Water Availability Analysis

Kenzo Estates, Inc.
c/o Mike Mulerath
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Mike Mulerath

Prepared by:

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November 4, 2019
REVISED October 5, 2021

Contents

Introduction

Kenzo Estates, Inc. is seeking permits to plant 11 acres of vineyard on three parcels along Wild Horse Road in southeastern Napa County (Napa County APNs 033-130-046, 033-190-014, and 033-190-015). This vineyard will be irrigated using groundwater from an existing well on APN 033-190-015, herein referred to as the project well, which is located within the County of Napa's Hillside groundwater zone (Figure 1). This parcel also contains two existing residences supplied by a second well, herein referred to as the residential well. This well, which is also located on APN 033-190-015, is only used to supply water to these residences and will not be used to supply water to the proposed vineyard.

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. Existing and proposed future water use on and near the project site is estimated based on information received from the applicant and on regionally-appropriate water duties for the observed and expected uses. The recharge estimates presented below are based on established soil water balance modeling techniques for calculating infiltration recharge and they do not account for the role of surface water/groundwater interaction or bedrock geology in controlling recharge and groundwater availability.

The depth to groundwater in the project well is at least 470 feet. Given this significant depth, the relationship between groundwater recharge generated within the project parcel and groundwater availability at the project well is not expected to be tightly coupled. The origin of groundwater obtained from project wells is uncertain, and may be as likely supplied by groundwater inflows from a broad surrounding area as from recharge from rainfall directly on the landscape overlying the project site. Analysis of the age and sources of the deep groundwater occurring beneath the project parcel is beyond the scope of this study.

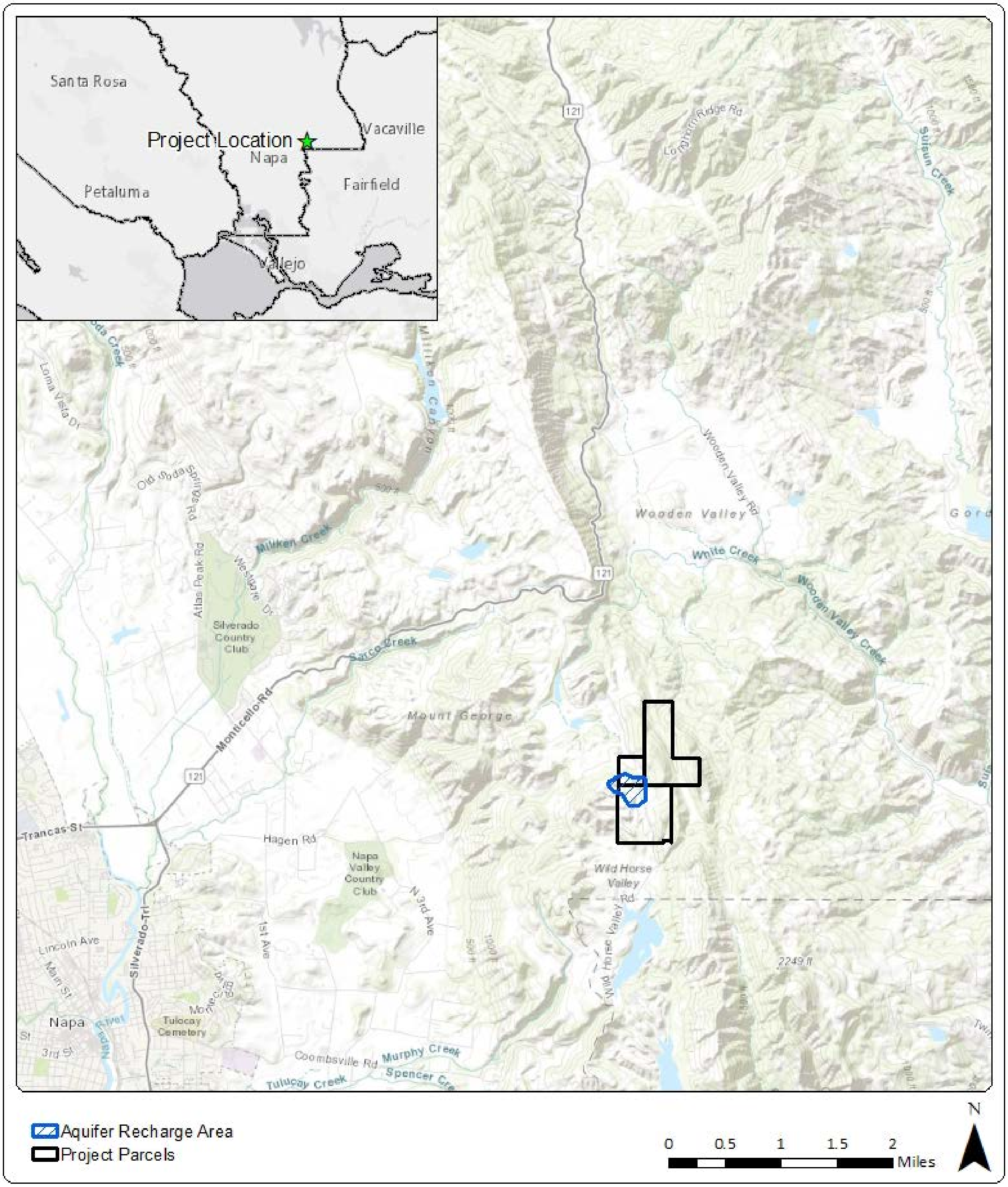


Figure 1: Project location map.

Hydrogeologic Conditions

The three project parcels are located in the mountains east of the Napa Valley, approximately one mile north of Lake Madigan (Figure 1). This area is underlain by Miocene and Pliocene-aged rocks of the Sonoma Volcanics and is intersected by several traces of the north to south trending Green Valley Fault (Figure 2). The western half of these parcels are underlain by the Pliocene-aged Dacite of Mount George (map unit Psvdg), which has been described as flows, domes, and shallow intrusion of gray to tan porphyritic dacite (Wagner and Gutierrez, 2017). The central portion of the project parcels is underlain by Miocene to Pliocene-aged Mafic Flows and Breccia which include andesitic to basalt flow rocks as well as andesitic tuff (map unit Tsvm). The far eastern portion of these parcels is underlain by Pliocene-aged rhyolite ash flow tuff and flows (map unit Psvrt). Numerous fault traces from the Green Valley Fault serve as contacts between these units. Some of these traces are mapped as Alquist-Priolo Fault Hazard Zones; seismic hazards are outside the scope of this analysis. However, it appears that the existing residences are not within these zones.

Bedrock units of the Sonoma Volcanics typically have low yields, averaging 16 to 50 gallons per minute (gpm), likely due to the high degree of consolidation and fine-grained nature of these units. However, yields within lava flow rocks and breccias are highly variable, and yields of over 100 gpm have been reported (LSCE, 2013). Primary porosity is often low and groundwater tends to occur in fractures. However, where these fractures are extensive, aquifers may be highly transmissive, supporting greater yields (Nishikawa, 2013).

Well Data

Well Completion Reports for wells near the project parcel were obtained from the California Department of Water Resources' Well Completion Report Map Application. The subset of these logs which could be accurately georeferenced based on parcel, location sketch, or State Well Number is discussed below and reports for these wells have been compiled in Appendix A. Well Completion Reports for the two wells on the project parcels could not be located through the Department of Water Resources, but the applicant was able to provide a Well Completion Report for one of these wells.

The project well is in the northwestern corner of APN 033-190-015 and will be used to irrigate the proposed vineyards. It was completed in 1999 to a depth of 700 feet. At the time of completion, the static water level was 470 feet, and based on a 12-hour pump test, the well was estimated to have a yield of 250 gpm (Table 1). It is screened at depths of 540 to 680 feet, intersecting a stratum of red cinders between 620 and 660 feet in depth that is believed to yield significant quantities of water. The rock types listed on the Geologic Log are broadly consistent with the Dacite of Mount George but suggest that the well may also be screened within other volcanics, such as lava flow rocks. The second well on the project parcels, the residential well, is located along the eastern edge of APN 033-190-015, and is only used to supply the two existing residences on this parcel. It was completed to a depth of 510 feet in 1974. At the time of completion, it had a static water level of 190 feet and an estimated yield of 30 gpm. The static water level was approximately 40 feet above the first depth water was encountered at, indicating that a pressure head may exist. The difference in depth to groundwater between the project well and residential well suggests that the fault lying between these wells may be a barriers to groundwater flow. The Geologic Log indicates alternating layers of volcanic tuff and basaltic flow rocks, more consistent with map unit Tsvm than map unit Psvdg.

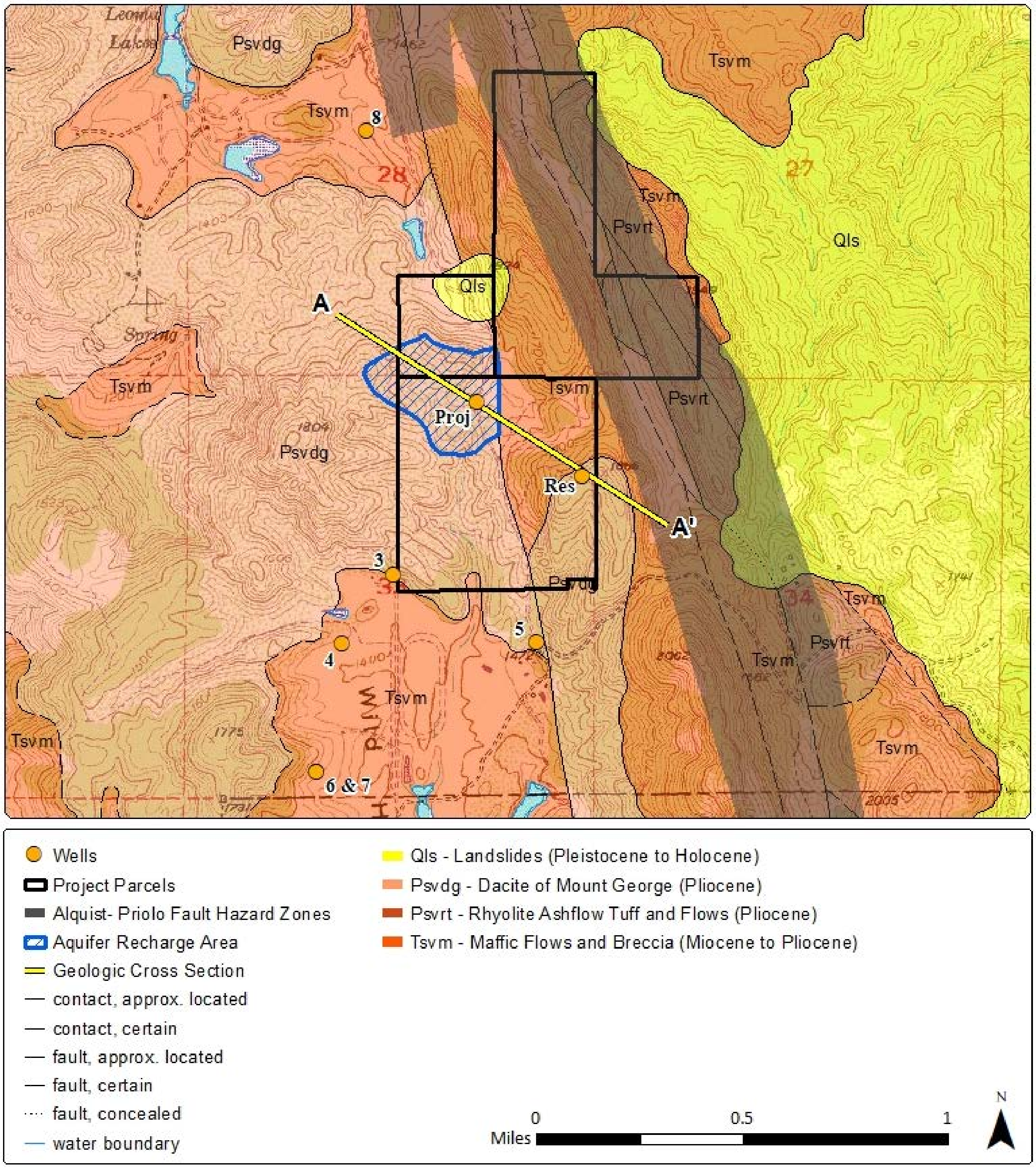


Figure 2: Surficial geology and locations of wells in the vicinity of the project parcel. Surficial geology based on data from the Preliminary Geologic Map of the Napa and Bodega Bay 30' x 60' Quadrangle (Wagner and Gutierrez, 2010).

Well Completion Reports could be accurately georeferenced for six other nearby wells. These wells are completed to depth of between 255 and 640 feet and have estimated yields of between 20 and 180 gpm (Table 1). These well are completed in a variety of bedrock units of the Sonoma Volcanics, but Well Completion Reports do not indicate significant differences in yield between these units. The groundwater table is relatively deep with many wells reporting depths to water in excess of 200 feet. When mapped the elevations of static water levels in these wells are heterogeneous and do not show a regionally consistent water table elevation, even among the three wells competed in map unit Psvdg. At the time of completion, all wells had pressure heads of between 25 and 80 feet, indicating confined or partially confined aquifer conditions.

Table 1: Well completion details for wells in the vicinity of the project parcel.

Well ID	Proj.	Res.	3	4	5	6	7	8
Year Completed	1999	1974	1985	1964	1974	1995	2009	2006
Estimated Yield (gpm)	250	30	75	25	30	60	20	180
Depth (ft)	700	510	255	300	510	400	355	640
Static Water Level (ft)	470	190	85	200	190	210	150	394
Top of Screen (ft)	540	Unk.	175	Unk.	Unk.	200	315	395
Bottom of Screen (ft)	680	Unk.	255	Unk.	Unk.	400	355	615
Geologic Map Unit	Psvdg	Tsvm	Psvdg	Tsvm	Psvdg	Tsvm	Tsvm	Tsvm

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 1,600 feet near the unnamed creek to almost 1,800 feet on the adjacent ridgelines. Static water levels are significantly different on either side of the fault contact. This may be due to heterogeneity of the volcanic units or the fault itself, which may function as a barrier to groundwater flow.

Project Recharge Area

The project aquifer, which may also describe the most likely surface area of the project recharge area, has been conceptualized for the project well as described below. To the north and west this aquifer is defined by ridgelines which may function as divides between groundwater flow gradients. To the east it is defined by a trace of the Green Valley Fault which has been conceptualized as a barrier to groundwater flow based on the extreme difference between depth to groundwater between the project and residential wells. To the south, the project aquifer is bounded by a west to east dogleg in an unnamed creek.

The project recharge area is 40 acres, all of which is underlain (based on rocks mapped at the surface), by the Dacite of Mount George. At greater depths, other volcanic units may be present. Given the typically low permeability of these units and the pressure heads reported at numerous nearby wells, this aquifer is likely confined or semi-confined.

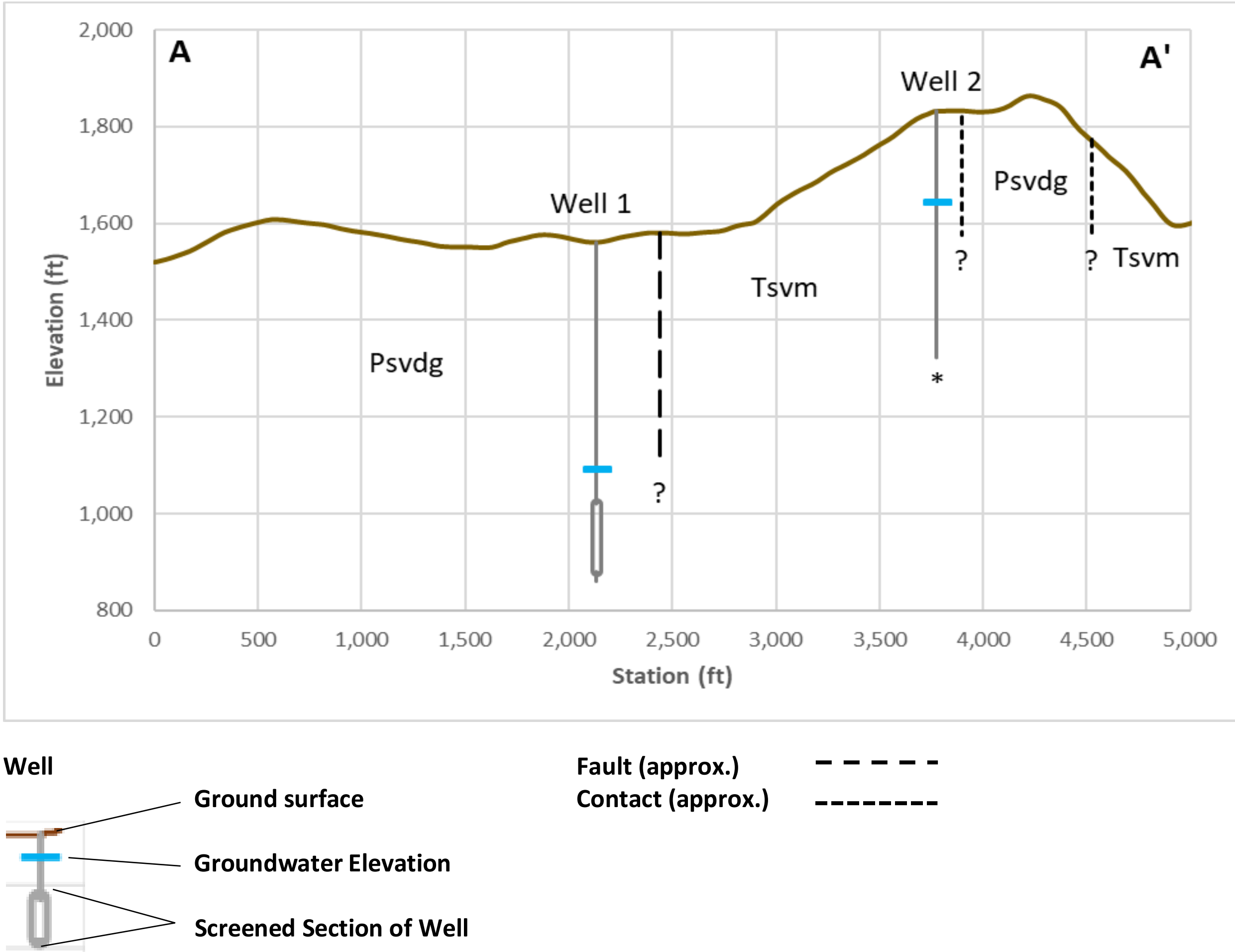


Figure 3: Hydrogeologic cross section A -A' through the project parcel (see Figure 2 for location and geologic map units). Note that the faults are shown as vertical however the actual orientation of the faults is unknown.

Water Demand

Existing and proposed water demands were calculated for the three project parcels and for the project recharge area, which encompasses a small portion of the three project parcels as well as an undeveloped portion of an adjacent parcel. Uses were based on site details provided by the project applicant and verified using satellite imagery. Use rates were estimated using the County of Napa's Water Availability Analysis Guidance Document dated May 12, 2015.

Existing Use

In the existing condition, there is no water use from the project well or within the project recharge area. Water is used by two primary residences on one of the project parcels (APN 033-190-015), but they are located outside of the project recharge. These residences receive water from the residential well, which is also located outside of the project recharge area. One of these residences has an uncovered pool and the other has approximately 9,000 ft^2 of drought tolerant landscaping. Combined, they are estimated to use approximately 1.64 acre-ft/yr (Table 2).

Table 2: Existing water use on the project parcels. Note that all water use is both withdrawn and used outside of the project recharge area.

	# of Units	Use per Unit	Annual Water Use (AF/yr)
Residential Use			**1.64**
Residences, Primary	2 Residences	0.75 AF/Residence	1.50
Pools	1 Pool	0.10 AF/Pool	0.10
Other Landscaping, Addtl.	8000 sq. ft.	0.05 AF/10,000 sq. ft.	0.04
Total			**1.64**

Proposed Use

In the proposed condition, two blocks of vineyard totaling 11 acres will be planted on the three project parcels. Using a conservative irrigation rate of 0.5 acre-ft/acre/yr from the Napa WAA Guidance Document, these vineyards will require 5.50 acre-ft/yr. They will use water from the project well and are the only proposed use within the project recharge area (Table 3). These vineyards increase in proposed water use on the three project parcels to 7.14 acre-ft/yr (Table 4).

Table 3: Proposed water use in the project recharge area.

	# of Units	Use per Unit	Annual Water Use (AF/yr)
Agricultural Use			**5.50**
Vineyard	11 Acres	0.50 AF/acre/yr	5.50
Total			**5.50**

Table 4: Proposed water use on the three project parcels including use from the project recharge area.

	# of Units	Use per Unit	Annual Water Use (AF/yr)
Residential Use			**1.64**
Residences, Primary	2 Residences	0.75 AF/Residence	1.50
Pools	1 Pool	0.10 AF/Pool	0.10
Other Landscaping, Addtl.	8000 sq. ft.	0.05 AF/10,000 sq. ft.	0.04
Agricultural Use			**5.50**
Vineyard	11 Acres	0.50 AF/acre/yr	5.50
Total			**7.14**

Groundwater Recharge Analysis

Groundwater recharge within the project recharge area and on the three project parcels 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 conditions because annual precipitation totals were between 41 and 73% of long-term 30-year averages for much of Napa County.

During Water Year 2010, precipitation averaged 33.7 inches across the project recharge area and actual evapotranspiration (AET) averaged 15.4 inches. Simulated groundwater recharge varied from 7.0 to 12.6 inches across the recharge area, with a spatial average of 9.4 inches. During Water Year 2014, precipitation averaged 20.8 inches across the project recharge area and actual evapotranspiration averaged 13.0 inches. Groundwater recharge varied from about to 2.4 to 9.0 inches across the recharge area with a spatial average of 5.3 inches (Table 5). The water budget for the three project parcels indicates higher rates of evapotranspiration and lower rates of recharge, particularly during Water Year 2014 when modeled recharge was 2.9 inches (Table 6).

Groundwater recharge estimates can also be expressed as a volume by multiplying the estimated recharge rate by a representative area. For the 40-acre project recharge area, these calculations yield an estimated total recharge of 17.7 acre-ft/yr during the drought conditions of water year 2014 and of 31.3 acre-ft/yr for the average water year of 2010 (Table 7). For the three project parcels, which have a combined area of 359 acres, these calculations yield an estimated total recharge of 212.4 acre-ft/yr of recharge for Water Year 2010 and 86.8 acre-ft/yr in Water Year 2014. Under average water year conditions (e.g. 2010), estimated recharge to the project recharge area is about 0.8 ac-ft/ac; estimated recharge for the project parcels is about 0.6 ac-ft/ac.

Water budget estimates have been prepared for several nearby watersheds including Tulocay Creek and Milliken Creek. Respectively, average annual recharge for these two watersheds is estimated to be 5% and 8% 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.

Table 5: Summary of water balance results for the project recharge area estimated by the SWB model.

	2010 Normal Year		2014 Dry Year	
	inches	% of precip	inches	% of precip
Precipitation	33.7	-	20.8	-
AET	15.4	46%	13.0	63%
Runoff	9.6	28%	5.9	28%
Δ Soil Moisture	-0.7	-2%	-3.4	-16%
Recharge	9.4	28%	5.3	25%

Table 6: Summary of water balance results for the three project parcels estimated by the SWB model.

	2010 Normal Year		2014 Dry Year	
	inches	% of precip	inches	% of precip
Precipitation	33.0	-	20.3	-
AET	19.3	58%	17.0	84%
Runoff	7.1	22%	4.1	20%
Δ Soil Moisture	-0.5	-2%	-3.7	-18%
Recharge	7.1	22%	2.9	14%

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). Simulated recharge for water year 2010 is equivalent to 25% of precipitation for the project recharge area and 22% of precipitation for the three project parcels, within the range of these regional estimates. It should be noted that the project recharge area covers a relatively small area and specific combinations of land cover and soil properties may cause recharge rates to be higher than average for the region. The three project parcels cover a larger area with a broader distribution of land use and soil types, providing a better comparison to regional studies.

Comparison of Water Demand and Groundwater Recharge

The total proposed groundwater use for the project recharge area is estimated to be 5.5 acre-ft/yr and 7.1 acre-ft/yr on the three project parcels. Groundwater use in the project recharge area is equivalent to 18% of the estimated average water year groundwater recharge of 31.3 acre-ft/yr and 31% of the estimated dry water year recharge of 17.7 acre-ft/yr (Table 7). Water use on the three project parcels is equivalent to 3% of the estimated recharge occurring on the project parcel during average water years and 8% of the estimated recharge during dry water years such as 2014. Given the magnitude of these surpluses, water use associated with the proposed vineyard expansion is highly unlikely to result in reductions in groundwater levels or depletion of groundwater resources over time. It should also be noted that the 159-acre area comprised of three parcels which contains both wells (APN 033-190-015) receives sufficient recharge to meet the proposed demand. Recharge from all three project parcels has been included to provide a full accounting of available recharge, not because transfers from these parcels are necessary.

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	5.5	31.3	25.8	18%	17.7	12.2	31%
Project Parcel	7.1	212.4	205.3	3%	86.8	79.6	8%

Well Interference Analysis

There are no neighboring wells within 500 feet of the either of the wells on the three project parcels. The project well is located more than 1,000 feet from any parcels not owned by Kenzo Estates, Inc. The residential well is located along the edge of the properties owned by Kenzo Estates, Inc. but no wells have been identified on nearby portions of the neighboring parcel (APN 033-190-017). Portions of this parcel located within 500 feet of Well 2 appear to be wholly undeveloped and are unlikely to contain a well. 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 three project parcels revealed that average water year the was approximately 7.1 inches/yr or 212.4 acre-ft/yr. During drought conditions, recharge was significantly lower at 2.9 inches/yr or 86.8 acre-ft/yr. The total proposed groundwater use on the three project parcels is estimated to be 7.1 acre-ft/yr. This represents 3% 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 either of the wells on the project parcels, indicating that a Tier 2 well interference analysis is not required.

References

Farrrar, C.D., Metzger, L.F., Nishikawa, T., Koczot, K.M., and Reichard, E.G., 2006. Geohydrological Characterization, Water-Chemistry, and Ground-water Flow Simulation Model of the Sonoma Valley Area, Sonoma County, California, U.S. Geological Survey Scientific Investigations Report 2006-5092.

Flint, L. E., A. L. Flint, J. H. Thorne, and R. Boynton. 2013. Fine-scale hydrologic modeling for regional landscape applications: the California Basin Characterization Model development and performance. Ecological Processes 2:25 http://dx.doi.org/10.1186/2192-1709-2-25

Kobor, J.S., and O'Connor, M., 2016. Integrated Surface and Groundwater Modeling and Flow Availability Analysis for Restoration Prioritization Planning: Green Valley/Atascadero and Dutch Bill Creek Watersheds, prepared by O'Connor Environmental, Inc. for the Gold Ridge Resource Conservation District, 175 pgs.

Luhdorff and Scalmanini Consulting Engineers (LSCE) and MBK Engineers, 2013. Updated hydrogeologic conceptualization and characterization of conditions. Prepared for Napa County.

Nishikawa, T. et al., 2013. Hydrologic and Geochemical Characterization of the Santa Rosa Plain Watershed, Sonoma County, California. Scientific Investigations Report 2013 – 5118 U.S. Department of the Interior U.S. Geological Survey.

Wagner, D.L., and Gutierrez, C.I., 2010. Preliminary Geologic Map of the Napa and Bodega Bay 30' x 60' Quadrangles, California. California Geologic Survey.

Westenbroek, S.M., Kelson, V.A., Dripps, W.R., Hunt R.J., and Bradbury, K.R., 2010. SWB - A Modified Thornthwaite-Mather Soil-Water-Balance Code for Estimating Groundwater Recharge, U.S. Geological Survey Techniques and Methods 6-A31, 60 pgs.

Woolfenden, L.R., and Hevesi, J.A., 2014. Santa Rosa Plain Hydrologic Model Results, Chapter E in Simulation of Groundwater and Surface-Water Resources of the Santa Rosa Plain Watershed, Sonoma County, California, U.S. Geological Survey Scientific Investigations Report 2014-5052.

APPENDIX A

WELL COMPLETION REPORTS

Well 1

Page 1 of 1 (#4)

Owner's Well No. ______ 572307

Date Work Began 12-?-98 Ended 1-15-99

Local Permit Agency NAPA COUNTY

Permit No. ______ Permit Date ______

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

STATE WELL NO./STATION NO. | LATITUDE | LONGITUDE | APN/TRS/OTHER

GEOLOGIC LOG

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

DEPTH TO FIRST WATER ______ (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION (Describe material, grain size, color, etc.)
0 – 20	HARD BASALT FRACTURED WITH CLAY
20 – 40	FRACTURED HARD BASALT
40 – 70	HARD BLACK ROCK
70 – 100	FRACTURED BLACK ROCKS WITH SAND AND SHALE
100 – 140	MED HARD BLACK SHALE
140 – 200	MED HARD BLACK ROCK WITH FINE SANDS
200 – 300	HARD BLACK ROCK WITH FINE GREEN SAND
300 – 400	VERY HARD BLACK VOLCANICS YIELDING 10 GPM
400 – 460	MED HARD BLACK VOLCANICS FRACTURED WITH FINE GRAIN SANDS
460 – 520	SOFT TO MED HARD BLACK VOLCANICS WITH FINE GRAIN SANDS
520 – 540	HARD BLACK VOLCANICS
540 – 600	MED HARD BLACK VOLCANICS
600 – 620	MED HARD GREEN VOLCANICS WITH QUARTZ FRACTURES
620 – 660	RED CINDERS YIELDING 300 GPM
660 – 700	VERY HARD GREEN BLACK VOLCANICS WITH FINE SANDS

TOTAL DEPTH OF BORING 700 (Feet)

TOTAL DEPTH OF COMPLETED WELL 700 (Feet)

WELL OWNER

Name WAYNE OKUBO

Mailing Address 4?75 OAKMEAD PARKWAY SUNNYVALE CA 94086

WELL LOCATION

Address 6700 WILD HORSE VALLEY RD.

City NAPA

County NAPA

APN Book ____ Page ____ Parcel 033-190-001

Township ____ Range ____ Section ____

Latitude ____ NORTH Longitude ____ WEST

LOCATION SKETCH

NORTH / SOUTH / WEST / EAST

SEE Attached map.

X-Country Well

Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

___ NEW WELL

MODIFICATION/REPAIR ___ Deepen ___ Other (Specify)

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

PLANNED USE(S) (✓)

___ MONITORING

WATER SUPPLY ___ Domestic ✓ Public ___ Irrigation ___ Industrial

___ TEST WELL

___ CATHODIC PROTECTION

___ OTHER (Specify)

DRILLING METHOD AIR ROTARY FLUID NONE

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 470 (Ft.) & DATE MEASURED 1-15-98

ESTIMATED YIELD* 250 (GPM) & TEST TYPE PUMP

TEST LENGTH 12 (Hrs.) TOTAL DRAWDOWN 90 (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 – 540	10	X				MS	5	5/16	
540 – 680	10		X			MS	5	5/16	050
680 – 700	10	X				MS	5	5/16	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.	CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0 – 100	✓	✓		
100 – 700			✓	MED AQUARIUM

ATTACHMENTS (✓)

X Geologic Log

___ Well Construction Diagram

___ Geophysical Log(s)

___ Soil/Water Chemical Analyses

X Other MAP

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 WATER DEVELOPMENT CORPORATION (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS 1002 E. KENTUCKY AVE. CITY WOODLAND STATE CA ZIP 95776

Signed [signature] WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED 2-11-99 C-57 LICENSE NUMBER 283326

DWR 188 REV. 7-90 IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

TOTAL P.04

Well 2 1974 Well

WILD HORSE VALLEY RANCH #1

TRIPLICATE
Retain this copy

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do Not Fill In
Nº 94415
State Well No.
Other Well No.

(1) OWNER:
Name Wild Horse Valley Ranch
Address Wild Horse Valley Rd.
Napa, California

(2) LOCATION OF WELL:
County Napa Owner's number, if any Wild Horse Valley Ranch
Township, Range, and Section
Distance from cities, roads, railroads, etc. P. #33-19-01

(3) TYPE OF WORK (check):
New Well [X] Deepening [ ] Reconditioning [ ] Destroying [ ]
If destruction, describe material and procedure in item 11.

(4) PROPOSED USE (check):
Domestic [X] Industrial [ ] Municipal [ ]
Irrigation [X] Test Well [ ] Other [ ]

(5) EQUIPMENT:
Rotary [ ]
Cable [ ]
Other [ ]

(6) CASING INSTALLED:
STEEL: SINGLE [X] DOUBLE [ ] OTHER:

From ft.	To ft.	Diam.	Gage or Wall
0	30	8 5/8"	.156

If gravel packed

Diameter of Bore	From ft.	To ft.

Size of shoe or well ring: None Size of gravel:
Describe joint Butt Weld

(7) PERFORATIONS OR SCREEN:
Type of perforation or name of screen None

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.

(8) CONSTRUCTION:
Was a surface sanitary seal provided? Yes [X] No [ ] To what depth 20' ft.
Were any strata sealed against pollution? Yes [ ] No [X] If yes, note depth of strata
From ft. to ft.
From ft. to ft.
Method of sealing Neat Cement

(9) WATER LEVELS:
Depth at which water was first found, if known 233' ft.
Standing level before perforating, if known 190' ft.
Standing level after perforating and developing 190' ft.

(10) WELL TESTS: Tested by bailing.
Was pump test made? Yes [ ] No [ ] If yes, by whom? Drillers
Yield: 30 gal./min. with 210' ft. drawdown after 4 hrs.
Temperature of water Was a chemical analysis made? Yes [ ] No [X]
Was electric log made of well? Yes [ ] No [X] If yes, attach copy

(11) WELL LOG:
Total depth 510' ft. Depth of completed well 510' ft.
Formation: Describe by color, character, size of material, and structure

ft.	to ft.	
0	23	Soft White Tuffa
23	31	Red & Yellow Rock
31	62	Red Pumice Rock & Tuffa
62	87	Conglomerate Rock & Tuffa
87	122	Black Volcanic Pumice
122	158	Tuffa
158	171	Soft Red Pumice & Rock
171	233	Hard Black Basalt
233	242	Soft Brown Rock w/Black Stringers
242	278	Soft Red & Yellow Pumice
278	492	Soft Gray & White Pumice
492	510	Broken Rock w/Imbedded Clay

"Thief Brew Area"

MAIN WELL

Work started Apr. 29 1974. Completed May 6 1974

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Doshier And Gregson Drilling, Inc.
(Person, firm, or corporation) (Typed or printed)
Address 5365 Napa-Vallejo Highway
Vallejo, Ca. 94590

[SIGNED]
(Well Driller)
License No. 258826 Dated May 13, 1974

SKETCH LOCATION OF WELL ON REVERSE SIDE

DWR 188 (REV. 3-68)

Well 3

NW 1/4 33

ORIGINAL
File with DWR

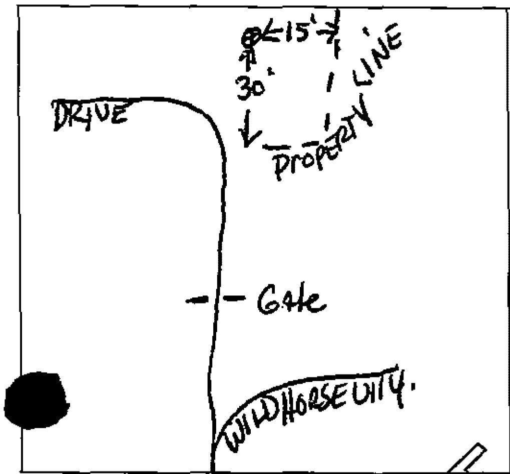
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

Do not fill in
No. 119641

State Well No.
Other Well No. 06N03W33

[redacted] of Intent No.
[redacted] Permit No. or Date

(2) LOCATION OF WELL (See instructions):
County Napa   Owner's Well Number 33-110-45
Well address if different from above End of Wild Horse Vlly Rd.
Township   Range   Section
Distance from cities, roads, railroads, fences, etc.



WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well XX Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic XX
Irrigation ☐
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other ☐

(5) EQUIPMENT:
Rotary ☐ Reverse ☐
Cable ☐ Air XX
Other ☐ Bucket ☐

(6) GRAVEL PACK:
Yes XX No ☐ Size 1/2"
Diameter of bore 14" & 9 7/8"
Packed from 50 to 255 ft.

(7) CASING INSTALLED:
Steel ☐ Plastic XX Concrete ☐

(8) PERFORATIONS:
Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
0	175	6	200	175	255	.032

(9) WELL SEAL:
Was surface sanitary seal provided? Yes XX No ☐ If yes, to depth 50 ft.
Were strata sealed against pollution? Yes ☐ No XX Interval ft.
Method of sealing grout

(10) WATER LEVELS:
Depth of first water, if known 150 ft.
Standing level after well completion 85 ft.

(11) WELL TESTS:
Was well test made? Yes XX No ☐ If yes, by whom? driller
Type of test Pump ☐ Bailer ☐ Air lift XX
Depth to water at start of test 85 ft. At end of test 255 ft
[redacted]arge 75 gal/min after 1 hours Water temperature
[redacted]ical analysis made? Yes ☐ No X If yes, by whom?
Was electric log made? Yes ☐ No X If yes, attach copy to this report

(12) WELL LOG: Total depth 255 ft. Depth of completed well 255 ft.

from ft.	to	ft.	Formation (Describe by color, character, size or material)
0	-	5	Topsoil
5	-	15	Brown clay, soft
15	-	25	Red clay soft
25	-	55	Black rock imbedded clay, grey
55	-	100	Red, black & brown rock med.
	-		hard fractured
100	-	150	Black & red rock fractured
	-		med hard
150	-	175	Grey, brown & black rock med.
			fractured
175	-	200	Dk. & lt. brown rock soft
200	-	250	Black rock stringers red rock
	-		soft
250	-	255	Brown tuffa soft

Work started 9-30 1985 Completed 10-2 1985

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
SIGNED Harold Gregson
(Well Driller)
NAME Doshier and Gregson Drilling, Inc.
(Person, firm, or corporation) (Typed or printed)
Address 5365 Napa-Vallejo Highway
City Vallejo Zip 94589
License No. 294001 Date of this report 10-3-85

Well 4

File Original, Duplicate and Triplicate with the REGIONAL WATER POLLUTION CONTROL BOARD No. 2
([illegible]rt appropriate number)

WATER WELL DRILLERS REPORT
(Sections 7076, 7077, 7078, Water Code) 324

THE RESOURCES AGENCY OF CALIFORNIA

06N/03W-33L2 (WM)

Do Not Fill In

Nº 107436

State Well No.

Other Well No.

(2) LOCATION OF WELL:

County: Napa Owner's number, if any—

R. F. D. or Street No. Wild Horse Canyon Rd. (No #)
Napa, Calif.
(See Diagram)

(3) TYPE OF WORK (check):

New well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☒
Cable ☐
Dug Well ☐

(6) CASING INSTALLED:

SINGLE ☒ DOUBLE ☐

From ft.	to ft.	Diam.	Gage or Wall	If gravel packed: Diameter of Bore	from ft.	to ft.
0	25	6"	12	6"		
				None		

Type and size of shoe or well ring: Size of gravel:

Describe joint: None

(7) PERFORATIONS:

Type of perforator used: None

Size of perforations: None in., length, by in.

From ft.	to ft.	Perf. per row	Rows per ft.

(8) CONSTRUCTION: By Owner

Was a surface sanitary seal provided? ☐ Yes ☐ No To what depth 10 ft.

Were any strata sealed against pollution? ☐ Yes ☒ No If yes, note depth of strata

From ft. to ft.

Method of Sealing

(9) WATER LEVELS:

Depth at which water was first found: 280 ft.

Standing level before perforating: 200 ft.

[illegible]ing level after perforating: 200 ft.

(10) WELL TESTS: Tested by bailing.

Was a pump test made? ☐ Yes ☐ No If yes, by whom?

Yield: 25 gal./min. with 30 ft. draw down after 2 hrs.

Temperature of water Was a chemical analysis made? ☐ Yes ☒ No

Was electric log made of well? ☐ Yes ☒ No

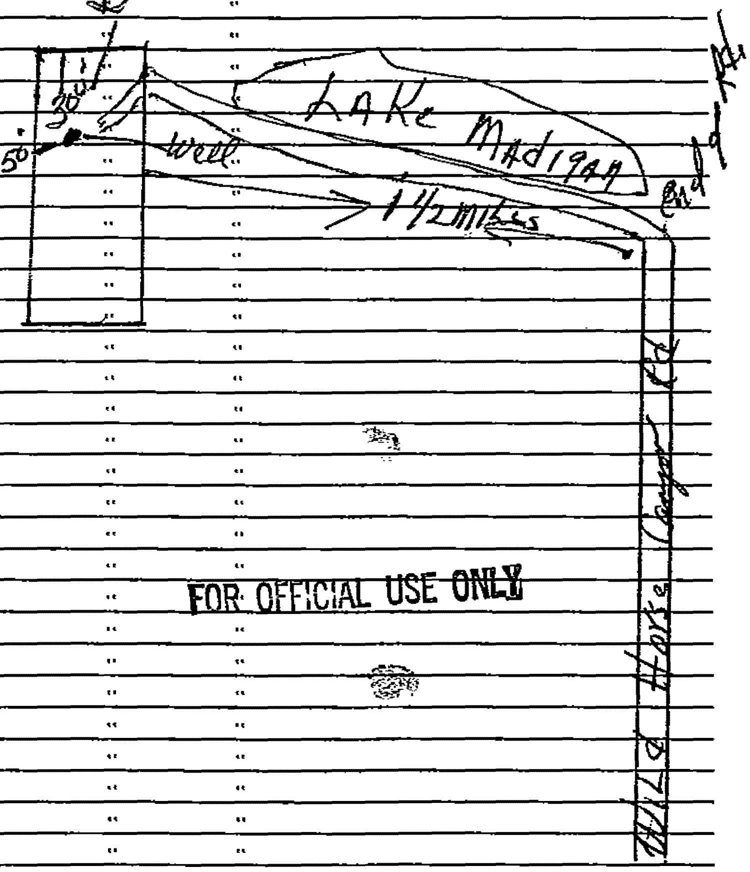
(11) WELL LOG:

Total depth 300 ft. Depth of completed well 300 ft.

Formation: *Describe by color, character, size of material, and structure.*

ft. to	ft.	Formation
0	5	Top Soil
5	110	Hard Black Rock
110	160	Red Rock
160	190	Black Rock
190	230	Brown Rock
230	240	Soft Gray Rock
240	260	Brown Rock
260	290	Red Rock
290	300	Hard Black Rock

Bronson Prop.



FOR OFFICIAL USE ONLY

Work started June 23 1964 Completed July 17 1964

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Doshier-Gregson Well Drilling Service
(Person, firm, or corporation) (Typed or printed)

Address 1554 Green Island Rd.
Vallejo, Calif.

[SIGNED] [signature]
Well Driller

License No. 208135 Dated July 20, 1964

87649 5-63 25M QUIN SPO DWR 188 (REV. 3-54)

Well 5

6/3-33

ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

②06N/03W-33ZL1 (WM) F

Do Not Fill In

Nº 94415

State Well No.
Other Well No. 06N03W33J

(2) LOCATION OF WELL:

County Napa   Owner's number, if any Wild

Township, Range, and Section Horse Valley Ranch

Distance from cities, roads, railroads, etc. P. #33-190-01

033-190-001

(3) TYPE OF WORK (check):

New Well ☒ Deepening ☐ Reconditioning ☐ Destroying ☐

If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☒ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☐
Cable ☐
Other ☐

(6) CASING INSTALLED:

STEEL: OTHER:
SINGLE ☒ DOUBLE ☐

If gravel packed

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore	From ft.	To ft.
0	30	8 5/8"	.156			

Size of shoe or well ring: None   Size of gravel:

Describe joint Butt Weld

(7) PERFORATIONS OR SCREEN:

Type of perforation or name of screen None

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.

(8) CONSTRUCTION:

Was a surface sanitary seal provided? Yes ☒ No ☐ To what depth 20' ft.

Were any strata sealed against pollution? Yes ☐ No ☒ If yes, note depth of strata

From ft. to ft.

From ft. to ft.

Method of sealing Neat Cement

(9) WATER LEVELS:

Depth at which water was first found, if known 233' ft.

Standing level before perforating, if known 190' ft.

Standing level after perforating and developing 190' ft.

(10) WELL TESTS: Tested by bailing.

Was pump test made? Yes ☐ No ☐ If yes, by whom? Drillers

d: 30 gal./min. with 210' ft. drawdown after 4 hrs.

perature of water   Was a chemical analysis made? Yes ☐ No ☒

Was electric log made of well? Yes ☐ No ☒ If yes, attach copy

(11) WELL LOG:

Total depth 510' ft. Depth of completed well 510' ft.

Formation: *Describe by color, character, size of material, and structure*

ft.	to ft.	
0	23	Soft White Tuffa
23	31	Red & Yellow Rock
31	62	Red Pumice Rock & Tuffa
62	87	Conglomerate Rock & Tuffa
87	122	Black Volcanic Pumice
122	158	Tuffa
158	171	Soft Red Pumice & Rock
171	233	Hard Black Basalt
233	242	Soft Brown Rock w/Black Stringers
242	278	Soft Red & Yellow Pumice
278	492	Soft Gray & White Pumice
492	510	Broken Rock w/Imbedded Clay

Work started Apr. 29 1974, Completed May 6 1974

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Doshier And Gregson Drilling, Inc.
(Person, firm, or corporation) (Typed or printed)

Address 5365 Napa-Vallejo Highway

Vallejo, Ca. 94590

[SIGNED] (signature) (Well Driller)

License No. 258826   Dated May 13, 1974

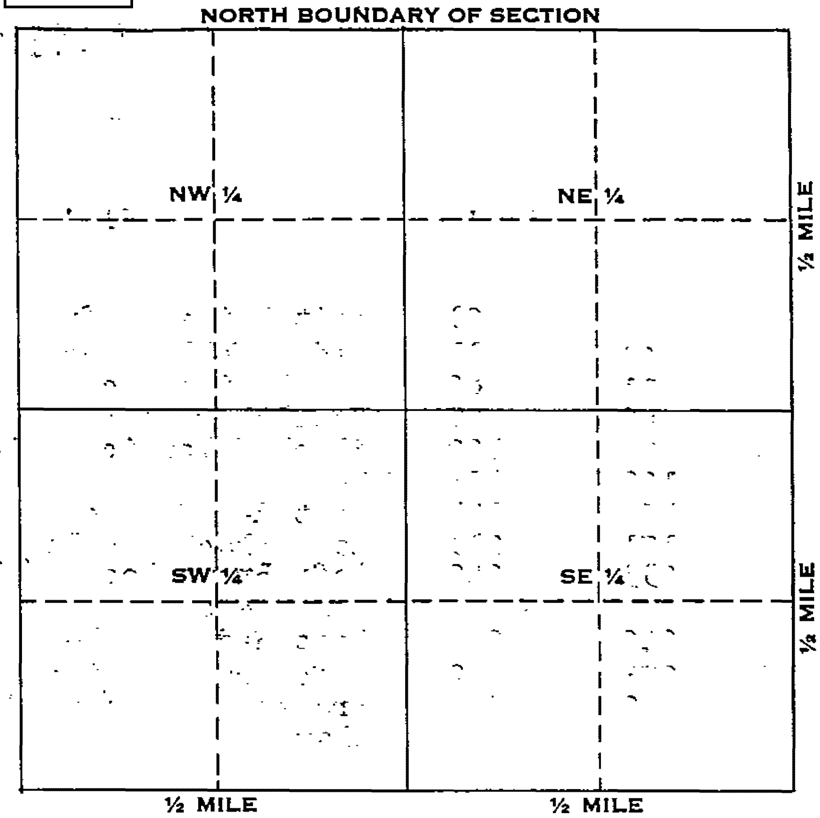
SKETCH LOCATION OF WELL ON REVERSE SIDE

DWR 188 (REV. 9-68)   25179-950 9-68 SCM TRIP ΔD OSP

Well 5, cont.

WELL LOCATION SKETCH

No 94415



Township 6 N/S

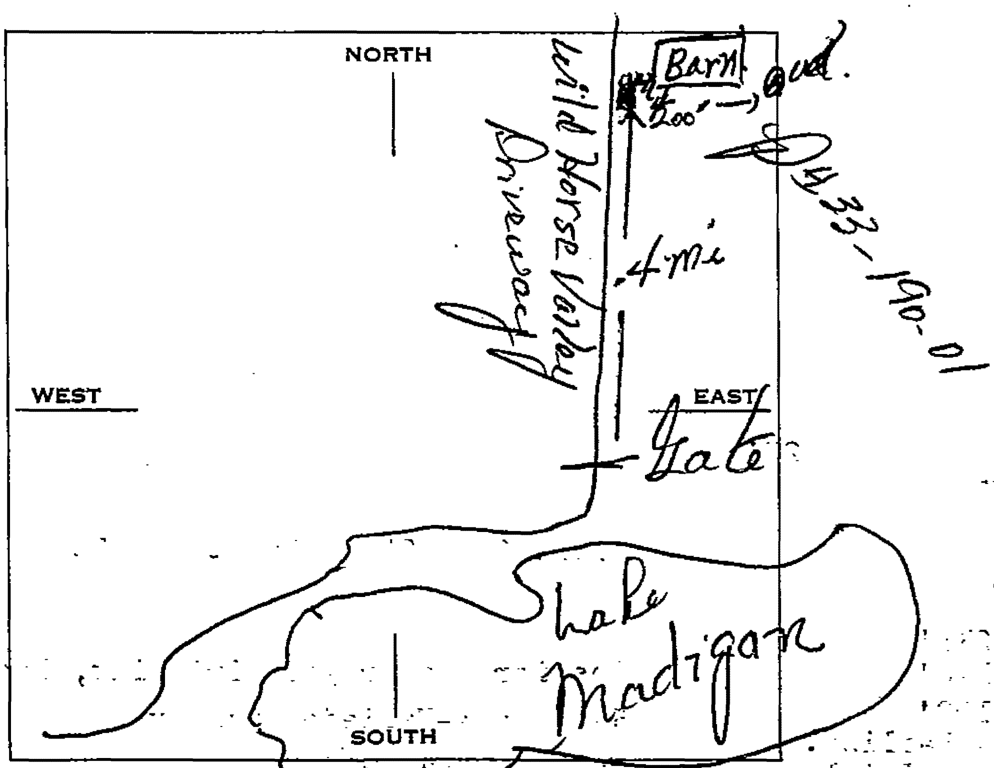
Range 3 ~~E~~/W

Section No. 33

1974 MAY 15 AM 11 23

DEPT. OF WATER RESOURCES

A. Location of well in sectionized areas.
Sketch roads, railroads, streams, or other features as necessary.



B. Location of well in areas ~~not sectionized~~.
Sketch roads, railroads, streams, or other features as necessary.
Indicate distances.

Well 6 DWR

Page 1 of 1

Owner's Well No.

Date Work Began 6/5/95, Ended 6/14/95

Local Permit Agency Napa County Environmental Health

Permit No. 39056 Permit Date 5/16/95

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 547441

DWR USE ONLY — DO NOT FILL IN

0bW03W33

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

GEOLOGIC LOG

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

DEPTH TO FIRST WATER 250 (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	3	Topsoil
3	26	Gray rock & brown clay
26	40	Black rock hard and fract
40	70	Black & gray rock hard
70	85	Black, gray & red rock hard
85	130	Brown, black & red rock hard
130	160	Black rock soft
160	190	Black & drk red rock med hard
190	220	Black & brown rock soft
220	250	Dk red,black & brown rock soft
250	265	Dk red rock med hard
265	295	Dk green & black rock med hard
295	340	Black rock med hard
340	370	Red & black rock med hard
370	400	Black & gray rock hard

TOTAL DEPTH OF BORING 400 (Feet)

TOTAL DEPTH OF COMPLETED WELL 400 (Feet)

WELL OWNER

Address 7410 Wild Horse Valley Raod

City Napa

County Napa

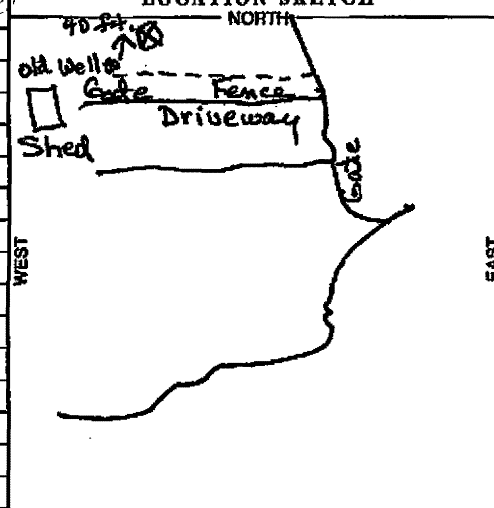
APN Book 033 Page 110 Parcel 28

Township ___ Range ___ Section ___

Latitude ___ NORTH Longitude ___ WEST (DEG. MIN. SEC.)

LOCATION SKETCH

NORTH



WEST EAST

SOUTH

Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL

MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

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

PLANNED USE(S) (✓)

___ MONITORING

WATER SUPPLY

X Domestic

___ Public

___ Irrigation

___ Industrial

___ "TEST WELL"

___ CATHODIC PROTECTION

___ OTHER (Specify)

DRILLING METHOD Air Rotary FLUID Water Foam

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 210 (Ft.) & DATE MEASURED 6/14/95

ESTIMATED YIELD* 60 (GPM) & TEST TYPE Air

TEST LENGTH 2 (Hrs.) TOTAL DRAWDOWN complete

* *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)
		9 7/8"								
400	200			X			I-C-1	6"	F-480	.032
200	1		X				I-C-1	6"	F-480	
2	1				X					

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
25	24		X		
24	1	X			
400	25			X	Pea gravel

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 Doshier-Gregson Inc. 220
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

5365 Napa Vallejo Highway, American Canyon, CA. 94589
ADDRESS CITY STATE ZIP

Signed Raymond Webster 6/16/95 258826
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 7-90 IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Well 7 NOV 0 5 2009

STAT E 7410 Wild Horse Valley Rd.
033-110-076

*The free Adobe Reader may be used to view and complete this form. However, software must be purchased to complete, save, and reuse a saved form.

File Original with DWR

State of California
Well Completion Report

Refer to Instruction Pamphlet

No. e0100418

Page 1 of 2

Owner's Well Number 1

Date Work Began 10/19/2009 Date Work Ended 10/29/2009

Local Permit Agency Napa

Permit Number 609-00439 Permit Date 10/12/09

DWR Use Only – Do Not Fill In

06N 03W 33

State Well Number/Site Number

38 19 02 N 122 12 04 W

Latitude Longitude

033-110-076

APN/TRS/Other

Geologic Log

Orientation ⦿ Vertical ○ Horizontal ○ Angle Specify

Drilling Method air Drilling Fluid water

Depth from Surface Feet	to Feet	Description (Describe material, grain size, color, etc)
0	2	top sooil
2	64	red shale
65	175	red shale clay and sand
175	240	Black Baslat
240	355	Brown shale,sand ,cllay

Total Depth of Boring Feet

Total Depth of Completed Well Feet

Well Owner

Well Location

Address 7410 Wildhorse Caynon Valley Rd

City Napa County Napa

Latitude Deg. Min. Sec. N Longitude Deg. Min. Sec. W

Datum Decimal Lat. Decimal Long.

APN Book 033 Page 110 Parcel 028

Township Range Section

Location Sketch

(Sketch must be drawn by hand after form is printed.)

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 and complete.

Activity

⦿ New Well
○ Modification/Repair
○ Deepen
○ Other
○ Destroy
Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

⦿ Water Supply
☑ Domestic ☐ Public
☐ Irrigation ☐ Industrial
○ Cathodic Protection
○ Dewatering
○ Heat Exchange
○ Injection
○ Monitoring
○ Remediation
○ Sparging
○ Test Well
○ Vapor Extraction
○ Other

Water Level and Yield of Completed Well

Depth to first water 175 (Feet below surface)

Depth to Static Water Level 150 (Feet) Date Measured 10/22/2009

Estimated Yield * 20 (GPM) Test Type Air Lift

Test Length 1.0 (Hours) Total Drawdown 2 (Feet)

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

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size If Any (Inches)
-2	315	103/4	Blank	ABS	1/4	6.5		
315	355		slot	abs	1/4	6.5	Milled Slots	0.200

Annular Material

Depth from Surface Feet	to Feet	Fill	Description
22	355	fill	gravel
-2	22	concrete	

Attachments

☐ Geologic Log
☐ Well Construction Diagram
☐ Geophysical Log(s)
☐ Soil/Water Chemical Analyses
☑ Other location

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 Courson
Person, Firm or Corporation

226 Mariposa Dr #2 Angwin CA
Address City State Zip

Signed [signature] 10/29/2009 580953
C-57 Licensed Water Well Contractor Date Signed C-57 License Number

DWR 188 REV. 1/2006

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM e0100418

EXHIBIT A

GRANT OF EASEMENTS AND WATER RIGHTS

FOR THE LANDS OF

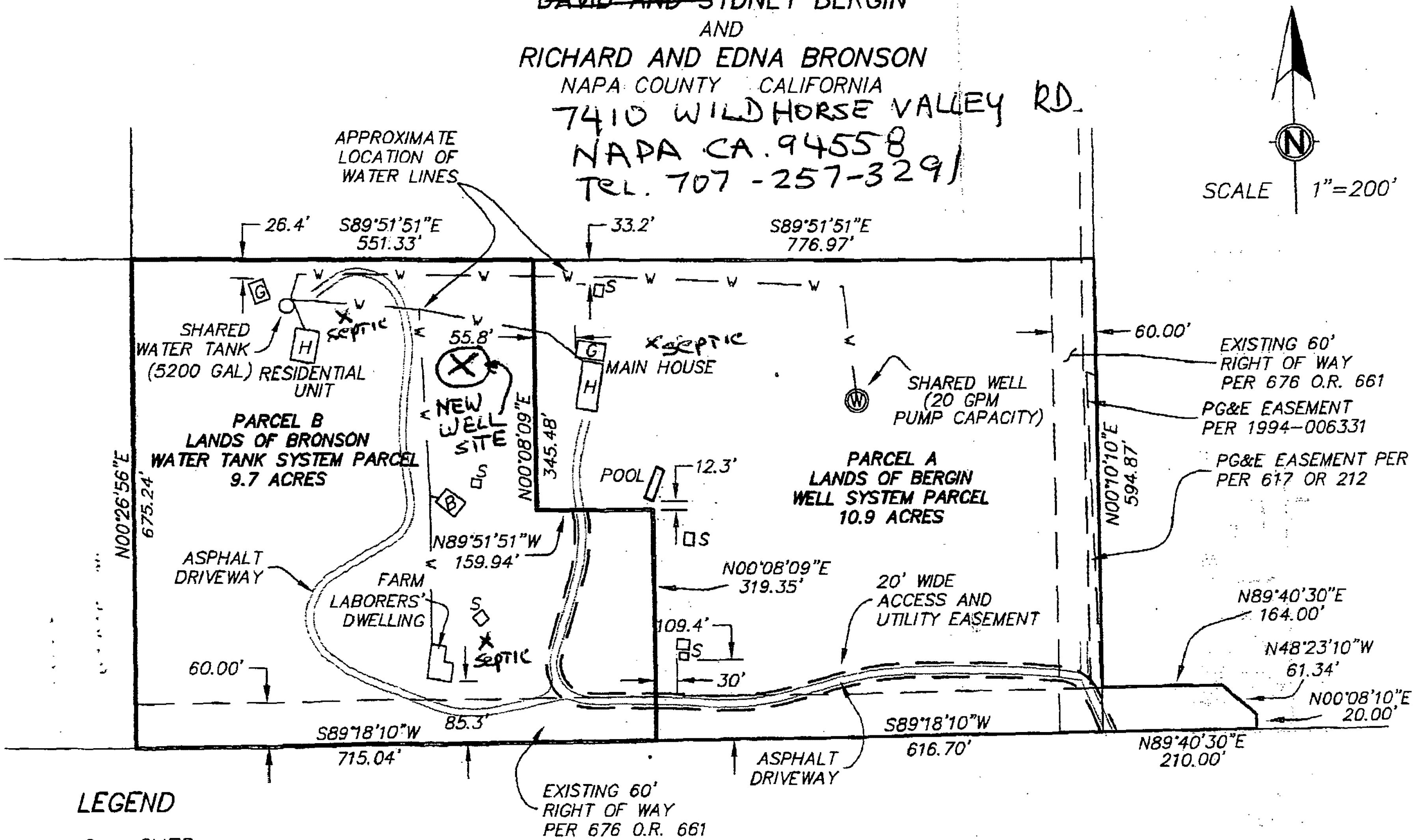
~~DAVID AND SYDNEY BERGIN~~

AND

RICHARD AND EDNA BRONSON

NAPA COUNTY CALIFORNIA

7410 WILDHORSE VALLEY RD.
NAPA CA. 94558
TEL. 707-257-3291



LEGEND

- S SHED
- H HOUSE
- G GARAGE
- (W) WELL
- B BARN
- — W — WATER LINE

PREPARED BY:
TERRA FIRMA SURVEYS, INC.
P.O. BOX 533
ST. HELENA CA 94574
PHONE: (707) 963-7565

DATE: June 18[illegible]09

Well 8

File with DWR

Page 1 of 1

Owner's Well No. Winery Well

Date Work Began 1/16/2006, Ended 2/10/2006

Local Permit Agency Napa County Environmental Mgmt

Permit No. E05-1067 Permit Date 12/5/2005

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. e033973

DWR USE ONLY — DO NOT FILL IN

06N03W28

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

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	20	DARK BROWN ASH W/EMBEDDED ROCK
20	30	BLACK VOLCANIC ROCK
30	75	YELLOW, WHITE TUFF
75	120	RED VOLCANICS
120	190	BLACK VOLCANICS
190	200	PEACH, BLACK VOLCANICS
200	220	YELLOW TUFF
220	320	BLACK VOLCANICS
320	340	MIXED VOLCANICS
340	420	DARK GRAY VOLCANICS
420	450	GRAY VOLCANICS
450	480	RED, BLACK VOLCANICS
480	640	DARK GRAY VOLCANICS
		CONTINUED CASING LAYOUT
515	615	SCREEN PVC 8" .032 SLOT
615	635	BLANK PVC 8"

TOTAL DEPTH OF BORING 640 (Feet)

TOTAL DEPTH OF COMPLETED WELL 635 (Feet)

WELL OWNER

CITY STATE ZIP

WELL LOCATION

Address 8999 Wild Horse Valley Road

City Napa CA

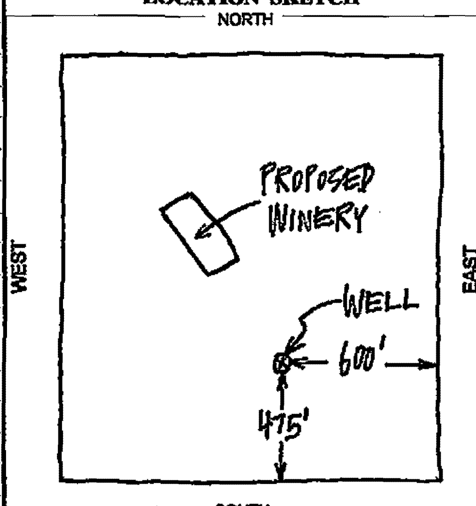
County Napa

APN Book 033 Page 110 Parcel 060

Township ___ Range ___ Section ___

Latitude ___ DEG. MIN. SEC. ___ 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

DEPTH TO FIRST WATER 450 (Ft.) BELOW SURFACE 1

DEPTH OF STATIC WATER LEVEL 394 (Ft.) & DATE MEASURED 2/10/2006

ESTIMATED YIELD * 180 (GPM) & TEST TYPE AIR LIFT

TEST LENGTH 5 (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)	BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	85	15								
85	640	12								
0	395		✓				PVC F480	8	SDR-21	
395	495			✓			PVC F480	8	SDR-21	.032
495	515		✓				PVC F480	8	SDR-21	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	82	✓			CONCRETE
82	635			✓	#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 HUCKFELDT WELL DRILLING, INC.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

2110 Penny Lane Napa CA 94559
ADDRESS CITY STATE ZIP

Signed [signature] 02/15/06 439-746
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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 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).

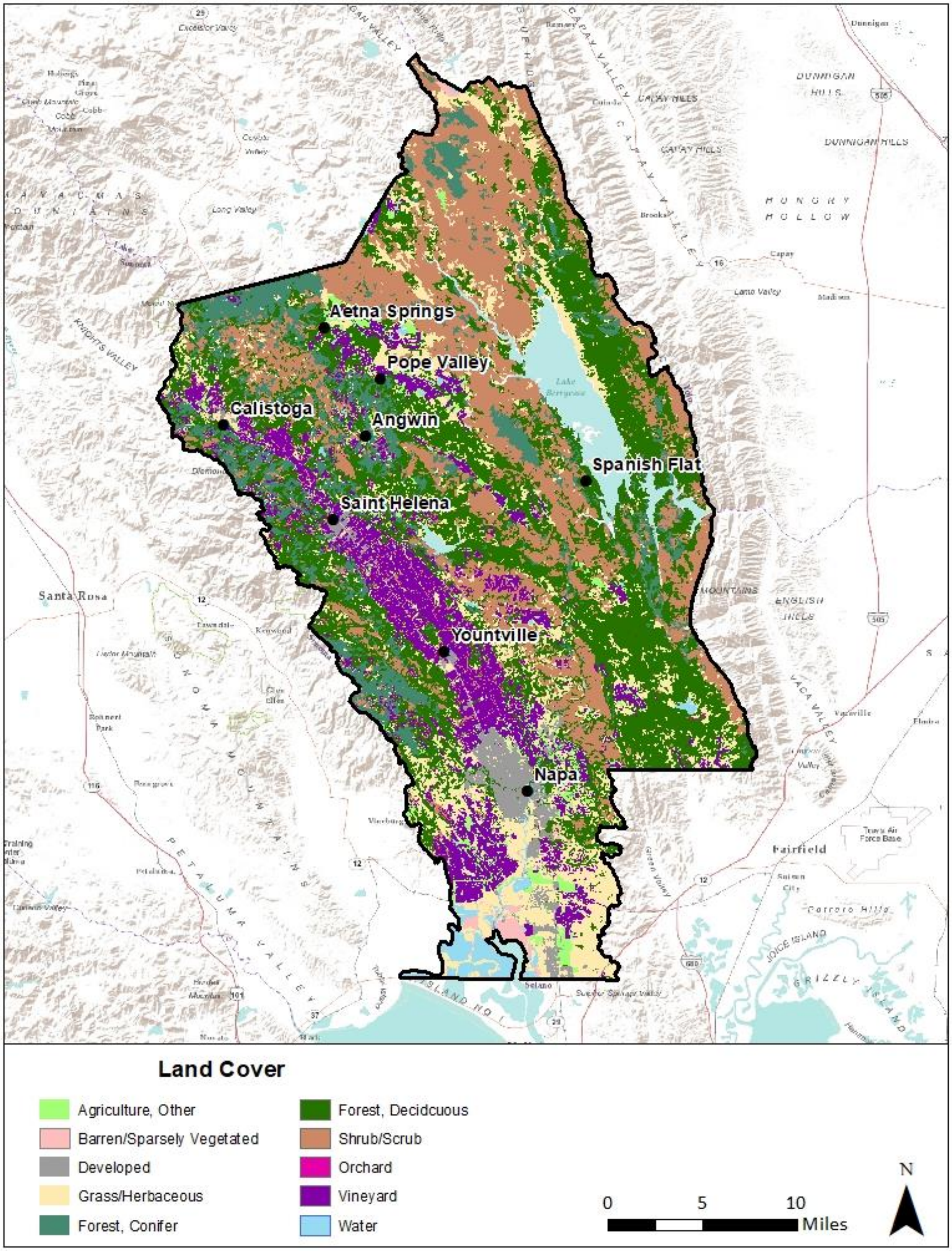

Figure 1: Land cover distribution used in the Napa County SWB model.

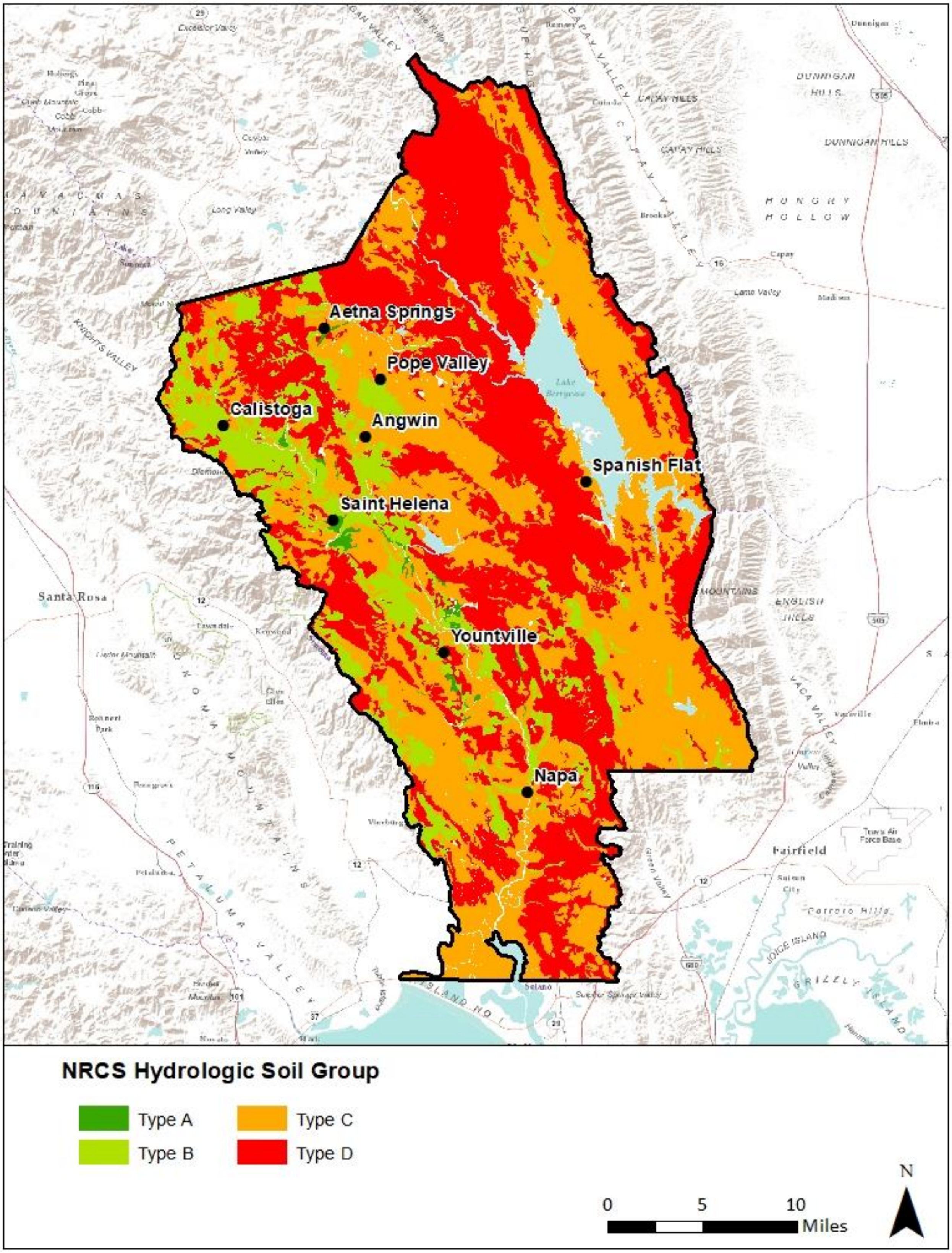

Figure 2: Hydrologic soil group distribution used in the Napa County SWB model.

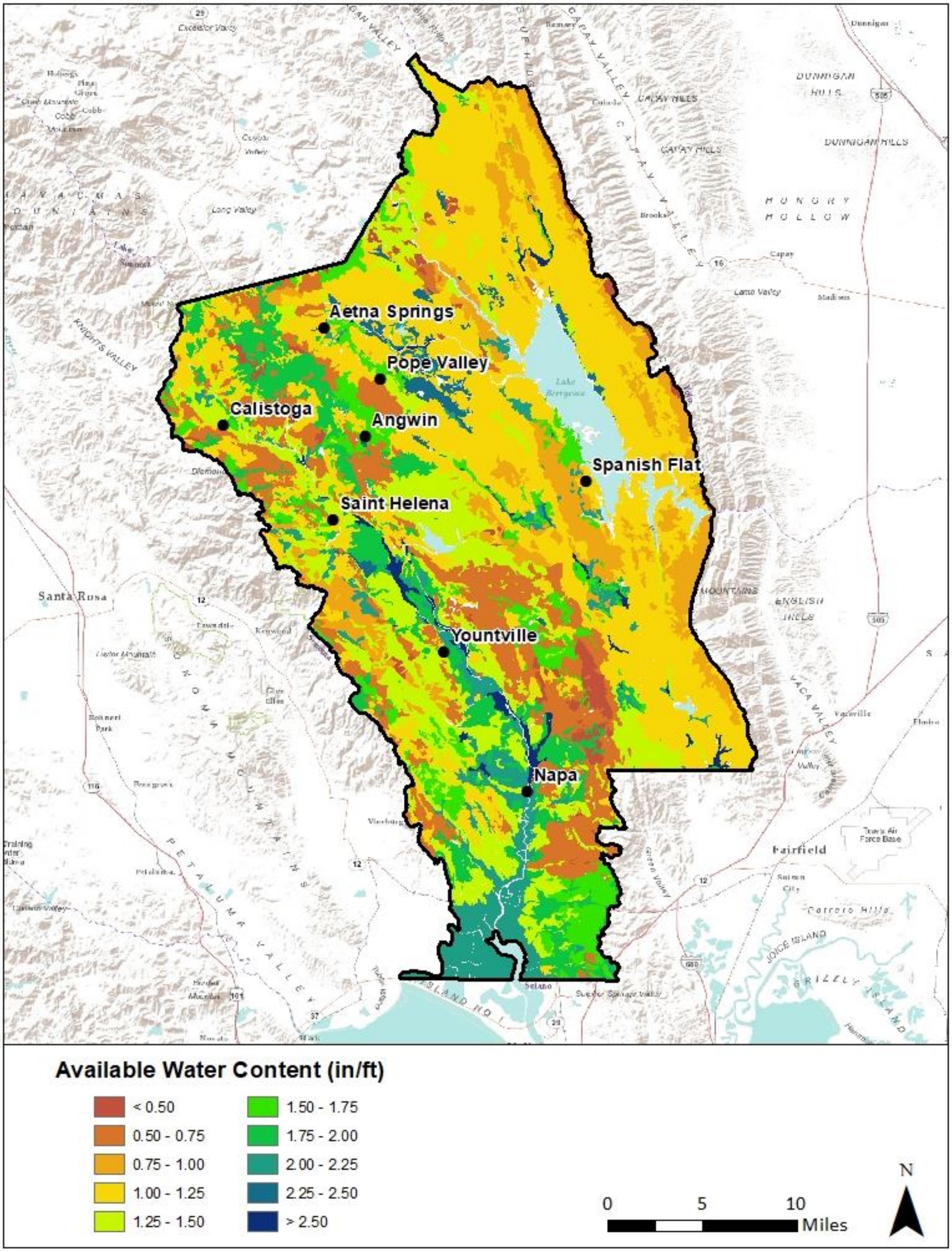

Figure 3: Available water capacity distribution used in the Napa County SWB model.

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

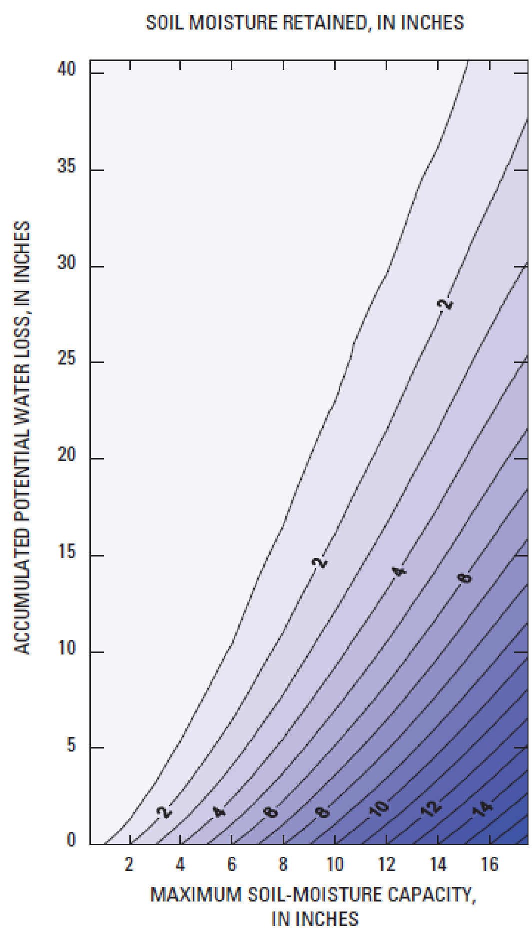

Figure 4: Soil-moisture-retention table (Thornthwaite and Mather 1957).

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

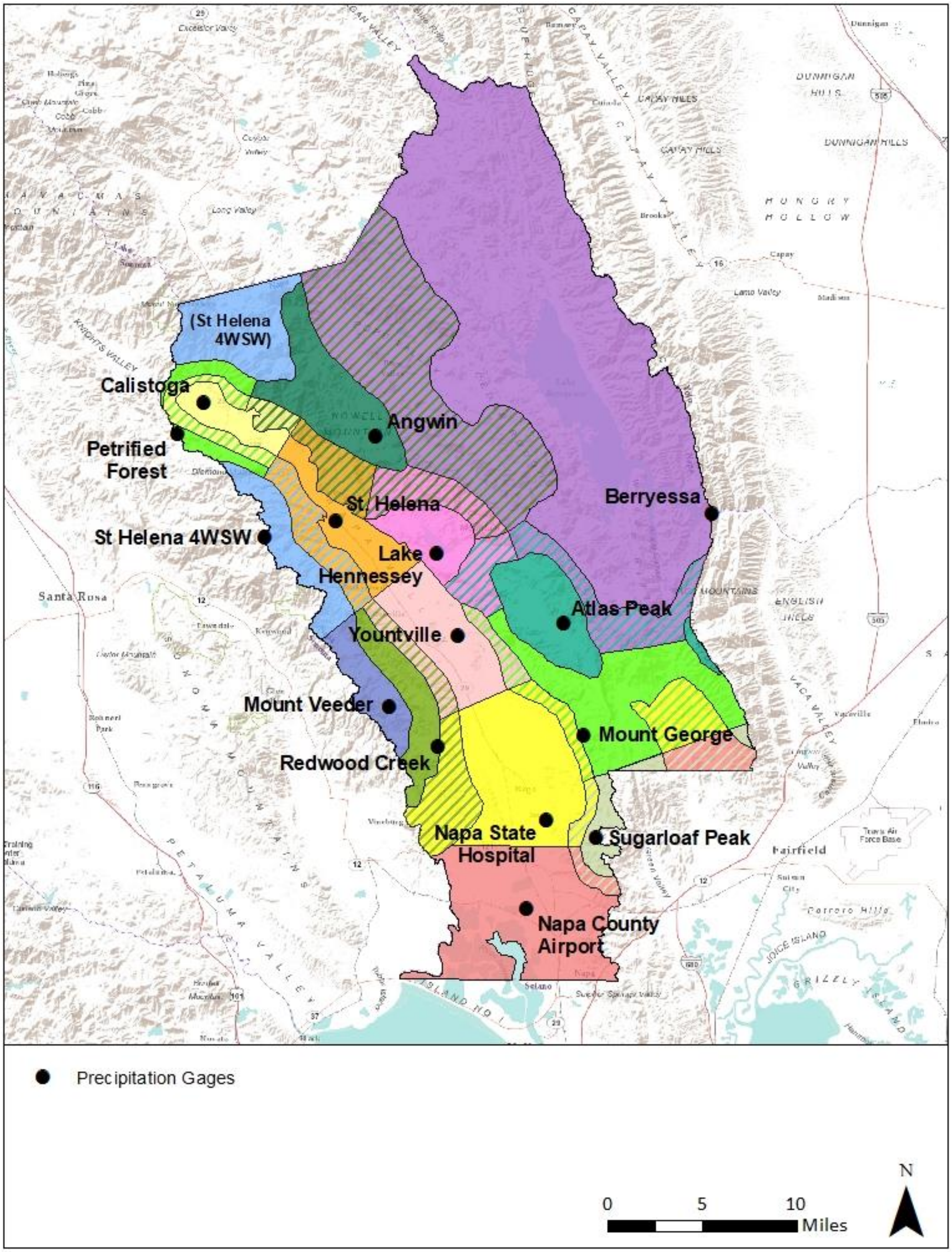

Figure 5: Precipitation zones used in the Napa County SWB model. Hatching indicates areas where two precipitation records were averaged across a zone.

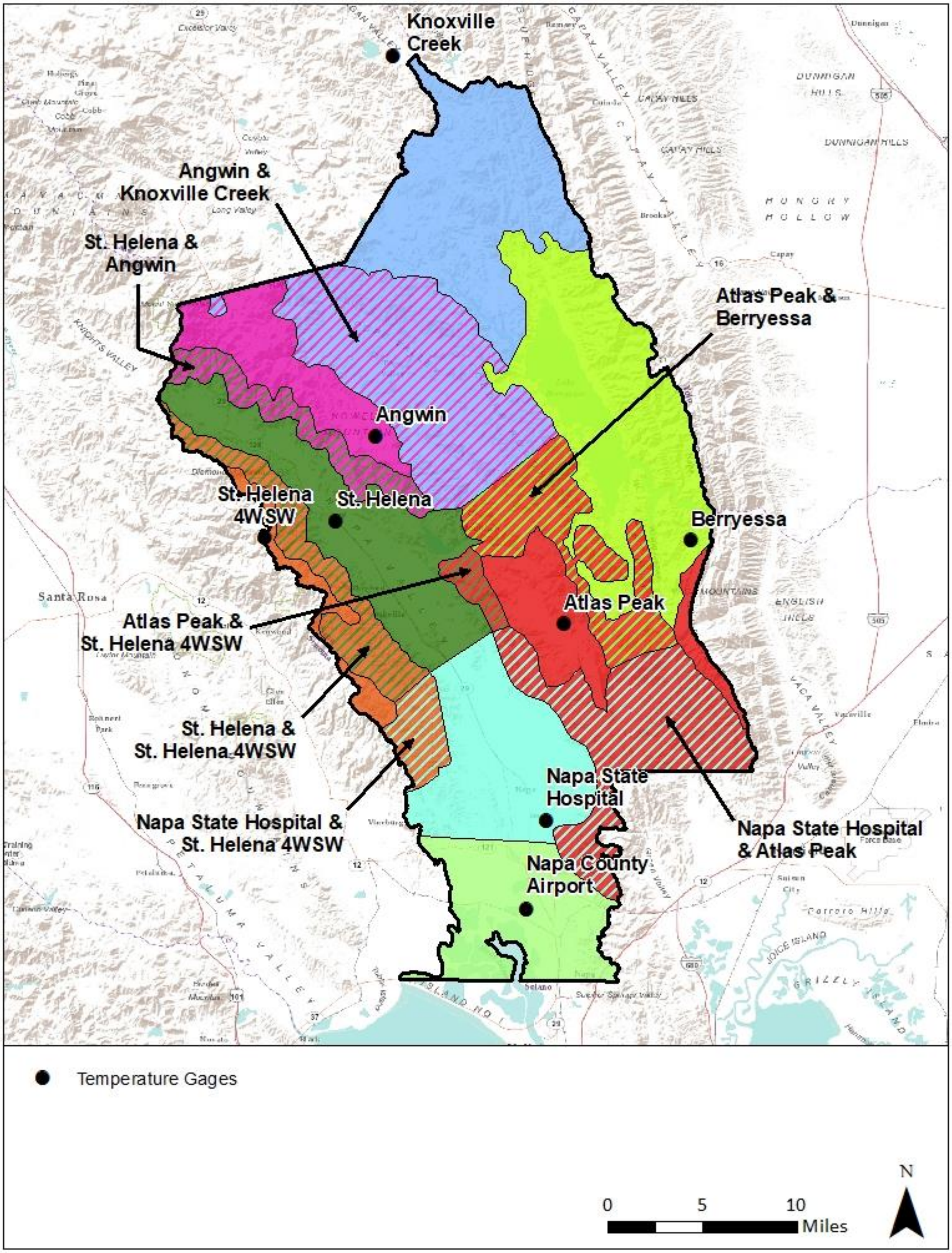

Figure 6: Temperature zones used in the Napa County SWB model. Hatching indicates areas where two temperature records were averaged across a zone.

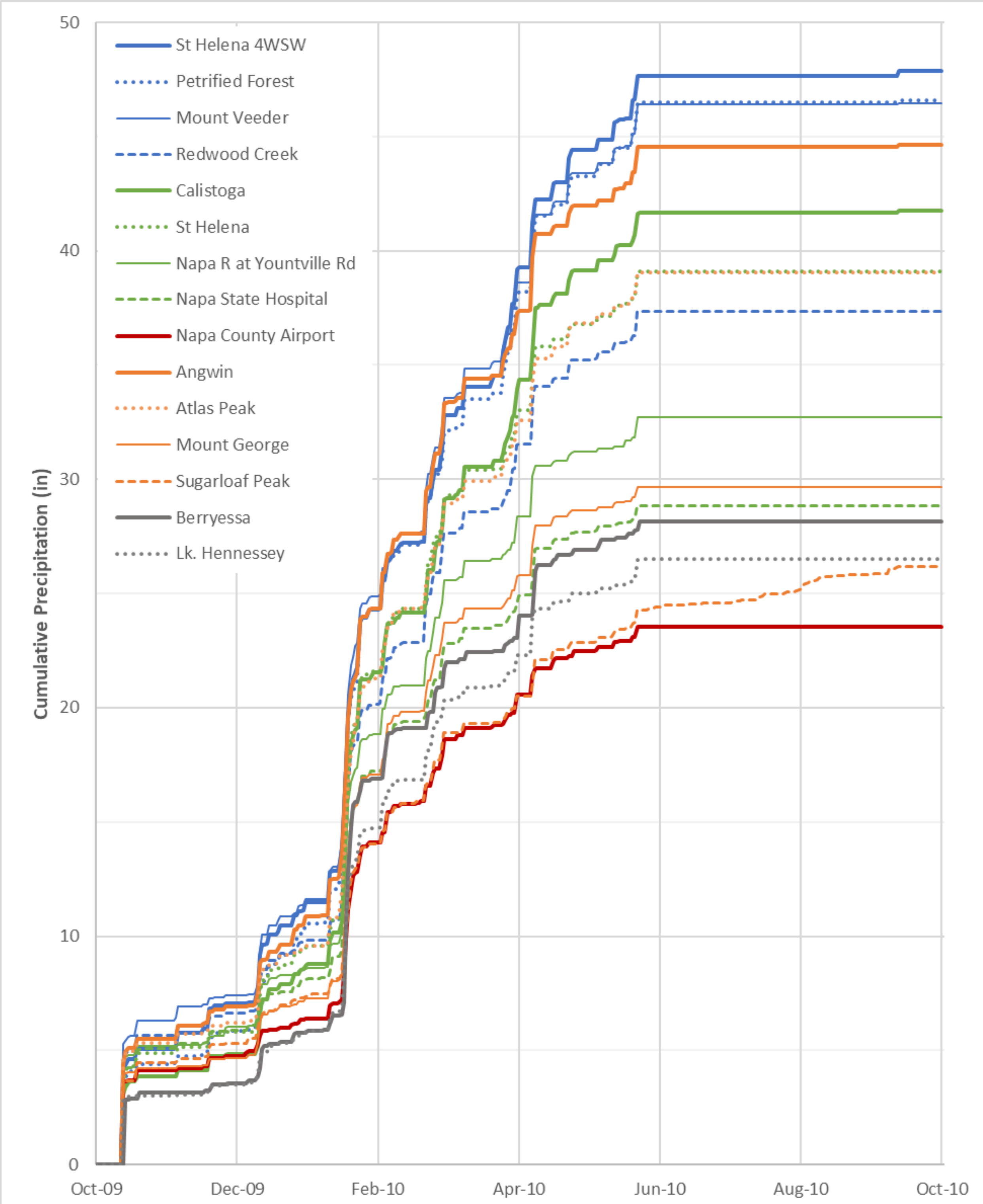

Figure 7a: Daily precipitation data used in the Napa County SWB model for WY 2010.

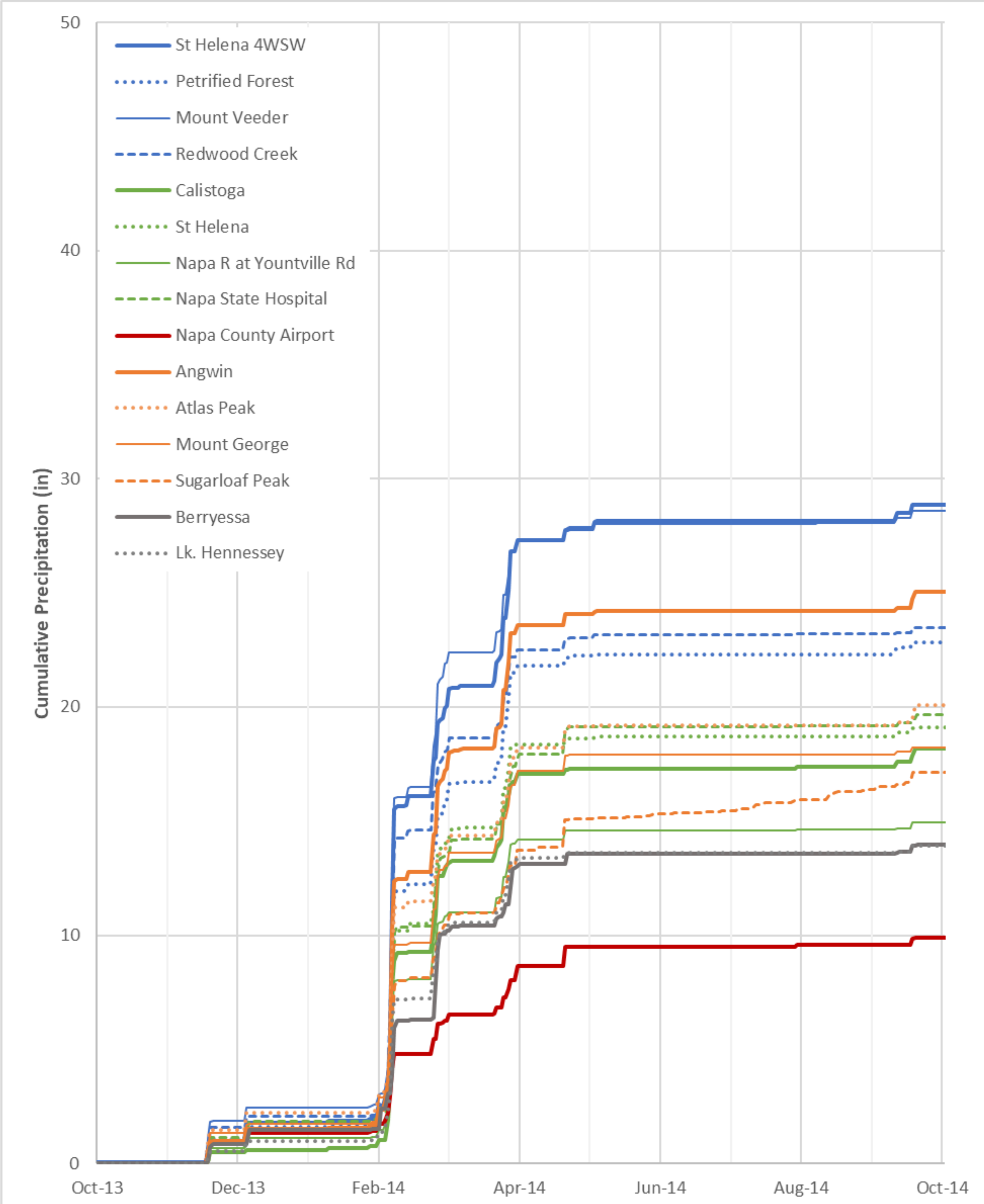

Figure 7b: Daily precipitation data used in the Napa County SWB model for WY 2014.

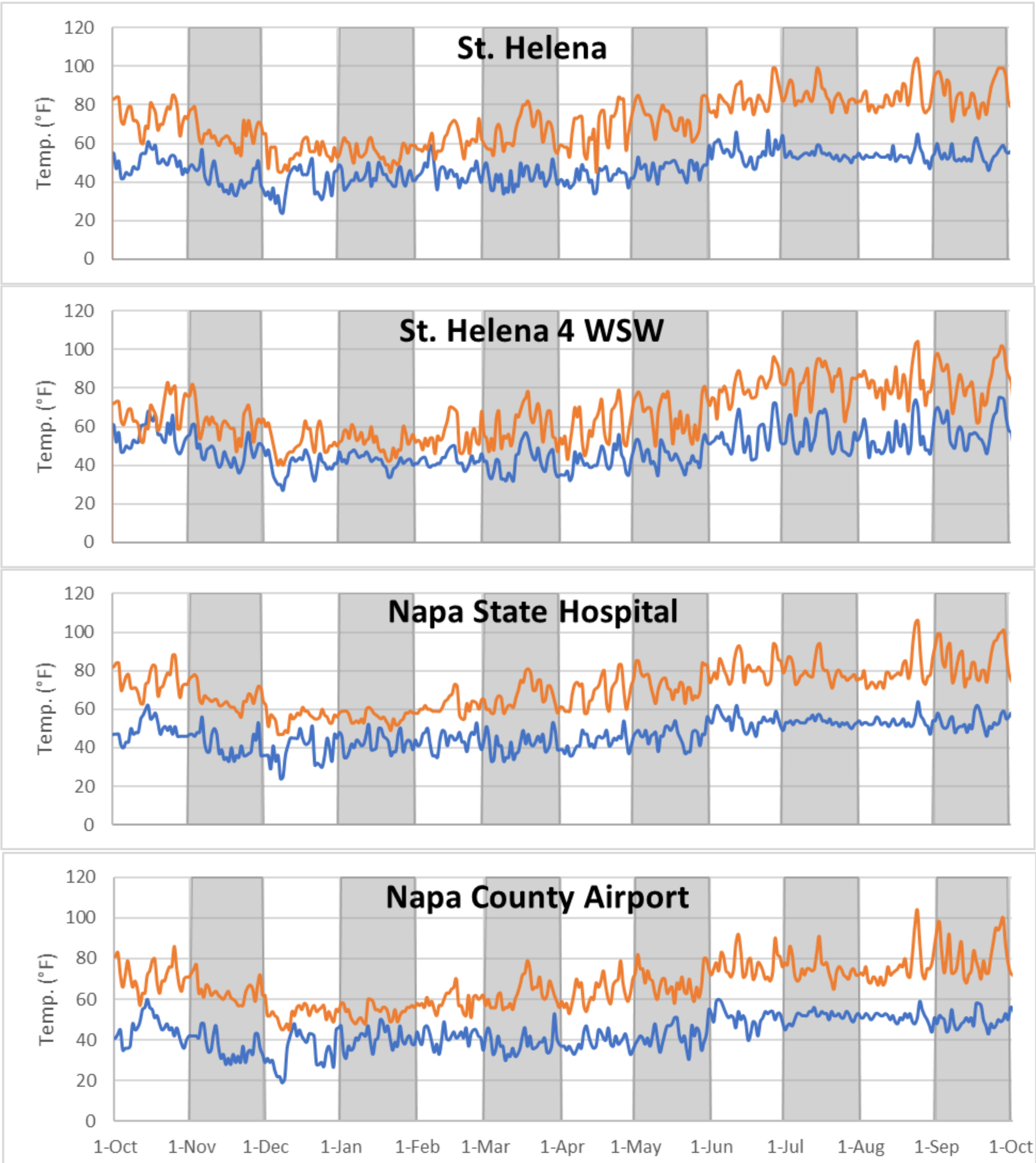

Figure 8: Daily minimum and maximum temperature data used in the Sonoma County SWB model for WY 2010.

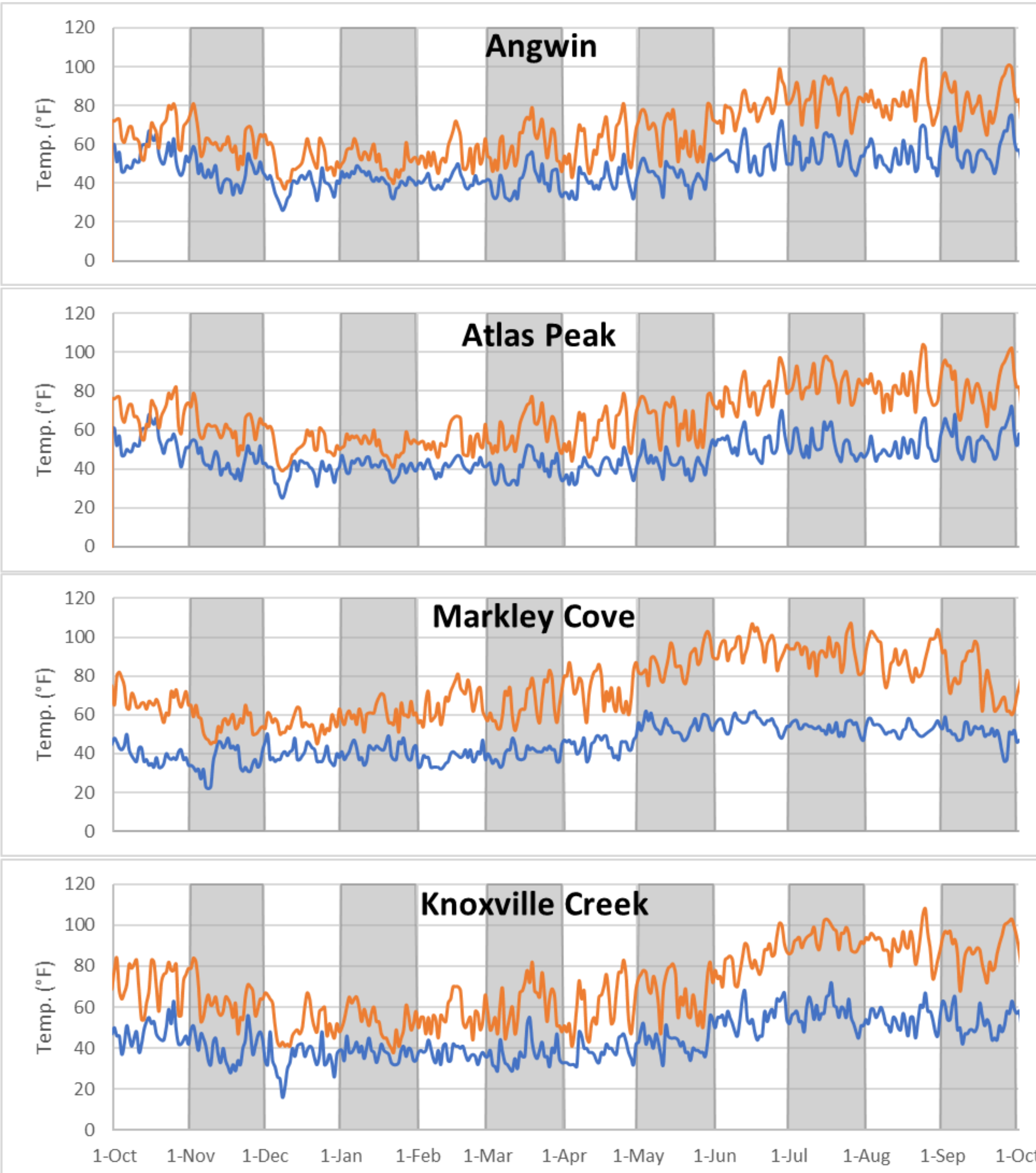

Figure 8 – cont.

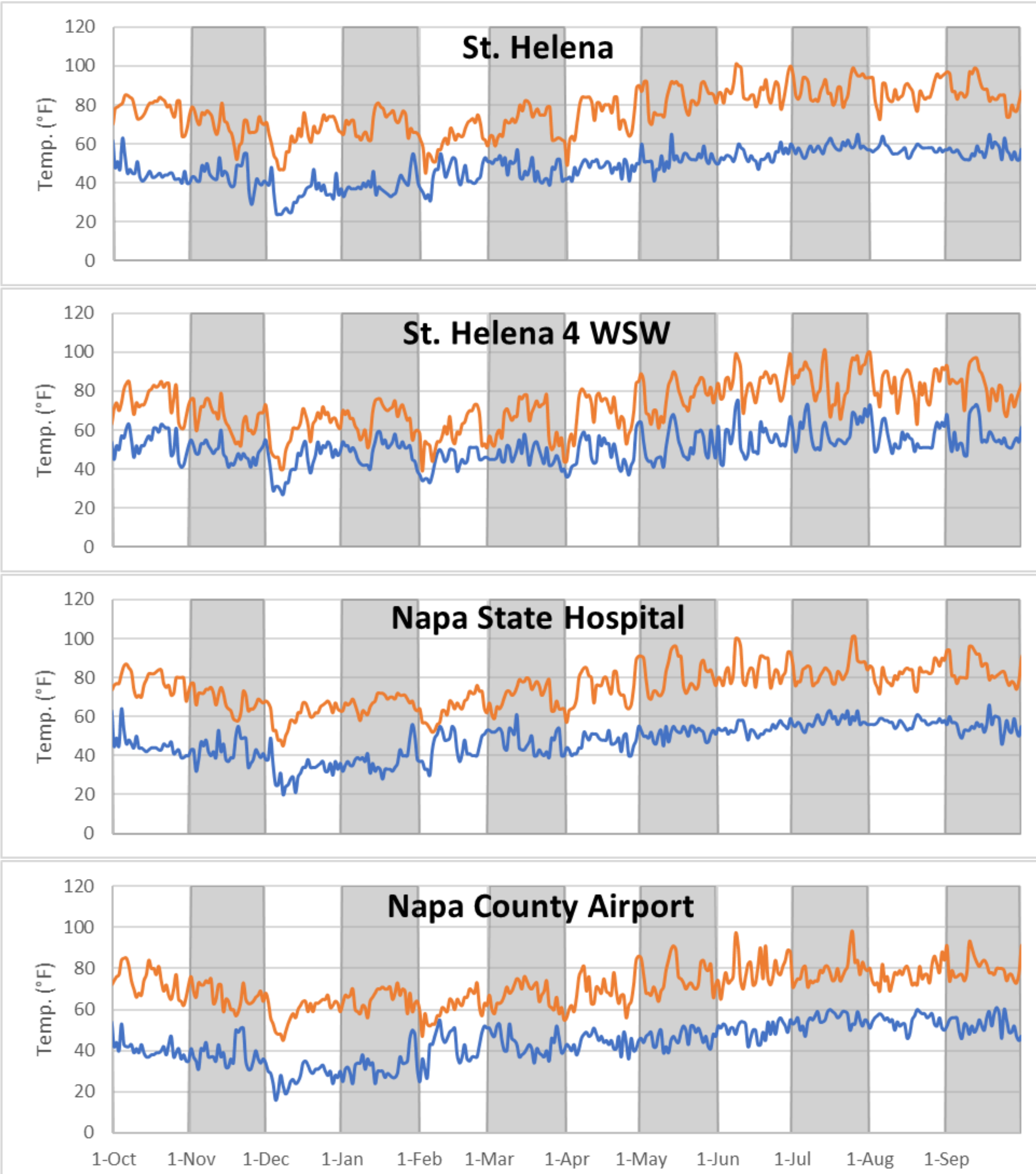

Figure 9: Daily minimum and maximum temperature data used in the Sonoma County SWB model for WY 2010.

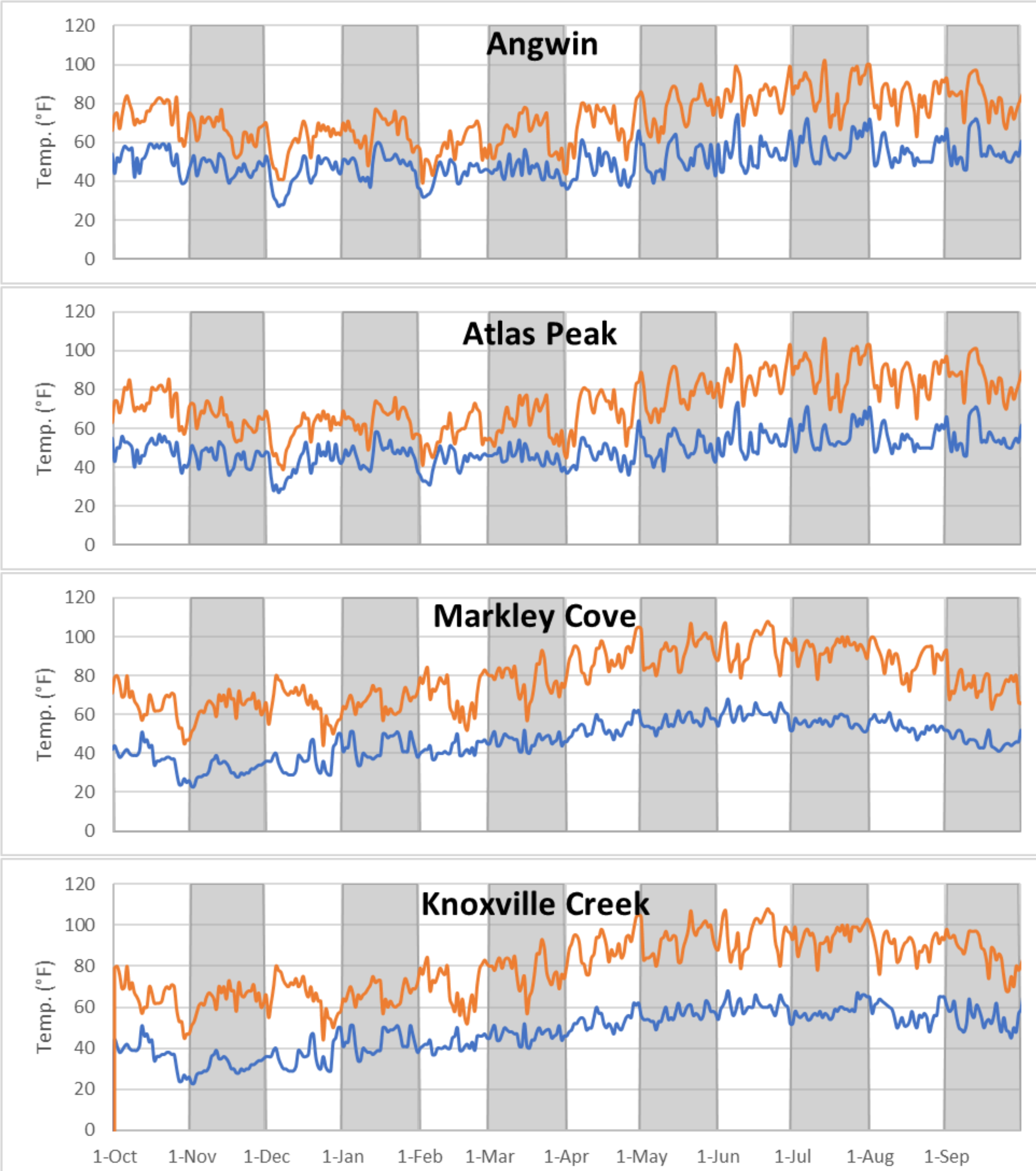

Figure 9 – cont.

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. 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.

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.

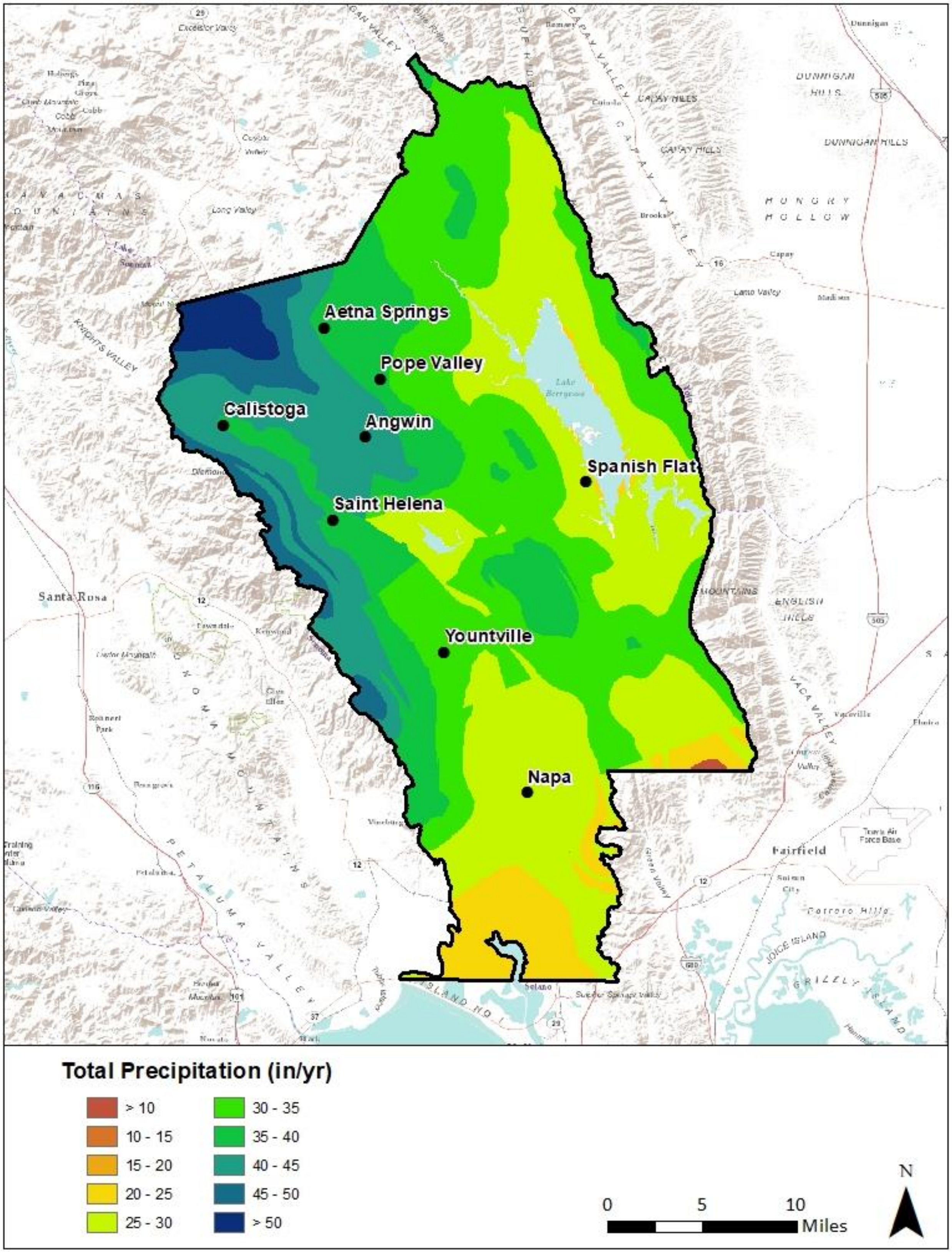

Figure 10: Water Year 2010 precipitation simulated with the Napa County SWB model.

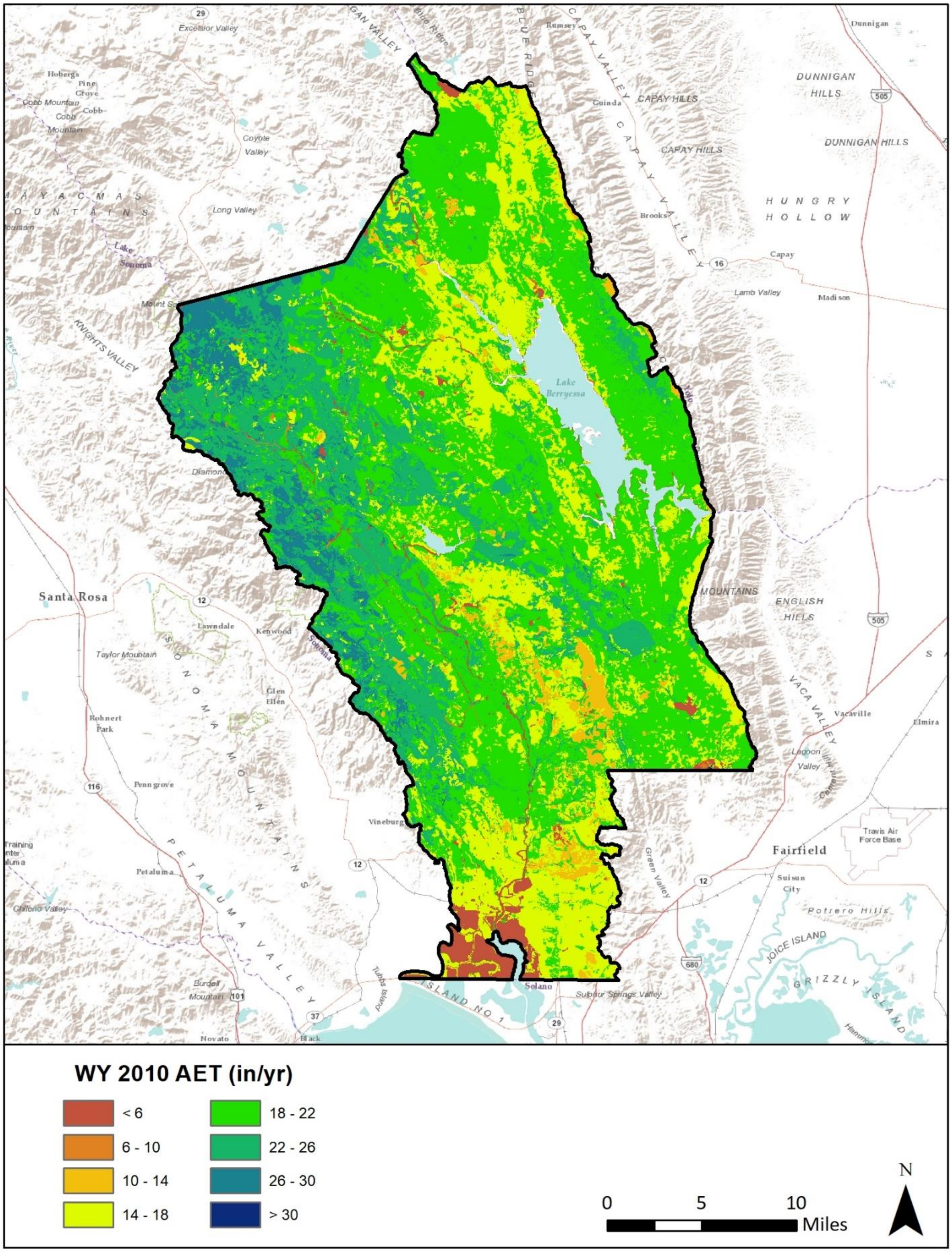

Figure 11: Water Year 2010 AET simulated with the Napa County SWB model.

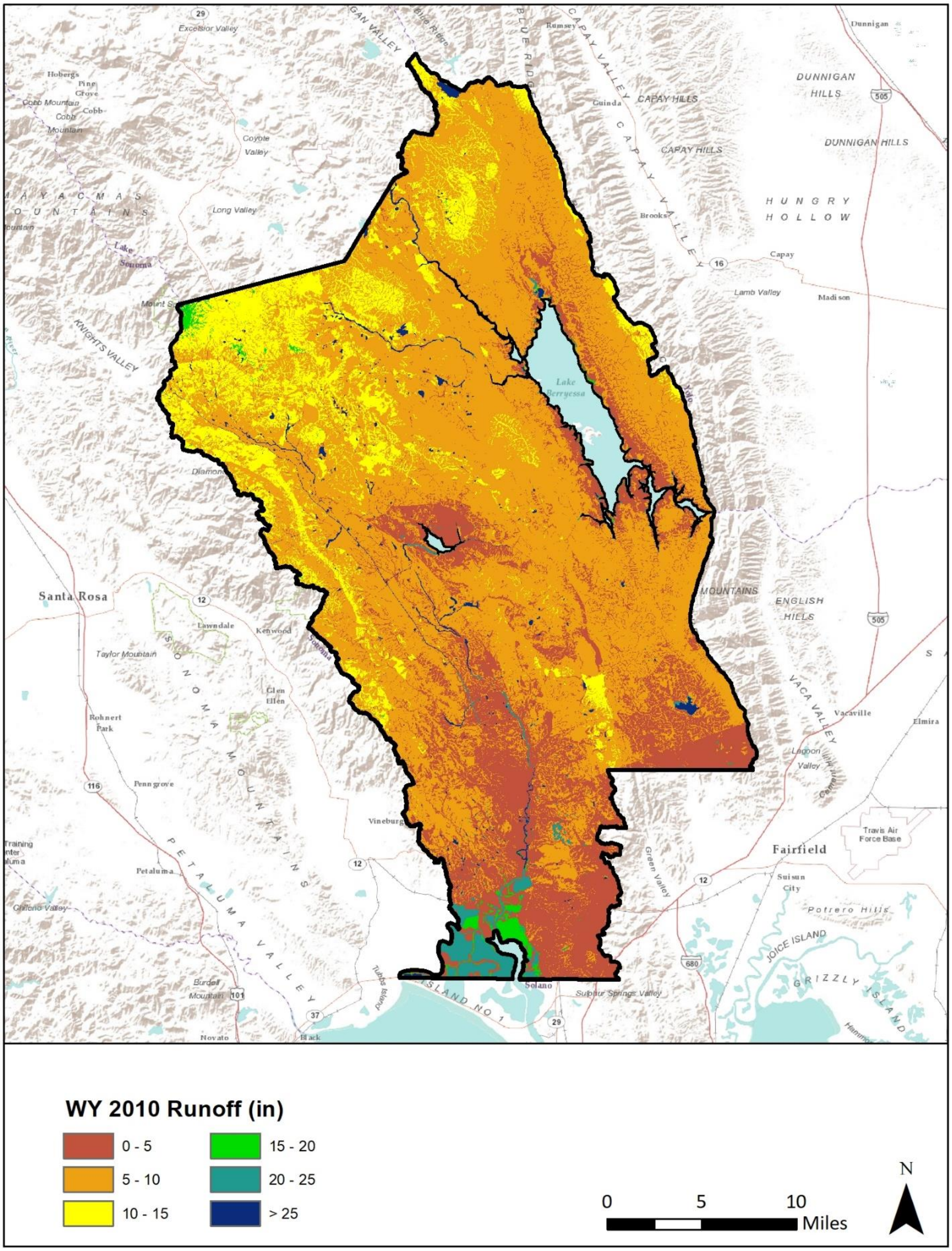

Figure 12: Water Year 2010 runoff simulated with the Napa County SWB model.

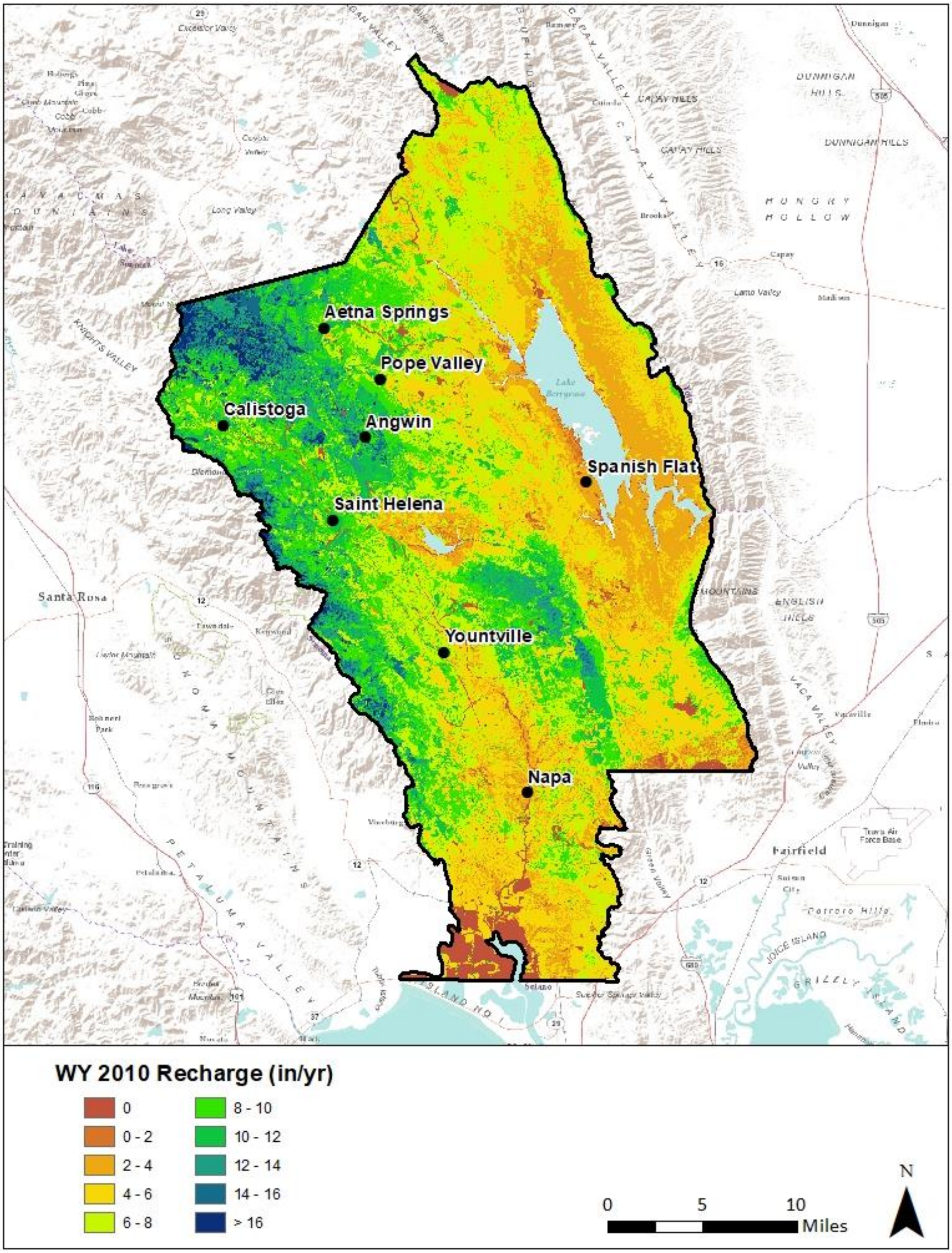

Figure 13: Water Year 2010 recharge simulated with the Napa County SWB model.

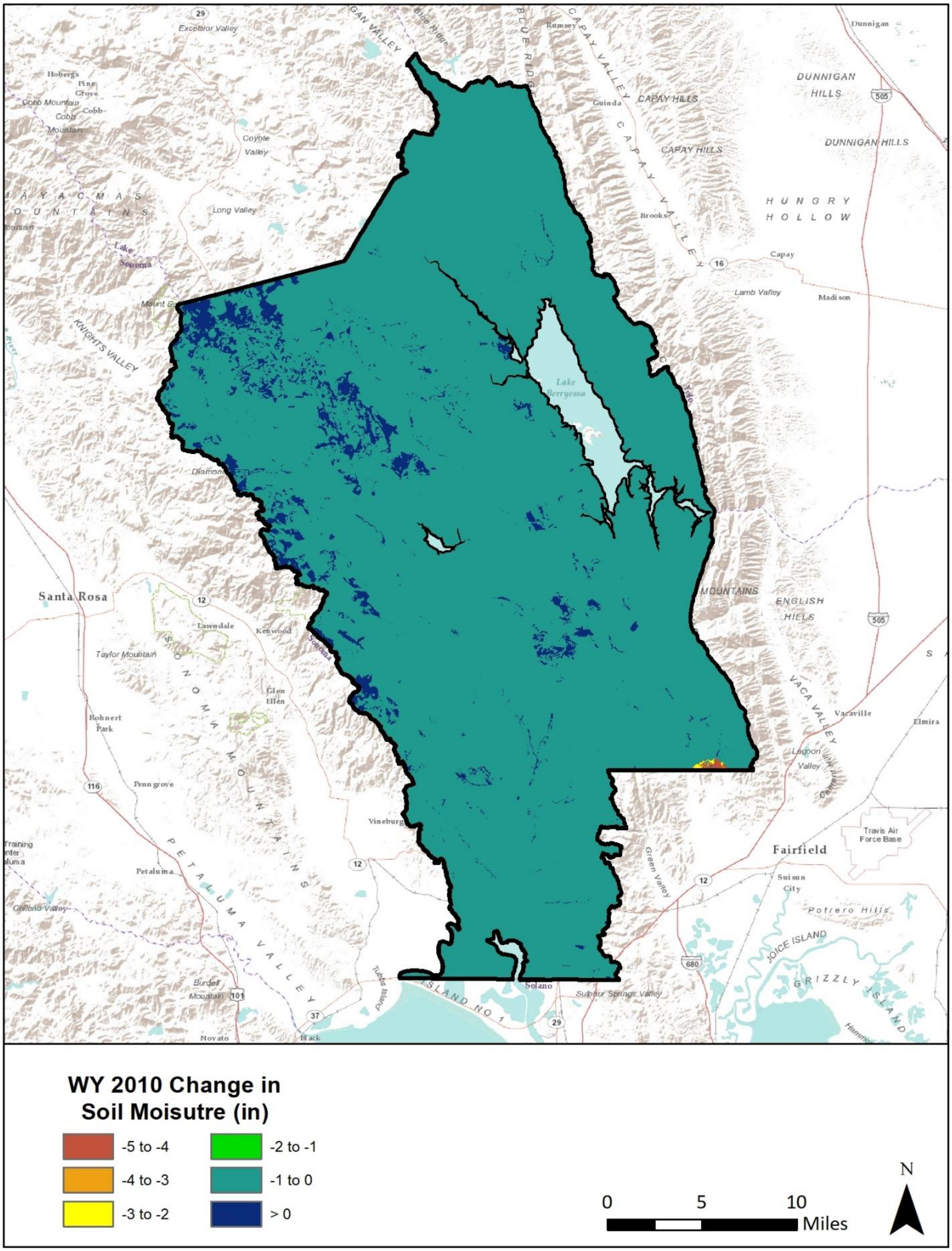

Figure 14: Water Year 2010 change in soil moisture content simulated with the Napa County SWB model.

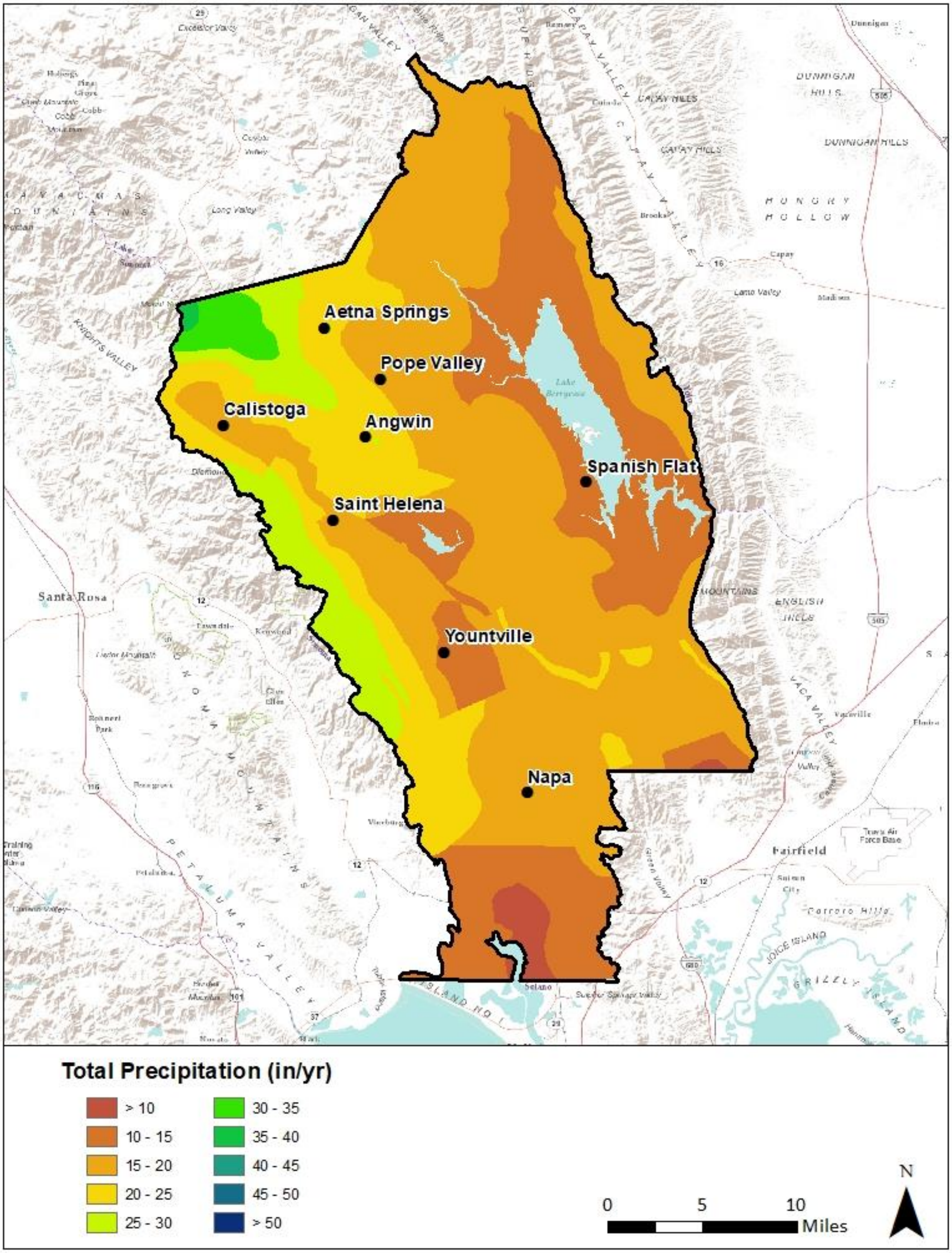

Figure 15: Water Year 2014 precipitation simulated with the Napa County SWB model.

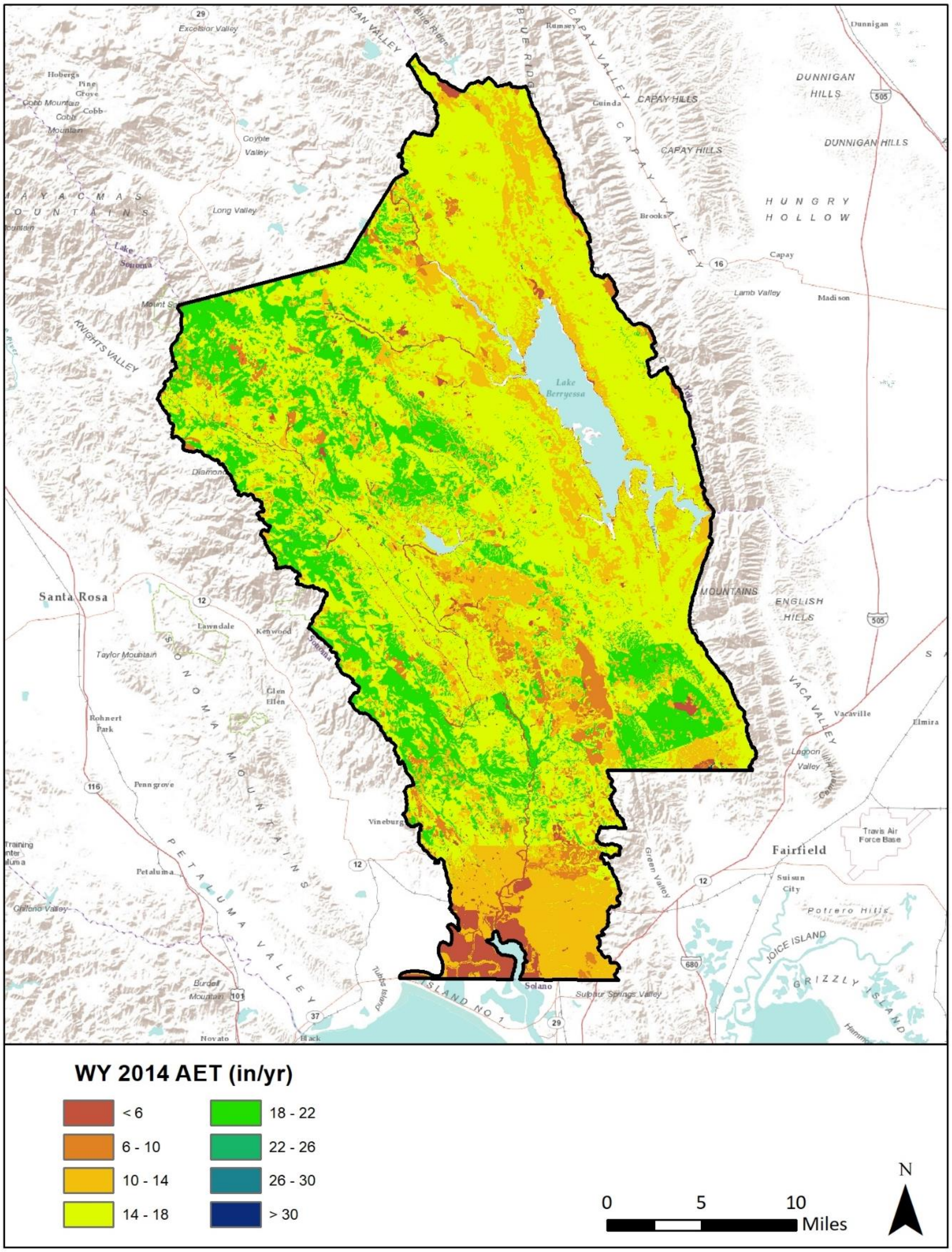

Figure 16: Water Year 2014 AET simulated with the Napa County SWB model.

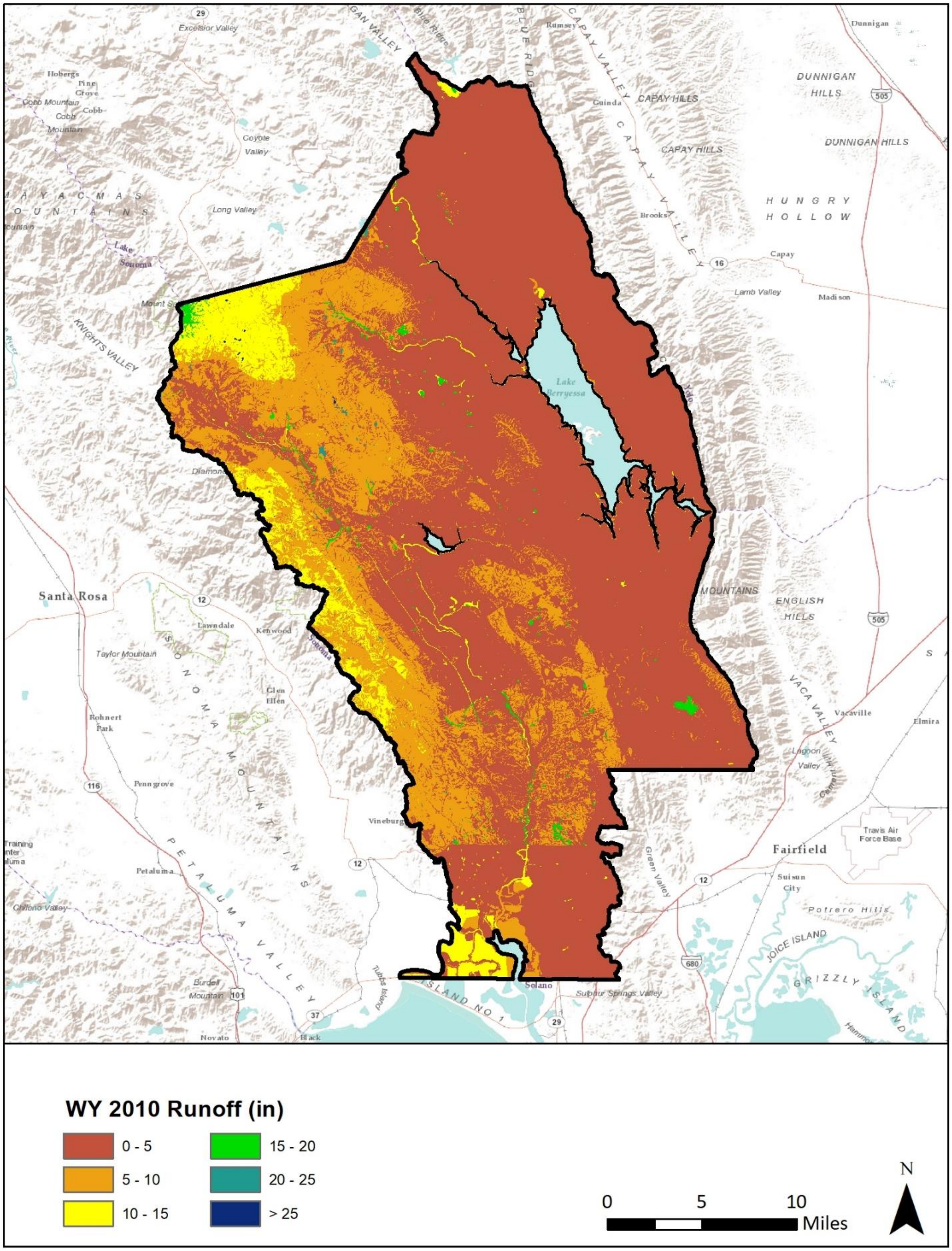

Figure 17: Water Year 2014 recharge simulated with the Napa County SWB model.

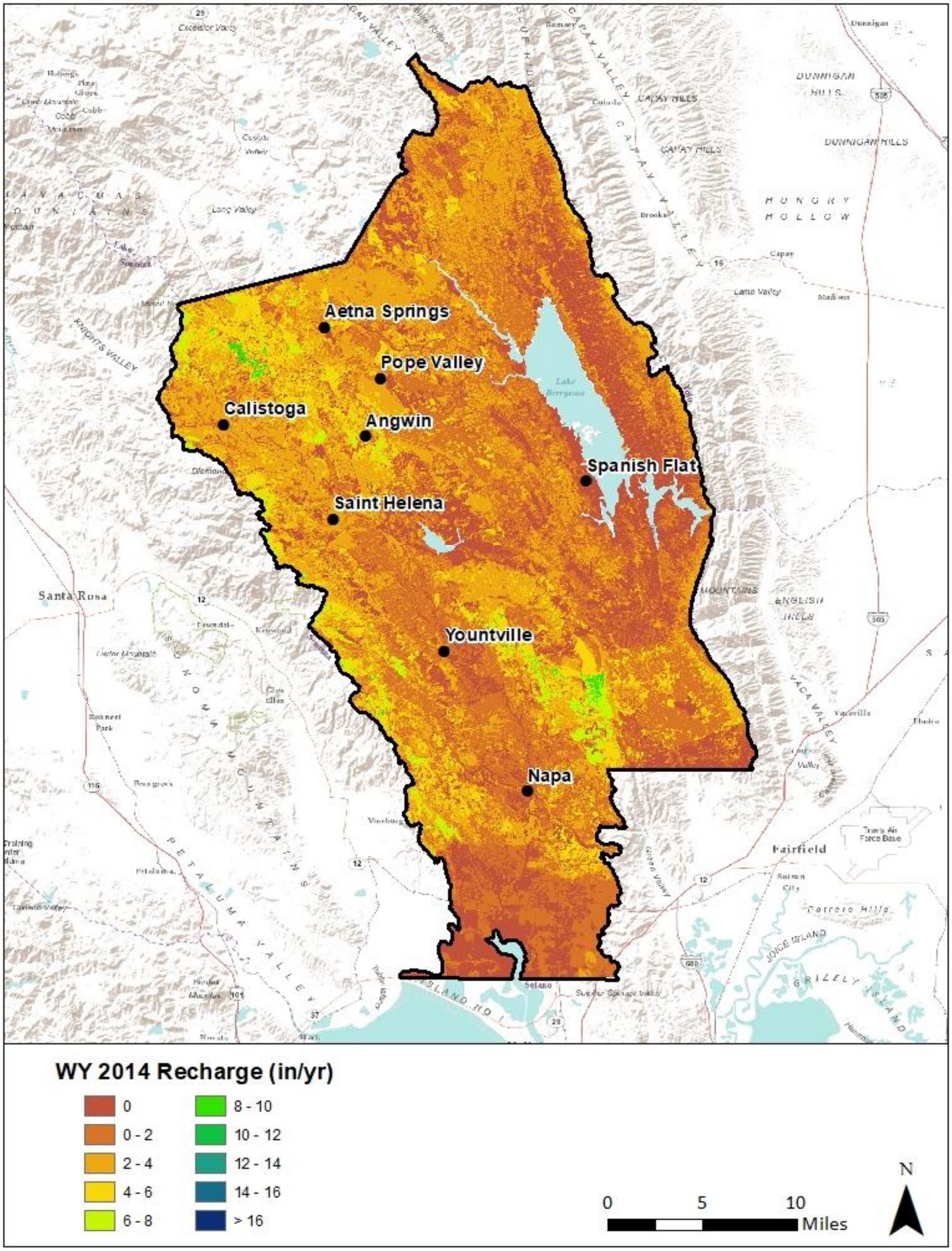

Figure 18: Water Year 2014 recharge simulated with the Napa County SWB model.

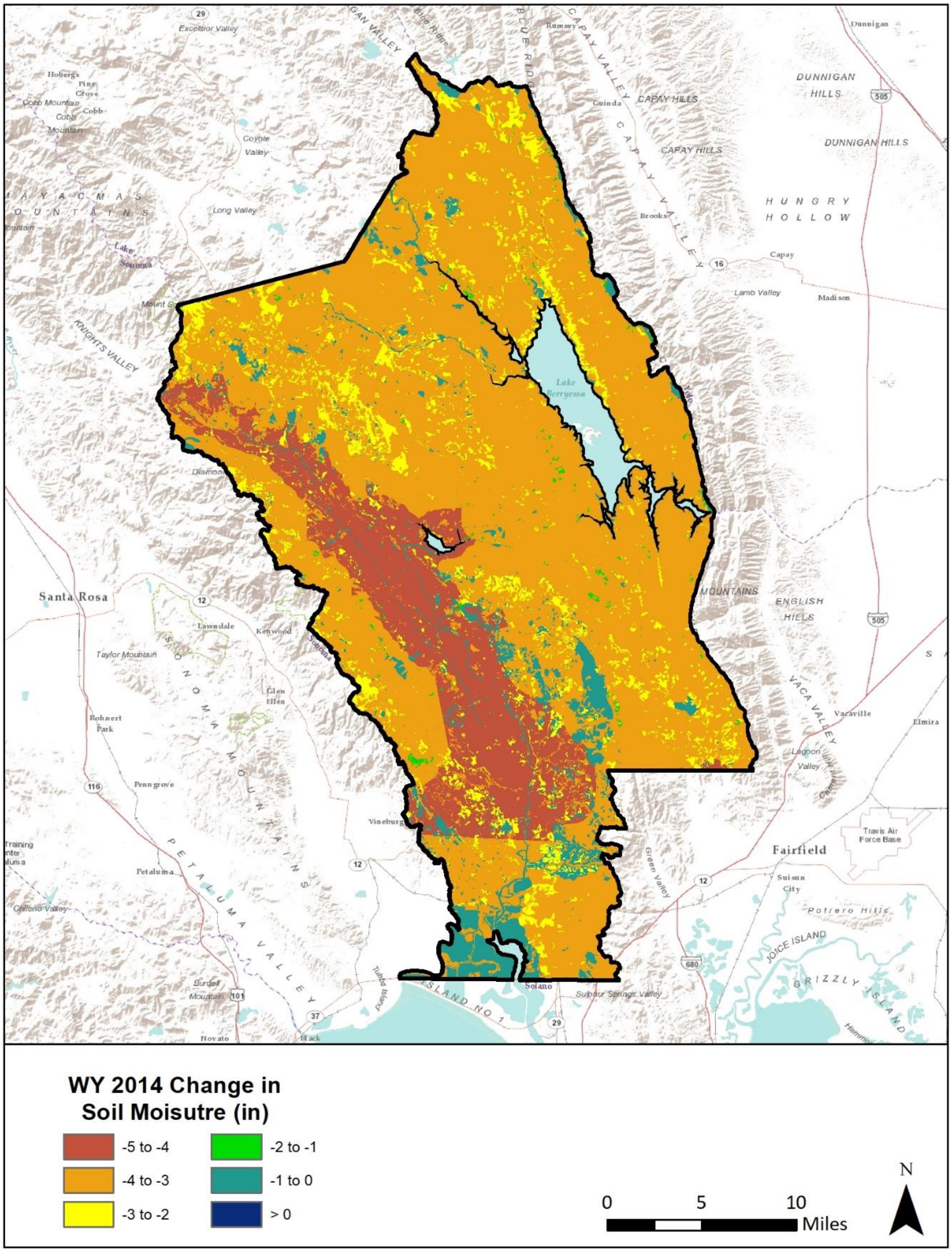

Figure 19: Water Year 2014 change in soil moisture content simulated with the Napa County SWB model.

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%

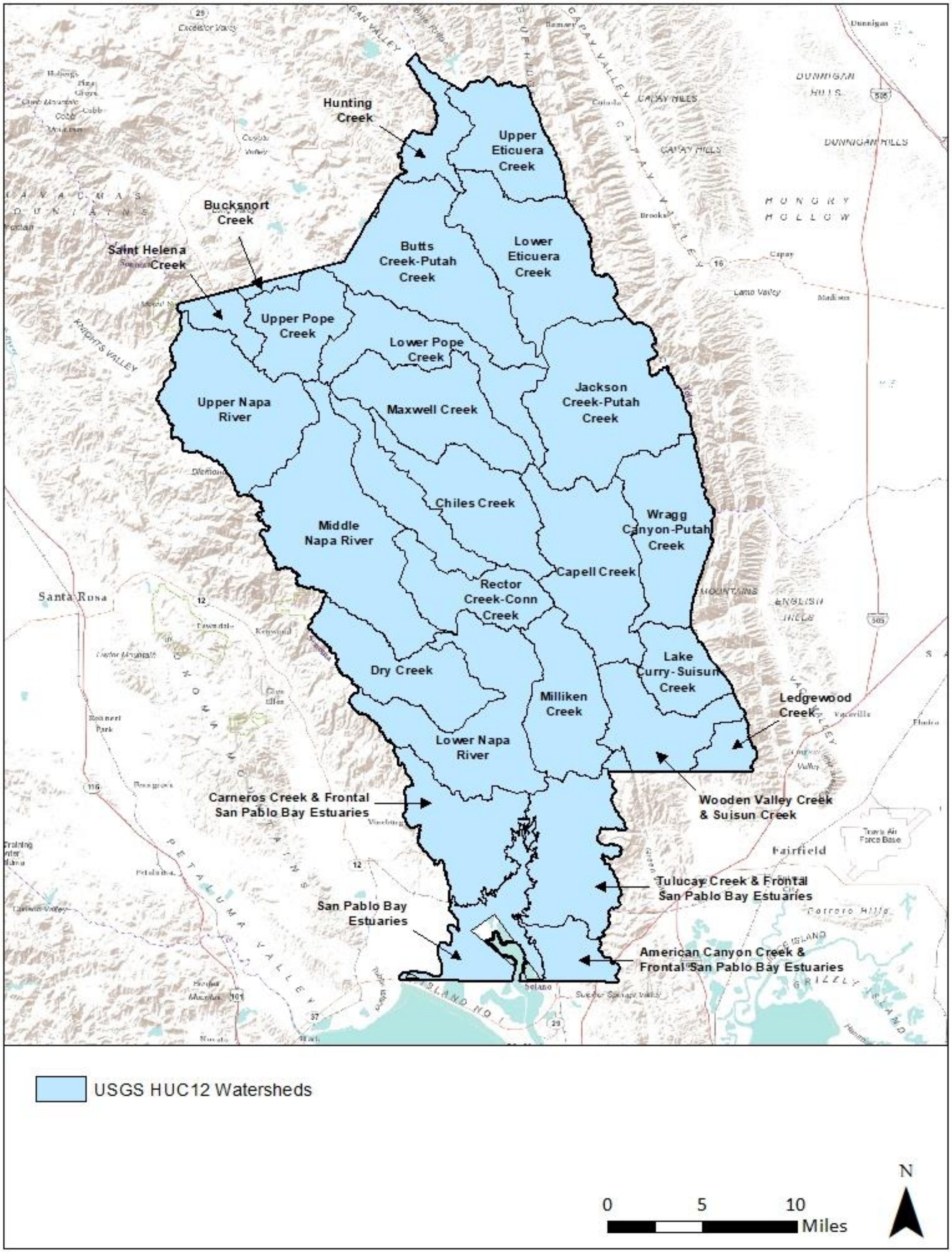

Figure 20: Major watersheds areas used to summarize water budget information in Tables 5 - 8.

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.

References

Cronshey, R., McCuen, R., Miller, N., Rawls, W., Robbins, S., and Woodward, D., 1986. Urban hydrology for small watersheds - TR-55 (2nd ed.), Washington, D.C., U.S. Department of Agriculture, Soil Conservation Service, Engineering Division, Technical Release 55, 164 p.

Eckhardt, K., 2005. How to Construct Recursive Digital Filters for Baseflow Separation. Hydrological Processes 19(2), pgs. 507-515.

Farrrar, C.D., Metzger, L.F., Nishikawa, T., Koczot, K.M., and Reichard, E.G., 2006. Geohydrological Characterization, Water-Chemistry, and Ground-water Flow Simulation Model of the Sonoma Valley Area, Sonoma County, California, U.S. Geological Survey Scientific Investigations Report 2006-5092.

Hargreaves, G.H. and Samani, Z.A., 1975. Reference Crop Evapotranspiration from Temperature. Applied Engineering in Agriculture Volume 1, No. 2, pg 96 – 99.

Healy, R. W., 2010. Estimating Groundwater Recharge. Cambridge University Press. 245 p.

Kobor, J.S., 2017. Sonoma County Groundwater Recharge Analysis. O'Connor Environmental, Inc.

Kobor, J.S., and O'Connor, M., 2016. Integrated Surface and Groundwater Modeling and Flow Availability Analysis for Restoration Prioritization Planning: Green Valley/Atascadero and Dutch Bill Creek Watersheds, prepared by O'Connor Environmental, Inc. for the Gold Ridge Resource Conservation District, 175 pgs.

Lim, K.J., Engel, B.A., Tang, Z., Choi, J., Kim, K., Muthukrishnan, S., and Tripath, D., 2005. Automated Web GIS Based Hydrograph Analysis Tool, WHAT, Journal of the American Water Resources Association, Paper Number 04133, pgs. 1407-1460.

PRISM, 2010. 30 arcsecond resolution gridded total precipitation data for the conterminous United States, PRISM Climate Group, Oregon State University, www.prismclimate.org.

Seiler, K.-P. and Gat, J.R., 2007. Groundwater Recharge from Run-Off, Infiltration and Percolation. Springer. 241 p.

Thornthwaite, C.W., and Mather, J.R., 1957. Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance, Publications in Climatology, v. 10, no. 3, pgs 185-311.

Westenbroek, S.M., Kelson, V.A., Dripps, W.R., Hunt R.J., and Bradbury, K.R., 2010. SWB - A Modified Thornthwaite-Mather Soil-Water-Balance Code for Estimating Groundwater Recharge, U.S. Geological Survey Techniques and Methods 6-A31, 60 pgs.

Woolfenden, L.R., and Hevesi, J.A., 2014. Santa Rosa Plain Hydrologic Model Results, Chapter E in Simulation of Groundwater and Surface-Water Resources of the Santa Rosa Plain Watershed, Sonoma County, California, U.S. Geological Survey Scientific Investigations Report 2014-5052.