6 SUSTAINABLE YIELD ANALYSIS (354.18)

SGMA requires that a water budget be developed for each high or medium priority basin or subbasin (Section 354.18(a)); specifically:

> *Each Plan shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form.*

In addition, SGMA requires that an agency develop "an estimate of sustainable yield for the basin" (Section 354.18(b)(7). Sustainable yield is defined by SGMA as:

> *the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result.*

This Basin Analysis Report presents the results of a base period determination and water budget analyses leading to an estimate of sustainable yield for the Napa Valley Subbasin (Subbasin). The water budget analyses are based on a land use based soil root zone water balance model for the Subbasin and a watershed scale water budget to account for inflows to the Subbasin from the adjoining Napa River Watershed and outflows from the Subbasin to the Napa-Sonoma Lowlands Subbasin.

6.1 Napa Valley Subbasin Hydrologic Base Period

A base period of time must be selected so that it is a representative period of study for groundwater basin conditions, with minimal bias that might result from the selection of a wet or dry period or significant changes in other conditions including land use and water demands. The study period selected for this Report spans from water years[1] 1988 to 2015. This period was selected on the basis of the following criteria: long-term mean annual water supply; inclusion of both wet and dry stress periods, antecedent dry conditions, adequate data availability, and inclusion of current cultural conditions and water management conditions in the basin.

6.1.1 Long-term Mean Water Supply

Long-term mean water supply is a measure of whether the basin has experienced natural groundwater recharge of the selected time period, and the primary measured component that contributes to natural groundwater recharge is precipitation. Daily precipitation records were obtained from the National Oceanic and Atmospheric Administration online data center for Napa State Hospital, St Helena, Angwin, Calistoga, Yountville, and Sonoma gages and from CIMIS for Oakville (locations and stations summaries are shown in **Figure 6-1.**When daily data were not available, they were estimated based on the rainfall at a nearby gage for which a proportional relationship had been determined. Ultimately, two plots with

[1] In this report a water year refers to the period from October 1 through the following September 30, designated by the calendar year in which it ends (e.g., November 1, 1987 and July 1, 1988 are both in the 1988 water year).

annual precipitation, mean annual precipitation and cumulative departure from mean annual precipitation were developed for Napa State Hospital and Calistoga gages (**Figures 6-2** and **6-3)**.

Notable on both of these plots are the long-term relatively dry period from the 1950s through the mid-1970s (negative, or downward slope of the cumulative departure curve), followed a wet late-1970s/early-1980s, dry late-1980s/early-1990s, wet late-1990s/early-2000s, and recently a dry period through 2015. A candidate base period of 1988 to 2015 was considered primarily for the relatively balanced study period lines across the lines of cumulative departure at both the Napa State Hospital and Calistoga gages (**Figures 6-2** and **6-3**). The 1988 to 2015 period includes about the same number of wet and dry years in each precipitation dataset. Nevertheless, the slightly positive slope of the study period line in each plot suggests that precipitation inputs to the Subbasin over the 1988 to 2015 period were not perfectly balanced relative to the long-term average. However, the generally shallow depth to groundwater in the Subbasin (see **Chapter 4**) and drought conditions that have persisted from 2012 to 2015 serve to limit the potential bias imparted by a small net accumulation of precipitation over the 28-year base period..

Additionally, with a long-term (1950-2015) average precipitation of 25.8 in/yr at Napa State Hospital, the selected base period from the 1988 to 2015 has essentially the same average annual precipitation of 26.0 in/yr, and similarly for Calistoga 38.7 in/yr over the selected base period as compared to the longer average of 38.8 in/yr.

Daily average streamflow discharge records were also obtained for Napa River near St. Helena and Napa River Near Napa (**Figure 6-1**). These records were reviewed as part of the base period selection process. Ultimately, discharge records from the Napa River near Napa and Napa River near St. Helena were not utilized for base period selection because of differences in the cumulative departure curves between the streamflow gages and the precipitation gages.

6.1.2 Antecedent Dry Conditions

Antecedent dry conditions is intended to minimize differences in groundwater in the unsaturated zone at the beginning and at the end of the study period. Given that the measure of water in the unsaturated zone is nearly impossible to determine, particularly at the scale of a large groundwater basin, selection of a base period with relatively dry conditions antecedent to the beginning and end is preferable in that any water unaccounted for in the unsaturated zone is minimized. In this case, the selected base periods begins in a dry year with one additional prior dry year and ends in a dry year with 2 prior dry years.

6.1.3 Data Availability

The available hydrologic and land and water use data use over the selected base period are sufficient to calculate the various parameters used to analyze groundwater conditions as related to groundwater budget and sustainability (e.g., precipitation, streamflow, land uses, groundwater pumping, groundwater levels, and imported water sources). Those data are presented in other sections of this report.

6.1.4 Cultural Conditions

For decades, the Napa Valley Subbasin has been dominated by agriculture and wine grape production in particular. It is understood that total acreages of vineyards, other agricultural commodities, and the native and urban footprints in the Valley have remained relatively constant over the selected base period. Land use surveys were conducted by the California Department of Water Resources (DWR) in 1987, 1999, and 2011 during which a comprehensive assessment of specific agricultural, urban, and native land use classes was made in the field by DWR staff. Additionally, in 1987 and 2011, irrigation water source and irrigation methods were identified which will be utilized in later analyses.

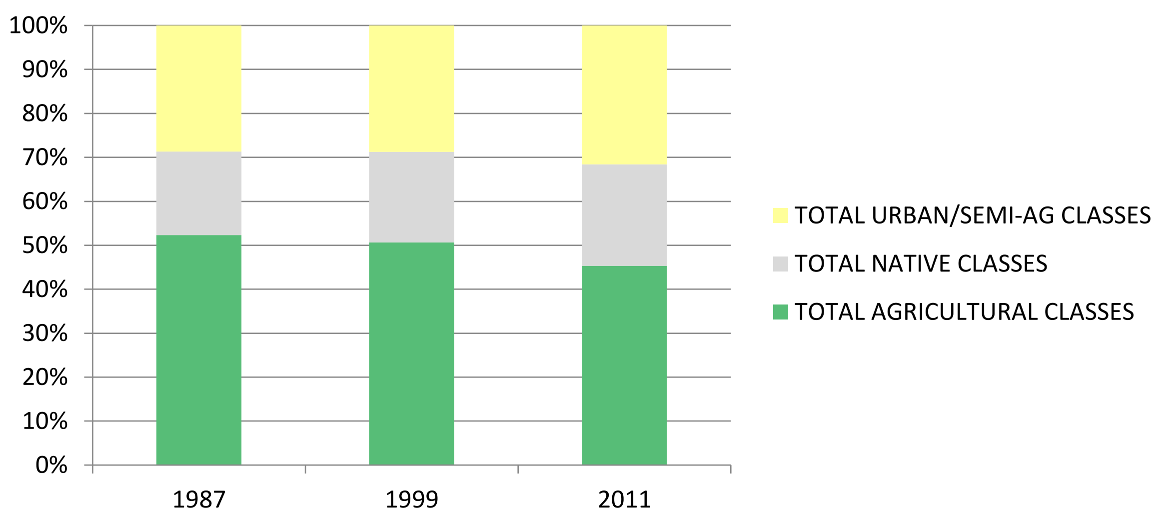
A summary of total acreages by major land use class is shown in **Table 6-1** and depicted in **Figure 6-4**. The native classes (including vegetation and water areas), have seen increased in acreage by 21% over the base period from 8,893 to 10,670. Urban classes have also increased in acreage over the base period from 12,937 to 14,122, an increase of 1,185 acres, or 9%.

Table 6-1. Napa Valley Subbasin Land Use Survey Summaries by Year

	1987 Acres	1999 Acres	2011 Acres
Total Agriculture Classes	24,167	23,333	21,101
Total Native Classes	8,793	9,481	10,670
Total Urban/Semi-Ag Classes	12,937	13,125	14,122
Total Napa Valley*	**45,897**	**45,939**	**45,893**

**Slight differences in total acreage are due to gaps in datasets.*

Figure 6-4. Napa Valley Subbasin Major Land Use Survey Classes by Year



A further summary of the subtotals for agricultural classes is shown in **Table 6-2** and depicted in **Figure 6-5**. As first seen in **Table 6-1**, out of 46,000 acres in the Valley [Subbasin? The “valley” is over 245,000 acres], about half of the total area has been used for agricultural purposes over the base period, ranging between 21,000-24,000 acres. Out of that agricultural acreage, vineyard was the dominant class at about 20,000-22,000 acres (**Table 6-2**). While acreages for each agricultural class declined from 1987 to

2011, the declines were evenly distributed between vineyards (1,551 acre decline) and all other agricultural classes (1,515 acre decline). As a result vineyard acreage increased as a percentage of all agriculture classes (from 90% in 1987 to 95% in 2011), apparently due to conversions of existing agricultural lands. Irrigated acreages across all agricultural classes increased over the same 1987 to 2011 period, due to an increase in irrigated vineyard acreage of 2,591 acres or 15% (**Figure 6-5**). **Figure 6-6** shows a net decrease of 161 irrigated acres across all other agricultural classes, partially offsetting the increase in irrigated vineyard acreage, though some increase in overall agricultural water demand may have occurred.

Table 6-2. Napa Valley Subbasin Agricultural Land Use Survey Summaries by Year

	1987 Acres		1999 Acres		2011 Acres	
Agricultural Class	Non-Irrigated	Irrigated	Non-Irrigated	Irrigated	Non-Irrigated	Irrigated
Vineyard	4,754	16,947	1,051	21,266	612	19,538
Orchard	489	82	80	55	62	87
Pasture	34	213	-	6	-	61
Grain	224	-	105	15	51	16
Truck/Field	-	186	-	57	19	156
Idle	1,238	-	698	-	500	-
Agricultural Sub-totals	**6,739**	**17,428**	**1,935**	**21,398**	**1,2433**	**19,858**

Figure 6-5. Napa Valley Subbasin Agricultural Land Use Survey Vineyard Class by Year – Irrigated Acreage Only

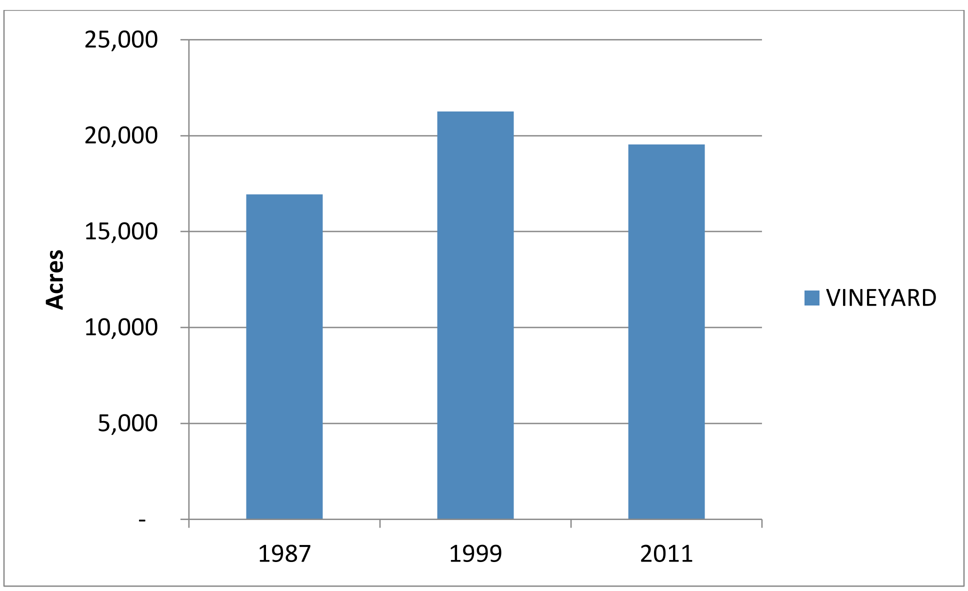
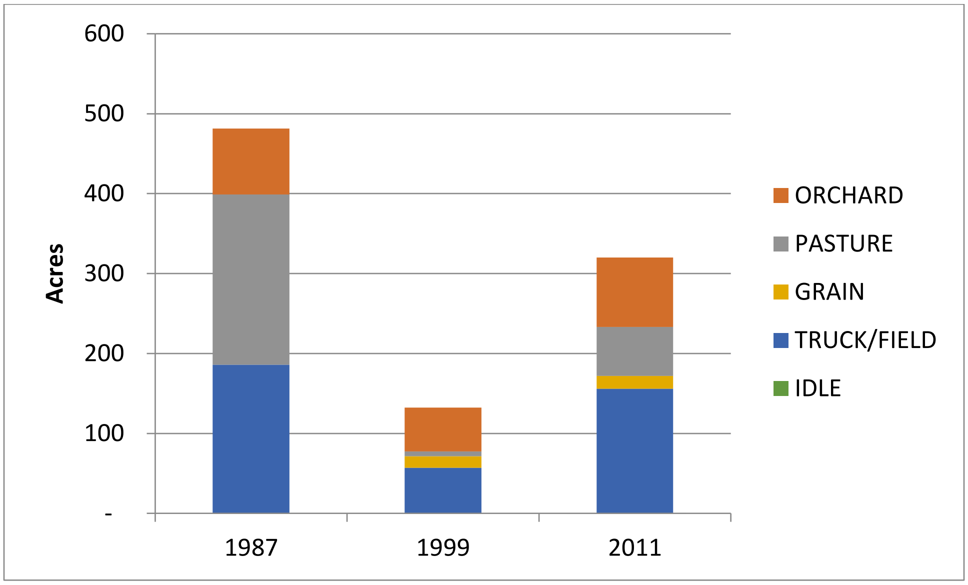


Figure 6-6. Napa Valley Subbasin Agricultural Land Use Survey Non-Vineyard Classes by Year – Irrigated Acreage Only



With relatively stable trends in major land uses, particularly the agricultural classes which are most dependent on water sources within the Subbasin, the selected base period of 1988 to 2015 provides the best period over which to assess the subbasin water budget and changes in water storage.

6.1.5 Water Management Conditions

Water supplies for agricultural and urban entities are currently sourced from groundwater pumped from the Napa Valley Subbasin, surface water diverted and captured off of local water ways within the Napa Valley Watershed, and imported surface water delivered from the State Water Project via the North Bay Aqueduct. Over the selected base period, the major water source for municipal supply has been surface water (see **Chapter 5**), so while the population within the Subbasin has increased from 1988 through 2015, the effect on water supplies within the Subbasin has been limited. For the agricultural sector, water demand is mostly met by groundwater as judged from the 2011 DWR Land Use Survey and reports of surface water diversion filed with the State Water Resources Control Board. The 1987 DWR Land Use survey indicated that agriculture was more reliant on surface water at the beginning of the base period, with about 60% of agricultural classes mapped as using surface water in 1987. However, those diversions of surface water would also have been sourced from the Subbasin, as opposed to reservoirs elsewhere, and would also be reflected in a Subbasin water budget.

Lastly, the selected base period should end near the present time, so that the study period can be used to assess groundwater conditions as they currently exist. Given these criteria, the base period of 1988 to 2015, provides an appropriate period of time to assess groundwater conditions with minimal introduced bias from land use changes or imbalances due to wet or dry conditions.

6.2 Summary of Water Year 2015 Hydrologic Conditions

Water year 2015 concluded with 20.72 inches of rain recorded at the Napa State Hospital reference gage. It was the fourth consecutive year of below average precipitation. **Table 6-3** summarizes recent annual precipitation totals for the Napa State Hospital gage. The precipitation totals shown include estimated totals for gaps in the original record based on correlations with two other gages in the Subbasin. See the Napa County Comprehensive Groundwater Monitoring Program 2015 Annual Report and CASGEM Update for additional information (LSCE, 2016).

Table 6-3. Recent Napa State Hospital Annual Precipitation Totals and Napa River Watershed Water Year Types

Water Year	Annual Precipitation (in)	Water Year Type
2009	21.31	Normal (below average)
2010	28.85	Wet
2011	36.62	Wet
2012	21.75	Normal (below average)
2013	20.26	Normal (below average)
2014	19.67	Dry
2015	20.72	Normal (below average)
Napa State Hospital (NSH) Average Annual Water Year Precipitation (1920 – 2015) = 24.86 inches		

Groundwater level trends in the Napa Valley Subbasin are stable in the majority of wells with long-term groundwater level records. While many wells have shown at least some degree of response to recent drought conditions, the water levels observed in recent years are generally higher than groundwater levels in the same wells during the 1976 to 1977 drought.

Groundwater quality data from wells with long-term records show stable conditions through 2015 compared to the conditions reported previously with data through 2008 (LSCE, 2011). Water quality standard exceedances in the Napa Valley Floor subareas and Napa Valley Subbasin were limited to the naturally-occurring constituent arsenic, with 4 of 26 sites showing maximum concentrations above the MCL of 10 µg/l. Wells with long-term water quality data in the Napa Valley Subbasin show stable TDS and nitrate concentrations, with one exception. Well 06N04W27L002M in the Napa Subarea had a peak of 7.7 mg/L NO3-N (nitrate as nitrogen) in 2011 compared to initial concentrations of 3.4 mg/L NO3-N and 4.0 mg/L NO3-N in 1982 and 1972, respectively.

6.3 Water Budget Framework

A quantitative approach to evaluating groundwater basin conditions is a key component of the requirements for sustainable groundwater management. To this point SGMA specifies that Groundwater Sustainability Plans (GSPs) “shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form." (Section 354.18).

This Basin Analysis Report provides a functionally equivalent evaluation of historical, current, and projected future conditions in the Napa Valley Subbasin (Subbasin). The 28-year base period presented in Section 6.1 encompasses a period of relatively balanced hydrologic conditions and stable water supplies and land uses within the Subbasin. With a stable base period determined, comparable water budget analysis can be performed to evaluate changes in groundwater storage within the Napa Valley Subbasin and assess whether the Subbasin has been operated within its sustainable yield.

The water budget analysis presented here is a comprehensive accounting of hydrologic processes affecting the Subbasin including:

- Surface water inflows to the Subbasin as streamflow from the Napa River Watershed Uplands,
- Surface water inflows to the Subbasin conveyed from municipal reservoirs located in the Napa River Watershed Uplands,
- Surface water inflows to the Subbasin from outside the Watershed through State Water Project facilities,
- Surface water outflows from the Subbasin as runoff and groundwater discharge to the Napa River,
- Groundwater inflows to the Subbasin from groundwater recharge and subsurface inflows from the bedrock of the Napa River Watershed Uplands adjacent to the Subbasin,
- Groundwater outflows from the Subbasin that enter the adjoining Napa-Sonoma Lowlands Subbasin,
- Groundwater outflows due to evapotranspiration and groundwater pumping in the Subbasin, and
- Changes in annual groundwater storage in the Subbasin.

Figure 6-7 shows the location of the Napa Valley Subbasin and Napa River Watershed Uplands (Uplands). The Uplands correspond to those portions of the Napa River Watershed that drain into the Napa Valley Subbasin. This excludes portions of the Napa River Watershed that drain into the Napa-Sonoma Lowlands Subbasin.

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

Figure 6-8 depicts the components and processes represented in the water budget. Inflows to the Subbasin include upland runoff from the surrounding Napa River Watershed, subsurface groundwater inflows from the same upland areas, and precipitation falling on the Subbasin directly. Outflows from the Subbasin include surface water outflow though the Napa River, subsurface groundwater outflow to the Napa-Sonoma Lowlands Subbasin, and evapotranspiration across the surface of the Subbasin. Inflows from upland areas adjacent to the Subbasin and outflows to the Napa-Sonoma Lowlands Subbasin are calculated based on outputs from the California Basin Characterization Model (Flint et al, 2013), streamflow data, and groundwater level data. With the exception of subsurface groundwater outflows, these components are calculated on a monthly time steps. Subsurface groundwater outflows are calculated based on semi-annual groundwater level measurements. Processes that affect the soil root zone including precipitation, infiltration, evapotranspiration, and applied water from groundwater pumping among other sources, are addressed on monthly time steps by a mathematical root zone model developed for this Basin Analysis Report.

6.4 Root Zone Model

A GIS-based Root Zone Model was developed for the Subbasin to account for vertical inflows (recharge) and outflows (pumping) to the Subbasin in response to consumptive uses of water by vegetation. Recharge and pumping are functions of land use, soil, precipitation, and evapotranspiration (ET). Land use is defined by cropping patterns, irrigation status, irrigation method, and irrigation water source. The Root Zone Model calculates recharge and irrigation pumping individually for each mapped land unit. Results are subsequently aggregated to Subbasin-wide totals in monthly time steps. Simulations were run for the entire 1988 – 2015 base period as well a future scenario from 2016 to 2025. The future scenario incorporates downscaled climate model projections for a “hot and low rainfall” condition from 2016 to 2025.

6.4.1 Methodology

The Root Zone Model is based on the water balance within the soil root zone:

$$\frac{\partial S}{\partial t} = p + i - e - y$$

where S is the moisture storage in the soil root zone, p is precipitation, i is irrigation, e is evapotranspiration, and y is yield (e.g. groundwater recharge).

The conceptual framework for the Root Zone Model is described in **Table 6-5**. Runoff is assumed to be negligible within the Subbasin due to the flat topography, and yield y represents groundwater recharge. The amount of water that a soil can store that is available for use by plants is called the available water capacity (AWC). AWC is the water held between field capacity and the wilting point. For each monthly time step and each individual land use unit the Root Zone Model compares the potential evaoptranspiration (ET) to the sum of the initial soil moisture storage and the current month’s precipitation. For irrigated land use units, the model calculates the amount of irrigation that is needed in addition to the initial soil moisture storage and precipitation to meet the potential ET demand. For non-irrigated land use units, calculated actual ET is limited by the sum of the initial soil moisture storage and the current month’s precipitation. A soil moisture retention (SMR) parameter was defined in the Root Zone Model that determines the percentage of AWC to which root zone soil moisture is maintained for irrigated land units. Grismer and Asato state in their 2012 paper on Sonoma vineyard and native vegetation root zone mass balances that wine grape vineyards are typically managed with deficit irrigation, allowing soil water to be substantially depleted to between 20% and 30% capacity. The soil moisture retention parameter was set to 40% for the results presented in this report. Changes to this parameter affect calculated pumping and recharge rates between months with varying hydrological inputs. Groundwater recharge is calculated as the soil moisture beyond field capacity. Recharge is theoretically limited by the saturated hydraulic conductivity (Ksat) of the soil, but mapped Ksat values in the Subbasin are generally higher than average monthly precipitation by more than an order of magnitude.

Three parameter values, grape crop coefficients, rooting depth, and soil moisture retention, were determined to have the greatest potential to effect the Root Zone Model results. Alternative values for these parameters were evaluated in a sensitivity analysis described in **Section 6.8.**

6.4.2 Land Use Model Inputs

The Root Zone Model performs the water balance calculations at the resolution of mapped land use units. Total acreages of vineyards, other lesser agricultural commodities, and the urban footprints in the Valley have remained relatively constant over the selected base period. The Root Zone Model was run based on the 1987 and 2011 Land Use Data from the Department of Water Resources (DWR). DWR's GIS data for 1987 and 2011 land use includes information for land use class, irrigation status, irrigation method, and irrigation water source. **Figure 6-9** and **Figure 6-10** show the 1987 and 2011 Land Use distribution within the Subbasin. The Root Zone Model was run separately using 1987 and 2011 land use data. Model results presented in this report are based on linear interpolation between these two runs, assuming a constant rate at which land use changed between 1987 and 2011. Model results for 2011 and beyond are based on 2011 land use data.

6.4.3 Soil Model Inputs

Available Water Capacity (AWC) and Saturated Hydraulic Conductivity (Ksat) were based on Soil Survey data by the Natural Resources Conservation Service (NRCS). **Figure 6-11** shows the mapped Available Water Capacity in the Subbasin. AWC depends on the mapped soils and land use class-dependent root zone depth. Root Zone depths were based on the NRCS National Engineering Handbook (NRCS, 1983). Available Water Storage is the product of AWC and root depth. Where multiple soil units have been mapped over a single land use unit, these land use units were split to maintain the different land use/soil type combinations. The combination of DWR land use and NRCS soil layers results in over 16,000 geographic units for which the Root Zone Model individually calculates the water balance. **Table 6-6** summarizes the applied root zone depths.

Table 6-5. Root Zone Model Framework

Soil Root Zone Budget Component and Processes	Assumptions	Approach	Data Sources
Root Zone Inflows			
Precipitation	None	Spatially continuous precipitation datasets are queried for monthly precipitation totals across the Subbasin.	BCM (1988 - 2010), PRISM Climate Group (2011 - 2015)
Infiltration	Precipitation falling on the subbasin infiltrates into soils subject to limitation by the saturated hydraulic conductivity of the upper most soil horizon.	Calculated as the difference between infiltration capacity and precipitation.	USDA NRCS Soil Survey Geographic (SSURGO) Database for Napa County (2014)
Applied Water (see Table 6-8)	Irrigated crops and land use units with a landscaping water demand may receive water in addition to precipitation. Source of applied water for a given land use unit (e.g., groundwater, surface water, or recycled water) is determined according to land use mapping.	Water is applied to land use units that have an identified source of irrigation in order to balance outflows due to evapotranspiration with available soil moisture and precipitation for each time step and to maintain a soil moisture content of 50% of total root zone available water content.	DWR 2011 Napa County Land Use Map (delineation of source water type for irrigated land use units)
Root Zone Outflows			
Evapotranspiration	Evapotranspiration occurs on all vegetated and open water (as evaporation only) land use units in the subbasin subject to the vegetation or crop type and the physical properties of soils in the root zone.	Actual evapotranspiration is calculated as a function of potential evapotranspiration, derived from meteorological data, based on the crop coefficient for appropriate crop type for each land use unit.	BCM (1988 - 2010), CIMIS (2011 - 2015)
Runoff	Runoff is assumed to be negligible within the Subbasin due to the flat topography and soil saturated hydraulic conductivity values that are generally higher than average monthly precipitation by more than an order of magnitude.	Assumed to be negligible on the Napa Valley floor.	USDA NRCS Soil Survey Geographic (SSURGO) Database for Napa County (2014)
Groundwater Recharge	Water percolating below the soil root zone is a function of land use derived water demands, soil moisture, and vertical hydraulic conductivity of the soil root zone.	Calculated as the volume of water in the soil root zone above the soil field capacity after accounting for reductions of soil moisture due to evapotranspiration.	*See above*

NOTES:

Total root zone available water content is defined as the volume difference between field capacity and wilting point for each soil unit.

BCM, Basin Characterization Model, is a hydrologic model of developed by the U.S. Geological Survey to simulate hydrologic processes including runoff and groundwater recharge across California.

CIMIS, California Irrigation Management Information System, is a program of the California Department of Water Resources to monitor meteorological conditions and provide data regarding to support efficient irrigation management.

Table 6-6. Assigned Model Root Depths

Land Use Class	Root Depth (feet)
BARREN AND WASTELAND	0.5
CITRUS AND SUBTROPICAL	3
COMMERCIAL	0.5
DECIDUOUS FRUITS AND NUTS	5
FIELD CROPS	3
GRAIN AND HAY CROPS	2
IDLE	2
INDUSTRIAL	0.5
NATIVE VEGETATION	5
PASTURE	2.5
RESIDENTIAL	0.5
RIPARIAN VEGETATION	10
SEMIAGRICULTURAL & INCIDENTAL TO AGRICULTURE	0.5
TRUCK, NURSERY AND BERRY CROPS	2
URBAN	0.5
URBAN LANDSCAPE	0.5
VACANT	0.5
VINEYARDS	3
WATER SURFACE	10

6.4.4 Hydrologic Model Inputs

GIS grids for historical monthly reference ET and precipitation values for 1988 to 2010 were obtained from the California Basin Characterization Model (BCM) at 270 meter resolution. The BCM used hydrologic projections for 2011 and beyond, and historical monthly ET values for 2011 to 2015 were downloaded from the California Irrigation Management Information System (CIMIS) at 5,000 foot spacing linearly interpolated to GIS grids at 270 meter resolution. GIS grids for monthly precipitation values for 2011 to 2015 were obtained from the PRISM Climate Group at 4 kilometer resolution and linearly interpolated to grids at 270 meter resolution. ET and precipitation values from the BCM hot and low rainfall scenario (BayArea_MIROC_esm_rcp85) were also used for 2016 to 2025 for the Root Zone Model future condition evaluation. The Root Zone Model interpolates the mean monthly precipitation and ET values for each mapped land use unit and for each time step.

6.4.5 Crop Coefficient Model Inputs

Crop coefficients were obtained from the Irrigation Training & Research Center (ITRC). ITRC provides adjusted monthly crop coefficients for different crop types, irrigation methods, and relative precipitation year (typical, wet, and dry). The crop coefficients provided by ITRC for water balances include a reduction in ET of approximately 7% to reflect bare spots and reduced vigor typically observed in crops at the landscape scale. The Root Zone Model applies a further reduction for ET of urban land units to reflect the fraction of each land unit that is subject to landscaping (irrigation), shown in **Table 6-7**.

Table 6-7. Fractions of urban land use units assumed to be landscaped (irrigated)

Land Use Classification	Fraction of land use unit assumed to be landscaped (irrigated)
Urban - Urban	
No Subclass	25%
Urban - Commercial	
No Subclass	10%
Hotels	10%
Institutions (hospitals, prisons, reformatories, asylums, etc.)	10%
Motels	10%
Municipal auditoriums, theaters, churches, etc.)	10%
Offices, retailers, etc	10%
Schools (yards to be mapped separately if large enough)	10%
Urban - Industrial	
Extractive industries (oil fields, rock quarries, etc.)	10%
Fruit and vegetable canneries and general food processing	10%
No Subclass	10%
Manufacturing, assembling, and general processing	10%
Sewage treatment plant including ponds.	10%
Storage and distribution (warehouses, substations, etc.)	10%
Waste accumulation sites (public dumps, sewage sludge sites, etc.)	10%
Wind farms, solar collector farms, etc	10%
Urban - Residential	
Multiple family (apartments, condos, townhouses, etc.)	25%
No Subclass	25%
Single family dwellings with a density of 1 unit/acre up to 8+ units/acre.	25%
Single family dwellings with lot sizes greater than 1 acre up to 5 acres	25%
Trailer courts	25%
Urban - Vacant	
Paved areas (parking lots, tennis court areas, auto sales lots, etc.)	5%
Railroad right of way.	5%

The Root Zone Model multiplies the typical crop coefficient that corresponds to the individual land use class and irrigation method (shown in **Table 6-8**) with the interpolated reference ET value to calculate the monthly potential ET.

Table 6-8. Applied Model Crop Coefficients, Kc

Drip/Microspray Irrigation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowers, Nursery and Christmas Tree	1.03	0.40	0.28	0.34	0.41	0.65	0.84	0.93	0.85	0.90	0.57	0.84
Grape Vines with 40% canopy	1.03	0.40	0.38	0.47	0.51	0.42	0.36	0.39	0.18	0.26	0.48	0.85
Melons, Squash, and Cucumbers	1.05	0.39	0.28	0.23	0.26	0.19	0.54	0.79	0.28	0.25	0.51	0.86
Misc. Subtropical	1.03	0.40	0.28	0.34	0.41	0.65	0.84	0.93	0.85	0.90	0.57	0.84
Misc. Deciduous	1.03	0.40	0.28	0.34	0.41	0.65	0.84	0.93	0.85	0.90	0.57	0.84
Strawberries	1.05	0.39	0.50	0.42	0.44	0.92	0.93	0.49	0.00	0.25	0.51	0.86
Sprinkler Irrigation	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Alfalfa Hay and Clover	0.53	0.93	0.97	1.06	1.14	1.19	0.82	0.93	0.94	0.94	0.51	0.74
Corn and Grain Sorghum	0.52	0.36	0.52	0.42	0.41	1.04	1.25	1.00	0.18	0.23	0.35	0.60
Flowers, Nursery and Christmas Tree	0.50	0.37	0.48	0.54	0.86	1.06	0.98	0.88	0.93	0.84	0.60	0.59
Melons, Squash, and Cucumbers	0.52	0.51	0.37	0.55	1.14	1.17	0.53	0.12	0.00	0.23	0.35	0.60
Misc Subtropical	0.51	0.36	0.35	0.37	0.48	0.56	0.51	0.48	0.32	0.24	0.33	0.59
Misc. Deciduous	0.50	0.37	0.48	0.54	0.86	1.06	0.98	0.88	0.93	0.84	0.60	0.59
Misc. field crops	0.52	0.51	0.38	0.46	0.91	1.13	1.04	0.50	0.00	0.23	0.35	0.60
Pasture and Misc. Grasses	0.52	0.70	0.76	0.95	1.12	1.12	1.07	0.98	0.99	0.89	0.65	0.60
Peach, Nectarine and Apricots	0.50	0.37	0.40	0.48	0.82	1.11	1.01	0.95	0.93	0.85	0.38	0.59
Walnuts	0.50	0.37	0.29	0.41	0.51	0.87	1.11	1.07	1.10	0.90	0.62	0.59
Surface Irrigation	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Alfalfa Hay and Clover	1.09	0.98	0.97	0.88	0.90	0.88	0.83	0.85	0.85	0.66	0.80	1.08
Apples, Plums, Cherries etc w/cover crop	1.05	1.02	0.94	0.87	0.99	1.05	1.06	1.07	1.03	1.01	0.88	1.10
Corn and Grain Sorghum	1.08	0.39	0.50	0.42	0.36	0.86	1.07	0.96	0.15	0.25	0.51	0.86
Idle	1.09	0.39	0.28	0.24	0.17	0.06	0.02	0.12	0.00	0.25	0.53	0.87
Melons, Squash, and Cucumbers	1.08	0.63	0.35	0.55	0.97	0.97	0.47	0.12	0.00	0.25	0.51	0.86
Misc Subtropical	1.04	0.40	0.46	0.50	0.74	0.88	0.84	0.86	0.86	0.89	0.88	0.85
Misc. Deciduous	1.04	0.40	0.46	0.50	0.74	0.88	0.84	0.86	0.86	0.89	0.88	0.85
Misc. field crops	1.08	0.62	0.36	0.43	0.79	0.93	0.90	0.46	0.00	0.25	0.51	0.86
Pasture and Misc. Grasses	1.08	0.74	0.72	0.89	0.96	0.93	0.92	0.95	0.91	0.97	0.96	0.86
Safflower and Sunflower	1.08	0.50	0.56	0.91	1.07	0.97	0.28	0.12	0.00	0.25	0.51	0.86
Walnuts	1.04	0.40	0.28	0.39	0.54	0.81	0.95	0.99	0.98	0.93	0.84	0.85

6.4.6 Root Zone Model Results

The results of the Root Zone Model analysis for the base period from the 1988 to 2015 show groundwater recharge to always exceed groundwater pumping within the Subbasin on a year-to-year basis, resulting in a net positive contribution to groundwater storage. Over the base period, average annual groundwater recharge is calculated to be 67,300 acre-feet, while average annual groundwater pumping to meet irrigation demands is 12,800 acre-feet, with an average annual net contribution to groundwater storage of 54,500 acre-feet. **Figure 6-12** shows total annual groundwater storage contributions from the root zone and precipitation from 1988 to 2025.

Table 6-9 summarizes the annual change in Root Zone Model components. **Table 6-10** shows the monthly totals of Root Zone Model components (WY 2010 shown). Precipitation drives recharge during the wet winter months, and the lack of precipitation and high ET during the summer months triggers groundwater pumping. This pattern is evident in **Table 6-10** where groundwater pumping to meet plant needs begins only after available soil moisture, accumulated through precipitation, has been reduced such that continuing evapotranspiration demands and the minimum soil moisture retention parameter require irrigation. In this way, the accumulation of soil moisture over the winter.

Figure 6-12. Root Zone Model total annual groundwater storage change and average precipitation for Subbasin from 1988 to 2025

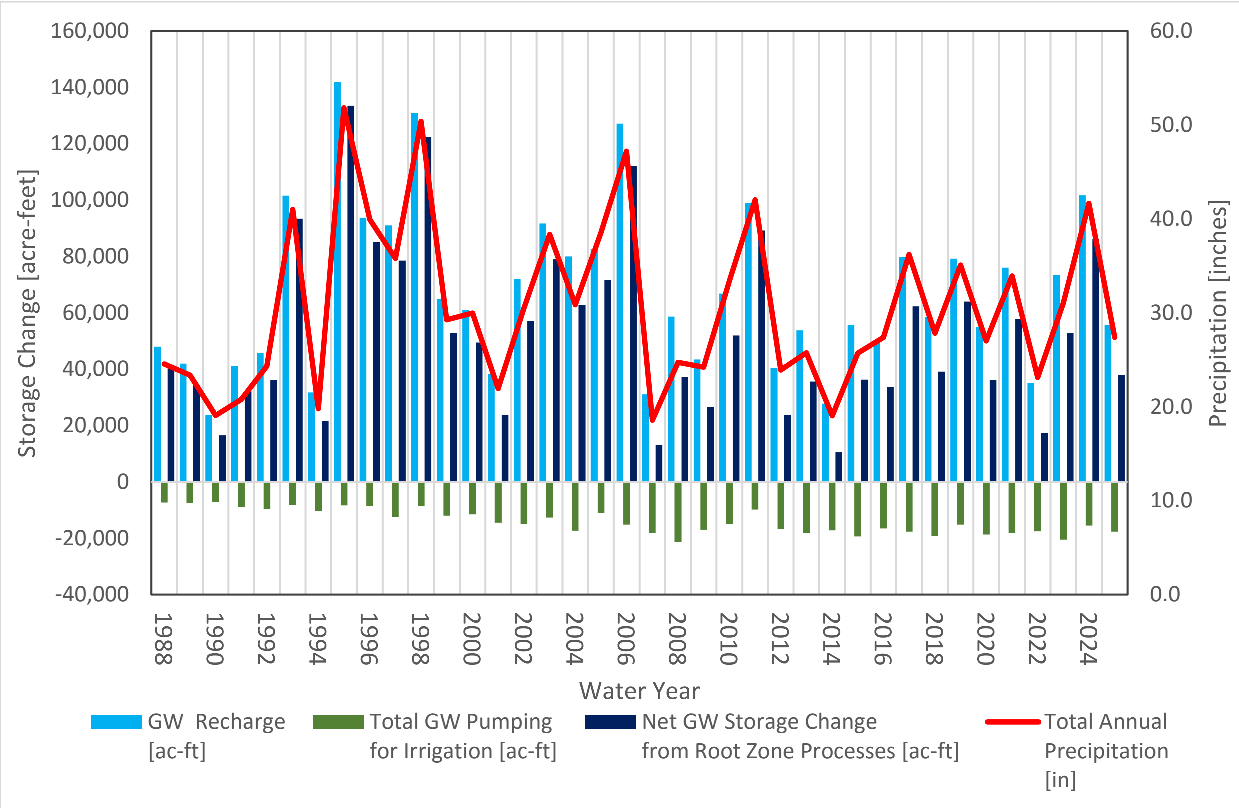


Table 6-9. Annual Change in Root Zone Model Components for Subbasin

Water Year	Total Annual Precipitation [in]	Infiltration from Precipitation [ac-ft]	ET [ac-ft]	GW Recharge [ac-ft]	GW Pumping for Vineyard Irrigation [ac-ft]	Total GW Pumping for Irrigation [ac-ft]	Net GW Storage Change from Root Zone Processes [ac-ft]	SW Water Use for Vineyard Irrigation [ac-ft]	Total SW Water Use [ac-ft]	Reclaimed Water Use [for Vineyard Irrigation [ac-ft]	Total Reclaimed Water Use [ac-ft]	Soil Moisture Change [ac-ft]
1988	24.9	93,886	63,607	48,004	-4,326	-7,296	40,709	-9,183	-10,713	0	0	284
1989	23.7	89,424	63,641	41,905	-4,685	-7,617	34,288	-9,254	-10,711	0	-5	2,210
1990	19.3	72,949	67,343	23,693	-4,277	-7,142	16,550	-7,366	-8,752	-1	-15	-2,177
1991	21.1	79,462	57,775	41,067	-5,647	-8,962	32,105	-8,814	-10,283	-1	-26	-109
1992	24.6	93,091	67,071	45,793	-6,269	-9,597	36,196	-8,751	-10,180	-2	-36	41
1993	41.8	156,943	71,348	101,592	-5,115	-8,224	93,368	-6,492	-7,809	-2	-41	77
1994	20.0	75,723	63,259	31,731	-6,678	-10,241	21,490	-7,546	-8,946	-3	-56	-24
1995	52.7	198,309	71,313	141,807	-5,096	-8,368	133,439	-5,164	-6,408	-2	-58	23
1996	40.3	152,714	73,515	93,731	-5,075	-8,611	85,120	-4,554	-5,809	-2	-69	-42
1997	36.2	136,888	67,077	90,940	-8,419	-12,501	78,439	-7,115	-8,518	-4	-93	-18
1998	51.0	192,783	75,519	130,932	-5,265	-8,600	122,332	-3,878	-5,000	-3	-76	8
1999	29.7	111,957	66,001	64,913	-8,149	-12,042	52,872	-5,530	-6,748	-5	-98	-70
2000	30.3	114,660	71,130	61,016	-7,632	-11,575	49,441	-4,687	-5,884	-5	-107	81
2001	22.3	83,873	67,385	38,168	-10,338	-14,530	23,639	-5,759	-6,971	-7	-122	-57
2002	30.9	116,462	65,965	72,055	-10,495	-14,936	57,118	-5,251	-6,476	-7	-137	-9
2003	39.0	146,697	72,673	91,689	-8,531	-12,696	78,993	-3,784	-4,881	-6	-130	42
2004	31.5	118,089	61,987	79,966	-12,253	-17,275	62,691	-5,041	-6,322	-8	-171	-95
2005	39.1	147,386	79,294	82,653	-7,084	-10,958	71,695	-2,612	-3,566	-5	-127	90
2006	47.8	180,629	73,319	127,108	-10,660	-15,138	111,970	-3,396	-4,442	-8	-158	-60
2007	18.8	71,018	63,136	31,056	-12,854	-18,088	12,968	-3,717	-4,889	-10	-199	2
2008	25.0	94,535	62,743	58,637	-15,911	-21,360	37,277	-4,053	-5,218	-12	-215	-52
2009	24.5	92,661	69,936	43,458	-11,932	-16,960	26,498	-2,623	-3,667	-9	-197	90
2010	33.9	127,954	79,074	66,840	-10,497	-14,904	51,935	-2,009	-2,886	-8	-167	-2
2011	42.7	160,805	73,717	98,955	-5,973	-9,831	89,124	-1,179	-1,927	-4	-140	31
2012	24.4	91,456	71,063	40,436	-12,074	-16,767	23,669	-2,113	-3,033	-9	-186	-57
2013	26.3	98,458	66,493	53,694	-12,827	-18,094	35,600	-2,445	-3,467	-10	-218	50
2014	19.3	72,775	65,678	27,716	-11,868	-17,267	10,449	-2,062	-3,098	-9	-228	-27
2015	26.1	98,383	65,912	55,615	-13,836	-19,319	36,296	-2,528	-3,596	-11	-226	-2
2016	27.8	104,802	74,389	50,119	-11,436	-16,526	33,593	-2,023	-3,016	-9	-202	38
2017	36.8	138,509	79,707	79,883	-12,794	-17,643	62,239	-2,246	-3,199	-10	-190	-48
2018	28.2	106,413	71,042	58,450	-13,905	-19,304	39,146	-2,509	-3,562	-11	-220	7
2019	35.6	134,147	73,126	79,223	-10,178	-15,211	64,012	-1,869	-2,845	-8	-200	55
2020	27.4	103,305	70,871	54,839	-13,307	-18,676	36,162	-2,412	-3,457	-10	-218	-53
2021	34.5	129,707	75,317	76,045	-13,019	-18,174	57,871	-2,355	-3,363	-10	-205	87
2022	23.5	88,501	74,591	34,969	-12,619	-17,578	17,391	-2,218	-3,189	-10	-196	-96
2023	31.5	118,626	69,776	73,355	-14,945	-20,490	52,865	-2,717	-3,800	-11	-227	13
2024	42.3	159,329	76,071	101,694	-10,420	-15,464	86,231	-1,826	-2,804	-8	-201	34
2025	27.8	104,743	70,285	55,648	-12,355	-17,677	37,972	-2,259	-3,295	-10	-216	-2

Table 6-10. Monthly Change in Root Zone Model Components for Subbasin

Year	Month	Initial Soil Moisture [ac-ft]	Total Monthly Precip. [in]	Infiltration from Precipitation [ac-ft]	Available Soil Moisture [ac-ft]	ET [ac-ft]	GW Recharge [ac-ft]	Total GW Pumping [ac-ft]	GW Storage Change [ac-ft]	SW Water Use [ac-ft]	Reclaimed Water Use [ac-ft]	End of Month Soil Moisture [ac-ft]	Soil Moisture Change [ac-ft]
2009	Oct	3,737	4.62	17,663	21,400	7,710	2,142	0	2,142	0	0	11,547	7,810
2009	Nov	11,546	0.74	2,810	14,357	4,151	143	-2	140	0	0	10,066	-1,481
2009	Dec	10,065	3.08	11,585	21,650	3,180	5,496	0	5,496	0	0	12,974	2,910
2010	Jan	12,972	10.77	40,591	53,563	4,217	32,319	0	32,319	0	0	17,026	4,055
2010	Feb	17,028	5.04	18,982	36,010	3,614	14,903	0	14,903	0	0	17,493	465
2010	Mar	17,496	3.10	11,743	29,238	6,411	5,275	0	5,275	0	0	17,552	57
2010	Apr	17,555	4.82	18,121	35,676	11,714	6,529	0	6,529	0	0	17,432	-123
2010	May	17,435	1.67	6,316	23,752	13,973	32	-619	-587	-116	-11	10,493	-6,943
2010	Jun	10,494	0.01	53	10,547	9,575	0	-2,934	-2,934	-524	-23	4,452	-6,042
2010	Jul	4,453	0.00	3	4,456	6,595	0	-4,929	-4,929	-987	-52	3,830	-624
2010	Aug	3,831	0.00	0	3,831	5,467	0	-4,459	-4,459	-876	-46	3,746	-85
2010	Sep	3,747	0.02	89	3,836	2,467	0	-1,962	-1,962	-383	-34	3,748	0

6.5 Subbasin Water Budget

A combined surface water and groundwater budget for the Napa Valley Subbasin was developed utilizing outputs from the Root Zone model as well as other data on Subbasin inflows and outflows that are not represented by root zone processes. **Table 6-11** summarizes the components of the overall Subbasin water budget.

6.5.1 Subbasin Inflows

Groundwater Recharge – Root Zone Model Output

Recharge from overlying soils is a function of land use derived water demands, available soil moisture, and vertical hydraulic conductivity of the soil root zone. Changes in storage in the unsaturated zone below the root zone and above the water table are assumed to be negligible at an annual scale for this analysis.

Uplands Runoff

Runoff from Subbasin soils occurs when precipitation falls in excess of the infiltration capacity of the soils. The Subbasin water budget utilizes runoff calculations from the BCM as the source for runoff from the Uplands into the Subbasin. Years for which BCM results are not available were estimated based on PRISIM precipitation data and the relationship between Uplands precipitation and runoff.

Uplands Subsurface Inflow

Subsurface inflow to the Subbasin from the surrounding bedrock is likely minor relative to the volume of precipitation received in the Subbasin and runoff to the Subbasin from the Uplands. Geologic formations surrounding the Subbasin consist of predominantly low permeability volcanic and sedimentary rocks (see **Chapter 2**). Data relating to subsurface inflow to the Subbasin from surrounding bedrock is limited to the MST. Johnson (1977) estimated that outflow from the MST into the Napa Valley was roughly 2,050 acre-feet per year (afy). Subsequently, Farrar and Metzger (2003) estimated that 600 acre-ft/yr of groundwater was entering the Napa Valley from the MST

Applied Water - Surface Water

The Subbasin water budget implicitly and explicitly considers the fraction of applied surface waters that have the opportunity to become recharge either as applied irrigation or releases to the Napa River from wastewater treatment facilities. **Table 6-12** details the sources of applied water accounted for in the water budget. In some cases, land use mapping designates areas receiving surface water for irrigation. Those land use units are assigned surface water for irrigation purposes subject to the irrigation demand calculated by the Root Zone Model.

Other uses of surface water in the Subbasin are largely for municipal purposes and include surface waters imported from reservoirs in the Uplands and State Water Project facilities. The Subbasin Water Budget assumes that the conveyance of those surface waters from local reservoirs or State Water Project facilities occurs efficiently without seepage losses. Discharges of treated wastewater from the municipalities are implicitly considered by the streamflow gage records from the Napa River near Napa gage, which is downstream of the wastewater treatment facilities that discharge within the Subbasin.

Applied Water – Recycled Water

Recycled water utilization within the subbasin is currently limited to parcels in and near Yountville receiving recycled water from the Town’s wastewater treatment facility. Recycled water deliveries are detailed, based on available data, in Chapter 5. The Root Zone Model calculates recycled water applications based on the irrigation demands for land use units receiving recycled water.

Table 6-11. Napa Valley Subbasin Water Budget Framework

Subbasin Water Budget Component and Processes	Assumptions	Approach	Data Sources	Uncertainties
Subbasin Inflows				
Napa Valley Subbasin Soil Root Zone: Groundwater Recharge	Recharge from overlying soils is a function of land use derived water demands, soil moisture, and vertical hydraulic conductivity of the soil root zone. Changes in storage in the unsaturated zone below the root zone and above the water table are negligible at an annual scale.	Calculated as the volume of water in the soil root zone above the soil field capacity after accounting for reductions of soil moisture due to evapotranspiration and applications of applied water to meet irrigation demands.	Napa Valley Subbasin Soil Root Zone Model	In some areas of the Subbasin, the occurrence of shallow groundwater may limit the actual amount of groundwater recharge calculated by the Root Zone Model that can physically be accepted by the Subbasin. As a result, the Root Zone Model may over allocate groundwater recharge.
Napa River Watershed Uplands: Uplands Runoff, surface runoff from the uplands of the Napa River Watershed to the Napa Valley Subbasin	Runoff from upland areas is represented by the mass balance modeling approach of the BCM.	Calculated as the sum of runoff calculated by BCM throughout the watershed above the Napa Valley Subbasin less the average annual diversion from major reservoirs. Uplands runoff for 2011-2015 was estimated based on PRISIM precipitation data for those years and the relationship between uplands precipitation and runoff calculated by the BCM from 1988 - 2015.	BCM (1988 - 2010), PRISM Climate Group (2011 - 2015)	Although calibrated to four streamflow gage records within Napa Valley, the BCM is a model and subject to uncertainties.
Napa River Watershed Uplands: Uplands Subsurface Inflow, groundwater flow from the geologic units of the Napa River Watershed into the Napa Valley Subbasin	Subsurface inflows are a relatively minor component of total Subbasin inflows, though previous studies have calculated some subsurface inflows along the boundary with the Milliken-Sarco-Tulucay Subarea.	Subsurface inflows are represented by the volume of recharge calculated by the BCM within 270 meters of the Subbasin boundary.	BCM	Subsurface inflows are likely to be highly variable due to the range of permeabilities of geologic formations surrounding the Subbasin. Relative errors for subsurface inflow have been reported to range from 10% to 100%.[1]
Napa Valley Subbasin Soil Root Zone: Applied Water - Surface Water (see subgroup table)	Surface water applications within the Subbasin occur to meet water demands where surface water is a source of supply for irrigated areas within the Subbasin.	Surface water applications are made within the Root Zone Model to meet irrigation demands. Other, non-irrigation uses of surface water are assumed to be for municipal uses which are either implicit in the Napa River above the Napa River near Napa streamflow record or conveyed out of the subbasin to the Napa Sanitation District Treatment Facility.	DWR land use mapping, Napa Valley Subbasin Soil Root Zone Model	Records maintained by the State Water Resources Control Board for surface water diversions from within the Subbasin are incomplete complicating efforts to compare the reported diversion amounts and areas of surface water use with the areas of surface water use mapped by the Department of Water Resources.
Napa Valley Subbasin Soil Root Zone: Applied Water - Recycled Water (see subgroup table)	Recycled water applications within the Subbasin occur to meet water demands where recycled water is a source of supply for irrigated areas within the Subbasin.	Recycled water applications are made within the Root Zone Model to meet irrigation demands.	DWR land use mapping, Napa Valley Subbasin Soil Root Zone Model	Inconsistencies may exist between the areas of recycled water application mapped by the Department of Water Resources and the location of actual deliveries by various suppliers.
Subbasin Outflows				
Napa Valley Subbasin Soil Root Zone: Applied Water - Groundwater Pumping (see subgroup table)	Groundwater pumping within the Subbasin occurs to meet water demands where groundwater is a source of supply for irrigation, municipal uses, wineries in unincorporated areas, and domestic use in the unincorporated areas within the Subbasin.	The Root Zone Model accounts for groundwater pumping from within the Subbasin to meet the water demands of irrigated crops and landscaped land use units when available soil moisture is insufficient to meet evapotranspiration demands. Groundwater pumped to supply non-irrigation water demands (ie., municipal uses, wineries in unincorporated areas, and domestic use in the unincorporated areas within the Subbasin) are calculated outside of the Root Zone Model (see the Applied Water subgroup).	Napa Valley Subbasin Soil Root Zone Model, U.S. Census Bureau, CA Water Plan Update 2013, Napa County Department of Planning, Building, and Environmental Services, City of Napa, City of Yountville, City of St. Helena, City of Calistoga	Groundwater pumping to meet irrigation demands assumes that water is efficiently applied to meet evapotranspiration demands without losses due to irrigation inefficiencies. Some proportion of landscaping irrigation demand within the municipal water system service areas may be met by

Napa Valley Subbasin Stream Channels: Stormflow and groundwater baseflow leaving the subbasin as Napa River discharge	None	The sum of Napa River discharge at the USGS Napa River near Napa gage and runoff from portions of the subbasin calculated by the BCM model.	USGS Napa River near Napa stream gage, BCM (1988 - 2010), PRISM Climate Group (2011 - 2015)	Runoff calculated by the BCM model for portions of the Subbasin below the Napa River near Napa stream gage may under represent the degree of runoff from impermeable surfaces. Relative errors for gaged streamflow have been reported to range from 5% to 10%.[1]
Subbasin Groundwater Outflow: Subsurface groundwater flow to the Napa-Sonoma Lowlands Subbasin	Groundwater outflows to the Napa-Sonoma Lowlands Subbasin take place primarily in the Quaternary alluvium and Quaternary sedimentary basin deposits near the boundary between the two subbasins. Vertical gradients are negligible near the boundary and groundwater flow is horizontal.	Groundwater outflow is calculated based on measured hydraulic gradients near the boundary of the Napa Valley Subbasin and Napa-Sonoma Lowlands Subbasin and estimates of hydraulic conductivity of aquifer materials in the Quaternary alluvium and Quaternary sedimentary basin deposits depicted in Cross Section G - G' of the Napa Valley Updated Hydrogeologic Conceptualization and Characterization of Conditions Report (LSCE and MBK, 2013).	Napa Valley Updated Hydrogeologic Conceptualization and Characterization of Conditions Report (LSCE and MBK, 2013), SWRCB Geotracker network.	Available groundwater elevation data are limited temporally and spatially in the vicinity of the boundary between the subbasins. Although depths to groundwater at two sites with available data are consistent with data at other sites showing shallow depths to groundwater, more frequent data collection at long term monitoring sites could improve the quality of groundwater outflow estimates. Relative errors for subsurface outflow have been reported to range from 10% to 100%.[1]
Subbasin Change in Storage				
The net annual inflow or outflow of groundwater to the Napa Valley Subbasin	Subbasin changes in groundwater storage are not subject to delayed effects of inflows and outflows beyond the scope of the base period.	Calculated as the difference between annual inflows and annual outflows.	Subbasin inflows and outflow as represented in the Napa Valley Subbasin water budget.	

NOTES:

BCM, Basin Characterization Model, is a hydrologic model of developed by the U.S. Geological Survey to simulate hydrologic processes including runoff and groundwater recharge across California.

1 Peters, H.J. 1974. “Ground Water Data”. Ch. 9 in Concepts of Ground Water Management, University of Extension, University of California – Davis, November 14, 1974.

6.5.2 Subbasin Outflows

Applied Water - Groundwater Pumping

The water budget accounts for groundwater pumping to meet irrigation demands, reported municipal pumping, calculated winery demands, and domestic uses in the unincorporated portion of the Subbasin. Groundwater pumping is used to meet irrigation demands according to the evapotranspiration and soil moisture requirement of each irrigated land use unit and soil type, as described in **Section 6.3**.

Municipal groundwater use is detailed in Chapter 5. Currently the City of St. Helena and Town of Yountville have the capacity to pump groundwater from the subbasin. The City of Calistoga formerly pumped groundwater for municipal use, though the wells are no longer in use. The City of Napa does not own any wells that could be used to pump groundwater from the Subbasin and has not utilized groundwater in the past.

Groundwater pumping for indoor domestic uses in unincorporated parts of the Subbasin are calculated in the water budget based the population within those areas and a per capita annual water demand factor of 0.19 acre-feet. The annual population totals for the unincorporated areas were determined first for 2000 and 2010 by spatial analysis of GIS datasets provided by the U.S. Census Bureau. Population estimates for other base period years were made by linearly interpolating based on the ratio of the total population reported for the County by the Census Bureau for years 1990, 2000, 2010, and 2015. Pumping calculated for meeting water demands associated with outdoor uses on residential, commercial, and industrial land uses in unincorporated parts of the Subbasin are determined by the Root Zone Model and are in addition to the amounts calculated based on per capita demand for indoor uses.

Groundwater pumping for winery uses in the unincorporated parts of the Subbasin were calculated based on the County's GIS dataset of active winery permits. Total winery water demands were calculated to include process water for wine production as well as water used for visitation, events, and staffing purposes as documented in the County's GIS dataset.

Streamflow

Streamflow includes both stormwater runoff and baseflow discharges of groundwater conveyed out of the Subbasin through the Napa River and its tributaries. The Subbasin water budget accounts for streamflow through a combination of discharge data from the Napa River near Napa gage operated by the U.S. Geological Survey and runoff calculated by the BCM for portions of the Subbasin below the Napa River near Napa gage.

Groundwater Outflows

Groundwater outflow from the Subbasin is calculated based on measured hydraulic gradients near the boundary of the Napa Valley Subbasin and Napa-Sonoma Lowlands Subbasin and estimates of hydraulic conductivity of aquifer materials in the Quaternary alluvium and Quaternary sedimentary basin deposits depicted in Cross Section G - G' of the Napa Valley Updated Hydrogeologic Conceptualization and Characterization of Conditions Report (LSCE and MBK, 2013).

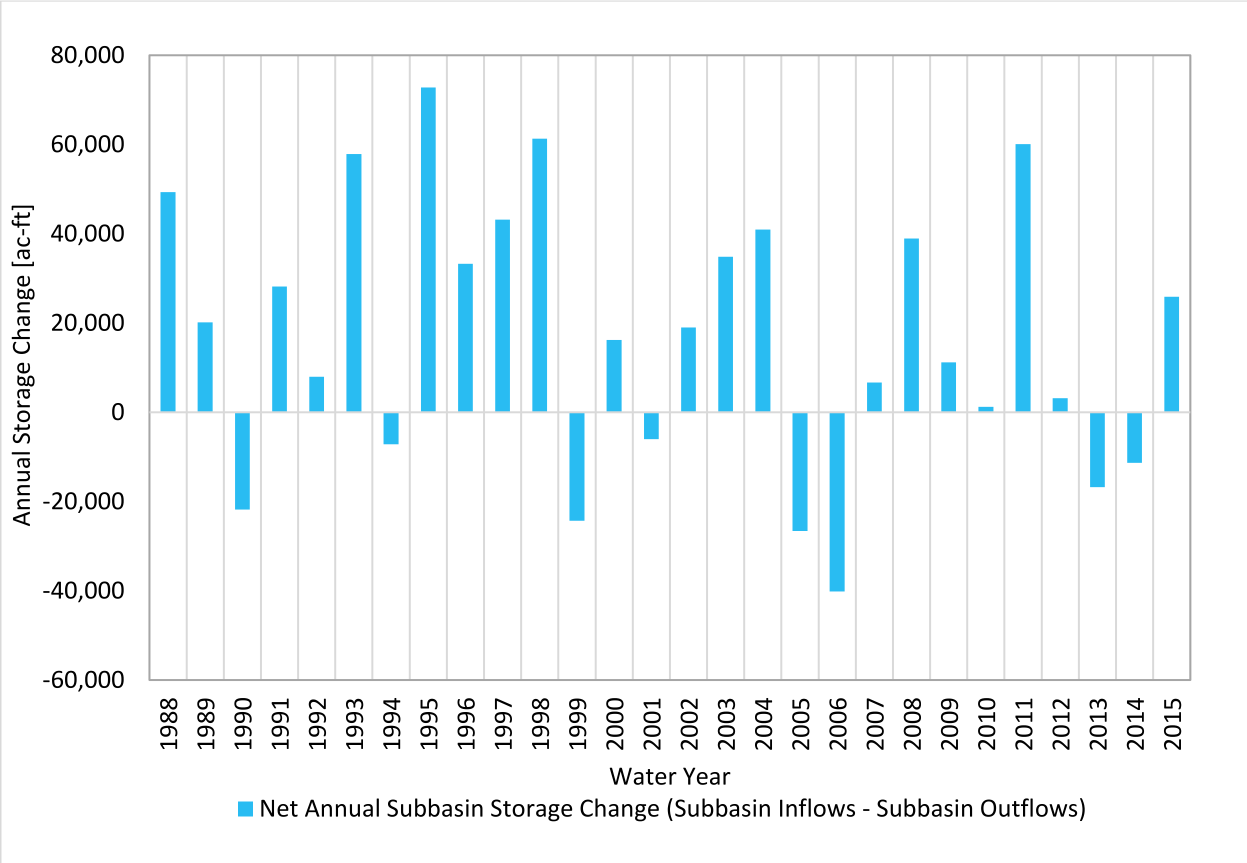
Table 6-12 Sources of Applied Water

Applied Water Component	Process	Assumptions	Approach	Data Sources
Groundwater Pumping	Groundwater pumped from the Napa Valley Subbasin to meet water demands including agricultural irrigation, landscaping irrigation, domestic uses (including those in municipal and unincorporated parts of the Subbasin), and commercial uses including uses by wineries.	Groundwater pumping within the Subbasin occurs only for the purpose of meeting water demands where groundwater is a source of supply within the Subbasin.	Groundwater is pumped from the Subbasin when available precipitation is insufficient to meet the water demands of irrigated crops and landscaped land use units. Groundwater is also pumped to supply other water uses reliant upon groundwater, including demands for domestic uses (in both unincorporated and incorporated areas), commercial and industrial uses within incorporated areas, and wineries in unincorporated areas.	Napa Valley Subbasin Soil Root Zone Model, U.S. Census Bureau, CA Water Plan Update 2013, Napa County Department of Planning, Building, and Environmental Services, City of Napa, Town of Yountville, City of St. Helena, City of Calistoga
Imported Surface Water from the Napa River Watershed Uplands	Water diverted from the Napa River Watershed to municipal reservoirs and later conveyed into to the subbasin by transmission pipes, includes some applications to agricultural lands documented by the municipalities.	Water from municipal reservoirs in the Napa River Watershed outside of the Subbasin is conveyed to the point of use without losses that would affect groundwater recharge or streamflows in the Subbasin.	Reported reservoir diversions are tabulated and presented in Chapter 5.	Napa County Department of Planning, Building, and Environmental Services, City of Napa, Town of Yountville, City of St. Helena, City of Calistoga
Imported Surface Water from the State Water Project (though the North Bay Aqueduct)	Water imported to the Napa Valley Subbasin from sources outside the Napa River Watershed to supply municipal water uses.	Water imported to the Subbasin from the State Water Project is conveyed to the point of use without losses that would affect groundwater recharge or streamflows in the Subbasin.	Reported reservoir diversions are tabulated and presented in Chapter 5.	Napa County Department of Planning, Building, and Environmental Services, City of Napa, Town of Yountville, City of St. Helena, City of Calistoga
In-subbasin Surface Water Diversions	Diversions of instream flow by water users with points of diversion located within the Napa Valley Subbasin.	Water diverted from instream flows in the Subbasin are reported accurately to the State Water Resources Control Board. (see Water Budget Framework Table for notes about uncertainty related to these data.)	Reported reservoir diversions are tabulated and presented in Chapter 5.	State Water Resources Control Board
Recycled Water (includes applications for municipal landscaping and agricultural irrigation)	Water re-applied to meet water demands in the Napa Valley Subbasin following treatment at municipal wastewater facilities.	Recycled water applications in the Subbasin are reported accurately to the State Water Resources Control Board.	Reported deliveries of recycled water are tabulated and presented in Chapter 5.	Town of Yountville, Napa Sanitation District

6.6 Subbasin Water Budget Results

The Subbasin water budget results show variations in Net Subbasin Storage from year to year that are largely driven by fluctuations in the Uplands Runoff and Streamflow components (**Figure 6-13** and **Table 6-13**). The water budget accounts for surface water and groundwater inflows to and outflows from the Subbasin. The magnitude of the surface water components, particularly uplands runoff and surface water outflow and baseflow, demonstrate that large quantities of water move through the Subbasin in most years as compared to the amounts of water pumped from the Subbasin or flowing out of the Subbasin as subsurface outflow. Average annual changes in storage over the base period are positive, demonstrating that current groundwater pumping below the sustainable yield for the Subbasin. However, the magnitude of annual changes in storage as well as the average annual change in storage indicate the effect of water budget component uncertainties.

Figure 6-13. Net Annual Subbasin Storage Change, 1988 - 2015



Data on groundwater levels in the Subbasin show stable trends during the base period. The average annual change in storage volume calculated by the water budget suggest an accrual of water within the subbasin that is not consistent with the stable spring to spring groundwater levels observed. The most likely explanations for this discrepancy are that inflows are overstated, outflows are understated, or some combination of the two.

Total groundwater pumping represented in the Subbasin water budget is greater than the groundwater pumping calculated by the Root Zone Model due to the addition of groundwater pumping demands from residential indoor water uses in unincorporated parts of the Subbasin, groundwater uses by wineries in unincorporated portions of the Subbasin, as well as municipal pumping (**Table 6-14**). The growth over time in groundwater pumping for irrigation is primarily due to the change in water sources for irrigated land uses between 1987 and 2011, which show a growth in acreages supplied by groundwater.

Table 6-13. Napa Valley Subbasin Annual Water Budget Results, 1988 – 2015 Hydrologic Base Period

		Subbasin Inflows				Subbasin Outflows				
	Water Year (10/1 - 9/30)	Upland Runoff [1] [ac-ft]	Uplands Subsurface Inflow [2] [ac-ft]	Imported Surface Water Deliveries [3] [ac-ft]	GW Recharge [4] [ac-ft]	Total GW Pumping [5] [ac-ft]	Urban Wastewater Outflow [6] [ac-ft]	Surface Water Outflow and Baseflow [7] [ac-ft]	Groundwater Outflow [8] [ac-ft]	Net Annual Subbasin Storage Change (Subbasin Inflows - Subbasin Outflows) [ac-ft]
Drier than Average	1988	94,896	5,030	14,345	48,004	9,171	7,800	76,981	19,000	49,323
	1989	58,157	4,082	14,696	41,905	9,501	7,800	62,384	19,000	20,156
	1990	3,841	1,349	14,809	23,693	9,035	7,800	29,662	19,000	-21,805
	1991	104,893	3,182	10,688	41,067	10,862	7,800	93,978	19,000	28,190
	1992	57,083	3,702	12,135	45,793	11,505	7,800	72,475	19,000	7,933
	1993	244,844	9,321	13,412	101,592	10,141	7,800	274,376	19,000	57,852
	1994	20,113	3,090	13,227	31,731	12,165	7,800	36,333	19,000	-7,137
Wetter than Average	1995	435,257	10,899	14,104	141,807	10,301	7,800	492,201	19,000	72,766
	1996	220,799	9,360	14,938	93,731	10,552	7,800	268,233	19,000	33,243
	1997	282,973	7,922	16,377	90,940	14,450	7,800	313,825	19,000	43,136
	1998	342,444	10,794	15,209	130,932	10,557	7,800	400,675	19,000	61,346
	1999	170,571	6,304	16,631	64,913	14,007	7,800	241,891	19,000	-24,280
	2000	119,720	5,099	16,595	61,016	13,549	7,800	145,837	19,000	16,243
Variable: Dry, Normal, and Wet	2001	63,694	2,716	17,771	38,168	16,535	7,800	85,009	19,000	-5,995
	2002	129,462	6,952	18,000	72,055	16,973	7,800	163,659	19,000	19,037
	2003	213,239	7,490	17,209	91,689	14,764	7,800	253,180	19,000	34,883
	2004	209,955	8,409	16,954	79,966	19,375	8,102	227,874	19,000	40,933
	2005	134,711	8,676	16,166	82,653	13,089	8,838	227,877	19,000	-26,598
	2006	254,046	12,809	16,732	127,108	17,301	8,102	406,435	19,000	-40,142
	2007	88,278	3,044	17,076	31,056	20,283	7,734	85,752	19,000	6,686
	2008	118,340	5,421	17,977	58,637	23,586	7,365	111,450	19,000	38,974
	2009	71,664	3,356	16,649	43,458	19,218	8,102	77,639	19,000	11,167
	2010	119,127	6,460	15,832	66,840	17,194	8,470	162,384	19,000	1,212
	2011	259,516	9,321	15,560	98,955	12,130	8,102	284,036	19,000	60,084
Drier than Average	2012	86,127	5,030	16,305	40,436	19,075	7,365	99,316	19,000	3,142
	2013	104,044	5,421	16,540	53,694	20,412	7,365	149,683	19,000	-16,760
	2014	37,120	1,349	14,473	27,716	19,594	7,365	46,032	19,000	-11,334
	2015	102,099	5,421	12,349	55,615	21,655	6,629	102,283	19,000	25,918
	Average:	**148,108**	**6,143**	**15,456**	**67,327**	**14,892**	**7,798**	**178,266**	**19,000**	**17,078**

[1] Upland runoff is the sum of surface water inflows to the Napa Valley Subbasin from the Napa River Watershed, an output of the California Basin Characterization Model, less the amounts withheld by large reservoirs in the watershed

[2] Mountain Front Recharge is the BCM calculated groundwater recharge in areas adjacent to the Subbasin border.

[3] Imported surface water deliveries are the sum of surface water imported to the Subbasin by municipalities, excluding the amounts used for irrigation determined by the Root Zone Model.

[4] Groundwater recharge represents the fraction of infiltration that drains into the Napa Valley subbasin from the root zone as calculated by the Root Zone Model.

[5] Total groundwater pumping is the sum of groundwater pumping calculated by the root zone model to meet irrigation demands and additional pumping for non-irrigation uses including winery operations, rural residential domestic use, and municipal uses.

[6] Urban wastewater outflow is the volume of municipal wastewater conveyed by pipeline out of the Subbasin to the Napa Sanitation District.

[7] Surface water outflow and Baseflow is the sum of measured streamflow discharge at the USGS Napa River near Napa gage and runoff calculated by the USGS Basin Characterization Model (BCM) for Upland areas that are not within the watershed gaged by the USGS gage.

[8] Groundwater outflow is the flow of groundwater from the unconsolidated formations of the Napa Valley Subbasin to the Napa-Sonoma Lowlands Subbasin calculated based on measured groundwater level gradients and a geologic cross section of the Napa Valley Subbasin.

Table 6-14. Napa Valley Subbasin Calculated Annual Groundwater Pumping, 1988 – 2015 Hydrologic Base Period

		Groundwater Pumping, All Demands						
	Water Year (10/1 - 9/30)	Municipal[1] [ac-ft]	Unincorporated Area Residential Indoor Uses[2] [ac-ft]	Semi-Ag, Residential, and Commercial Unincorporated Areas, Irrigation[3] [ac-ft]	Unincorporated Area Wineries, Indoor Uses[4] [ac-ft]	Vineyard Irrigation[3] [ac-ft]	Other Ag Irrigation g[3] [ac-ft]	Total GW Pumping [ac-ft]
Drier than Average	1988	334	654	1,966	1,222	4,326	670	9,171
	1989	334	662	1,938	1,222	4,685	660	9,501
	1990	334	670	1,932	1,222	4,277	599	9,035
	1991	334	678	2,304	1,222	5,647	677	10,862
	1992	270	686	2,410	1,222	6,269	648	11,505
	1993	105	695	2,434	1,222	5,115	570	10,141
	1994	292	703	2,642	1,222	6,678	628	12,165
Wetter than Average	1995	205	711	2,515	1,222	5,096	552	10,301
	1996	195	719	2,753	1,222	5,075	587	10,552
	1997	262	727	3,184	1,222	8,419	636	14,450
	1998	237	735	2,603	1,222	5,265	494	10,557
	1999	264	744	3,060	1,222	8,149	569	14,007
	2000	373	752	3,023	1,222	7,632	547	13,549
Variable, Dry to Wet	2001	467	783	3,150	1,222	10,338	574	16,535
	2002	349	815	3,511	1,222	10,495	581	16,973
	2003	476	846	3,147	1,222	8,531	542	14,764
	2004	499	878	3,899	1,222	12,253	624	19,375
	2005	382	910	3,050	1,222	7,084	442	13,089
	2006	410	941	3,552	1,222	10,660	516	17,301
	2007	521	973	4,138	1,222	12,854	575	20,283
	2008	479	1,004	4,355	1,222	15,911	615	23,586
	2009	508	1,036	4,011	1,222	11,932	509	19,218
	2010	320	1,067	3,650	1,222	10,497	438	17,194
	2011	227	1,077	3,287	1,222	5,973	345	12,130
Drier than Average	2012	179	1,086	4,054	1,222	12,074	460	19,075
	2013	334	1,095	4,428	1,222	12,827	505	20,412
	2014	334	1,105	4,470	1,222	11,868	595	19,594
	2015	334	1,114	4,619	1,222	13,836	530	21,655

[1] Municipal groundwater pumping reflects values reported by Calistoga, St. Helena, and Yountville and includes pumping for all water uses and users served by those municipalities.

[2] Groundwater pumping for residential indoor uses is calculated based on the population of the unincorporated portions of the Subbasin and an average per capita demand of 0.19 ac-ft/year.

[3] Irrigation related groundwater pumping demands outside of the Subbasin municipalities is calculated by the Root Zone Model

[4] Groundwater pumping by wineries in the unincorporated is based on a dataset of permitted wineries as of 2015 and includes estimates of water use for winemaking, wine tasting, visitation, and events. Data for prior years were not available, so the 2015 value is applied across the base period.

6.6.1 Qualitative Consideration of the Napa-Sonoma Lowlands Subbasin

Outflows from the Napa Valley Subbasin enter the Napa-Sonoma Lowlands Subbasin through Napa River flow (including stormflows and groundwater baseflow) and subsurface flow of groundwater. Subsurface groundwater outflows are likely between ten thousand and twenty thousand acre-feet per year, based on the outflow analysis conducted with groundwater level data collected from 2005 – 2013 (see **Section 6.5.2**). Surface water outflows vary seasonally with the largest discharges occurring during winter and spring storm flows.

6.7 Groundwater Level Change in Storage Analysis

The water budget analysis presented in this **Section 6.2** is complemented by an analysis of changes in groundwater storage computed separately through observed changes in groundwater levels over the base period. Results from the groundwater level change in storage analysis provide a means to check the results of the water budget analysis by comparison with the average annual changes in storage computed by the water budget.

6.7.1 Groundwater Contours and Potentiometric Surfaces for Key Base Period Years

Available groundwater level data from wells completed in the alluvium were extracted from the Napa DMS and plotted spatially on a map to assess coverage. To achieve satisfactory coverage, it was necessary to interpolate over the extent of the alluvial basin by creating auxiliary points just beyond the extent of the basin. Additionally, some wells near the basin boundary did not have water level data present for each year of the base period. Therefore, an estimated measurement of depth to water was developed using regression analysis. The groundwater level data used for this analysis are summarized in **Table 6-15**. The locations of the data points are shown in **Figure 6-14**.

A depth to the base of the aquifer grid was developed (**Figure 6-15**) from mapped alluvium isopach contours and geologic cross sections (LSCE and MBK, 2013), and a depth to water grid was developed for each year of the base period (2015 shown in **Figure 6-16**). By raster algebra within GIS, a difference grid between the base of the alluvium and the top of the water table was calculated for each year to determine a volumetric change in saturated aquifer volume for each year. Groundwater storage was calculated by multiplying the saturated aquifer volume with an estimated specific yield of 6% (Kunkel and Upson, 1960).

The resulting annual changes in storage are shown along with annual total precipitation in **Figure 6-17**. The calculated net change in storage over the base period of 1988 to 2015 is +3,398 acre-feet. The largest decrease in storage of -18,919 acre-feet was calculated for 1991. The largest increase in storage of +25,509 acre-feet was calculated for 1992. Large year-to-year changes in calculated groundwater storage are likely in part related to the sparsity of available groundwater level data and the uncertainty of the interpolated depth to water grids. However, groundwater level storage change calculated with this method appears to follow trends in precipitation records for the base period.

Figure 6-17. Groundwater Level Change in Storage

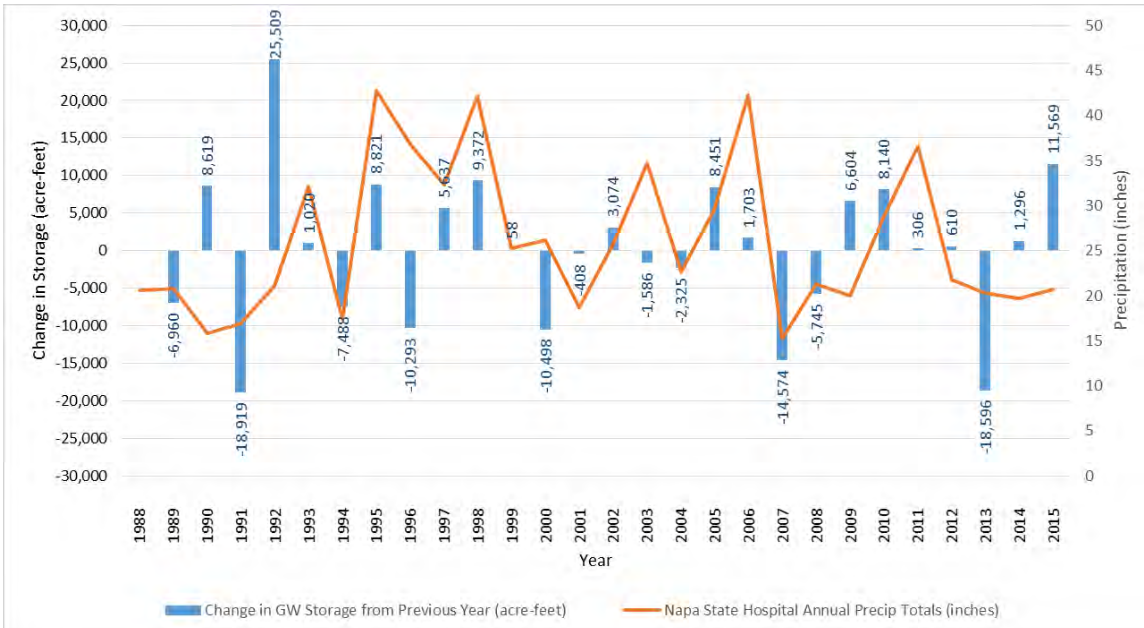


Table 6-15. Spring Water Levels (Depth, feet)

Well ID	RPE[7]	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
NapaCounty-127-AUX[6]	392.5	10.9	8.5[1]	13.9	7.8	7.9	11.2[1]	12.0	7.4[1]	7.5	7.6[1]	5.0[1]	5.0[1]	6.6	7.7	8.6	15.2	33.8	6.7	5.5	8.6	7.1	7.2	7.1	7.6	7.2	10.4	11.1	14.3	13.4
NapaCounty-127	392.5	10.9	8.5[2]	13.9	7.8	7.9	11.2[2]	12.0	7.4[2]	7.5	7.6[2]	5.0[2]	5.0[2]	6.6	7.7	8.6	15.2	33.8	6.7	5.5	8.6	7.1	7.2	7.1	7.6	7.2	10.4	11.1	14.3	13.4
NapaCounty-128	343.7	9.5		7.5	12.5		7.6	7.9		6.0				6.7	7.2	6.8	6.0	7.5	5.6	4.5	7.9	8.4	7.2	5.2	6.3	4.9	9.1	6.0	6.5	6.3
NapaCounty-129	338.7	27.6		10.5	14.7	9.8	8.8	10.0		11.1				9.5	11.4	9.6	8.2	10.4	7.0	6.2	10.5	14.0	10.0	6.0	8.3	9.2	9.6	13.8	8.7	7.0
NapaCounty-203	304.0																											24.9		
08N06W10Q001M	293.4	7.7	6.9	6.7	9.1	5.9	8.8	7.0	6.2	3.8	6.3	4.5	4.5	6.0	6.5	8.7	7.3	7.2	6.2	6.0	7.4	7.4	7.2	6.7	7.2	7.2	6.9	11.2	7.5	
NapaCounty-222s-swgw5	218.5																												25.1	22.8
07N05W09Q002M	158.2	13.1	15.4	16.0	20.8	11.3	10.0	14.6	13.7	10.0	11.9	9.4	10.2	12.0	16.3	11.7	12.9	11.8	10.4	9.5	18.2	13.5	16.3	14.0	12.7	19.0	14.9	31.9	15.5	
NapaCounty-132	142.7	11.6		14.4	21.8	9.2	9.3	13.6		8.5	42.2			10.1	22.8	11.8	11.7	10.8	9.2	8.2	19.6		19.4	12.3	10.1	12.2	14.7	25.7	16.1	13.0
NapaCounty-131	173.5	25.4		19.1	48.5	12.5	13.7	14.2		11.9				11.5	15.7	16.8	15.0	14.5	9.4	7.3	34.0	19.5	15.8	12.2	9.4	13.1	31.5	21.2	17.7	10.0
NapaCounty-138	195.1	16.4		8.0	71.1	9.0	7.0	13.5		7.3				16.4	12.4	9.9	8.1	12.6	6.7	7.8	12.6	41.0	11.8	6.4	8.6	6.5	79.2	6.3	9.3	6.9
NapaCounty-204	141.7																												20.0	18.2
NapaCounty-177	149.3																											9.7	9.7	8.7
NapaCounty-220s-swgw4	99.7																												15.4	10.2
NapaCounty-133	94.7	14.0		16.6	22.5	8.9	8.9	13.0		8.2	11.3			8.5	11.4	9.2	8.8	9.2	7.4	8.0	14.6	17.7	10.1	7.0	8.4	7.5	11.3	18.0	10.5	8.4
NapaCounty-179	74.3																											20.2	14.4	10.0
NapaCounty-180	76.9																											22.3	15.1	
06N04W17A001M	70.3	18.9	36.3	28.1	24.0	9.0	5.5	15.8	5.9	1.3	6.6	4.2	3.8	5.0		6.5	6.8	6.3	4.3	2.0	22.4	27.7	16.0	10.9	4.6	8.2	13.7	23.3	12.6	
NapaCounty-218s-swgw3	52.8																												20.9	13.9
NapaCounty-216s-swgw2	105.8																												21.4	15.0
NapaCounty-139	85.8	13.4		16.5	28.2	9.8	8.8	15.0		7.5	10.0			9.0	11.9	8.9	8.7	9.4	8.2	7.3	14.8	11.9	11.4	8.0	7.9	9.5	11.3	19.0	12.2	9.3
NapaCounty-135	129.2	21.0		18.8	21.0	21.2	21.0	22.0		34.5				41.5	16.7	23.2	30.8	23.5	23.5	18.8	25.4	29.0	33.8	29.0	28.0	29.8	44.5	77.8		30.8
NapaCounty-185	83.0																											22.6		16.5
NapaCounty-183	48.9																											15.2	11.1	10.7
NapaCounty-190	73.8																												25.0	
NapaCounty-75	41.2	27.6		47.9	30.3	26.3	8.5	28.5		24.2				27.8	28.8	32.7	49.3	45.0	35.2		41.9	55.1	46.9	46.1	38.7	44.2	45.7	53.2		
06N04W27L002M	53.6	30.9	32.9	30.6	34.5	36.1	32.5	29.9	24.0	21.2	25.7	23.0	22.2	27.0	27.3	25.1	22.2	25.8	25.8	21.7	34.9	27.5	29.3	27.7	24.5	31.8	28.3	41.0	29.7	
NapaCounty-152	78.3																									6.8	14.8	10.8	11.0	9.0
NapaCounty-136	53.2	27.5	28.4[3]	23.9	36.5	22.0	21.0	28.0	20.0[3]	48.8	21.6[3]	19.1[3]	18.3[3]	22.9	23.8	21.0	20.7	23.6	15.0	17.8[3]	24.2	32.6	27.0	18.6	19.6	17.4	29.9	23.5	24.5	19.5
NapaCounty-214s-swgw1	22.1																												16.9	16.3
NapaCounty-18	124.3	22.3[4]	22.7[4]	20.9[4]	26.0[4]	20.1[4]	19.7[4]	22.5[4]	19.3[4]	31.0[4]	19.9[4]	18.9[4]	18.6[4]	17.1	18.0	19.2	19.1	20.5	19.0	18.4[4]	20.0	23.2	22.5	18.5	19.3	17.2	21.8	21.8	23.5	23.5
NapaCounty-18-AUX[6]	124.3	22.3[5]	22.7[5]	20.9[5]	26.0[5]	20.1[5]	19.7[5]	22.5[5]	19.3[5]	31.0[5]	19.9[5]	18.9[5]	18.6[5]	17.1	18.0	19.2	19.1	20.5	19.0	18.4[5]	20.0	23.2	22.5	18.5	19.3	17.2	21.8	21.8	23.5	23.5

[1] Constant depth to water was assumed northward/downstream from NapaCounty-127
[2] Estimated using linear regression between NapaCounty-127 and 08N06W10Q001M
[3] Estimated using linear regression between NapaCounty-136 and 06N04W27L002M
[4] Estimated using linear regression between NapaCounty-18 and NapaCounty-136
[5] Constant depth to water was assumed southward/downstream from NapaCounty-18
[6] Auxiliary data point to achieve water level interpolation covering entire sub-basin
[7] Reference Point Elevation

6.8 Sensitivity Analysis

Root Zone Model

The Root Zone Model estimates recharge and pumping as functions of input data including land use, soil, precipitation, and evapotranspiration (ET), as well as model parameters for crop coefficients, effective root zone depth, and soil moisture retention for irrigated land use units. The uncertainties in each of these input data and parameters translate into uncertainties in model results. The Root Zone Model results presented in this report are based on typical (relative precipitation year) ITRC crop coefficients listed above in **Table 6-8**, root zone depths listed in **Table 6-6**, and soil moisture retention (SMR) of 40%. Root Zone Model results are sensitive to changes to each of each parameter. Model parameters can be calibrated to improve model results (e.g., to minimize the difference between estimates of groundwater pumping and measured pumping data when they are available). **Table 6-16**, **Table 6-17**, and **Table** 6**6-18** show the model sensitivity for estimated average annual vineyard irrigation (sum of groundwater, surface water, and reclaimed water) in the Subbasin from 2005 to 2014 to changes to crop coefficients, effective root depths, and minimum maintained soil moisture.

Table 6-16. Crop Coefficient Sensitivity Analysis Results (with 3 ft grape root depth, and 40% SMR)

Crop Coefficients	Average Annual Vineyard Irrigation WY 2005-2014 (ac-ft/ac)	Kc											
		January	February	March	April	May	June	July	August	September	October	November	December
ITRC, Dry Year, Grape Vines with 40% canopy	0.60	0.76	1.06	0.90	0.51	0.39	0.38	0.34	0.27	0.19	0.10	0.76	0.71
ITRC, Typical Year, Grape Vines with 40% canopy	0.70	1.03	0.40	0.38	0.47	0.51	0.42	0.36	0.39	0.18	0.26	0.48	0.85
ITRC, Wet Year, Grape Vines with 40% canopy	0.90	0.98	1.00	0.80	0.80	0.75	0.44	0.35	0.27	0.20	0.17	0.84	0.89
Williams VSP (Oakville 2000)	0.73	1.03	0.40	0.38	0.14	0.21	0.33	0.45	0.51	0.55	0.26	0.48	0.85
Williams Wye (Oakville 2000)	1.55	1.03	0.40	0.38	0.20	0.47	0.69	0.79	0.83	0.83	0.26	0.48	0.85

Table 6-17. Grape Root Depth Sensitivity Analysis Results (with ITRC Typical Year Crop Coefficients, and 40% SMR)

Grape Root Depth (ft)	Average Annual Vineyard Irrigation WY 2005-2014 (ac-ft/ac)
1	0.91
2	0.79
3	0.70
4	0.61
5	0.53

Table 6-18. Soil Moisture Retention Sensitivity Analysis Results (with ITRC Typical Year Crop Coefficients, and 3 ft grape root depth)

Minimum Maintained Soil Moisture	Average Annual Total Vineyard Irrigation WY 2005-2014 (ac-ft/ac)
60%	0.79
50%	0.74
40%	0.70
30%	0.66
20%	0.61

Groundwater Level Change in Storage Analysis

The groundwater level change in storage analysis estimates fluctuations in groundwater storage based on changes in measured groundwater levels. The relationship of uncertainties in groundwater levels and uncertainties in groundwater storage estimates is:

$$\pm\text{Groundwater Level } \times \text{Subbasin Area } \times \text{Specific Yield} = \pm\text{Groundwater Storage}$$

For example, an uncertainty in groundwater levels of 1 foot across the Subbasin would result in:

$$\pm 1\text{ foot } \times 45{,}900\text{ acres } \times 6\% = \pm 2{,}754\text{ acre-feet}$$

The uncertainty in applied groundwater levels are due to errors in recorded values at monitoring locations, and to a larger degree due to uncertainty in interpolated levels for areas in between monitoring locations. Available groundwater levels from 30 monitoring locations were interpolated over the extent of the alluvial basin. An increase in the number of monitoring locations would improve accuracy of future groundwater level change in storage analysis estimates.

The uncertainty in the applied value for specific yield across the Subbasin affects groundwater storage change estimates as follows:

$$\pm\text{Specific Yield} \times \text{Groundwater Level Change} \times \text{Subbasin Area} = \pm\text{Groundwater Storage Change}$$

For example, an uncertainty of ±1% in the applied value for specific yield at a change in groundwater levels of 1 foot across the Subbasin would result in an uncertainty in storage change estimates of ±459 acre-feet:

$$\pm 1\ \% \times 1\text{ foot } \times 45{,}900\text{ acres} = \pm 459\ \text{ acre-feet}$$

6.9 Napa Valley Subbasin Sustainable Yield

Long-term conditions in the Napa Valley Subbasin, during the 1988 to 2015 base period, have been marked by stable land uses and stable supplies of imported surface water. Groundwater utilization has increased over time. Results from the Root Zone Model and water budget analyses as well as the groundwater level change in storage analysis show positive average annual changes in storage over this period. The stability of groundwater levels observed during recent drought conditions, from 2012 through 2015, indicate that rates of groundwater pumping over that period have not exceeded the sustainable yield of the Subbasin as it is currently managed. As a result, the sustainable yield has been approximately 20,000 acre-feet per year. The sustainable yield is not considered to be constant value (DWR, 2003). It could change with variations in water budget components or as a result of management decisions. Those changes could lead to increased or decreased sustainable yields in the future. Updated evaluations of Subbasin conditions will continue to account for the sustainability goal and sustainability indicators.

REFERENCES

California Irrigation Management Information System (CIMIS). Available online at http://www.cimis.water.ca.gov, and CIMIS Web API at http://et.water.ca.gov. Accessed August 9 2016

California Landscape Conservation Cooperative (CALCC), 2014 California BCM (Basin Characterization Model) Downscaled Climate and Hydrology - 30-year Summaries. Available online at http://climate.calcommons.org/dataset/2014-CA-BCM. Accessed March 2 2016.

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

Flint, L.E., A.L. Flint, J.H. Thorne, R. Boynton, 2013. Fine-scale hydrologic modeling for regional landscape applications: the California Basin Characterization Model development and performance. Ecological Processes, 2(25).

Grismer M. and C. Asato. 2012. Converting oak woodland or savanna to vineyard may stress groundwater supply in summer. California Agriculture, 66(4).

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

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

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

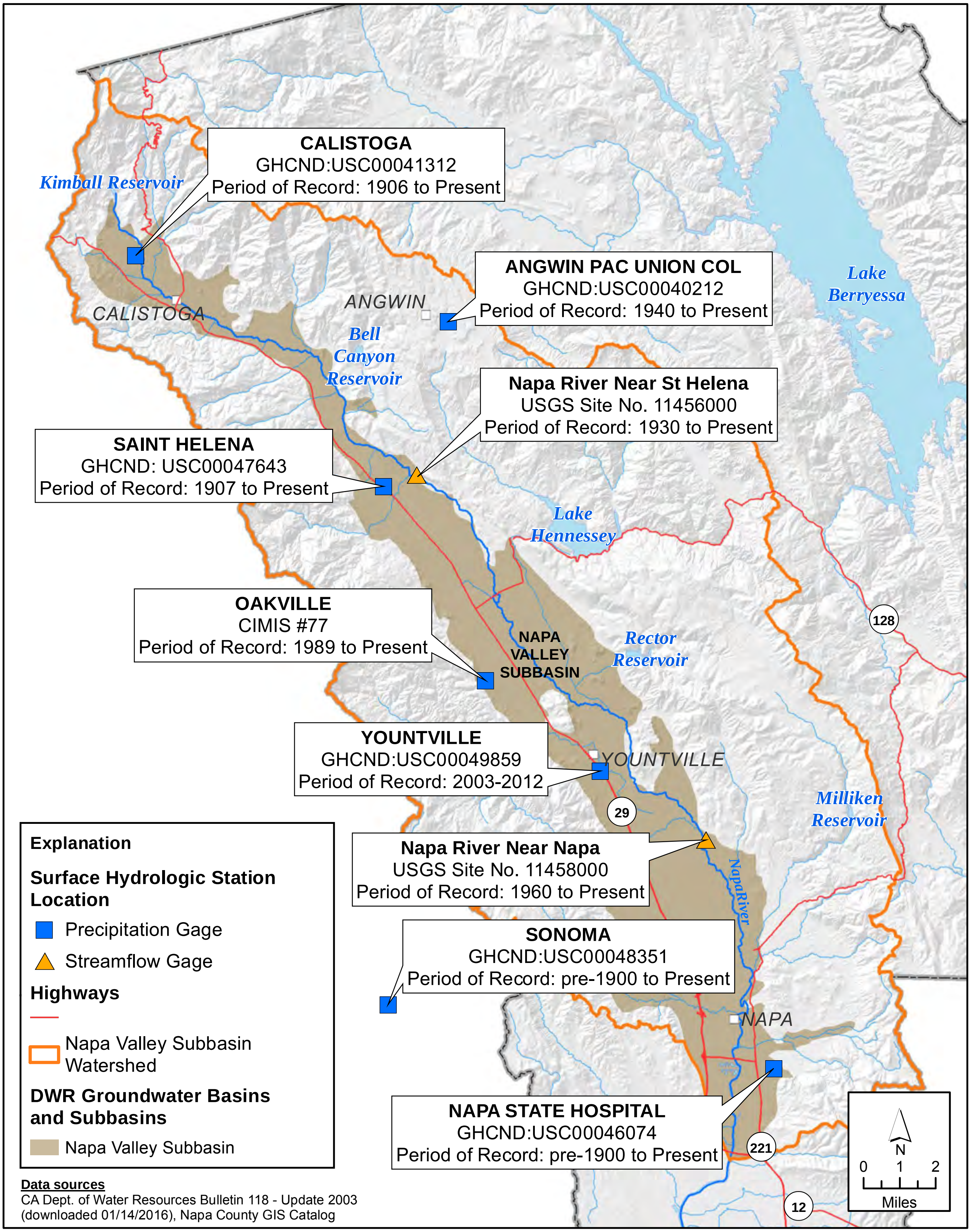
Luhdorff & Scalmanini, Consulting Engineers (LSCE). 2016. Napa County comprehensive groundwater monitoring program 2015 annual report and CASGEM update, prepared for Napa County Department of Public Works, March 2016.

LSCE and MBK Engineers. 2013. Updated hydrogeologic conceptualization and characterization of conditions in Napa County Natural Resources Conservation Service (NRCS).

Natural Resources Conservation Service, United States Department of Agriculture, 1983. National Engineering Handbook, Chapter 11, Section 15

Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database. Available online at http://sdmdataaccess.nrcs.usda.gov/. Accessed August 15 2016.

PRISM Climate Group, Oregon State University. Available online at http://prism.oregonstate.edu. Accessed August 9 2016.



Data sources
CA Dept. of Water Resources Bulletin 118 - Update 2003 (downloaded 01/14/2016), Napa County GIS Catalog

X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Figure 6-1 Sfc Hydro Station Location Map.mxd

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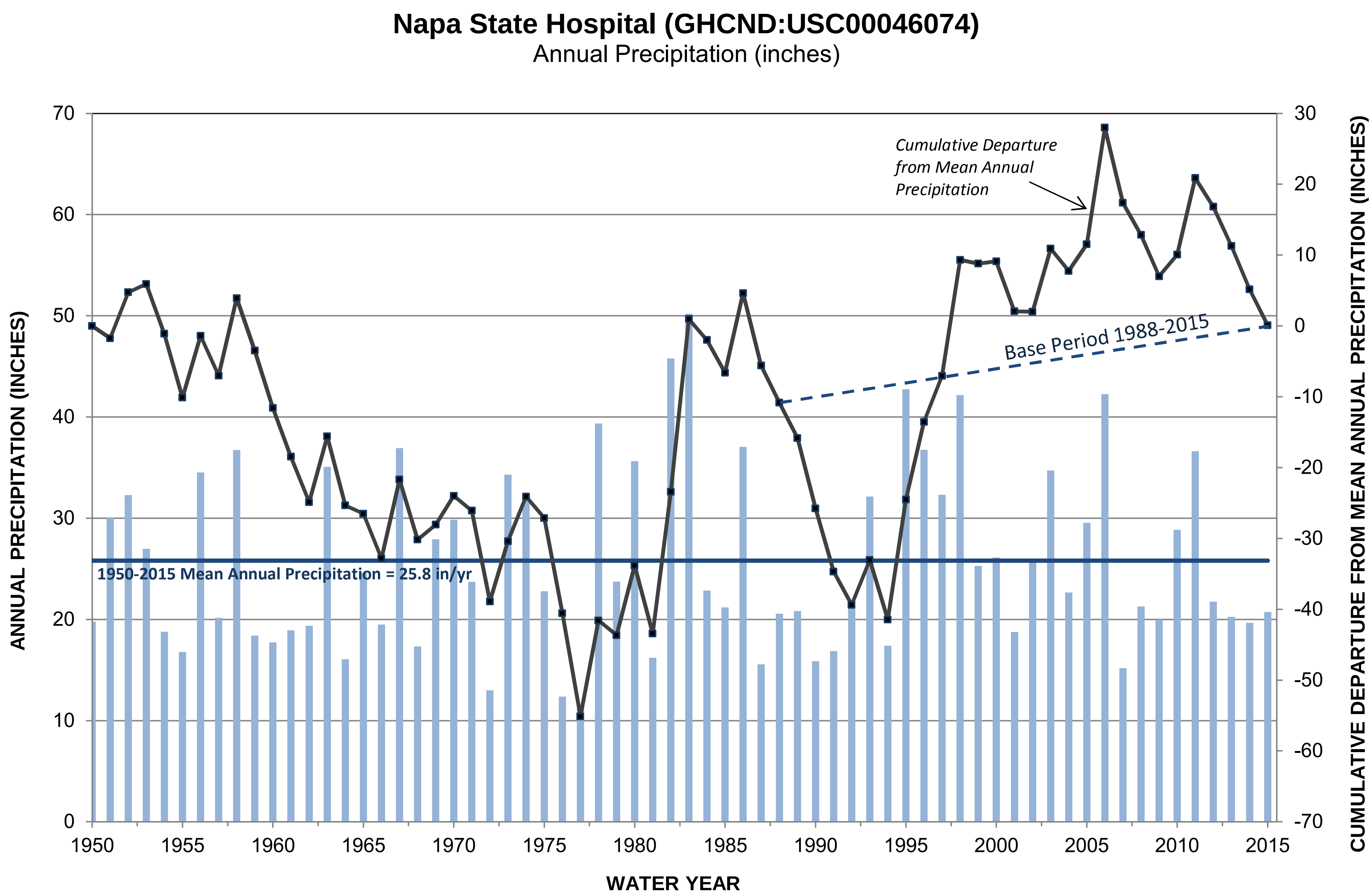
FIGURE 6-1

Napa Valley Precipitation and Streamflow Gage Locations



NOTE: Gaps in this data record have been reconstructed using data from the Oakville CIMIS station (77) and NOAA Saint Helena, CA US station (GHCND:USC00047643).

X:\2014 Job Files\14-054\Data\Precip\NCDC Data Summary UPDATED Feb2016.xlsx\NSH_CD_50-15plot Annual Rep (2

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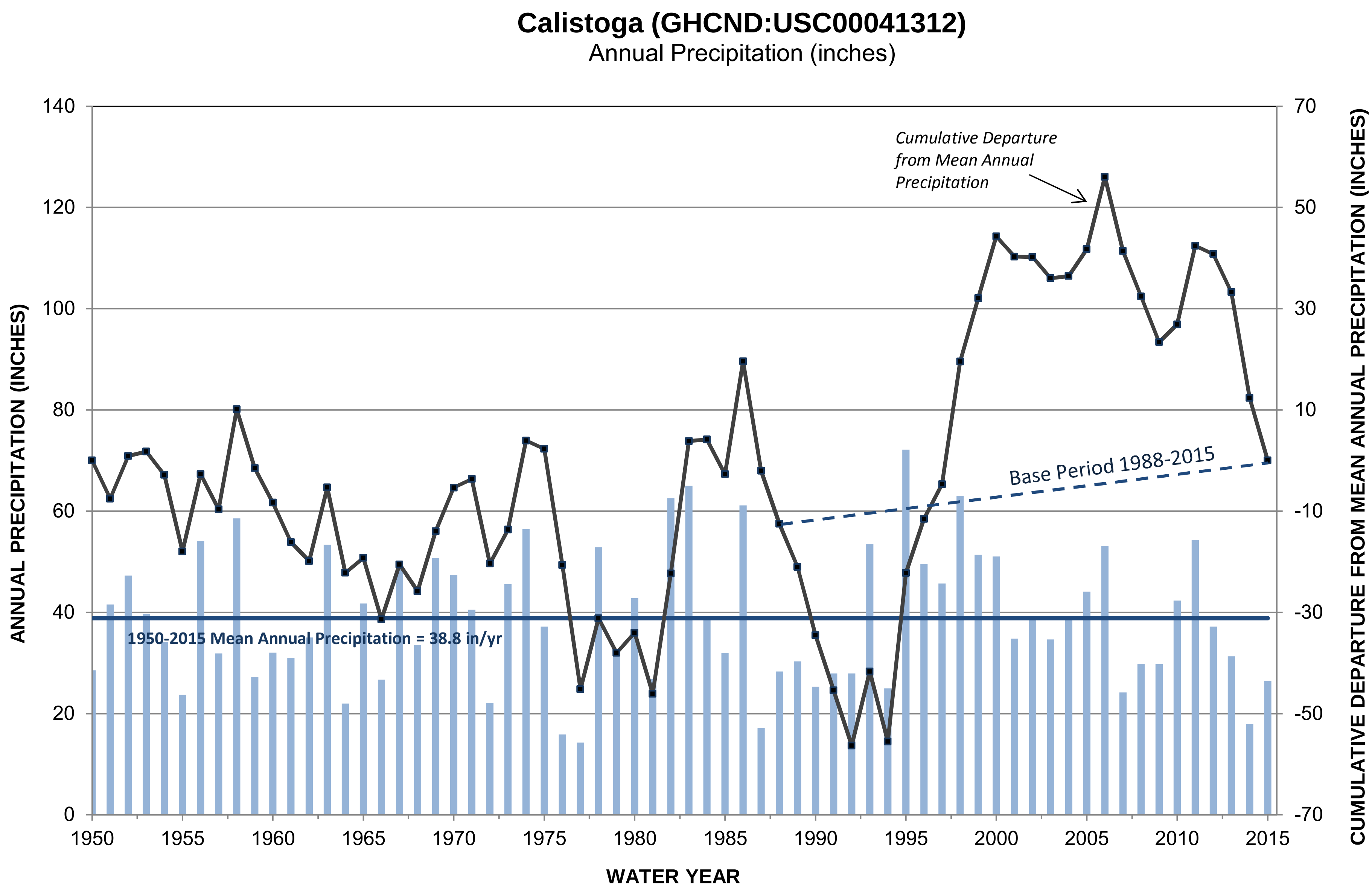
Figure 6-2
Napa State Hospital Gage Water Year Precipitation (1950-2015) and Cumulative Departure
Napa Valley Groundwater Sustainability:
A Basin Analysis Report for the Napa Valley Subbasin



NOTE: Gaps in this data record have been reconstructed using data from the NOAA Napa State Hospital, CA US Station (GHCND:USC00046074).

X:\2014 Job Files\14-054\Data\Precip\NCDC Data Summary UPDATED Feb2016.xlsx\NSH_CD_50-15plot Annual Rep (2

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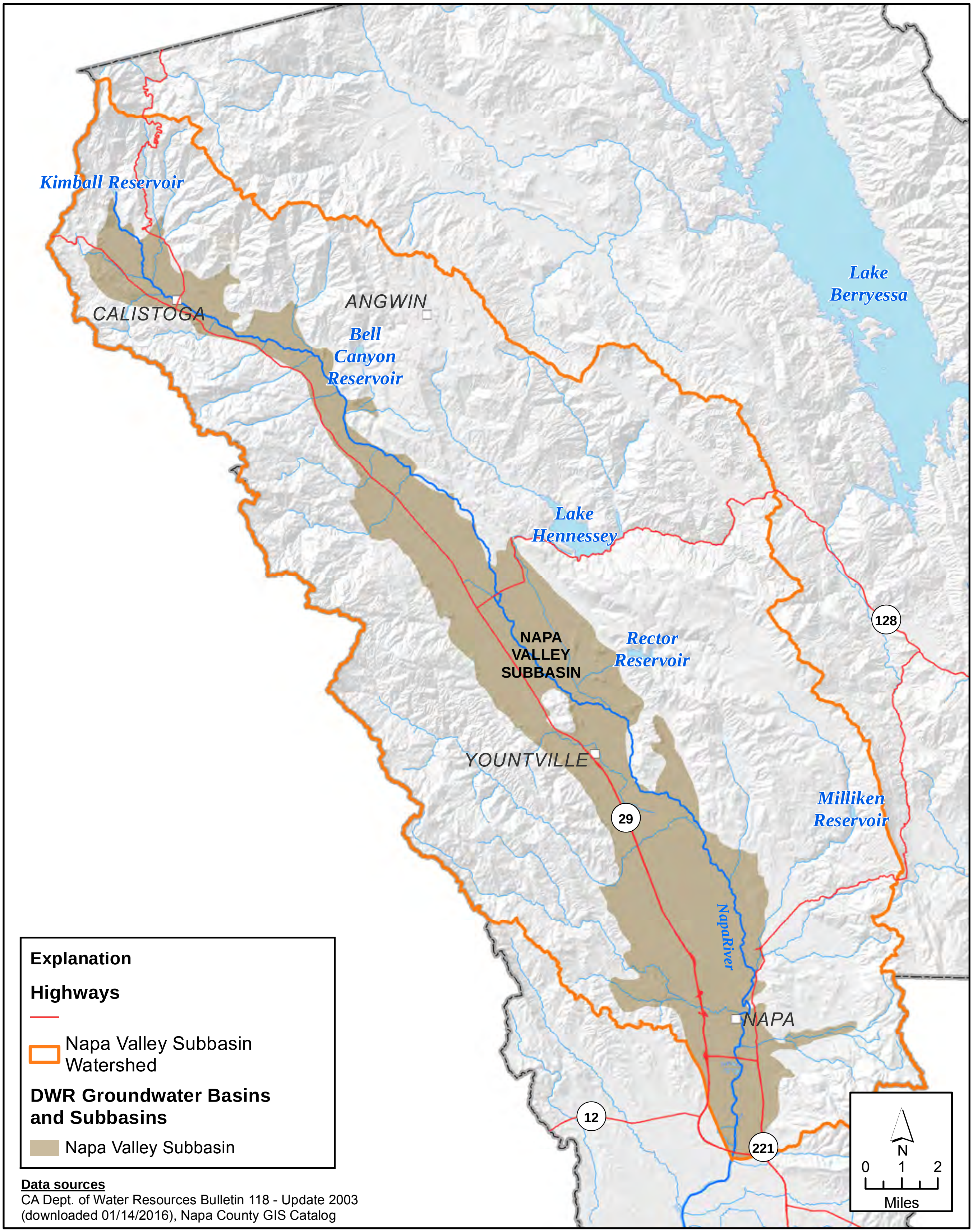
Figure 6-3
Calistoga Gage Water Year Precipitation (1950-2015) and Cumulative Departure
Napa Valley Groundwater Sustainability:
A Basin Analysis Report for the Napa Valley Subbasin



X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Figure 6-6 Napa Valley Subbasin and Watershed.mxd

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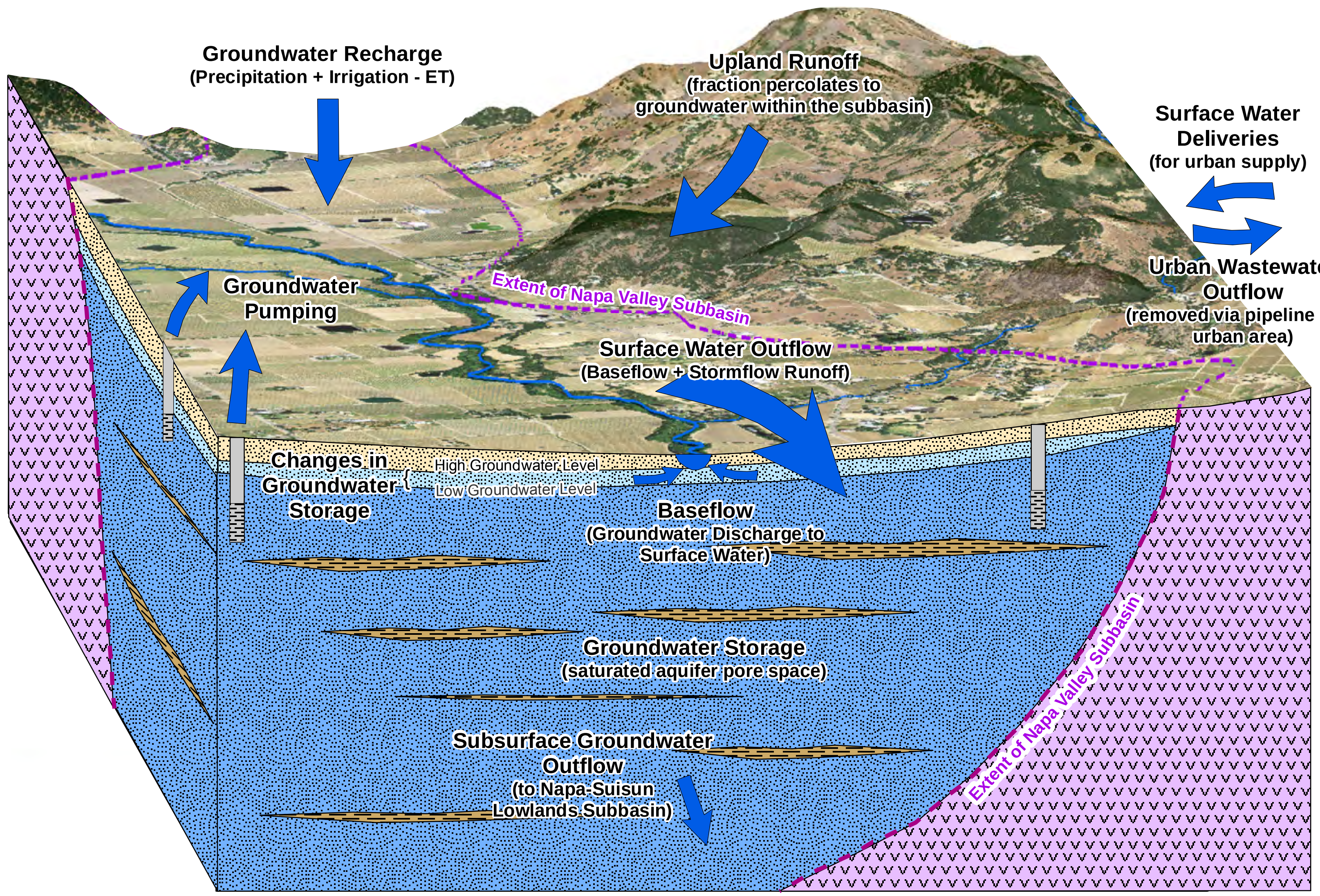
FIGURE 6-7

Napa Valley Subbasin and Subbasin Watershed

Napa Valley Groundwater Sustainability:
A Basin Analysis Report for the Napa Valley Subbasin



X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Conceptual Diagram\Figure 6-7 3D_WaterBudgetConceptualDiagram_wSWcomponents.mxd

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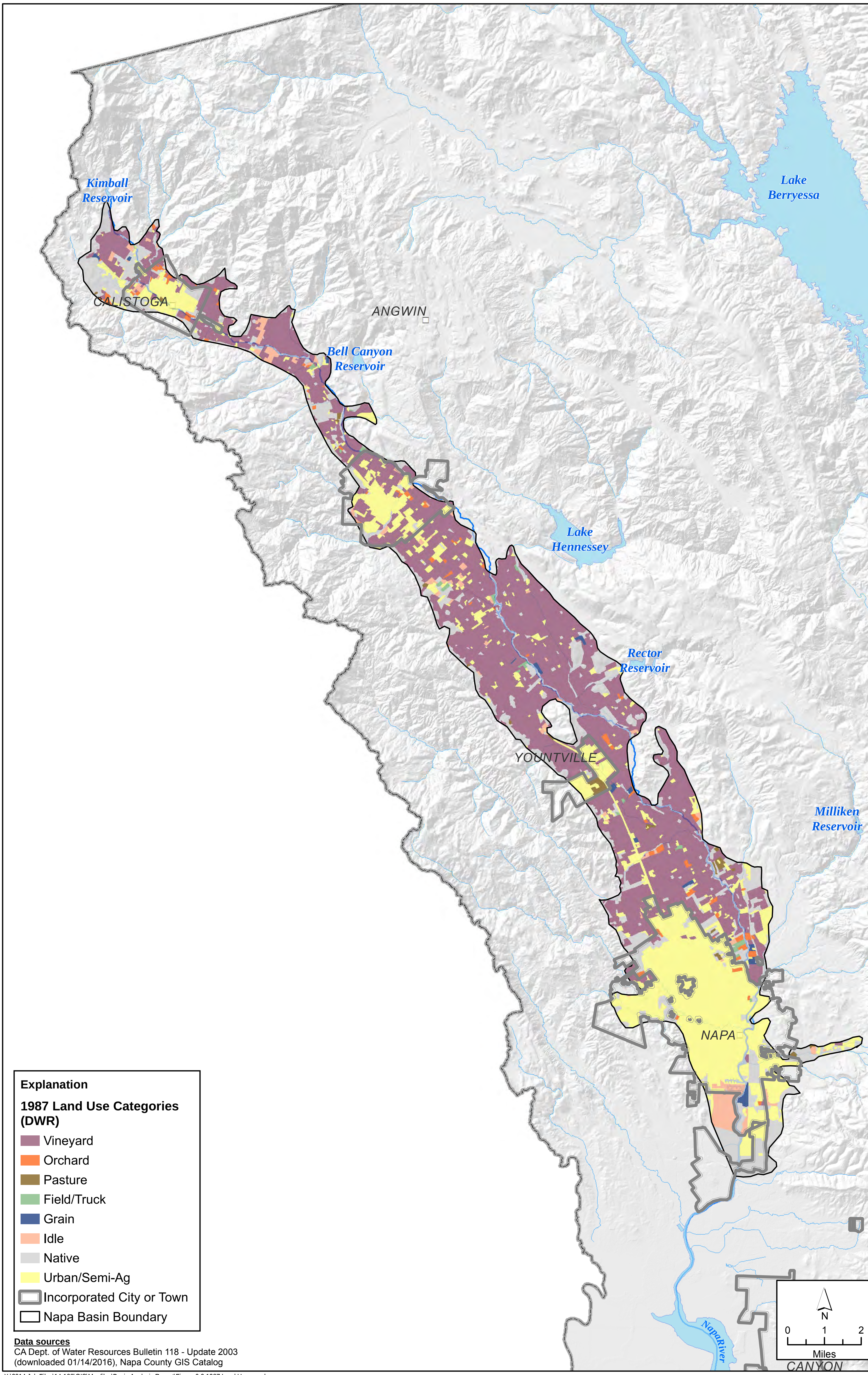
FIGURE 6-8
Schematic of Water Budget Components in the Napa Valley Subbasin

Napa Valley Groundwater Sustainability:
A Basin Analysis Report for the Napa Valley Subbasin



Data sources
CA Dept. of Water Resources Bulletin 118 - Update 2003
(downloaded 01/14/2016), Napa County GIS Catalog

X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Figure 6-9 1987 Land Use_.mxd

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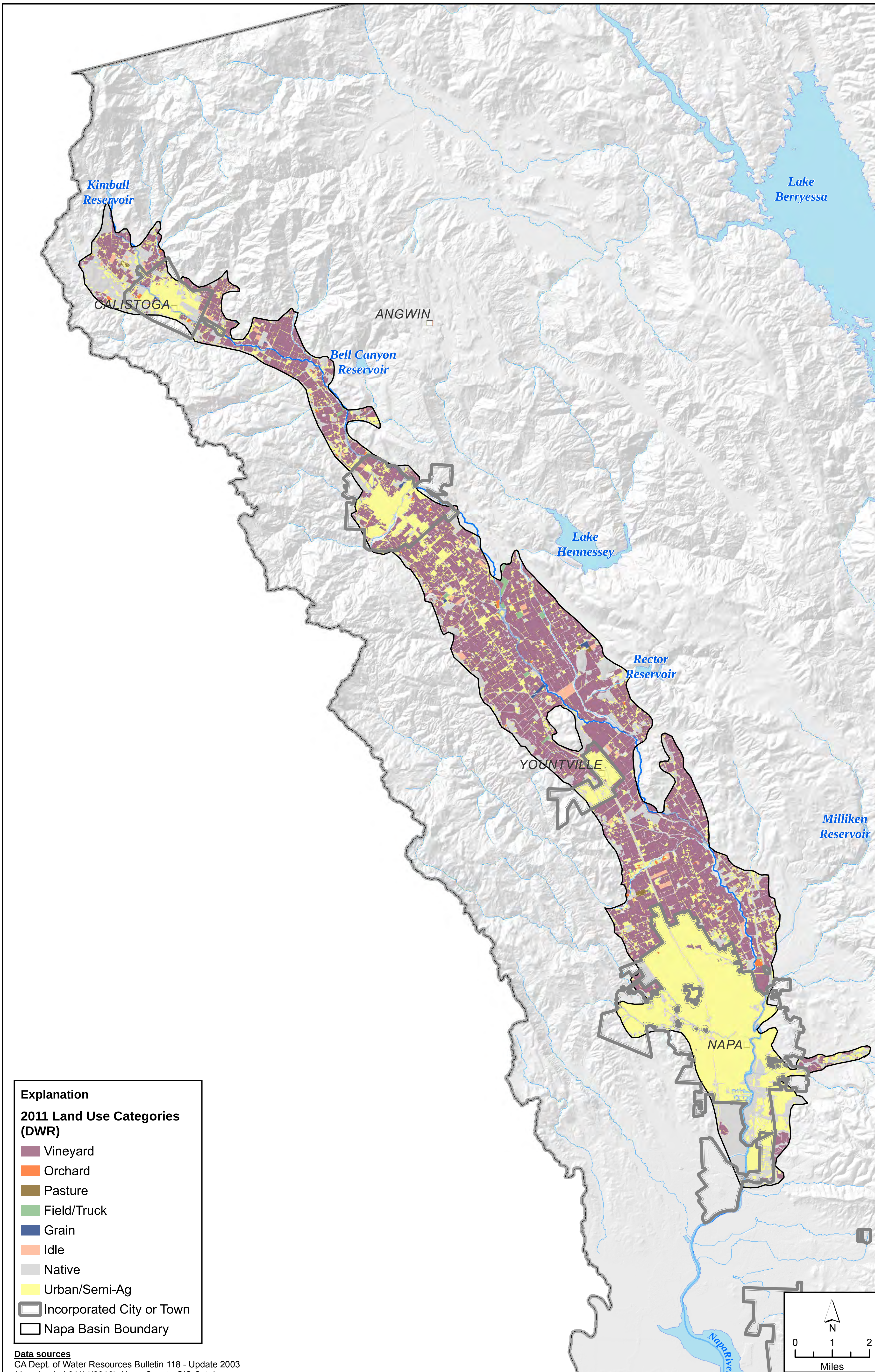
FIGURE 6-9

1987 Land Use Categories

Napa Valley Groundwater Sustainability:
A Basin Analysis Report for the Napa Valley Subbasin



X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Figure 6-10 2011 Land Use.mxd

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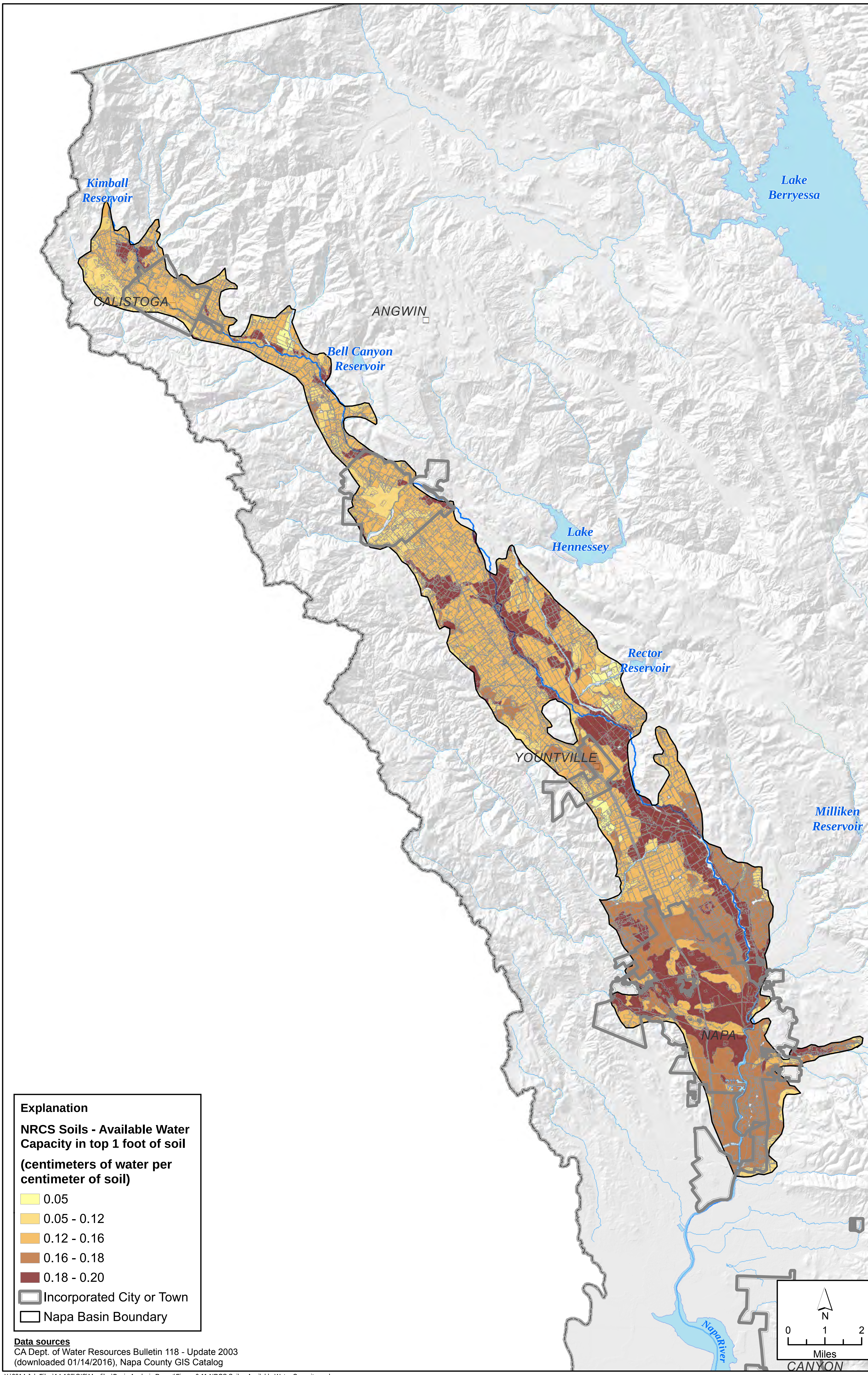
FIGURE 6-10

2011 Land Use Categories

Napa Valley Groundwater Sustainability:
A Basin Analysis Report for the Napa Valley Subbasin



X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Figure 6-11 NRCS Soils - Available Water Capacity.mxd

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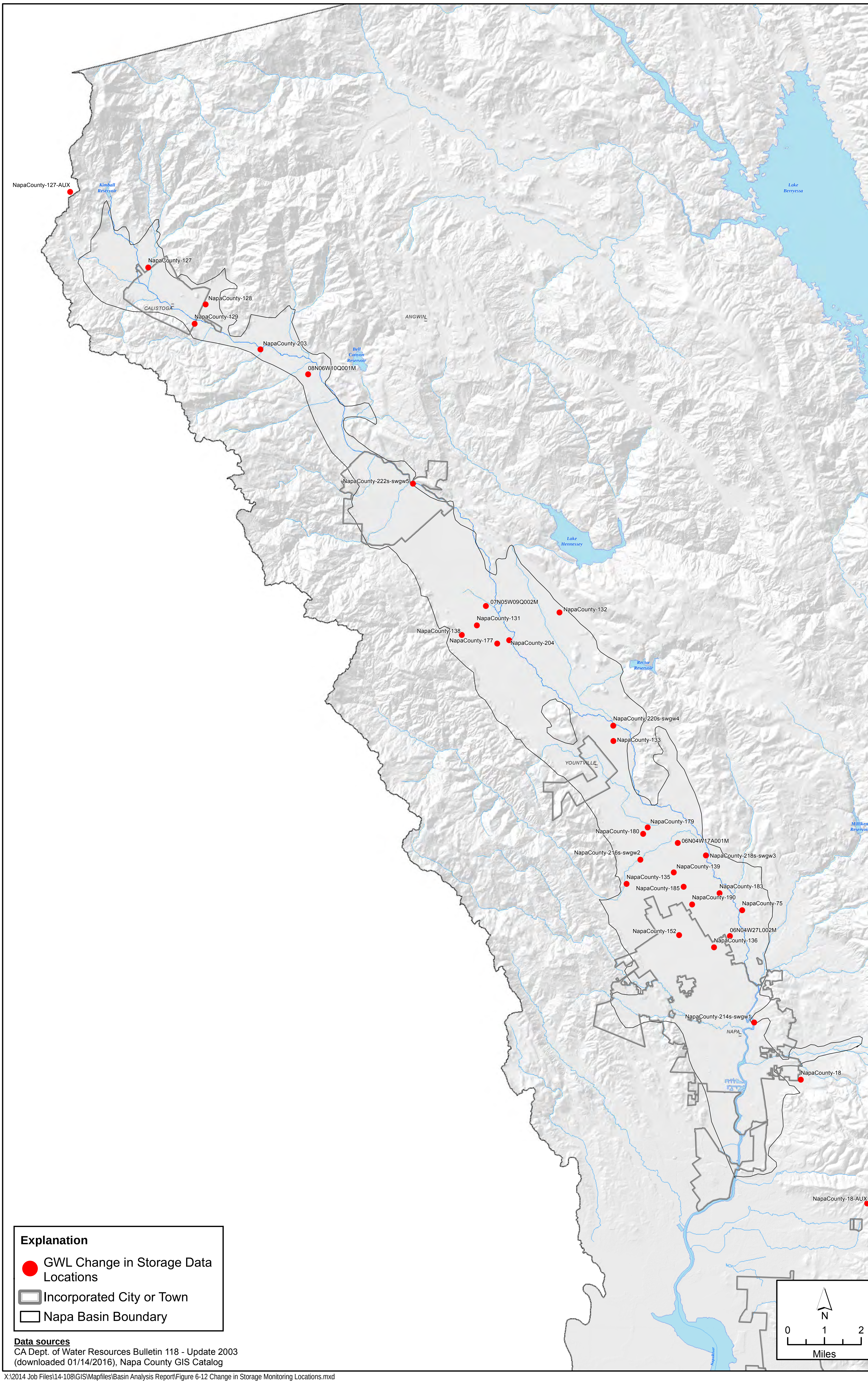
FIGURE 6-11

NRCS Soils - Available Water Capacity

Napa Valley Groundwater Sustainability: A Basin Analysis Report for the Napa Valley Subbasin



X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Figure 6-12 Change in Storage Monitoring Locations.mxd

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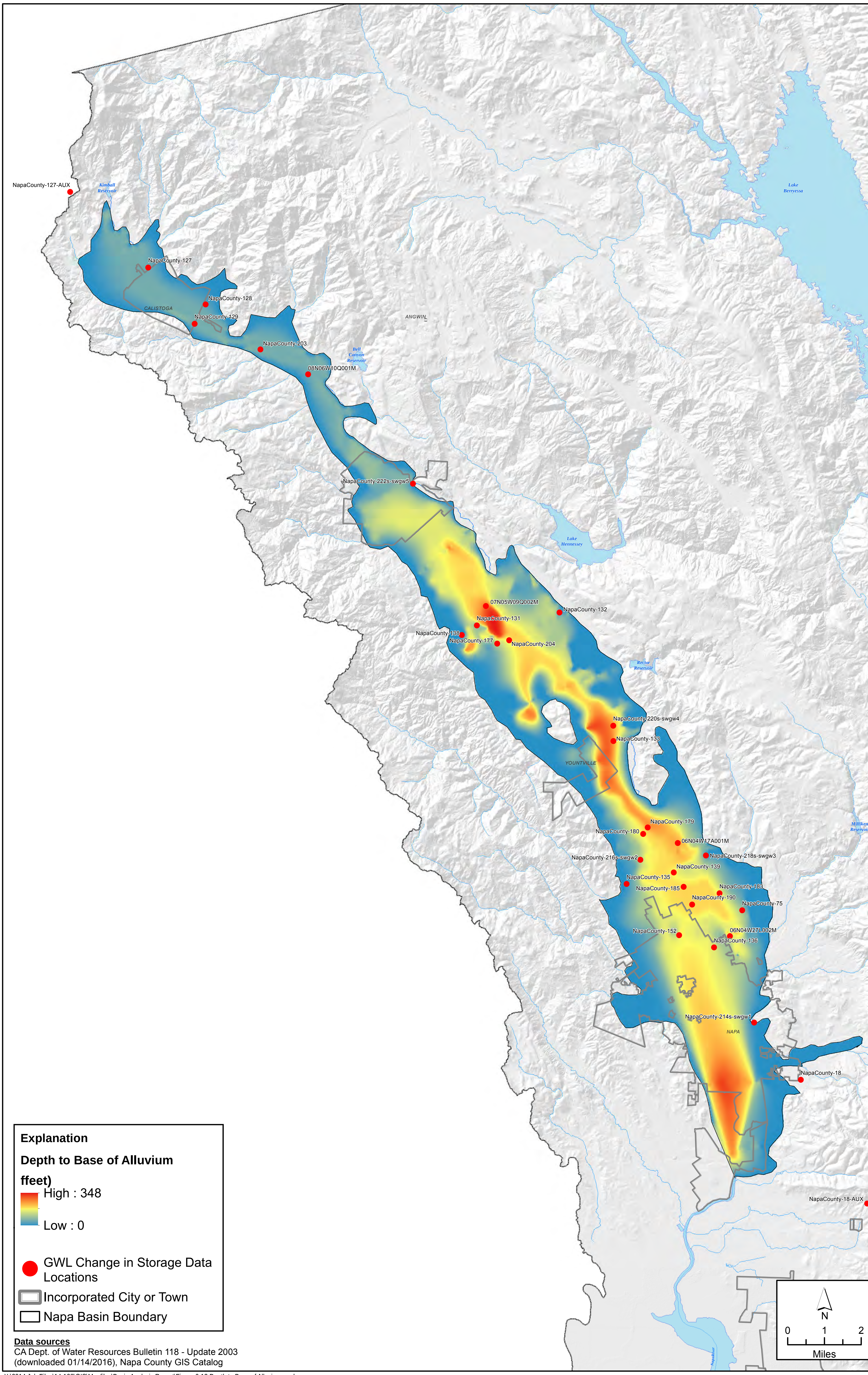
FIGURE 6-14

Groundwater Level Change in Storage - Data Locations

Napa Valley Groundwater Sustainability: A Basin Analysis Report for the Napa Valley Subbasin



X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Figure 6-13 Depth to Base of Alluvium.mxd

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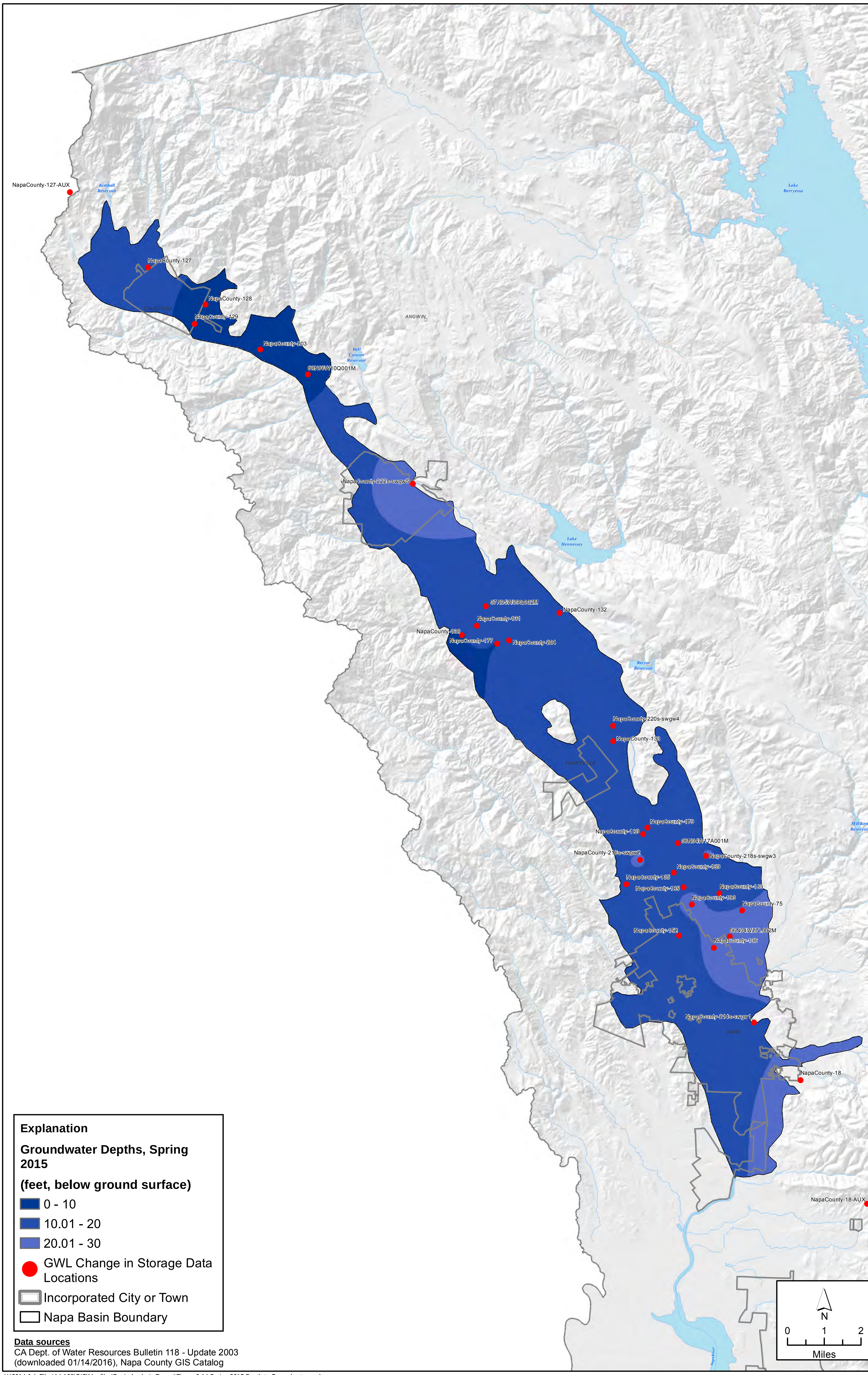
FIGURE 6-15

Depth to Base of Aquifer

Napa Valley Groundwater Sustainability:
A Basin Analysis Report for the Napa Valley Subbasin



X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Figure 6-14 Spring 2015 Depth to Groundwater.mxd

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FIGURE 6-16

Depth to Groundwater - Spring 2015

Napa Valley Groundwater Sustainability:
A Basin Analysis Report for the Napa Valley Subbasin

7 NAPA VALLEY SUBBASIN SUSTAINABILITY GOALS (SECTION 354.24)

As part of Napa County's General Plan update in 2008, and within the Plan's Conservation Element, six goals are set forth relating to the county's water resources, including to "Conserve, enhance and manage water resources on a sustainable basis to attempt to ensure that sufficient amounts of water will be available for the uses allowed by this General Plan, for the natural environment, and for future generations" (Goal CON-10; LSCE, 2016).

Additionally, based on the Groundwater Resources Advisory Council (GRAC's)[1] charge from the Napa County Board of Supervisors in 2011 and a review of many definitions in published literature, the GRAC (2014) defined "groundwater sustainability[2]" as:

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

The GRAC concluded that groundwater sustainability is both a goal and a process; most importantly, it is a shared responsibility. Everyone living and working in the county has a stake in protecting groundwater resources, including groundwater supplies, quality, and associated watersheds (GRAC, 2014). The GRAC further found that healthy communities, healthy agriculture and healthy environments exist together and not in isolation. Without sustainable groundwater resources, the character of the county would be significantly different in terms of its economy, communities, rural character, ecology, housing, and lifestyles.

The sustainability goal and groundwater sustainability objectives[3] developed by the GRAC included (GRAC, 2014; **Appendix**):

> *GRAC Sustainability Goal: To protect and enhance groundwater quantity and quality for all the people who live and work in Napa County, regardless of the source of their water supply.*
>
> *GRAC Sustainability Objectives:*
>
> 1. Initiate and carry out outreach and education efforts.
>   a. Develop public outreach programs and materials to make everyone who lives and works in the County aware that the protection of water supplies is a shared responsibility and everyone needs to participate.
>   b. Through education, enable people to take action.

[1] GRAC formation and charge are described in Chapter 1.

[2] The definition for Groundwater Sustainability developed by the GRAC is separate from the definition of Sustainable Groundwater Management applied in the 2014 Sustainable Groundwater Management Act.

[3] These are overarching groundwater sustainability objectives; "measurable objectives", per SGMA requirements, are discussed in Section 7.5.

2. Optimize existing water supplies and systems.
    a. Support landowners in implementing best sustainable practices.
    b. Enhance the water supply system and infrastructure – including but not limited to system efficiencies, reservoir dredging, recycled water, groundwater storage and recharge, conjunctive use – to improve water supply reliability.
3. Continue long-term monitoring and evaluation.
    a. Collect groundwater and surface water data and maintain a usable database that can provide information about the status of the county's groundwater and surface water resources and help forecast future supplies.
    b. Evaluate data using best analytical methods in order to better understand characteristics of the county's groundwater and water resources systems.
    c. Share data and results of related analytical efforts while following appropriate confidentiality standards.
4. Improve our scientific understanding of groundwater recharge and groundwater-surface water interactions.
5. Improve preparedness to address groundwater issues that might emerge.
    a. Improve preparedness for responding to long-term trends and evolving issues, such as adverse groundwater trends (including levels and quality), changes in precipitation and temperature patterns, and saltwater intrusion.
    b. Improve preparedness for responding to acute crises, such as water supply disruptions and multi-year drought conditions.

The GRAC's sustainability goal and groundwater sustainability objectives were presented to and accepted by the Napa County Board of Supervisors on April 8, 2014. The Board of Supervisors and public commended the GRAC for their multi-year commitment and work in assisting the County and its consulting team with the development of groundwater sustainability objectives, completion of a groundwater monitoring plan, expansion of the County's groundwater monitoring network, assessment of technical and procedural updates to the County's Water Availability Analysis (WAA) Policy and groundwater ordinances, and development of community education and outreach materials. Upon receiving the GRAC's conclusions and recommendations, the Napa County Board of Supervisors directed County staff to propose updates and amendments to the WAA for the Board's consideration and to continue implementation and expansion of the County's groundwater monitoring program to better assess and monitor the sustainability of the County's groundwater resources.

7.1 SGMA Requirement to Develop a Sustainability Goal (Section 354.24)

SGMA requires that each agency shall establish a sustainability goal (Section 354.24); specifically:

> *Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline. The Plan shall include a description of the sustainability goal, including information from the basin setting used to establish the sustainability goal, a discussion of the measures that will be implemented*

to ensure that the basin will be operated within its sustainable yield, and an explanation of how the sustainability goal is likely to be achieved within 20 years of Plan implementation and is likely to be maintained through the planning and implementation horizon.

This Basin Analysis Report[4] provides a functionally equivalent definition of a sustainability goal. This Report is based on an understanding of hydrogeologic conditions and management measures that demonstrate the basin has already been operated within the sustainable yield for at least 10 years. Chapter 6 summarizes the water budget details that show the Napa Valley Subbasin, on a subbasin scale, has been operated within the sustainable yield. The Napa County Board of Supervisors establishment of the GRAC, acceptance of the GRAC's sustainability goal and objectives for all of Napa County, and implementation of key GRAC recommendations demonstrates the County's intent to maintain sustainable conditions indefinitely. The corresponding groundwater sustainability objectives recognized by the Board of Supervisors serve as the "measures that will be implemented to ensure that the basin will be operated within its sustainable yield" and are memorialized in this Report adopted by the Napa County Board of Supervisors (**Appendix ___**).

The GRAC also provided supplemental recommendations:

1. *Support the WICC[5] and RCD[6] in implementing the objectives.*
2. *If a County or sub-regional groundwater stewardship and sustainability plan is developed in the future, these should be the foundational objectives.*

These supplemental recommendations, developed by the GRAC in February 2014 well before SGMA was adopted, emphasize the County's intent to integrate groundwater stewardship and sustainability planning in future planning and resource management.

In conformance with SGMA and the intent of the GRAC (February 2014) and the County Board of Supervisors (April 2014), the GRAC sustainability goal is expanded to:

Napa Valley Subbasin SGMA Sustainability Goal: To protect and enhance groundwater quantity and quality for all the people who live and work in Napa County, regardless of the source of their water supply. The County and everyone living and working in the county will integrate stewardship principles and measures in groundwater development, use, and management to protect economic, environmental, and social benefits and maintain groundwater sustainability indefinitely without causing undesirable results, including unacceptable economic, environmental, or social consequences.

7.2 Sustainability Indicators and Undesirable Results (Section 354.26)

SGMA establishes undesirable results for applicable sustainability indicators, including a description of the process and criteria used to define undesirable results for the Napa Valley Subbasin. A "sustainability indicator" (SGMA Article 2) refers to any of the effects caused by groundwater

[4] SGMA Section 10733.6 (b)(3), Alternative Submittal
[5] Watershed Information Conservation Council
[6] Napa County Resource Conservation District

conditions occurring throughout the basin that, when significant and unreasonable, cause undesirable results, as described in Water Code Section 10721(x). Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are "caused by groundwater conditions occurring *throughout* the basin" (Section 354.26; emphasis added). Undesirable results include one or more of the following (SGMA Definitions[7]):

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

California has a long-history of groundwater development, which in many basins in the state has resulted in evidence of undesirable results.[8] The Napa Valley Subbasin, an elongated alluvial river valley, has benefited from high precipitation and the corresponding potential for a substantial amount of recharge, as discussed in Chapter 6. Overall, the groundwater table in the alluvial aquifer of the Napa Valley Subbasin is quite shallow; the depth to groundwater in the main part of the Valley Floor in the spring is approximately 5 to 35 feet. While agricultural land use, especially vineyards, have covered much of the Valley Floor for decades, the water requirements for this type of agricultural land use are significantly lower than agricultural commodities grown elsewhere in California, such as the Central Valley. As a result, due to high recharge potential in most years, low water requirements and a hydrogeologic setting conducive to recharge, the Napa Valley Subbasin remains full overall. However, because Napa Valley also enjoys a relatively flat valley landscape and a river system that is seasonally and temporally connected spatially to the underlying groundwater system, there is an interplay between factors that affect both the surface water and groundwater systems of the Subbasin. When groundwater levels have temporarily declined during drier years or seasonal dry periods during the year, the river system can also be more sensitive during drier years and also drier periods of the year when baseflow (i.e., groundwater discharge to surface water) is diminished. As discussed further below, the Napa River has experienced these effects over many decades, particularly during the summer to fall period.

[7] http://water.ca.gov/groundwater/sgm/definitions.cfm
[8] 21 basins/subbasins have been designated by DWR to be critically overdrafted; http://www.water.ca.gov/groundwater/sgm/cod.cfm

As described in Chapter 4, groundwater levels in the Napa Valley have been stable over the hydrologic base period (1988-2015), and the prior historical period where data are available, with recognition that groundwater levels in some areas have been lower during dry water year types. Stable groundwater levels, on average, over the 28-year base period indicate that there have been *no significant and unreasonable effects* occurring throughout the basin related to:

- Chronic lowering of groundwater levels
- Reduction of groundwater storage
- Seawater intrusion
- Degraded water quality
- Land subsidence

At some locations during the summer to fall period, the historical occurrence of diminished baseflow could be considered an undesirable result. SGMA provides that a plan[1] or alternative submittal are not required to address undesirable results that occurred before and have not been corrected by, January 1, 2015. However, the Groundwater Sustainability Agency or local agency have the discretion to set measurable objectives and the timeframes for achieving them.[2] (Section 10727.2).

The Napa Valley Subbasin has been operated in a sustainable manner for more than 10 years, where overall groundwater conditions have been stable, and baseflow is lower and/or not present at some locations during the summer to fall period, pending the water year type (Grossinger, 2012; Faye, 1973). Since the river system is considered the most sensitive sustainability indicator in the Napa Valley Subbasin, the measurable objectives and minimum thresholds discussed below are recommended to ensure groundwater sustainability or improve groundwater conditions, and provide ongoing monitoring targets devised to address potential future effects on surface water.

7.3 Representative Monitoring Sites

SGMA defines "representative monitoring" as "a monitoring site within a broader network of sites that typifies one or more conditions within the basin or an area of the basin" (Section 351). This subset of monitoring sites is for the purpose of monitoring groundwater conditions that are representative of the basin or an area of the basin (Section 354.36). For SGMA purposes for the Napa Valley Subbasin, these sites are where sustainability indicators are monitored, and minimum thresholds and measurable objectives are defined. Many sites are monitored for more than one sustainability indicator.

Groundwater elevations are used at many sites for monitoring a number of sustainability indicators. As discussed in Chapter 4, there are strong relationships between surface water flow measured at gages along the Napa River system and groundwater level trends. Since the river system is the most sensitive sustainability indicator in the Napa Valley Subbasin, minimum

[1] Plan refers to the development of a Groundwater Sustainability Plan. The Basin Analysis Report is related in that it is an Alternative to a GSP, but it is required to be functionally equivalent to the elements of a Plan required in Articles 5 and 7 for GSPs (Section 358.2).
[2] An Alternative to a GSP does not require the formation of a Groundwater Sustainability Agency. The governing body that prepares and approves the Alternative could establish measurable objectives for achieving any objectives for undesirable results that exceed the express requirements of the Act.

thresholds and measurable objectives that are set to be protective of the river system (i.e., established to prevent the occurrence of further depletion of surface water that has significant and unreasonable adverse impacts on beneficial uses of the surface water, including avoidance of longer durations of no flow days in summer to fall at some locations) *and ensure groundwater sustainability* necessarily preclude the occurrence of undesirable results. By maintaining groundwater elevations at the selected representative monitoring sites at levels comparable to the hydrologic base period, this precludes the occurrence of significant and unreasonable chronic groundwater level declines, reduction of groundwater storage, land subsidence, and seawater intrusion.

Napa County has used the term “representative” in reference to hydrographs presented in previous reports (LSCE, 2011; 2015; 2016). In this Basin Analysis Report, the term representative is refined to align with SGMA. Specific representative monitoring sites are designated that typify conditions in the basin. Eighteen selected wells are summarized in **Table 7-1** and shown in **Figure 7-1**. Seven of the SGMA representative wells were selected because of their long historical groundwater level record and their prior use in Napa County groundwater-related reports as “representative” wells with hydrographs that typify groundwater conditions and trends in the Napa Valley Subbasin. Ten relatively new wells were selected because of their construction (as part of DWR’s Local Groundwater Assistance Grant that was awarded to Napa County) for the specific purpose of assessing surface water and groundwater interaction. One other well was selected because of its location in the southern part of the subbasin, moderate historical groundwater level record, likely construction in unconfined part of the groundwater system, and purpose for tracking groundwater trends and gradients near the adjoining subbasin.

Table 7-1. Representative Monitoring Sites, Napa Valley Subbasin

Well ID	Data Source	Aquifer Design-ation	Subarea	Well Depth (ft)	Basis for Selection
06N04W17A001M	DWR	Qa	NVF_Yount	250	Long record
06N04W27L002M	DWR	Qa	NVF_Napa	120	Long record
07N05W09Q002M	DWR	NA	NVF_SH	232	Long record
08N06W10Q001M	DWR	NA	NVF_Calis	200	Long record
NapaCounty-128	Napa County	Qa	NVF_Calis	50	Long record
NapaCounty-133	Napa County	Qa	NVF_Yount	120	Long record
NapaCounty-135	Napa County	Qa	NVF_Yount	125	Long record
5N/4W-15E1	SWRCB Geotracker	Qa	NVF_Napa	158	Moderate record
Napa County 214s-swgw1	Napa County	Qa	NVF_Napa	53	Designated SW/GW[9] facility
Napa County 215d-swgw1	Napa County	Qa	NVF_Napa	98	Designated SW/GW facility
Napa County 216s-swgw2	Napa County	Qa	NVF_Yount	50	Designated SW/GW facility
Napa County 217d-swgw2	Napa County	Qa	NVF_Yount	86	Designated SW/GW facility
Napa County 218s-swgw3	Napa County	Qa	NVF_Napa	40	Designated SW/GW facility
Napa County 219d-swgw3	Napa County	Qa	NVF_Napa	93	Designated SW/GW facility
Napa County 220s-swgw4	Napa County	Qa	NVF_Yount	45	Designated SW/GW facility
Napa County 221d-swgw4	Napa County	Qa	NVF_Yount	85	Designated SW/GW facility
Napa County 222s-swgw5	Napa County	Qa	NVF_SH	40	Designated SW/GW facility
Napa County 223d-swgw5	Napa County	Qa	NVF_SH	100	Designated SW/GW facility

7.4 Minimum Thresholds (Section 354.28)

SGMA defines a “minimum threshold” as “a numeric value for each sustainability indicator used to define undesirable results” (Section 351). This section discusses the preliminary minimum thresholds established to quantify groundwater conditions for each applicable sustainability indicator at

[9] Designated SW/GW facility: refers to surface water and groundwater monitoring facilities installed as part of the DWR Local Groundwater Assistance Program grant awarded to Napa County for purposes of evaluating the connectivity between groundwater and surface water.

representative monitoring sites. Justification is provided for the thresholds based on best available data, including groundwater levels, groundwater quality, and surface water flows. As noted above, groundwater level thresholds are used as a proxy for multiple sustainability indicators. **Table 7-2** shows the relationship between representative monitoring sites, the sustainability indicators applicable to those sites, the data category for the measurable objective and minimum threshold (e.g., groundwater level, groundwater quality or other), and which sustainability indicators use groundwater elevations as a proxy.

7.4.1 Minimum Threshold: Streamflow Depletion and Other Sustainability Indicators

Based on the analyses of surface water and groundwater interconnections, including the relationship of this connection to seasonal and annual groundwater elevation fluctuations (Chapter 4), minimum thresholds are set at 16 wells in the subbasin (**Table 7-3**). These thresholds represent the lowest static groundwater level elevation that has occurred historically in the fall and an elevation below which additional streamflow depletion is likely to be occur, i.e., expand the duration of annual no flow days in some reaches of the Napa River. These thresholds represent the lowest static groundwater elevation to which groundwater levels may reasonably be lowered at the end of a dry season without exacerbating streamflow depletion. These levels are not acceptable on a continuous basis as this would contribute to a worsening of existing conditions. These groundwater elevation thresholds also serve as proxies for many other sustainability indicators, as shown in **Table 7-2.**

Table 7-2. Representative Monitoring Sites and Sustainability Indicators

Well ID	Sustainability Indicators[3]					
	Chronic Lowering of GWLs	Reduced GW Storage	Seawater Intrusion	Degraded GW Quality	Land Subsidence	Streamflow Depletion
06N04W17A001M	GWE	GWE		GWQ[2]	GWE	GWE[1]
06N04W27L002M	GWE	GWE		GWQ	GWE	GWE
07N05W09Q002M	GWE	GWE		GWQ	GWE	GWE
08N06W10Q001M	GWE	GWE		GWQ	GWE	GWE
NapaCounty-128	GWE	GWE		GWQ	GWE	GWE
NapaCounty-133	GWE	GWE		GWQ	GWE	GWE
NapaCounty-135	GWE	GWE		GWQ	GWE	
5N/4W-15E1			GWQ	GWQ		
Napa County 214s-swgw1	GWE	GWE				GWE
Napa County 215d-swgw1	GWE	GWE				GWE
Napa County 216s-swgw2	GWE	GWE				GWE
Napa County 217d-swgw2	GWE	GWE				GWE
Napa County 218s-swgw3	GWE	GWE				GWE
Napa County 219d-swgw3	GWE	GWE				GWE
Napa County 220s-swgw4	GWE	GWE				GWE
Napa County 221d-swgw4	GWE	GWE				GWE
Napa County 222s-swgw5	GWE	GWE				GWE
Napa County 223d-swgw5	GWE	GWE				GWE

1. GWE (blue): Groundwater Elevation; data category for establishing minimum thresholds and measurable objectives for avoiding the undesirable result of depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water (e.g., streamflow depletion). Since the river system in the Napa Valley Subbasin is considered sensitive to climate and groundwater condition variability, GWE's set for the streamflow depletion sustainability indicator serve as a proxy for many other sustainability indicators.
2. GWQ (green): Groundwater Quality
3. Where neither GWE nor GWQ is indicated, this does not mean that groundwater elevations and/or quality are not being measured, rather it means that groundwater elevations and/or groundwater quality are not being assessed for purposes of evaluating one or more sustainability indicators at this representative monitoring site.

Table 7-3. Minimum Thresholds to Avoid Streamflow Depletion

Well ID	Minimum Threshold: Minimum Fall Groundwater Elevation (Feet AMSL)
NapaCounty-128	320
08N06W10Q001M	269
07N05W09Q002M	127
NapaCounty-133	72
06N04W17A001M	37
06N04W27L002M	-2
NapaCounty-214s-swgw1	2[1]
NapaCounty-215d-swgw1	2
Napa County 216s-swgw2	61
Napa County 217d-swgw2	61
NapaCounty-218s-swgw3	29
NapaCounty-219d-swgw3	29
NapaCounty-220s-swgw4	75
NapaCounty-221d-swgw4	75
NapaCounty-222s-swgw5	185
NapaCounty-223d-swgw5	164

1. The Napa County surface water/groundwater monitoring facilities are relatively new with limited data; minimum thresholds will be re-evaluated with additional data.

7.4.2 Minimum Threshold: Avoid Degraded Groundwater Quality

The minimum threshold for avoidance of degraded groundwater quality is based on groundwater quality concentrations remaining above water quality objectives. The focus for SGMA purposes is on constituents contributed due to activities at the land surface rather than on the presence of naturally occurring constituents. An example is shown in **Table 7-4** for nitrate as nitrogen.

Table 7-4. Minimum Threshold to Avoid Degraded Groundwater Quality

Well ID	Minimum Threshold: GW Quality Objective (example Nitrate-N mg/L[1])
06N04W17A001M	10 mg/L
06N04W27L002M	10 mg/L
07N05W09Q002M	10 mg/L
08N06W10Q001M	10 mg/L
NapaCounty-128	10 mg/L
NapaCounty-133	10 mg/L
NapaCounty-135	10 mg/L

1. The Maximum Contaminant Level (MCL) for Nitrate as Nitrogen is 10 mg/L.

7.4.3 Minimum Threshold: Seawater Intrusion

The minimum threshold for avoidance of seawater intrusion is based on groundwater quality concentrations remaining stable in the representative well designated for this sustainability indicator (**Table 7-5**). Well 5N/4W-15E1 is located in the southern part of the Napa Valley Subbasin and has a long historical record.

Table 7-5. Minimum Threshold to Avoid Seawater Intrusion

Well ID	Minimum Threshold: Maintain TDS At or Below Historically Observed TDS Concentration[1] (mg/L)
5N/4W-15E1	450

1. Secondary Recommended Maximum Contaminant Level for TDS is 500 mg/L.

7.4.4 Minimum Threshold: Chronic Lowering of Groundwater Levels, Land Subsidence and Reduced Groundwater Storage

The minimum thresholds for avoidance of chronic groundwater level decline, land subsidence, and a reduction in groundwater storage are based on groundwater levels set at minimum fall level observed over the historical period. Most representative wells use the groundwater elevations for avoidance of streamflow depletion as the proxy (**Table 7-3**). One other representative well, Napa County 135 located away from the Napa River, is also used for these sustainability indicators (**Table 7-6**). The minimum threshold is the lowest fall level observed over the entire historical period.

Table 7-6. Minimum Threshold to Avoid Chronic Lowering of Groundwater Levels and Reduced Groundwater Storage

Well ID	Minimum Threshold: Avoid Groundwater Level Decline over Successive Years and Land Subsidence (Fall GWE, Feet AMSL)	Minimum Threshold: Avoid Reduced Groundwater Storage (Avoidance of Chronic GWE Decline is Proxy; Fall GWE, Feet AMSL)
NapaCounty-135	20	20

7.5 Measurable Objectives (Section 354.30)

SGMA defines "measurable objectives" as "specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions" (Section 351). This section establishes measurable objectives for each sustainability indicator, based on quantitative values using the same metrics and monitoring sites that are used to define the minimum thresholds. These objectives provide a reasonable margin of operational flexibility under adverse conditions where applicable and utilizes components such as historical water budgets, seasonal and long-term trends, and periods of drought. Similar to the minimum thresholds discussed in Section 7.4, groundwater elevations serve as the proxy for multiple sustainability indicators where reasonable.

7.5.1 Measurable Objective: Streamflow Depletion and Other Sustainability Indicators

Based on the analyses of surface water and groundwater interconnections, including the relationship of this connection to seasonal and annual groundwater elevation fluctuations (Chapter 4), measurable objectives for streamflow depletion are set at 16 wells in the subbasin (**Table 7-7**). These objectives represent the mean fall groundwater level elevations that occurred historically. These objectives represent the fall groundwater elevations within which groundwater elevations are reasonably likely to fluctuate during fall without exacerbating streamflow depletion. These measureable groundwater elevation objectives also serve as proxies for many other sustainability indicators, as shown in **Table 7-2.** (Measurable objectives and minimum thresholds are shown together in **Table 7-11**.)

Table 7-7. Measurable Objectives for Streamflow

Well ID	Measurable Objective for Streamflow: Fall Groundwater Elevation (Feet AMSL)
NapaCounty-128	331
08N06W10Q001M	281
07N05W09Q002M	135
NapaCounty-133	76
06N04W17A001M	50
06N04W27L002M	12
NapaCounty-214s-swgw1	4
NapaCounty-215d-swgw1	4
Napa County 216s-swgw2	76
Napa County 217d-swgw2	76
NapaCounty-218s-swgw3	32
NapaCounty-219d-swgw3	32
NapaCounty-220s-swgw4	77
NapaCounty-221d-swgw4	77
NapaCounty-222s-swgw5	190
NapaCounty-223d-swgw5	175

7.5.2 Measurable Objective: Maintain or Improve Groundwater Quality

The measurable objective for maintaining or improving groundwater quality is based on groundwater sample concentrations remaining above water quality objectives and groundwater quality at concentrations similar to and/or improved compared to historical observations in the groundwater basin. One representative well (06N04W27L002M, also referred to as 6N/4W-27L2) has a historical groundwater quality record. Other wells in **Table 7-8** that have long groundwater level monitoring records are proposed to be added to track groundwater quality trends at locations representative of basin conditions. Beginning in spring 2017, groundwater quality sampling on an annual basis will incorporate these wells in the ongoing monitoring program. Measurable objectives for the newly designated representative wells will be re-evaluated after baseline water quality conditions are established (approximately three years of sampling and analysis of conditions). An example of measurable objectives for nitrate-nitrogen is shown in **Table 7-8**.

Table 7-8. Measurable Objective: Groundwater Quality

Well ID	Measurable Objective: GW Quality Objective (example Nitrate-N mg/L)[1]
06N04W17A001M	8 mg/L
06N04W27L002M	8 mg/L
07N05W09Q002M	8 mg/L
08N06W10Q001M	8 mg/L
NapaCounty-128	8 mg/L
NapaCounty-133	8 mg/L
NapaCounty-135	8 mg/L

1.The Maximum Contaminant Level for Nitrate as Nitrogen is 10 mg/L.

7.5.3 Measurable Objective: Avoid Seawater Intrusion

The measurable objective for avoidance of seawater intrusion is based on groundwater quality concentrations remaining stable in the representative well designated for this sustainability indicator (**Table 7-9**). Well 5N/4W-15E1 is located in the southern part of the Napa Valley Subbasin and has a long historical record.

Table 7-9. Measurable Objective to Avoid Seawater Intrusion

Well ID	Measurable Objective: Maintain TDS At or Below Historically Observed TDS Concentration (mg/L)
5N/4W-15E1	300
1. Secondary Recommended Maximum Contaminant Level for TDS is 500 mg/L.	

7.5.4 Measurable Objective: Avoid Chronic Lowering of Groundwater Levels, Reduced Groundwater Storage, and Land Subsidence

This measurable objective for avoidance of chronic groundwater level decline, land subsidence, and a reduction in groundwater storage is based on fall groundwater levels at representative wells that use the fall groundwater elevations for avoidance of streamflow depletion as the proxy (**Table 7-3**). Napa County 135, located away from the Napa River, is one other representative well used for these sustainability indicators (**Table 7-10**). The measurable objective is the fall level observed prior to the recent drought period. As described above, for the selected representative sites for this indicator, the minimum threshold is the fall groundwater elevation above which groundwater elevations are to be maintained in order to avoid undesirable results. Similarly, for these sites, the measurable objective is the fall groundwater elevation, at or above which, to maintain groundwater sustainability or improve groundwater conditions.

Table 7-10. Measurable Objective to Avoid Chronic Lowering of Groundwater Levels and Reduced Groundwater Storage

Well ID	Measurable Objective: Avoid GWL Decline over Successive Years and Land Subsidence (Fall GWE, Feet AMSL)	Measurable Objective: Avoid Reduced Groundwater Storage (Avoidance of Chronic GWE Decline is Proxy; Fall GWE, Feet AMSL)
NapaCounty-135	60	60

Tables 7-11 summarizes the minimum thresholds and measurable objectives ((respectively) for all representative sites and sustainability indicators.

Table 7-11. Representative Monitoring Sites: Minimum Thresholds and Measurable Objectives for Sustainability Indicators

Well ID	Sustainability Indicators and Minimum Thresholds and Measurable Objectives											
	Min Threshold	Measur-able Objective	Min Threshold	Measur-able Objective	Min Threshold	Measur-able Objective	Min Threshold	Measur-able Objective	Min Threshold	Measur-able Objective	Min Threshold	Measur-able Objective
	Chronic Lowering of GWLs (Fall GWE, Feet AMSL)	Chronic Lowering of GWLs (Fall GWE, Feet	Reduced GW Storage (Fall GWE, Feet AMSL)	Reduced GW Storage (Fall GWE, Feet AMSL	Seawater Intrusion (TDS, mg/L)	Seawater Intrusion (TDS, mg/L)	Degraded GW Quality (NO3-N mg/L)	Degraded GW Quality (NO3-N mg/L)	Land Subsid-ence (Fall GWE, Feet AMSL)	Land Subsid-ence (Fall GWE, Feet AMSL)	Streamflow Depletion (Fall GWE, Feet AMSL)	Streamflow Depletion (Fall GWE, Feet AMSL)
06N04W17A001M	37	50	37	50			10	8	37	50	37	50
06N04W27L002M	-2	12	-2	12			10	8	-2	12	-2	12
07N05W09Q002M	127	135	127	135			10	8	127	135	127	135
08N06W10Q001M	269	281	269	281			10	8	269	281	269	281
NapaCounty-128	320	331	320	331			10	8	320	331	320	331
NapaCounty-133	72	76	72	76			10	8	72	76	72	76
NapaCounty-135	20	60	20	60			10	8	20	60		
5N/4W-15E1					450	300	10	8				
Napa County 214s-swgw1	2	4	2	4							2	4
Napa County 215d-swgw1	2	4	2	4							2	4
Napa County 216s-swgw2	61	76	61	76							61	76
Napa County 217d-swgw2	61	76	61	76							61	76
Napa County 218s-swgw3	29	32	29	32							29	32
Napa County 219d-swgw3	29	32	29	32							29	32
Napa County 220s-swgw4	75	77	75	77							75	77
Napa County 221d-swgw4	75	77	75	77							75	77
Napa County 222s-swgw5	185	190	185	190							185	190
Napa County 223d-swgw5	164	175	164	175							164	175

7.6 Management Area

SGMA defines a “management area” as an area within a basin for which the Plan (in this case, the Basin Analysis Report) may identify different minimum thresholds, measurable objectives, monitoring, or projects and management actions based on differences in water use sector, water source type, geology, aquifer characteristics, or other factors (Section 351). Within the Napa Valley Subbasin, there is an area that is in the Subbasin where groundwater level trends are different than those that are typical of groundwater level trends for the overall groundwater basin. This area, referred to below as the Study Area, is not considered to be representative of the overall Napa Valley Subbasin. At this time, there are no Management Areas that have been defined in the Napa Valley Subbasin. However, the investigation described below will determine whether a Management Area is warranted.

As described in Chapter 4, groundwater level trends in the Napa Valley Subbasin of the Napa-Sonoma Valley Groundwater Basin are stable in the majority of wells with long-term groundwater level records. While many wells have shown at least some degree of response to recent drought conditions, the water levels observed in recent years are generally higher than groundwater levels in the same wells during the 1976 to 1977 drought. Elsewhere in the County long-term groundwater level records are limited, with the exception of the Milliken-Sarco-Tulucay (MST) Subarea.

Although designated as a groundwater subarea for local planning purposes, the majority of the MST is not part of a groundwater basin as mapped by DWR[10]. Groundwater level declines observed in the MST Subarea as early as the 1960s and 1970s have stabilized since about 2008. Groundwater level responses differ within the MST Subarea and even within the north, central, and southern sections of this subarea, indicating that localized conditions, whether geologic or anthropogenic in nature, might be the primary influence on groundwater conditions in the MST Subarea.

While the majority of wells with long-term groundwater level records exhibit stable trends, periods of year-to-year declines in groundwater levels have been observed in some wells. These wells are located near the Napa Valley margin, east of the Napa River, in an area where the East Napa Fault follows the Napa River and the Soda Creek Fault follows the eastern basin margin. This area (**Figure 7-2**) is characterized in part by relatively thin alluvial deposits, which may contribute to more groundwater being withdrawn from underlying semi-consolidated deposits.

Water levels in northeastern Napa Subarea wells monitored by the County (NapaCounty-75 and Napa County-76) east of the Napa River have stabilized since 2009, though declines were observed over approximately the prior decade. To ensure continuation of the current stable groundwater levels, further study in this area was recommended in the *Napa County Groundwater Monitoring Program 2015 Annual Report and CASGEM Update* (LSCE, 2016). The study was recommended given the potential for a hydraulic connection between the aquifer units in the vicinity of these wells and those of the MST Subarea and an apparent increase in new well permits over the past 10 years. The Napa County Board of Supervisors discussed the recommended Study Area and provided direction to staff at their April 5, 2016 meeting, with approved of the contract for the study on July 19, 2016. The study is designed to examine

[10] http://www.water.ca.gov/groundwater/bulletin118/gwbasins.cfm

existing and future water use in the area, sources of groundwater recharge, and the geologic setting to address questions regarding the potential for long-term effects. The study will also investigate the potential influence of previously documented groundwater cones of depression in the MST subarea on the Study Area both east and west of the Napa River.
The study, planned to begin in fall 2016, involves the following tasks:

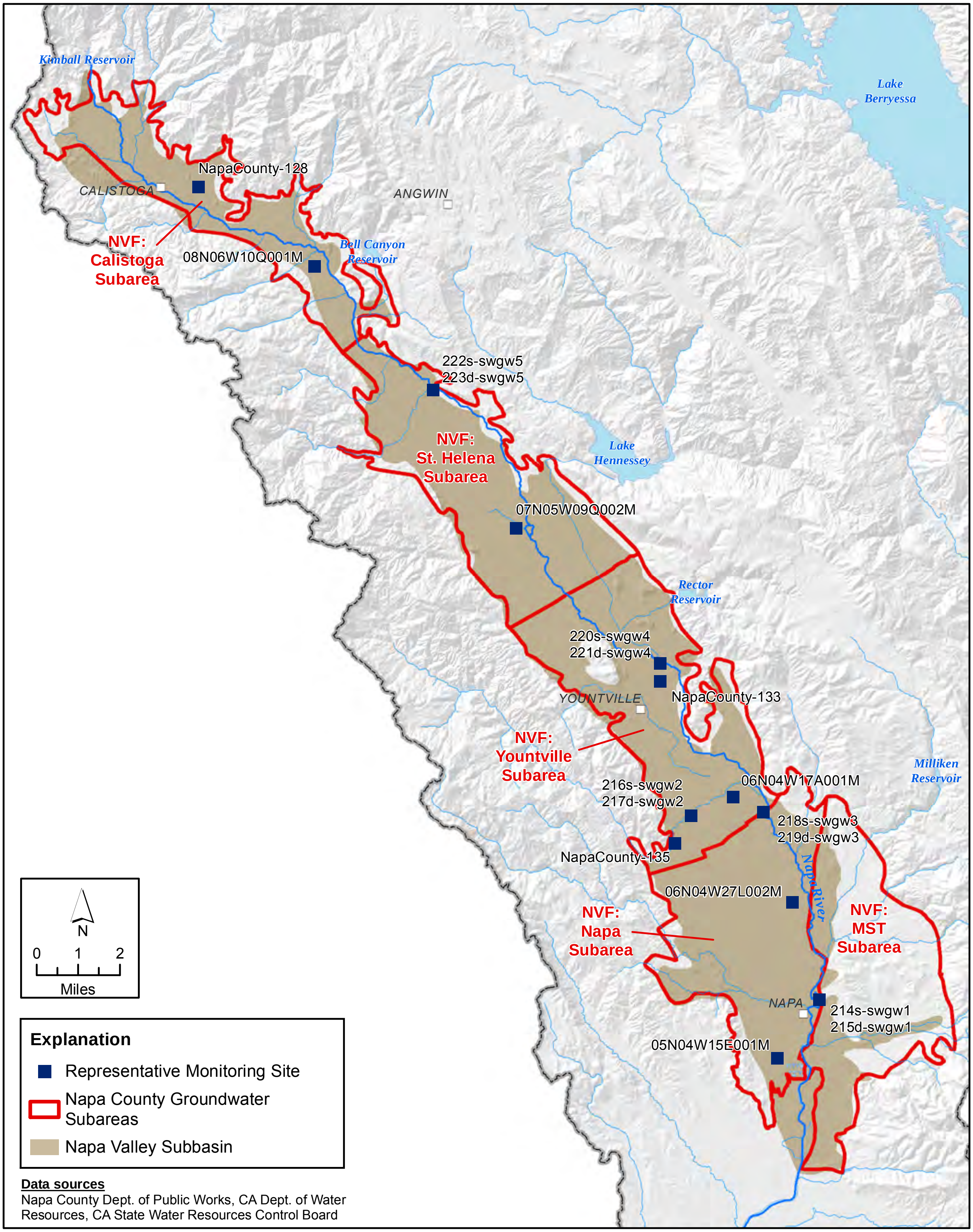
1. Obtain and review existing information pertaining to Study Area data, including Petra Drive well locations, drillers' reports, water use information (if known), etc.;
2. Evaluate the geologic and hydrogeologic setting and historical groundwater conditions and trends for the Study Area, including previously mapped faults, the thickness of the alluvium in the Study Area, especially near the Napa River and Soda Creek;
3. Tabulate and evaluate existing well performance data (to the extent available) including yield, specific capacity, and pump test data (if any);
4. Estimate potential recharge to the Study Area;
5. Conduct well interference analysis, including an analysis of potential effects from the wells located in the Petra Drive area and also within the overall Study Area. A simplified numerical model will be used to assess mutual well interference and also to assess potential streamflow effects from current use and known proposed projects;
6. Estimate water demands for the overall Study Area along with sources of supply used to meet Study Area water demands. Water demands and supplies will be tabulated for the overall Study Area for variable water year types; and
7. Estimate groundwater supply sufficiency to meet the current and potential future groundwater demands for the overall Study Area and other potential considerations with respect to proposed future groundwater use.

The County will evaluate the study results to determine if potential groundwater management measures or controls (similar to those that have been successfully implemented in the MST) or a Management Area designation are warranted.

The County's current monitoring network includes several wells in the Study Area. Napa County-76 will continue to be monitored and will be used to establish minimum thresholds and measurable objectives related to the chronic groundwater level declines sustainability indicator until the investigation is completed in winter/spring 2017 (**Table 7-12**).

Table 7-12. Study Area Minimum Threshold and Measurable Objective

Well ID	Minimum Threshold: Avoid Chronic GWL Decline (Feet AMSL)	Measurable Objective: Stabilize GWLs (Feet AMSL)
NapaCounty-76	-30	20

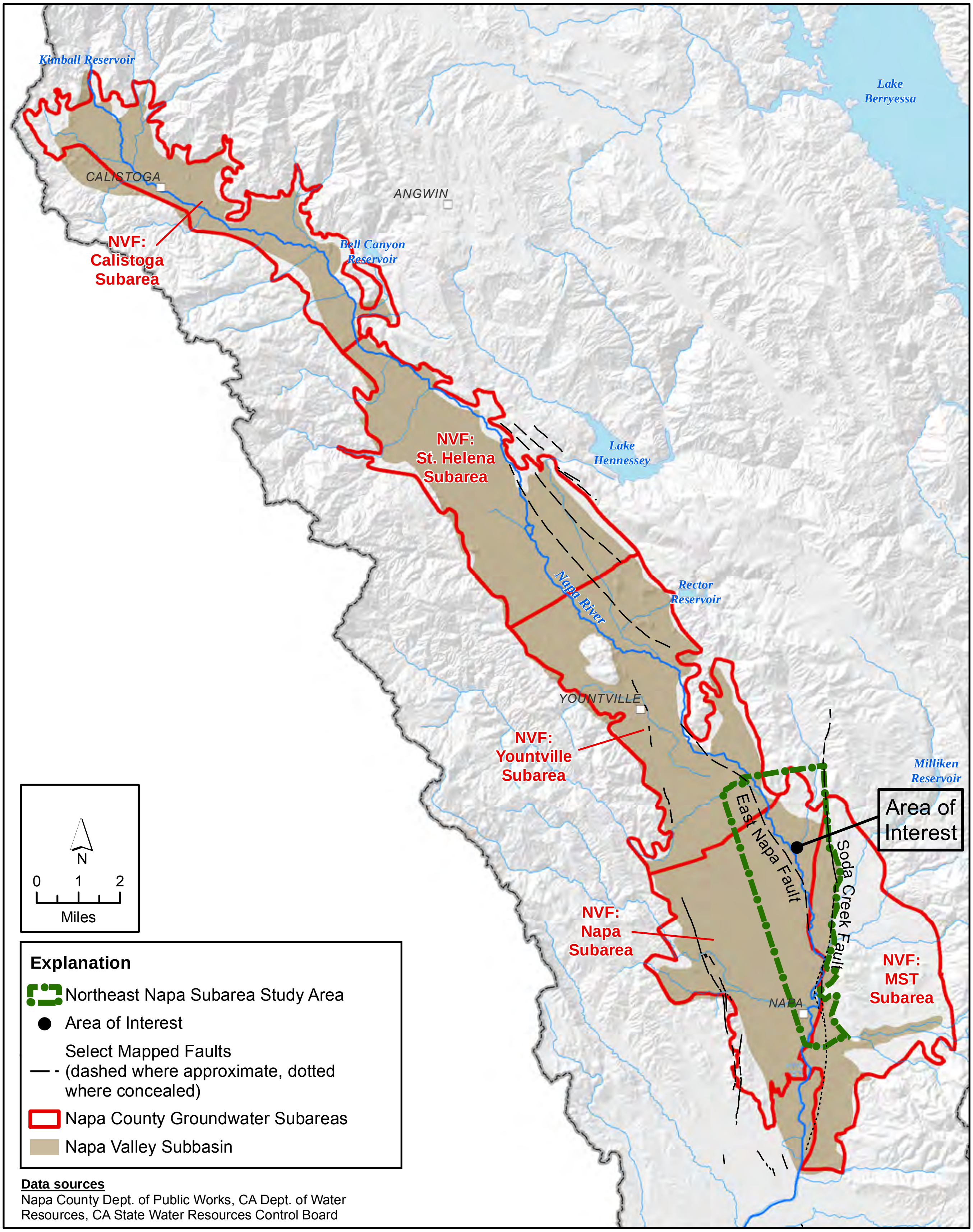


X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Figure 7-1 NV Subbasin Representative Monitoring Sites_revised.mxd

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

FIGURE 7-1
Napa Valley Subbasin Representative Monitoring Sites

Napa Valley Groundwater Sustainability: A Basin Analysis Report for the Napa Valley Subbasin



X:\2014 Job Files\14-108\GIS\Mapfiles\Basin Analysis Report\Figure 7-2 Napa County Northeast Study Area.mxd

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FIGURE 7-2

Northeast Napa Subarea Study Area

Napa Valley Groundwater Sustainability: A Basin Analysis Report for the Napa Valley Subbasin

GROUNDWATER SUSTAINABILITY OBJECTIVES

GROUNDWATER SUSTAINABILITY OBJECTIVES AD-HOC COMMITTEE

Napa County Groundwater Resources Advisory Committee (GRAC)

February 27, 2014, GRAC Meeting

1. Goal of Developing Groundwater Sustainability Objectives

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

2. Definition of Groundwater Sustainability

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

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

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

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

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

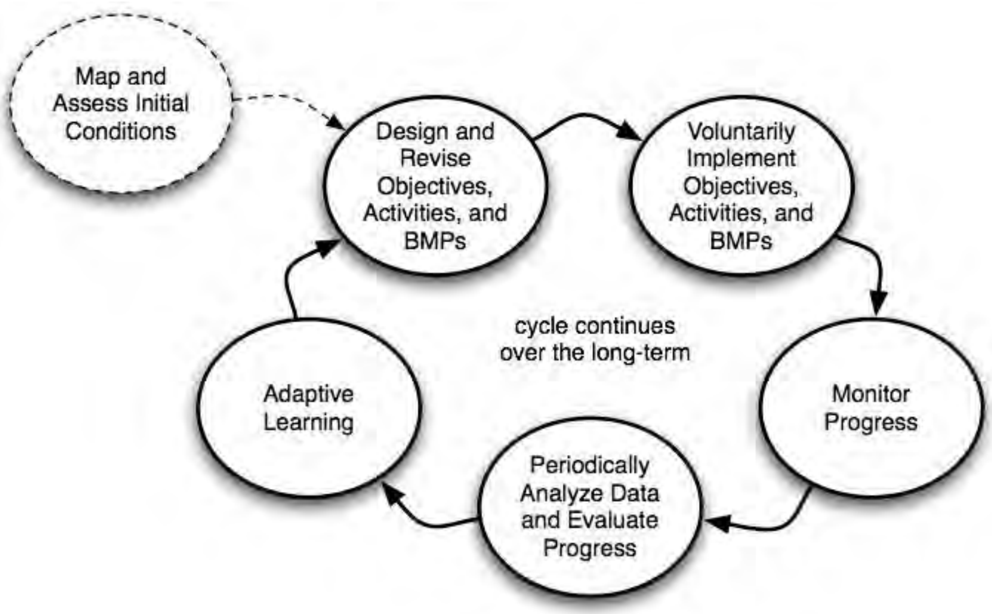
3. Shared Responsibility for Groundwater Sustainability

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

4. Monitoring as a Means to Achieving Groundwater Sustainability

Groundwater

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



5. Principles underlying the Objectives

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

6. Groundwater Sustainability Objectives

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

Objectives:

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

Supplemental recommendations:

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

SUSTAINABILITY OBJECTIVES

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

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

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

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

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

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