# TECHNICAL MEMORANDUM

**FINAL**

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**SUBJECT: GUIDANCE ON PRECIPITATION AND STREAMFLOW MONITORING ACTIVITIES NAPA COUNTY, CA**

## 1 Executive Summary

The purpose of this Technical Memorandum is to provide Napa County (County) with guidance on the design of a county-wide network of precipitation and streamflow monitoring stations that would help:

1. Improve the County's understanding of the major watersheds' responses to precipitation and natural and/or anthropogenic changes, and
2. Attain goals outlined in the *Napa River Sediment TMDL and Habitat Enhancement Plan* (Napa River TMDL) (San Francisco Bay RWQCB, 2009) that pertain to instream sediment occurrence and temperature.

Data collected from this monitoring network would provide the necessary information to continue the calibration of the County's water quantity and water quality models (Napa County Models), discussed in the *Napa County Baseline Data Report* (Napa County BDR) (Jones and Stokes & EDAW, 2005) and its appendix the *Final BDR Technical Appendix – Water Quantity and Water Quality Report, Napa County, CA* (Napa County BDR Technical Appendix) (DHI, 2006).

In addition, this Technical Memorandum discusses near-stream groundwater level monitoring for assessing surface water/groundwater interactions and aiding the interpretation of streamflow changes that cannot be explained solely with surface water data and modeling.

The following key conclusions and recommendations were formulated based on the review and evaluation of pertinent available documents, including data input to the Napa County Models, calibration results, and model limitations; current monitoring activities; subjects pertaining to in-channel sediment erosion, transport, and deposition; and historic groundwater extraction and level trends:

1. **Precipitation Gauging – Napa Valley Model Domain:** A relatively large number of public precipitation stations collect precipitation data of sufficient resolution in the Napa River watershed. Data from these stations are recommended for continuous model development. The addition of other existing (fee-based) stations or the establishment of new weather stations in this watershed is not recommended at this time unless there is a project-motivated need for project-specific analysis.

   Precipitation data from stations that are very near each other (i.e., Corp Yard and Lincoln Bridge; Highway 29 at Hopper Creek and Yountville at Cross Road) should be compared to assess if data from one of each of the station pairs would be sufficient to represent local precipitation and to avoid data redundancy.

   A major weakness of the initial model calibration (which was identified as such by the model developers) is the short calibration period (January 2000 – December 2003). Therefore, it is recommended the precipitation record be updated with current data, and the model calibration period be extended. In coordination with specific development plans, areas of additionally needed information may be identified (see *Sections 7.1* and *7.1.1*).

2. **Precipitation Gauging – Lake Berryessa Model Domain:** It is recommended that, in addition to the Angwin, Atlas Peak, and Lake Berryessa precipitation stations that were used for model development (DHI, 2006), data from existing public stations at Knoxville Creek, Mount St. Helena, and Mount George be employed for continuous model development. Also, three new precipitation gauges are recommended to improve understanding of the hydrologic response to rainfall in the Lake Berryessa area. These stations should be strategically placed in (i) Pope Valley, (ii) the lower third of the Eticuera Creek watershed, and (iii) the lower portion of the Capell Creek watershed (see *Sections 7.1* and *7.1.1*).

3. **Stream Gauging – Napa Valley Model Domain:** It is recommended that seven existing stream gauging stations, for which discharge rating curves are available, be added as calibration points in the Napa Valley Surface Water Model. These stations are Atlas Peak at Milliken; CAH; CAS; Hwy 29 at Napa Creek; Sulfur Creek at Pope; Washington at Dry Creek; and York Creek at Hwy 29. Concurrently, the discharge record for the original 9 gauging stations (used for the calibration of the Napa Valley Surface Water Model) should be updated with current data, and reservoir operational records should be improved (e.g., Bell and Rector Reservoirs and Lake Hennessey) (see *Section 7.2*).

4. **Stream Gauging – Lake Berryessa Model Domain:** Three new stream gauges are recommended to improve understanding of the hydrologic response to rainfall in the Lake Berryessa area. These gauges should be co-located with the recommended new precipitation gauges, i.e., Pope Valley, the Eticuera Creek watershed, and the Capell Creek watershed (see above *Item 2*). Data from these three stream gauges would provide a means to check Lake Berryessa inflow estimates and, collectively, provide insight into the hydrologic response of most of the modeled area (see *Section 7.2*).

5. **Instream Temperature:** Although regional instream temperature modeling is not recommended, temperature measurements can and should be directly linked to specific restoration projects or other areas where land use changes are anticipated to occur to support in-channel effectiveness monitoring and evaluate channel response to management actions and natural processes. Instream water temperature monitoring should include pre-project and post-project monitoring (see *Section 7.3*). Presently, there are several projects that provide promising opportunities to gather environmental data (including instream water temperature) documenting habitat changes due to vineyard development and the effects of restoration projects. These are (i) the Napa County RCD's Carneros Creek watershed study, (ii) the Rutherford Napa River Restoration Project, (iii) a planned stream-riparian habitat enhancement project downstream of the Rutherford Napa River Restoration Project, and (iv) selected

stream reaches to be determined in conjunction with acreage certified under the Fish Friendly Farming Program (see *Section 7.4*).

6. **Sediment Load:** The Napa River TMDL identified two measurable numerical targets, including streambed permeability and scour to evaluate instream sediment dynamics as affected by human activity. As with instream water temperature monitoring, streambed permeability and scour measurements should be directly linked to specific restoration projects (or other areas where land use changes are anticipated to occur) and consist of pre-project and post-project monitoring. Presently, there are several areas that lend themselves to this kind of study; and these are the same as identified for instream water temperature monitoring in Item 5. Regarding the Carneros Creek watershed study, we support Napa County RCD's recommendations to continue the discharge and suspended sediment measurements and to walk the reach between the CAS and CAH stations (see *Section 5.2.1*).
7. **Surface Water/Groundwater Interactions:** The comprehensive review and analysis of available groundwater level elevation data for the Napa Valley in conjunction with historical stream gauging records, land use information, and groundwater pumping records may yield initial correlations between groundwater levels and streamflow. This approach would aid the identification of areas where near-stream monitoring wells could be placed to assess potentially changing surface water/groundwater interactions. Such new monitoring wells would be most useful in areas where historical groundwater level elevation data are available to facilitate the comparison to historical conditions (see *Section 6*).

## 2 Report Organization

The remainder of this Technical Memorandum is organized as follows:

- **Section 3 – Hydrologic Data used for Model Development**
  Review and summary of (i) precipitation, streamflow, instream temperature, and sediment data records obtained for the development and calibration of the Napa County Surface Water Models, (ii) data gaps identified by DHI (2006), and (iii) DHI's suggestions for future data collection efforts.
- **Section 4 – Current Monitoring Activities**
  Identification and compilation of current monitoring activities.
- **Section 5 – Sediment Considerations**
  Summary of pertinent goals of the Napa River TMDL (San Francisco Bay RWQCB, 2009), water quality objectives for sediment, numeric targets, and types of effectiveness monitoring; and summary of Napa County Resources Conservation District (RCD) sediment investigations.
- **Section 6 – Groundwater Considerations**
  Surface water/groundwater interactions are briefly described and the role of near-stream groundwater level monitoring is discussed using the Lower MST area as an example.
- **Section 7 – Evaluation of Monitoring Activities**
  Comparison of current monitoring activities to monitoring activities and data records used to develop and calibrate the Napa County Surface Water Models; identification of data gaps.
- **Section 8 – Summary of Key Conclusions and Recommendations**
  Recommended modifications to the existing monitoring network; recommended prioritization.
- **Section 9 – References**

## 3 Hydrologic Data Used for Model Development

The Napa County BDR Technical Appendix (DHI, 2006) documents the development, calibration, and application of several surface and groundwater models (i.e., the Napa County Models). The names and purposes of the Napa County Models are as follows:

1. Napa Valley Surface Water (streamflow and water budgets)
2. Napa Valley Groundwater (groundwater levels)
3. Napa Valley Water Quality (surface and groundwater quality)
4. Lake Berryessa Surface Water (streamflow and water budgets)
5. Lake Berryessa Water Quality (surface water quality)
6. SEAGIS (sediment erosion and transport)

The model domain for the Napa Valley Surface Water Model and the Napa Valley Water Quality Model is the Napa River watershed (**Figure 1**). The model domain for the Napa Valley Groundwater Model is the Napa River watershed except its southernmost portion. The model domain for the Lake Berryessa Models is comprised of the Putah Creek and Suisun Creek watersheds within Napa County. Finally, the model domain for the SEAGIS Model is all of Napa County. The work conducted for this Technical Memorandum is most relevant to the Napa Valley and Lake Berryessa Surface Water Models.

The Napa County BDR Technical Appendix states the objectives for the Napa County Models are as follows:

> "The various models described in this appendix (Table 1-1) were designed to establish baseline (existing) conditions by which county-wide planning efforts and programs can be assessed and evaluated for their benefits, constraints, and environmental impacts. The models are an analytical tool and data management system capable of evaluating the hydrologic and water quality effects of landscape-scale planning decisions. The models were also structured for future applications of more site-specific (project-scale) analyses[1], although such project-scale analyses were not developed for this report."

### 3.1 Precipitation Data

Precipitation input to the Napa County Models was obtained from 24 gauging stations (all located in the Napa River watershed) as shown in Table 2-3 of the Napa County BDR Technical Appendix (**Attachment 1**). The precipitation records (both daily and hourly data) were obtained from the California Data Exchange Center (CDEC), the California Irrigation Management Information System (CIMIS), and Terra Spāse.

For the Napa Valley Surface Water Model, gauge precipitation data were spatially distributed using a combination of the Thiessen Polygon method and information from isohyetal maps. This approach was chosen to account for orographic effects, which cause high spatial variability of precipitation in the Napa Valley. The result was a relatively complex spatial distribution of precipitation with 69 polygons (**Attachment 2**).

For the Lake Berryessa Surface Water Model, gauge precipitation data were much sparser. Therefore, the spatial distribution of precipitation was primarily based on a statewide isohyetal map in conjunction with data from the Lake Berryessa station and two additional stations located in the Napa River watershed (i.e., the Angwin and Atlas Peak stations). The result was less spatial resolution (see **Attachment 2**).

### 3.2 Discharge Data

The Napa County Models were calibrated using a 4-year record (January 2000 to December 2003) of discharge data (i.e., streamflow and reservoir stage data) from 10 stations as shown in Table 2-13 of the Napa County BDR Technical Appendix (see **Attachment 1**). Records were obtained from the U.S. Geological Survey (USGS), Napa County RCD, the City of Napa, and the California Department of Water Resources (DWR). Nine of these stations are located in the Napa River watershed, and eight of these stations were used to calibrate the Napa Valley Surface Water Model (i.e., the data record from the Tulucay Creek station was insufficient for inclusion in the calibration effort). These eight stations are shown on Figure 2-34 of the Napa County BDR Technical Appendix (see **Attachment 2**). In addition, records of Lake Hennessey reservoir stage and releases (not identified in Table 2-13) were used for the model calibration.

[1] Since publication of the Napa County BDR (DHI, 2006), site-specific model applications have been invoked by Napa County staff.

For the development of the Lake Berryessa Surface Water Model, Lake Berryessa outflow (at the USGS stream gauge downstream of Monticello Dam) (not identified in Table 2-13); Lake Berryessa inflow (computed by the reservoir's operator, the U.S. Bureau of Reclamation (USBR), based on change in storage, releases, and evaporation); and Putah Creek flow upstream of Lake Berryessa and the model domain (at the Putah Creek at Guenoc station) (not identified in Table 2-13) were available.

The calibration effort for the Napa River Surface Water Model focused on streamflows at 2 Napa River stream gauges located near St. Helena and Napa. These locations were chosen as indicators for the overall system water balance in the northern and central portions of the basin. The calibration effort for the Lake Berryessa Surface Water Model was limited to Lake Berryessa inflow.

Pertinent calibration results discussed in *Section 2.3.2 Calibration Results* of the Napa County BDR Technical Appendix are summarized below:

1. Generally, the simulated hydrographs for the Napa River at St. Helena and the Napa River at Napa stations were found to match the observed hydrographs fairly well.
2. Underprediction of the highest peak flows at these stations was likely due to differences between the rainfall data input and the actual temporal and spatial distribution of rainfall.
3. The total runoff volume error over the 4-year calibration period was –6% (i.e., the observed runoff was underpredicted by 6%) at the Napa River at St. Helena station.
4. The total runoff volume error at the Napa River at Napa station was 20% (i.e., the observed runoff was over predicted by 20%). This was attributed to the over estimation of Lake Hennessey outflow and groundwater baseflow (i.e., recharge to surface streams).
5. The total runoff volume errors for Lake Hennessey inflow and outflow were 20% and 361%, respectively. Overprediction of Lake Hennessey outflow was attributed to inaccurate representation of lake storage and management.
6. The calibration effort for locations south of the Napa River at Napa gauge was very limited and volumetric errors are not given. The very short data record available for the Salvador Creek station was noted. It was further stated that the model performance could be improved by further parameter calibration and more detailed representation of the important hydrological features in this area.
7. The total runoff volume error for Lake Berryessa inflow was –11%. This was attributed to differences between the rainfall data input and the actual temporal and spatial distribution of rainfall.

The Napa County BDR Technical Appendix identifies several data limitations encountered during the development and calibration of the Napa County Surface Water Models:

1. Lack of comprehensive stream gauge data;
2. Uncertainty associated with the spatial distribution of precipitation across the County;
3. Relatively short calibration period (January 2000 – December 2003), which does not capture historical climatic variability;
4. Lack of information on surface water diversions (location, timing, and magnitude);
5. Lack of reservoir operational information;
6. Lack of stream cross-sectional and reservoir bathymetric data; and
7. Insufficient representation of other important hydrogeologic variables.

The Napa County BDR Technical Appendix states that future data collection efforts should be focused on areas that have a significant impact on the timing and volume of surface water flows. However, these areas were not identified with the exception of reservoir operational information (see above *Item 5*) in general and Lake Hennessey outflow data in particular (see *Section 7.2*).

### 3.3 Instream Temperature

Instream temperature modeling required the input of meteorological information such as air temperature, relative humidity, and solar radiation. These data were obtained from two CIMIS weather stations and several Terra Spāse stations. The water temperature at the upstream reaches was assumed to be equal to ambient air temperature. Discharge to upstream tributaries was derived from overland flow calculations.

The simulated instream temperatures were calibrated against measured stream temperatures (30-minute intervals) gathered by Napa County RCD at 4 locations during July through October 2002 (Sulphur Site 1 and Site 2, Carneros Site 1 and Site 3) and at 10 sites from August 2003 to October 2004 (calibration results were shown and discussed for 5 of these 10 stations, i.e., Bell, Canon, Rector, and York Creeks, and Napa River at Zinfandel Lane)[2]. Calibration results for the Napa Valley Water Quality Model were mixed, ranging from good to poor (the Lake Berryessa Water Quality Model was not temperature calibrated). The lack of a longer-term instream temperature record was noted as a limiting factor in the model calibration. It was also noted that instream temperature modeling in the Napa River watershed is quite challenging for the following reasons:

- The Napa County watersheds are characterized by very dry summers with no flow or very limited flow in most tributaries and very sudden peak flows during the wet season. Calculating the heat balance and water quality processes on a minimal water volume can be problematic.
- Many of the tributaries are very steep. Steep tributaries (i.e., fast running creeks) are modeled with a shorter time step. Shorter time steps require longer computational time and longer simulation periods.

### 3.4 Sediment Load

The Napa County BDR Technical Appendix assesses sediment erosion and transport with the SEAGIS Model. The modeling effort required the input of attribute data such as soil type, slope angle, slope length, rainfall, and land management. Parameters used in the model were developed over several decades by the USDA Natural Resource Conservation Service and Napa County RCD to estimate soil loss/transport associated with vineyard development[3]. Soil loss was then estimated with the universal soil loss equation. The volume of sediment reaching the mouth of each watershed was calculated using a delivery ratio, which accounts for local re-deposition of sediment. The SEAGIS Model was not calibrated.

### 3.5 Groundwater Levels

Groundwater levels are of interest to this Technical Memorandum inasmuch as they relate to the magnitude and direction of water exchange between the stream channel and the subsurface, because this exchange affects the magnitude and duration of streamflow. In this context, groundwater level input, including the quality, number, and spatial distribution of calibration points, and calibration results, are only of tangential interest. Therefore, a discussion of these topics is not provided in this Technical Memorandum. Groundwater monitoring considerations are discussed in *Section 6* in relation to stream-aquifer interaction and work completed by the USGS in the Lower MST area.

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[2] Water temperature was also monitored by Stillwater Sciences as part of the June 2002 Napa River Basin Limiting Factors Analysis (Stillwater Sciences, 2002). Stream temperature for this effort was continuously monitored at 22 sites in 13 tributaries and 6 main stem sites, over two dry seasons and one wet season (August 2000-October 2001) with 15-minute intervals. However, these data were not available for model development and calibration. Other temperature measurements include single measurements using an YSI meter. The YSI meter is a hand held instrument made by Yellow Springs Instrument Company that measures salinity, temperature, pH, and dissolved oxygen electronically from a probe lowered into the water. Water temperature data were collected using this device from 1996 to 2001 for 19 sites, and from 2001 to 2005 for 15 sites.

[3] Napa County RCD estimates soil loss on a site-specific basis from vineyards in Napa County using the USLE in conjunction with local meteorological data. Site-specific soil loss estimates are presently available for essentially all vineyards in Napa County. These estimates are being updated periodically (personal communication David Steiner (Napa County RCD), 12-01-2009)

## 4 Current Monitoring Activities

Data from presently maintained and operated precipitation and stream gauging stations are provided by several agencies and entities (**Tables 1** and **2**, **Figure 2**):

- *Napa Valley Regional Rainfall and Stream Monitoring System* (http://napa.onerain.com)

  A collaborative Napa Valley area website project of local Napa County cities, the County of Napa, and the Napa County Flood Control and Water Conservation District that provides current and historical rainfall, creek, and river level monitoring data. This website, first operational in November 2006, is intended to replace the former "Storm Watch" website maintained by the City of Napa. The site incorporates all of the former website functionality plus provides improved features and an expanded network of over 30 site locations in the Napa Valley region where weather or stream data are collected.

- *Napa County Resources Conservation District (Napa County RCD)* (http://www.naparcd.org)

  The Napa County RCD is a local non-regulatory organization whose mission is to promote responsible watershed management through voluntary community stewardship and technical assistance. Funding is currently provided by the Napa County Flood Control and Water Conservation District and local water users.

  Napa County RCD maintains automated water level measuring and recording stations to measure stream water levels on two Napa River tributaries (Huichica Creek and Carneros Creek)[4]. During the rainy season, supplemental manual measurements of creek depths and flow velocity are obtained at these stations plus seven additional locations (Napa Creek, Napa River at Dunaweal, Milliken Creek, Dry Creek, Salvador Creek, Sulphur Creek, and York Creek). The data are used to develop rating curves for the streams for use in flood monitoring and modeling, water use planning, and evaluation of fish passage and protection. Water samples at the gauging stations are collected during stream gauging visits for analysis of suspended sediment concentration (SSC) using USGS-approved equipment and the equal transit rate method. SSC data are used to develop sediment load – stream discharge rating curves for use in a variety of purposes, including water quality and fish habitat studies.

  Presently, streamflow rating curves exist for 12 stations in the Napa River watershed. From north to south, these include:

  1. *York Creek at Hwy 29 (29) (‡)*
  2. *Sulphur Creek at Pope (41) (‡)*
  3. Napa River near St. Helena (11456000, STH)
  4. Napa River near Napa (11458000, NAP)
  5. *Washington at Dry Creek (15) (‡)*
  6. *Atlas Peak at Milliken (13) (‡)*
  7. *Salvador Creek (28) (‡)*
  8. *Highway 29 at Napa Creek (17) (‡)*
  9. *Carneros Creek (CAS) (‡)*
  10. *Carneros Creek (CAH) (‡)*
  11. *Carneros Creek (CAO) (‡)*
  12. *Huichica Creek (HRV) (‡)*

  *Note: Station identifiers are given in parentheses.*

[4] The Murphy Creek station was abandoned due to channel movement and resulting inaccurate discharge estimates (personal communication Paul Blank (Napa County RCD), 06-19-2009).

At ten of the above sites *(‡ italic font*), Napa County RCD also collects SSC data. Between 2000 and August 2009, 5 (Washington at Dry Creek) to 25 (Highway 29 at Napa Creek) samples have been collected per site. In addition, SSC samples were also collected at the Garnett Creek station in 2001 (5 samples).

Three additional stations do not have rating curves but are equipped with low v-notch weirs, which allow flow calculations for low flow conditions.

1. Sage Creek Bridge (Lake Hennessey Inflow) (23)
2. Chiles Creek (Lake Hennessey Inflow) (24)
3. Conn Valley (Lake Hennessey Inflow) (26)

Lastly, streamflow rating curves are available for three stations along Putah Creek.

1. Putah Creek near Guenoc
2. Putah Creek near Winters
3. Berryessa.

- *Terra Spāse* (http://www.terraspase.com)

  Terra Spāse was founded in 1994 to offer Geographic Information System (GIS) solution-oriented consulting services to vineyard owners and wineries relating to soil, weather, vine, and wine data. Meteorologic data collected from stations throughout the Napa Valley can be obtained for a fee.

- *California Data Exchange Center (CDEC)* (http://cdec.water.ca.gov)

  CDEC installs, maintains, and operates an extensive hydrologic data collection network. CDEC provides a centralized location to store and process real-time hydrologic information gathered by various cooperators throughout the state. CDEC then disseminates this information to the cooperators, public and private agencies, and news media. Currently, over 140 agencies provide data to CDEC and also obtain data through CDEC's cooperative hydrologic database.

- *California Irrigation Management Information System (CIMIS)* (http://wwwcimis.water.ca.gov/cimis/welcome.jsp)

  CIMIS is a program in the Office of Water Use Efficiency (OWUE of DWR) that manages a network of over 120 automated weather stations in California. CIMIS was developed in 1982 by DWR and the University of California at Davis to assist California's irrigators with their efforts to manage water resources efficiently.

- *United States Geological Survey (USGS)* (http://www.usgs.gov)
  The USGS operates and maintains approximately 7,500 stream gauges nationwide. This network is currently funded in partnership with over 800 federal, state, and local agencies. Data are available on the National Streamflow Information Program (NSIP) web page of the USGS.

# 5 Sediment Considerations

## 5.1 Napa River TMDL

Section 303(d) of the Clean Water Act requires states to compile a list of "impaired" water bodies that do not meet water quality standards. In 1990, the RWQCB, San Francisco Region, listed the Napa River as impaired by sedimentation based on evidence of widespread erosion and concerns regarding adverse impacts to fish.

The Napa River TMDL (San Francisco Bay RWQCB, 2009) contains staff analyses and findings pertaining to sediment impairment in the Napa River. The Napa River TMDL also provides a framework for discussion of implementation actions that may be needed to resolve sediment impairment and to enhance steelhead and salmon populations within the Napa River watershed.

The goals of the Napa River TMDL are to:

- Conserve the steelhead trout population;
- Establish a self-sustaining Chinook salmon population;
- Enhance the overall health of the native fish community; and
- Enhance the aesthetic and recreational values of the river and its tributaries.

Findings with regard to the sediment problem are listed below:

- Steelhead and salmon populations in the Napa River and its tributaries have declined substantially since the late 1940s.
- There is evidence of accelerated erosion and sedimentation in the Napa River and its tributaries.
- High concentrations of fine sediment have been observed in the streambed at potential steelhead and salmon spawning and rearing sites. Excess fine sediment in the streambed can cause poor incubation conditions for fish eggs, which results in high mortality prior to emergence. When large amounts of fine sediment are deposited, the streambed is also more vulnerable to deep scour during storms, which can wash away eggs and thereby further reduce survival during incubation. High concentrations of fine sediment in the streambed also decrease the growth and survival of juvenile salmon and steelhead.
- Rapid and active channel incision, or downcutting, in the mainstem of the Napa River and its lower tributary reaches and associated rapid and intensive erosion of stream terrace banks are causing significant adverse changes to salmon habitat and are significant sources of fine sediment in the Napa River.

Three additional conditions attributed to the impairment of fish populations are:

- Poor baseflow occurring in combination with water temperatures that appear to severely limit the growth of juvenile steelhead.
- Poor access to-and-from potential spawning and rearing habitat due to human structures in channels and water uses that directly or indirectly block or impede migration by adult and/or juvenile fish.
- Removal of large woody debris in the channels causing habitat simplification and associated loss of spawning and rearing habitat.

The Napa River TMDL states that the total sediment delivery to channels associated with land use activities needs to be reduced by 50 percent from contemporary values (1994-2004) in order to meet the proposed numeric sediment targets and allocations. Sediment allocations in the document are expressed as a percentage of the natural sediment load. Five significant categories of human caused sediment sources were identified in the Napa River watershed. These sources are on public and private lands and include sources such as: road-related erosion, vineyards, grazing, erosion from the bed and banks of the Napa River, and urban stormwater. Erosion processes that relate to these sources are: (i) sheetwash from land uses (grazing and vineyards), (ii) road-related erosion (e.g., surface erosion from roads and erosion at stream crossings), (iii) gullies and landslides caused by land uses that concentrate runoff (grazing, roads, and hillside vineyards), and (iv) channel incision and bank failure associated stream terrace bank erosion (confined channels and excess stream energy).

### 5.1.1 Water Quality Objectives for Sediment

The increased deposition of fine-grained materials in the streambed and associated increased scour have been identified as major contributors to native anadromous fish mortality. The Napa River TMDL identifies both required and recommended water quality objectives for settleable material and aquatic population and community ecology.

- **Settleable material**
  Waters shall not contain substances in concentrations that result in deposition of materials that cause nuisance or adversely affect beneficial uses.

- **Population and Community Ecology**
  All waters shall be maintained free of toxic substances in concentrations that are lethal to the receiving water biota or that produce significant alterations in population or community ecology of the receiving water biota. In addition, the health and life history characteristics of aquatic organisms in waters affected by controllable water quality factors shall not differ significantly from those for the same waters in areas unaffected by controllable water quality factors.

### 5.1.2 Numeric Targets

The water quality objectives for sediment establish two numeric targets, including:

- **Streambed Permeability**
  The median value for streambed permeability shall be ≥ 7000 cm per hour at potential steelhead and salmon spawning sites in the Napa River watershed.

  *Rationale:* Streambed permeability is a function of the size distribution and packing of coarse sediment (gravels) and finer sediment contained in the streambed. Streambed permeability is inversely related to fine sediment concentration, primarily sand grains with diameters ≤ 1 mm that are deposited in the streambed. Streambed permeability is a key factor influencing the survival of incubating salmonid eggs and larvae, and it is significantly and positively correlated with survival to emergence.

- **Streambed Scour**
  The mean depth of scour ($d_s$) shall be ≤ 15 cm below the level of the overlying streambed substrate at typical pool-tails/riffle-heads in all gravel-bedded reaches of the mainstem of the Napa River and in the lower alluvial reaches of its perennial tributaries where the streambed slope is gentle (S= 0.001 to 0.01). The target applies in response to all peak flows ≤ bankfull discharge.

  *Rationale*: Scour depth is a function of the force per unit area exerted by flowing water on the streambed, channel features that either concentrate or disperse flow energy (e.g., debris, vegetation, bedrock, gravel bars, etc.), and the abundance and sizes of sand and coarser sediment grains supplied to the channel (bedload). Human actions that increase the rate of bedload supply, and/or cause it to become finer, will cause the streambed materials to become finer, which tends to increase the rate of bedload transport through a channel reach. As the bedload transport rate increases, so do the mean depth and/or spatial extent of streambed scour. Similarly, land use activities that increase storm runoff peak flow and/or volume (e.g., forest clearing and pavement), and/or increase the amount of energy that occurs on the streambed at potential spawning sites for a given runoff event (e.g., human constructed levees, straightened channel reaches, removal of large debris jams, etc.), also have the potential to increase bedload transport rate and, therefore, streambed scour.

### 5.1.3 Effectiveness Monitoring

The Napa River TMDL describes several approaches to achieve sediment reductions. These were developed based on source categories and range from established practices to meet existing performance standards for vineyard operations (e.g., Napa County Conservation Regulations, Chapter 18.108) to partnering with the University of California Cooperative Extension (UCCE), the Natural Resources and Conservation Service (NRCS), and/or the Napa County RCD to reduce sheetwash erosion from livestock grazing and reach-scale stream-riparian restoration projects.

The Napa River TMDL recognizes monitoring as a means to assess the effectiveness of sediment reduction actions. The Napa River TMDL complements the Basin Plan Amendment (San Francisco Bay RWQCB, 2009), which describes three types of monitoring to assess progress toward achievement of numeric sediment targets and load allocations:

1. **Implementation Monitoring** is meant to document that required sediment control and habitat enhancement actions have been implemented and continue to occur. This type of monitoring would be conducted by landowners or designated agents.
2. **Upslope Effectiveness Monitoring** is meant to evaluate effectiveness of sediment control actions in reducing rates of sediment delivery to stream channels. The CRWQCB would conduct this type of monitoring.
3. **In-channel Effectiveness Monitoring** (e.g., spawning gravel permeability and redd scour) is meant to evaluate channel response to management actions and natural processes. This type of monitoring should be conducted by local government agencies with scientific expertise and demonstrated ability in working effectively with private property owners and other interested parties.

*Item 3* above is of particular interest to this Technical Memorandum. Enhancements to the county-wide network of streamflow monitoring stations present an opportunity to include objectives that address sediment-related in-channel effectiveness monitoring.

### 5.2 Recent Work by Napa County RCD

The Napa County RCD recently conducted a field study in the Carneros Creek watershed that examined runoff and sediment transport (Napa County RCD, 2005b). The RCD study was designed to develop baseline streamflow and sediment load information in an area of the watershed where future vineyard development is anticipated. The study consisted of two components. The first component was a small-scale vineyard study that investigated the effect of different vineyard practices (e.g., till versus no-till) on off-site sediment transport (this corresponds to the aforementioned upslope effectiveness monitoring). The second component related to instream effectiveness monitoring. For purposes of the study, two new stream gauging stations were installed in 2002 and 2003. These are the Carneros Creek (CAS) and Carneros Creek (CAH) stations, located approximately 2.3 and 4.3 miles upstream from the Carneros Creek (CAO) station, respectively. Flow and sediment data were collected between December 2003 and February 2004, and between December 2004 and May 2005. Using the turbidity threshold sampling (TTS) methodology, high frequency sediment samples were obtained during 25 discrete rainstorm events. Automated sampling activities were checked with numerous field measurements.

The suspended sediment loads estimated for the two stations were virtually identical (<2 percent difference). The Napa County RCD noted this to be somewhat surprising, as 3,391 acres of land (including 220 acres of vineyard) are drained at CAH, but only 1,759 acres of the uppermost area of the watershed (without any significant vineyards) are drained at CAS. Napa County RCD suggested two potential explanations for this phenomenon. One possibility was a major 1996/97 dam failure upstream of CAS and an associated mobilization of approximately 4,000 cubic yards of sediment that entered the stream. A plug of sediment may have moved downstream and was in the process of passing CAS during the field measurements, but may not have yet reached the downstream station, CAH. The second possibility was a systematic measurement error biased toward an underestimation of the sediment load during high-flow conditions that caused a proportionally greater underestimation of the sediment load at the downstream CAH station due to its higher streamflow.

Key recommendations were to (i) continue the discharge and suspended sediment measurements and (ii) walk the reach between the CAS and CAH stations to look for signs of recent sediment accumulations (i.e., recent depositions) to test the plug-flow hypothesis.

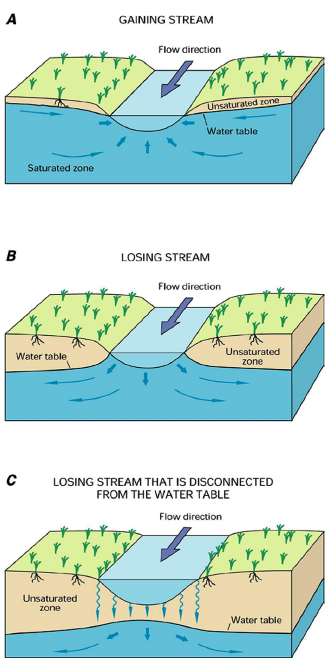
#### 5.2.1 Discussion

The fundamental finding of the Napa County RCD study was that the same amount of suspended sediment that entered the reach upstream also exited at its downstream end. However, instream sediment transport is not limited to transport in suspension. Substantial sediment movement can occur in the form of saltation and bed load transport. Therefore, it is possible that significant amounts of sediment entered and/or exited the investigated reach without being quantified.

Processes related to sediment erosion, transport, and deposition within the reach were not part of the Napa County RCD investigation. Knowledge of these processes and sediment residence time within the reach are needed to better understand the study results.

These observations underscore the complexity of fluvial processes such as erosion, transport, and deposition and also the importance of combining visual observations (such as the Napa County RCD's recommended stream walking) with comprehensive data collection efforts. Therefore, we support Napa County RCD's recommendations to continue the discharge and suspended sediment measurements and to walk the reach between the CAS and CAH stations.

## 6 Groundwater Considerations




USDA FS-881 (2007)

When a stream is in direct hydraulic communication with the underlying groundwater body, the relation between groundwater levels and the surface water elevation in the stream exerts control over the magnitude and direction of water exchange between the stream channel and the subsurface. Groundwater discharges into the stream when groundwater levels adjacent to the stream are higher than the surface water elevation in the stream (i.e., a gaining stream reach). Conversely, stream seepage losses occur when groundwater levels adjacent to the stream are lower than the surface water elevation in the stream (i.e., a losing stream reach). Seepage losses increase as groundwater levels decline until an unsaturated zone develops under the streambed. At this point, the direct saturated hydraulic connection is interrupted, and seepage continues independent of groundwater levels and the thickness of the unsaturated zone.

The interaction between surface water and groundwater can be dramatically altered when groundwater levels are lowered by pumping and an unsaturated zone develops under a reach, which otherwise would be in direct hydraulic communication with groundwater. In this case, a gaining or slightly losing reach can be converted to a perennially losing reach. Therefore, groundwater level monitoring in near-stream wells can provide necessary information to interpret streamflow changes that cannot be explained solely with surface water data.

Based on increasing groundwater extraction between 1975 and 2002 and declining groundwater levels in the lower Milliken-Sarco-Tulukay Creeks (MST) area (Farrar and Metzger, 2003) (**Attachment 3**), this area provides an example of where near-stream shallow groundwater monitoring along with streamflow measurements would improve understanding of surface water/groundwater interaction. Johnson (1977) estimated 3,050 afy of streamflow infiltration in the MST area based on streamflow measurements retrieved in winter, spring, and summer 1975 (an average water year). The author determined that most of this infiltration occurred in 22 stream segments located roughly along the eastern groundwater storage boundary (i.e., infiltration zones) (**Attachment 4**). The methods, locations, and number of measurements that contributed to these estimates and conclusions were not disclosed.

Farrar and Metzger (2003) recorded streamflow observations at 72 temporary stations along the Milliken, Sarco, and Tulucay Creeks (and tributaries) (**Attachment 5**). Observations were made in three separate sets in spring 2000 and 2001. Due to access difficulties, measurements could not be repeated in the infiltration zones identified by Johnson (1977), with three exceptions. In these three cases, the results did not show significant streamflow losses along the infiltration zones that were delineated by Johnson (1977). However, the results indicated that significant infiltration sometimes takes place in reaches downstream from Johnson's infiltration zones, including on the main stem of Milliken Creek about 2 to 3 miles upstream of the confluence with Napa River. Overall, only a few reaches were found to have significant streamflow losses, and those reaches were not consistently losing reaches. The authors concluded most winter runoff leaves the MST area as streamflow to the Napa River and only a small amount infiltrates beneath the streambeds.

Farrar and Metzger (2003) suggest groundwater may be a source of streamflow gains in some of the lower reaches of Milliken, Sarco, and Tulucay Creeks near Napa River. This was based on observations in a well located near a Sarco Creek streamflow gauging station at the confluence with Milliken Creek (see **Attachment 5**, station 11), where groundwater levels were at an elevation similar to the channel bottom when high groundwater levels occurred in the winter and spring. However, neither the perforated interval nor the total depth of the subject well is known. Consequently, the relation between surface water stage and groundwater levels is uncertain.

Based on the reported increase in groundwater extraction and declining groundwater levels in the Lower MST area, the potential exists for an interruption of direct hydraulic communication between surface water (e.g., in stream channels) and groundwater. This occurrence would lead to increased stream seepage and also the potential for reduced baseflow.

Spring groundwater level elevations (1975 – 2002) in three wells located near the cities of Calistoga, St. Helena, Yountville, and Napa were very shallow (typically 5 to 10 feet below ground surface (bgs); and 10 to 20 feet (bgs) in the well near Napa) and appeared stable over the period of record despite an increase from approximately 25,000 to 40,000 acres of irrigated wine grape vineyards over the same period (West Yost, 2005) (**Attachment 6**). Based on this observation, the authors concluded that groundwater supplies are adequate to meet current agricultural demands. However, groundwater supplies were found to be likely insufficient to meet projected increases in annual water demands (2020 and 2050 projections). Therefore, as in the MST area, the potential exists for an interruption of direct hydraulic communication between surface water (e.g., in stream channels) and groundwater.

In general, the comprehensive review and analysis of available groundwater level elevation data for the Napa Valley in conjunction with the historical stream gauging records, land use information, and groundwater pumping records may yield initial correlations between groundwater levels and streamflow. This approach would aid the identification of areas where near-stream monitoring wells could be placed to assess potentially changing surface water/groundwater interactions. Such new monitoring wells would be most useful in areas where historical groundwater level elevation data are available to facilitate the comparison to historical conditions.

Targeted near-stream groundwater level monitoring will not improve simulations with the Napa County Surface Water Models. Although these models dynamically link to a groundwater model, the numerical solution in the surface water/groundwater coupling lacks the gradient-driven properties of flow of a fully physically-based solution (see *Section 2.5.1.1*, Napa County BDR Technical Appendix). In addition, the coupled model does not simulate recharge from rivers to groundwater. Instead, water is only allowed to flow from the groundwater into rivers, and the algorithm for the saturated zone acts like a storage unit from which water is released when it exceeds a certain threshold in the storage[5]. Consequently, the coupled model is not capable of addressing the effects of any long-term groundwater level elevation changes on streamflow. For example, the current model approach would not identify changing seepage losses due to declining groundwater levels[6].

[5] As a result of the model limitations, the Napa Valley Groundwater Model greatly overestimates groundwater baseflow, i.e., groundwater discharge to streams. Specifically, baseflow constituted 42 percent of rainfall input.
[6] This simplification also has a significant effect on the groundwater mass balance, as the model does not account for the (limited) positive correlation between groundwater extraction and groundwater recharge.

Another challenge is the use of subsurface drains that are believed to exist beneath large portions of the Napa Valley floor and drain rapidly during saturated conditions in the winter months. The San Francisco Estuary Institute (http://www.sfei.org) is investigating the effect of subsurface drains on the water budget of the Napa Valley as part of its Napa Watershed Project. However, to date, no reliable and consistent information on subsurface drains has been procured (personal communication Meredith Williams (San Francisco Estuary Institute), 11-20-2009).

# 7 Evaluation of Monitoring Activities

## 7.1 Precipitation Monitoring

As discussed in *Section 3*, precipitation input to the Napa County Surface Water Models was obtained from 24 gauging stations (mainly from a private enterprise, Terra Spāse). Based on the station locations, it was possible to distribute precipitation input with a relatively high degree of spatial representation in the Napa Valley. However, it was not possible to achieve the same representation in the Putah Creek and Suisun Creek watersheds, and homogeneity assumptions had to be made over large areas. Accordingly, the Napa County BDR Technical Appendix identified uncertainty associated with the spatial distribution of precipitation as a major data limitation during the development of the Lake Berryessa Surface Water Model. Underprediction of the highest peak flows at the Napa River stream gauges was similarly explained.

For comparison, LSCE identified 22 active (publicly run) precipitation stations in the Napa River watershed, two in the Putah Creek watershed (the Lake Berryessa station and the Knoxville Creek station, which is outside of the County), and a single station in the Suisun Creek watershed (Mount George) (see **Tables 1** and **2**, **Figure 2**). Two of these stations, i.e., Angwin Pacific Union Col and Napa Fire Department, report monthly precipitation data. For the other stations, higher frequency data (i.e., hourly or more frequently) are available.

In addition, Terra Spāse presently operates 26 weather stations in Napa County. These stations are generally located near one or more of the publicly run stations (see **Figure 2**).

### 7.1.1 Discussion

Ideally, increasing the volume of data input to a model would lead to improved model performance. In an area such as the Napa River watershed, where orographic effects cause substantial spatial variability of precipitation, a relatively large number of gauging stations is needed to capture this natural variability. Similarly, the very knowledge of this spatial variability stems from the relatively dense network of gauging stations. However, there is a limit to the usefulness of an ever-increasing volume of input data. It is important to find a balance between the amount of input data and the desired model performance; the investigation objectives help establish this balance. For example, a small-scale investigation of processes driving pesticide and sediment runoff from a hillside orchard may require 10 precipitation gauges over an area of 5 acres. Clearly, for the Napa River Surface Water Model, such a station density would be cost prohibitive, excessive, and unworkable.

The publicly available precipitation gauge data appears sufficient for use in lieu of the previously used fee-based data from Terra Spāse (see **Figure 2**). Select Terra Spāse stations could be used to supplement the public data record to enhance overall model performance. For example, station #4037 is located on the Napa Valley floor in an area not currently serviced by public precipitation stations. Prior to adding station #4037 (or any of the existing Terra Spāse precipitation gauges) to the network that provides input to the Napa County Models, its historical record should be compared to records for nearby stations (in this case the Lincoln Bridge and Yountville at Cross Road stations) to avoid unnecessary data duplication. Based on the correlation between these stations, station #4037 may add useful new model input.

It may be possible to improve local model performance (e.g., on a subbasin scale) by adding local precipitation data (including other existing Terra Spāse stations). An example is the headwater areas east and northeast of Lake Hennessey, where topographic differences are substantial but no precipitation gauges exist. However, addition of such precipitation gauge data needs to be weighed against the modification of other model input variables, which might exert more control over the magnitude and timing of simulated stream discharge, e.g., soil type and depth, evapotranspiration, land use, elevation, aspect, slope, slope length, surface water diversions, etc. Therefore, the addition of precipitation gauge data for a specific project (e.g., a residential housing development or conversion of natural vegetation to vineyard) should be evaluated on a project-by-project basis. Typically, the model developer best understands the potential effect of the addition on the overall model performance.

As a corollary to the above, the mere existence of a precipitation gauge does not mean it should be incorporated into the network that supplies data to the Napa County Models. For example, the Angwin Pacific Union Col (CDEC) and the Napa Fire Department (CDEC) stations report monthly data, which offer little value to Napa County's efforts. Also, in an effort to avoid unnecessary data redundancy, precipitation data from stations that are very near each other should be compared. For example, the records from the Corp Yard and Lincoln Bridge stations should be compared to assess whether data from one of these stations would be sufficient. Similarly, the record from the stations Highway 29 at Hopper Creek and Yountville at Cross Road should be compared.

In summary, a relatively large number of public precipitation stations collect precipitation data of sufficient resolution in the Napa River watershed. Data from these stations are recommended for continuous model development (see **Table 1** and **Figure 3**). The addition of other existing (fee-based) stations or the establishment of new weather stations in this watershed is not recommended at this time unless there is a project-motivated need for project-specific analysis. A major weakness of the initial model calibration (which was identified as such by the model developers) is the short calibration period (January 2000 – December 2003). Therefore, it is recommended the precipitation record be updated with current data, and the model calibration period be extended. In coordination with specific development plans, areas of additionally needed information may be identified (see *Sections 7.1* and *7.1.1*).

Only a few precipitation stations exist in the Lake Berryessa Surface Water Model domain area. Therefore, the spatial distribution of precipitation in this area is largely unknown. As previously mentioned, homogeneity assumptions were made to address this issue. It is recommended that, in addition to the Angwin, Atlas Peak, and Lake Berryessa precipitation stations that were used for model development (DHI, 2006), data from existing public stations at Knoxville Creek, Mount St. Helena, and Mount George be employed for continuous model development (see **Table 2**). Also, the addition of three new precipitation stations could substantially improve the representation of the spatial distribution of precipitation input to the model (**Figure 4**). One of the gauges should be located in Pope Valley to capture potential differences between stations at higher elevations such as Mount St. Helena and Angwin. This new station could provide valuable data for the Pope Creek watershed, including its major tributaries, the Burton and Hardin Creeks. Another new gauge should be located in the lower third of the Eticuera Creek watershed to capture potential differences between the valley floor and the Knoxville station located at a higher elevation. This new station together with the Knoxville station could provide valuable data for the entire northern and northeastern model area. A third new gauge should be located in the lower portion of the Capell Creek watershed to capture potential precipitation differences between the lower and higher portions of the watershed (e.g., the Atlas Peak station located at higher elevation).

### 7.2 Discharge Monitoring

As discussed in *Section 3*, the Napa Valley Surface Water Model was calibrated against discharge records from eight stations plus Lake Hennessey stage data. The Lake Berryessa Surface Water Model was calibrated against a single station (Lake Berryessa), and the lack of comprehensive stream gauge data is a data limitation (DHI, 2006). This limitation relates not only to the distribution of streamflow gauging stations but also to the time period for which both discharge and precipitation data were available.

For comparison, LSCE identified 29 active stream (including reservoir) monitoring stations located in the Napa Valley Model domain with readily available data (see **Table 1**, **Figure 2**). The list of stations includes the nine stations used for the model calibration (see *Section 3.2*) plus seven additional stations for which discharge rating curves are available (i.e., stations Atlas Peak at Milliken; CAH; CAS; Hwy 29 at Napa Creek; Sulfur Creek at Pope; Washington at Dry Creek; and York Creek at Hwy 29). Only stage data are currently available for the remaining stations.

As stated in *Section 3*, the calibration effort for the Napa Valley Surface Water Model focused on streamflows at two Napa River stream gauges located near St. Helena and Napa. These locations were chosen as indicators of the overall system water balance in the northern and central portions of the basin. Limited calibration efforts on tributary streams were generally less successful. The limited success was attributed largely to the insufficient representation of important hydrogeologic variables and the short calibration period.

The ongoing data collection at the above seven gauging stations offers an opportunity to augment the initial calibration effort and these stations should be added to the calibration points (see **Figure 3**). It is anticipated that the incorporation of these additional calibration points will provide greater insight into hydrologic processes exerting major control over the watershed's hydrologic rainfall response and result in the refinement of hydrogeologic input variables, especially when used in conjunction with improved reservoir operational information (e.g., Bell Canyon and Rector Reservoirs, and Lake Hennessey).

For the Lake Berryessa Surface Water Model, discharge data are available from three stations (see **Table 2**, **Figure 2**). However, only the calculated inflow to Lake Berryessa can be used for model calibration. Streamflow records from the Putah Creek station near Guenoc serve as model input. Releases from Lake Berryessa at Monticello Dam reflect operational decisions (not a watershed response to rainfall) and have no bearing on model performance as these flows exit the model domain. Finally, the Putah Creek near Winters station is located downstream from Monticello Dam. Therefore, flow at this station cannot be used to evaluate model performance.

The hydrologic response to rainfall in the Lake Berryessa area can be better understood with the installation of a few new stream gauges. The location of these gauges should be correlated with the areas where additional precipitation data are collected, i.e., Pope Valley, the Eticuera Creek watershed, and the Capell Creek watershed (see **Figure 4**). Data from these three additional stream gauges would provide a means to check Lake Berryessa inflow and, collectively, the data would provide insight into the hydrologic response of most of the modeled area.

### 7.3 Instream Water Temperature

The Napa River TMDL recognizes elevated instream water temperatures that are stressful to fish populations as a major concern. Elevated temperatures are caused predominantly by poor baseflow during the spring and the dry season. Dietrich et al. (2004) identified over 1,000 dams within the Napa River watershed, over 400 of which are located on tributary channels that drain approximately 30 percent of the total land area. These dams exert significant control over the flow regime in the watershed and are thought to reduce both magnitude and duration of baseflow in some tributaries and also some reaches of the mainstem of the Napa River.

Given the (i) high local variability and tremendous complexity of processes affecting instream water temperature, (ii) highly variable instream temperature distribution, (iii) sweeping assumptions and simplifications made to simulate these temperatures on the watershed scale, and (iv) high computational effort needed to model fast flowing, flashy tributaries, it is clear that a regional approach to instream temperature modeling would not be fruitful. However, project-scale instream temperature modeling can be a helpful assessment tool.

Instream temperature modeling in conjunction with restoration projects will require large data input sets, including local meteorological and hydrologic variables. The potential benefit of such local modeling efforts would be to simulate the effects of local changes to near-creek habitat (e.g., change from healthy riparian vegetation to vineyard) on instream temperatures. However, depending on the project size and the overall streamflow, temperature effects are expected to disperse quickly with distance from the project, and effects may not be measurable in the mainstem of the Napa River (unless a major cold water plume is developed[7]).

Temperature measurements can and should be used to support in-channel effectiveness monitoring linked to specific restoration projects. For example, projects to (i) enhance loading of large woody debris (to increase pool frequency, depth, and cover), (ii) foster near-stream riparian vegetation to provide leaf cover, or (iii) create a wider riparian corridor to decrease ambient air temperature via increased leaf cover, plant transpiration, and relative air humidity, are generally reflected in decreased downstream water temperatures. As such, instream monitoring provides a means to monitor the cumulative effect of a complex restoration project on temperature.

Based on the above, instream water temperature monitoring should be directly linked to specific restoration projects (or other areas where land use changes are anticipated to occur) and consist of pre-project monitoring and ongoing monitoring after project completion. *Section 7.4* describes several projects that have developed or will be developing environmental data documenting instream habitat changes due to vineyard development and the effects of restoration projects.

### 7.4 Sediment Discharge

The Napa River TMDL identified two measurable numerical targets to evaluate instream sediment dynamics as affected by human activity: streambed permeability and scour. These targets relate to depositional and erosional processes. In contrast, the sediment sampling activities discussed for the Napa River watershed have focused on suspended sediment measurement, which relates to fluvial transport processes. The Napa River TMDL specifically identifies in-channel effectiveness monitoring such as spawning gravel permeability and redd scour to evaluate channel response to management actions and natural processes.

As with instream water temperature monitoring, streambed permeability and scour measurements should be directly linked to specific restoration projects (or other areas where land use changes are anticipated to occur) and consist of pre-project and post-project monitoring. Presently, an ongoing project in the Carneros Creek watershed aims to establish baseline conditions for streamflow and sediment loads (below item 1) and several ongoing or planned projects are designed (among other things) to reduce fine sediment delivery rates and decrease instream temperature (below items 2, 3, and 4). As such, these projects provide promising opportunities to gather environmental data documenting instream habitat changes due to vineyard development (item 1) and the effects of restoration projects (items 2, 3, and 4):

1. The Carneros Creek area, where Napa River RCD conducted its sediment study (see *Section 5.2*). This study covered an area of the watershed where future vineyard development is anticipated. As such, it was designed to develop baseline streamflow and sediment load information (i.e., pre-project information), which can be used as a basis for comparison should future vineyard development materialize.
2. The Rutherford Napa River Restoration Project (first phase implementation initiated in 2009) – a stream-riparian habitat enhancement project located on the mainstem of the Napa River between Zinfandel Lane and Oakville Cross Road (4.3 miles long). This project is specifically designed to reduce fine sediment delivery rates. The project includes the construction of floodplains (1.5-year inundation recurrence interval), planting and maintenance of native riparian vegetation, removal of invasive species, re-connection of remnant side channels with the main stream, set back of 4,100 feet of agricultural levees, and installation of log jams to enhance streambed topography.
3. A planned stream-riparian habitat enhancement project located on the mainstem of the Napa River (downstream of the Rutherford Project) between Oakville Cross Road and Oak Knoll Avenue (9 miles long). This project will utilize construction and maintenance approaches similar to those of the Rutherford Napa River Restoration Project. Areas with functional floodplains and complex channel

[7] If a cold water plume is sufficiently persistent, it could provide localized beneficial conditions for fish populations.

habitat will be identified and considered as potential reference models to guide restoration efforts elsewhere in the reach.

4. Selected stream reaches to be determined in conjunction with acreage certified under the Fish Friendly Farming Program. This program involves implementation of farm plans certified as protective of water quality and salmonid fisheries by National Oceanic and Atmospheric Administration (NOAA) Fisheries and the State Water Resources Control Board. For example, farmers agree to establish and maintain a riparian corridor setback of specified width, invasive plant species are removed from the property, native vegetation is planted in the riparian corridor, and vegetation maintenance plans are established to control invasive plant species.

## 8 Summary of Key Conclusions and Recommendations

This section summarizes key conclusions and recommendations.

1. **Precipitation Gauging – Napa Valley Model Domain:** A relatively large number of public precipitation stations collect precipitation data of sufficient resolution in the Napa River watershed. Data from these stations are recommended for continuous model development (see **Table 1** and **Figure 3**). The addition of other existing (fee-based) stations or the establishment of new weather stations in this watershed is not recommended at this time unless there is a project-motivated need for project-specific analysis.

   Precipitation data from stations that are very near each other (i.e., Corp Yard and Lincoln Bridge; Highway 29 at Hopper Creek and Yountville at Cross Road) should be compared to assess if data from one of each of the station pairs would be sufficient to represent local precipitation and to avoid data redundancy.

   A major weakness of the initial model calibration (which was identified as such by the model developers) is the short calibration period (January 2000 – December 2003). Therefore, it is recommended the precipitation record be updated with current data, and the model calibration period be extended. In coordination with specific development plans, areas of additionally needed information may be identified (see *Sections 7.1* and *7.1.1*).

2. **Precipitation Gauging – Lake Berryessa Model Domain:** It is recommended that, in addition to the Angwin, Atlas Peak, and Lake Berryessa precipitation stations that were used for model development (DHI, 2006), data from existing public stations at Knoxville Creek, Mount St. Helena, and Mount George be employed for continuous model development (see **Table 2** and **Figure 4**). Also, three new precipitation gauges are recommended to improve understanding of the hydrologic response to rainfall in the Lake Berryessa area. These stations should be strategically placed in (i) Pope Valley, (ii) the lower third of the Eticuera Creek watershed, and (iii) the lower portion of the Capell Creek watershed (see *Sections 7.1* and *7.1.1*).

3. **Stream Gauging – Napa Valley Model Domain:** It is recommended that seven existing stream gauging stations, for which discharge rating curves are available, be added as calibration points in the Napa Valley Surface Water Model. These stations are Atlas Peak at Milliken; CAH; CAS; Hwy 29 at Napa Creek; Sulfur Creek at Pope; Washington at Dry Creek; and York Creek at Hwy 29. Concurrently, the discharge record for the original 9 gauging stations (used for the calibration of the Napa Valley Surface Water Model) should be updated with current data, and reservoir operational records should be improved (e.g., Bell and Rector Reservoirs and Lake Hennessey) (see *Section 7.2*).

4. **Stream Gauging – Lake Berryessa Model Domain:** Three new stream gauges are recommended to improve understanding of the hydrologic response to rainfall in the Lake Berryessa area. These gauges should be co-located with the recommended new precipitation gauges, i.e., Pope Valley, the Eticuera Creek watershed, and the Capell Creek watershed (see above *Item 2*). Data from these three stream gauges would provide a means to check Lake Berryessa inflow estimates and, collectively, provide insight into the hydrologic response of most of the modeled area (see *Section 7.2*).

5. **Instream Temperature:** Although regional instream temperature modeling is not recommended, temperature measurements can and should be directly linked to specific restoration projects or other areas where land use changes are anticipated to occur to support in-channel effectiveness monitoring and evaluate channel response to management actions and natural processes. Instream water temperature monitoring should include pre-project and post-project monitoring (see *Section 7.3*). Presently, there are several projects that provide promising opportunities to gather environmental data (including instream water temperature) documenting habitat changes due to vineyard development and the effects of restoration projects. These are (i) the Napa County RCD's Carneros Creek watershed study, (ii) the Rutherford Napa River Restoration Project, (iii) a planned stream-riparian habitat enhancement project downstream of the Rutherford Napa River Restoration Project, and (iv) selected stream reaches to be determined in conjunction with acreage certified under the Fish Friendly Farming Program (see *Section 7.4*).
6. **Sediment Load:** The Napa River TMDL identified two measurable numerical targets, including streambed permeability and scour to evaluate instream sediment dynamics as affected by human activity. As with instream water temperature monitoring, streambed permeability and scour measurements should be directly linked to specific restoration projects (or other areas where land use changes are anticipated to occur) and consist of pre-project and post-project monitoring. Presently, there are several areas that lend themselves to this kind of study; and these are the same as identified for instream water temperature monitoring in Item 5. Regarding the Carneros Creek watershed study, we support Napa County RCD's recommendations to continue the discharge and suspended sediment measurements and to walk the reach between the CAS and CAH stations (see *Section 5.2.1*).
7. **Surface Water/Groundwater Interactions:** The comprehensive review and analysis of available groundwater level elevation data for the Napa Valley in conjunction with historical stream gauging records, land use information, and groundwater pumping records may yield initial correlations between groundwater levels and streamflow. This approach would aid the identification of areas where near-stream monitoring wells could be placed to assess potentially changing surface water/groundwater interactions. Such new monitoring wells would be most useful in areas where historical groundwater level elevation data are available to facilitate the comparison to historical conditions (see *Section 6*).

### 8.1 Prioritization of Recommended Actions

The recommendations pertaining to existing precipitation and streamflow monitoring areas in the Napa Valley Model Domain provide an opportunity for the County to reduce costs by discontinuing the use of fee-based precipitation data (which were used for the model development) and instead using publicly available data for continued model development and refinement. Prioritization for installing new precipitation and stream gauges in the Lake Berryessa Model Domain will largely depend on regulatory requirements (e.g., the Napa River TMDL) and/or the perceived project-based need in specific areas.

The Napa River TMDL identifies channel incision as the highest priority (above vineyards, grazing, roads, and urban stormwater runoff) for source reduction and control because of its destruction of the basic physical structure of the river and its immediate impact on fine sediment deposition. Two of the projects listed under above Items 5 and 6 should be given higher priority than the others. These projects include the Carneros Creek study and the Rutherford Napa River Restoration Project. The Carneros Creek study develops baseline information (i.e., pre-project information) that can be used as a basis for comparison to the potential effects of future vineyard development projects, should they occur. The significant amount of data already collected and analyzed is an additional advantage. The Rutherford Napa River Restoration Project is specifically mentioned in the Napa River TMDL as a project that addresses adverse impacts of channel incision. The first phase of project construction was implemented in summer 2009 and will continue in 2010. Therefore, instream monitoring activities for this project should be given priority to facilitate the collection of sufficient pre-project data. Downstream monitoring for this project could possibly also serve as upstream monitoring for the planned stream-riparian habitat enhancement project located downstream of the Rutherford Napa River Restoration Project.

The extent and nature of surface water/groundwater interactions are largely unknown in Napa County with the exception of the MST area. As discussed in *Section 6*, groundwater levels throughout much of the Napa Valley are within 5 to 20 feet (bgs) during times of seasonally high groundwater levels in the spring. Such shallow groundwater conditions suggest that groundwater is in direct hydraulic communication with stream channels for at least part of the year. Under these conditions, relatively small groundwater level declines have the potential to significantly influence surface water/groundwater interactions such that stream percolation losses increase and stream baseflow decreases. Given that public and regulatory interest in surface water/groundwater interactions will likely continue to grow during the implementation of the Napa River TMDL, increasing pressure on natural resources and land use, and since it is important to better understand water resource availability to meet projected increases in annual water demands (2020 and 2050 projections), monitoring of near-stream shallow groundwater conditions in key locations can contribute to this understanding. Therefore, such monitoring efforts should be given high priority.

## 9 References

1. DHI. **2006**. *Final BDR Technical Appendix – Water Quantity and Water Quality Report, Napa County, CA*. October 2006.
2. DHI. **2008**. *Recommendations for building on existing work to gain an improved understanding of the county's groundwater resources*. Memorandum from Jeremy Kobor to Jeff Sharp (Napa County CDPD). August 1, 2008.
3. Dietrich, W.E., D. Bellugi, R. Real De Asua, I. Iordache, D. Allen, and M. Napolitano. **2004**. *The Use of Airborne Laser Swath Mapping Data in Watershed Analysis to Guide Restoration Priorities: The Napa River Watershed Study*. Eos Transactions of the American Geophysical Union 85(47), Fall Meeting Supplement, Abstract G11B-06.
4. Farrar, Christopher D. and Loren F. Metzger. **2003**. *Ground-Water Resources in the Lower Milliken-Sarco-Tulucay Creeks Area, Southeastern Napa County, California, 2000-2002*. U.S. Geological Survey Water Resources Investigations Report 03-4229.
5. Johnson, Michael J. **1977**. *Ground-Water Hydrology of the Lower Milliken-Sarco-Tulucay Creeks Area, Napa County, California*. Water Resources Investigations Open File Report 77-82. August 1977.
6. Jones and Stokes & EDAW. **2005**. *Napa County Baseline Data Report*. November 30, 2005.
7. Napa County Resource Conservation District. **2005a**. *Hydrologic Monitoring and Modeling of Napa River Tributaries and Stewardship Support Services, 2004-05 Final Report*. June 2005.
8. Napa County Resource Conservation District. **2005b**. *Sediment and Stewardship Project 2002-05 Final Report*. September 1, 2005.
9. Personal communication Paul Blank (Napa County RCD) with Till Angermann (LSCE). June 19, 2009.
10. Personal communication Meredith Williams (San Francisco Estuary Institute) with Till Angermann (LSCE). November 20, 2009.
11. Personal communication David Steiner (Napa County RCD) with Till Angermann (LSCE). December 1, 2009.
12. San Francisco Bay Regional Water Quality Control Board. **2009**. *Basin Plan Amendment*. p. 20, (to be inserted into Chapter 7, *Water Quality Attainment Strategies including Total Maximum Daily Loads (TMDLs)*. Adopted September 9, 2009.
13. San Francisco Bay Regional Water Quality Control Board. **2009**. *Napa River Sediment TMDL and Habitat Enhancement Plan*. Staff Report. September 2009. Michael Napolitano, Sandia Potter, and Dyan Whyte (adopted September 9, 2009).
14. Stillwater Sciences and W. Dietrich. **2002**. *Napa River Basin Limiting Factors Analysis, Final Technical Report*.
15. U.S. Department of Agriculture. **2007**. *Technical Guide to Managing Ground Water Resources*. FS-881. May 2007.
16. West Yost and Associates. **2005**. *2050 Napa Valley Water Resources Study*. October 2005.

## Tables



## Figures



## Attachments

# Tables

**Table 1:**
**Presently Active Surface Water Gauging and Precipitation Stations (public, non-fee based)**
**Napa River Watershed**

| Site Name | Station ID* | Gauged Stream | Streamflow Calibration Station (2006 Model) | Precipitation Gauge | Recommended for Continuous Model Development** Precipitation*** | Recommended for Continuous Model Development** Streamflow |
|---|---|---|---|---|---|---|
| Angwin | AGN | - - - | - - - | yes | **yes** | - - - |
| Angwin Pacific Union Col | APU (CDEC) | - - - | - - - | yes[4] | no | - - - |
| Atlas Peak | ATL | - - - | - - - | yes | **yes** | - - - |
| Atlas Peak @ Milliken | 13 | Milliken Creek[1,2] | - - - | - - - | - - - | yes |
| Carneros | 109 (CIMIS) | - - - | - - - | yes | **yes** | |
| Carneros Creek | CAO (RCD) | Carneros Creek[1,2] | yes | - - - | - - - | **yes** |
| Carneros Creek | CAH (RCD) | Carneros Creek[1,2] | - - - | - - - | - - - | yes |
| Carneros Creek | CAS (RCD) | Carneros Creek[1,2] | - - - | - - - | - - - | yes |
| Chiles Creek (Lake Hennessey Inflow) | 24 | Chiles Creek[3] | yes | - - - | - - - | **yes** |
| Conn Dam (Lake Hennessey Outflow) | 20 | Conn Creek | yes | yes | yes | **yes** |
| Conn Dam Spillway (Lake Hennessey Outflow) | 25 | Conn Creek | - - - | - - - | - - - | - - - |
| Conn Valley (Lake Hennessey Inflow) | 26 | Conn Creek[3] | yes | - - - | - - - | **yes** |
| Corp Yard | 5 | - - - | - - - | yes | yes | - - - |
| Dry Creek Fire | 8 | - - - | - - - | yes | yes | - - - |
| Garnett Creek | 10 | Garnett Creek | - - - | - - - | - - - | - - - |
| Hwy 29 @ Hopper Creek | 16 | Hopper Creek | - - - | yes | yes | - - - |
| Hwy 29 @ Napa Creek | 17 | Napa Creek[1,2] | - - - | - - - | | yes |
| Huichica Creek | HRV (RCD) | Huichica Creek[1,2] | yes | - - - | - - - | **yes** |
| Lincoln Bridge | 3 | Napa River | - - - | yes | yes | - - - |
| Lodi Lane | 11 | Napa River | - - - | - - - | - - - | - - - |
| Mc Cormick Lane | 27 | Napa Creek | - - - | - - - | - - - | - - - |
| Milliken Dam | 19 | Milliken Creek | - - - | yes | yes | - - - |
| Milliken Inlet | 21 | Milliken Creek | - - - | - - - | - - - | - - - |
| Mount St. Helena | 6 | - - - | - - - | yes | yes | - - - |
| Mount Veeder | 1 | - - - | - - - | yes | yes | - - - |
| Napa (Airport) | KAPC | - - - | - - - | yes | yes | - - - |
| Napa Fire Department | NSH (CDEC) | - - - | - - - | yes[4] | no | - - - |
| Napa River @ Dunaweal | 2368 | Napa River | - - - | yes | yes | - - - |
| Napa River near Napa | 11458000, NAP | Napa River[1] | yes | - - - | - - - | **yes** |
| Napa River near St. Helena | 11456000, STH | Napa River[1] | yes | - - - | - - - | **yes** |
| Oakville | 077 (CIMIS) | - - - | - - - | yes | **yes** | - - - |
| Petrefied Forest | 7 | - - - | - - - | yes | yes | - - - |
| Redwood @ Forest | 4 | Redwood Creek | - - - | - - - | - - - | - - - |
| Redwood @ Mt. Veeder | 2 | Redwood Creek | - - - | yes | yes | - - - |
| Sage Creek Bridge (Lake Hennessey Inflow) | 23 | Sage Creek[3] | yes | - - - | - - - | **yes** |
| Salvador Creek | 28 | Salvador Creek[1,2] | yes | - - - | - - - | **yes** |
| St. Helena 4WSW | SH4 | - - - | - - - | yes | yes | - - - |
| St. Helena @ Sulphur Creek | 14 | Sulpher Creek | - - - | yes | yes | - - - |
| Sugarloaf Radio Site | 18 | - - - | - - - | yes | yes | - - - |
| Sulfur Creek @ Pope | 41 | Sulphur Creek[1,2] | - - - | - - - | - - - | yes |
| Washington @ Dry Creek | 15 | Dry Creek[1,2] | - - - | - - - | - - - | yes |
| York Creek @ Hwy 29 | 29 | York Creek[1,2] | - - - | - - - | - - - | yes |
| Yountville at Cross Road | 12 | Napa River | - - - | yes | yes | - - - |

* Available on OneRain unless otherwise noted (CDEC=California Data Exchange Center; CIMIS=California Irrigation Management Information System; RCD=Napa County Resource Conservation District).
** Boxed gauging stations were included in the original model development.
*** Mount George (Suisun Creek Watershed, see Table 2) should also be used for continuous model development.
1. Volumetric flow rate estimates are available in addition to stage measurements.
2. Sediment sampling conducted by Napa County RCD (Garnett Creek not sampled since 2001).
3. Equipped with v-notch weir.
4. Monthly data.

**Table 2:**
**Presently Active Surface Water Gauging and Precipitation Stations (public, non-fee based)**
**Putah Creek and Suisun Creek Watersheds**

| Site Name | Station ID* | Gauged Stream | Streamflow Calibration Station (2006 Model) | Precipitation Gauge | Recommended for Continuous Model Development** Precipitation | Recommended for Continuous Model Development** Streamflow |
|---|---|---|---|---|---|---|
| Putah Creek near Winters | 11454000 | Putah Creek[1] | - - - | - - - | - - - | - - - |
| Putah Creek near Guenoc | 14453500 (USGS) | Putah Creek[1] | - - - | - - - | - - - | - - - |
| Berryessa | BER (CDEC) | Putah Creek[1] | yes | yes[2] | **yes[3]** | **yes[4]** |
| Knoxville Creek | KNO (CDEC) | - - - | - - - | yes | yes | - - - |
| Mount George | 9 | - - - | - - - | yes | yes | - - - |

* Available on OneRain unless otherwise noted (USGS=United Stated Geological Survey; CDEC=California Data Exchange Center)

** Boxed gauging stations were included in the original model development.

1. Volumetric flow rate estimates are available in addition to stage measurements.
2. Daily data.
3. Angwin and Atlas Peak precipitations stations (Napa River watershed) were used in the original model development; these stations should also be used for continuous model development. The Mount St. Helena precipitation station (Napa River watershed) should also be used for continuous model development. Three additional new precipitation gauges are recommended (in Pope Valley, the Eticuera Creek watershed, and the Capell Creek watershed).
4. Three additional new streamflow gauges are recommended (in Pope Valley, the Eticuera Creek watershed, and the Capell Creek watershed).

# Figures

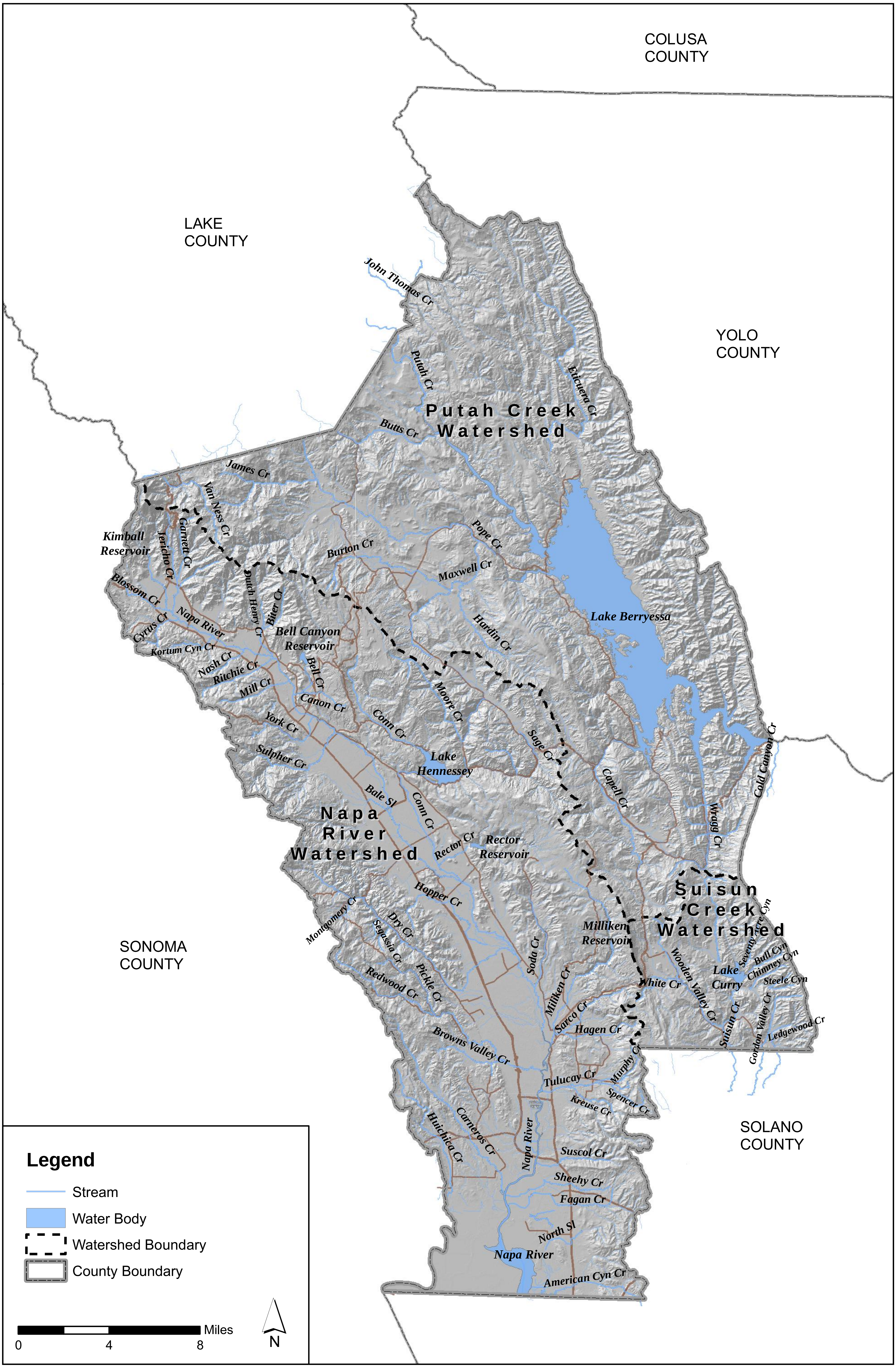



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**Figure 1**
**Streams and Surface Water Location Map**
**Napa County, CA**

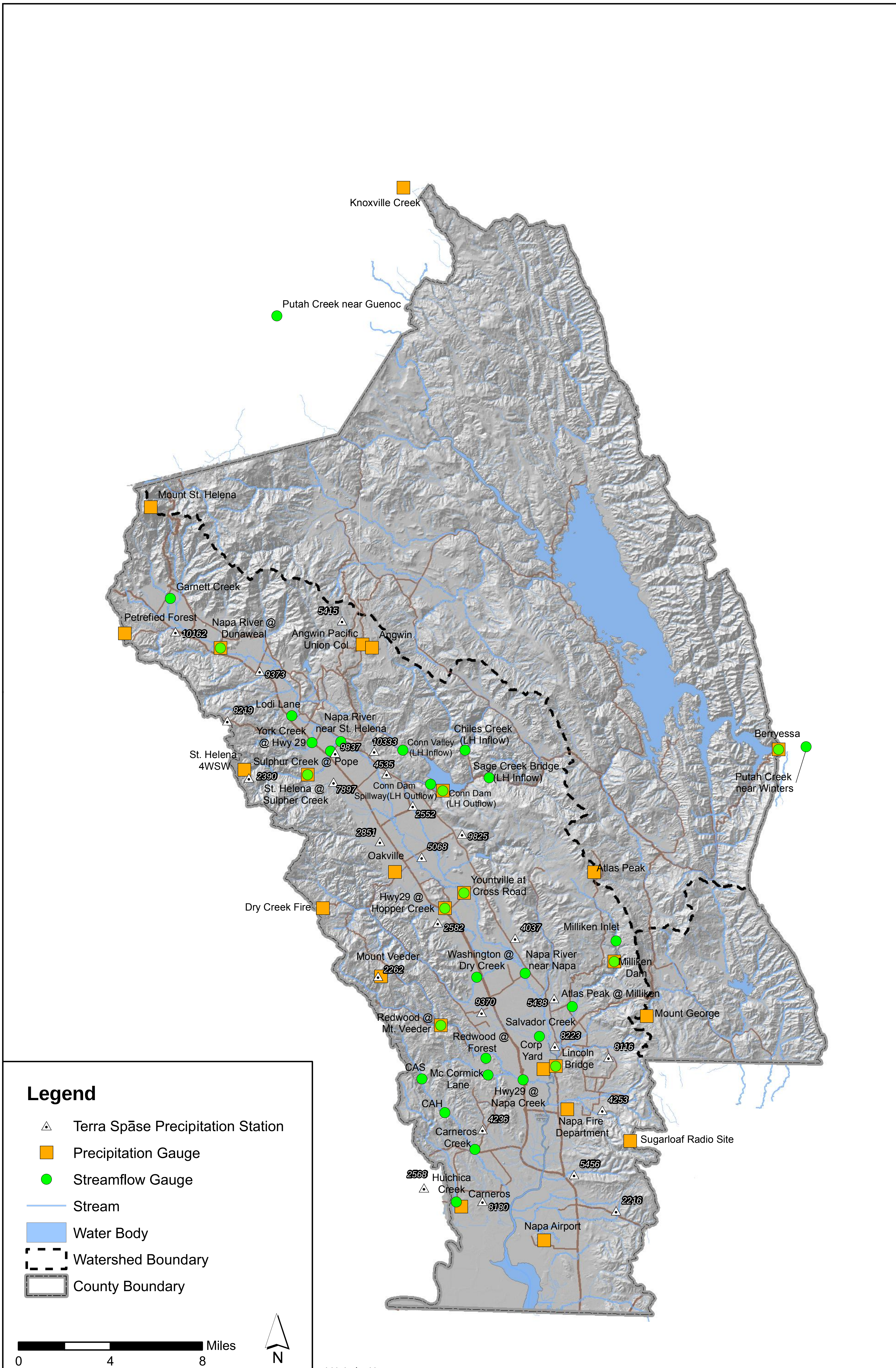


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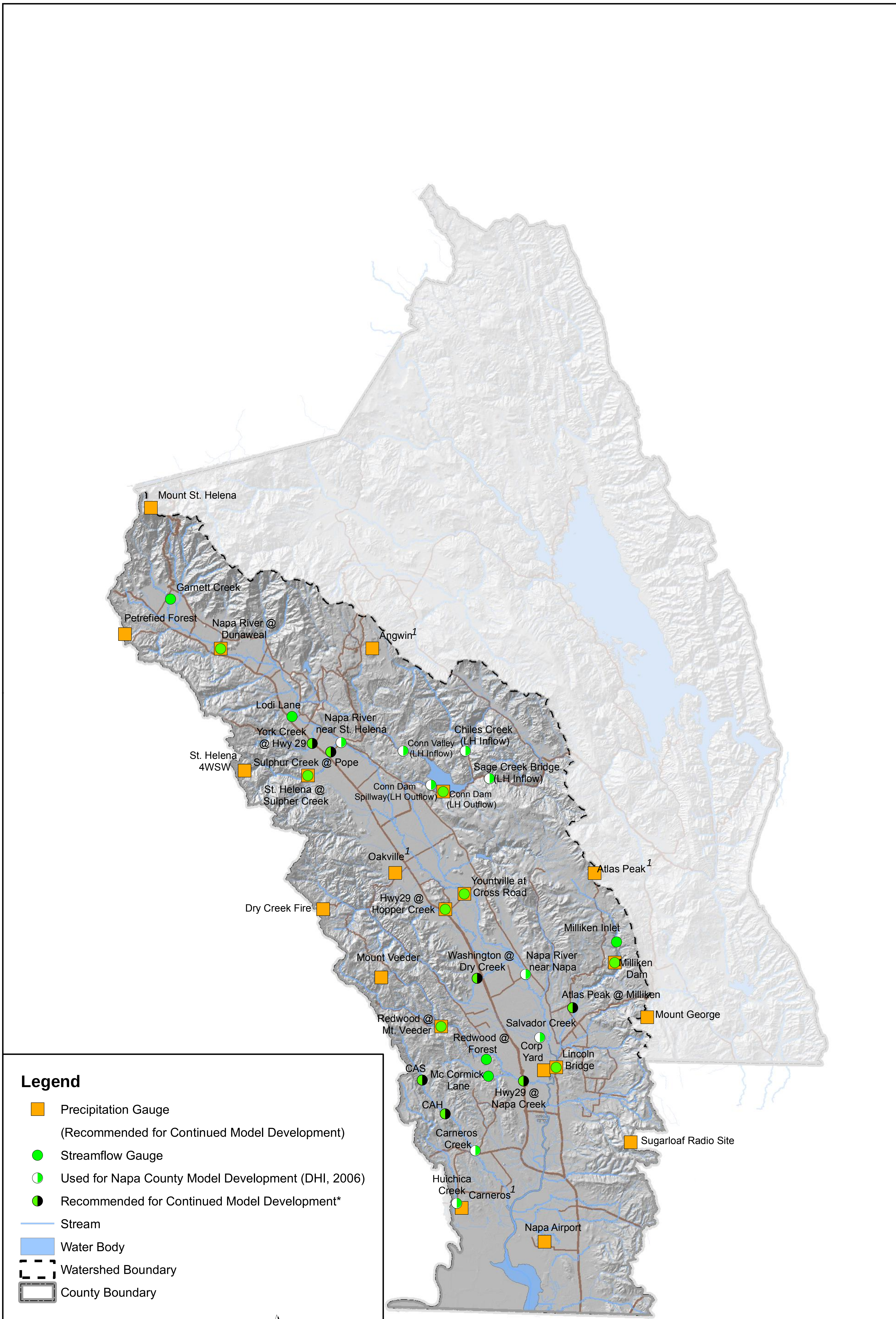
**Figure 2**
**Existing Precipitation and Streamflow Gauging Stations**
**Napa County, CA**




*LH: Lake Hennessey*
*Note: Private (fee-based) weather stations are not shown.*
**These streamflow stations are recommended in addition to those previously used for model development.*
*1. These precipitation stations were used in the original model development (DHI, 2006).*

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**Figure 3**
**Precipitation and Streamflow Gauging Stations for Model Development**
**Napa River Watershed**
**Napa County, CA**

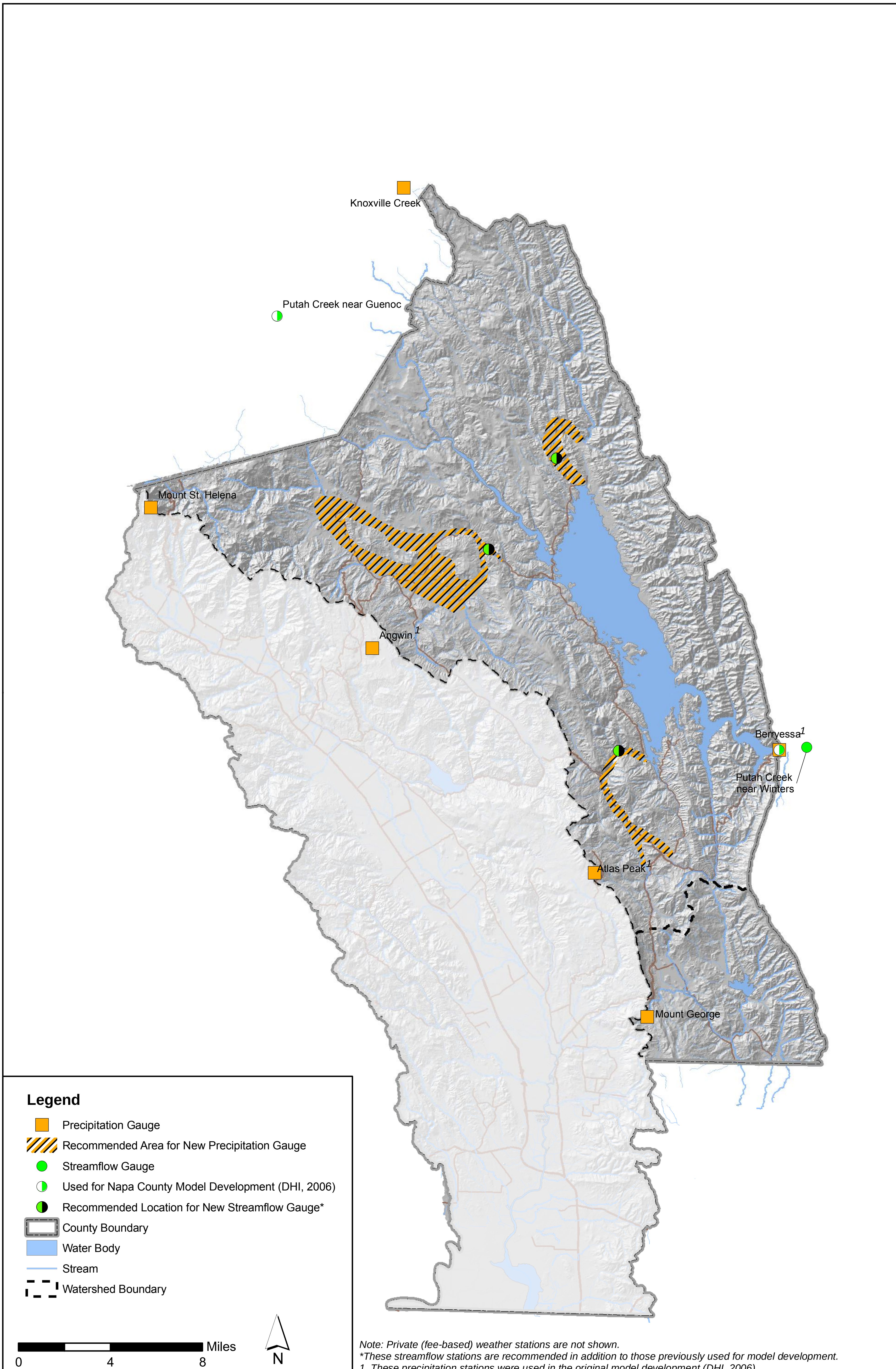


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**Figure 4**
**Precipitation and Streamflow Gauging Stations for Model Development**
**Putah Creek and Suisun Creek Watersheds**
**Napa County, CA**

# Attachment 1

**Table 2-3: Available precipitation data for Napa County (CDEC, 2005; CIMIS, 2005; Terra Space, 2005).**

| Station | Source - Frequency | Period of Record | Max Rate (in/hr) | Cumulative Average Annual (in) |
|---|---|---|---|---|
| Angwin | CDEC -daily | 1987-present | 0.25 | 43.9 |
| Oakville | CIMIS -daily | 1989-present | 0.18 | 37.5 |
| Carneros | CIMIS -daily | 1993-present | 0.13 | 25.7 |
| Atlas Peak | CDEC -daily | 1987-present | 0.25 | 43.9 |
| Berryessa | CDEC -daily | 1997-present | 0.15 | 25.5 |
| 2216 | Terra Space – hourly | 2000-present | 0.53 | 25.7 |
| 2262 | Terra Space – hourly | 2000-present | 0.83 | 53.7 |
| 2390 | Terra Space – hourly | 2000-present | 0.91 | 62.3 |
| 2582 | Terra Space – hourly | 2000-present | 1.36 | 41.7 |
| 2851 | Terra Space – hourly | 2000-present | 1.09 | 41.3 |
| 4037 | Terra Space – hourly | 2000-present | 0.93 | 36.4 |
| 4236 | Terra Space – hourly | 2000-present | 0.86 | 34.8 |
| 5415 | Terra Space – hourly | 2000-present | 0.67 | 45.5 |
| 5438 | Terra Space – hourly | 2000-present | 0.8 | 33.0 |
| 5456 | Terra Space – hourly | 2000-present | 0.75 | 27.8 |
| 7897 | Terra Space – hourly | 2000-present | 0.85 | 39.0 |
| 8116 | Terra Space – hourly | 2000-present | 0.8 | 31.2 |
| 8180 | Terra Space – hourly | 2000-present | 1.19 | 23.6 |
| 8219 | Terra Space – hourly | 2000-present | 0.78 | 54.3 |
| 8223 | Terra Space – hourly | 2000-present | 0.8 | 31.9 |
| 9370 | Terra Space – hourly | 2000-present | 0.87 | 35.3 |
| 9373 | Terra Space – hourly | 2000-present | 0.68 | 42.0 |
| 9837 | Terra Space – hourly | 2000-present | 1.14 | 40.9 |
| 10162 | Terra Space – hourly | 2000-present | 0.8 | 43.2 |

**Table 2-4: Potential evapotranspiration rates in the Napa Valley.**

| Month | ET rate (inches/month) |
|---|---|
| January | 1.2 |
| February | 1.7 |
| March | 3.4 |
| April | 4.0 |
| May | 5.8 |
| June | 6.3 |
| July | 6.3 |
| August | 5.6 |
| September | 4.4 |
| October | 3.1 |
| November | 1.6 |
| December | 1.0 |

**Table 2-13: Available discharge calibration data for the Napa County Surface Water and Groundwater models.**

| Name | Source | Period of Record | Average (cfs) | Maximum (cfs) |
|---|---|---|---|---|
| Napa River @ St. Helena | USGS | 1929 - 2004 | 92 | 3,858 |
| Napa River @ Napa | USGS | 1929 - 2004 | 199 | 11,733 |
| Tulucay Creek | USGS | 11/2001-5/2002 | 15 | 250 |
| HuichicaCreek | Napa RCD | 3/2000-8/2003 | 7 | 741 |
| CarnerosCreek | Napa RCD | 12/2001-2/2004 | 9 | 1,426 |
| SalvadorCreek | Napa RCD | 11/2003-2/2004 | 13 | 751 |
| Conn Creek upstream of Lake Hennessey | City of Napa | 1999-2004 | 9.5 | 430 |
| Sage Creek | City of Napa | 1999-2004 | 11.7 | 1050 |
| Chiles Creek | City of Napa | 1999-2004 | 9.0 | 343 |
| Lake Berryessa Inflow | CDWR | 1994 - 2004 | 502 | 29,453 |

Notes:

Statistics are for the simulation period (2000-2003)
cfs = cubic feet per second
USGS = United States Geological Survey
Napa RCD = Napa Resource Conservation District
CDWR = California Department of Water Resources

**Table 2-14: Selected water-level calibration data used for the Napa Valley Groundwater model.**

| Name | Source | Period of Record | Number of Observations |
|---|---|---|---|
| 005N003W06R001M | USGS | 4/2000 – 10/2002 | 7 |
| 005N003W08E001M | USGS | 4/2000 – 10/2002 | 9 |
| 006N004W23K003M | USGS | 4/2000 – 10/2002 | 7 |
| 007N004W31M001M | CDWR | 10/1978 – 4/2003 | 50 |
| 007N005W09Q002M | CDWR | 10/1949 – 2/2004 | 434 |
| 009N006W31Q001M | CDWR | 10/1949 – 4/2003 | 95 |

Notes:

USGS = United States Geological Survey
CDWR = California Department of Water Resources

# Attachment 2

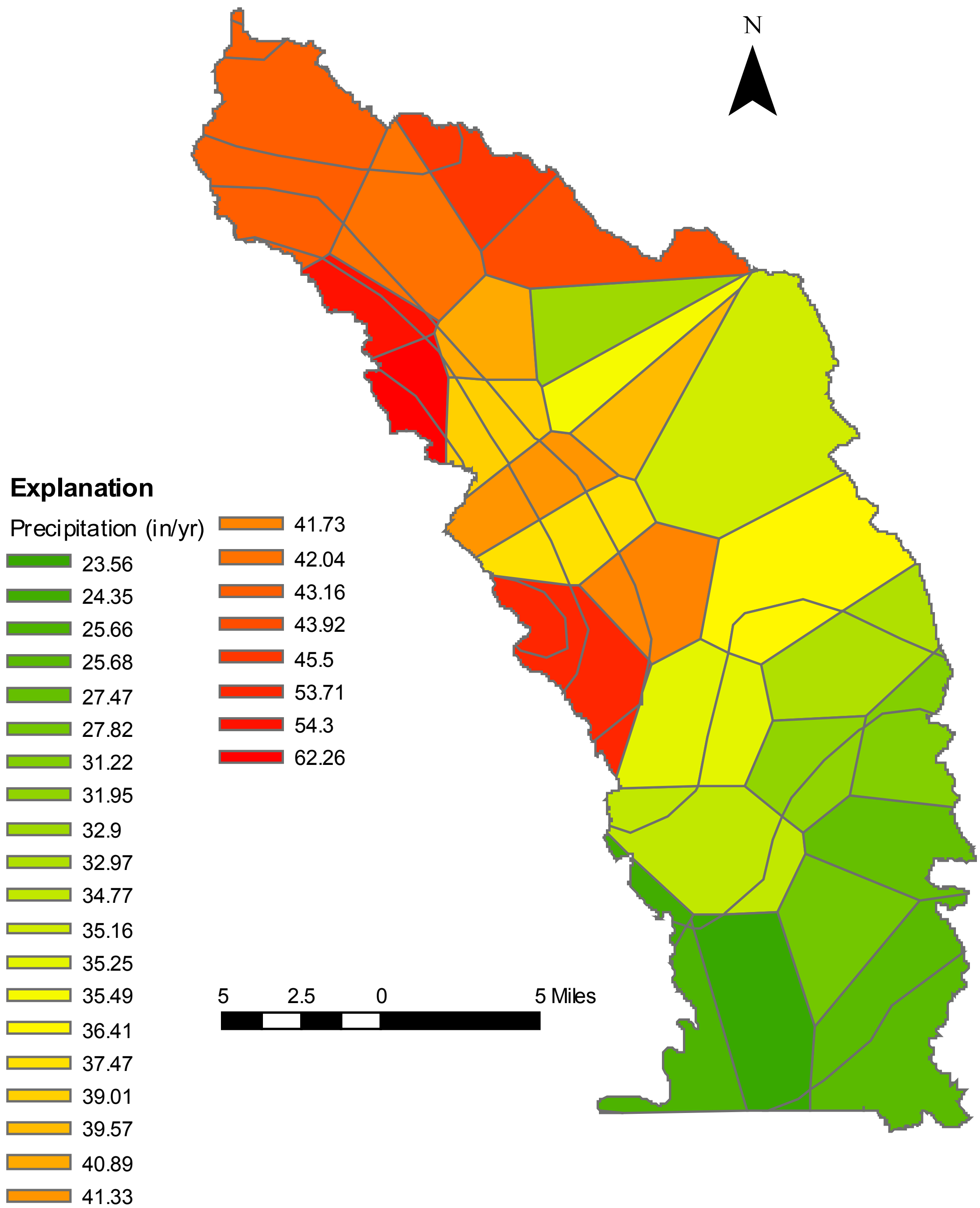



**Figure 2-7: Precipitation distribution used in the Napa Valley Surface Water model and the Napa Valley Groundwater model (rates are mean values over the simulation period, 2000-2003).**

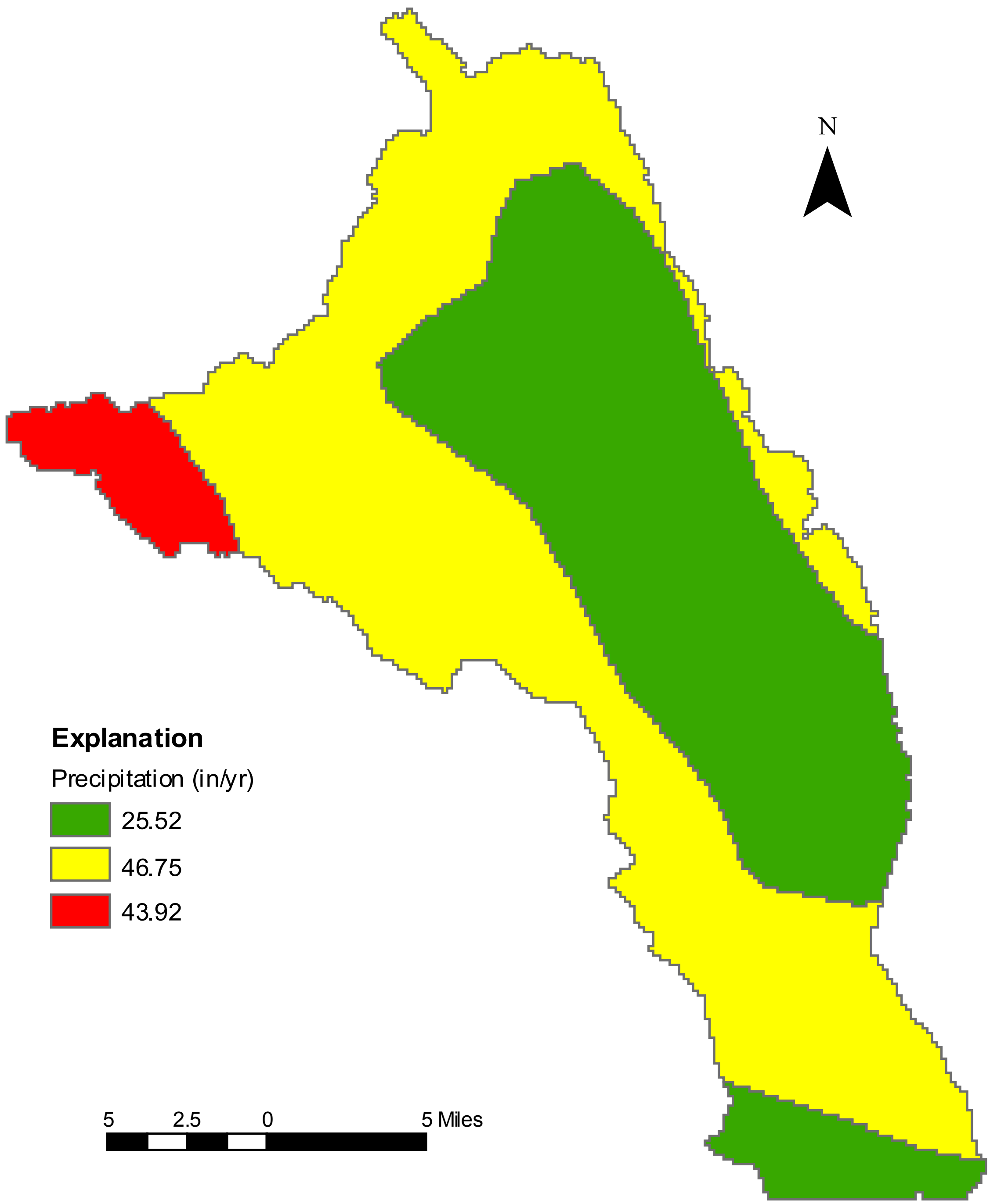



**Figure 2-8: Precipitation distribution used in the Lake Berryessa Surface Water model (rates are mean values over the simulation period, 2000-2003).**

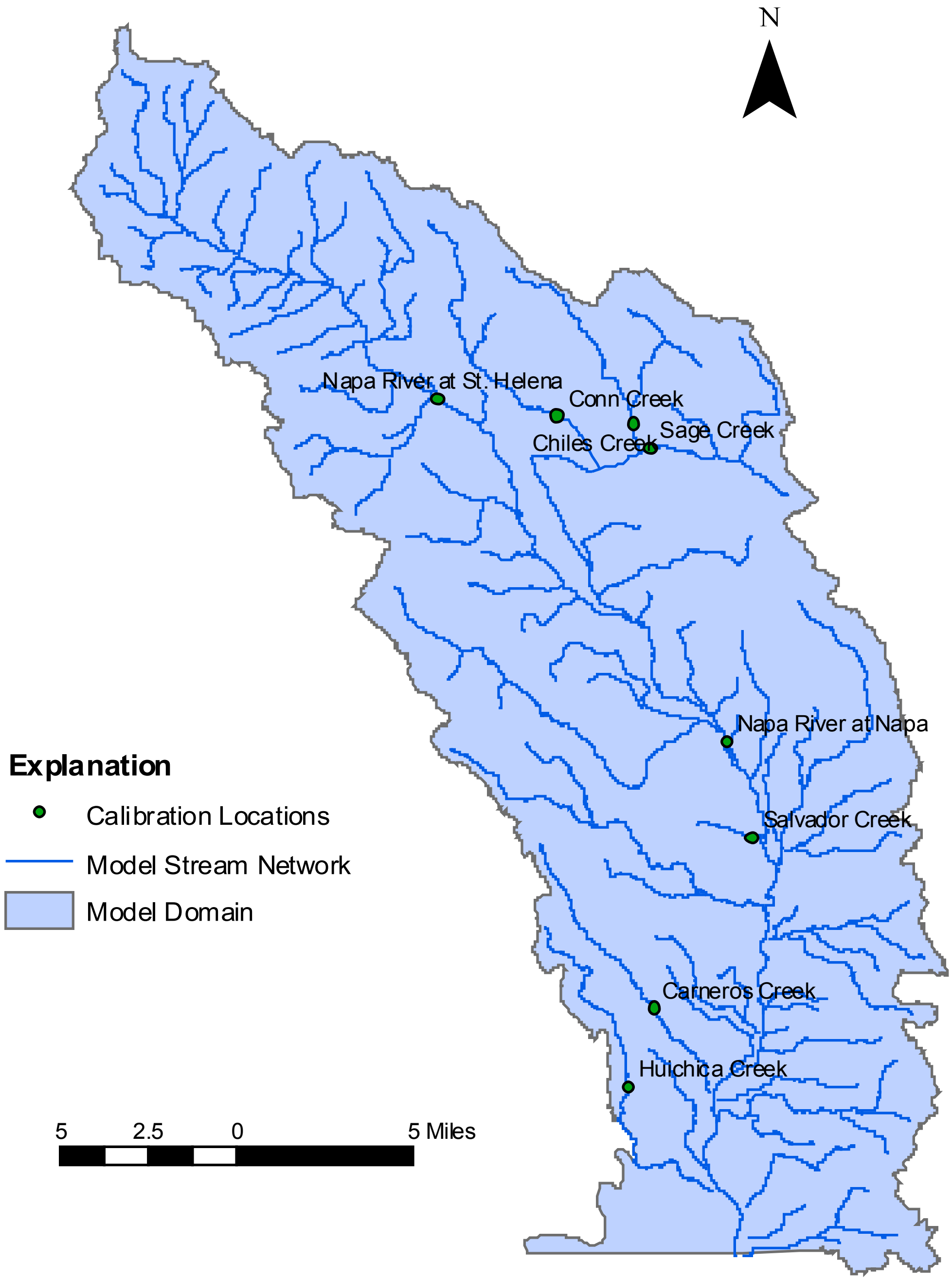



**Figure 2-34: Discharge calibration locations in the Napa Valley Surface Water model and the Napa Valley Groundwater model.**

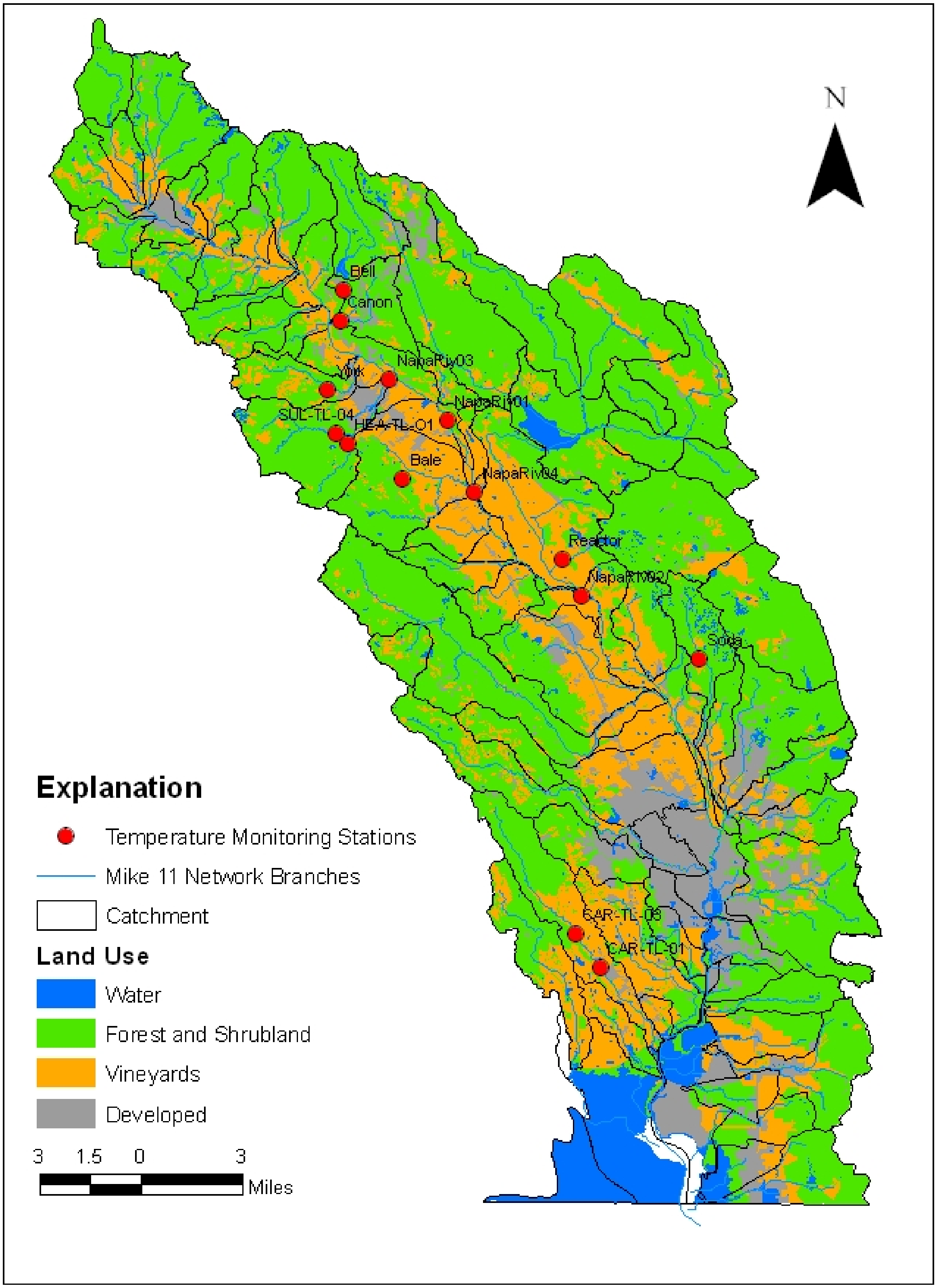



**Figure 3-9: Napa Valley model area temperature monitoring stations (Napa County 2005).**
**Note: No temperature monitoring stations are available for the Lake Berryessa model area.**

# Attachment 3

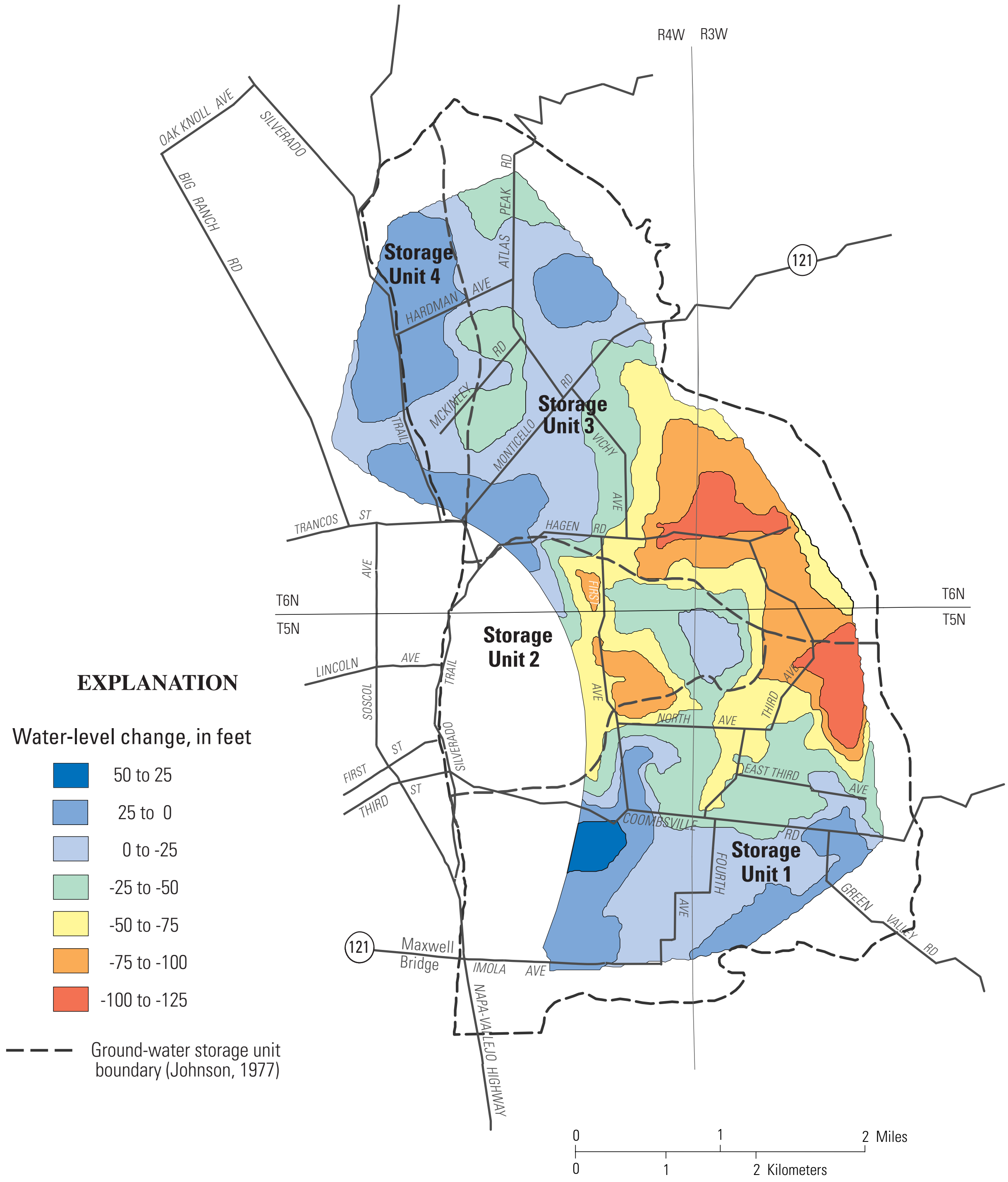
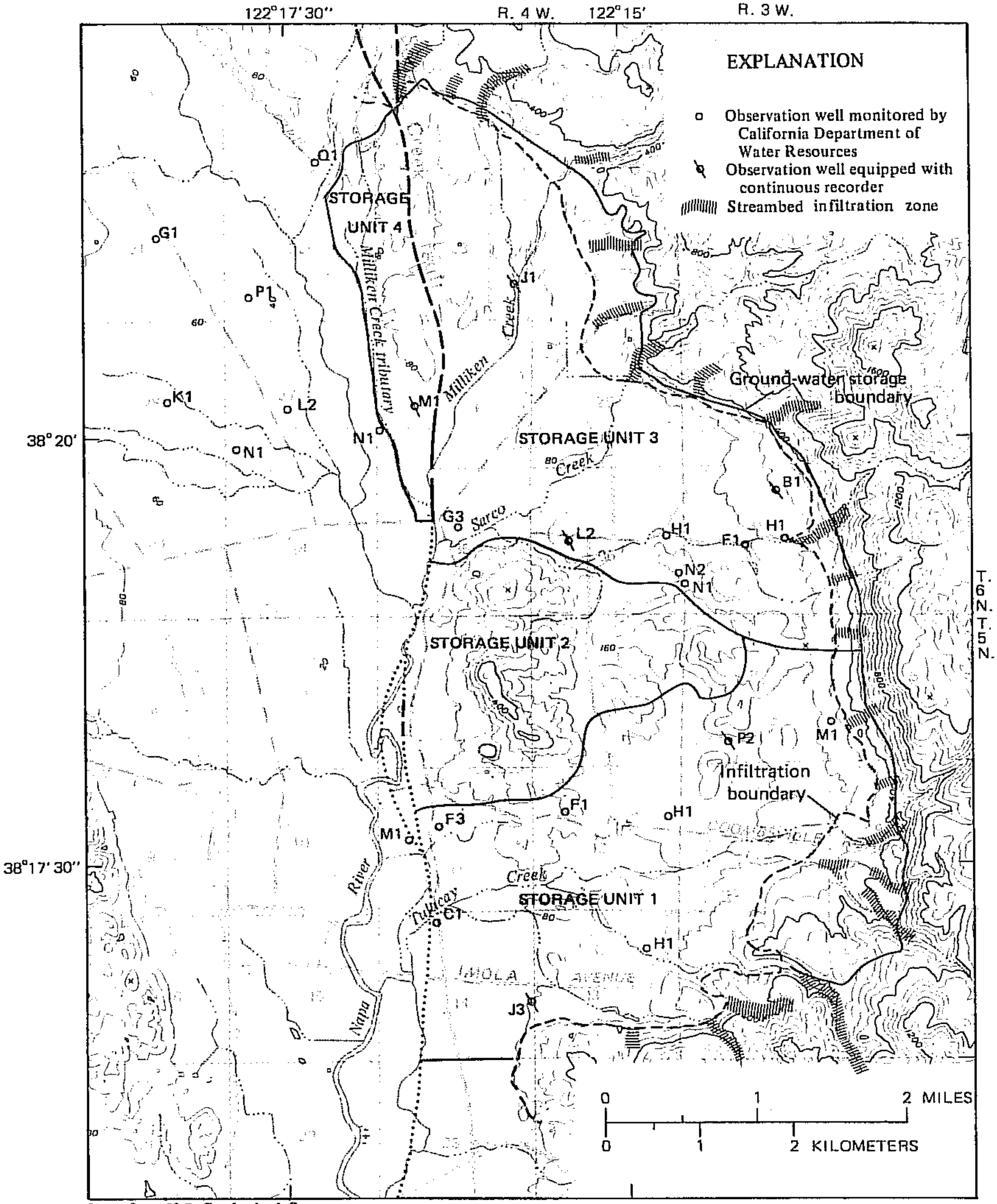



Figure 24. Change in water levels in the lower Milliken–Sarco–Tulucay Creeks area, southeastern Napa County, California, autumn 1975 to autumn 2001.

# Attachment 4

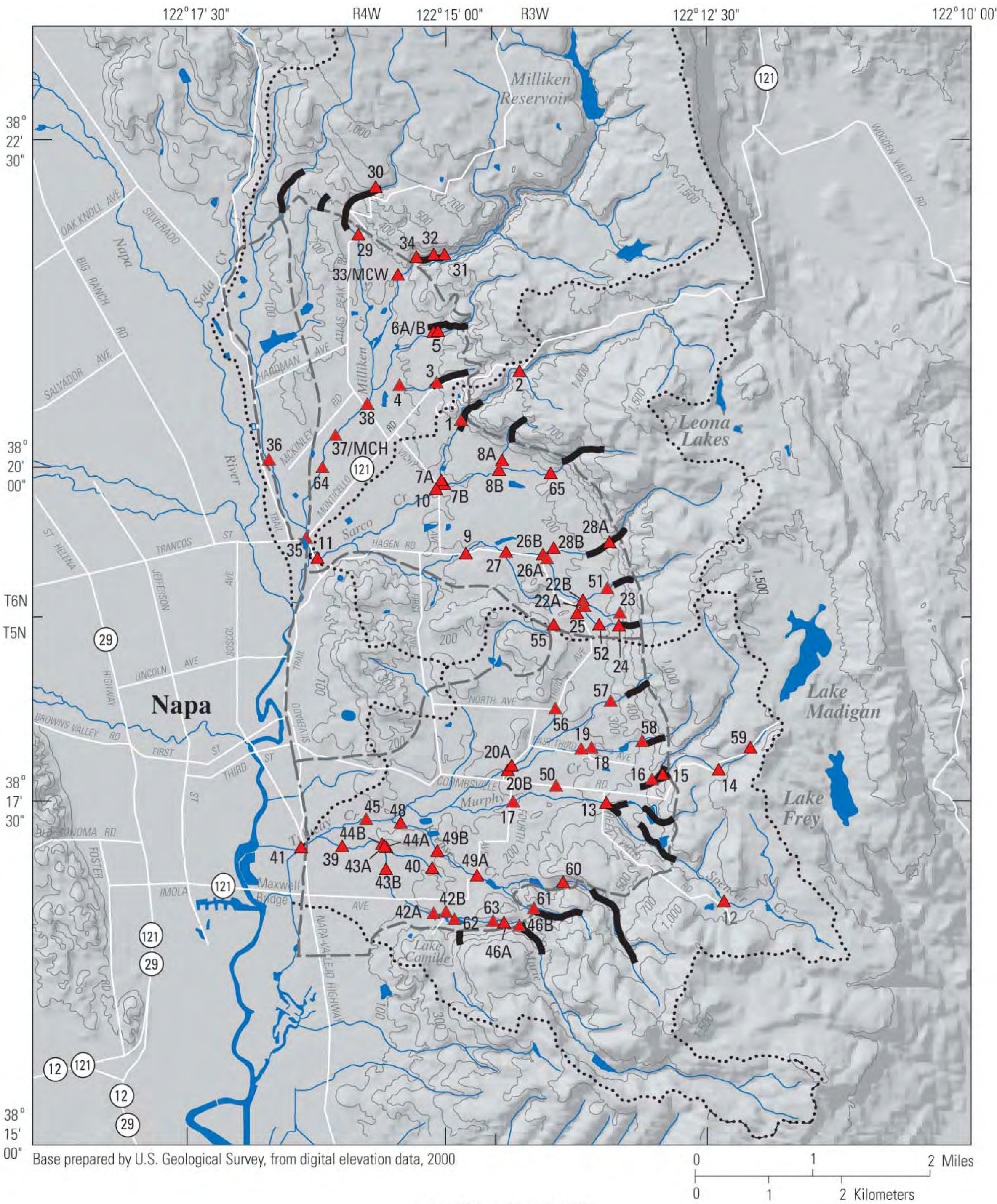



Base from U.S. Geological Survey
Mt. Vaca, 1951 and Sonoma, 1951

CONTOUR INTERVAL 80 FEET
DOTTED LINES REPRESENT 20 FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

FIGURE 11.--Infiltration boundary, location of observation wells, and ground-water storage units.

# Attachment 5




# EXPLANATION

Drainage basin boundary

Ground-water storage unit boundary (Johnson, 1977)

**Topographic contour**—Shows altitude of land surface. Contour interval variable. Datum is sea level

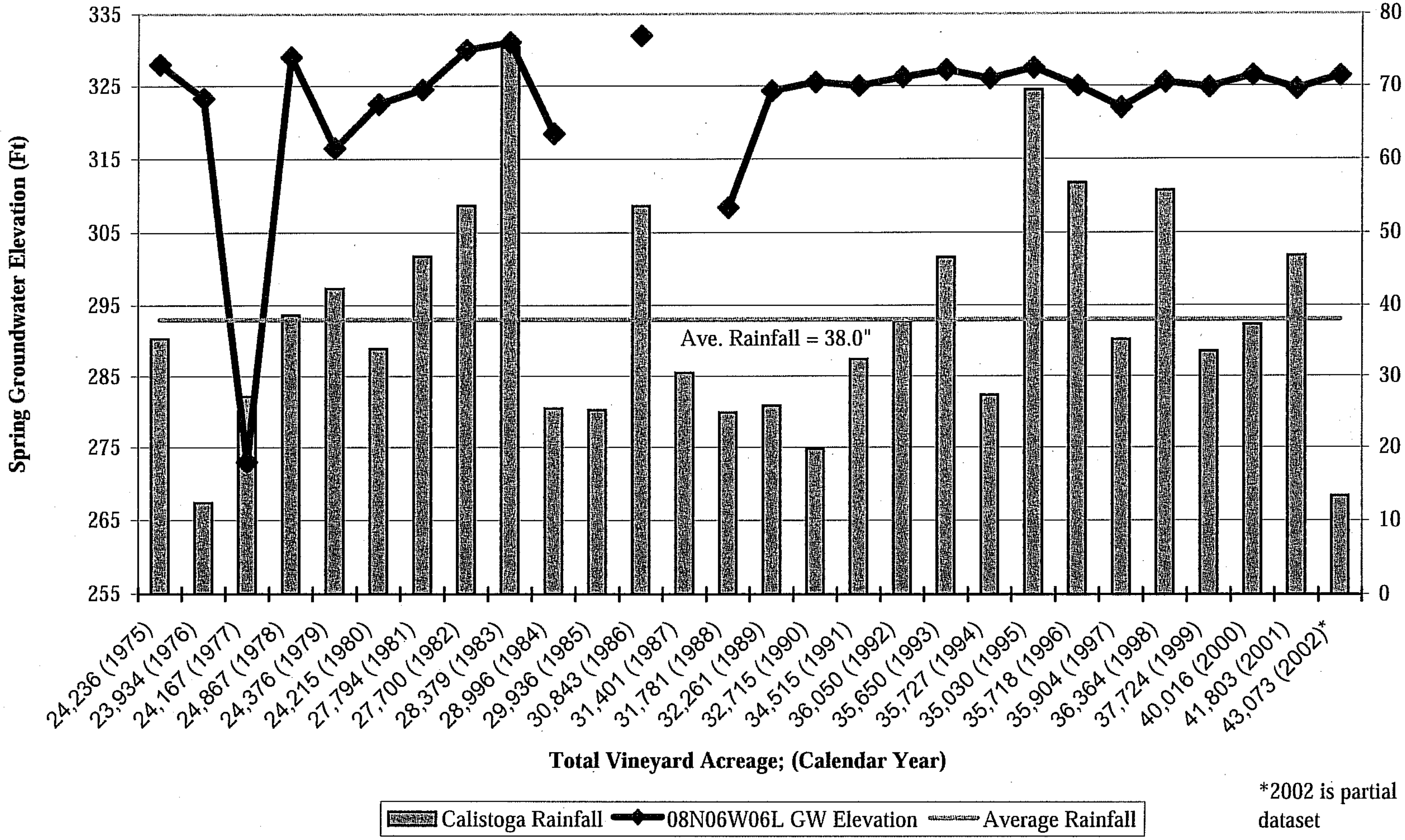
Streambed infiltration zone (Johnson, 1977)

Temporary streamflow-measurment station and station identifier

Figure 10. Locations of streamflow-measurement stations and streambed infiltration zones in the lower Milliken–Sarco–Tulucay Creeks area, southeastern Napa County, California.

# Attachment 6

**Figure 3. Spring Groundwater Elevation**
**Well 08N06W06L near City of Calistoga (1975-2002)**
**Ground Surface Elevation = 335ft MSL**



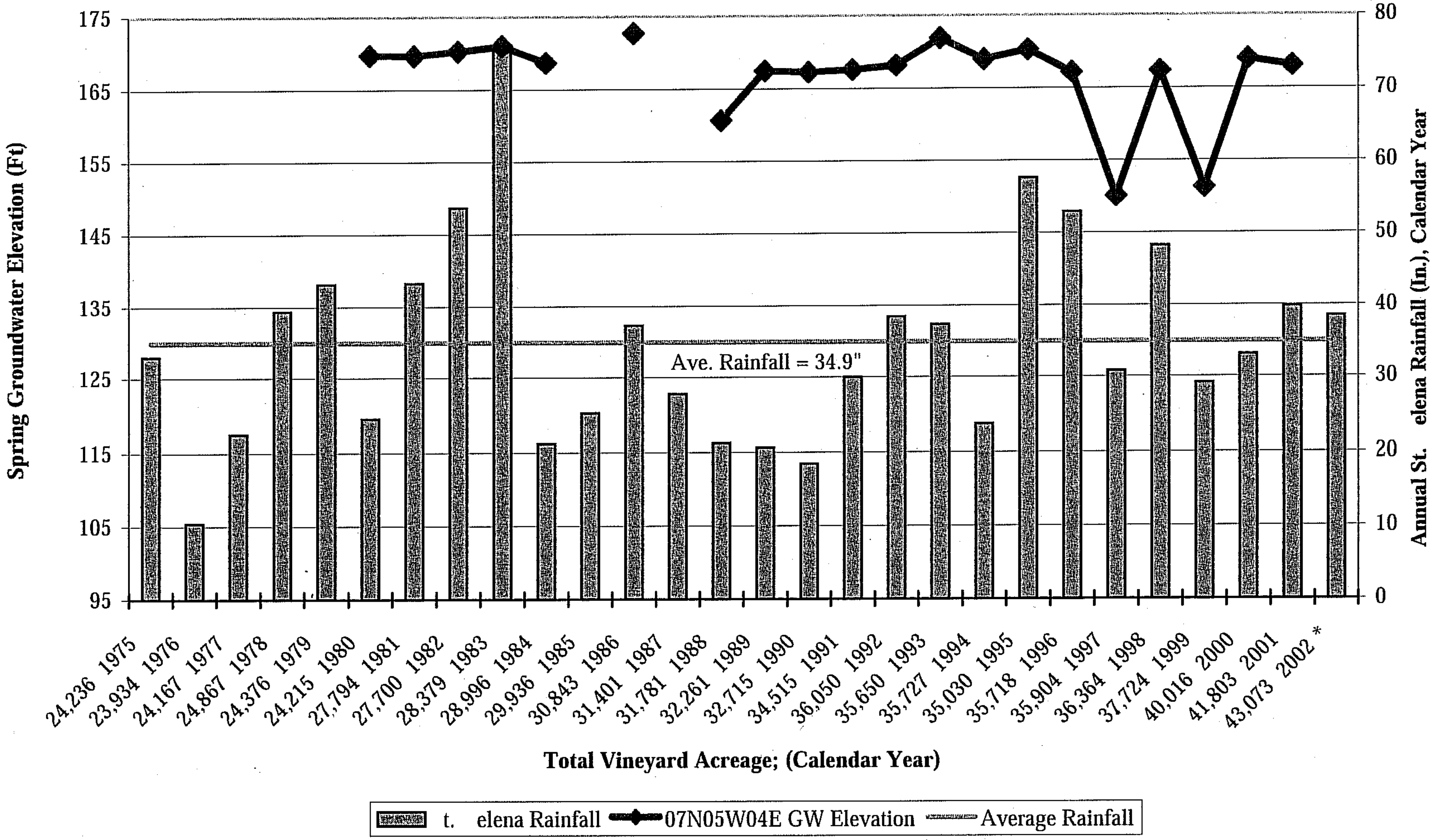

*2002 is partial dataset

J:e/423/TM5
vineyard acreages.xls, 08N06W06L chart Elevation
Last Revised 10/27/04

West Yost & Associates

**FINAL**

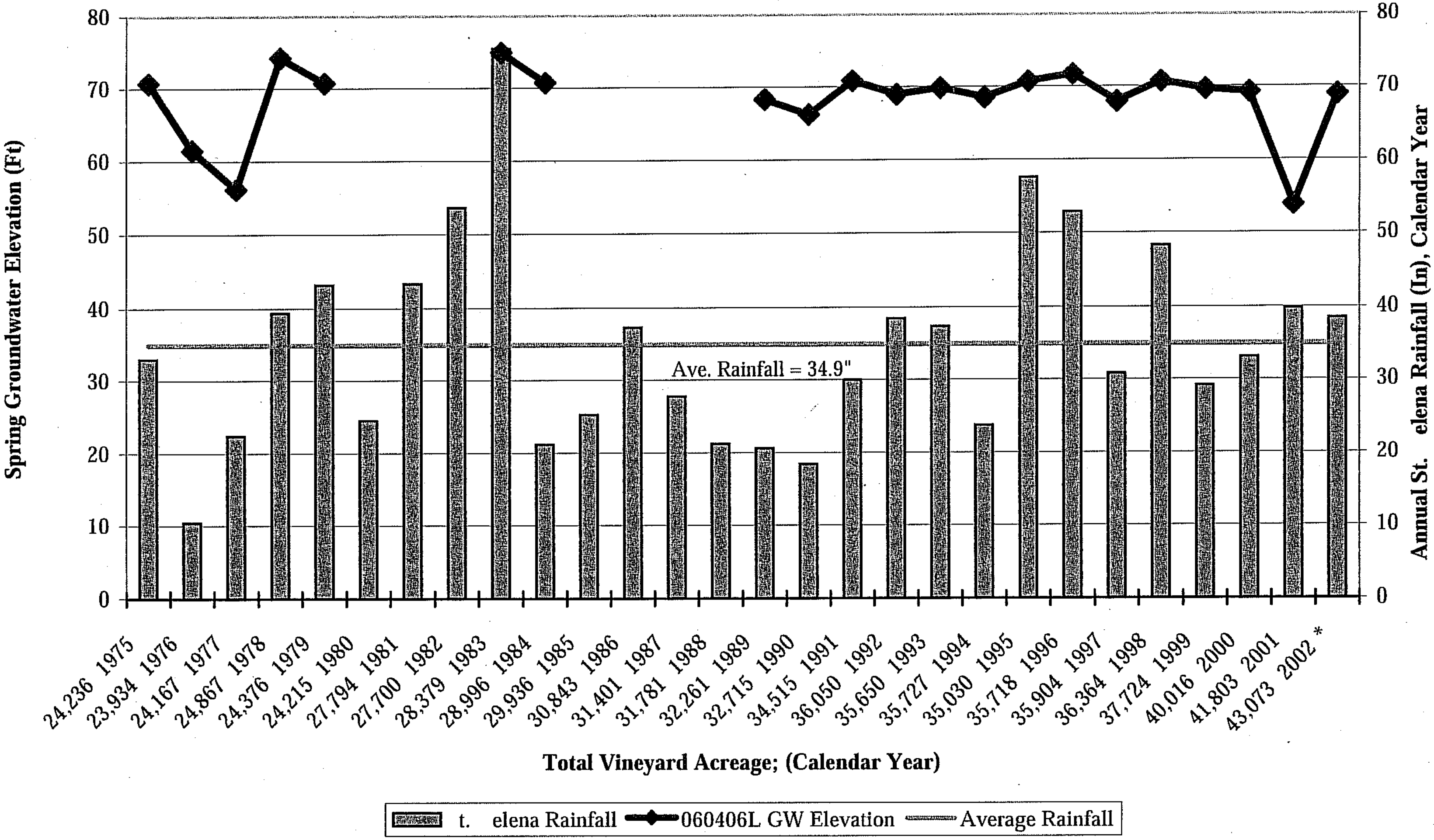
**Figure 5. Annual Spring Groundwater Elevation**
**Well 07N05W0 E near City of St. elena (1975-2002)**
**Ground Surface Elevation = 175 ft MSL**




J:e/423/TM5
vineyard acreages.xls, Chart 070504E elevation
Last Revised 10/27/04

West Yost & Associates

**Figure 7. Annual Spring Groundwater Elevation**
**Well 06N0 W06L near Town of Yountville (1975-2002)**
**Ground Surface Elevation = 80 ft MSL**

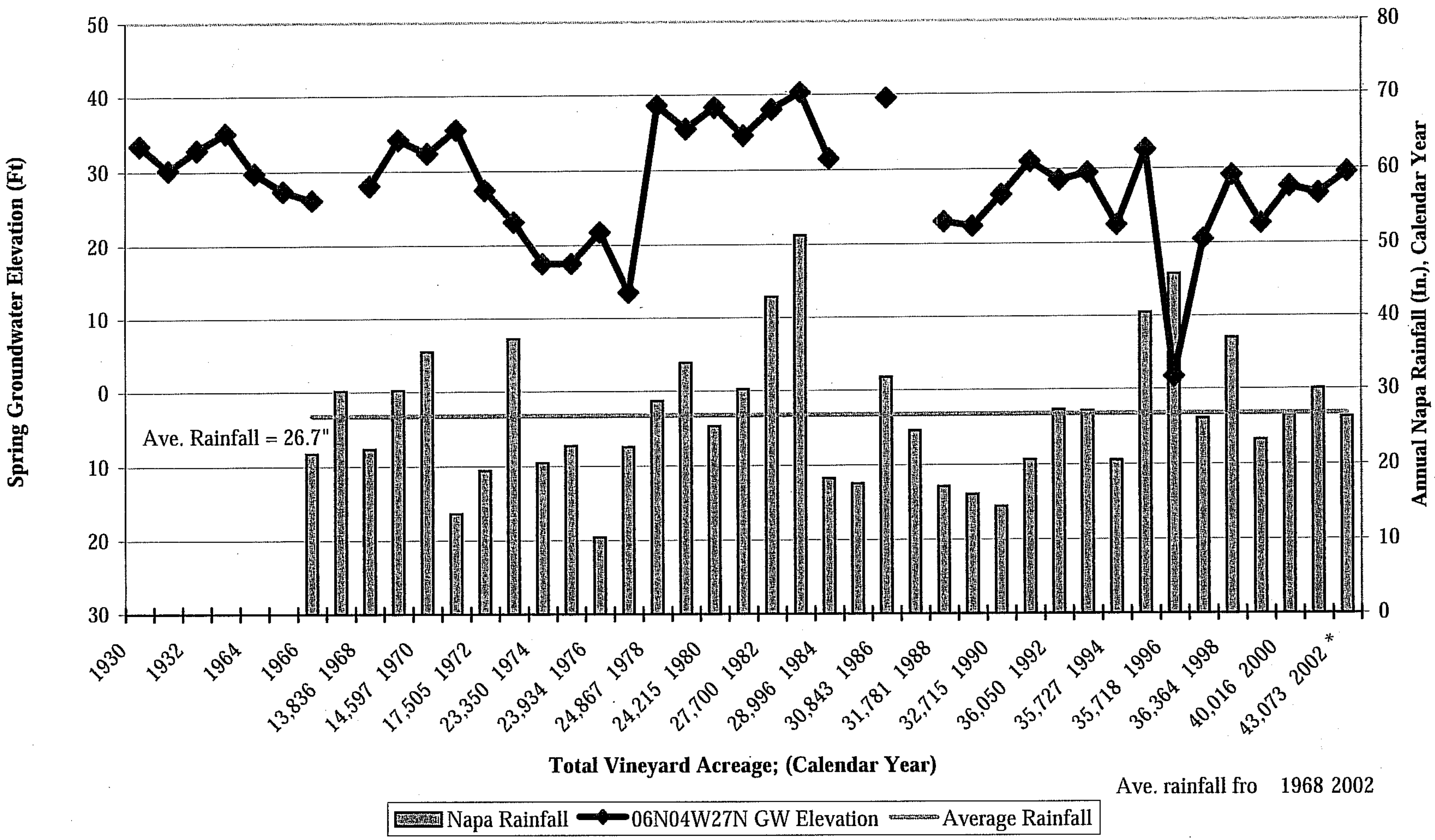



J:e/423/TM5
vineyard acreages.xls, 060406L chart elevation
Last Revised 10/27/04

West Yost & Associates

**FINAL**

# Figure 9. Spring Groundwater Elevation
# Well 06N0 W27N near City of Napa (1930-2002)
# Ground Surface Elevation = 50 ft MSL




J:e/423/TM5
vineyard acreages.xls, 060427N chart elevation
Last Revised 10/27/04

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