Water Availability Analysis

Babu Vineyard
3300 and 3600 White Sulphur Springs Road
St. Helena, California 94574
APN 027-010-033

Prepared by:

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Contents

Introduction

The Babu Vineyard project is located at 3300 and 3600 White Sulphur Springs Road, St. Helena, CA (APN 027-010-033) in the western hills above the Napa Valley about 2.6 miles west of St. Helena. The property owner ultimately plans to develop 1.6 acres of vineyard and one single family residence in the west-central portions of the property; the presently-proposed land use is vineyard. This Water Availability Analysis (WAA) was developed based on the guidance provided in the Napa County Department of Planning, Building, & Environmental Services' (PBES) 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 use 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), an analysis for potential for well interference at neighboring wells located within 500-ft of the project well (Tier 2), and evaluation of the potential streamflow depletion for project wells within 1500 ft of streams of concern designated by PBES as of late 2022 (Tier 3). The Tier 1 groundwater recharge analysis has been updated based on mean annual precipitation for the period 2012-2021 using a PRISM GIS data set as required by PBES beginning in December 2022.

This WAA has been updated in August 2021 to include the addition of a third 0.24 acre vineyard block (Block C). Water use associated with the additional acreage of vines has been incorporated into the water use calculations and comparisons with groundwater recharge estimates. In addition, in the fall of 2020 the Glass fire burned through the project area destroying the houses on the neighboring parcel. Although it is unknown if these neighbors will rebuild, all water use estimates include pre fire water use assumptions. Similarly, all parameters used in our water balance calculations including landcover and soil properties use pre-fire conditions.

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 judgement. This analysis is based on limited available data and relies significantly on interpretation of data from disparate sources of disparate quality.

The water balance approach used to estimate groundwater recharge for this study simulates potential recharge from infiltration of precipitation and does not include verifiable estimates of the capacity of the project aquifer materials to accept recharge. Where bedrock of low permeability bedrock underlies the subject parcel and study area, a significant proportion of the potential recharge may exit the project area as shallow subsurface flow rather than percolating and recharging the local aquifer. Quantifying the proportion of the potential recharge that percolates to underlying bedrock aquifers is beyond the scope of this analysis. Data describing subsurface conditions of soil and bedrock, local aquifer hydraulic characteristics, and local processes and pathways of groundwater percolation are rarely available and difficult to obtain in the absence of focused and well-funded hydrogeologic investigations.

Hydrogeologic Conditions

The project parcel is in the foothills west of the Napa Valley in the northern portion of a large (~14 square miles) block of the graywacke and mélange unit of the Franciscan Complex (map unit KJfs, Graymer et al. 2007) (Figure 1). The KJfs consists of massive to distinctly bedded, lithic wacke and dark-gray or black siltstone, shale, and slate, grading into mélange consisting of sheared argillite and graywacke matrix enclosing blocks and lenses of sedimentary, metamorphic, and volcanic rocks. A 22.4 acre landslide deposit is mapped through the central portion of the parcel (Wagner & Gutierrez, 2010) which has been classified in the field as a dormant rockslide[1] (Figure 1).

Rocks of the Franciscan Complex generally have low primary porosity with groundwater occurring primarily in fractures. Available groundwater that can be pumped from wells is typically limited in these materials with 'dry holes' being common and successful wells producing only low to moderate yields. The strained and fracture rock within the landslide deposit, on the other hand, has the potential to store and transmit significant quantities of groundwater.

Driller's logs (Well Completion Reports) for wells on and around the project parcel were obtained from the California Department of Water Resources. A subset of these logs were compiled and georeferenced based on parcel and location sketch information (Figure 1). The project parcel well (PW) is in the west-central portion of the parcel and was completed in 2015 to a depth of 270-ft (Table 1). The static water level was 38-ft at the time of well completion on June 17, 2015 and was 44-ft prior to performing a pump test on June 25, 2015. The specific capacity based on an 8-hr pump test was 2.94 gpm/ft of drawdown (Appendix B).

Nearby wells were completed to depths ranging from 260 to 313-ft and had static water levels ranging from 70 to 147-ft (Table 1). Sufficient data was not available to calculate specific capacities for these wells. The Well Completion Reports describe a variety of rocks, but the most common are sandstone, brown sandstone, shale, and blue shale.

The specific capacity at the PW is much higher than is typically encountered in the Franciscan Formation and suggests that much of the well yield likely originates from the landslide deposit (apparently comprised of highly fractured sandstone and shale) overlying Franciscan rocks. The static water level is relatively close to the surface (38 to 44-ft) and about 100-ft higher than the static water level at the closest neighboring well (Well #1). Well #1 is located in bedrock outside the landslide deposit (Figure 1). The difference between depth to water in the landslide deposit and outside the landslide deposit strongly suggests that the PW is completed in a perched aquifer

[1] The surface of rupture of the slide body occurred at substantial depth (10's of feet) below ground surface in bedrock material (Cruden and Varnes, 1996; Keaton and DeGraff, 1996).

within the landslide deposit which overlies the Franciscan bedrock. The presence of a perched aquifer is supported by field observations of a seepage from the steep slopes on the west side of Sulphur Creek. The seepage zone likely coincides with the truncated landslide toe at the eastern edge of the mapped landslide deposit where the water table in the perched aquifer intersects the steep slopes above the stream (Figure 1).

Table 1: Well completion details for the project well (PW) and wells on adjacent parcels.

Well ID	PW	1	2
Year Completed	2015	2010	2009
Depth (ft)	270	313	260
Static Water Level (ft)	44	147	70
Top of Screen (ft)	70	173	80
Bottom of Screen (ft)	270	293	260
Casing Diameter (inches)	5	5	5
Pumping Rate (gpm)	50	16	20
Drawdown (ft)	17	-	-
Test Length (hrs)	8	3	2
Specifc Capacity (gpm/ft)	2.94	-	-

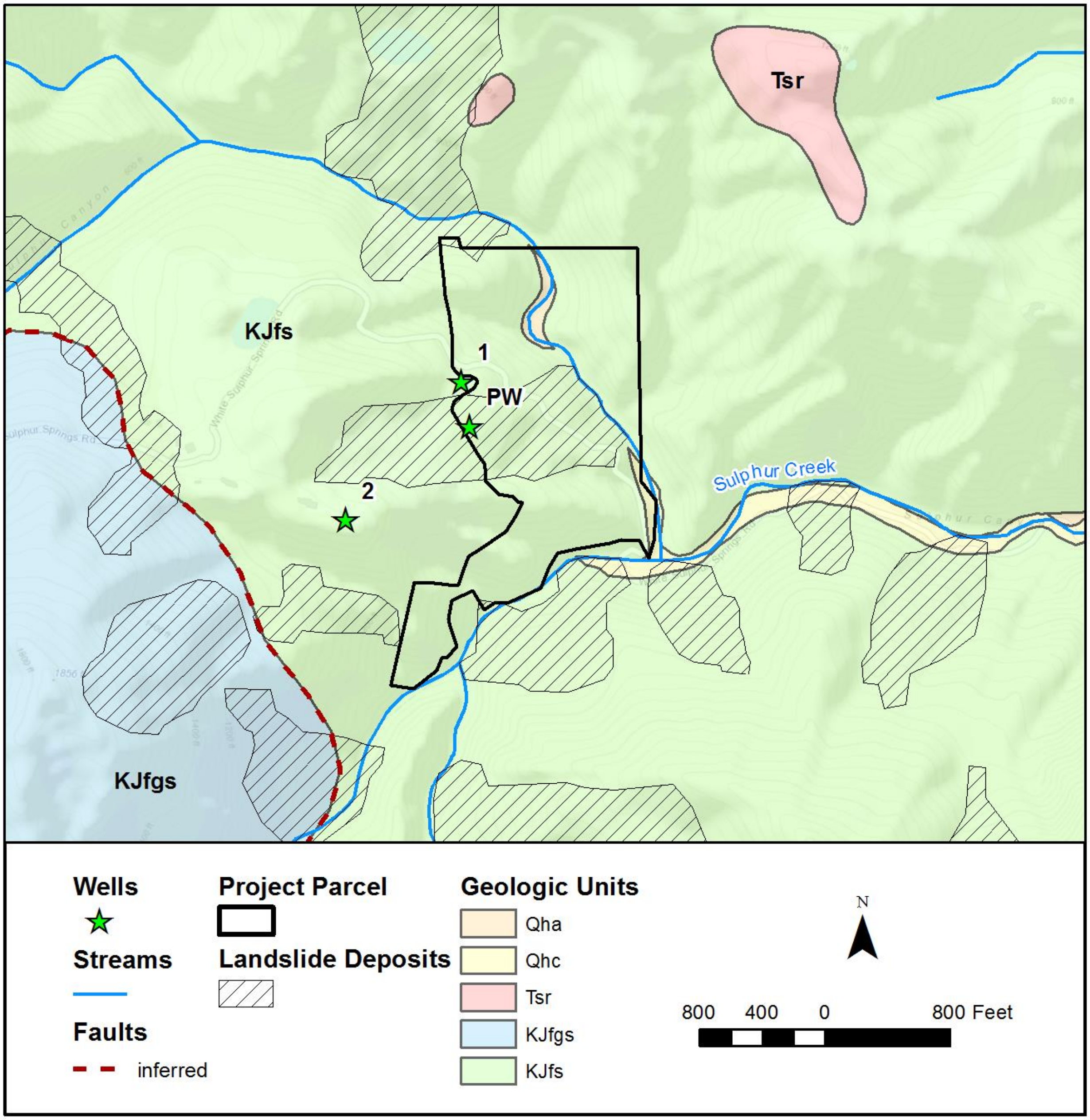

Figure 1: Surficial geology and well locations in the vicinity of the project parcel, geology and faults from Graymer et al. (2007), landslide deposits from Wagner & Gutierrez (2010). Units are as follows:

Qha – Holocene alluvium **Qhc – Stream channel deposits** **Tsr – Sonoma Volcanics – rhyolite flows**
KJfgs – Franciscan Complex – greenstone **KJfs – Franciscan Complex – graywacke and melange**

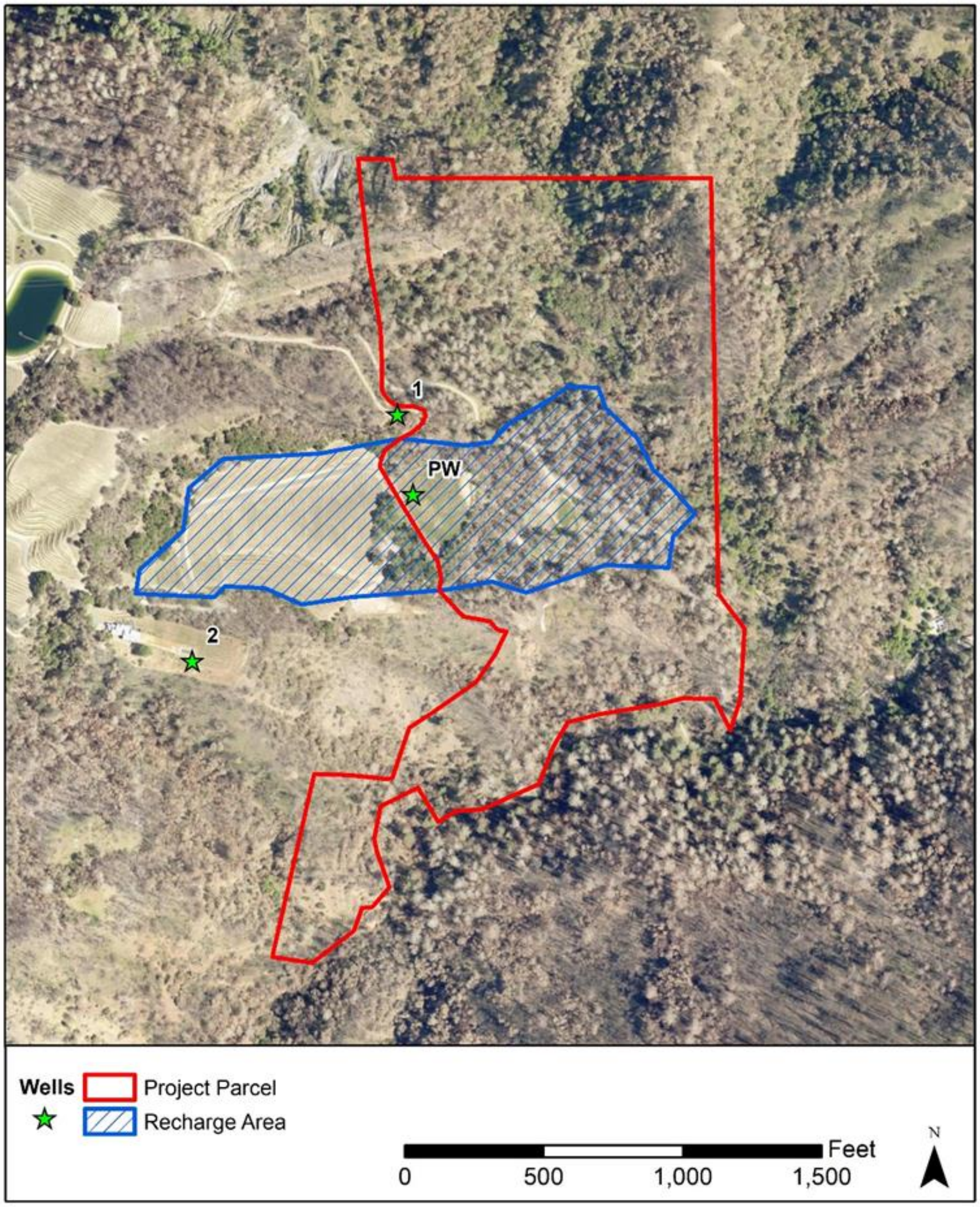

Figure 2: The project recharge area and project parcel.

Water Demand

To our knowledge, no other existing wells intersect the landslide that the PW is completed in, however there are 6.75 acres planted vineyard (8.2 acres gross) overlying the landslide deposit on the adjacent parcel to the west of the project parcel, and one primary residence and one additional structure assumed to be a secondary residence located on or just south of the deposit (Figure 2). In 2020 the Glass Fire burned through the project area and the neighboring parcel. The residence and secondary unit located on the neighboring parcel were destroyed. Plans for rebuilding these dwellings are not known but for the purposes of this analysis we will assume that they will be rebuilt and include their water use in our existing and proposed calculations. <u>To be conservative and to account for the possibility that these uses could be served by new wells in the landslide deposit at a future date, we have included these water uses for these uses in our calculation of existing groundwater use</u>. We understand that existing wells penetrate bedrock bodies beyond the lateral boundaries of the perched aquifer in the landslide deposit.

Existing use in the project recharge area is 1.1 ac-ft/yr for residential/domestic purposes on an adjacent parcel and 4.03 ac-ft/yr for vineyard irrigation of which 3.38 ac-ft/yr would be on an adjacent parcel. Existing use on the project parcel is for irrigation of 1.50 acres of vineyard. The existing use (qualified by assumptions above) attributed to the project recharge area is 5.13 ac-ft/yr Irrigation Use is estimated to total 3.38 ac-ft/yr for a total Existing Water Use of 4.48 ac-ft/yr (Table 2).

Proposed new groundwater use is for vineyard Block C (0.24 acres planted, 0.42 acres gross); existing irrigation use on the project parcel is for vineyard Block A (1.05 acres planted, 1.44 acres gross) and vineyard Block B (0.45 acres planted, 0.62 acres gross). Total annual groundwater use for project parcel vineyard irrigation with the addition of Block C is 0.87 ac-ft/yr (1.74 acres x 0.5 ac-ft/ac/yr). Although no new residential use is proposed, it is possible that a residence could eventually be constructed on the project parcel if driveway improvements and an on-site wastewater treatment system can be constructed. For purposes of anticipating potential groundwater demand associated with a future residence on the project parcel, 0.5 ac-ft/yr is included with vineyard irrigation use for a total use on the project parcel of 1.37 ac-ft/yr.

Combining potential future project parcel groundwater use (0.62 ac-ft/yr) with the existing uses (5.23 ac-ft/yr) in the project recharge/impact area, total proposed water use of 5.85 ac-ft/yr. Recall that 4.48 ac-ft/yr of the existing use is not utilizing groundwater from the project recharge/impact area and that these uses are included in the analysis to provide a conservative interpretation of potential long-term groundwater demand from the local aquifer utilized by the project well. The assumptions behind the various water use estimates are provided in Tables 3 through 5. Proposed project parcel use (1.37 ac-ft/yr) will be met entirely by the existing PW.

Table 2: Existing and proposed groundwater uses within the project recharge area.

	Irrigation Use	Residential Use	Total Use
Existing Use	4.13	1.10	**5.23**
Proposed Use	4.25	1.60	**5.85**

Table 3: Existing and proposed irrigation use within the project recharge area.

Use Category	Number of Acres	Use per Acre (ac-ft/yr)	Annual Water Use (ac-ft/yr)
Existing Irrigation	8.25	0.50	4.13
Proposed Irrigation	8.49	0.50	4.25
TOTAL			**4.25**

Table 4: Existing residential use within the project recharge area.

Use Category	# of Units	Use per Unit (ac-ft/yr)	Annual Water Use (ac-ft/yr)
Main Residence	1	0.75	0.75
Secondary Residences	1	0.35	0.35
TOTAL			**1.10**

Table 5: Proposed additional residential use within the project recharge area.

Use Category	# of Units	Use per Unit (ac-ft/yr)	Annual Water Use (ac-ft/yr)
Main Residence	1	0.5	0.50
TOTAL			**0.50**

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 C.

To address elevated concerns regarding groundwater availability Napa County PBES has adopted a 10-year precipitation average from Water Years 2012 to 2021 developed by the PRISM Group at Oregon State University. The PRISM data provides spatially distributed data adjusted for orographic factors based on gauged precipitation data.

Consistent with OEI's approach to estimating groundwater recharge for WAA's, groundwater recharge was simulated for two selected Water Years. The first, Water Year 2010, was selected to represent average year precipitation conditions because annual precipitation totals across most of Napa County were close to their long-term 30-year averages in WY 2010. The second, Water Year 2014, was selected to represent dry year conditions because annual precipitation totals were between 41 and 73% of long-term 30-year averages for Napa County in WY 2014. We used SWB model predictions of groundwater recharge for WY 2010 and WY 2014 rainfall and climate conditions to bracket rainfall conditions for the 2012-2021 average annual; this allowed us to estimate groundwater recharge for this hypothetical average year condition as described below.

Results

Water Years 2012 to 2021 average precipitation is 34.2 inches across the project recharge area as determined by spatially averaging precipitation data from the PBES PRISM GIS data. For the simulated Water Year 2010 (average water year) precipitation averaged 44.5 inches across the project recharge area and simulated actual evapotranspiration (AET) averaged 25.5 inches. Simulated groundwater recharge varied from 6.9 to 14.8 inches across the recharge area, with a spatial average of 11.0 inches (Table 6). Components of the water balance were also calculated for the project parcel (Table 7). In simulated Water Year 2014 (dry water year), precipitation averaged 26.5 inches across the project recharge area and simulated AET averaged 18.3 inches. Simulated groundwater recharge varied from zero to 5.9 inches across the recharge area, with a spatial average of 3.5 inches (Table 6).

Assuming a linear relationship between the precipitation of the selected average and dry year results of simulated recharge percent, Water Years 2012 to 2021 had an average of 6.2 inches of recharge (Table 6). The general linearity of this relationship was confirmed by a review of all prior WAA analyses using the SWB model to estimate groundwater recharge at individual project sites in Napa County. It is also consistent with the general interrelationship between precipitation, evapotranspiration, and water available for groundwater recharge. Nevertheless, the accuracy of the prediction of recharge embodied in Figure 3 remains uncertain.

Table 6: Summary of water balance results for the recharge area estimated by the SWB model for WY 2010 & 2014 and estimated recharge from the precipitation average of 2012-2021 WYs.

	2010 Normal Year		2014 Dry Year		2012-2021 WY Average	
	inches	% of precip	inches	% of precip	inches	% of precip
Precipitation	44.5	-	26.5	-	34.2	-
AET	25.5	57%	18.3	69%	-	-
Runoff	8.3	19%	8.4	32%	-	-
Δ Soil Moisture	-0.2	-1%	-3.6	-14%	-	-
Recharge	11.0	25%	3.5	13%	6.2	18%

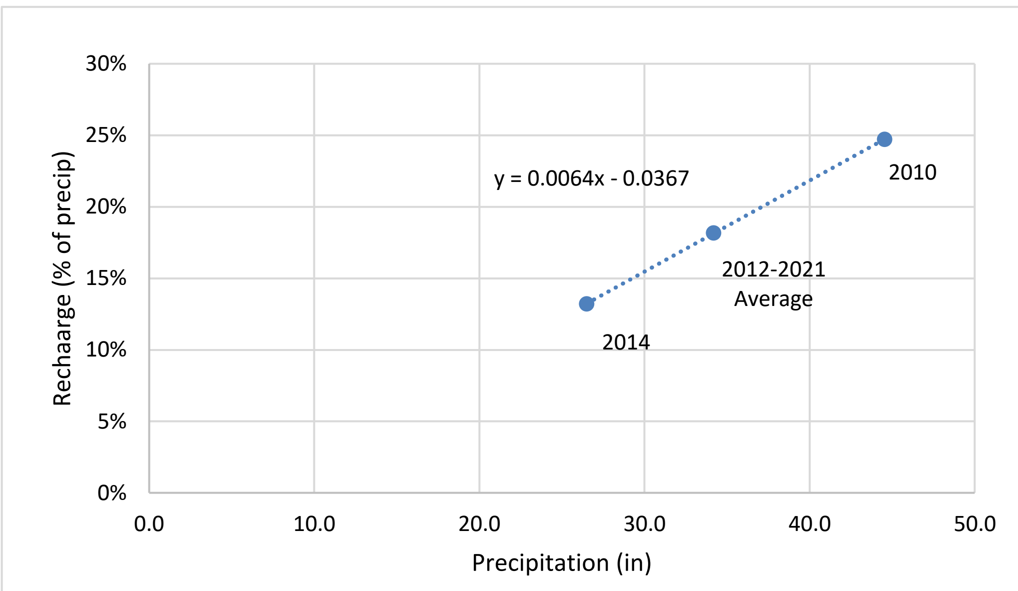

Figure 3: Relationship between precipitation and percent of precipitation as recharge from SWB models for Water Year 2010 and Water Year 2014 and interpolated for mean precipitation 2012-2021

Groundwater recharge estimates can also be expressed as a total volume by multiplying the estimated recharge rate by a representative area. For the 21.9-acre project recharge area, estimated average annual groundwater recharge for the period 2012-2021 is estimated to be 11.3 ac-ft. For the 11.9 acre portion of the project parcel within the recharge area, estimated average annual recharge for the period 2012-2021 is estimated to be 4.3 ac-ft (Table 7).

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

		2012-2021 WY Average		
	Total Proposed Demand (ac-ft/yr)	Recharge (ac-ft/yr)	Recharge Surplus (ac-ft/yr)	Demand as % of Recharge
Recharge Area	5.85	11.3	5.5	52%
Project Parcel	1.37	4.3	2.9	32%

		Average Water Year (2010)			Dry Water Year (2014)		
	Total Proposed Demand (ac-ft/yr)	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
Recharge Area	5.85	20.1	14.2	29%	6.4	0.5	92%
Project Parcel	1.37	9.0	7.7	15%	1.9	0.5	72%

Comparison of Water Demand and Groundwater Recharge

The total proposed groundwater use within the project recharge area is estimated to be 5.85 ac-ft/yr; this includes all water use in the project recharge area of which only 1.37 ac-ft occurs on the project parcel. Furthermore, water use on adjoining parcels are not currently supplied from the project aquifer. The water demand considered for the Tier 1 analysis is therefore extremely conservative in that it significantly over-states groundwater demand from the project aquifer by assuming that all water use is supplied from the project aquifer.

Compared to the estimated annual groundwater recharge based on mean precipitation for the period 2012-2021, average use is equivalent to 52% of the 11.3 acre-ft/yr mean annual recharge. A similar comparison can be drawn for the project parcel: estimated use of 1.37 ac-ft/yr represents 32% of the 4.3 acre-ft/yr of average annual recharge (Table 7). Groundwater use associated with the proposed project is believed unlikely to result in significant reductions in groundwater levels or depletion of groundwater resources over time. The project aquifer is well-defined and is expected to be replenished by annual winter rainfall.

Well Interference Analysis-Tier 2

The nearest neighboring well to the existing well on the project parcel appears to be located about 295 feet north of the project well on the adjacent parcel APN 027-010-038 (Well #1 in Figure 4). The PW is completed to a depth of 270-ft; Well #1 is completed to a depth of 293-ft within the Franciscan bedrock. However, as discussed above in the Hydrogeologic Conditions section of this report, the PW is believed to draw groundwater from a perched aquifer in the landslide deposits mapped on the property. Well #1 draws water from fractured bedrock of the Franciscan Complex. The fact that the static water level in the PW (about 40-ft below ground surface) is substantially higher than the static water level in the neighboring well (about 145-ft)[2] supports this conclusion as does the relatively high specific capacity for the PW (2.9 gpm/ft of drawdown) which is at least an order of magnitude higher than is typical for wells in Franciscan bedrock aquifers.

An 8-hr pump test performed on the PW in June of 2015 with a pumping rate of 50 gpm indicated that drawdown stabilized at about 17-ft with relatively rapid recovery to 9-ft within 30 minutes (Appendix A). This well yield and well recovery pattern is atypical of Franciscan bedrock aquifers. A total of 24,000 gallons of water (0.074 acre-feet) was pumped during the test which is equivalent to a high-end estimate of peak daily water use for the proposed uses, providing a strong indication of the sufficiency of the well for proposed use and a reasonable representation of drawdown and recovery associated with peak groundwater use. The County of Napa criteria for the allowable drawdown caused by well interference for well casing diameters of less than six inches is 10 ft (both wells have five-inch diameter casings). Distance-drawdown curves in these types of aquifers are expected to show a significant decline in drawdown with distance from a pumping well.

Given that the PW and Well #1 use water from different aquifer materials, have significantly different static water levels, have substantial horizontal separation (about 300 ft), and given that a pump test of the PW roughly equivalent to the anticipated peak daily demand resulted in drawdown of only 17-ft, it is evident that the potential for well interference associated with the proposed use of the PW is minimal.

Streamflow Depletion Risk Assessment-Tier 3

Tier 3 WAA Criteria

As shown in Figure 4, the project well (PW) is within 1,500 ft of the nearest stream of concern for potential streamflow depletion identified by County of Napa (Sulphur Creek). Well 1 is about 725 ft southwest of Sulphur Creek. The Tier 3 WAA guidance provides well set-back standards and construction assumptions that "if applicable would be expected to preclude any significant adverse effects on surface waters". Specifically, the “Tier 3 Groundwater Surface Water

[2] The ground surface at the PW (~840-ft) is about 30-ft below the ground surface at Well #1 (~870-ft), so the difference in water elevations adjusted for approximate well-head elevation would be about 75-ft (105-ft – 30-ft).

Interaction Criteria" section (pp. 10-13 of the Napa County guidance document dated May 12, 2015) states:

> *The groundwater/surface water criteria are presumptively met if the distance standards and project well construction assumptions are met (see Tables 3, 4, and 5).* (p. 10)

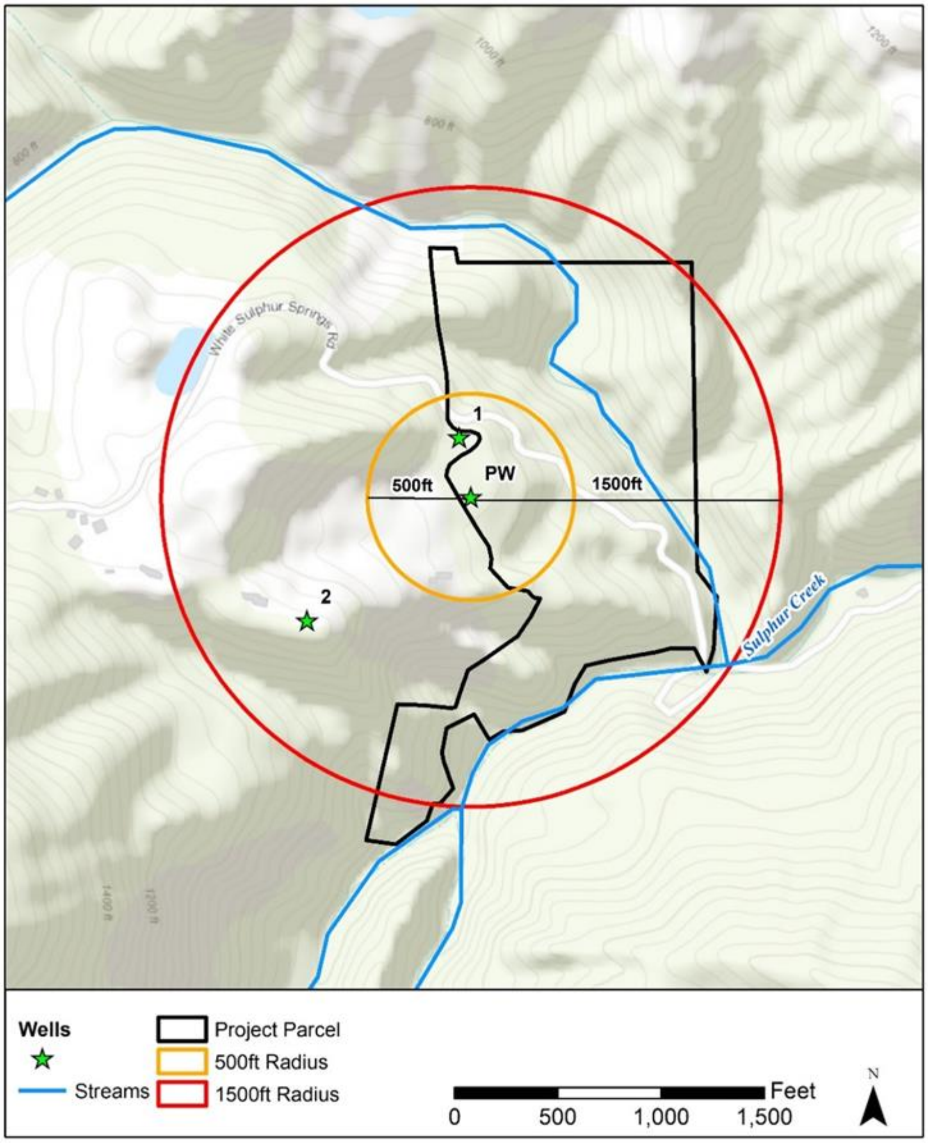

Figure 4: Project Well with a 500ft and 1500ft radius showing surrounding wells and streams in the area.

Because the PW is more than 500 ft from the stream of concern, it can potentially be utilized to supply water for the proposed vineyard without further analysis regarding County Tier 3 WAA criteria if operated at "Very low capacity pumping rates, (i.e. less than 10 gallons per minute)". This pumping rate is consistent with existing and proposed groundwater use as described below.

The Tier 3 criteria also indicate that the minimum depth of the well surface seal should be 50 ft and the depth of uppermost well perforations should be 100 ft. The surface seal for this well is 25 deep and the uppermost perforations are at a depth of 173 ft. The deviation from the guidelines for depth of well seal (25 ft versus 50 ft) has no significance with respect to groundwater-surface water interaction and potential streamflow depletion because the well is situated on a hillside about 300 ft above Sulphur Creek.

The effective pumping rate for the PW can be estimated based on estimated annual project groundwater use. Total annual project groundwater use is comprised of 0.87 ac-ft for irrigation and 0.50 ac-ft for residential use. Assuming a 150 day irrigation season, average daily irrigation demand is 0.0058 ac-ft. Assuming residential use is spread evenly through the year, average daily use is 0.00137 ac-ft. The average daily demand during the irrigation season would be 0.00717 ac-ft, equivalent to about 2340 gallons per day. The pumping rate required to supply this quantity of water in a 24 hour period is about 1.6 gallons per minute (gpm). This quantity of water could be pumped over a 4 hour period at a rate of 9.75 gpm. These calculations demonstrate that the PW would operate as a “very low capacity well”; consequently, the well complies with Tier 3 guidelines.

Summary

Analysis of the averaged 10-year period of precipitation for Water Years 2012 to 2021 resulted in recharge of ~6.2 inches/yr, equivalent to 11.3 ac-ft/yr across the project recharge/impact area (Table 6). Total groundwater use of 5.85 ac-ft/yr, including water uses on adjacent parcels in the recharge area that are not supplied from the project aquifer, is equivalent to 52% of mean annual recharge across the recharge area (Table 7). Proposed project groundwater use on the project parcel of 1.37 ac-ft/yr is equivalent to 32% of mean annual discharge (Table 7). Groundwater use associated with the proposed project is believed unlikely to result in significant reductions in groundwater levels or depletion of groundwater resources over time. The project aquifer is well-defined and is expected to be replenished by annual winter rainfall.

Potential well interference between PW and Well 1 was evaluated based on hydrogeologic conditions inferred from well data and the PW pump test. The PW aquifer (rock slide deposits) is distinct from the Well 1 bedrock aquifer, strongly suggesting that there would not be well interference across the aquifer boundary. Furthermore, the magnitude of drawdown (17 ft) and recovery of groundwater elevation in PW exhibited in a pump test indicates that drawdown in Well 1 located 295 ft from PW would not exceed the County drawdown threshold of 10 ft.

Potential streamflow depletion in Sulphur Creek that could be caused by operation of PW located 725 ft to the southwest of the stream was evaluated. The PW’s effective pumping rate will be less than 10 gpm. This pumping rate is that of a “very low capacity well”. The construction and effective pumping capacity of PW is consistent with County guidelines indicating that “groundwater/surface water criteria are presumptively met”.

References

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APPENDIX A

WELL COMPLETION REPORTS

DUPLICATE
Driller's Copy PW

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. e0272211

Owner's Well No. WELL #1
Date Work Began 6/4/2015, Ended 6/17/2015
Local Permit Agency Napa County Environmental
Permit No. E15-00302 Permit Date 4/30/2015

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD Mud Rotary FLUID Bentonite

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	75	Brown sandstone
75	100	Fractured brown sandstone
100	200	Fractured sandstone shale
200	275	Shale with clayee areas

TOTAL DEPTH OF BORING 275 (Feet)
TOTAL DEPTH OF COMPLETED WELL 270 (Feet)

WELL OWNER

Name Aravinth Babu
Mailing Address 1875 Mountain View Drive
Tiburon CA
CITY STATE ZIP

WELL LOCATION

Address 3600 White Sulphur Springs Road
City Saint Helena CA
County Napa
APN Book 027 Page 010 Parcel 033
Township ___ Range ___ Section ___
Latitude 38 29 488 N (DEG. MIN. SEC.) Longitude 122 30 726 W (DEG. MIN. SEC.)

LOCATION SKETCH

NORTH

WEST

EAST

SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
✓ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER N/A (Ft.) BELOW SURFACE 1
DEPTH OF STATIC WATER LEVEL 38 (Ft.) & DATE MEASURED 6/17/2015
ESTIMATED YIELD * 100 (GPM) & TEST TYPE Air Developed
TEST LENGTH 1.5 (Hrs.) TOTAL DRAWDOWN 260 (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	20	11								
20	160	9 7/8								
160	275	7 7/8								
+3	70		✓				PVC	5	SDR21	
70	90			✓			PVC	5	SDR21	.032
90	110		✓				PVC	5	SDR21	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	22	✓			
22	28		✓		
28	270			✓	#6 Sand

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME Weeks Drilling & Pump
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
P.O. Box 176 Sebastopol CA 95473
ADDRESS CITY STATE ZIP
Signed WELL DRILLER/AUTHORIZED REPRESENTATIVE 06/22/15 DATE SIGNED 177681 C-57 LICENSE NUMBER

ORIGINAL
File with DWR

Well 1

Page 1 of 1

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. e0112808

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO.

LATITUDE — LONGITUDE

APN/TRS/OTHER

Owner's Well No. 1-2010

Date Work Began 8/6/2010, Ended 8/12/2010

Local Permit Agency Napa County Environmental Mgmt

Permit No. E10-00318 Permit Date 7/28/2010

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD ROTARY FLUID AIR

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION Describe material, grain, size, color, etc.
0	90	BROWN CLAY & SHALE
90	170	50% SANDSTONE / 50% SHALE
170	210	80% SANDSTONE / 20% SHALE
210	235	GRAY HARD FRACTURED SANDSTONE
235	260	DARK GRAY HARD SANDSTONE
260	320	60% SANDSTONE / 40% SHALE

RECEIVED
SEP 7 2010
DEPT. OF ENVIRONMENTAL MANAGEMENT

TOTAL DEPTH OF BORING 320 (Feet)

TOTAL DEPTH OF COMPLETED WELL 313 (Feet)

WELL OWNER

Name [redacted]

Mailing Address P.O. Box 696

[redacted] CA [redacted]

CITY STATE ZIP

WELL LOCATION

Address 3434 White Sulphur Springs Road

City St. Helena CA

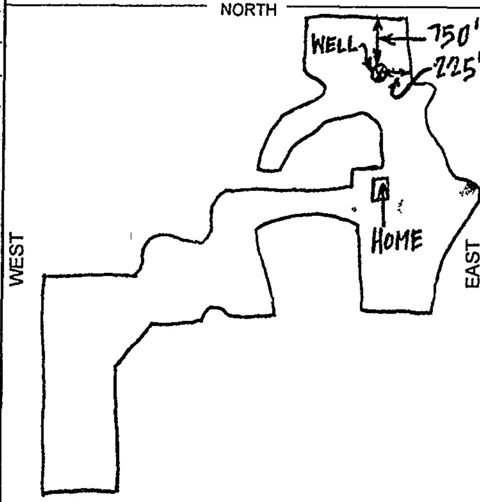
County Napa

APN Book 027 Page 010 Parcel 038

Township ___ Range ___ Section ___

Latitude ___ DEG. MIN. SEC. Longitude ___ DEG. MIN. SEC.

LOCATION SKETCH



Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
— Deepen
— Other (Specify)

— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
✓ Domestic ___ Public
✓ Irrigation ___ Industrial

MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

1

DEPTH TO FIRST WATER 210 (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL 147 (Ft.) & DATE MEASURED 8/12/2010

ESTIMATED YIELD • 16 (GPM) & TEST TYPE AIR LIFT

TEST LENGTH 3 (Hrs.) TOTAL DRAWDOWN N/A (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	25	10								
25	320	9								
0	173		✓				PVC F480	5	SDR-21	
173	293			✓			PVC F480	5	SDR-21	.032
293	313		✓				PVC F480	5	SDR-21	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	5	✓			CONCRETE
5	25		✓		CHIPS
25	313			✓	PEA GRAVEL

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME HUCKFELDT WELL DRILLING, INC.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

2110 Penny Lane Napa CA 94559
ADDRESS CITY STATE ZIP

Signed [signature] 08/13/10 439-746
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

QUADRUPLICATE
For Local Requirements

Well 2

STATE OF CALIFORNIA WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 1073678

Page __ of __

Owner's Well No. ____

Date Work Began 4-1-09, Ended 4-13-09

Local Permit Agency Napa County

Permit No. ____ Permit Date ____

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./STATION NO.
LATITUDE / LONGITUDE
APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD rotary FLUID mud

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION — Describe material, grain size, color, etc.
0	30	brown Clay & rock
30	75	blue Clay & Shale
75	200	blue Shale streaks of Sandstone
200	260	blue Shale

TOTAL DEPTH OF BORING 260 (Feet)

TOTAL DEPTH OF COMPLETED WELL 260 (Feet)

WELL OWNER

Name [redacted]

Mailing Address [redacted]

CITY ____ STATE ____ ZIP [redacted]

WELL LOCATION

Address 3450 White Sulphur Spr rd

City St Helena

County Napa

APN Book ____ Page ____ Parcel 027-010-039

Township ____ Range ____ Section ____

Lat ____ DEG. MIN. SEC. N Long ____ DEG. MIN. SEC. W

LOCATION SKETCH

NORTH / SOUTH / WEST / EAST

White Sulpur spr rd

well — 2 mi →

Crane Av.

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (*Describe Procedures and Materials Under "GEOLOGIC LOG"*)

USES (✓)

WATER SUPPLY
___ Domestic ___ Public
✓ Irrigation ___ Industrial

MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 30 (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL 70 (Ft.) & DATE MEASURED 4-13-09

ESTIMATED YIELD * 20 (GPM) & TEST TYPE Air lift

TEST LENGTH 2 (Hrs.) TOTAL DRAWDOWN 230 (Ft.)

* *May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	200	11	X				Plastic	5"	200	
200	240	"	X				"	"	"	
240	260	"		X			"	"	"	.032

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	20	X			
20	260				pea gravel

RECEIVED
SEP 10 2009
DEPT OF ENVIRONMENTAL MANAGEMENT

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ____

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME William Well Dr.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

2277 Piedmont Av. Napa Ca. 94558
ADDRESS CITY STATE ZIP

Signed ____ 4-29-09 248277
C-57 LICENSED WATER WELL CONTRACTOR / DATE SIGNED / C-57 LICENSE NUMBER

DWR 188 REV. 05-03

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

APPENDIX B

Project Well Pump Test

WEEKS DRILLING & PUMP CO. **TEST PUMP LOG**

Job
Aravinth Babu

WO#
185167

Location
3600 White Sulphur Springs St. Helena

Date Started
6/25/2015

Well Depth
270'

Casing Size
5" PVC

Static Level
44'

Meter Reading

Size Pump
Grundfos 40S30 3HP

Setting
240'

Date	Time AM	Time PM	Operator	Water Level	Est GPM	Water Color	Water Temp	Sand Chute	COMMENTS
6/25/15	10:00		Sean	44	50	clear			
6/25/15	10:30			50	50	clear			
6/25/15	11:00			55	50	clear			
6/25/15	11:30			55	50	clear			
6/25/15		12:00		56	50	clear			
6/25/15		12:30		57	50	clear			
6/25/15		1:00		57	50	clear			
6/25/15		1:30		58	50	clear			
6/25/15		2:00		59	50	clear			
6/25/15		2:30		60	50	clear			
6/25/15		3:00		60	50	clear			
6/25/15		3:30		61	50	clear			
6/25/15		4:00		61	50	clear			
6/25/15		4:30		61	50	clear			
6/25/15		5:00		61	50	clear			
6/25/15		5:30		61	50	clear			
6/25/15		6:00		61	50	clear			
									Recovered to 53' in 30 minutes

APPENDIX C

SOIL WATER BALANCE 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 factors 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 (Healy 2010, Seiler and Gat 2007).

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).

This modeling work and summary report has been prepared by O'Connor Environmental, Inc., for it's private use in relation to Water Availability Analyses (WAA) prepared on behalf of private clients for projects using groundwater in "hillside" areas of Napa County as required by Napa Planning, Building & Environmental Services. The modeling to-date is complete in its current form but remains subject to revision; it is considered a working draft with information suitable for use to support WAA projects. Parties interested in obtaining more information regarding the modeling or who may wish to offer comments should contact O'Connor Environmental, Inc.

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).

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 covering Sonoma County and calibrated using runoff volumes from several stream gages (OEI 2017).

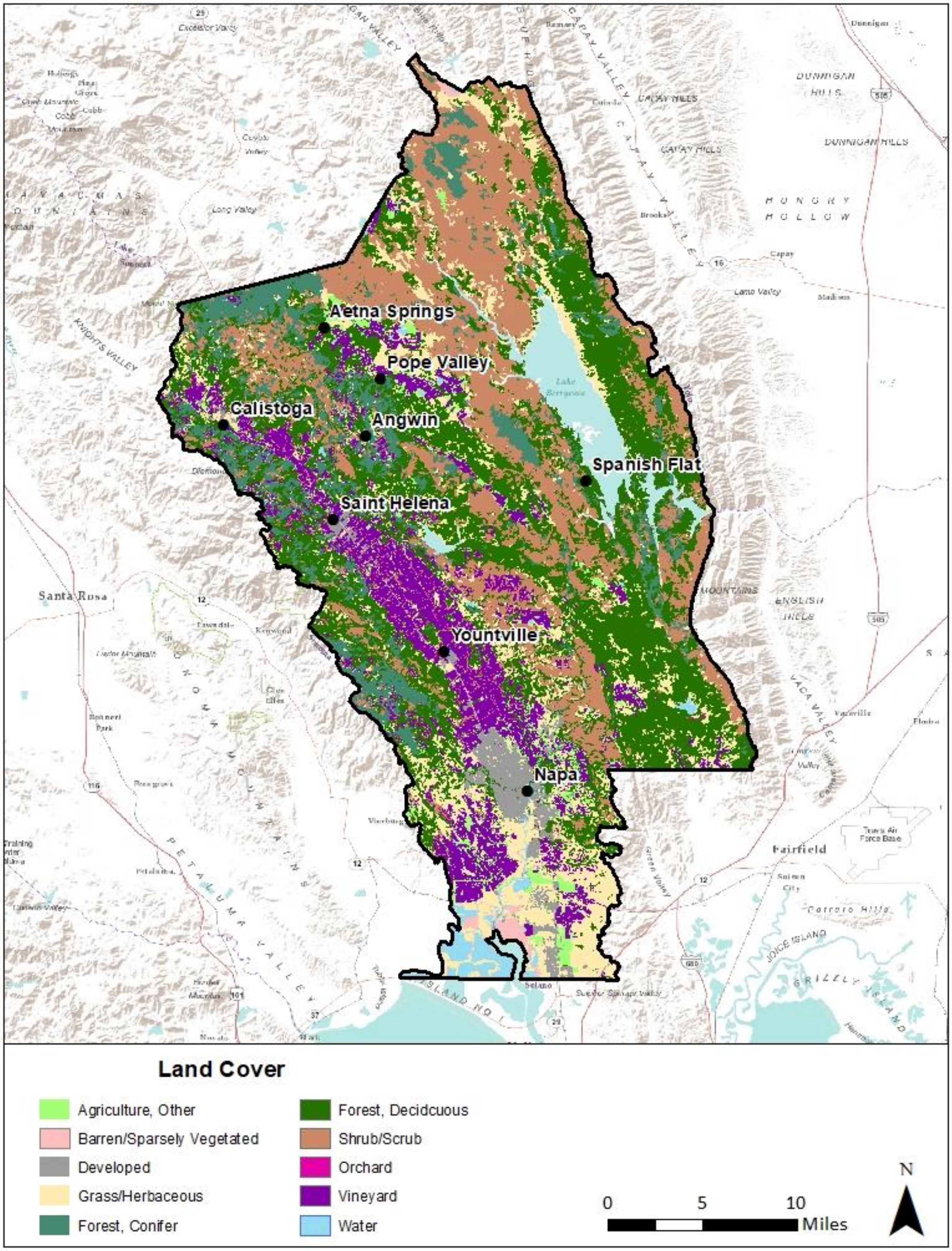


Figure 1: Land cover distribution used in the Napa County SWB model.

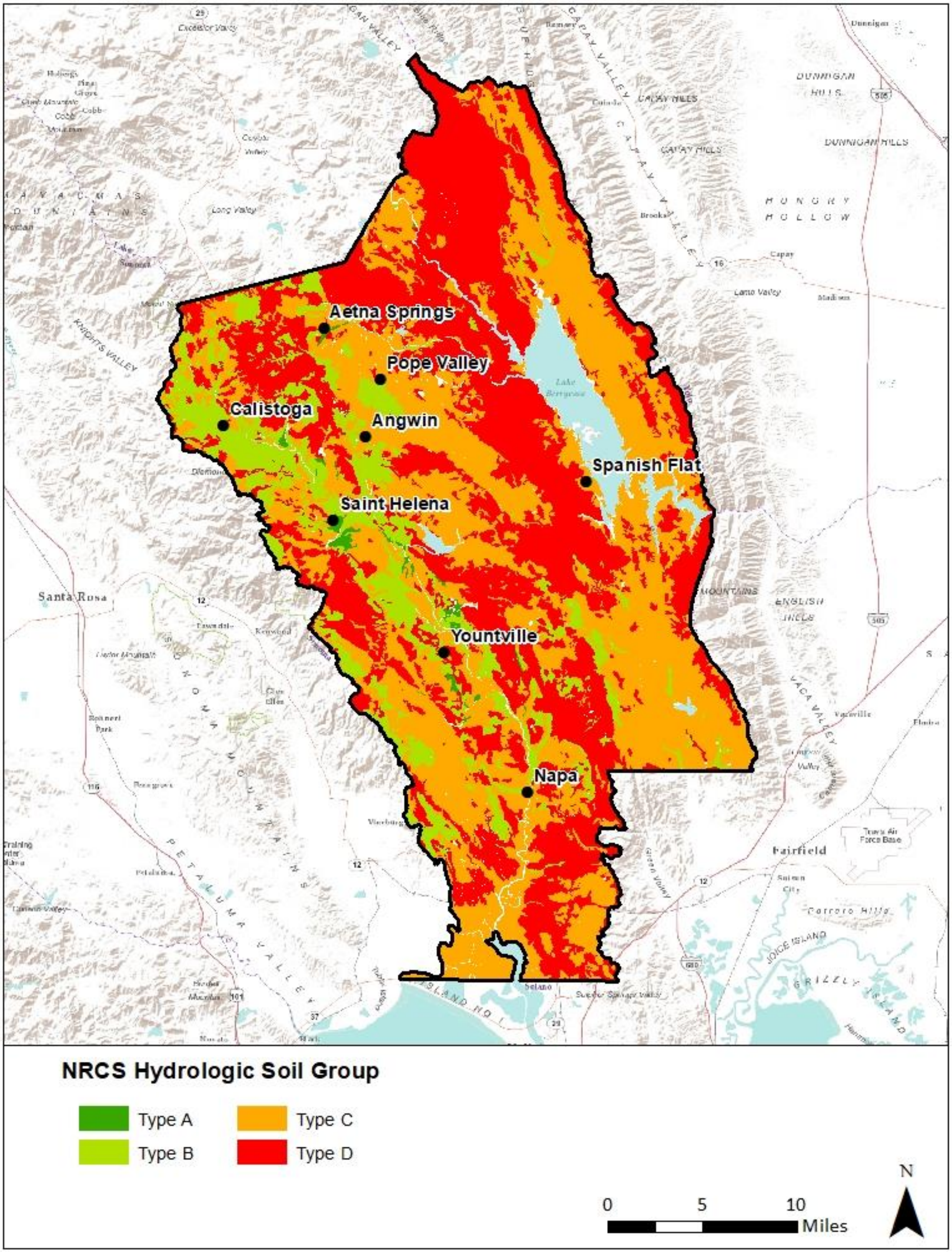


Figure 2: Hydrologic soil group distribution used in the Napa County SWB model.

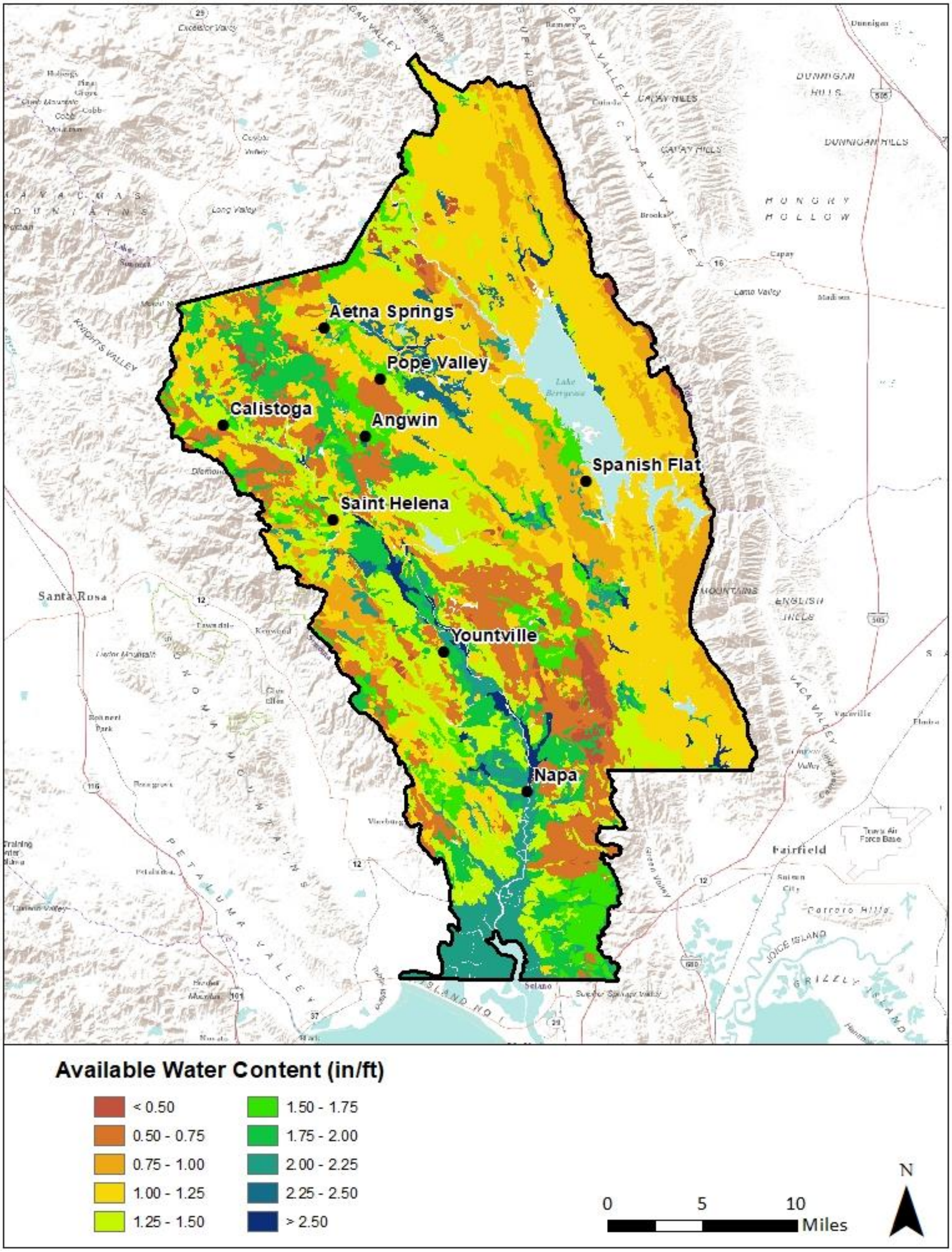


Figure 3: Available water capacity distribution used in the Napa County SWB model.

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

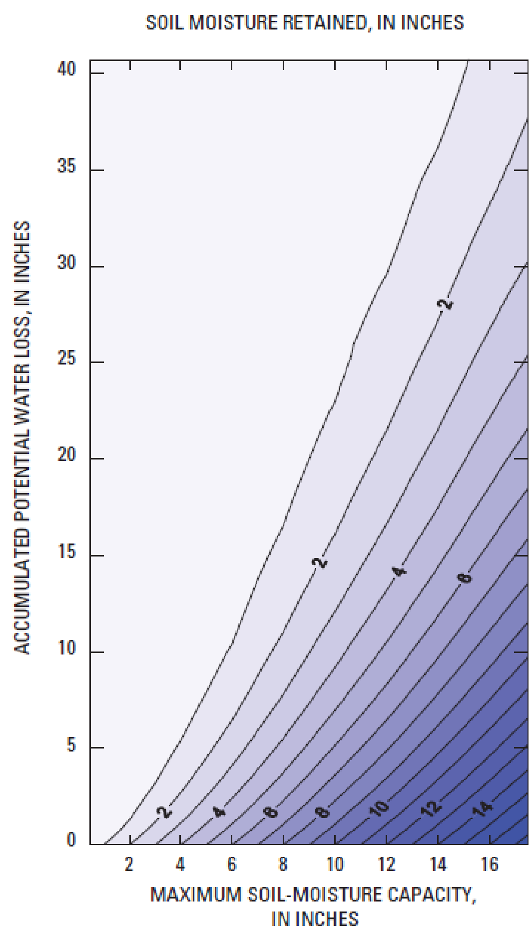


Figure 4: Soil-moisture-retention table (Thornthwaite and Mather 1957).

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 (spatially-distributed) 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 representative of 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 5 and 6). 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 7- 9 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

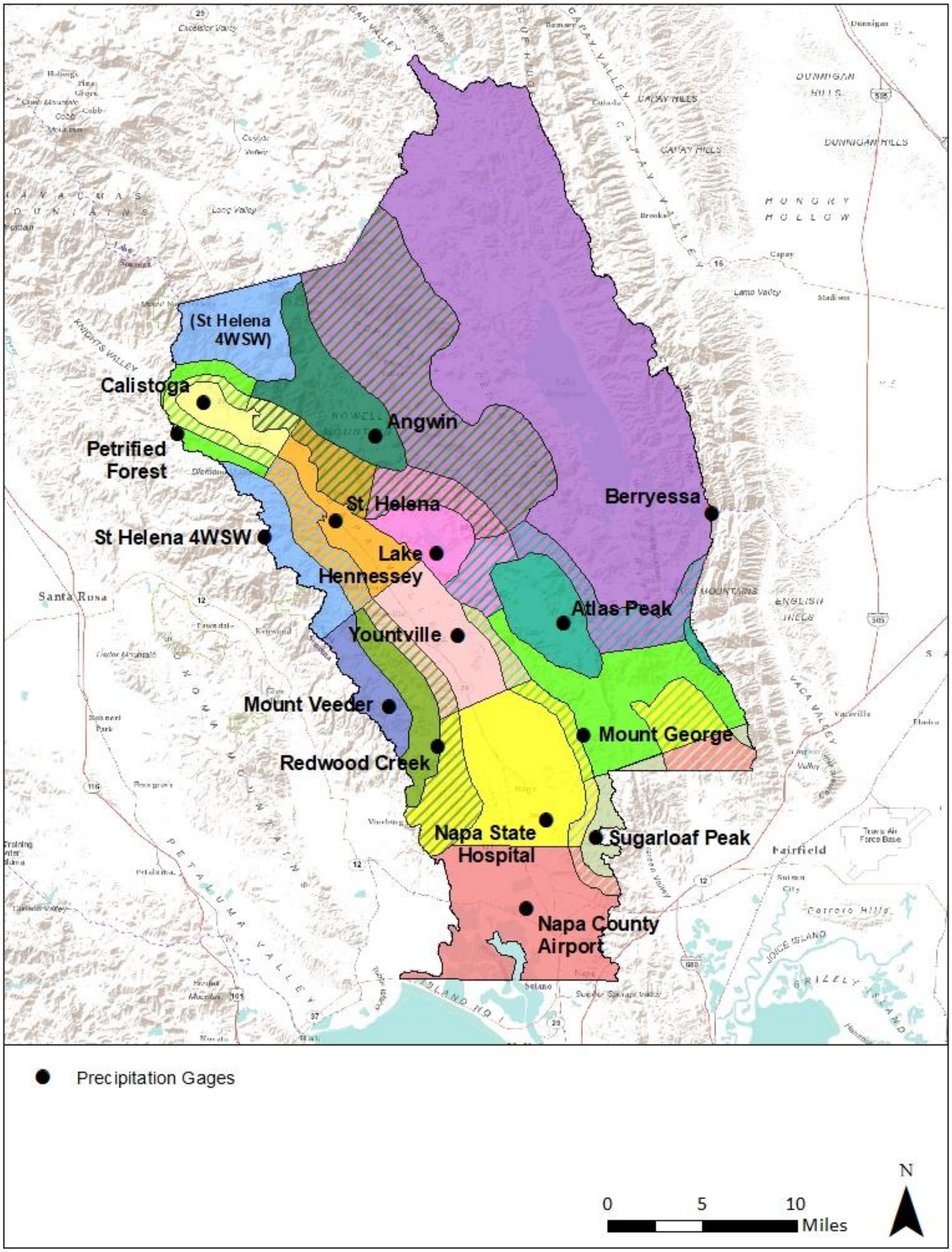


Figure 5: Precipitation zones used in the Napa County SWB model. Hatching indicates areas where two precipitation records were averaged across a zone.

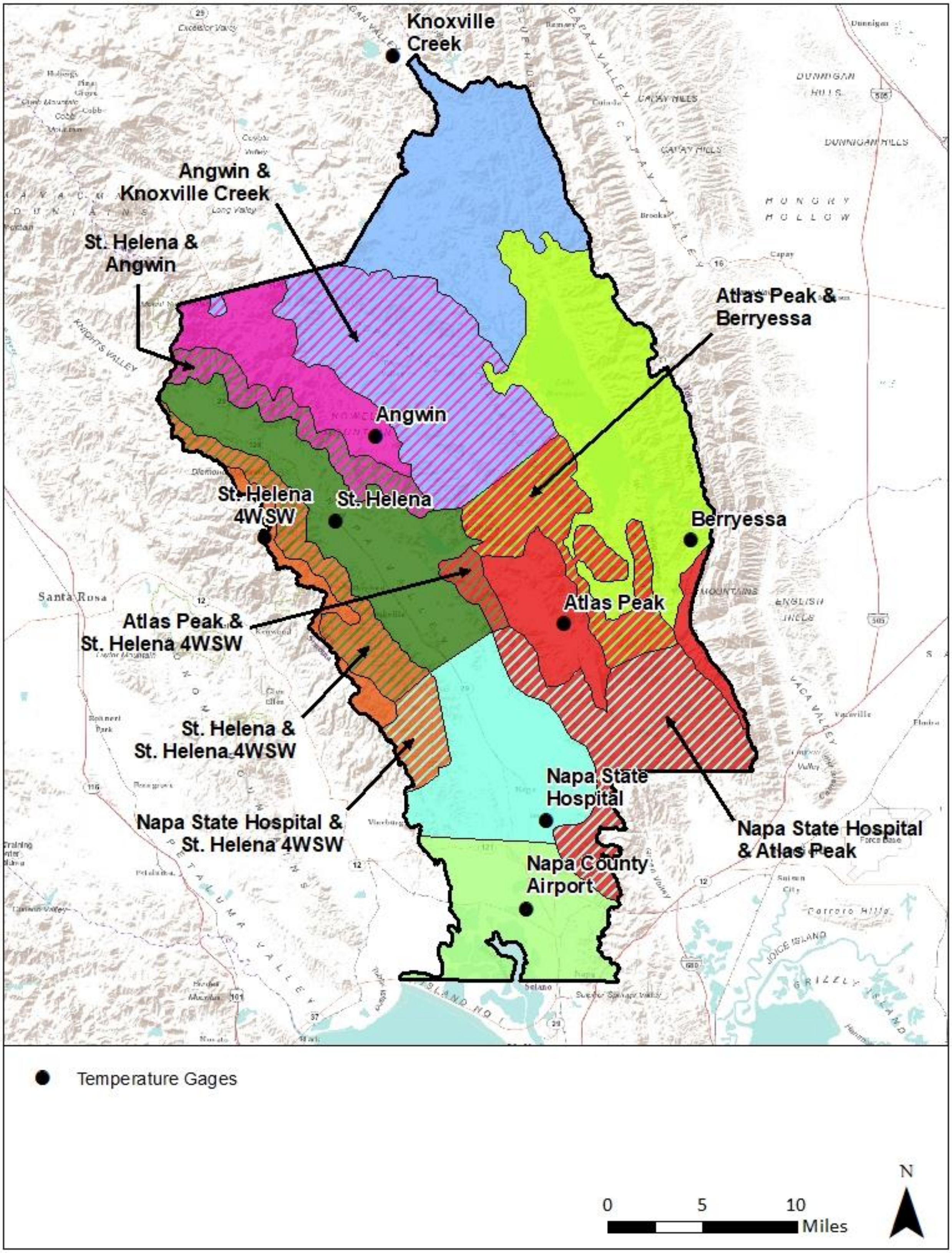


Figure 6: Temperature zones used in the Napa County SWB model. Hatching indicates areas where two temperature records were averaged across a zone.

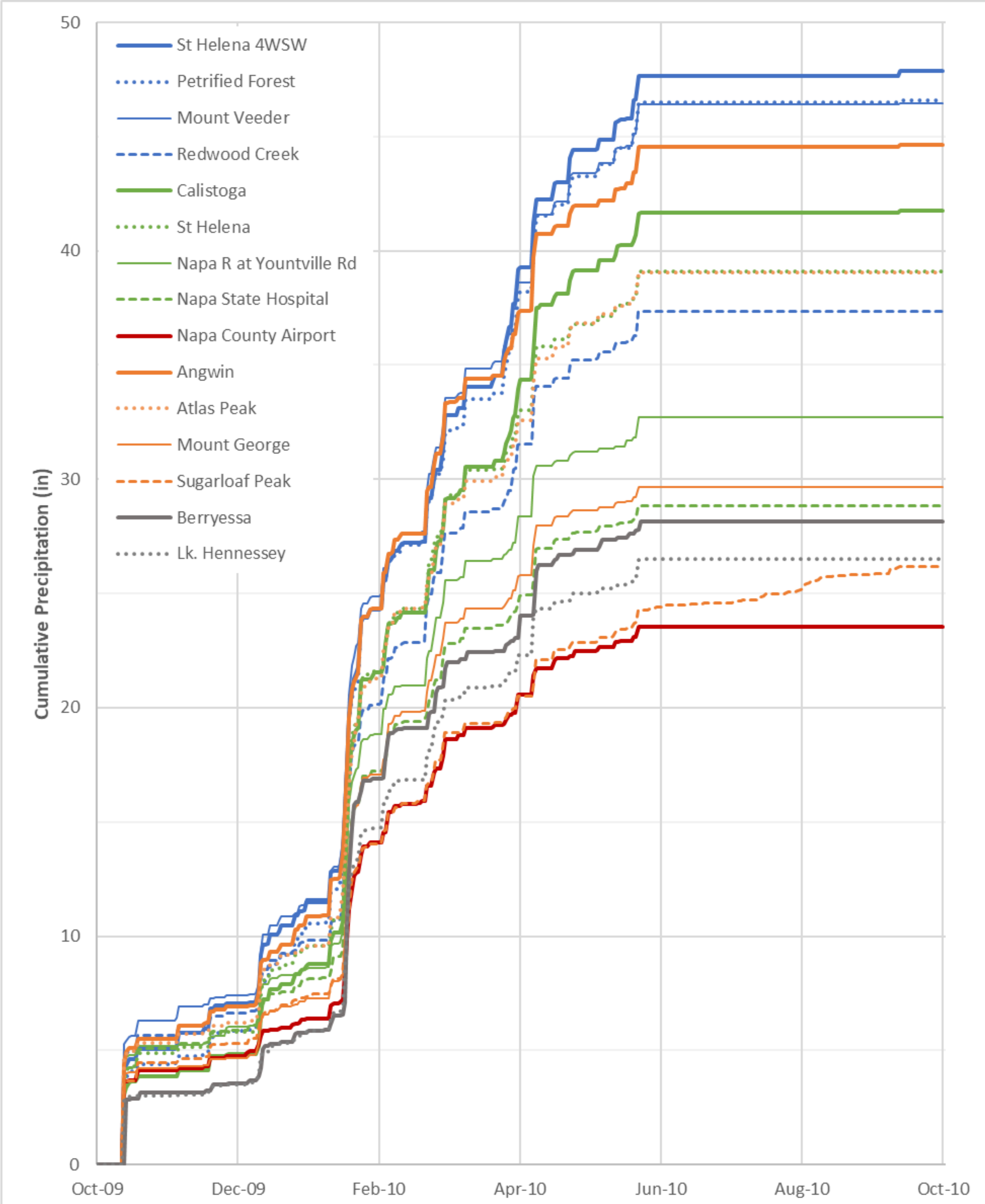


Figure 7a: Daily precipitation data used in the Napa County SWB model for WY 2010.

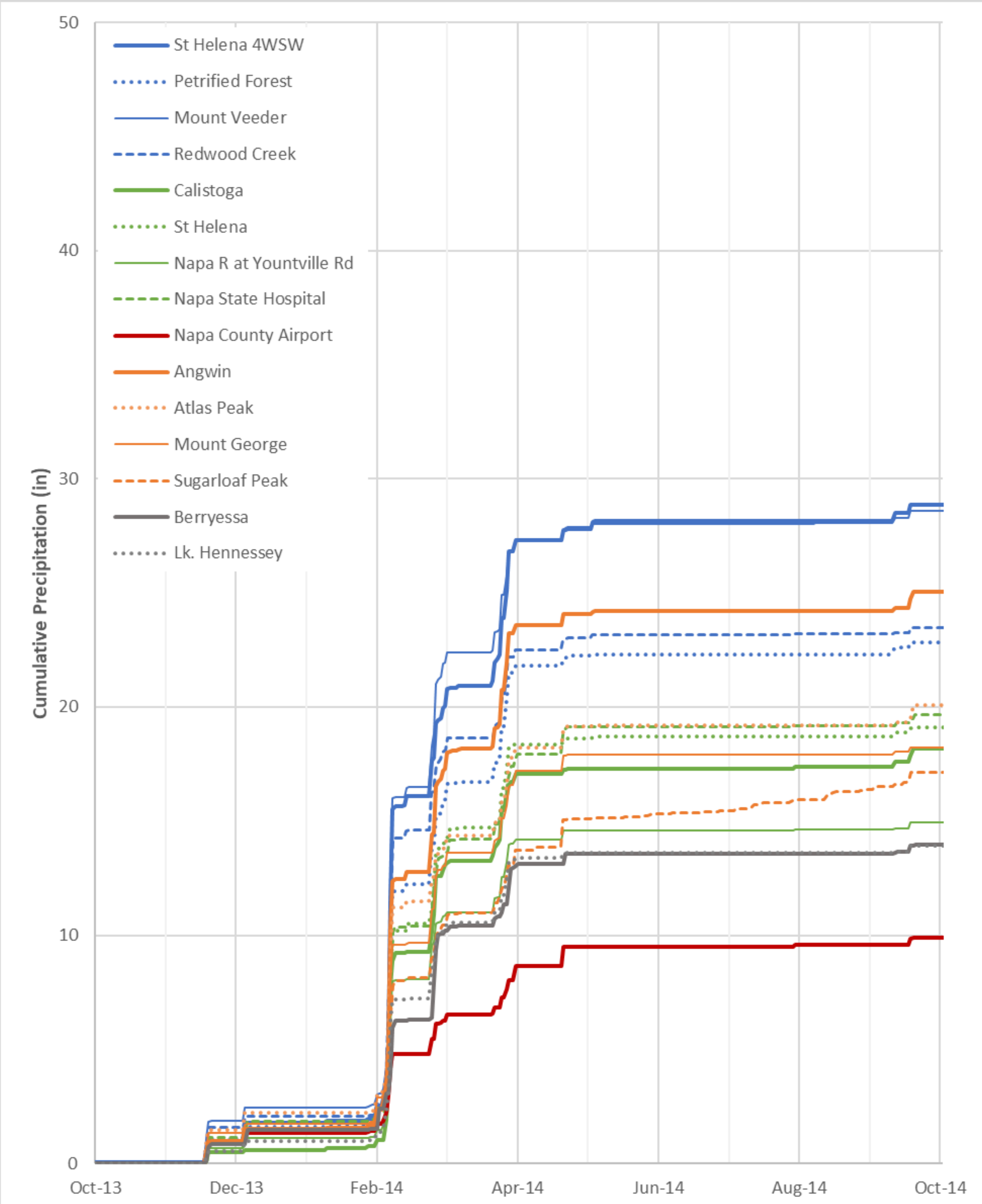


Figure 7b: Daily precipitation data used in the Napa County SWB model for WY 2014.

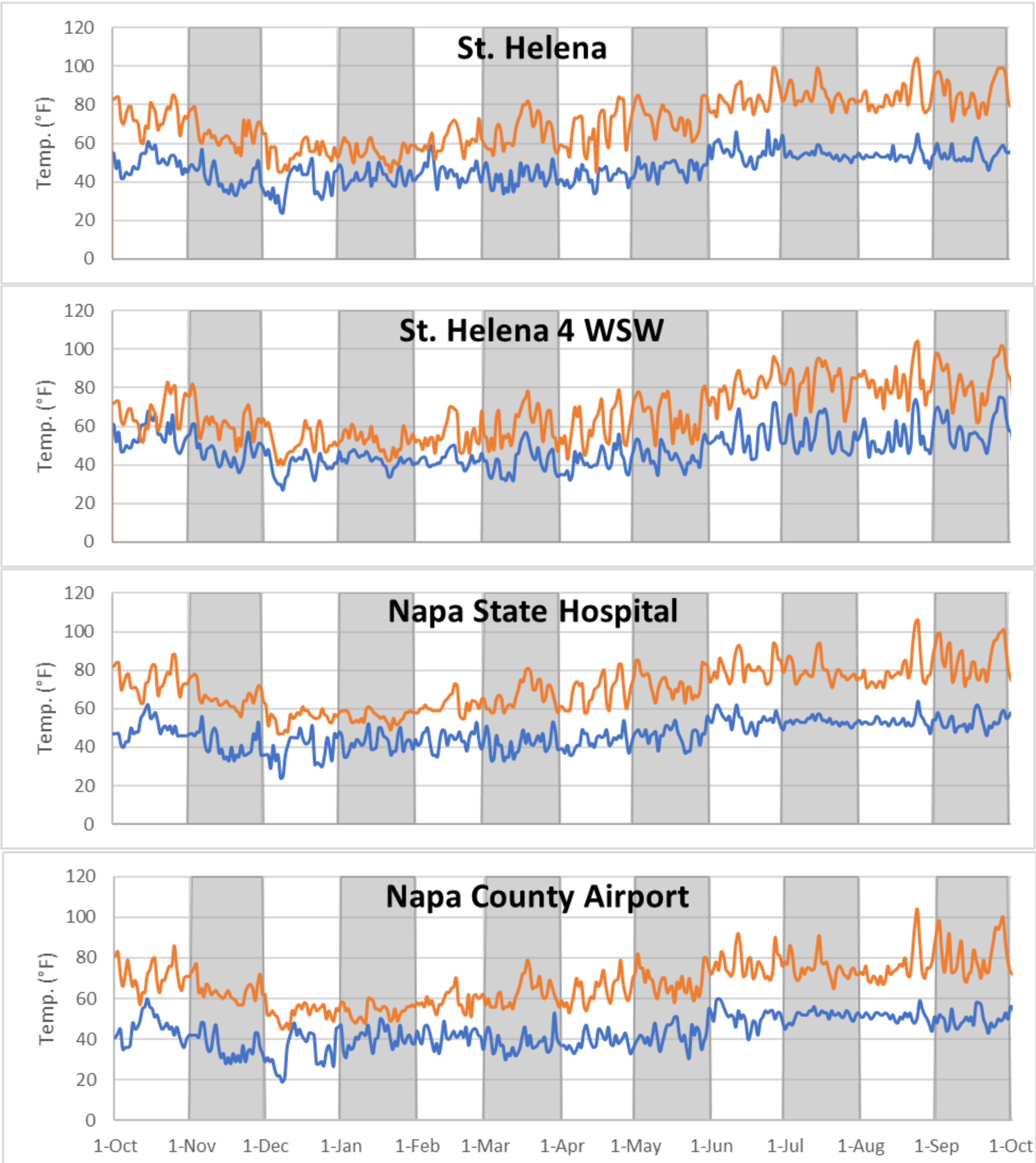


Figure 8: Daily minimum and maximum temperature data used in the Sonoma County SWB model for WY 2010.

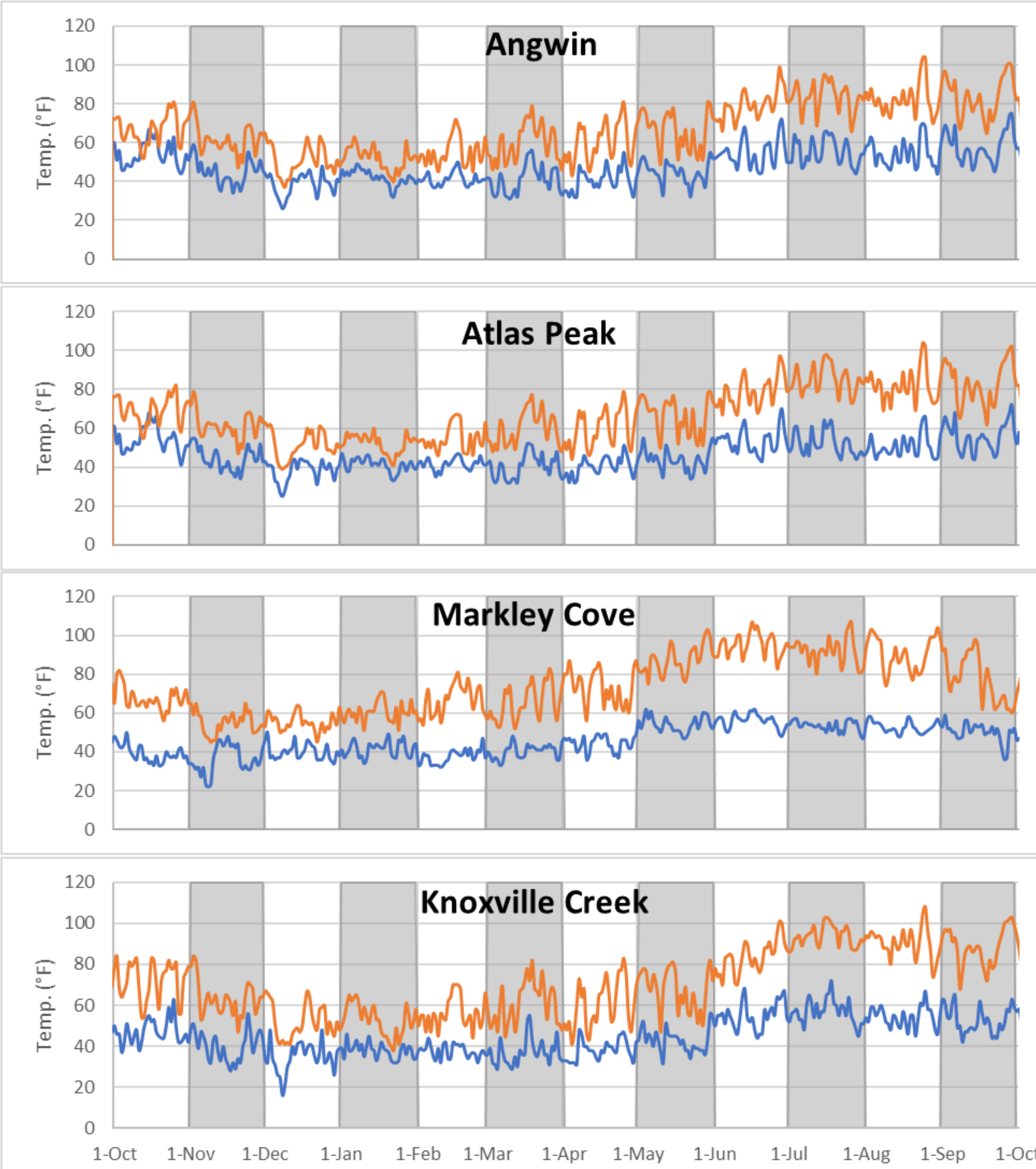


Figure 8 – cont.

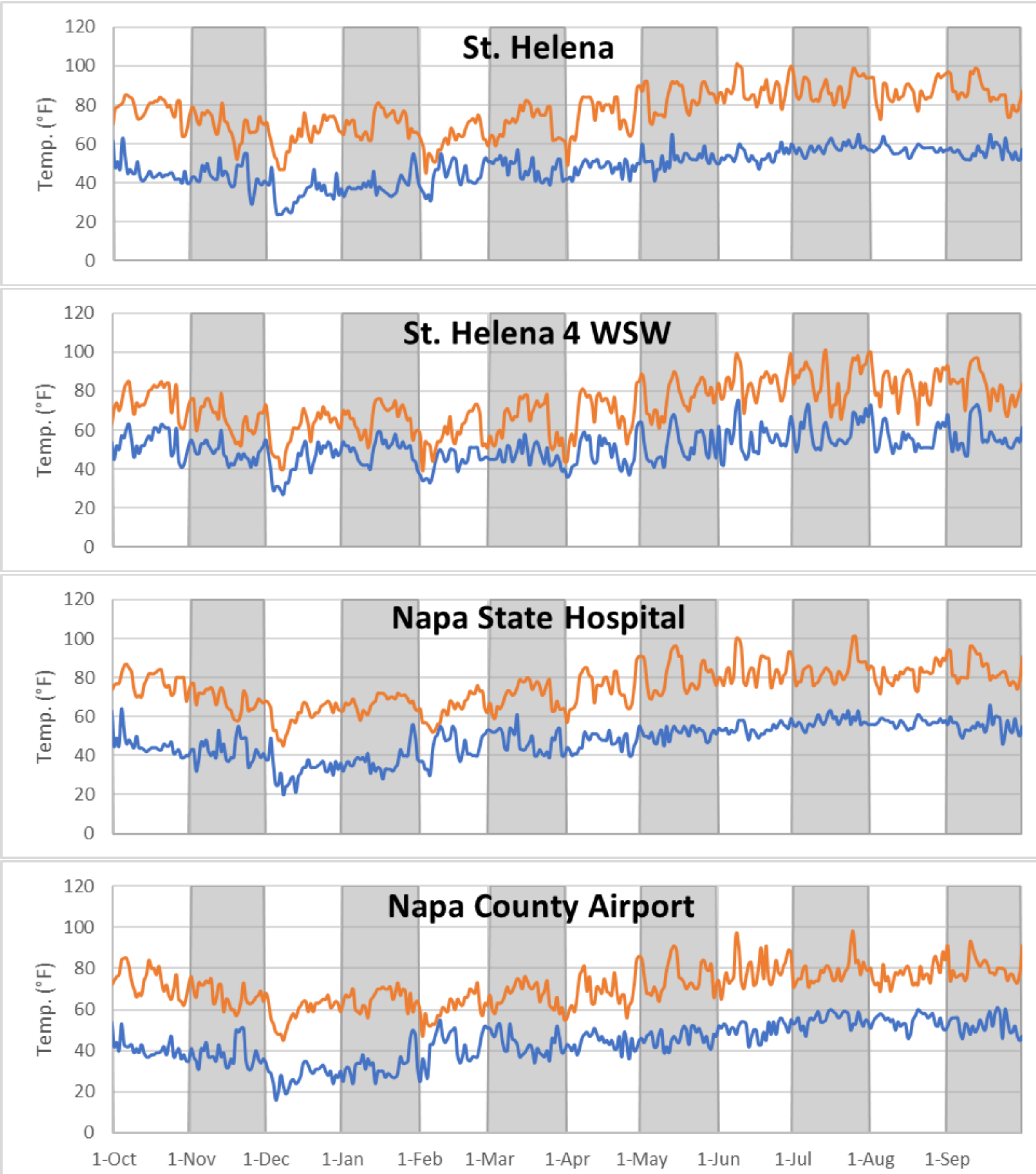


Figure 9: Daily minimum and maximum temperature data used in the Sonoma County SWB model for WY 2010.

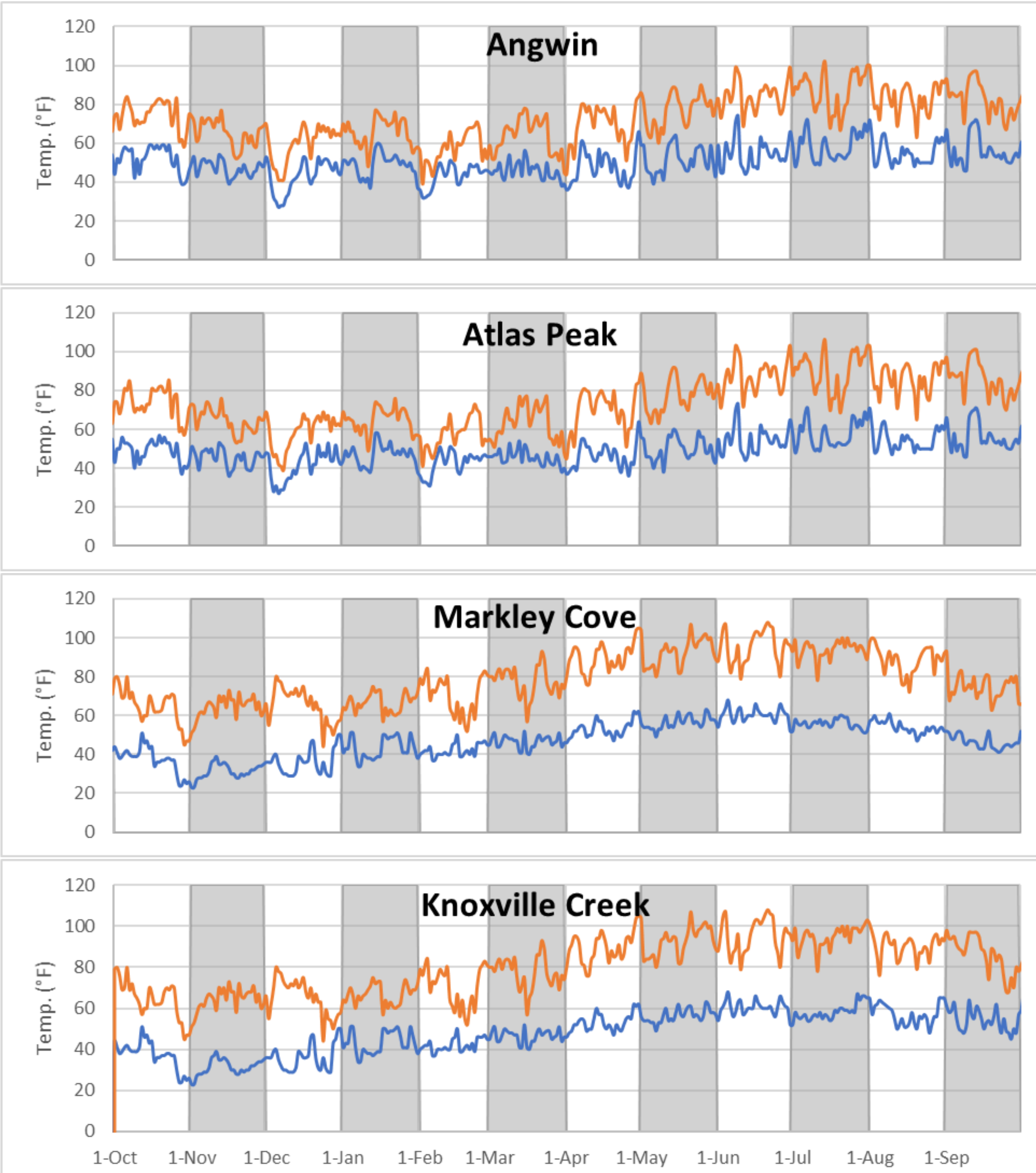


Figure 9 – cont.

Model Calibration

Available data are insufficient to calibrate the Water Year 2010 and 2014 SWB simulations; however, the land cover and soil properties used in the model were obtained from a previously prepared and calibrated SWB model of Sonoma County (OEI 2017). The Sonoma County 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 periods. 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 approach to simulating surface runoff.

The SWB model of Sonoma County reproduced 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 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 One Rain 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 provided estimates of average annual 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 than the model prepared by LSCE, which predicts slightly lower AET but significantly more runoff (Table 4). Differences in methodology between these two models complicate direct comparisons. The LSCE 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. <u>Inclusion of baseflow with direct runoff in these calculations may inappropriately reduce the estimated volume of water infiltrated into the soil and available for recharge</u>.

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

USGS Gage	HUC	Mean Precip, 2010 (in)	Mean AET, 2010 (% Precip)		Mean Runoff, 2010 (% Precip)		Mean Recharge, 2010 (% Precip)	
			SWB	LSCE	SWB	LSCE	SWB	LSCE
Conn Ck nr Oakville	11456500	34.8	59%	53%	21%	25%	21%	21%
Dry Ck nr Napa	11457000	41.5	56%	50%	18%	43%	25%	6%
Milliken Ck nr Napa	11458100	32.3	52%	41%	20%	51%	28%	8%
Napa Ck at Napa	11458300	36.6	61%	43%	16%	46%	23%	11%
Napa R nr Napa	11458000	39.5	56%	48%	20%	35%	24%	17%
Napa R nr St Helena	11456000	47.9	46%	45%	23%	42%	30%	14%
Redwood Ck nr Napa	11458200	39.6	53%	49%	26%	40%	22%	10%
Tulucay Ck nr Napa	11458300	27.0	64%	49%	16%	47%	20%	5%

Model Results

The principal elements of the annual water budget simulated with the Napa County SWB model for Water Years 2010 and 2014 are presented in map form in Figures 10 - 19 and in tabular form for 27 major watershed areas in Napa County (Tables 5 - 8). The watersheds are based on USGS HUC-12 watersheds and are named for the stream which comprises the largest proportion of the area; in many cases the areas consist of multiple tributary streams (Figure 20).

In Water Year 2010 (representing "average" hydrologic conditions) precipitation varied from 21.8 inches in the Ledgewood Creek watershed to 53.3 inches in the Saint Helena Creek watershed (Figure 10, Table 5). Actual evapotranspiration (AET) ranged from 13.4 inches in the Jackson Creek watershed to 25.2 inches in the Saint Helena Creek watershed (Figure 11). Surface runoff ranged from 3.4 inches in the Ledgewood Creek watershed to 13.5 inches in the Saint Helena Creek watershed (Figure 12). Recharge ranged from 3.3 inches in the Ledgewood Creek watershed to 14.4 inches in the Saint Helena watershed. (Figure 13). Small decreases in soil moisture storage (up to 1.8 inches) occurred in most watersheds, with changes in most watersheds being less than an inch (Figure 14). Note that the San Pablo Bay estuaries have been excluded from these comparisons.

Expressed as a percentage of the annual precipitation, AET ranged from 77% in the Ledgewood Creek watershed to 45% in the Jackson Creek watershed (Table 6). Surface runoff ranged from 15% of precipitation in the Ledgewood Creek watershed to 42% in the Jackson Creek watershed. Recharge ranged from 10% of the precipitation in the Jackson Creek watershed to 27% in the Saint Helena watershed.

In Water Year 2014 (representing “dry” hydrologic conditions during the second year of an extreme three-year drought) precipitation varied from 10.1 inches in the American Canyon Creek watershed to 32.2 inches in the Saint Helena Creek watershed (Figure 15, Table 7). Actual evapotranspiration (AET) ranged from 10.3 inches in the Jackson Creek watershed to 17.8 inches in the Saint Helena Creek watershed (Figure 16). Surface runoff ranged from 0.7 inches in the American Canyon Creek watershed to 13.2 inches in the Saint Helena Creek watershed (Figure 17). Recharge ranged from 0.6 inches in the Wragg Canyon watershed to 4.1 inches in the Saint Helena watershed. (Figure 18). Large decreases in soil moisture storage of between 2.3 and 4.3 inches were also simulated (Figure 19).

Expressed as a percentage of the annual precipitation, AET ranged from 55% in the Saint Helena Creek watershed to 121% in the Jackson Creek watershed (Table 8). These very large AET rates caused significant decreases in soil moisture. Decreases in soil moisture ranged from 9% of precipitation in the Saint Helena watershed to 36% in the American Canyon Creek watershed. Surface runoff ranged from 7% of precipitation in the American Canyon Creek watershed to 41% in the Saint Helena Watershed. Recharge ranged from 18% in the Milliken Creek Watershed to 5% in the Jackson Creek and Wragg Canyon watersheds.

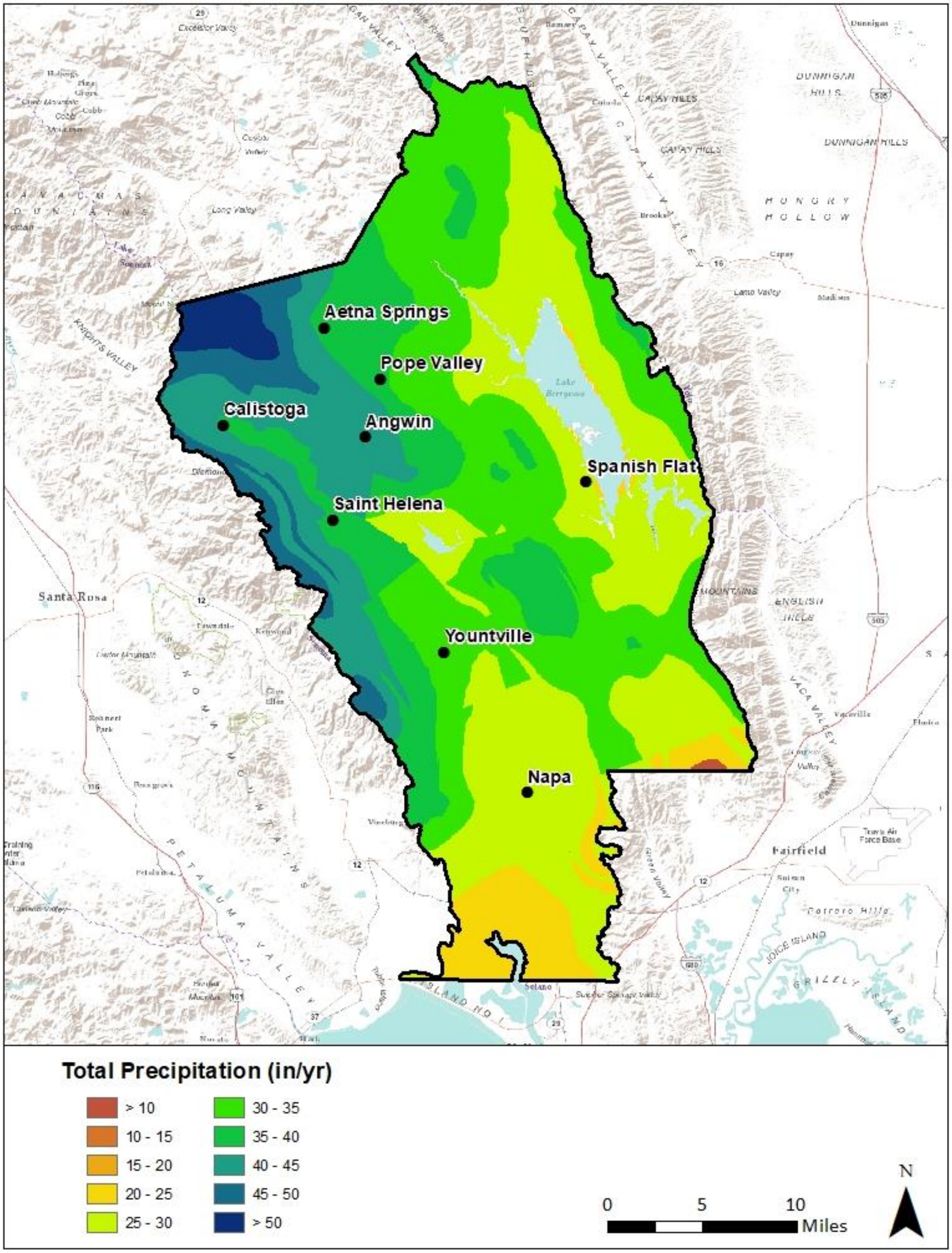


Figure 10: Water Year 2010 precipitation simulated with the Napa County SWB model.

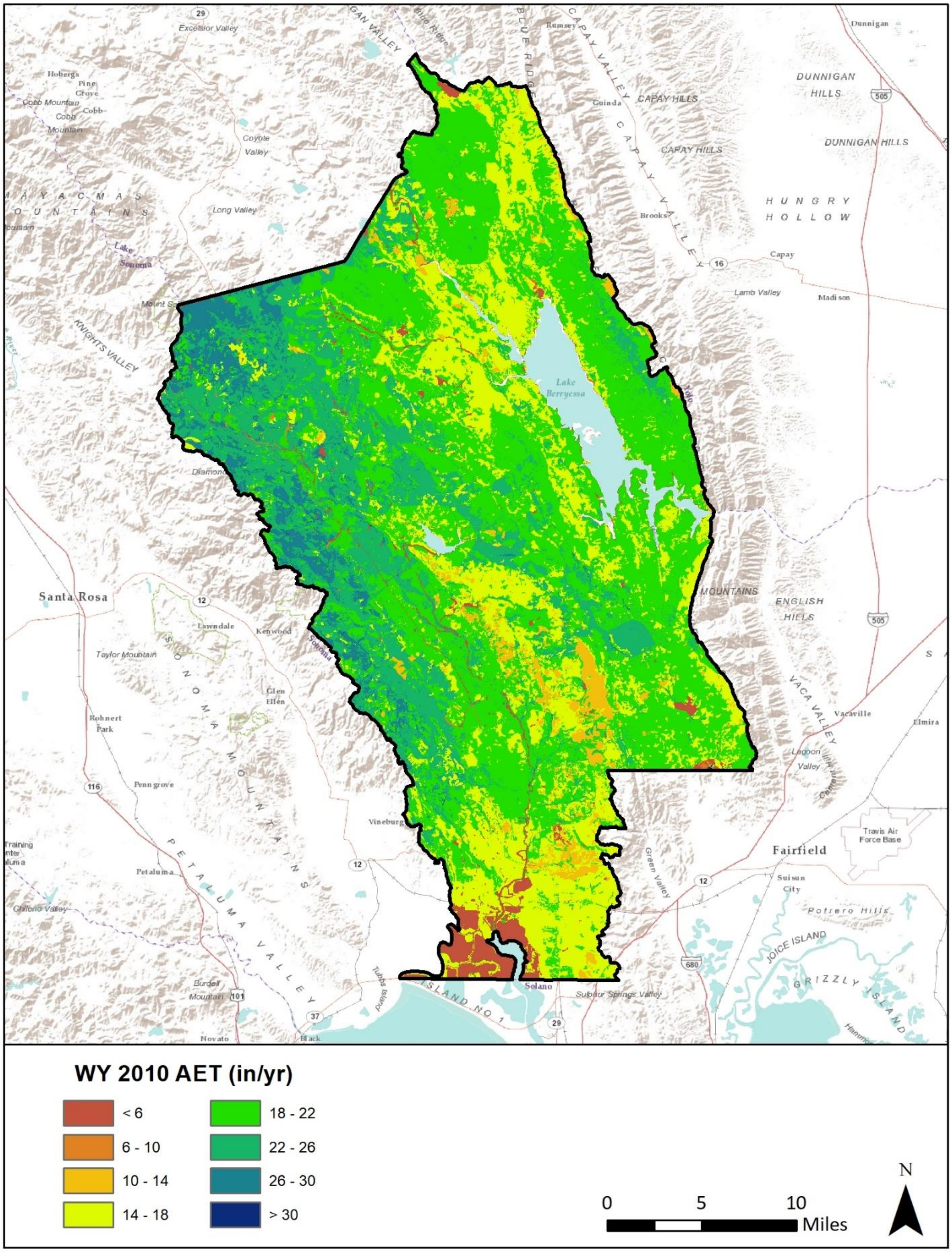


Figure 11: Water Year 2010 AET simulated with the Napa County SWB model.

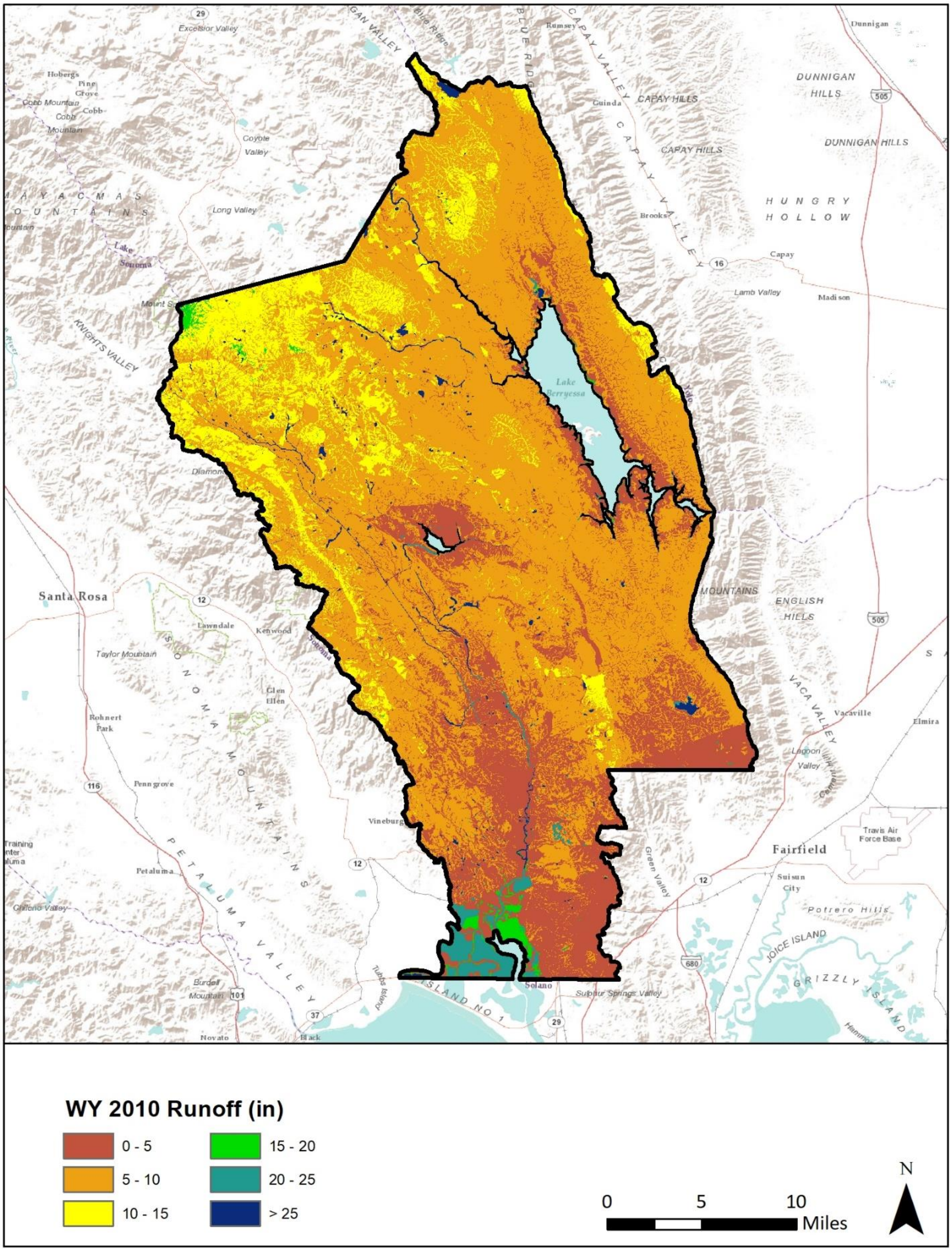


Figure 12: Water Year 2010 runoff simulated with the Napa County SWB model.

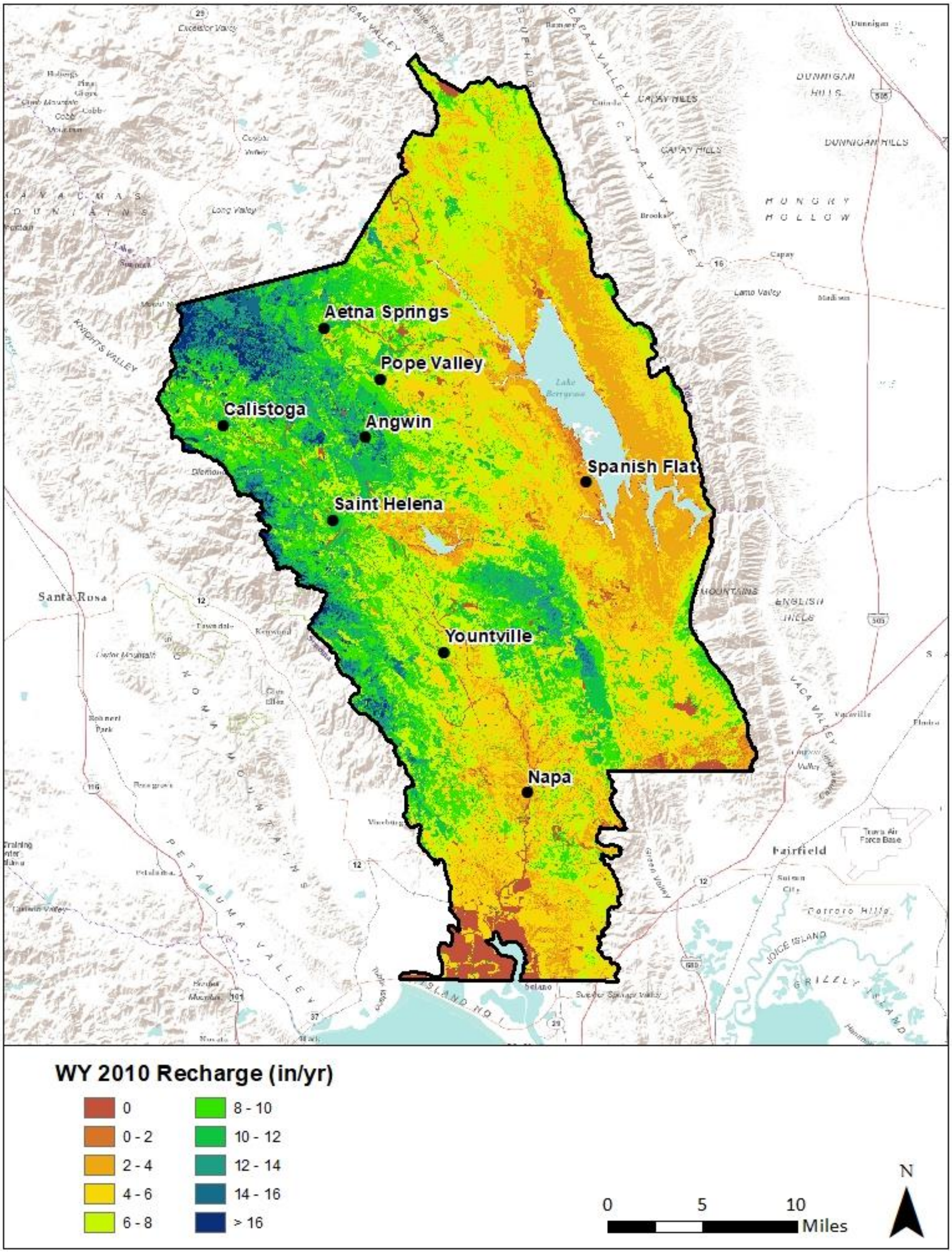


Figure 13: Water Year 2010 recharge simulated with the Napa County SWB model.

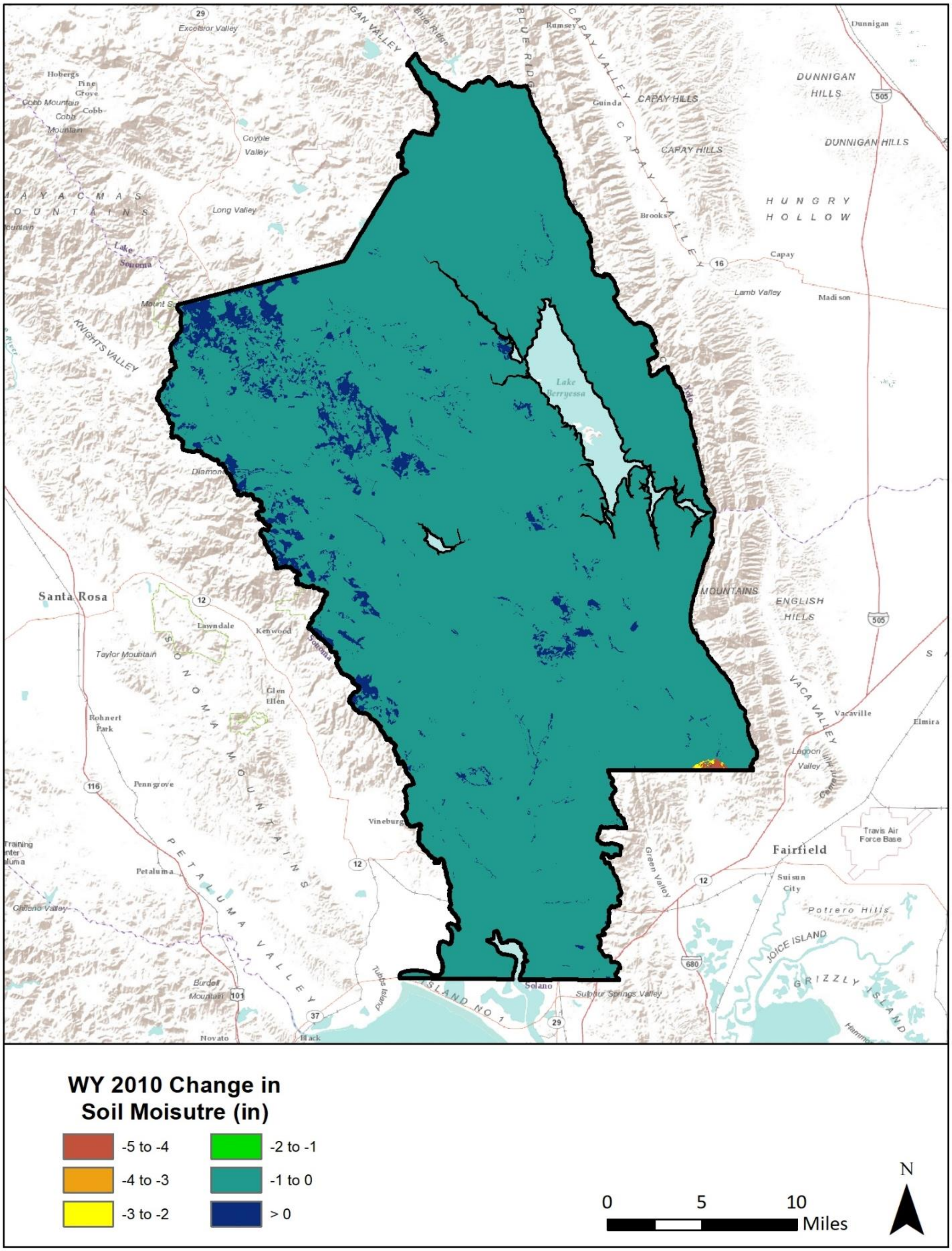


Figure 14: Water Year 2010 change in soil moisture content simulated with the Napa County SWB model.

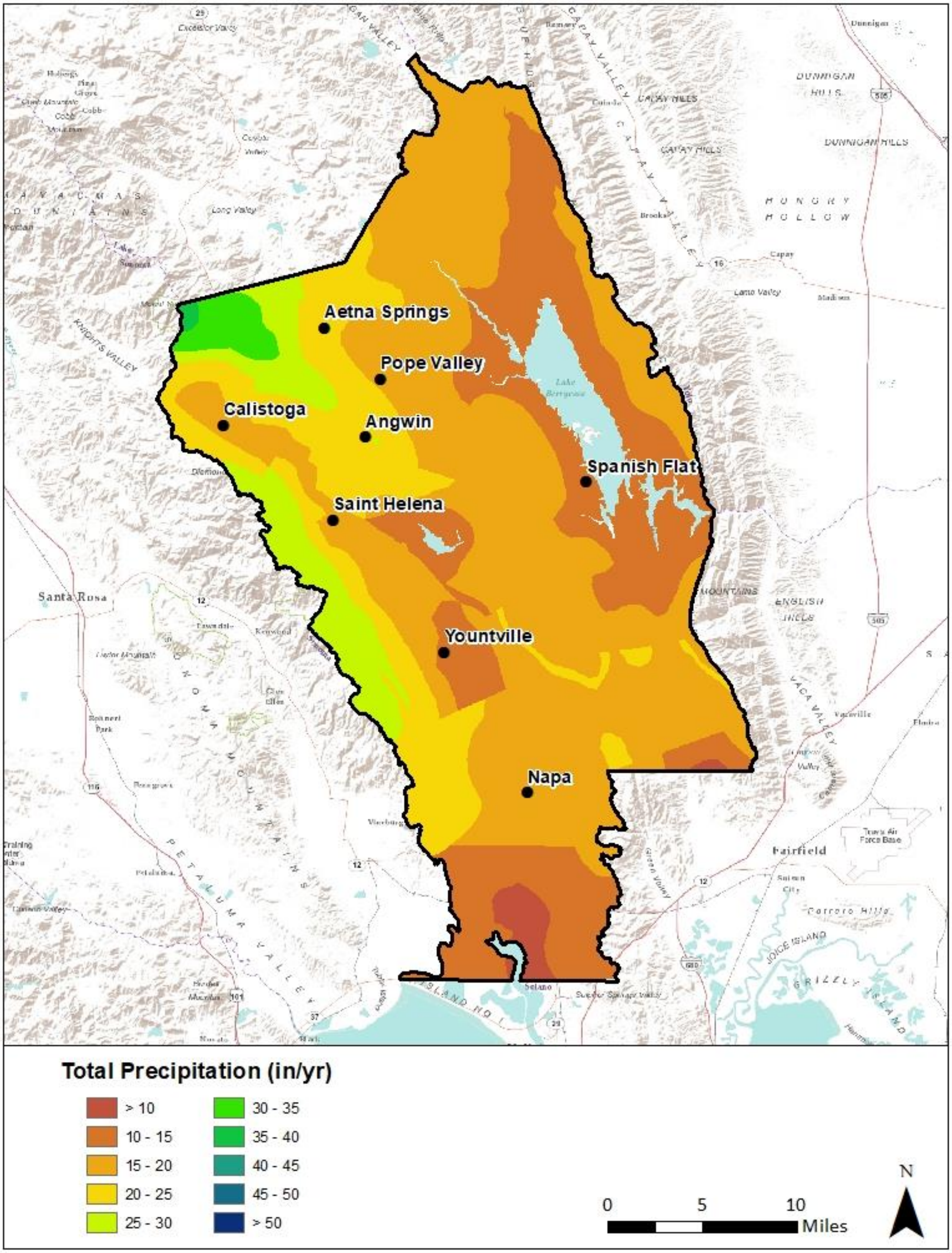


Figure 15: Water Year 2014 precipitation simulated with the Napa County SWB model.

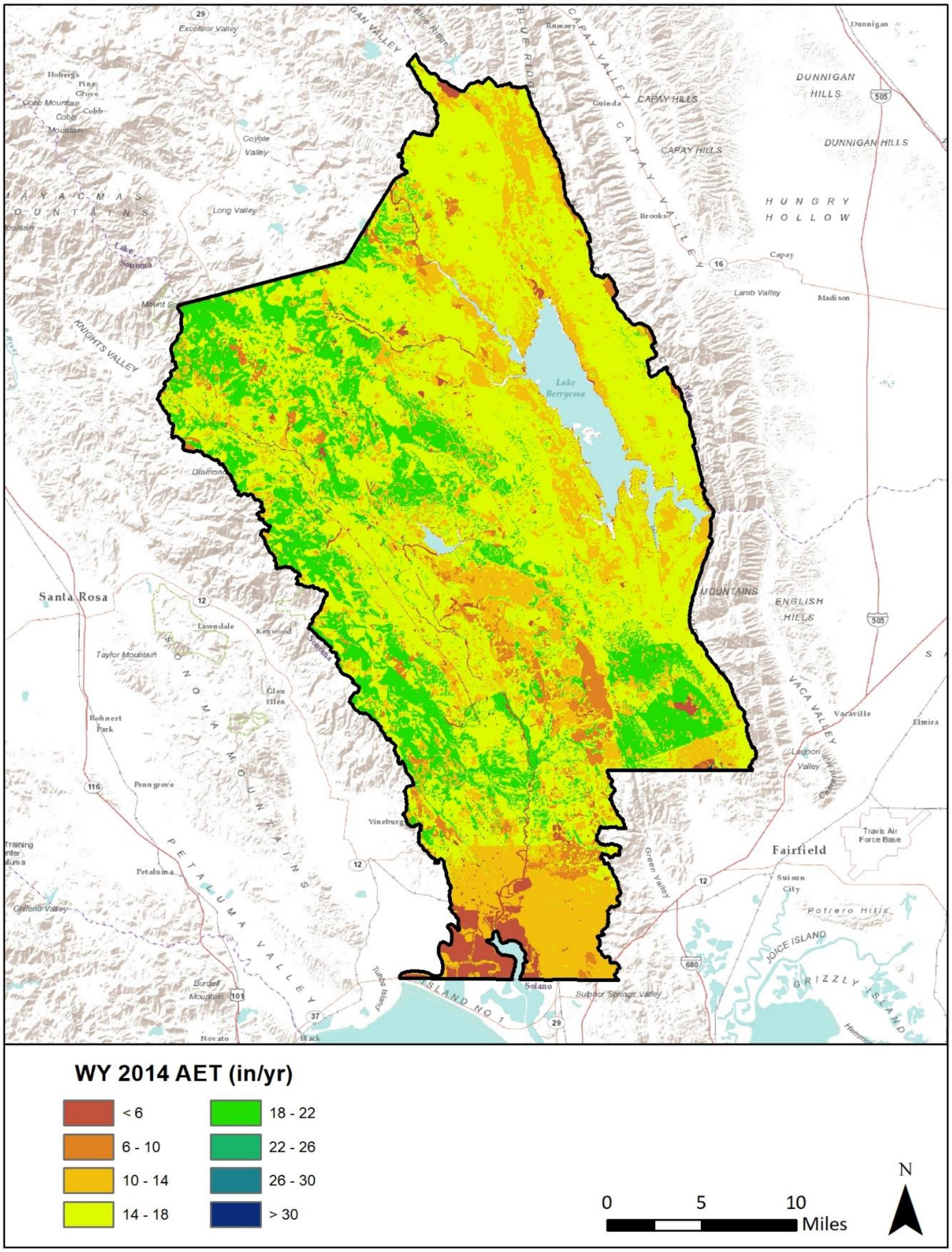


Figure 16: Water Year 2014 AET simulated with the Napa County SWB model.

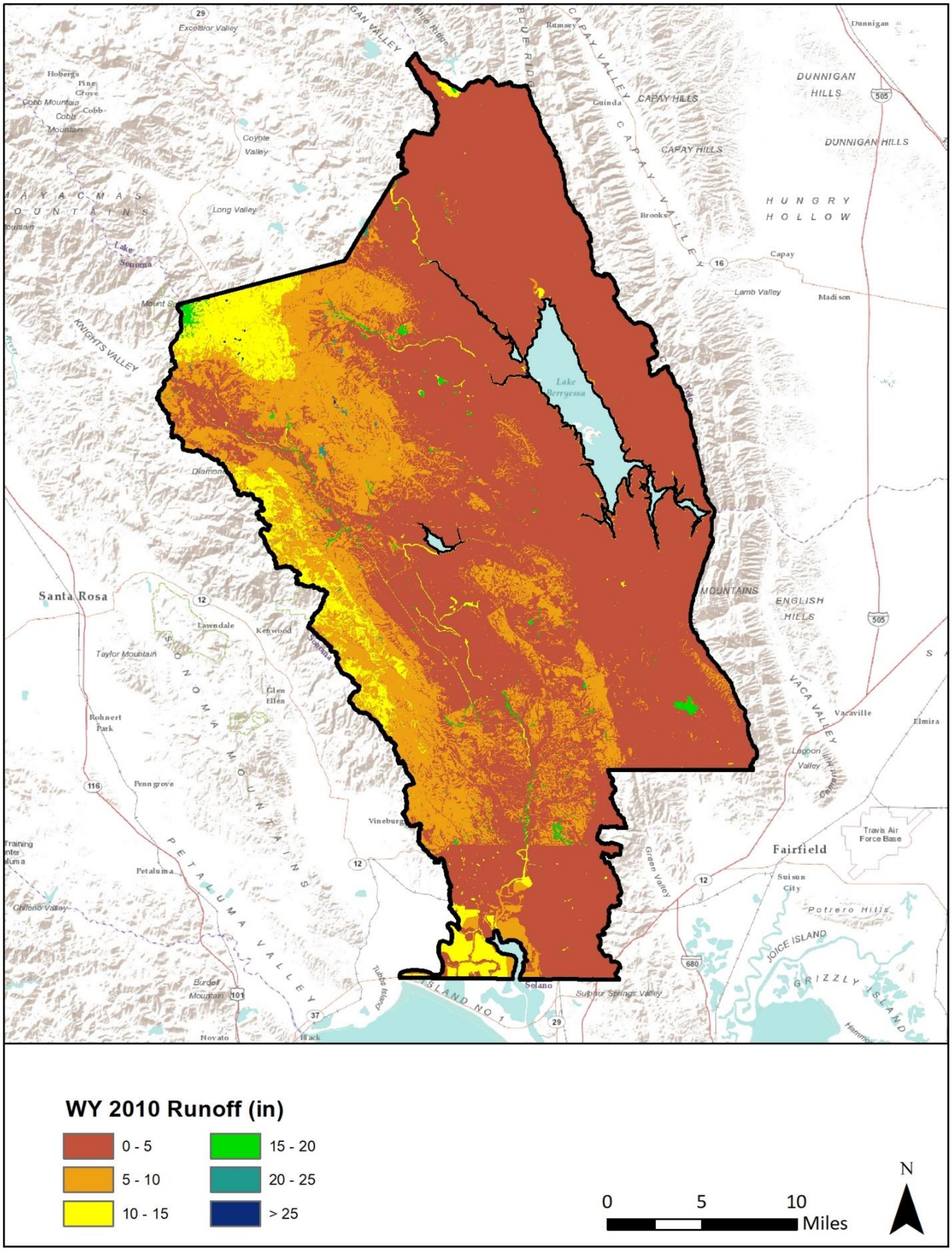


Figure 17: Water Year 2014 recharge simulated with the Napa County SWB model.

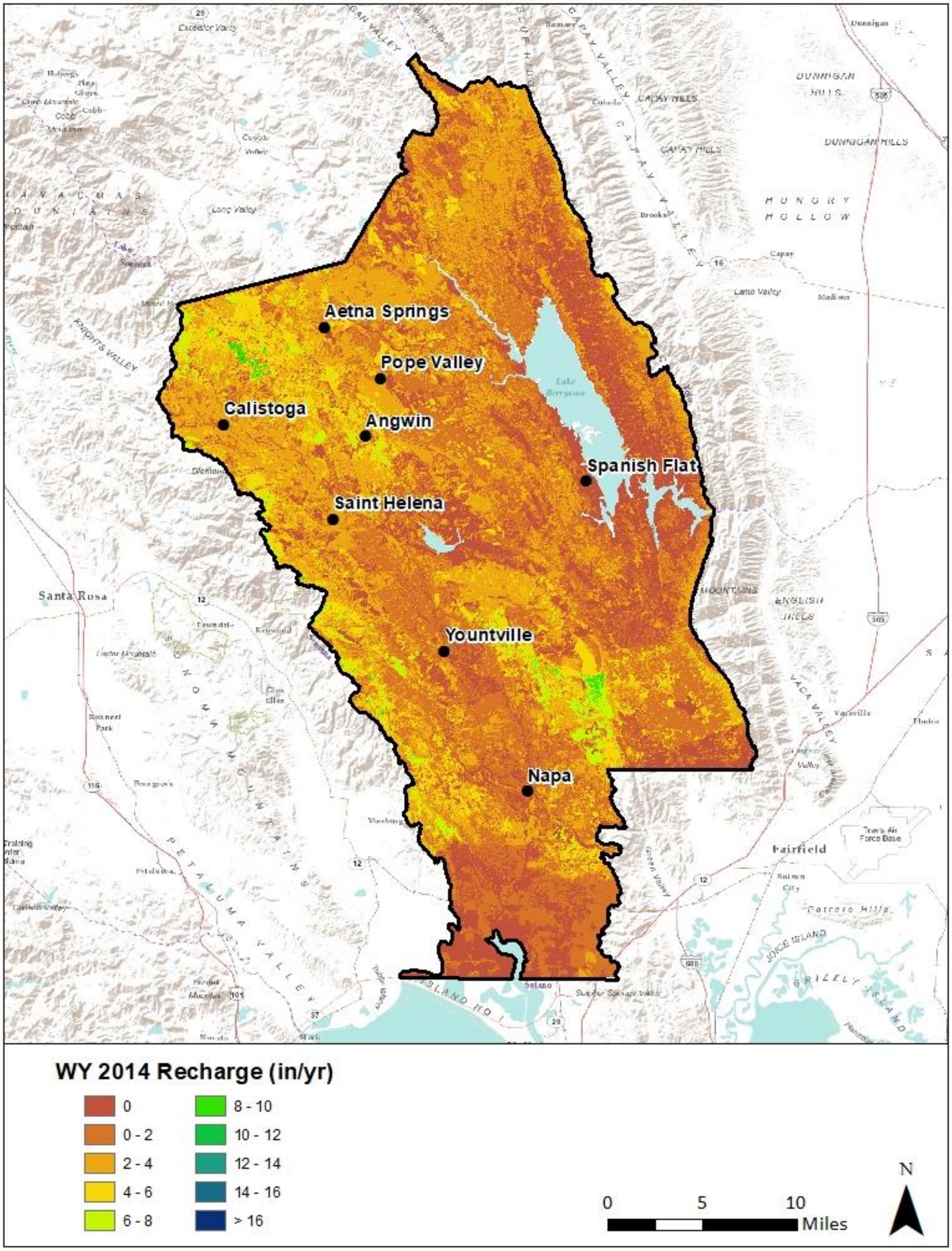


Figure 18: Water Year 2014 recharge simulated with the Napa County SWB model.

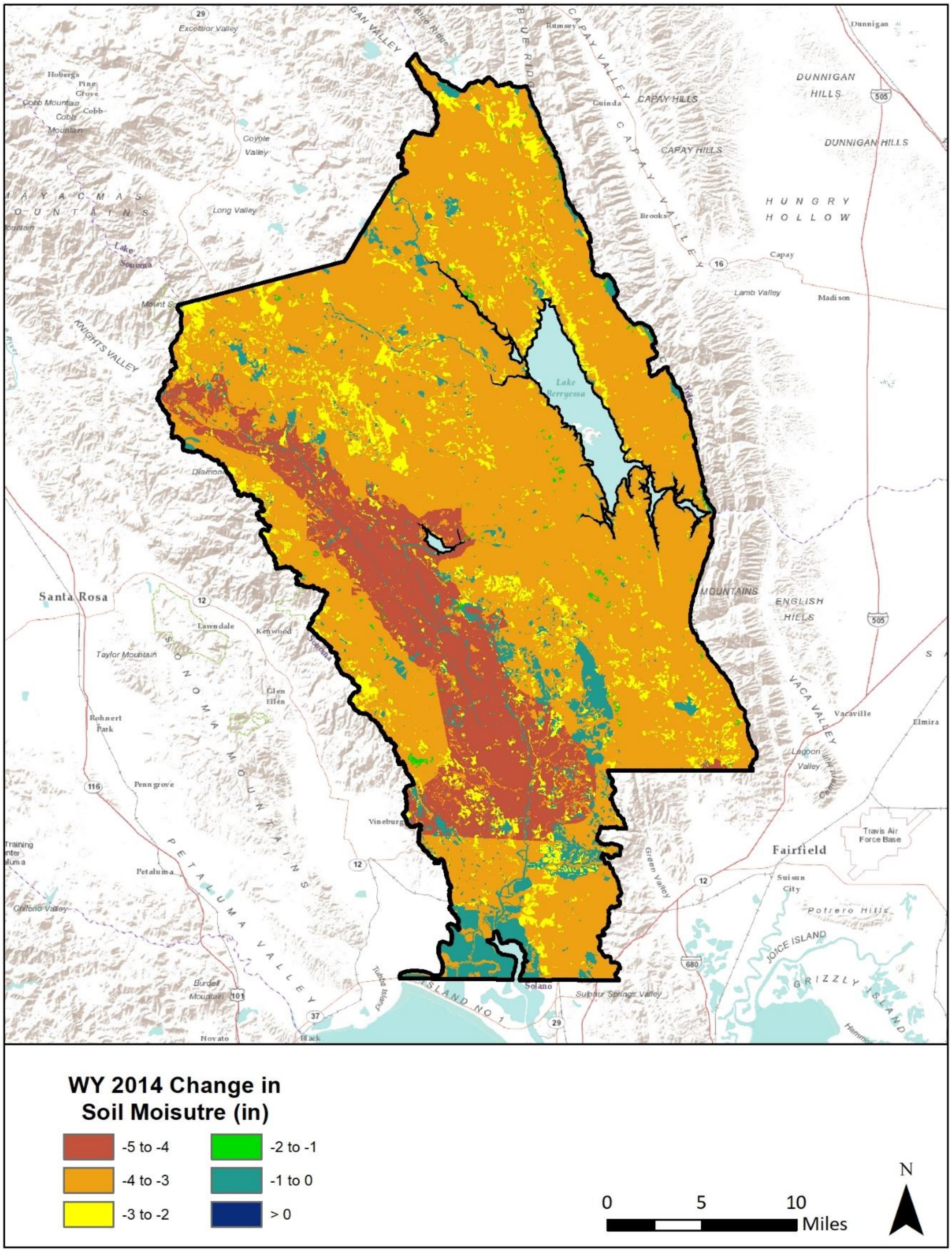


Figure 19: Water Year 2014 change in soil moisture content simulated with the Napa County SWB model.

Table 5: Simulated precipitation and recharge values averaged across HUC-12 watersheds in Napa County for Water Year 2010 expressed as depths. See Figure 20 for watershed locations.

Name	Drainage Area (mi^2)	Precipitation (in)	AET (in)	Surface Runoff (in)	Recharge (in)	Soil Moisture Change (in)
American Canyon Creek	10.8	24.1	16.3	3.7	4.7	-0.6
Bucksnort Creek	1.9	47.9	24.5	12.1	11.1	0.1
Butts Creek-Putah Creek	49.9	33.0	17.4	9.7	6.2	-0.7
Capell Creek	43.0	31.1	19.1	7.4	5.0	-0.6
Carneros Creek	29.7	28.0	18.6	5.2	5.5	-0.6
Chiles Creek	32.0	34.6	21.1	7.1	6.8	-0.5
Dry Creek	28.8	37.0	22.2	7.2	8.4	-0.5
Hunting Creek	12.0	33.7	19.0	9.7	5.7	-0.8
Jackson Creek-Putah Creek	54.5	29.9	13.4	12.6	3.0	-0.5
Lake Curry-Suisun Creek	16.4	30.7	18.9	6.5	5.9	-0.6
Lake Hennessey-Conn Creek	20.0	35.1	19.6	8.5	7.3	-0.4
Ledgewood Creek	6.4	21.8	16.9	3.4	3.3	-1.8
Lower Eticuera Creek	44.0	30.0	17.7	8.1	4.7	-0.7
Lower Napa River	45.0	31.7	19.9	5.6	6.7	-0.6
Lower Pope Creek	31.8	33.9	18.0	9.7	6.5	-0.6
Maxwell Creek	35.1	34.7	19.6	8.7	6.9	-0.6
Middle Napa River	60.3	39.9	22.8	8.5	9.2	-0.5
Milliken Creek	29.7	30.9	16.9	6.6	7.9	-0.6
Rector Creek-Conn Creek	22.3	32.8	18.0	7.1	8.2	-0.7
Saint Helena Creek	7.7	53.3	25.2	13.5	14.4	0.1
San Pablo Bay Estuaries	19.5	23.9	8.1	13.8	2.3	-0.3
Tulucay Creek	34.2	26.1	16.7	4.6	5.4	-0.7
Upper Eticuera Creek	25.6	31.2	17.2	8.6	6.1	-0.8
Upper Napa River	44.6	44.7	23.6	10.6	10.8	-0.4
Upper Pope Creek	21.7	44.5	22.7	10.5	11.5	-0.3
Wooden Valley & Suisun Creeks	23.3	29.0	19.0	5.1	5.5	-0.6
Wragg Canyon-Putah Creek	34.2	28.3	16.3	8.6	3.3	-0.6

Table 6: Simulated precipitation and recharge values averaged across HUC-12 watersheds in Napa County for Water Year 2010 expressed as a percentage of precipitation. See Figure 20 for watershed locations.

Name	Drainage Area (mi^2)	Precipitation (in)	AET (%)	Surface Runoff (%)	Recharge (%)	Soil Moisture Change (%)
American Canyon Creek	10.8	24.1	67%	15%	19%	-3%
Bucksnort Creek	1.9	47.9	51%	25%	23%	0%
Butts Creek-Putah Creek	49.9	33.0	53%	29%	19%	-2%
Capell Creek	43.0	31.2	61%	24%	16%	-2%
Carneros Creek	29.7	29.7	66%	19%	20%	-2%
Chiles Creek	32.0	34.6	61%	21%	20%	-1%
Dry Creek	28.8	37.8	60%	20%	23%	-1%
Hunting Creek	12.0	33.7	56%	29%	17%	-2%
Jackson Creek-Putah Creek	54.5	29.7	45%	42%	10%	-2%
Lake Curry-Suisun Creek	16.4	30.7	61%	21%	19%	-2%
Lake Hennessey-Conn Creek	20.0	36.0	56%	24%	21%	-1%
Ledgewood Creek	6.4	21.8	77%	15%	15%	-8%
Lower Eticuera Creek	44.0	30.0	59%	27%	16%	-2%
Lower Napa River	45.0	31.7	63%	18%	21%	-2%
Lower Pope Creek	31.8	33.9	53%	29%	19%	-2%
Maxwell Creek	35.1	34.7	56%	25%	20%	-2%
Middle Napa River	60.3	40.4	57%	21%	23%	-1%
Milliken Creek	29.7	30.9	55%	21%	26%	-2%
Rector Creek-Conn Creek	22.3	32.8	55%	22%	25%	-2%
Saint Helena Creek	7.7	53.3	47%	25%	27%	0%
San Pablo Bay Estuaries	19.5	23.9	34%	58%	10%	-1%
Tulucay Creek	34.2	26.1	64%	18%	21%	-3%
Upper Eticuera Creek	25.6	31.2	55%	28%	19%	-3%
Upper Napa River	44.6	44.7	53%	24%	24%	-1%
Upper Pope Creek	21.7	44.5	51%	23%	26%	-1%
Wooden Valley & Suisun Creeks	23.3	29.0	65%	18%	19%	-2%
Wragg Canyon-Putah Creek	34.2	28.3	58%	31%	12%	-2%

Table 7: Simulated precipitation and recharge values averaged across HUC-12 watersheds in Napa County for Water Year 2014 expressed as depths. See Figure 20 for watershed locations.

Name	Drainage Area (mi^2)	Precipitation (in)	AET (in)	Surface Runoff (in)	Recharge (in)	Soil Moisture Change (in)
American Canyon Creek	10.8	10.1	12.3	0.7	0.7	-3.6
Bucksnort Creek	1.9	28.8	17.6	11.5	2.6	-3.0
Butts Creek-Putah Creek	49.9	16.9	14.2	3.9	1.9	-3.2
Capell Creek	43.0	15.8	14.8	3.1	1.1	-3.1
Carneros Creek	29.7	15.0	14.7	4.6	2.0	-3.7
Chiles Creek	32.0	18.3	16.5	3.7	1.5	-3.3
Dry Creek	28.8	21.5	16.5	6.8	2.5	-3.7
Hunting Creek	12.0	16.7	15.4	3.1	1.6	-3.4
Jackson Creek-Putah Creek	54.5	14.9	10.3	6.1	0.7	-2.3
Lake Curry-Suisun Creek	16.4	18.4	16.1	3.7	1.9	-3.4
Lake Hennessey-Conn Creek	20.0	19.1	14.8	5.7	2.2	-3.2
Ledgewood Creek	6.4	12.2	13.9	1.7	0.8	-4.3
Lower Eticuera Creek	44.0	14.9	14.0	2.6	1.3	-3.1
Lower Napa River	45.0	19.4	15.9	5.0	2.2	-3.6
Lower Pope Creek	31.8	17.8	14.5	4.5	2.0	-3.2
Maxwell Creek	35.1	18.3	15.9	3.8	2.0	-3.3
Middle Napa River	60.3	21.3	16.5	6.6	2.5	-3.7
Milliken Creek	29.7	18.7	13.7	4.5	3.4	-2.9
Rector Creek-Conn Creek	22.3	16.5	13.6	4.0	2.3	-3.4
Saint Helena Creek	7.7	32.2	17.8	13.2	4.1	-3.0
San Pablo Bay Estuaries	19.5	10.4	6.0	5.6	0.5	-1.6
Tulucay Creek	34.2	14.6	13.5	2.6	1.7	-3.3
Upper Eticuera Creek	25.6	15.5	14.1	2.5	2.1	-3.2
Upper Napa River	44.6	22.9	16.2	6.9	3.3	-3.5
Upper Pope Creek	21.7	25.6	16.8	8.5	3.5	-3.2
Wooden Valley & Suisun Creeks	23.3	17.9	16.4	3.1	2.0	-3.5
Wragg Canyon-Putah Creek	34.2	14.1	12.6	3.6	0.6	-2.8

Table 8: Simulated precipitation and recharge values averaged across HUC-12 watersheds in Napa County for Water Year 2014 expressed as a percentage of precipitation. See Figure 20 for watershed locations.

Name	Drainage Area (mi^2)	Precipitation (in)	AET (%)	Surface Runoff (%)	Recharge (%)	Soil Moisture Change (%)
American Canyon Creek	10.8	10.1	121%	7%	7%	-36%
Bucksnort Creek	1.9	28.8	61%	40%	9%	-10%
Butts Creek-Putah Creek	49.9	16.8	84%	23%	11%	-19%
Capell Creek	43.0	15.8	94%	20%	7%	-20%
Carneros Creek	29.7	17.6	98%	30%	13%	-25%
Chiles Creek	32.0	18.4	90%	20%	8%	-18%
Dry Creek	28.8	22.1	77%	32%	12%	-17%
Hunting Creek	12.0	16.7	92%	18%	10%	-20%
Jackson Creek-Putah Creek	54.5	14.7	69%	41%	5%	-16%
Lake Curry-Suisun Creek	16.4	18.4	88%	20%	10%	-19%
Lake Hennessey-Conn Creek	20.0	19.6	78%	30%	12%	-17%
Ledgewood Creek	6.4	12.2	114%	14%	7%	-35%
Lower Eticuera Creek	44.0	14.9	94%	18%	9%	-21%
Lower Napa River	45.0	19.4	82%	26%	11%	-19%
Lower Pope Creek	31.8	17.8	81%	25%	11%	-18%
Maxwell Creek	35.1	18.3	87%	21%	11%	-18%
Middle Napa River	60.3	21.8	77%	31%	12%	-18%
Milliken Creek	29.7	18.7	74%	24%	18%	-16%
Rector Creek-Conn Creek	22.3	16.5	83%	24%	14%	-21%
Saint Helena Creek	7.7	32.2	55%	41%	13%	-9%
San Pablo Bay Estuaries	19.5	10.4	58%	53%	4%	-16%
Tulucay Creek	34.2	14.6	93%	18%	12%	-23%
Upper Eticuera Creek	25.6	15.5	91%	16%	14%	-21%
Upper Napa River	44.6	22.9	71%	30%	14%	-15%
Upper Pope Creek	21.7	25.6	66%	33%	14%	-12%
Wooden Valley & Suisun Creeks	23.3	17.9	91%	17%	11%	-20%
Wragg Canyon-Putah Creek	34.2	14.1	90%	26%	5%	-20%

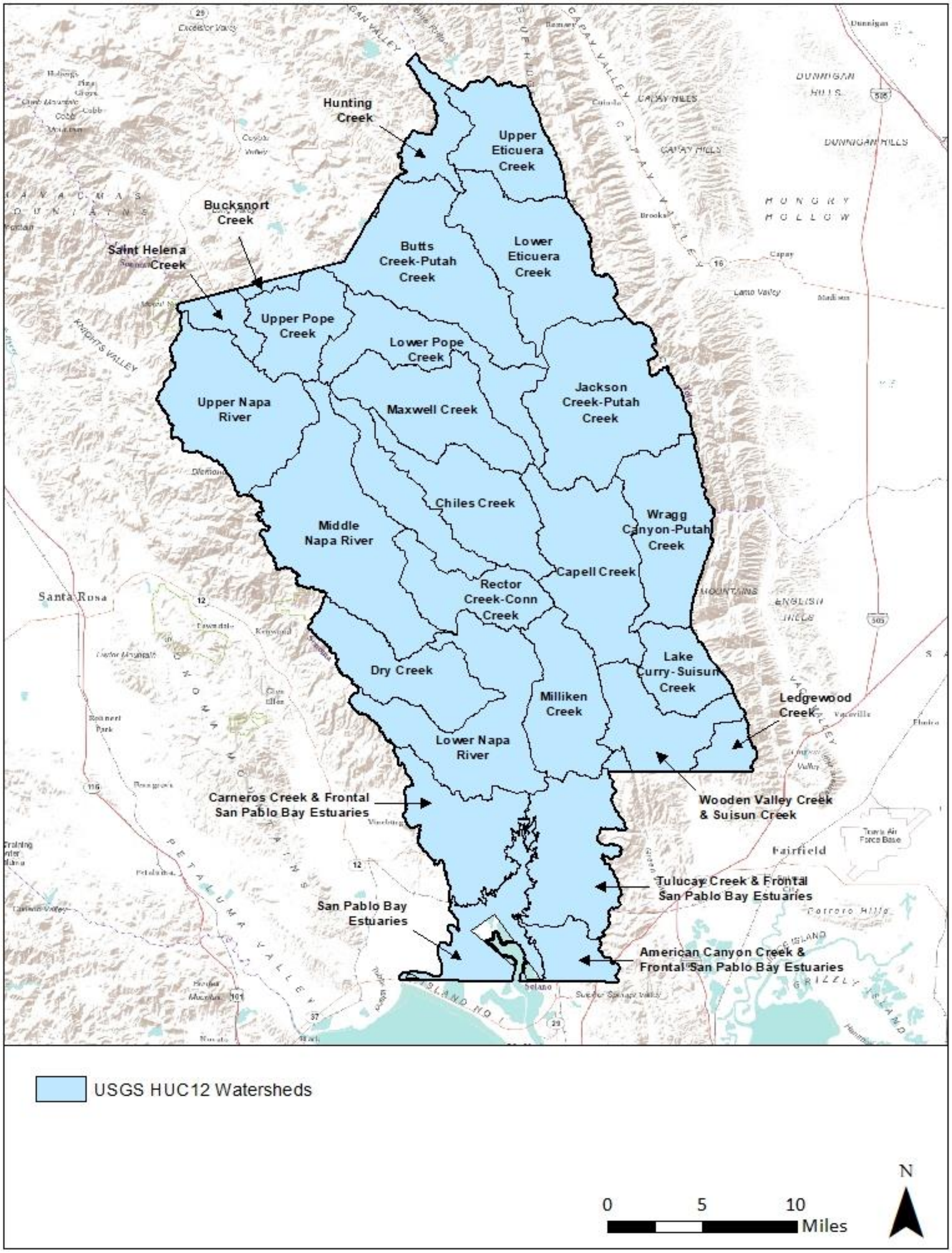


Figure 20: Major watersheds areas used to summarize water budget information in Tables 5 - 8.

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%.

Water budgets for the Napa River and selected sub-basins were also estimated in a previous study by Luhdorff and Scalmanini Engineers and MBK Engineers (LSCE 2013). The LSCE study estimated that, as a percentage of annual precipitation, AET comprised slightly less, runoff significantly more, and recharge substantially less of the typical annual water budget. LSCE (2013) calculated infiltration of precipitation based on the difference between total monthly streamflow at selected gaging stations and total monthly precipitation for the gages' drainage area. Streamflow volumes include both direct runoff (overland flow and interflow) and baseflow from groundwater. <u>Inclusion of baseflow with direct runoff in these calculations may inappropriately reduce the estimated volume of water infiltrated into the soil and available for recharge; the LSCE approach therefore tends to underestimate groundwater recharge</u>. Additionally, many of the gauging stations used for the analysis are located in reaches that may be significantly influenced by upstream reservoir releases, surface water diversions, groundwater abstraction, and/or surface water groundwater exchanges, further complicating the interpretation of the LSCE (2013) runoff rates and the interrelated calculations of AET and recharge rates. In contrast, the SWB model presented here is based on calibrated parameter values developed for a similar model in Sonoma County which was calibrated to gauges specifically selected to minimize the effects of reservoir releases, water use, or significant surface water/groundwater interaction, and after separating and removing the baseflow component of streamflow.

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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