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Water Availability Analysis

Chateauneuf du Pott Winery P19-00408 & P19-00409
Planning Commission Hearing July 21, 2021

Water Availability Analysis

Chateauneuf du Pott Wines
2072 Mt. Veeder Road
Napa, CA 94558

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NAPA PBES REVIEW DRAFT

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Introduction

Chateauneuf du Pott Wines is applying for permits from the County of Napa to establish a 20,000 gallon per year (gpy) winery on the project parcel located at 2072 Mount Veeder Road (Napa County APN 034-100-046). Water for this winery will come from an existing well located on an adjacent parcel to the north (APN 034-100-045) which is also owned by the applicant. This well is currently used to irrigate vineyards on another parcel owned by the applicant (APN 034-100-047). However, with the completion of this project, other water sources will be developed for these vineyards, reducing demand on the aforementioned well.

The project parcel is located approximately eight miles northwest of the City of Napa in the County of Napa's Hillside groundwater zone (Figure 1). This Water Availability Analysis (WAA) was developed based on the guidance provided in the Napa County Department of Planning, Building, & Environmental Services' Water Availability Analysis Guidance Document formally adopted by the Napa County Board of Supervisors in May 2015. The WAA includes the following elements: estimates of existing and proposed water uses within the project recharge area, compilation of drillers' logs from the area and characterization of local hydrogeologic conditions, analyses to estimate groundwater recharge relative to proposed uses (Tier 1), and a screening analysis of the potential for well interference at neighboring wells located within 500-ft of the project well (Tier 2).

Limitations

Groundwater systems of Napa County and the Coast Range are typically complex, and available data rarely allows for more than general assessment of groundwater conditions and delineation of aquifers. Hydrogeologic interpretations are based on the drillers' reports made available to us through the California Department of Water Resources, available geologic maps and hydrogeologic studies, and professional judgment. This analysis is based on limited available data and relies significantly on interpretation of data from disparate sources of disparate quality.

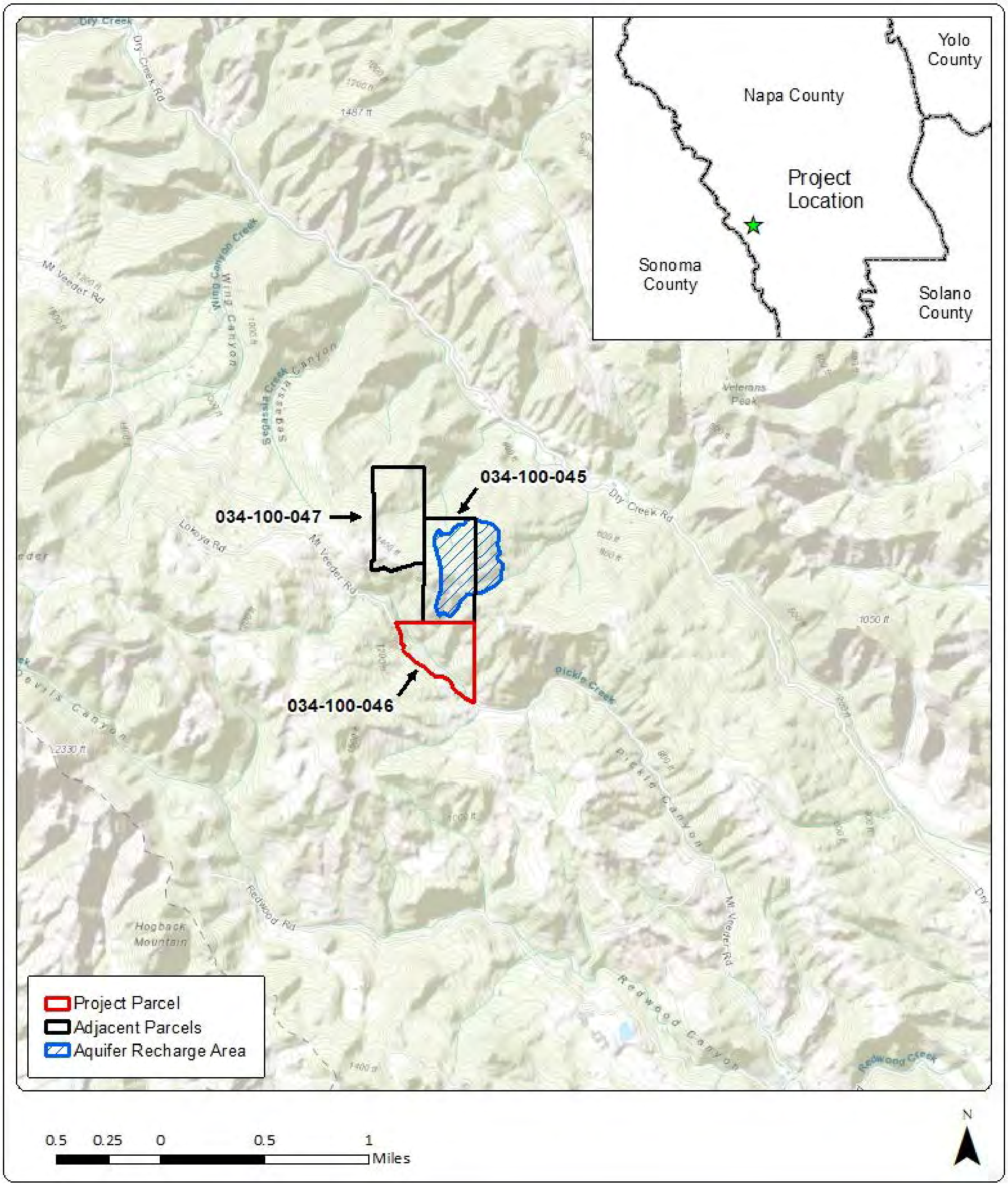

Figure 1: Project location map.

Hydrogeologic Conditions

The project parcel is located in the Mayacamas Mountains west of the Napa Valley along Pickle Creek in Pickle Canyon. The project parcel and the ridgeline north of Pickle Creek where the project well is located are underlain by a long, narrow block of the Cretaceous-aged Great Valley Sequence (map unit KJgv)(Figure 2). This block, which dips to the northeast, is approximately two miles wide and is bounded by two northwest to southeast trending faults. These faults arethe contact between this block and large blocks of the Sonoma Volcanics to the northeast and southwest. The Sonoma Volcanics also overlie the Great Valley Sequence on this block in the vicinity of Mount Veeder (about 2 miles to the west), but these units are far from the project well and are unlikely to influence hydrogeologic conditions along the ridge.

The Great Valley Sequence consists of marine shale, sandstone, and conglomerate and has not been further divided on the available geologic maps (Wagner and Gutierrez, 2017). Primary porosity within this sequence is low and groundwater occurs primarily in fractures. Yields are low, typically on the order of a few gallons per minute (gpm)(LSCE 2013). Dry holes are also common within this formation.

Well Data

Well Completion Reports for wells within the vicinity of the project parcel were obtained through the California Department of Water Resources (DWR) Well Completion Report Map Application. Additional detail about well location was provided by the project applicant, including the location of the project well and the location of three wells on one of his properties (APN 034-100-047). Well completion reports could be located for the project well and one of the wells on this adjacent parcel. Well completion reports were obtained for two other wells on the adjacent parcel (Wells 3 & 4) but could not be associated with a specific well. A subset of these logs was compiled (Appendix A) and georeferenced based on parcel and location sketch information (Figure 2).

The well which will supply water to the proposed winery (i.e., the project well, Well 1) is located on top of the ridge between Pickle and Dry Creeks on an adjacent parcel owned by the project applicant (APN 034-100-045). This well was drilled to a depth of 440 feet and is completed to a depth of 338 feet. At the time the well was completed (January 2017), the well had a static water level of 146 feet and an estimated yield of 60 gpm (Table 1). The well is screened between 138 and 278 feet in a thick layer of shale with sandstone stringers, strata that are consistent with the geology of the Great Valley Sequence.

Eighteen additional wells, most of which are completed in the block of the Great Valley Sequence, could be accurately georeferenced in the vicinity of the project parcel (Figure 2). With the exception of a relatively shallow well completed in a landslide deposit (Well 11), these wells were typically completed to depths of 160 to 400 feet. Static water levels range from as shallow as 15 feet to 202 feet. Water levels do not follow an obvious spatial distribution; many of the wells along the same ridgeline as the project well have relatively shallow static water levels.

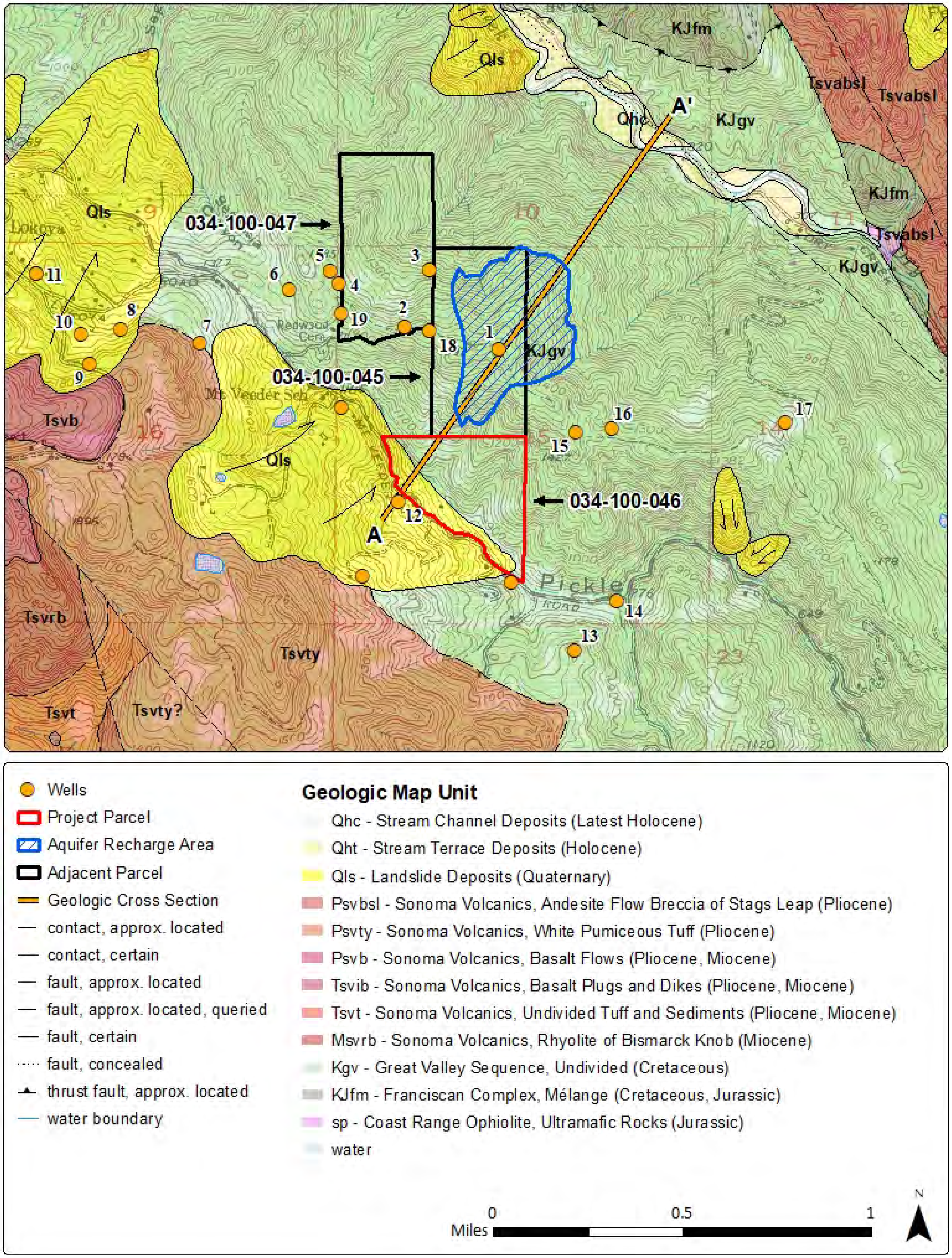

Figure 2: Surficial geology and locations of wells in the vicinity of the project parcel. Surficial geology based on data from the Preliminary Geologic Map of the Napa and Bodega Bay 30' x 60' Quadrangle (Wagner and Gutierrez, 2010).

Estimated yields are similarly variable, ranging from as little as 0.5 gpm in Well 12 to 100 gpm in Well 5. Yields show a clear spatial distribution with estimated yields from most wells on the same ridgeline as the project parcel being roughly an order of magnitude higher than wells completed on the south side of Pickle Canyon. Almost all wells report mixed sandstone and shale, consistent with the Great Valley Sequence. One dry hole was reported on the south side of Pickle Canyon and other, un-georeferenced well completion reports within the same section as the project parcel report dry holes.

Table 1: Well completion details for wells in the vicinity of the project parcel. Well Completion Reports were available for wells 3 & 4, but it could not be determined which of the two wells they corresponded to. Values listed for wells 3 & 4 may be interchangeable.

Well ID	1	2	3	4	5	6	7	8	9
Year Completed	pre-2017	pre-2011	1995	1995	1996	1996	1988	pre-2014	1999
Depth (ft)	338	300	249	180	198	198	315	400	160
Estimated Yield (gpm)	60	30	2	12	100	35	5	4	8
Static Water Level (ft)	146	60	30	30	58	78	42	202	69
Top of Case (ft)	138	100	60	40	88	97	55	277	58
Bottom of Case (ft)	278	140	240	>100	188	197	315	337	118
Geologic Map Unit	KJgv	KJgv	KJgv	KJgv	KJgv	KJgv	KJgv	KJgv	Tsvty

Well ID	10	11	12	13	14	15	16	17	18 & 19
Year Completed	2000	1976	1979	pre-2009	2007	pre-2004	1988	2002	Unk.
Depth (ft)	160	62	202	680	214	240	200	200	Unk.
Estimated Yield (gpm)	0	30	0.5	2	15	70	10	60	Unk.
Static Water Level (ft)	N/A	40	15	42	140	58	50	86	Unk.
Top of Case (ft)	N/A	42	30	40	150	80	40	45	Unk.
Bottom of Case (ft)	N/A	62	198	630	214	200	199	185	Unk.
Geologic Map Unit	KJgv	Qls	KJgv	KJgv	KJgv	KJgv	KJgv	KJgv	Unk.

Geologic Cross Section

A geologic cross-section oriented southwest to northeast is shown in Figure 3 (see Figure 2 for location). Elevations along this cross-section range from less than 400 feet near Dry Creek to almost 1,600 feet along the ridgeline the project well (Well 1) is located on. The range of relief from the top of the ridge to the creeks on either side is significantly greater than the depth of wells along this ridge (Table 1). Little information is available about the geology of this ridge but the few available well completion reports indicate a relatively homogenous mixture of shale and sandstone with the upper few hundred feet of the ridge near the project well dominated by shale. The California Geologic Survey's (CGS) Preliminary Geologic Map of the Napa Bodega 30' x 60' quadrangle indicates that the block of the Great Valley Sequence underlying this ridge dips 45 to 50 degrees to the northeast in this area.

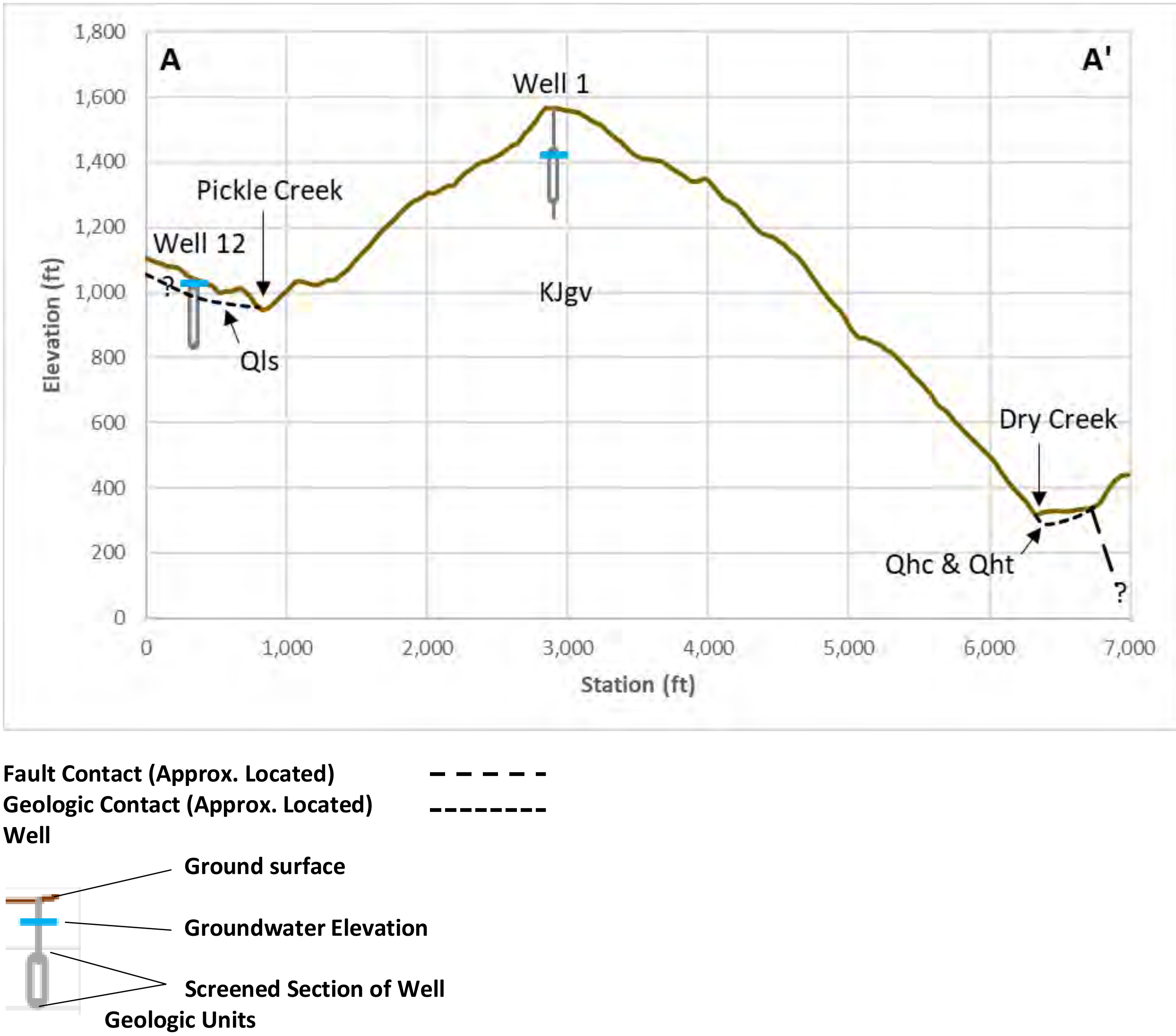

Figure 3: Hydrogeologic cross section A -A' through the project parcel (see Figure 2 for location and geologic map units).

Project Recharge Area

The project well is completed in a large block of the Great Valley Sequence without any nearby mapped faults or contacts which may function as barriers to groundwater flow. In the absence of such features, the project recharge area is defined primarily by surface water drainage patterns, which the groundwater gradient may mimic. Specifically, the southeastern boundary is defined by two prominent drainages which are believed to form groundwater drainage divides; the northwestern boundary is defined by spur ridges also believed to from groundwater drainage divides. The northeastern and southwestern boundaries are defined by the surface contour elevation equal to the elevation of the bottom of the project well's screened interval.

The total area of the project recharge area is 67 acres, all of which is underlain by undifferentiated rocks of the Great Valley Sequence. Given the low permeability of the fine-grained bedrock and groundwater elevation in Well 1 above the screened interval indicative of pressure head within the aquifer above atmospheric pressure, the aquifer comprising the project recharge area is likely confined or semi-confined.

Water Demand

The County of Napa's Water Availability Analysis Guidance Document requires that water demand be calculated for the project parcel. However, because the project well is located on an adjacent parcel under common ownership and provides for water demands on other parcels, additional demand from these parcels has been included (Well 1). Demand for the project parcel and adjacent parcels have been tabulated separately. The project well is also the only well within the project recharge area. Consequently, the water demand calculated for the project well is the same as demand within the entire project recharge area.

Water uses for this well were determined using site details provided by the project applicant and verified using satellite imagery. Water use rates for these uses were obtained from the County of Napa's Water Availability Analysis Guidance Document (Napa, 2015) and from vineyard irrigation logs provided by the applicant.

Existing Use

In the existing condition there is no water use on the project parcel. A previously existing residence on the parcel was destroyed during the October 2017 Nuns Fire and the project applicant does not plan to rebuild this structure.

The project well is currently used to irrigate approximately 4.69 acres of vineyard on another of the applicant's parcels (APN 034-100-047). Detailed irrigation records provided by the applicant show that these vineyards were irrigated at a rate of 0.29 acre-ft/acre/yr (Table 2). This vineyard is also irrigated using water from another well (Well 2). Because the water management for this vineyard is complex and variable, a simplifying assumption was made that Well 1 provides half of the water required to irrigate the vineyard (Table 3).

Based on these uses, existing water demand for the project well and the project recharge area is 0.67 acre-ft/yr (Table 4). All of this is used to irrigate vineyards on an adjacent parcel. There is no existing water use on the project parcel.

Table 2: Reported vineyard irrigation rates for 2018.

Vineyard Block	Area (ac)	# Vines	Gal/Vine/Yr	AF/Yr/Block
1	0.63	1146	68	0.24
2	0.44	794	49	0.12
3	0.68	1227	46	0.17
4	0.87	1581	71	0.34
5	0.29	535	48	0.08
6	0.56	1014	16	0.05
7	0.49	886	50	0.14
8	0.53	968	49	0.15
9	0.2	430	45	0.06
Total	**4.69**	**8581**	**-**	**1.35**

Table 3: Estimated existing water use on the neighboring parcel (APN 034-100-047)

	# of Units	Use per Unit	Annual Water Use (AF/yr)
Agricultural Use			**0.67**
Vineyard	2.35 Acres	0.29 AF/acre/yr	0.67
Total			**0.67**

Table 4: Estimated existing and proposed water demand from the project well and within the project recharge area.

	Existing Condition (acre-ft/yr)	Proposed Condition (acre-ft/yr)
Project Parcel	**0.00**	**0.58**
Winery Use	0.00	0.53
Neighboring Parcels	**0.67**	**0.00**
Irrigation Use	0.67	0.00
Total	**0.67**	**0.58**

Proposed Use

In the proposed condition, a winery with 20,000 gpy capacity will be established on the project parcel. This winery will have up to two full time employees during the normal operating season and up to four additional full- and part-time employees during harvest. The winery will host three annual marketing events with up to 30 people per event and plans on hosting tasting for an average of 25 people per week. All food will be catered offsite.

Following construction of the winey, the vineyard will no longer be irrigated using water from the project well (Well 1). Instead, it will be irrigated using water from a proposed well and pond that the applicant is in the process of permitting and which will be constructed at a later date.

In this condition, water use will decrease to approximately 0.58 acre-ft/yr (Tables 4 & 5). All of this use will be from the winery on the project parcel. The vineyard on the adjacent parcel will be switched to an alternative water supply and will not use water from the project recharge area.

Table 5: Estimated proposed water demand from the project parcel.

	# of Units	Use per Unit	Annual Water Use (AF/yr)
Winery Use			**0.53**
Process Water	20000 Gallons	2.15 AF/100,000 gal.	0.43
Domestic & Landscaping	20000 Gallons	0.50 AF/100,000 gal.	0.10
Guest & Employee Use			**0.05**
Daily Tours & Tastings	1300 Guests	3 gal./Guest	0.01
Annual Marketing Events	90 Guests	3 gal./Guest	< 0.01
Year-Round Employees	2 Employees	15 gal./shift @ 250 shifts/yr	0.02
Addt'l. Harvest Employees	4 Employees	15 gal./shift @ 60 shifts/yr	0.01
Total			**0.58**

Groundwater Recharge Analysis

Groundwater recharge within the project recharge area was estimated using a Soil Water Balance (SWB) of Napa County developed by OEI. This model implements the U.S. Geologic Survey's SWB modeling software and produces a spatially distributed estimate of annual recharge. This model operates on a daily timestep and calculates runoff based on the Natural Resources Conservation Service (NRCS) curve number approach and Actual Evapotranspiration (AET) and recharge based on a modified Thornthwaite-Mather soil-water-balance approach (Westenbroek et al., 2010). Details of this model are included in Appendix B.

Groundwater recharge was simulated for two water years. The first, Water Year 2010, was selected to represent average year conditions because annual precipitation totals across most of Napa County were close to their long-term 30-year averages. The second, Water Year 2014, was selected to represent drought average conditions because annual precipitation totals were between 41 and 73% of long-term 30-year averages for much of Napa County.

During the simulation of Water Year 2010, precipitation averaged 39.9 inches across the project recharge area and actual evapotranspiration (AET) averaged 24.9 inches. Simulated groundwater recharge varied from 6.7 to 12.0 inches across the recharge area, with a spatial average of 8.3 inches. During the simulation of Water Year 2014, precipitation averaged 25.1 inches across the project recharge area and actual evapotranspiration averaged 19.2 inches. Groundwater recharge varied from 0.5 to 5.2 across the recharge area with a spatial average of 2.0 inches (Table 6).

Groundwater recharge estimates can also be expressed as a total volume by multiplying the estimated recharge rate by a representative area. For the 67 acre project recharge area, these calculations yield and estimated total recharge of 11.2 acre-ft/yr during the drought conditions of water year 2014 and of 46.3 acre-ft/yr for the average water year of 2010 (Table 7). For the 58.3 acre-project parcel, these calculations yield an estimated total recharge of 40.3 AF/yr of recharge for Water Year 2010 and 9.7 AF/yr in Water Year 2014.

While the project parcel will receive water from an adjacent parcel, this transfer will occur because of the configuration of the existing infrastructure, not because insufficient recharge occurs on the project parcel. The average annual recharge of 40.3 acre-ft/yr may be considered as the screening criterion for the project parcel, a number which is significantly larger than proposed demand.

Table 6: Summary of water balance results for the project recharge area estimated by the SWB model for Water Year 2010 (average water year conditions).

	2010 Normal Year		2014 Dry Year	
	inches	% of precip	inches	% of precip
Precipitation	39.9	-	25.1	-
AET	24.9	62%	19.2	76%
Runoff	6.7	17%	3.9	16%
Recharge	8.3	21%	2.0	8%

Water budget estimates are available for several nearby watersheds including Dry Creek and Napa Creek. Average annual recharge for these two watersheds is estimated to be 6% and 11% of average annual precipitation (LSCE, 2013). Regional estimates are also available for the Napa River watershed, the Santa Rosa Plain, Sonoma Valley, and the Green Valley Creek watershed. Comparisons to these water budgets are useful for determining the overall reasonableness of the results although one would not expect precise agreement owing to significant variations in climate, land cover, soil types, and underlying hydrogeologic conditions. These regional analyses estimated that mean annual recharge was equivalent to between 7% and 28% of mean annual precipitation (Farrar et. al., 2006; Flint and Flint 2014, Kobor and O'Connor, 2016; Wolfenden and Hevesi, 2014). The simulated water year 2010 groundwater recharge for the project recharge area represents approximately 21% (Table 6) of the precipitation, in upper end of the range of these regional estimates.

Comparison of Water Demand and Groundwater Recharge

The total proposed groundwater use for the project recharge area is estimated to be 0.58 acre-ft/yr, all of which will originate on the project parcel. Groundwater use in the project recharge area is equivalent to 1% of the estimated average water year groundwater recharge of 46.3 acre-ft/yr and 5% of the estimated dry water year recharge of 11.2 acre-ft/yr (Table 7). Water use on the project parcel is equivalent to 1% of the estimated recharge occurring on the project parcel during average water years and 6% of the estimated recharge during dry water years such as 2014. Given the magnitude of these surplus, water use associated with the proposed winery is highly unlikely to result in reductions in groundwater levels or depletion of groundwater resources over time.

Table 7: Comparison of proposed water use to average and dry year groundwater recharge for the project recharge area and for the project parcel.

Domain	Total Proposed Demand (ac-ft/yr)	Average Water Year (2010)			Dry Water Year (2014)		
		Recharge (ac-ft/yr)	Recharge Surplus (ac-ft/yr)	Demand as % of Recharge	Recharge (ac-ft/yr)	Recharge Surplus (ac-ft/yr)	Demand as % of Recharge
Project Recharge Area	0.6	46.3	45.8	1%	11.2	10.6	5%
Project Parcel	0.6	40.3	39.7	1%	9.7	9.1	6%

Well Interference Analysis

There are no neighboring wells within 500 feet of the project well (Well 1). The nearest well, Well 18, is located approximately 1,100 feet away. Based on the WAA guidance document, a Tier 2 well interference analysis is not required given that all non-project wells are located greater than 500-feet from the project wells.

Summary

Application of the Soil Water Balance model (SWB) to the project recharge area revealed that average water year recharge was approximately 8.3 inches/yr or 46.3 acre-ft/yr. During drought conditions, recharge was significantly lower at 2.0 inches/yr or 11.2 acre-ft/yr. The total proposed water use for the project recharge area is estimated to be 0.58 acre-ft/yr. This represents approximately 1% of the mean annual recharge indicating that the project is unlikely to result in declines in groundwater elevations or depletion of groundwater resources over time. The nearest neighboring well is located more than 500-ft from the project well indicating that a Tier 2 well interference analysis is not required.

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APPENDIX A

WELL COMPLETION REPORTS

APPENDIX B

NAPA COUNTY GROUNDWATER RECHARGE ANALYSIS

Napa County Groundwater Recharge Analysis

Introduction

Developing accurate estimates of the spatial and temporal distribution of groundwater recharge is a key component of sustainable groundwater management. Efforts to quantify recharge are inherently difficult owing to the wide variability of controlling hydrologic processes, the wide range of available tools/methods for estimating recharge, and the difficulty in assessing the accuracy of estimates because direct measurement of recharge rates is, for the most part, infeasible.

Numerical modeling is a common approach for developing recharge estimates. Soil-water-balance modeling is one category of numerical models particularly well-suited for estimating recharge across large areas with modest data requirements. This study describes an application of the U.S. Geological Survey's (USGS) Soil Water Balance Model (SWB) (Westenbroek et al., 2010) to develop spatial and temporal distributions of groundwater recharge across Napa County. This model operates on a daily timestep and calculates surface runoff based on the Natural Resources Conservation Service (NRCS) curve number method and potential evapotranspiration based on the Hargreaves-Samani methods (Hargreaves and Samani, 1985). Actual evapotranspiration (AET) and recharge are calculated using a modified Thornthwaite-Mather soil-water-balance approach (Westenbroek et al., 2010).

It is important to note that the SWB model focuses on surface and soil-zone processes and does not simulate the groundwater system or track groundwater storage over time. The model also does not simulate surface water/groundwater interaction or baseflow; thus, the runoff estimates represent only the surface runoff component of streamflow resulting from rainstorms and the recharge estimates represent only the infiltration recharge component (also referred to as diffuse recharge) of total recharge (stream-channel recharge is not simulated).

Model Development

The model was developed using a 30-meter (98.4 ft) resolution rectangular grid. Water budget calculations were made on a daily time step. Key spatial inputs included a flow direction map developed from the USGS 1 arc-second resolution Digital Elevation Model (DEM), a land cover map derived from the U.S. Forest Service (USFS) CALVEG dataset that was supplemented by a database of agricultural areas maintained by the County of Napa (Figure 1), a distribution of Hydrologic Soil Groups (A through D classification from lowest to highest runoff potential; Figure 2), and a distribution of Available Water Capacity (AWC) developed from the NRCS Soil Survey Geographic Database (SSURGO) (Figure 3).

A series of model parameters were assigned for each land cover type/soil group combination including an infiltration rate, a curve number, dormant and growing season interception storage values, and a rooting depth (Table 1).

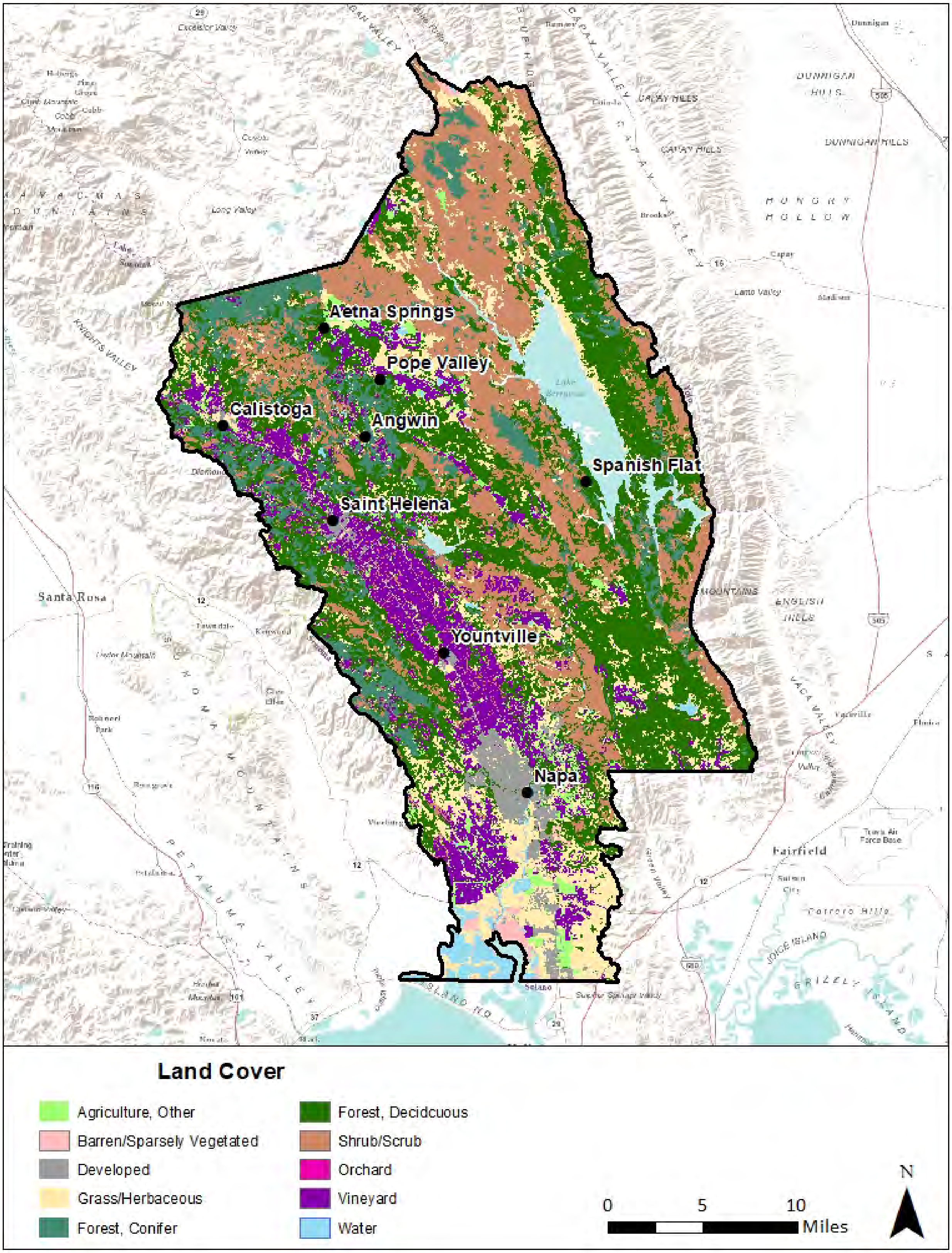

Figure 1: Land cover distribution used in the Napa County SWB model.

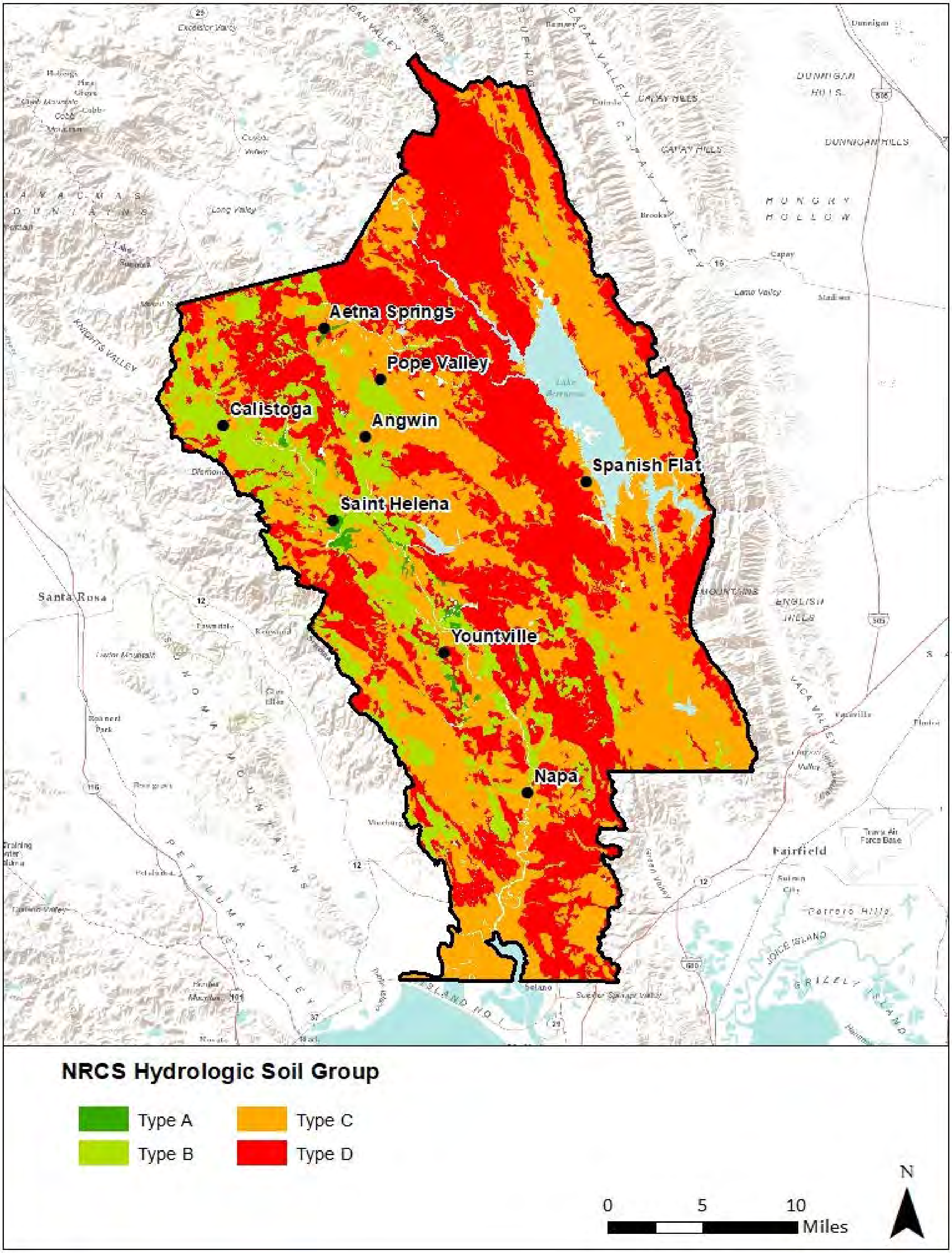

Figure 2: Hydrologic soil group distribution used in the Napa County SWB model.

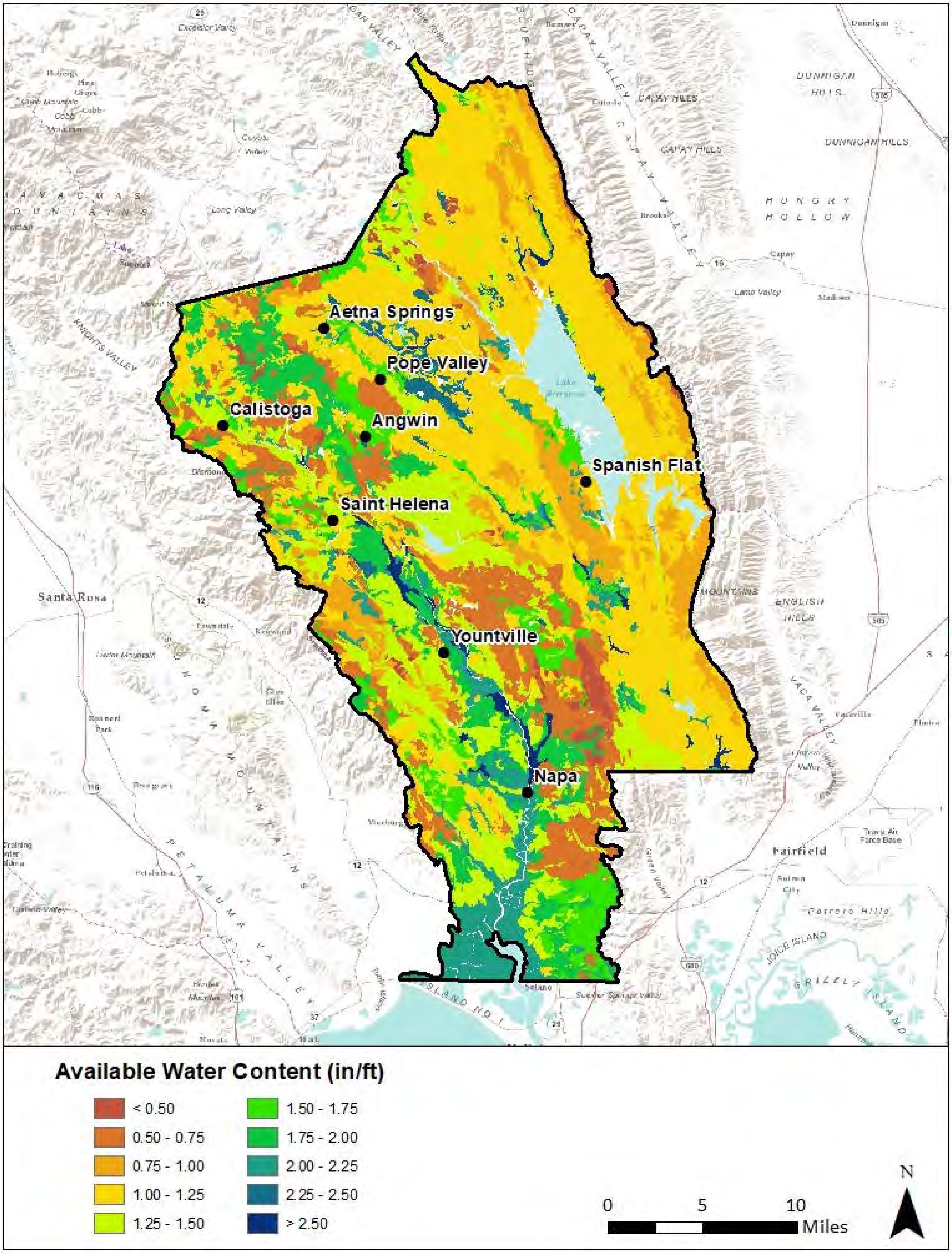

Figure 3: Available water capacity distribution used in the Napa County SWB model.

Table 1: Soil and land cover properties used in the Napa County SWB model.

Land Cover	Interception Storage Values ()		Curve Number by NRCS Soil Type ()				Rooting Depth by NRCS Soil Type (ft)			
	Growing Season	Dormant Season	Type A	Type B	Type C	Type D	Type A	Type B	Type C	Type D
Agriculture, Other	0.080	0.040	38	61	75	81	2.0	1.9	1.8	1.7
Barren	0.000	0.000	77	86	91	94	0.0	0.0	0.0	0.0
Developed	0.005	0.002	61	75	83	87	2.3	2.1	2.0	1.8
Grassland/Herbaceous	0.005	0.004	30	58	71	78	1.3	1.1	1.0	1.0
Forest, Coniferous	0.050	0.050	30	55	70	77	5.9	5.1	4.9	4.7
Forest, Deciduous	0.050	0.020	30	55	70	77	5.9	5.1	4.9	4.7
Shrub/Scrub	0.080	0.015	30	48	65	73	3.2	2.8	2.7	2.6
Orchard	0.050	0.015	38	61	75	81	3.2	2.8	2.7	2.6
Vineyard	0.080	0.015	38	61	75	81	2.2	2.1	2.0	1.9
Water	0.000	0.000	100	100	100	100	0.0	0.0	0.0	0.0

Table 2: Infiltration rates for NRCS hydrologic soil groups (Cronshey et al., 1986).

Soil Group	Infiltration Rate (in/hr)
A	> 0.3
B	0.15 - 0.3
C	0.05 - 0.15
D	<0.05

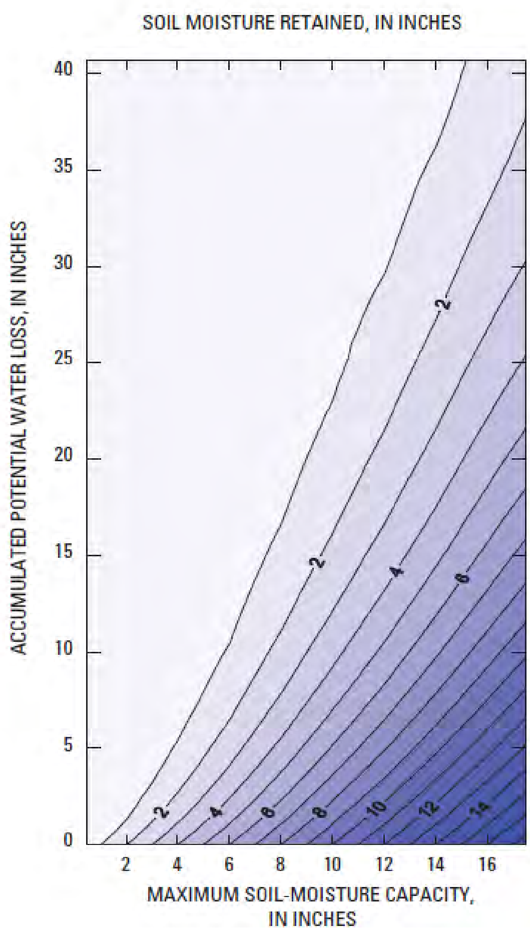

Figure 4: Soil-moisture-retention table (Thornthwaite and Mather, 1957).

Infiltration rates for hydrologic soil groups A through D were applied based on Cronshey et al. (1986) (Table 2) along with default soil-moisture-retention relationships based on Thornthwaite and Mather (1957) (Figure 4). Curve numbers were assigned based on standard NRCS methods. Interception storage values and rooting depths were assigned based on literature values and from previous modeling experience including a SWB model prepared for Sonoma County and calibrated using runoff volumes from several stream gages (OEI, 2017).

The SWB model utilizes daily precipitation and mean daily temperature data derived from climate stations. To account for the spatial variability of these parameters, daily precipitation and mean daily temperature were input as gridded time-series. The gridded precipitation time-series was created using data from 15 weather stations in Napa County, and the gridded mean temperature time-series was created using data from 8 stations (Table 3). These stations were selected based on completeness of the records and to provide station data across the range of climates experienced in the county. Data was obtained from the California Data Exchange Center (CDEC), the National Climatic Data Center (NCDC), and from Napa One Rain.

To create the gridded time-series, the model domain was divided into discrete areas represented by individual weather stations (Figures 4 and 5). This delineation was based on climate variations described by existing gridded mean annual (1981-2010) precipitation and temperature data (PRISM, 2010) and local knowledge of climatic variations across the county.

For the precipitation time-series, each area representing a weather station was subdivided into four to twenty-three zones based on 1-inch average annual precipitation contours. Within each zone the raw station data was multiplied by a unique scaling factor. This scaling factor was calculated as the ratio of average annual precipitation within a zone to average annual precipitation at the representative rain gage. In certain locations, typically near the boundary of areas represented by gages located on the valley bottom and at higher elevations, this scaling was unable to smoothly resolve differences in annual and event precipitation totals. To more accurately estimate precipitation near these boundaries, precipitation records from the two gages in question were averaged using weights calculated proportionally to the difference between PRISM mean annual precipitation at a rain gage and within a selected zone. The resulting gridded time-series is comprised of 220 individual time-series based on the scaled station data from 15 stations.

The assignment of temperature stations was based on the understanding that the spatial variability of temperatures across Napa County is relatively homogenous, with elevation being the primary variable. Temperature records were classified either as Mountain, Valley Bottom, or East County and applied within areas the PRISM datasets described as being similar. To smooth the transition from Mountain zones to Valley Bottom and East County zones, Hillside zones were created where the temperature records of the two nearest gages were averaged.

Missing and suspect data was encountered in the raw precipitation and temperature data from the weather stations used by the model. Values that were significantly outside the typical range and where similar observations were not found at nearby stations were removed from the datasets. These and missing values were filled using scaled data from other nearby stations. Precipitation data used for gap filling was scaled using the ratio of the 1981 to 2010 mean annual precipitation (PRISM 2010) between the two stations. Temperature data was scaled using the ratio of the 1981 to 2010 mean monthly minimum and maximum temperatures (PRISM, 2010) between the two stations.

The current analysis focuses on Water Year 2010 (October 1, 2009 – September 30, 2010) and Water Year 2014 (October 1, 2013 – September 30, 2014). These years were selected because they represent periods with data available from most weather stations in the county and where most stations reported annual precipitation totals close to the long term average (WY 2010) and significantly below the long term average (WY 2014). Based on a comparison between station data and PRISM average precipitation depths during Water Year 2010, rainfall averaged 101% of long-term average conditions and ranged from 78% at Lake Hennessey to 111% at the Napa County Airport. In Water Year 2014, rainfall averaged 55% of long-term average conditions and ranged from 41% at Lake Hennessey to 73% at the Napa State Hospital (Table 3).

Table 3: Weather stations used in the Napa County SWB model. See Figures 6 and 7 for associated timeseries.

Station	Data Used	1981 - 2010 Mean Annual Precip (in)	WY 2010		WY 2014	
			Precip (in)	% Avg	Precip (in)	% Avg
Angwin[1]	Precip & Temp	42.54	44.64	105%	25.04	59%
Atlas Peak[1]	Precip & Temp	41.76	39.04	93%	20.08	48%
Berryessa[1]	Precip & Temp	28.97	28.16	97%	13.97	48%
Calistoga[2]	Precip	39.41	41.75	106%	18.18	46%
Knoxville Creek[1]	Temp Only	-	-	-	-	-
Lake Hennessey[3]	Precip Only	34.09	26.52	78%	13.92	41%
Mt. George[3]	Precip Only	31.15	29.64	95%	18.24	59%
Mt. Veeder[3]	Precip Only	44.81	46.44	104%	28.6	64%
Napa County Airport[2]	Precip & Temp	21.14	23.56	111%	9.87	47%
Napa River at Yountville Cross Rd[3]	Precip Only	31.86	32.72	103%	14.93	47%
Napa State Hospital[2]	Precip & Temp	26.81	28.85	108%	19.66	73%
Petrified Forest[3]	Precip Only	42.39	46.6	110%	22.84	54%
Redwood Creek At Mt. Veeder Road[3]	Precip Only	34.71	37.36	108%	23.48	68%
Saint Helena[2]	Precip & Temp	37.43	39.11	104%	19.11	51%
Saint Helena 4WSW[1]	Precip & Temp	45.44	47.88	105%	28.88	64%
Sugarloaf Peak[3]	Precip Only	32.20	26.16	81%	17.12	53%

1 – Data accessed from California Data Exchange Center (CDEC)
2 – Data accessed from National Climate Data Center (NCDC)
3 – Data access from Napa One Rain

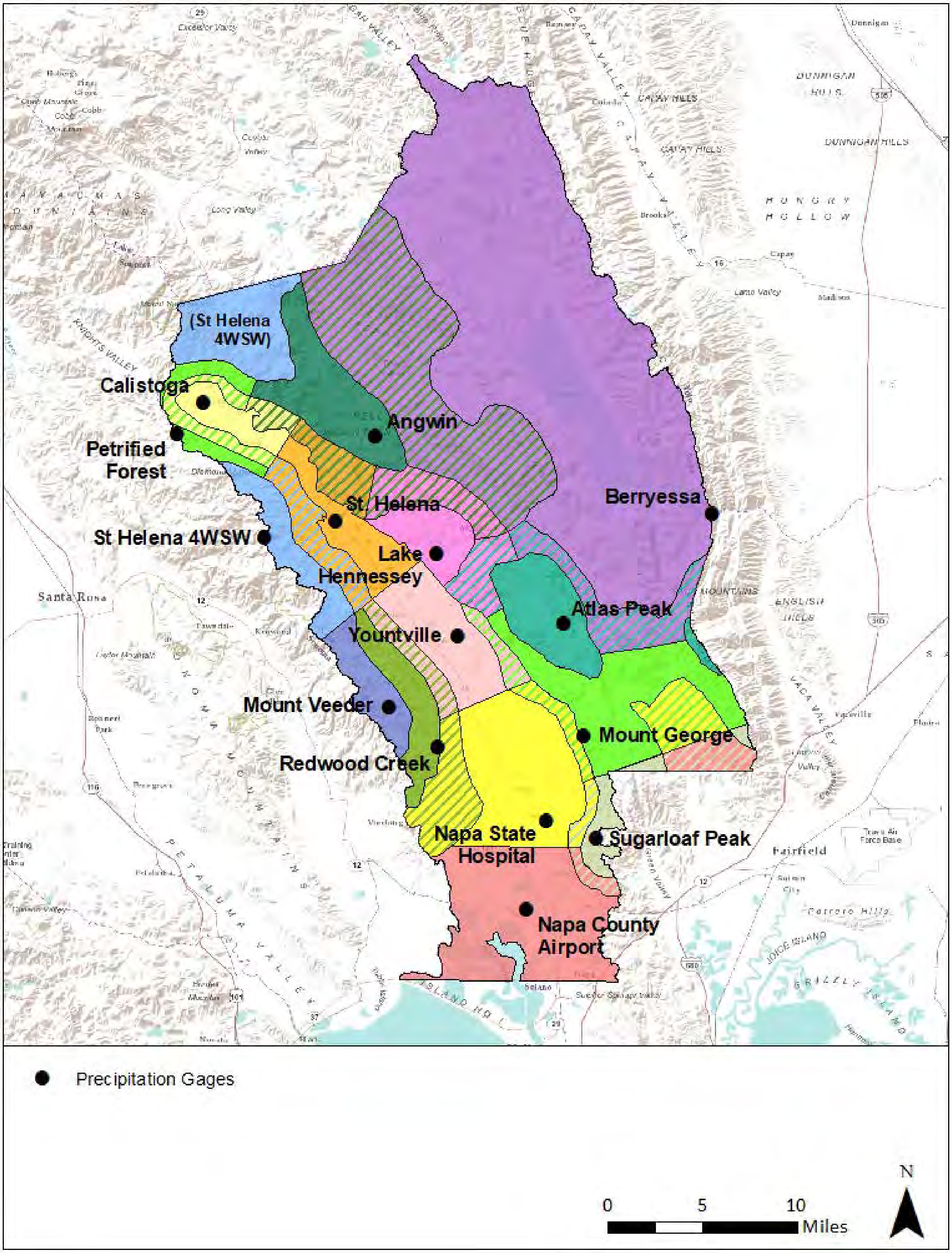

Figure 4: Precipitation zones used in the Napa County SWB model. Hatching indicates two precipitation records were averaged across a zone.

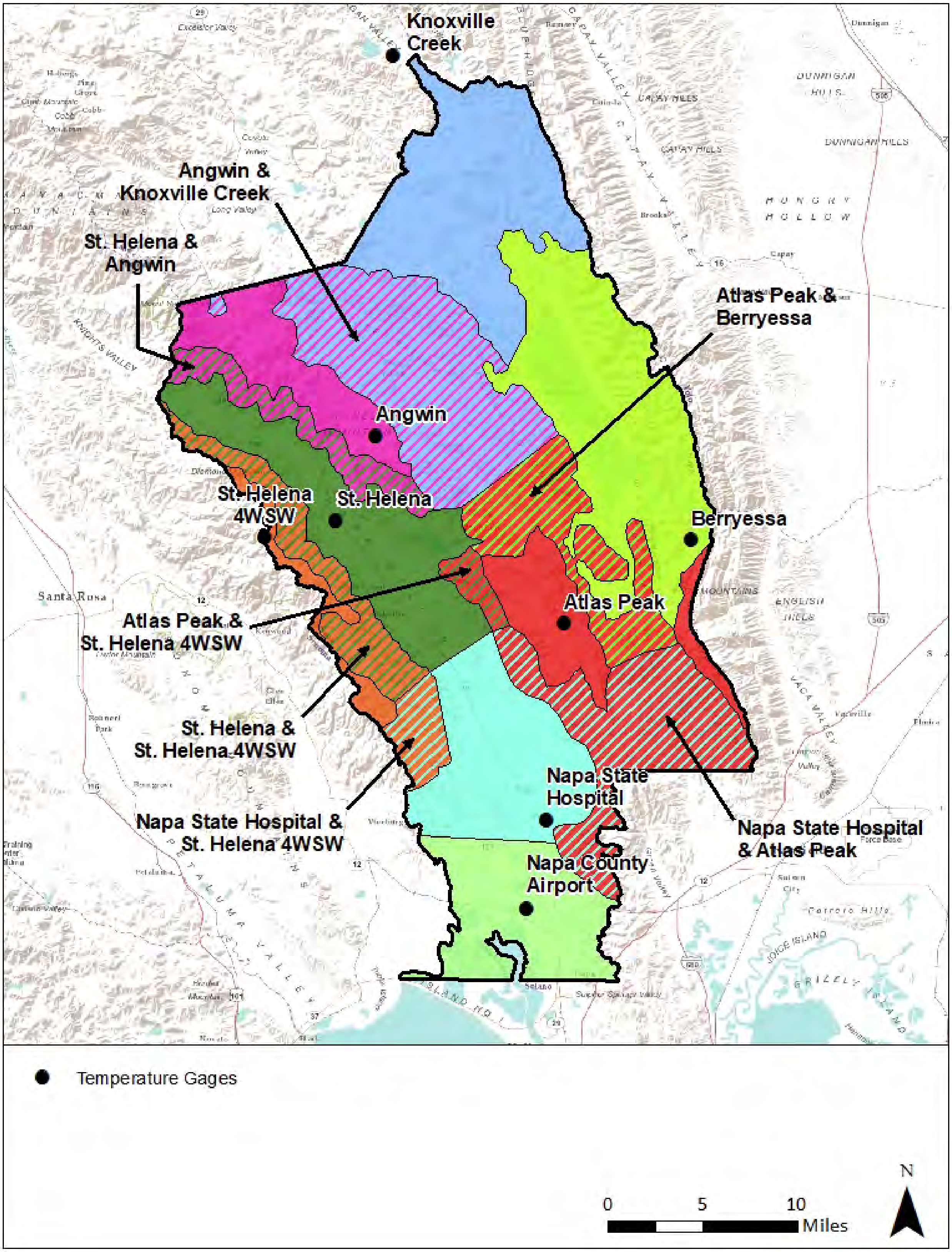

Figure 5: Temperature zones used in the Napa County SWB model. Hatching indicates that two temperature records were averaged across a zone.

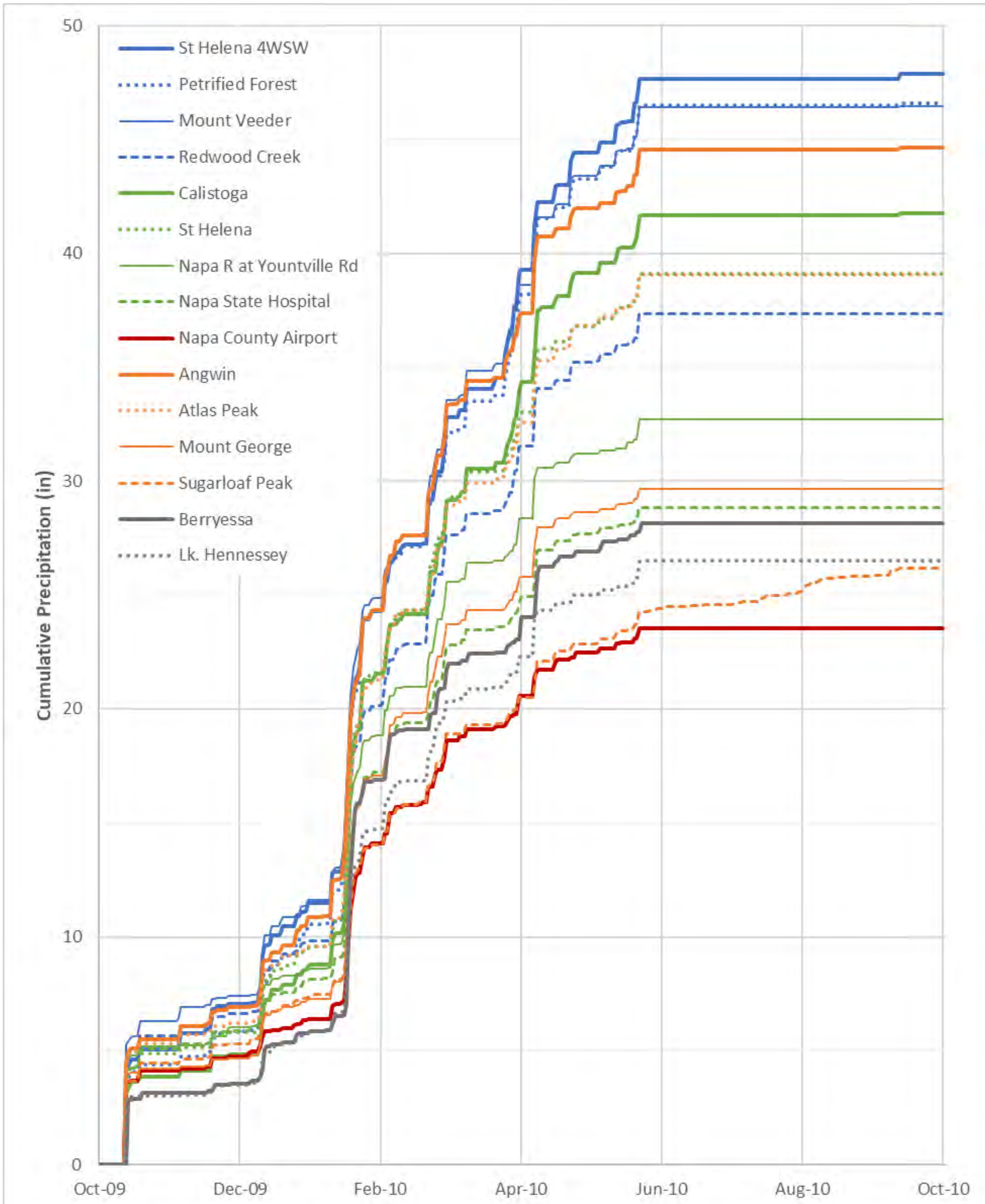

Figure 6a: Daily precipitation data used in the Napa County SWB model for WY 2010.

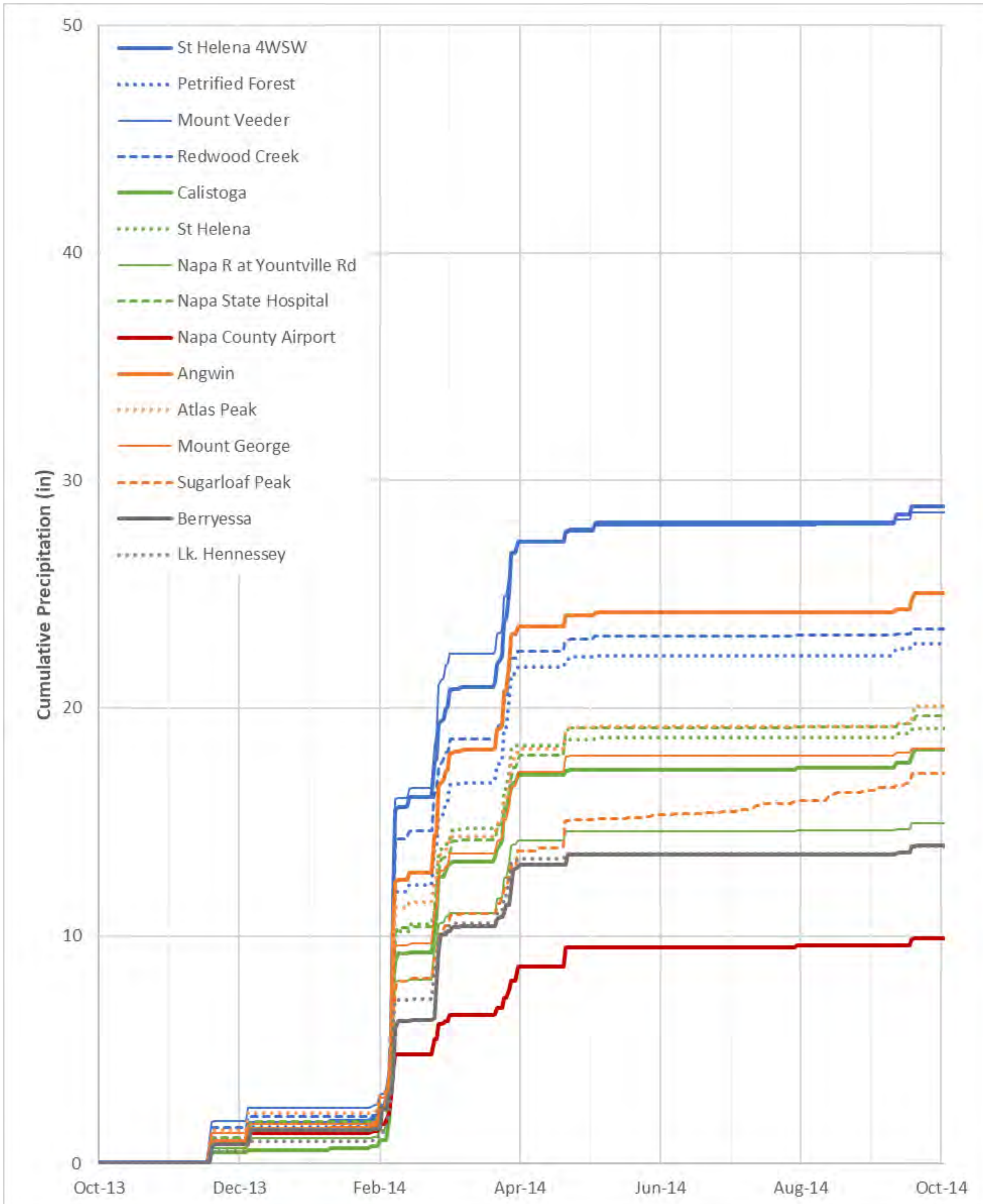

Figure 6b: Daily precipitation data used in the Napa County SWB model for WY 2014.

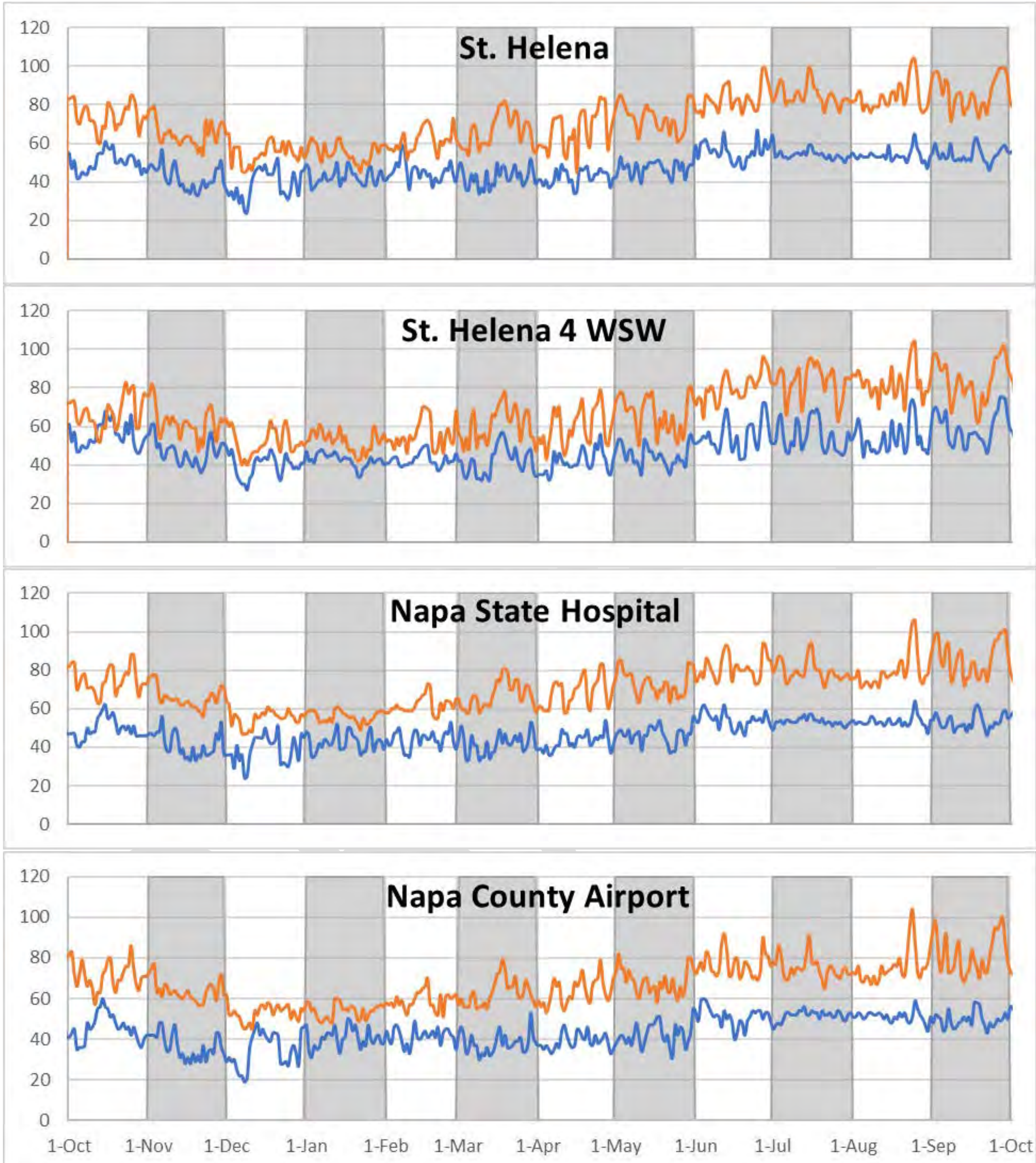

Figure 7: Daily minimum and maximum temperature data used in the Sonoma County SWB model for WY 2010

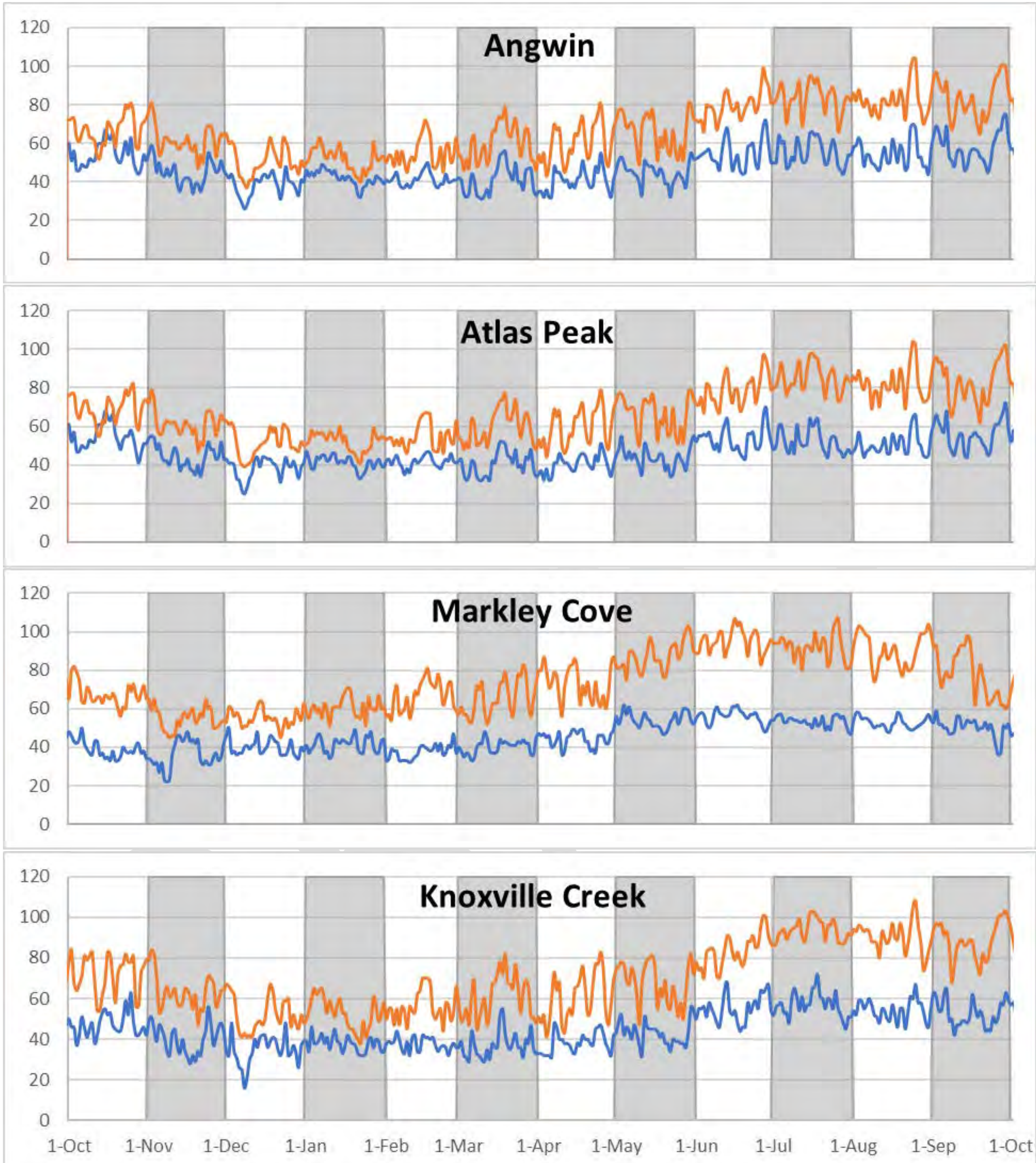

Figure 7 – cont.

Model Calibration

Insufficient data was available to calibrate the water year 2010 and 2014 SWB simulations. However, the land cover and soil properties used in the model were taken from a previously prepared and calibrated SWB model of Sonoma County (OEI, 2017). This model was calibrated against total monthly runoff volumes derived using baseflow separation of streamflow data for five watersheds within Sonoma County. Gages were selected because they represented relatively small watersheds (1.2 – 14.3 mi^2) without significant urbanization, diversions, groundwater abstraction, reservoir impoundments, or large alluvial bodies where significant exchanges between surface water and groundwater may be expected. These attributes are desirable because the hydrographs can more readily be separated into surface runoff and baseflow components and the surface runoff pattern is more directly comparable to the SWB simulated surface runoff which does not account for water use, reservoir operations, or surface water/groundwater exchange.

SWB utilizes a simplified routing scheme whereby surface runoff is routed to downslope cells or out of the model domain on the same day in which it originates as rainfall, thus it is not capable of accurately estimating streamflow over short-time frames. The use of the total monthly surface runoff volumes provided a means of calibrating the Sonoma County SWB model to measured surface runoff data within the limitations of the model's routing.

The SWB model of Sonoma County was capable of reproducing seasonal variations in surface runoff in all five calibration watersheds. Monthly Mean Errors (ME) ranged from -0.2 to 0.4 inches with a mean value of 0.1 inches. Annual surface runoff totals ranged from an under-prediction of approximately 10% at Franchini Creek to an over-prediction of approximately 19% at Buckeye Creek, with a mean over-prediction of approximately 6% across the five watersheds. These results indicate that the SWB model was able to reproduce monthly surface runoff volumes with a reasonable degree of accuracy and that the model tends to over-predict surface runoff somewhat, suggesting that the model may generate a low-range estimate of recharge.

Although the climate in Napa County is slightly drier than in Sonoma County, the vegetation, soils, and geology are very similar and parameters calibrated using data from Sonoma County should be applicable to Napa County. Calibration of the Napa County SWB model was not performed due to a lack of publicly-available contemporary discharge records in suitable watersheds. Contemporary discharge records exist for USGS gaging stations located along the Napa River near St. Helena and Napa, but the watersheds above these gages are large and contain significant groundwater abstraction, reservoir impoundments, and alluvial bodies. USGS gages on smaller watersheds in Napa County have been inactive since 1983 or earlier. Discharge records exist through Napa OneRain for several streams gaged by the Napa County Resource Conservation District (RCD) but the RCD has cautioned against use of these discharge records for calibration purposes due to incomplete rating curve development.

Estimates of groundwater recharge are also available from an earlier model prepared by Luhdorff and Scalmanini Engineers and MBK Engineers (LSCE, 2013). This report calculated average recharge as a percentage of average annual precipitation for nine watersheds in Napa County. Averaged across the same nine watersheds, the SWB model predicts significantly higher rates of recharge (Table 4). However, differences in methodology between these two models complicate direct comparisons. The earlier model calculated infiltration into the soil as the difference between monthly precipitation and discharge volumes within each watershed. Discharge volumes were calculated from USGS stream gages and included both direct runoff and baseflow from groundwater. Inclusion of baseflow with direct runoff in these calculations may artificially reduce the volume of water infiltrated into the soil and available for recharge.

Table 4: Comparison of results from SWB model and Luhdorff and Scalmanini model.

USGS Gage	HUC	Mean Precip, 2010 (in)	Mean Recharge, 2010 (in)	Mean Recharge, 2010 (% Precip)	Mean Recharge, LSCE (% Precip)
Conn Ck nr Oakville	11456500	34.8	7.2	21%	21%
Dry Ck nr Napa	11457000	41.5	10.5	25%	6%
Milliken Ck nr Napa	11458100	32.3	9.2	28%	8%
Napa Ck at Napa	11458300	36.6	8.5	23%	11%
Napa R nr Napa	11458000	39.5	9.5	24%	17%
Napa R nr St Helena	11456000	47.9	14.6	30%	14%
Redwood Ck nr Napa	11458200	39.6	8.6	22%	10%
Tulucay Ck nr Napa	11458300	27.0	5.3	20%	5%

Model Results

Total annual precipitation and groundwater recharge are shown for Water Years 2010 and 2014 in map form in Figures 8 - 11 and in tabular form (sorted by total annual precipitation) for 27 major watershed areas in Napa County (Table 5). The watersheds are based on USGS HUC-12 watersheds and are named for the stream which comprises the largest proportion of the area; although in many cases the areas consist of multiple tributary streams (Figure 14).

Water year 2010 precipitation varied from 21.8 inches in the Ledgewood Creek watershed to 53.3 inches in the Saint Helena Creek watershed (Figure 8). Recharge ranged from 2.3 inches in the San Pablo Bay Estuaries to 14.6 inches in the St. Helena Creek watershed (Table 5, Figure 10). Water year 2014 precipitation varied from 10.1 inches in the American Canyon Creek watershed to 32.2 inches in the Saint Helena Creek watershed (Figure 11). Recharge ranged from 0.5 inches in the San Pablo Bay Estuaries to 4.1 inches in the St. Helena Creek watershed (Figure 13). When expressed as a percentage of the annual precipitation, recharge ranged from 10% of annual precipitation in the San Pablo Bay Estuaries to 27% in the Saint Helena Creek watershed in water year 2010. In water year 2014, recharge ranged from 4% of annual precipitation in the San Pablo Bay Estuaries to 18% in the Milliken Creek watershed.

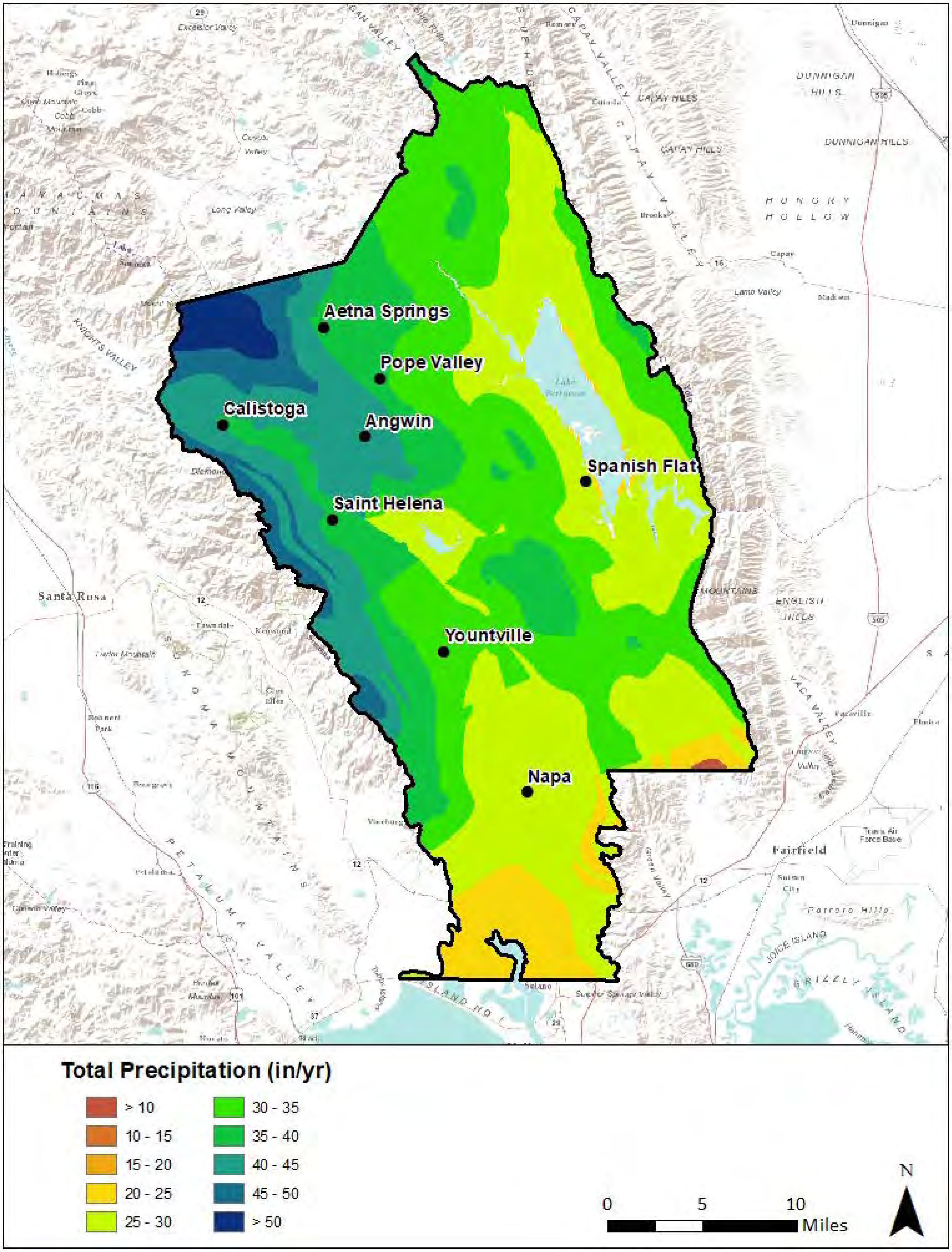

Figure 8: Water year 2010 Precipitation simulated with the Napa County SWB model.

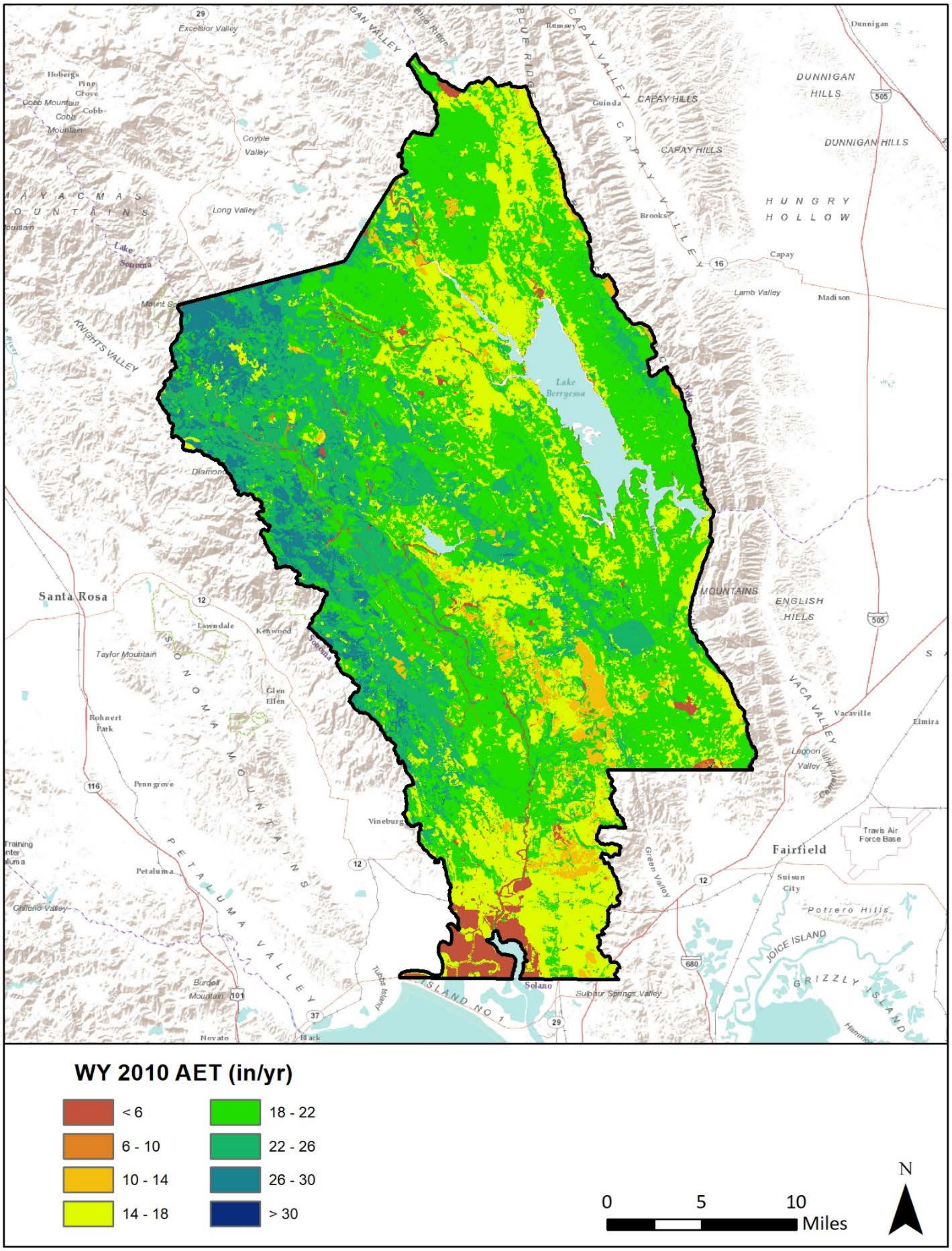

Figure 9: Water year 2010 AET simulated with the Napa County SWB model.

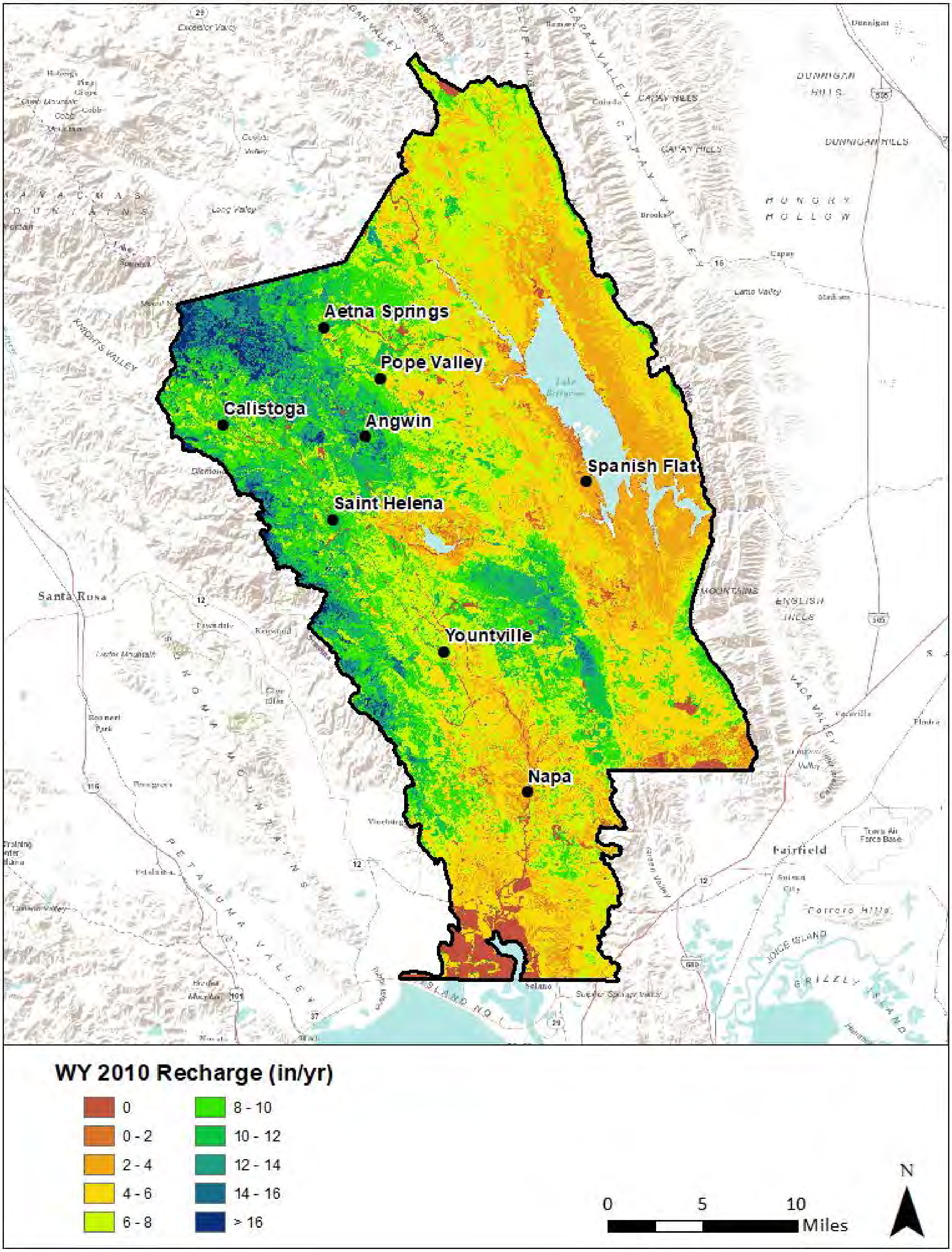

Figure 10: Water year 2010 Recharge simulated with the Napa County SWB model.

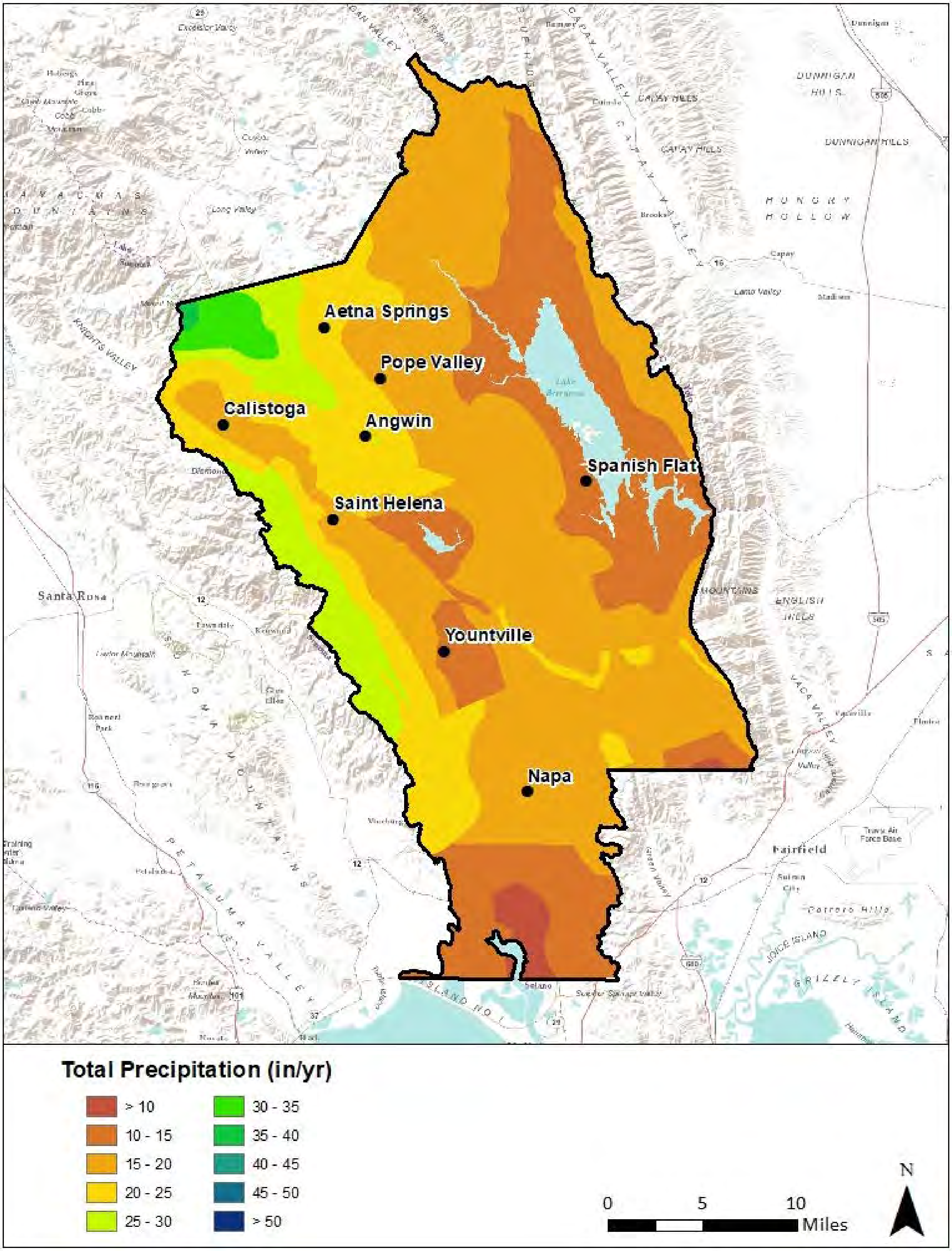
Aetna Springs
Pope Valley
Calistoga
Angwin
Spanish Flat
Saint Helena
Yountville
Napa
Santa Rosa
Fairfield
Total Precipitation (in/yr)
> 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
> 50
0
5
10
Miles
N

Figure 11: Water year 2014 Precipitation simulated with the Napa County SWB model.

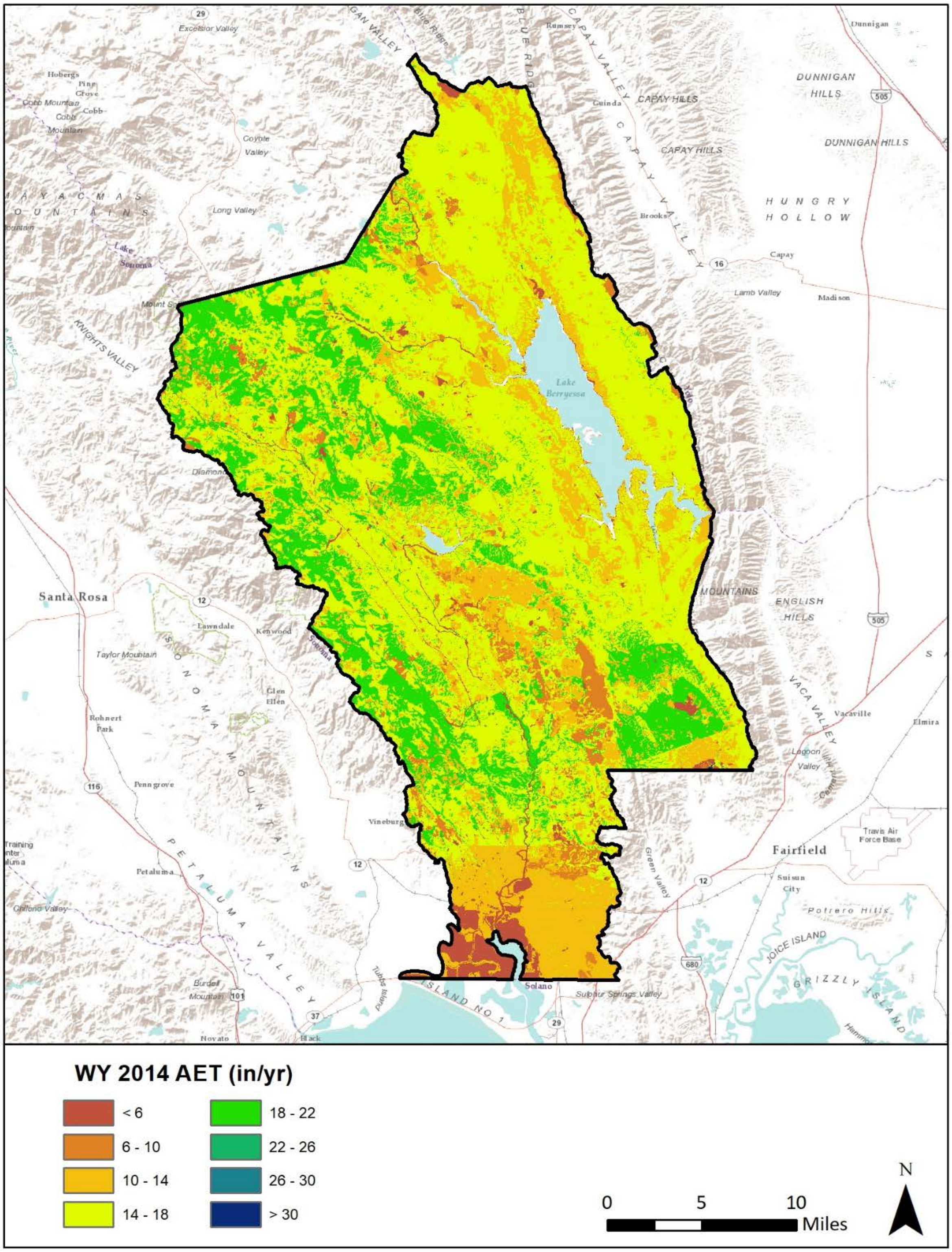

Figure 12: Water year 2014 AET simulated with the Napa County SWB model.

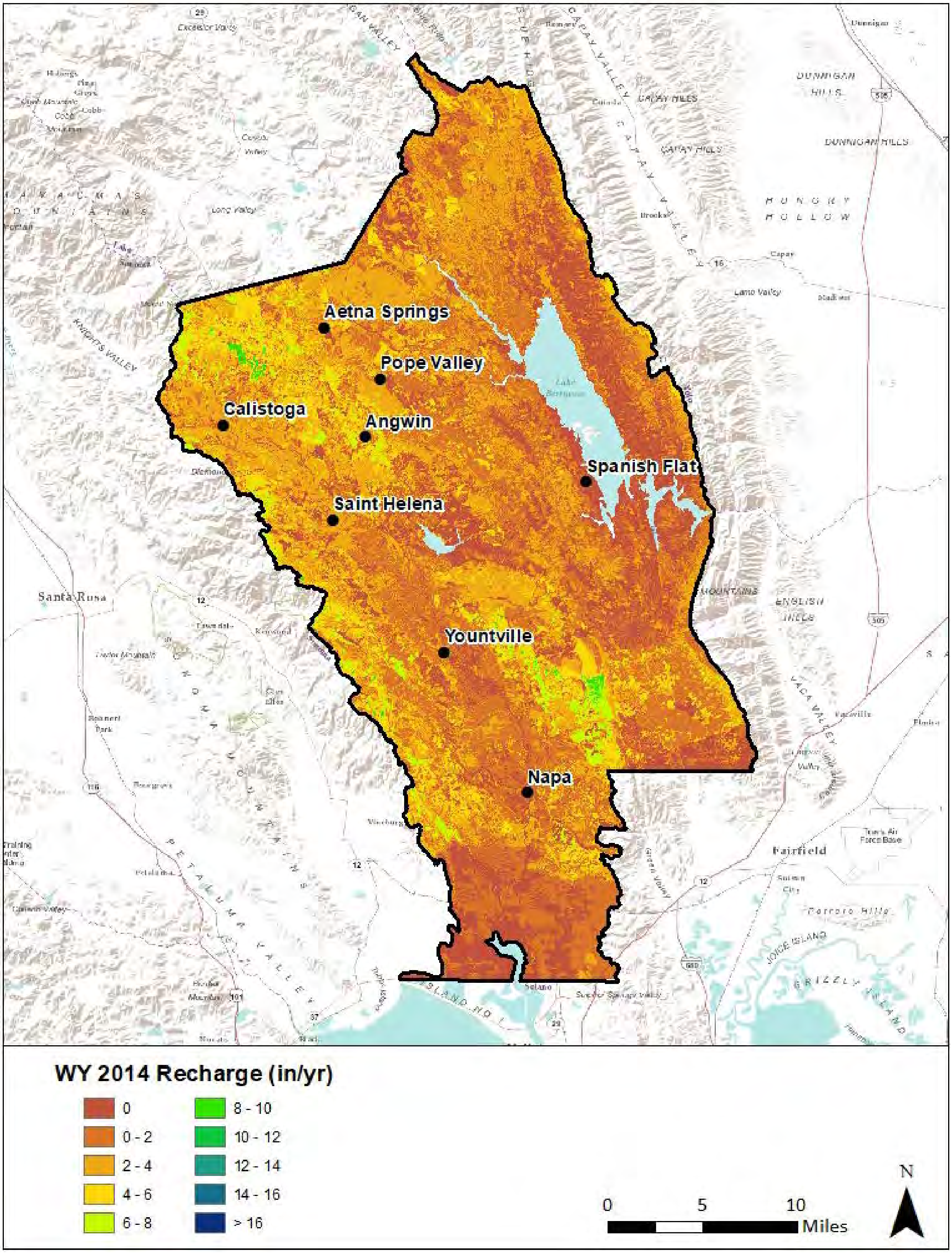

Figure 13: Water year 2014 Recharge simulated with the Napa County SWB model.

Table 5: Simulated precipitation and recharge values averaged across HUC-12 watersheds in Napa County. See Figure 14 for watershed locations.

HUC-12 Watershed Name	Mean Precip, 2010 (in)	Mean Recharge, 2010 (in)	Mean Recharge, 2010 (% Precip)	Mean Precip, 2014 (in)	Mean Recharge, 2014 (in)	Mean Recharge, 2014 (% Precip)
Saint Helena Ck	53.3	14.6	27%	32.2	4.1	13%
Bucksnort Ck	47.9	11.3	24%	28.8	2.6	9%
Upper Napa River	44.7	11.0	25%	22.9	3.3	14%
Upper Pope Creek	44.5	11.7	26%	25.6	3.5	14%
Middle Napa River	40.4	9.5	24%	21.8	2.5	11%
Dry Ck	37.8	8.9	24%	22.1	2.5	11%
Lake Hennessey-Conn Ck	36.0	8.2	23%	19.6	2.2	11%
Maxwell Ck	34.7	7.0	20%	18.3	2.0	11%
Chiles Ck	34.6	6.8	20%	18.4	1.5	8%
Lower Pope Ck	33.9	6.8	20%	17.8	2.0	11%
Hunting Ck	33.7	5.8	17%	16.7	1.6	10%
Butts Ck-Putah Ck	33.0	6.5	20%	16.8	1.9	11%
Rector Ck-Conn Ck	32.8	8.3	25%	16.5	2.3	14%
Lower Napa River	31.7	6.9	22%	19.4	2.2	11%
Capell Ck	31.2	5.3	17%	15.8	1.1	7%
Upper Eticuera Ck	31.2	6.1	20%	15.5	2.1	14%
Milliken Ck	30.9	8.0	26%	18.7	3.4	18%
Lake Curry-Suisun Ck	30.7	6.0	20%	18.4	1.9	10%
Lower Eticuera Ck	30.0	5.0	17%	14.9	1.3	9%
Carneros Ck	29.7	6.5	22%	17.6	2.0	11%
Jackson Ck-Putah Ck	29.7	4.2	14%	14.7	0.7	5%
Wooden Valley Ck-Suisun Ck	29.0	5.6	19%	17.9	2.0	11%
Wragg Canyon	28.3	3.9	14%	14.1	0.6	5%
Tulucay Ck	26.1	5.5	21%	14.6	1.7	12%
American Canyon Ck	24.1	4.8	20%	10.1	0.7	7%
San Pablo Bay Estuaries	23.9	2.3	10%	10.4	0.5	4%
Ledgewood Ck	21.8	3.4	16%	12.2	0.8	7%

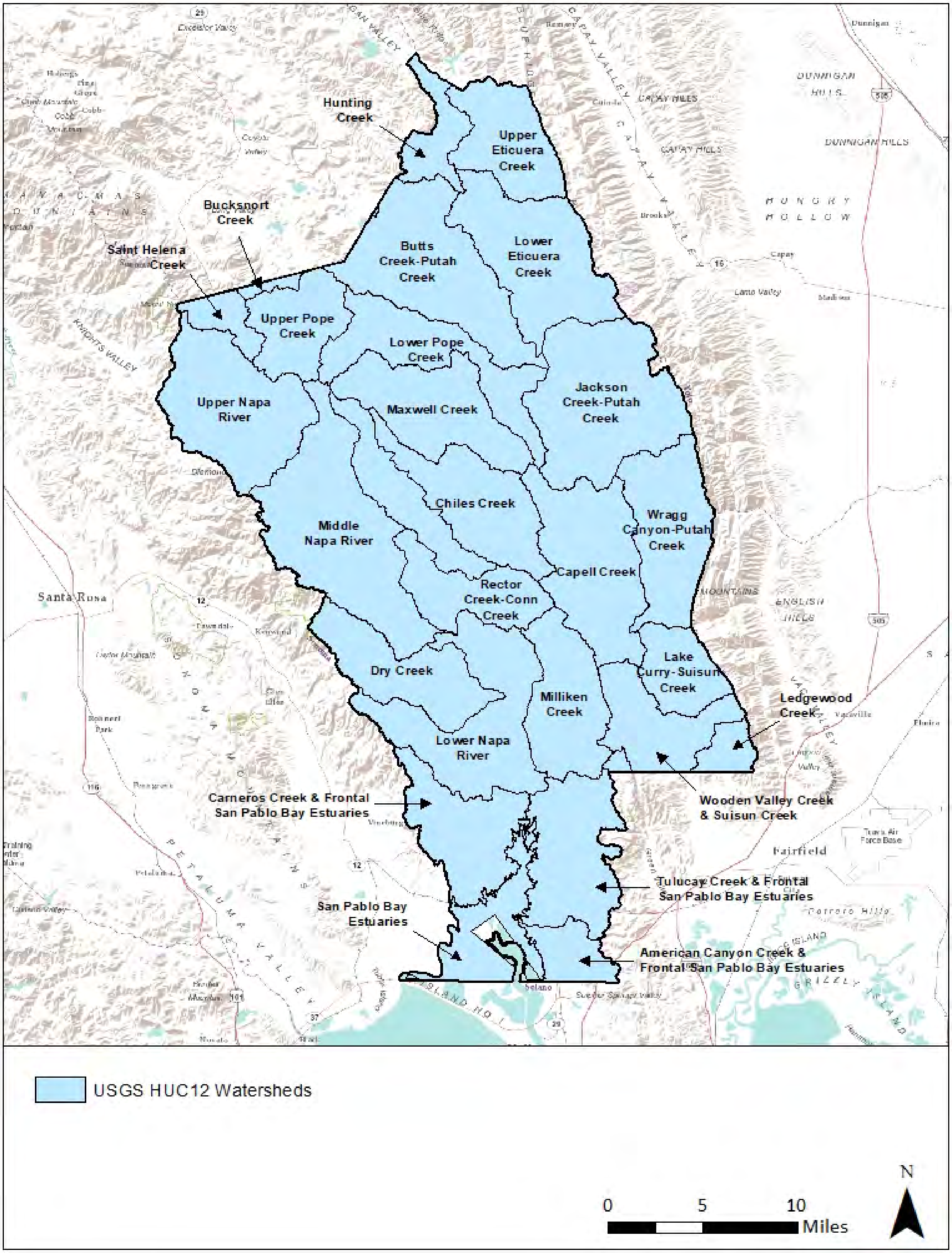

Figure 14: Major watersheds areas used to summarize water budget information in Table 6.

Discussion and Conclusion

Numerous previous modeling studies have estimated water budget components in several larger watershed areas in Sonoma and Napa Counties including the Santa Rosa Plain, the Green Valley and Dutch Bill Creek watersheds, and the Sonoma Valley (Farrar et. al., 2006; Kobor and O'Connor, 2016; Woolfenden and Hevesi, 2014). Comparisons to these water budgets are useful for evaluating the SWB results, but one would not expect precise agreement owing to significant variations in climate, land cover, soil types, underlying hydrogeologic conditions, and different spatial scales of modeling studies. These regional analyses estimate that average annual recharge varies from 7% to 19% of the annual precipitation. The equivalent county-wide value from this study is slightly higher at 20%.

The recharge estimates presented here arguably represent the best available county-wide estimates produced at a fine spatial resolution using a consistent and objective data-driven approach. This analysis focused on two water years, 2010 and 2014, which represent average and drought conditions respectively. Input parameters were determined based on literature values and values calibrated through prior modeling experience in Sonoma County.

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