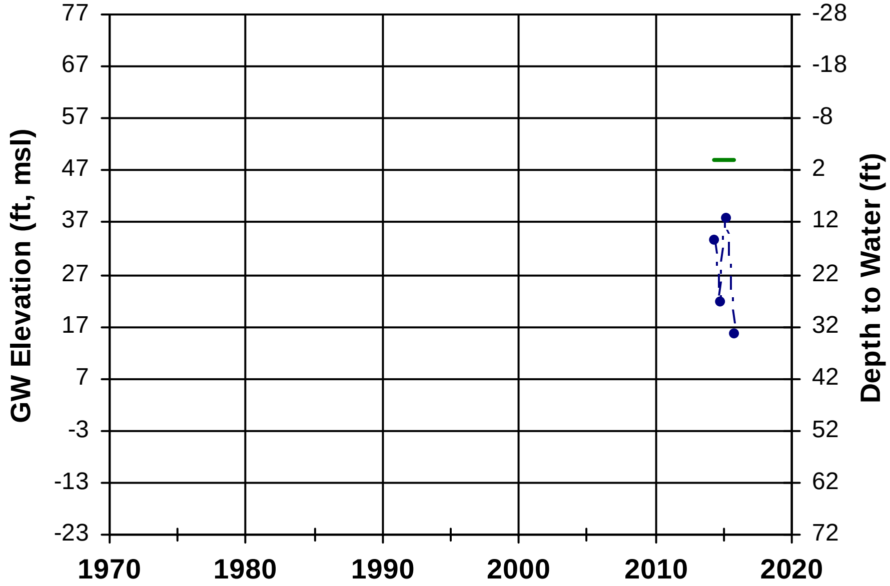


WellID: NapaCounty-152
RPE: 78.3 ft, msl
Subarea: NVF_Napa
SWN: 006N004W28Mx
Source: NapaCounty
GW Elevation (ft, msl)
Depth to Water (ft)
115
105
95
85
75
65
55
45
35
25
15
-37
-27
-17
-7
3
13
23
33
43
53
63
1970
1980
1990
2000
2010
2020

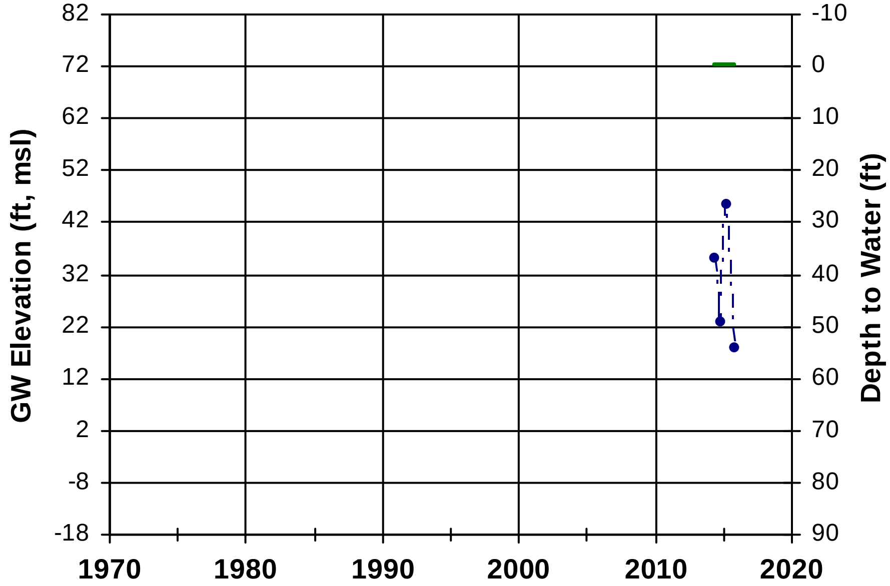


WellID: NapaCounty-182
RPE: 48.1 ft, msl
Subarea: NVF_Napa
SWN: Unknown
Source: NapaCounty
GW Elevation (ft, msl)
Depth to Water (ft)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
48
58
68
78
88
98
108
118
128
138
148
1970
1980
1990
2000
2010
2020

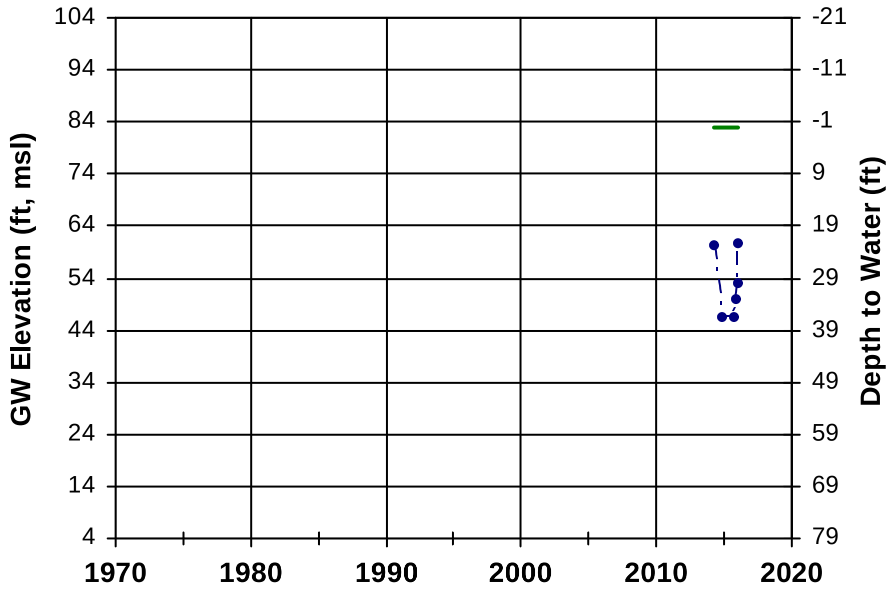
WellID: **NapaCounty-183** RPE: 48.9 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



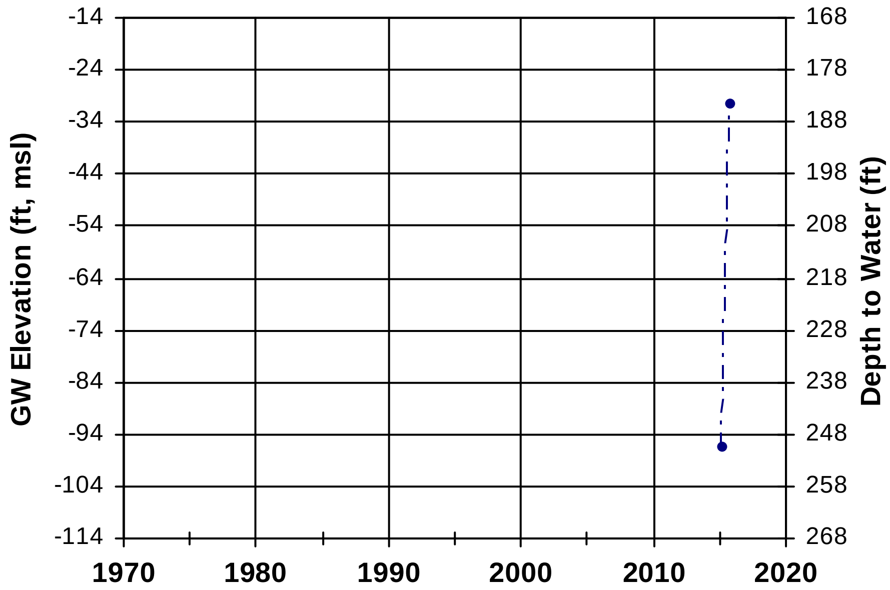
WellID: **NapaCounty-184** RPE: 72.5 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



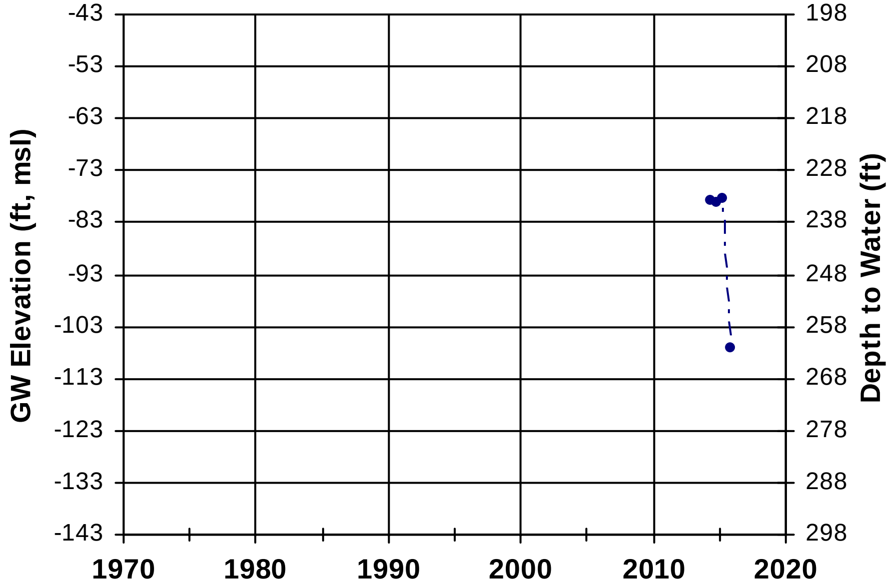
WellID: **NapaCounty-185** RPE: 83 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



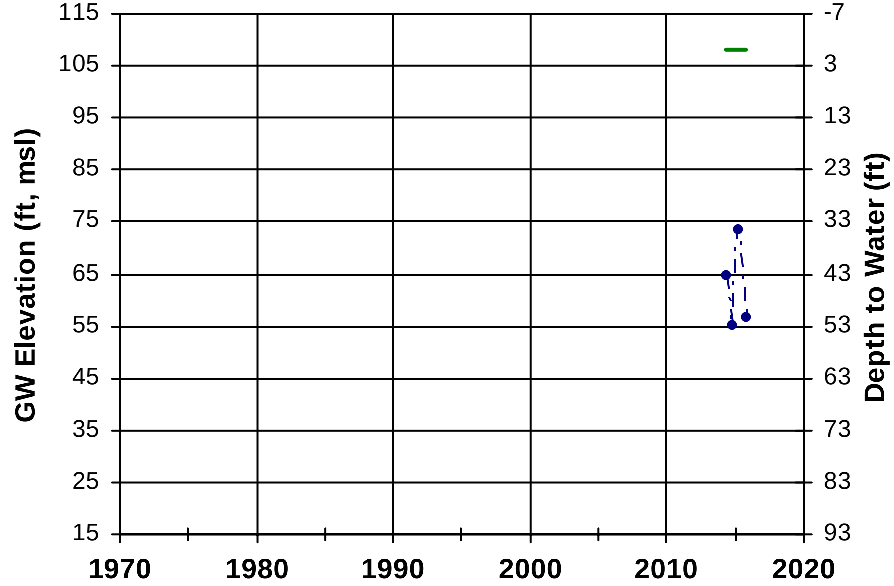
WellID: **NapaCounty-187** RPE: 153.5 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



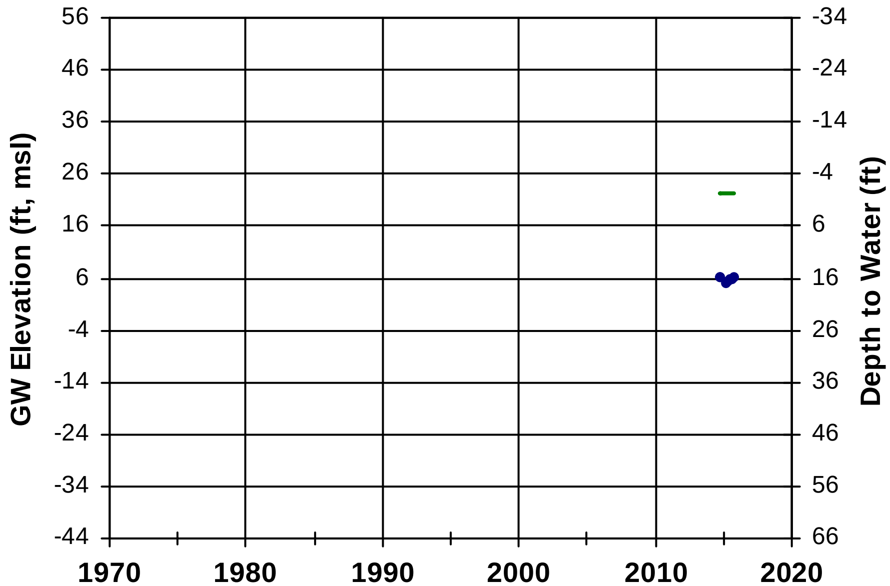
WellID: **NapaCounty-188** RPE: 154.6 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



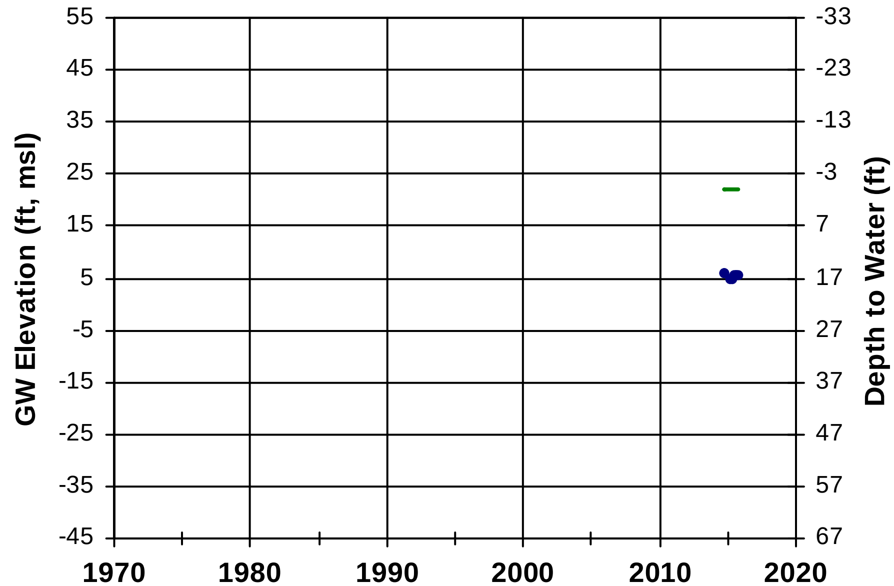
WellID: **NapaCounty-189** RPE: 108.25 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



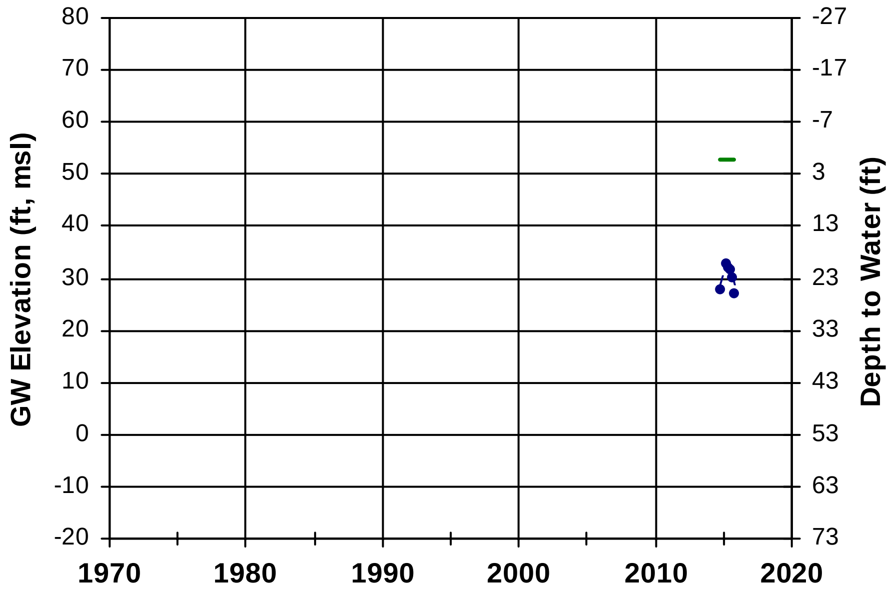
WellID: **NapaCounty-214s-s** RPE: 22.1 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



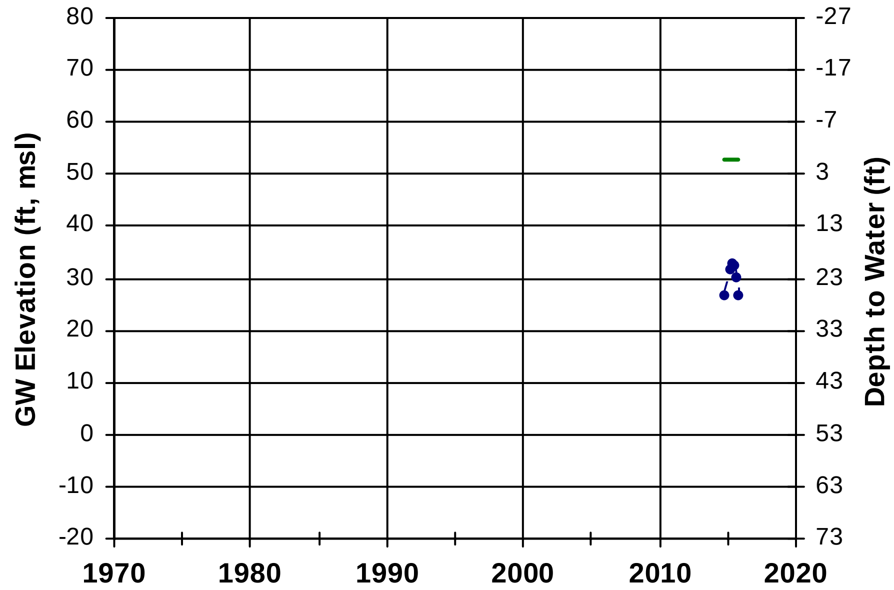
WellID: **NapaCounty-215d-s** RPE: 22.05 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



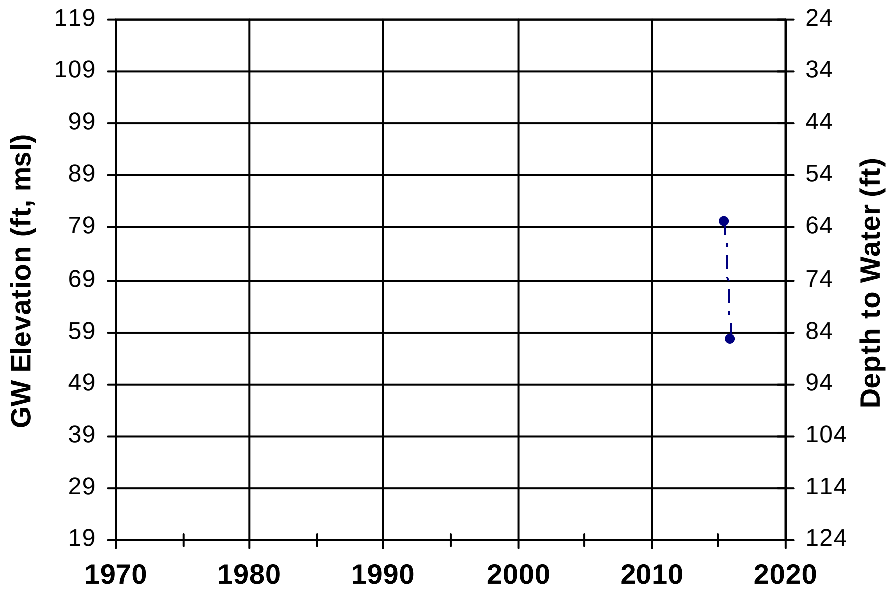
WellID: **NapaCounty-218s-s** RPE: 52.8 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



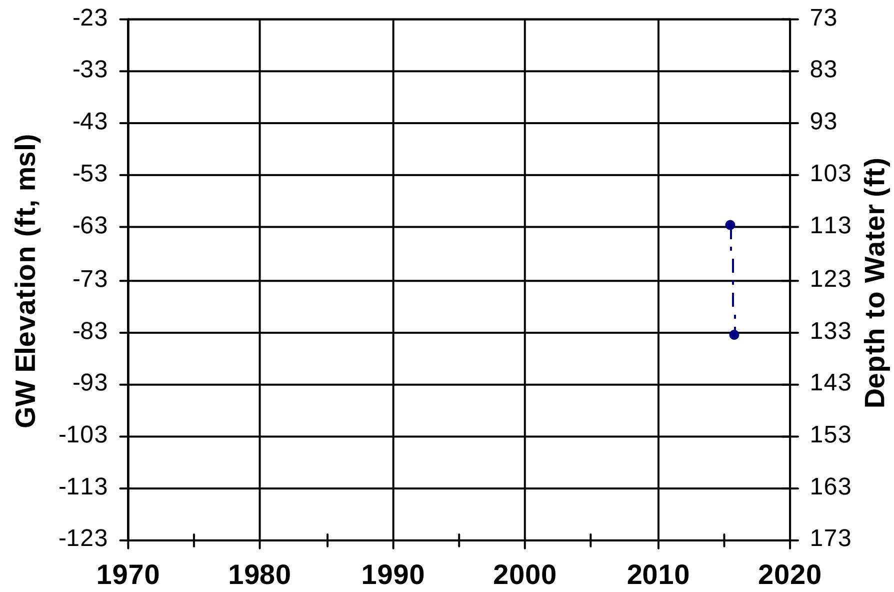
WellID: **NapaCounty-219d-s** RPE: 52.75 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



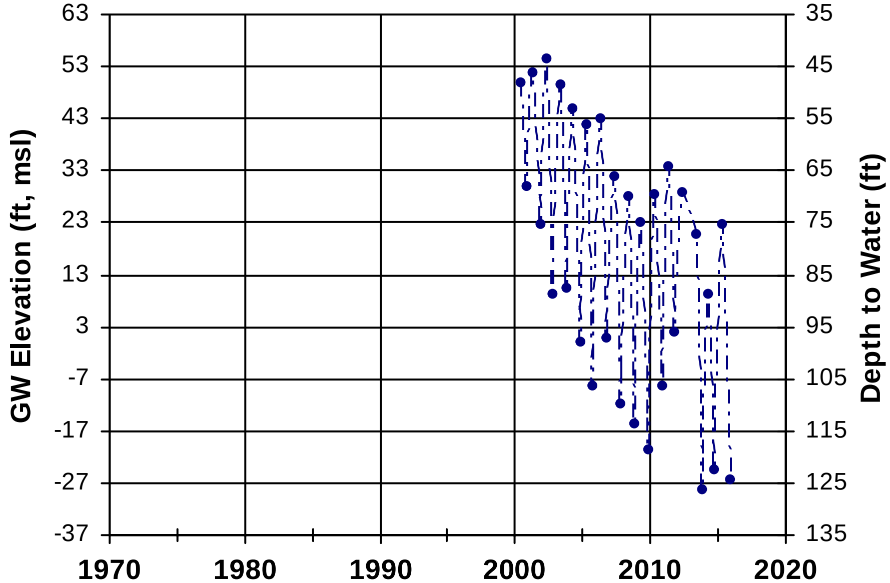
WellID: **NapaCounty-227** RPE: 143.3 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



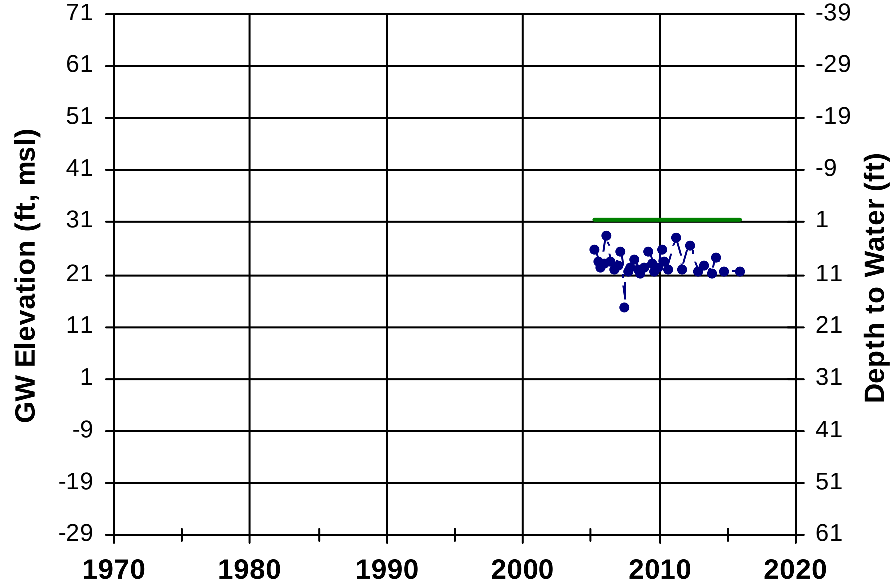
WellID: **NapaCounty-228** RPE: 50.2 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: NapaCounty



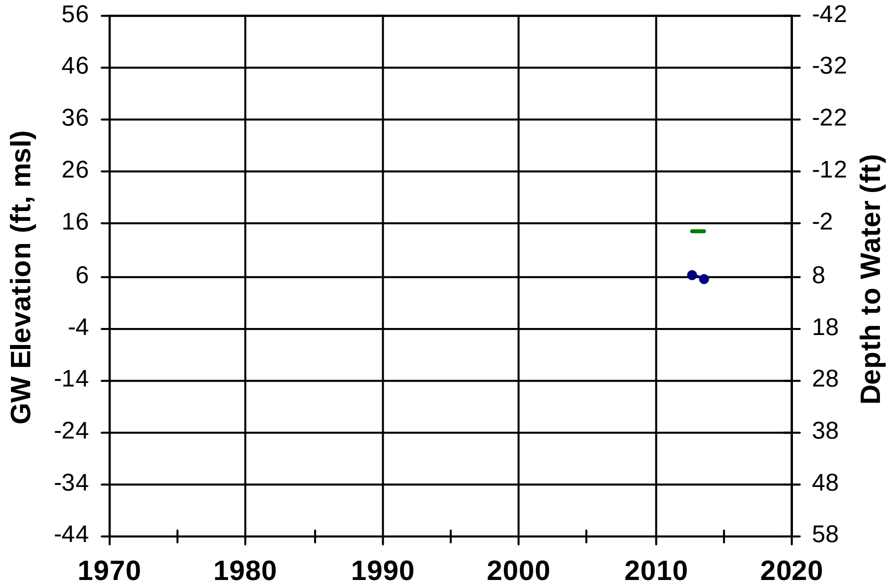
WellID: **NapaCounty-76** RPE: 97.7 ft, msl Subarea: NVF_Napa
SWN: 006N004W15R003M Source: NapaCounty



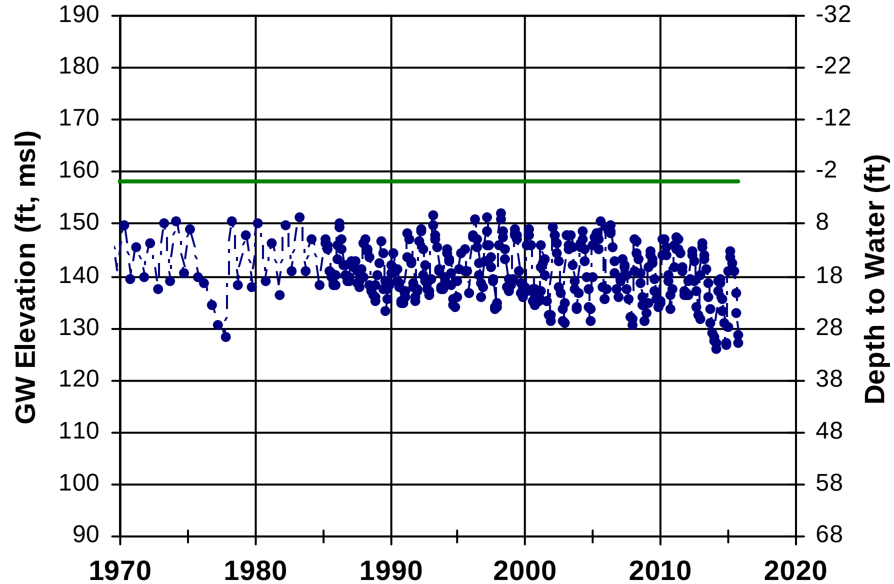
WellID: **SL0605536682MW-** RPE: 31.63 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: Geotracker



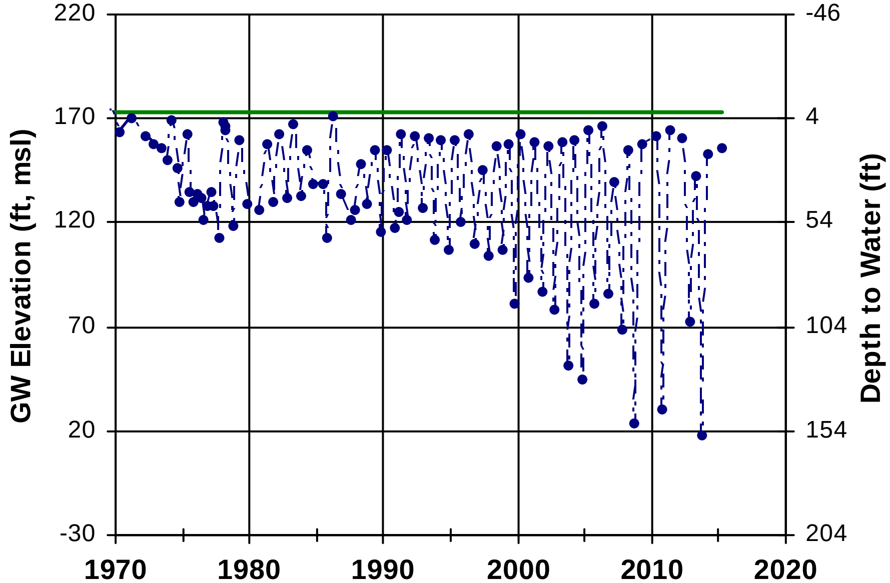
WellID: **T0605514064DPE1** RPE: 14.47 ft, msl Subarea: NVF_Napa
SWN: Unknown Source: Geotracker



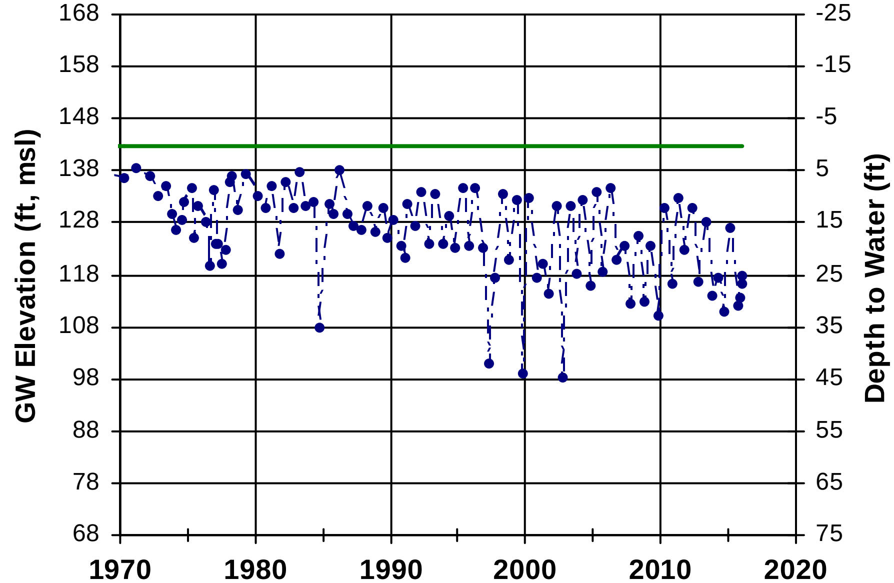
WellID: **07N05W09Q002M** RPE: 158.24 ft, msl Subarea: NVF_SH
SWN: 007N005W09Q002M Source: DWR



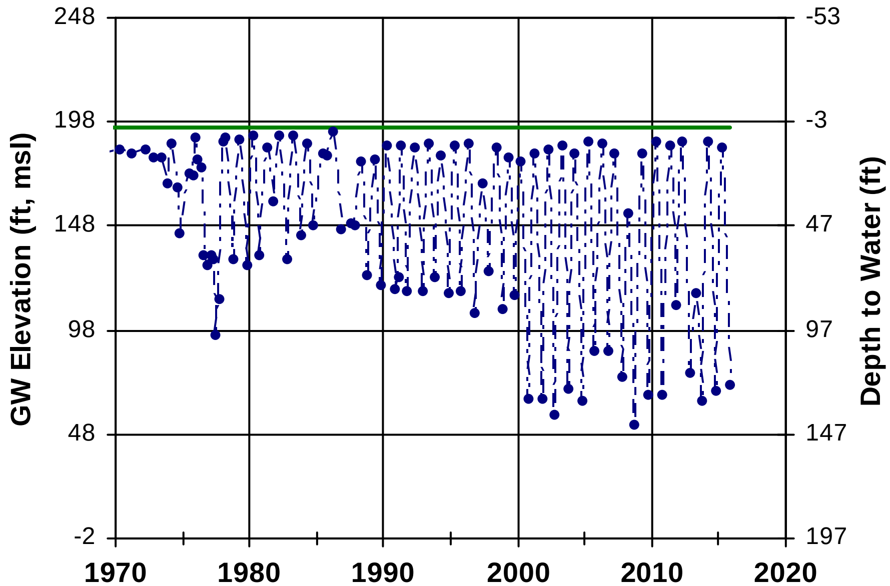
WellID: **NapaCounty-131** RPE: 173.5 ft, msl Subarea: NVF_SH
SWN: 007N005W16L001M Source: NapaCounty



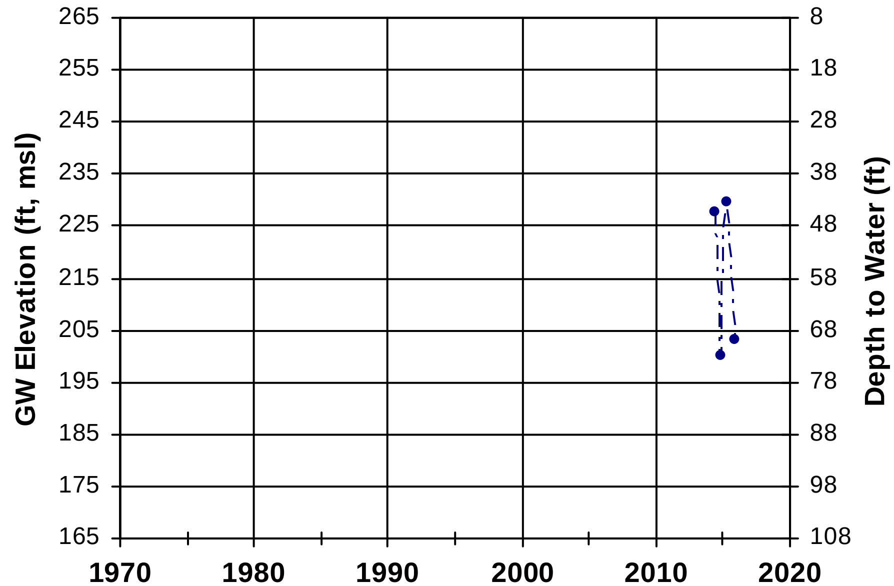
WellID: **NapaCounty-132** RPE: 142.7 ft, msl Subarea: NVF_SH
SWN: 007N005W14B002M Source: NapaCounty



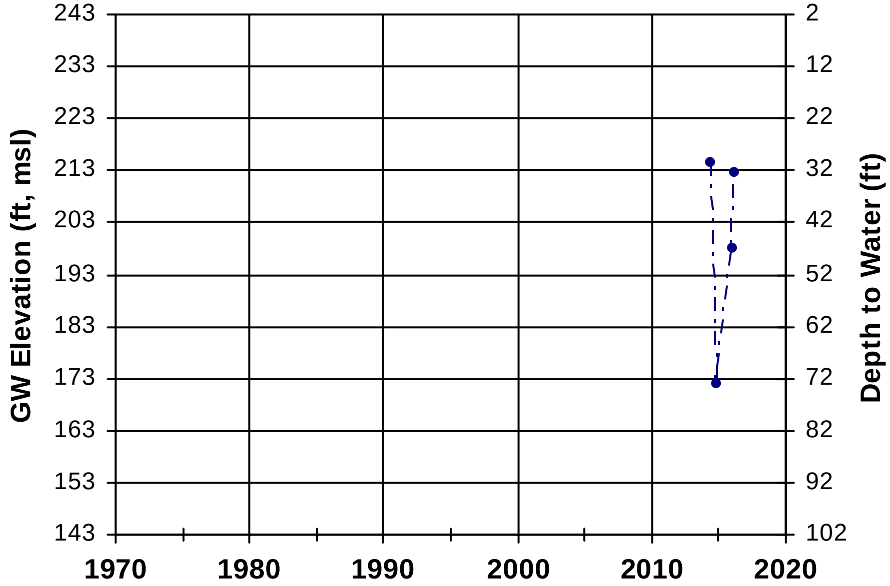
WellID: **NapaCounty-138** RPE: 195.1 ft, msl Subarea: NVF_SH
SWN: 007N005W16N002M Source: NapaCounty



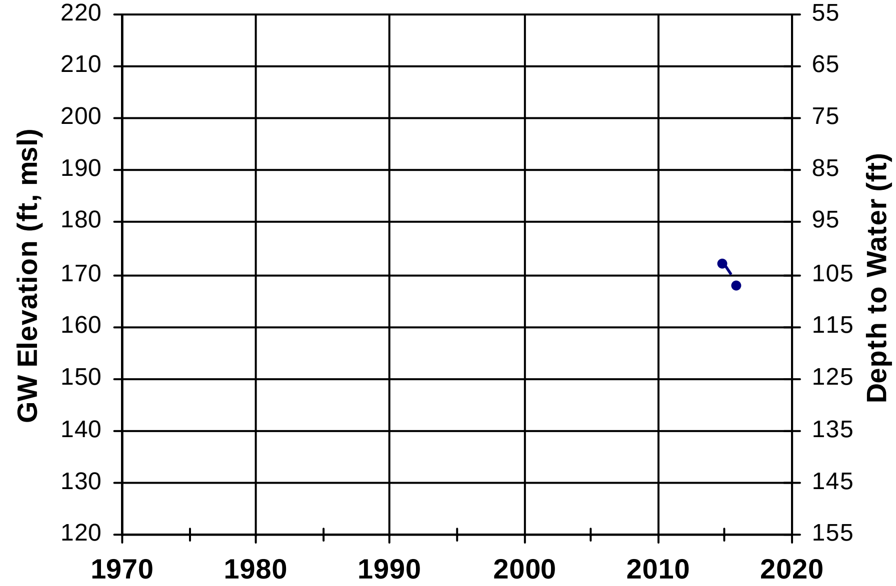
WellID: **NapaCounty-169** RPE: 273.4 ft, msl Subarea: NVF_SH
SWN: Unknown Source: NapaCounty



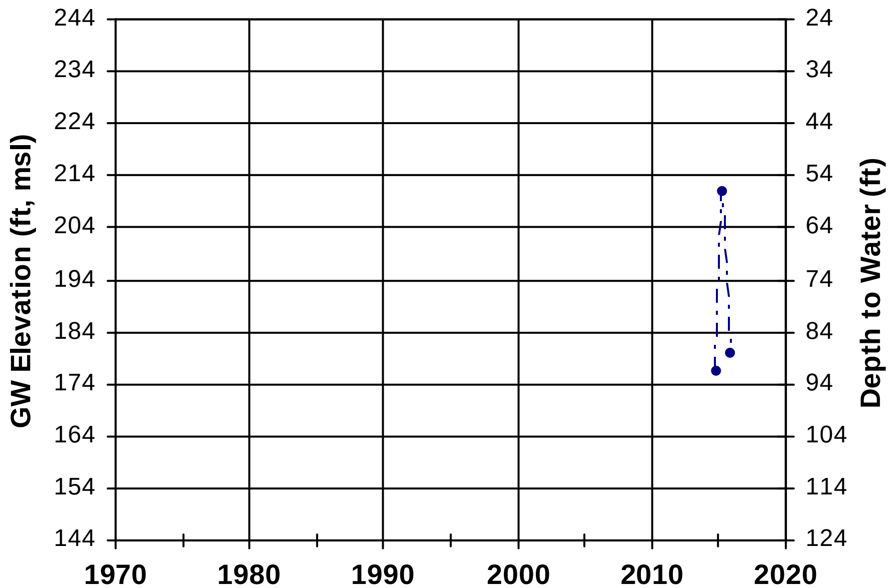
WellID: **NapaCounty-171** RPE: 245.1 ft, msl Subarea: NVF_SH
SWN: Unknown Source: NapaCounty



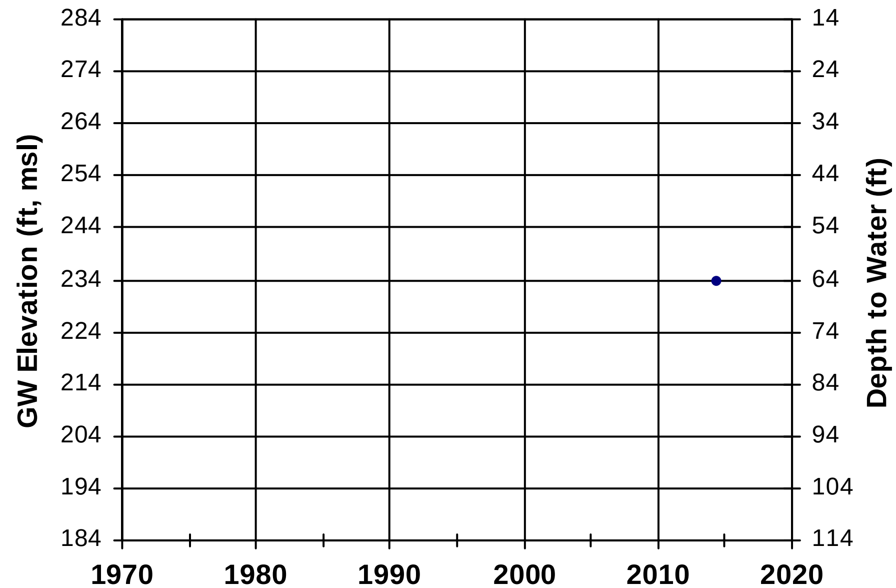
WellID: **NapaCounty-172** RPE: 275.2 ft, msl Subarea: NVF_SH
SWN: Unknown Source: NapaCounty



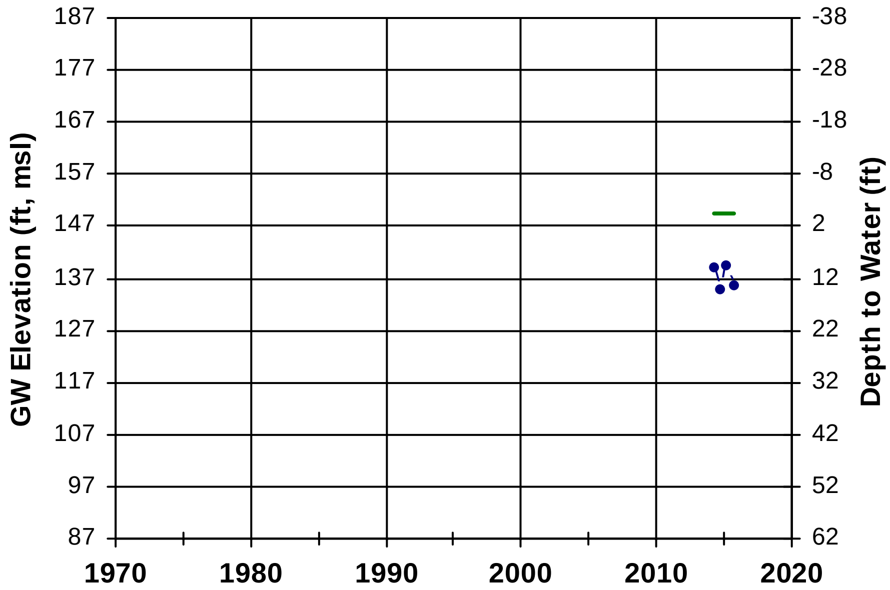
WellID: **NapaCounty-173** RPE: 268.3 ft, msl Subarea: NVF_SH
SWN: Unknown Source: NapaCounty



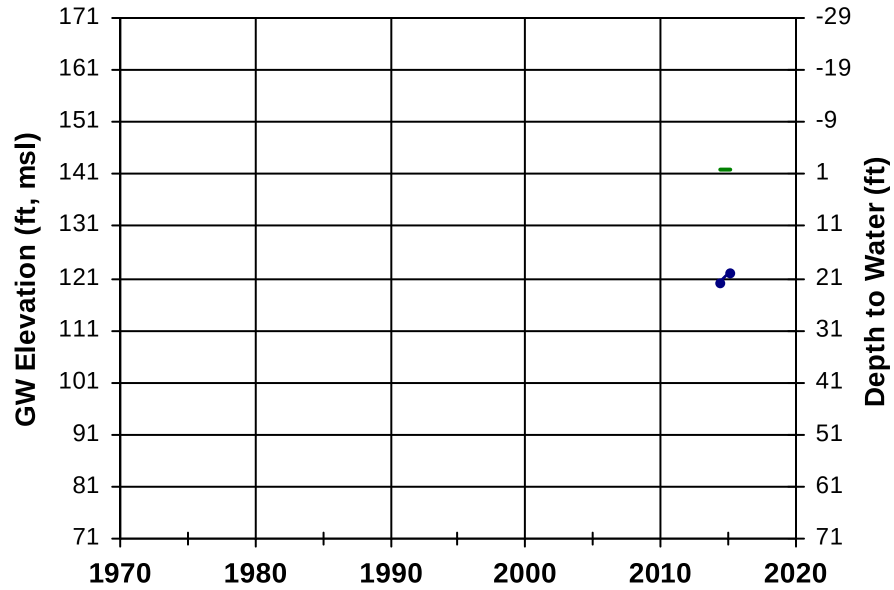
WellID: **NapaCounty-174** RPE: 298.2 ft, msl Subarea: NVF_SH
SWN: Unknown Source: NapaCounty



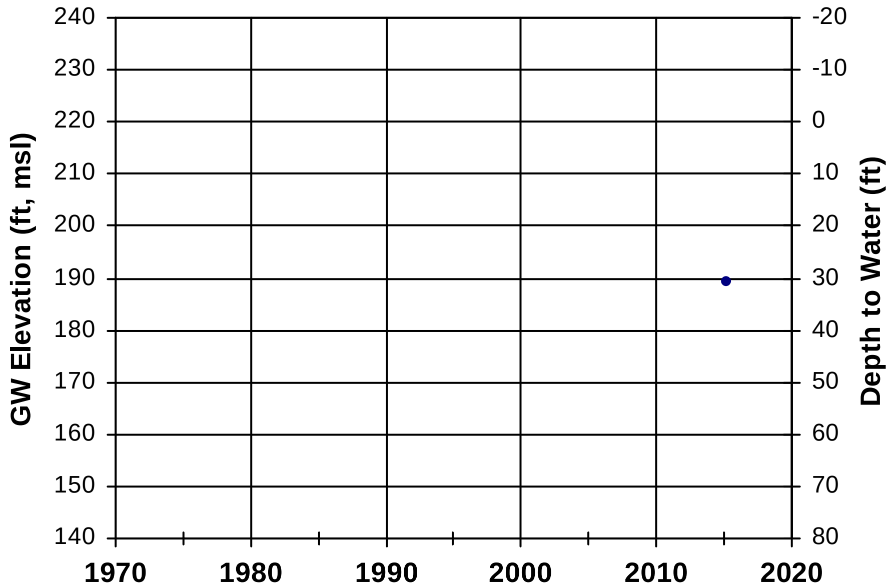
WellID: **NapaCounty-177** RPE: 149.3 ft, msl Subarea: NVF_SH
SWN: Unknown Source: NapaCounty



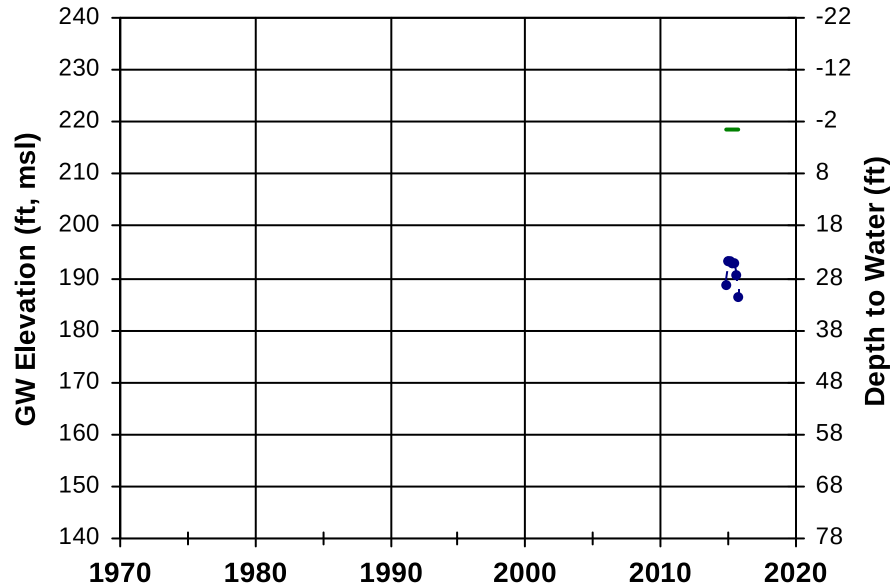
WellID: **NapaCounty-204** RPE: 141.7 ft, msl Subarea: NVF_SH
SWN: Unknown Source: NapaCounty

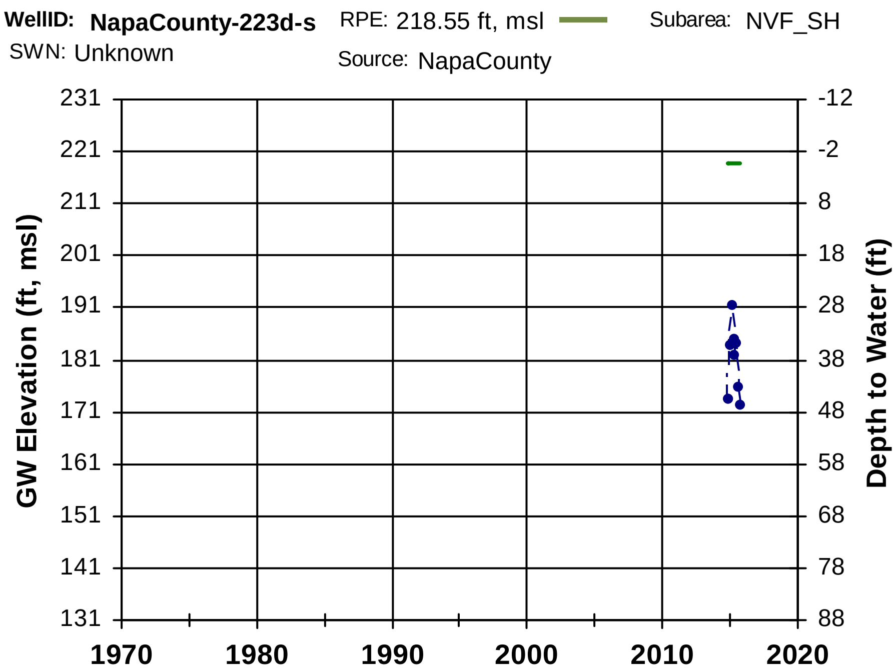


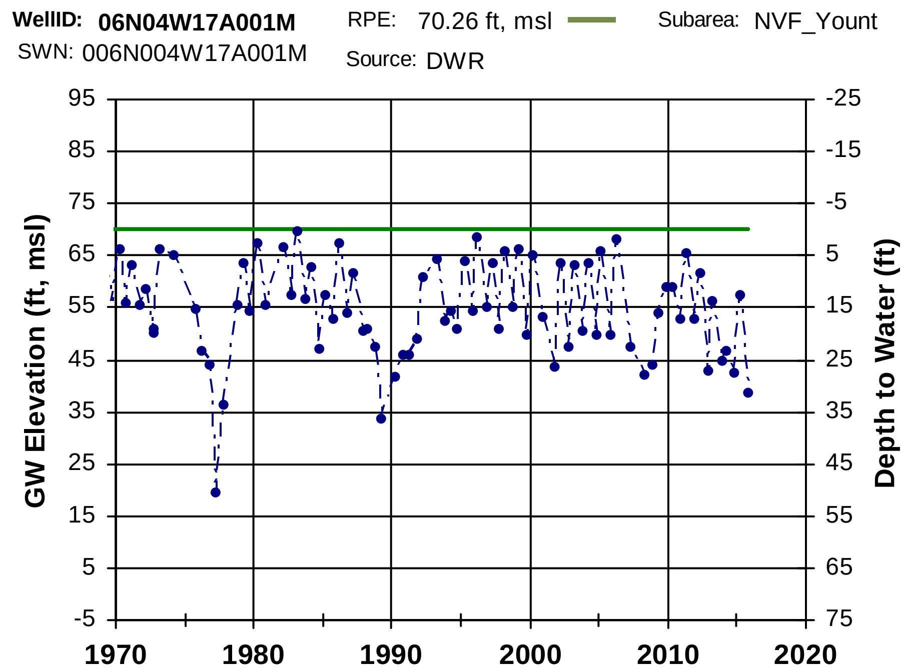
WellID: **NapaCounty-212** RPE: 220.5 ft, msl Subarea: NVF_SH
SWN: Unknown Source: NapaCounty

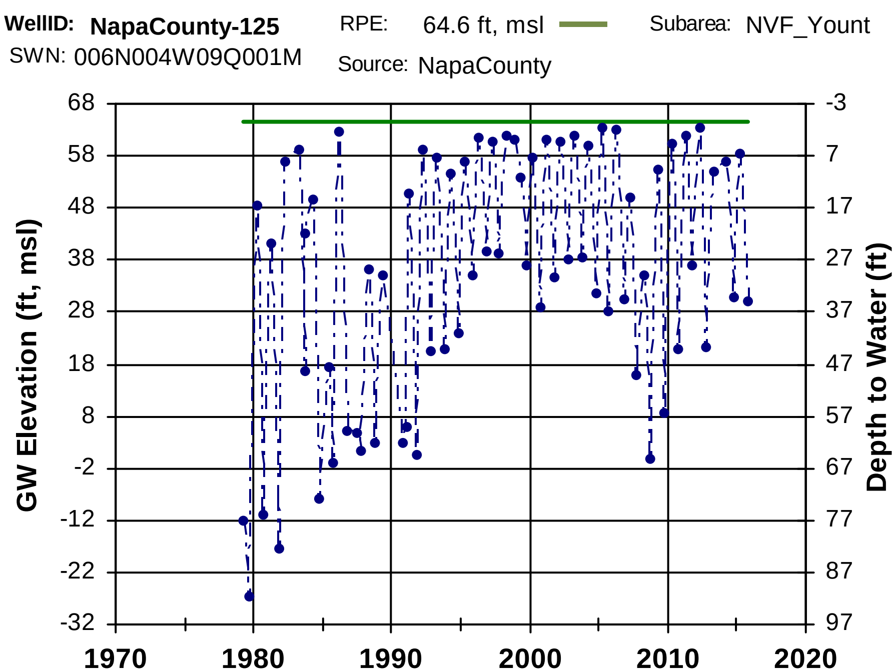


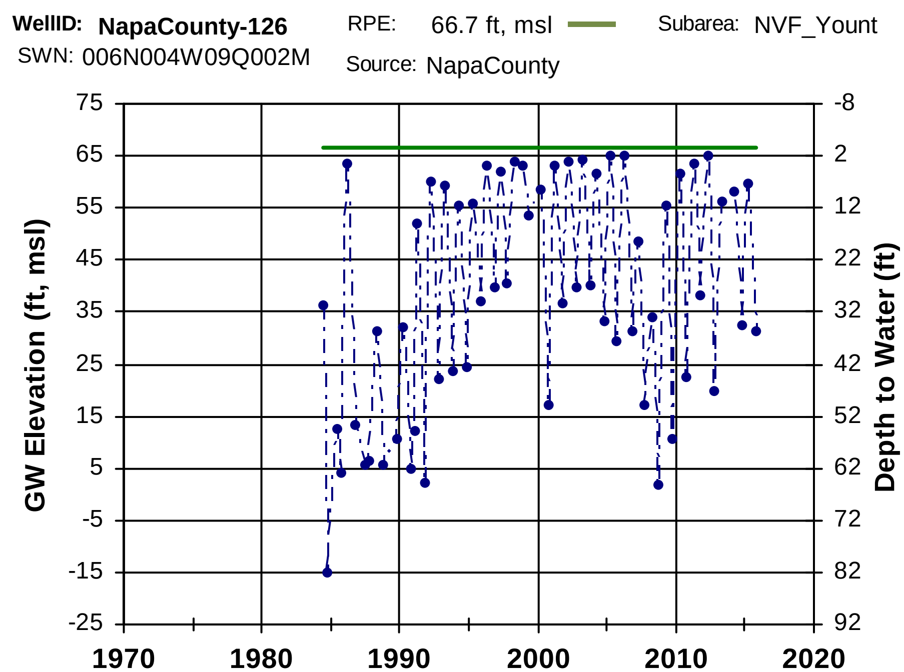
WellID: **NapaCounty-222s-s** RPE: 218.5 ft, msl Subarea: NVF_SH
SWN: Unknown Source: NapaCounty



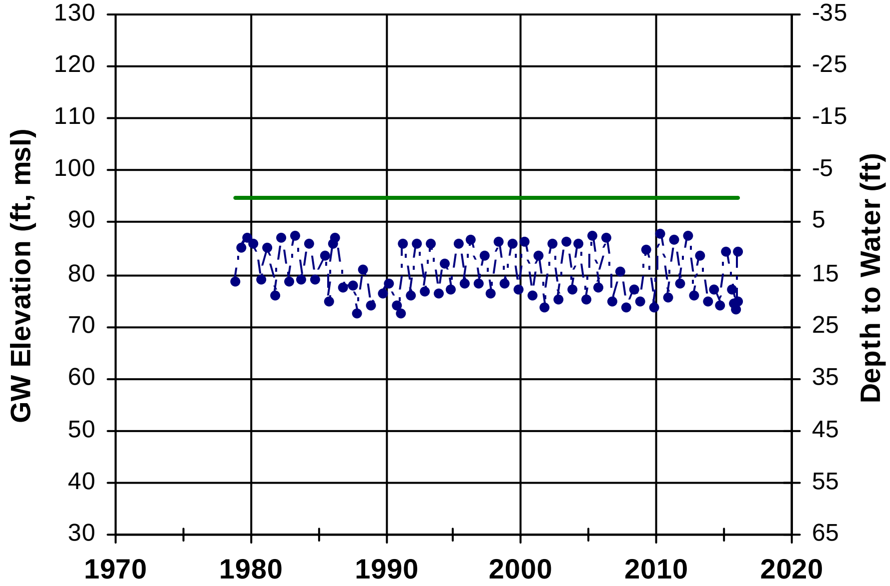

WellID: NapaCounty-223d-s
RPE: 218.55 ft, msl
Subarea: NVF_SH
SWN: Unknown
Source: NapaCounty
GW Elevation (ft, msl)
Depth to Water (ft)
231
221
211
201
191
181
171
161
151
141
131
-12
-2
8
18
28
38
48
58
68
78
88
1970
1980
1990
2000
2010
2020


WellID: 06N04W17A001M
RPE: 70.26 ft, msl
Subarea: NVF_Yount
SWN: 006N004W17A001M
Source: DWR
GW Elevation (ft, msl)
Depth to Water (ft)
95
85
75
65
55
45
35
25
15
5
-5
-25
-15
-5
5
15
25
35
45
55
65
75
1970
1980
1990
2000
2010
2020

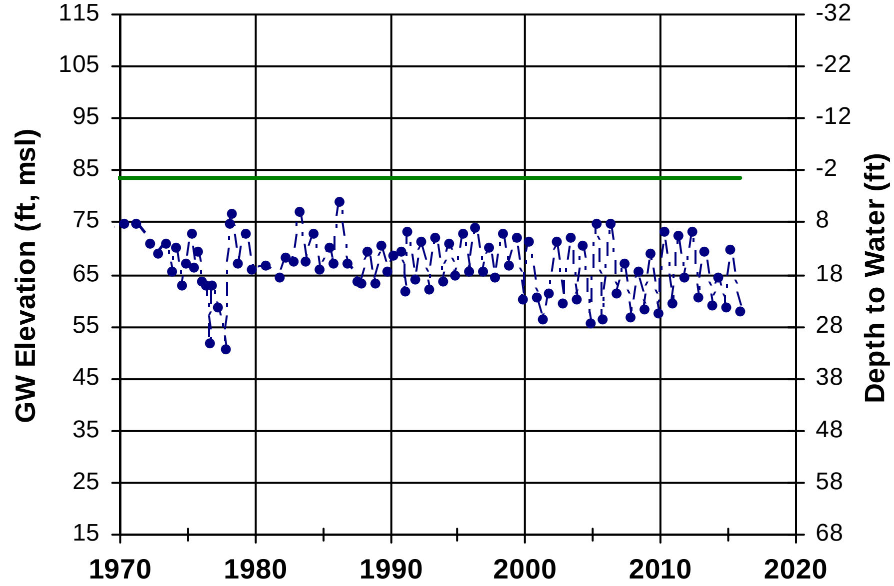

WellID: NapaCounty-125
RPE: 64.6 ft, msl
Subarea: NVF_Yount
SWN: 006N004W09Q001M
Source: NapaCounty
GW Elevation (ft, msl)
Depth to Water (ft)
68
58
48
38
28
18
8
-2
-12
-22
-32
-3
7
17
27
37
47
57
67
77
87
97
1970
1980
1990
2000
2010
2020


WellID: NapaCounty-126
RPE: 66.7 ft, msl
Subarea: NVF_Yount
SWN: 006N004W09Q002M
Source: NapaCounty
GW Elevation (ft, msl)
Depth to Water (ft)
75
65
55
45
35
25
15
5
-5
-15
-25
-8
2
12
22
32
42
52
62
72
82
92
1970
1980
1990
2000
2010
2020

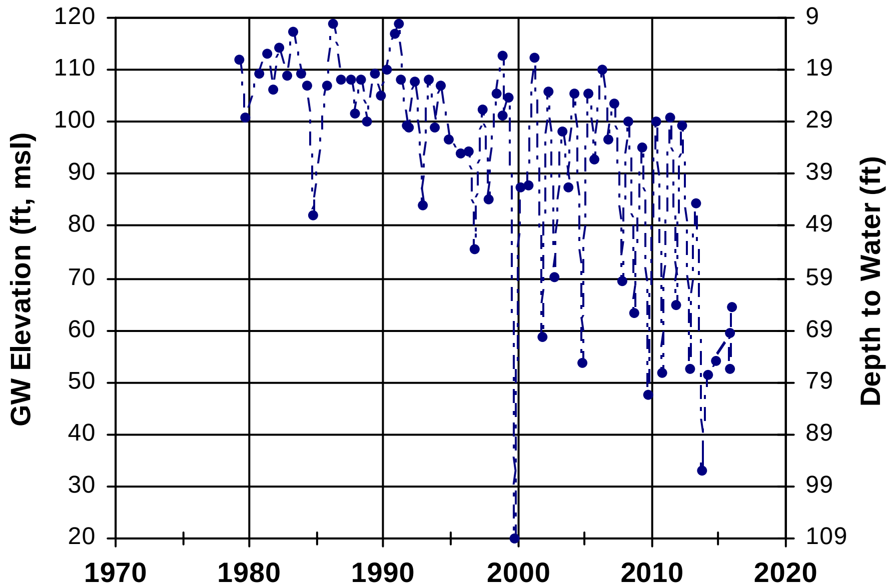
WellID: **NapaCounty-133** RPE: 94.7 ft, msl Subarea: NVF_Yount
SWN: 007N004W31M001M Source: NapaCounty



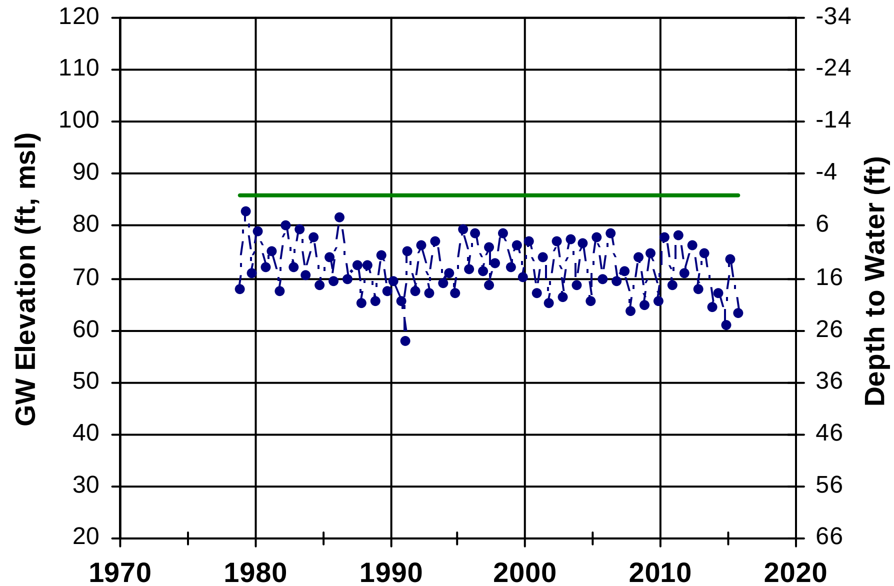
WellID: **NapaCounty-134** RPE: 83.4 ft, msl Subarea: NVF_Yount
SWN: 006N004W06L002M Source: NapaCounty



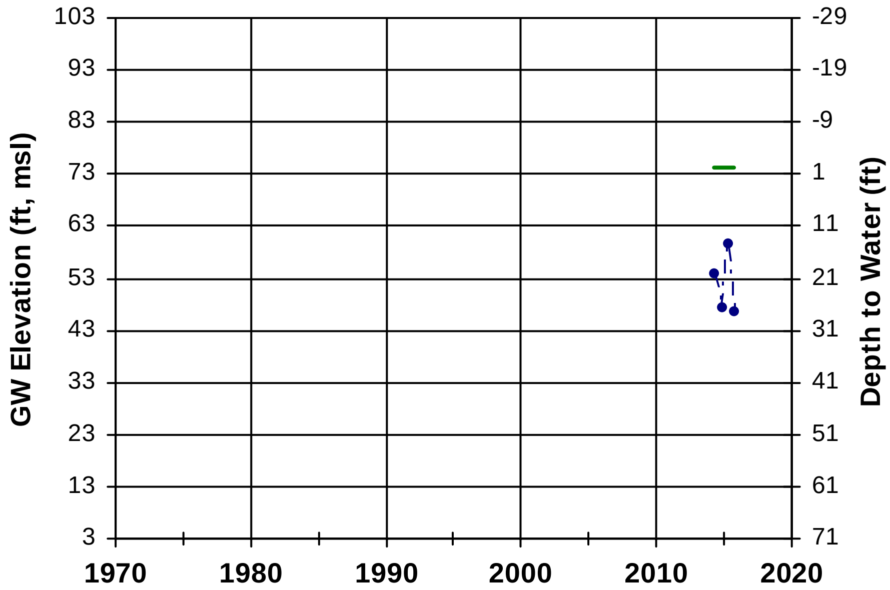
WellID: **NapaCounty-135** RPE: 129.2 ft, msl Subarea: NVF_Yount
SWN: 006N004W19B001M Source: NapaCounty



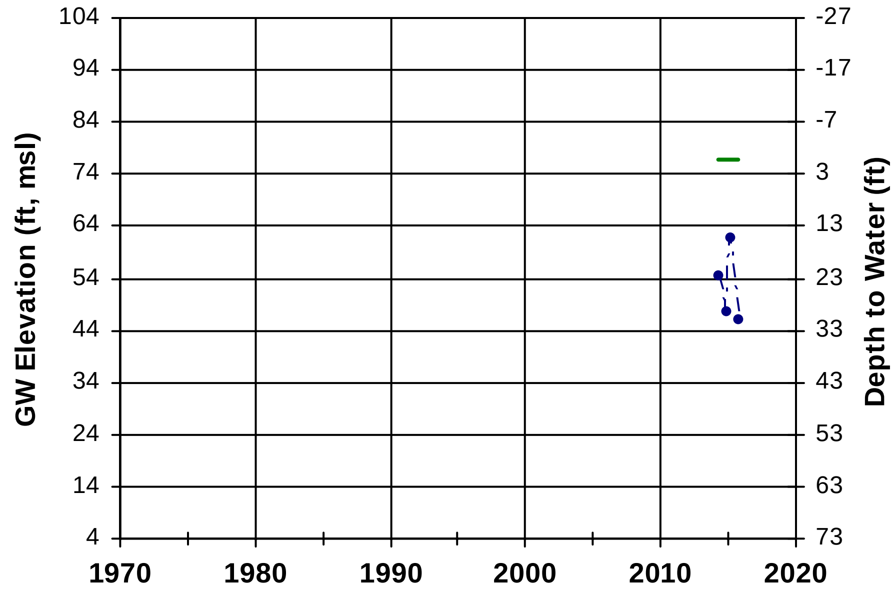
WellID: **NapaCounty-139** RPE: 85.8 ft, msl Subarea: NVF_Yount
SWN: 006N004W17R002M Source: NapaCounty



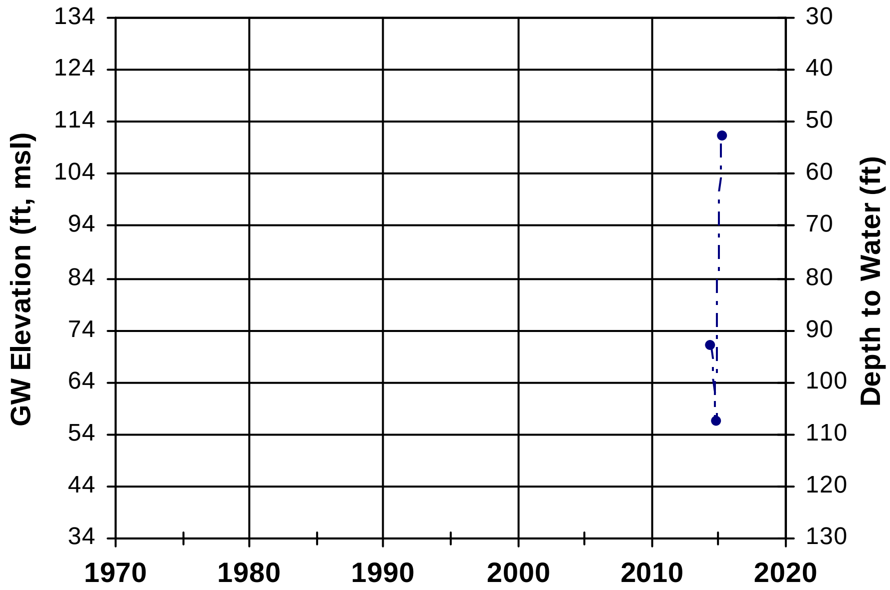
WellID: NapaCounty-179 RPE: 74.3 ft, msl Subarea: NVF_Yount
SWN: Unknown Source: NapaCounty



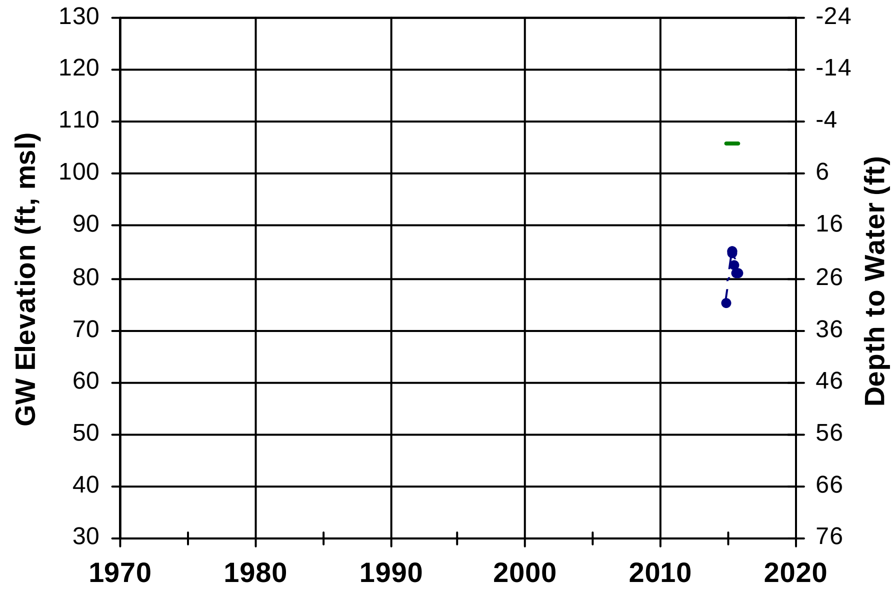
WellID: NapaCounty-180 RPE: 76.9 ft, msl Subarea: NVF_Yount
SWN: Unknown Source: NapaCounty



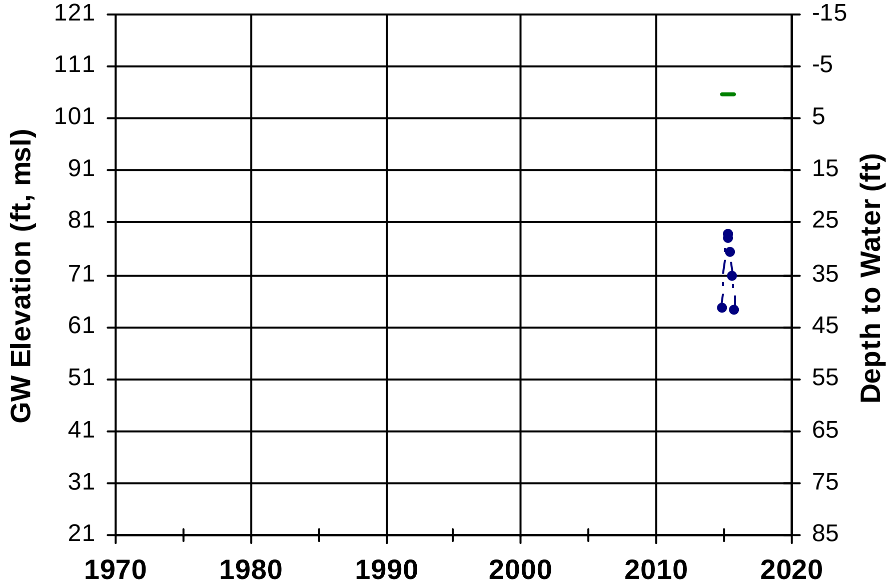
WellID: NapaCounty-181 RPE: 163.6 ft, msl Subarea: NVF_Yount
SWN: Unknown Source: NapaCounty



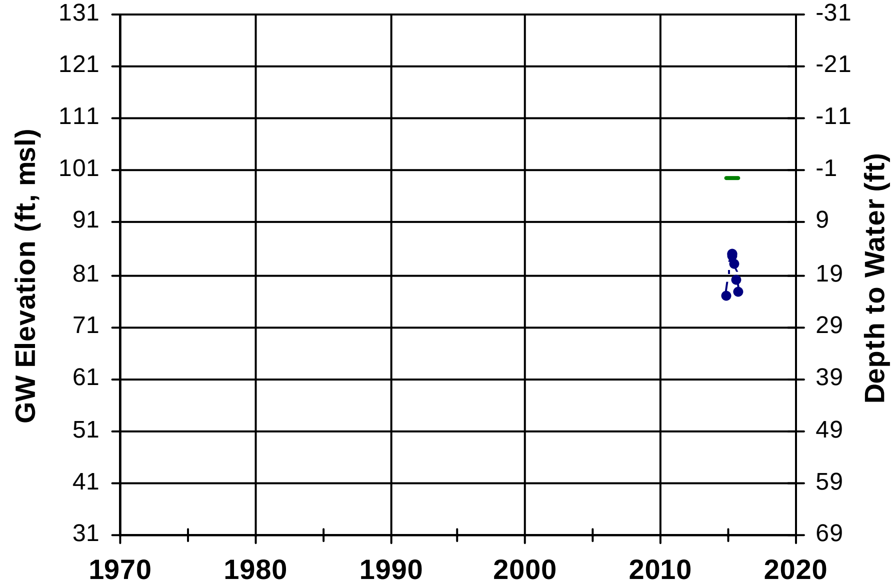
WellID: NapaCounty-216s-s RPE: 105.8 ft, msl Subarea: NVF_Yount
SWN: Unknown Source: NapaCounty



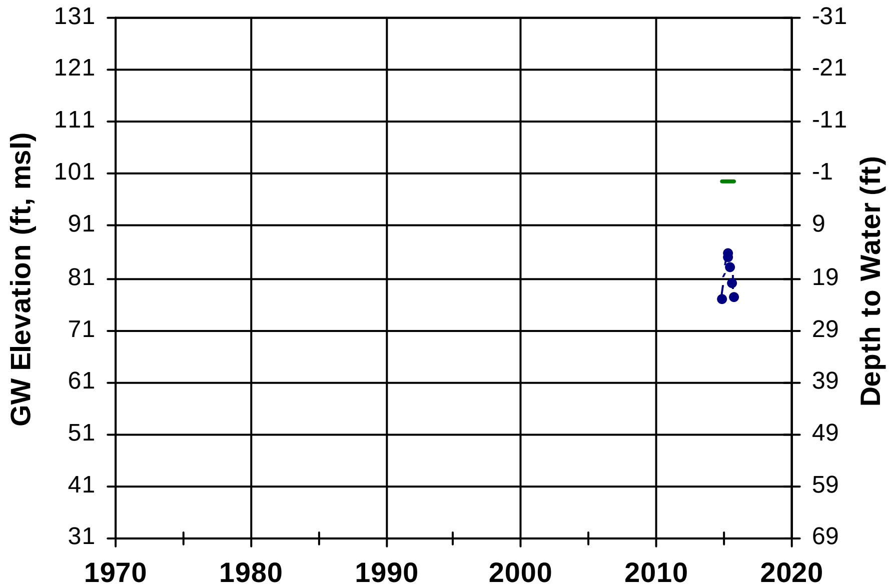
WellID: **NapaCounty-217d-s** RPE: 105.8 ft, msl Subarea: NVF_Yount
SWN: Unknown Source: NapaCounty



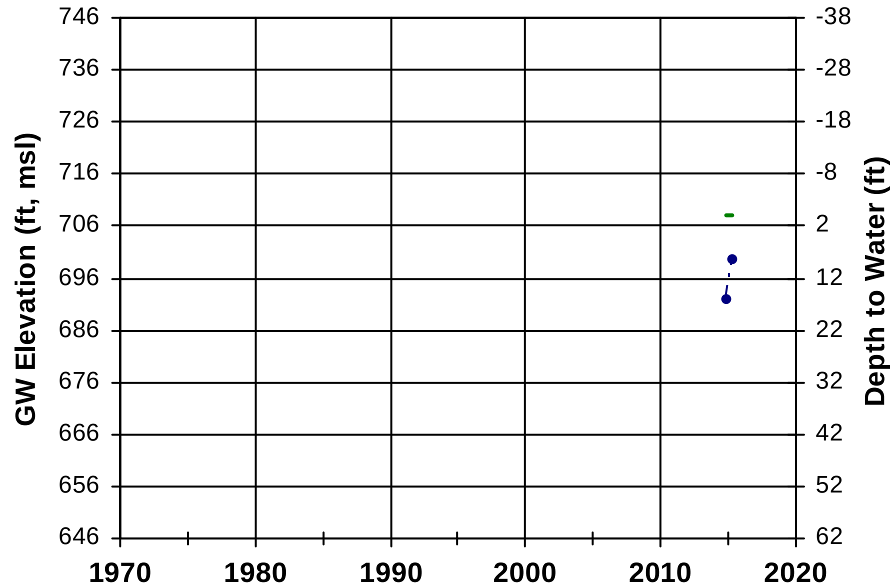
WellID: **NapaCounty-220s-s** RPE: 99.7 ft, msl Subarea: NVF_Yount
SWN: Unknown Source: NapaCounty

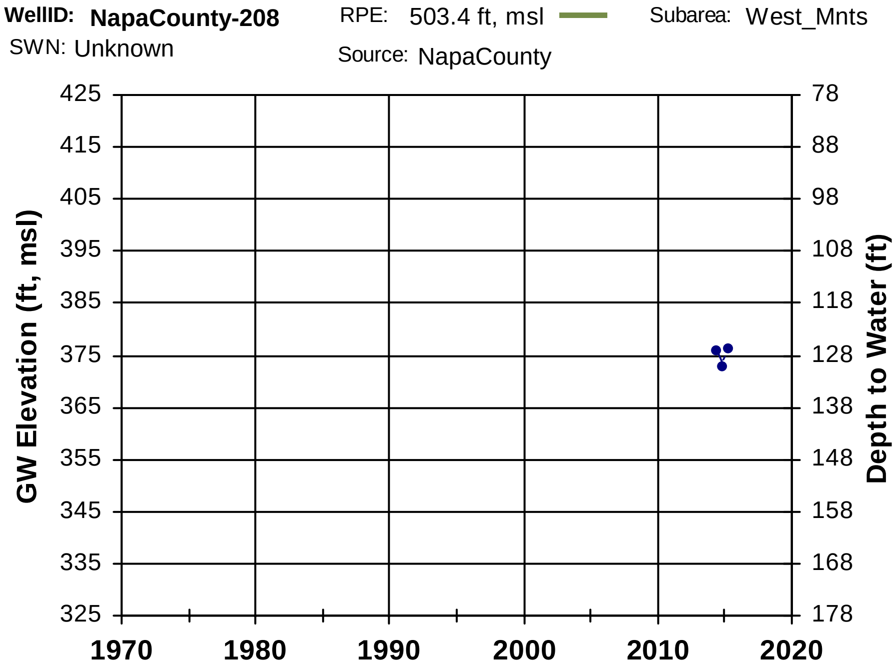


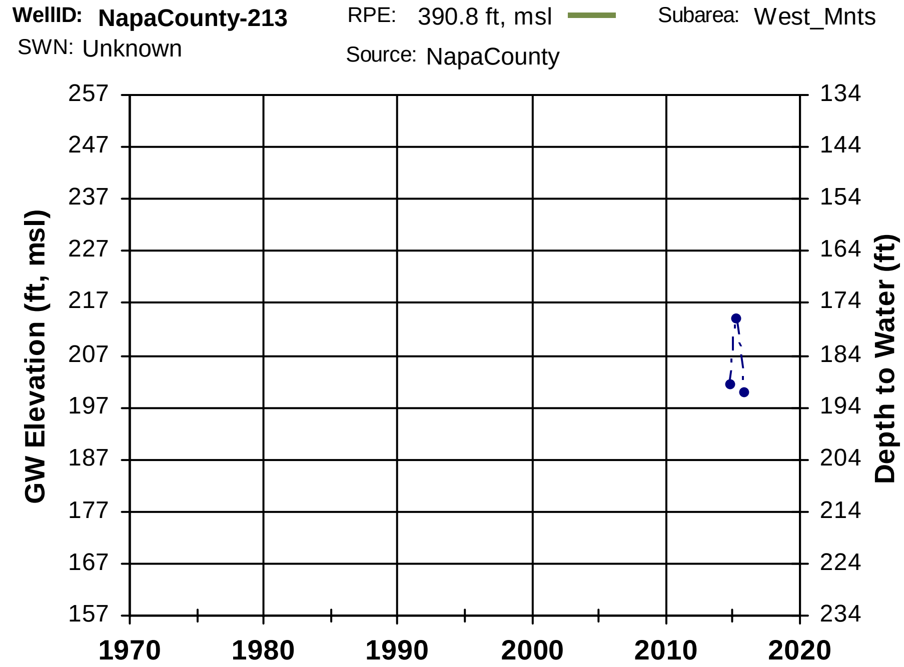
WellID: **NapaCounty-221d-s** RPE: 99.7 ft, msl Subarea: NVF_Yount
SWN: Unknown Source: NapaCounty



WellID: **NapaCounty-211** RPE: 708.2 ft, msl Subarea: PV
SWN: Unknown Source: NapaCounty




WellID: NapaCounty-208
SWN: Unknown
RPE: 503.4 ft, msl
Source: NapaCounty
Subarea: West_Mnts
GW Elevation (ft, msl)
Depth to Water (ft)
425
415
405
395
385
375
365
355
345
335
325
78
88
98
108
118
128
138
148
158
168
178
1970
1980
1990
2000
2010
2020


WellID: NapaCounty-213
SWN: Unknown
RPE: 390.8 ft, msl
Source: NapaCounty
Subarea: West_Mnts
GW Elevation (ft, msl)
Depth to Water (ft)
257
247
237
227
217
207
197
187
177
167
157
134
144
154
164
174
184
194
204
214
224
234
1970
1980
1990
2000
2010
2020

APPENDIX C
Napa County Procedure for Measuring Groundwater Levels

NAPA COUNTY PROCEDURE FOR MEASURING THE DEPTH TO WATER IN MONITORING AND PRODUCTION WELLS

Purpose

To obtain an accurate dated and timed measurement of the static depth to water in a well that can be converted into a water level elevation in reference to a commonly used reference datum (e.g., NAVD 1988). In this context, static means that the water level in the well is not influenced by pumping of the well. For comparability, measurements should be obtained according to an established schedule designed to capture times of both highest and lowest seasonal water level elevations. Also for comparability, measurements during a particular field campaign should be obtained consecutively and without delay within the shortest reasonable time.

Measurement Procedure

- If a well is being pumped, do not measure; return later, but not sooner than 60 minutes and preferably after 24 hours (see below "Special Circumstances" for additional instructions).
- Turn on water level indicator signaling device and check battery by hitting the test button.
- Remove access plug or well cap from the well cover and lower probe (electric sounder) into the well.
- When probe hits water a loud "beep" will sound and signal light will turn red.
- Retract slightly until the tone stops.
- Slowly lower the probe until the tone sounds.
- Note depth measurement at rim (i.e., the surveyed reference point for water level readings) of well to the nearest 0.01 foot and rewind probe completely out of well.
- Remove excess water and lower probe once again into well and measure again.
- If difference is within ±0.02 foot of first measurement, record measurement.
- If difference is greater repeat the same procedure until three consecutive measurements are recorded within ± 0.02 foot.
- Rewind and remove probe from well and replace the access plug or well cap in the well cover.
- Clean and dry the measuring device/probe and continue to next well.

Special Circumstances

Oil Encountered in Well

If oil is detected in the well structure, the depth to the air-oil interface is measured. To obtain such a measurement, the electric sounder is used similar to the way chalked steel tapes were traditionally used for depth-to-water measurements.

1. Lower the cleaned probe well below the air-oil interface (e.g., 1 foot). Read and record the depth at the reference point (since this depth is chosen somewhat arbitrarily by the field technician, an even number can be chosen, e.g., 37.00 feet). This measurement is the length of cable lowered into the well and corresponds to a line that the oil leaves on the probe or cable (i.e., the oil inundation line). Above this line, smudges of oil may appear on the cable. Below this line, the cable/probe is completely covered with oil. If the probe is lowered too far, completely penetrates the oil, and is far submerged in the water below the oil, parts of the probe/cable below the oil inundation line may also appear smudgy.
2. Retrieve probe, identify and record the oil inundation line on the cable (e.g., 2.72 feet). This measurement does not reflect the thickness of the oil. It reflects the length of the cable below the air-oil interface.
3. Compute the depth to oil by subtracting the length of line below the air-oil interface from the corresponding measurement at the reference point: Depth to oil = 37.00 feet – 2.72 feet = 34.28 feet.

Since oil has a slightly smaller density than water, a depth-to-oil measurement will always be smaller than a corresponding depth-to-water measurement in the same well if oil were not present. Depth-to-oil measurements yield a reasonable approximation to depth-to-water measurements unless the oil thickness is great. For each foot of oil in the well casing, the depth-to-oil measurement will be approximately 0.12 foot smaller than a corresponding depth-to-water measurement if oil were not present.

Pumping Water Level on Arrival

If well is being pumped, do not measure. Return later when the water level has stabilized. Using past field notes, the field technician will use his/her experience to determine the appropriate duration necessary for static measurements. Upon returning to the well site (at a location where pumping was previously noted on the same day), the technician will measure the water level. The technician will have available historical water level data to determine whether the measurement is consistent with past measurements. If the initial measurement appears anomalous, the technician will measure water levels every 10 minutes over a period of 30 minutes.[8] If measurements vary significantly from past measurements (taking into account seasonal variations), the technician will note the circumstances (i.e., the date and time when the well was first visited, total time it was pumping (if known), when it was shutoff, when the technician returned, and subsequent water level measurements [on the same day, or as the case may be based on experience, the day immediately following]). Subsequent consideration of pumping effects at a site-specific well location will be addressed as necessary.

[8] During this period, if the groundwater level difference is greater [than +/- 0.02 feet], repeat the same procedure until three consecutive measurements are recorded within ± 0.02 foot.

Recordation

1. Name of field technician
2. Unique identification of well
3. Weather and site conditions (e.g., clear, sunny, strong north wind, intense dust blowing over wellhead from nearby plowed field; dry ground, easy access)
4. Condition of well structure (e.g., well cap cracked – replaced with new one; wasp hive between well casing and well housing; no action, discuss with project manager)
5. Time and date of depth-to-water reading
6. Any other pertinent comments (e.g., sounder hangs up at 33 feet, thus no measurement; or: fifth measurement of ~55.68 feet in a row…residual water in end cap?; or: oil in well…measurement is depth to oil; or: intense sulfur odor upon opening well cap; or: nearby (west ~100 feet) irrigation well pumping)