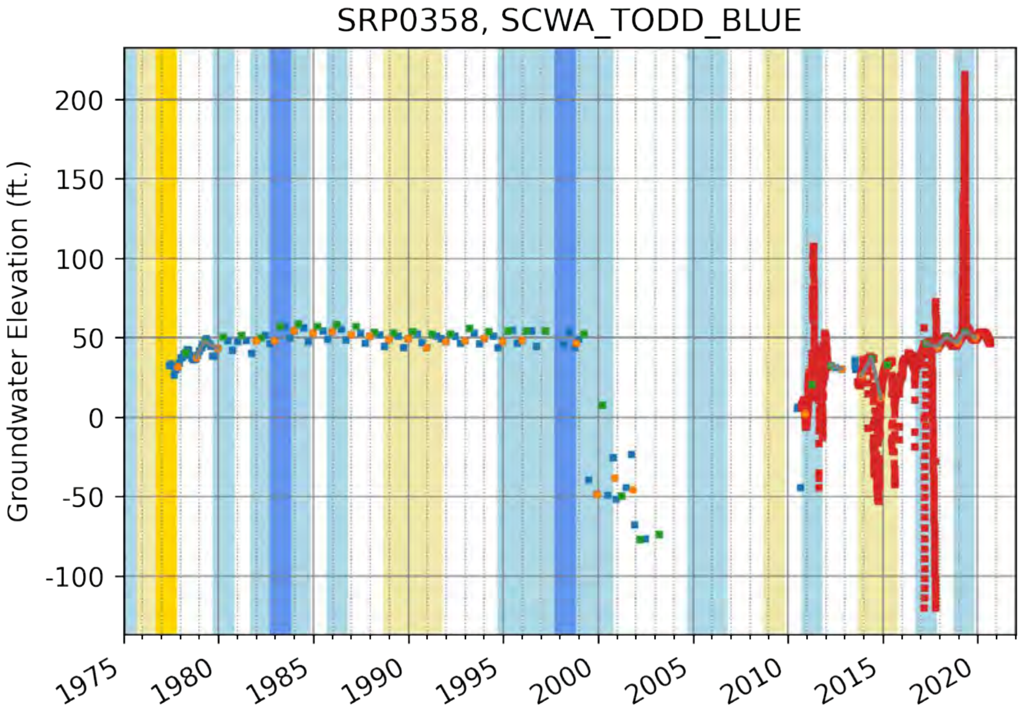
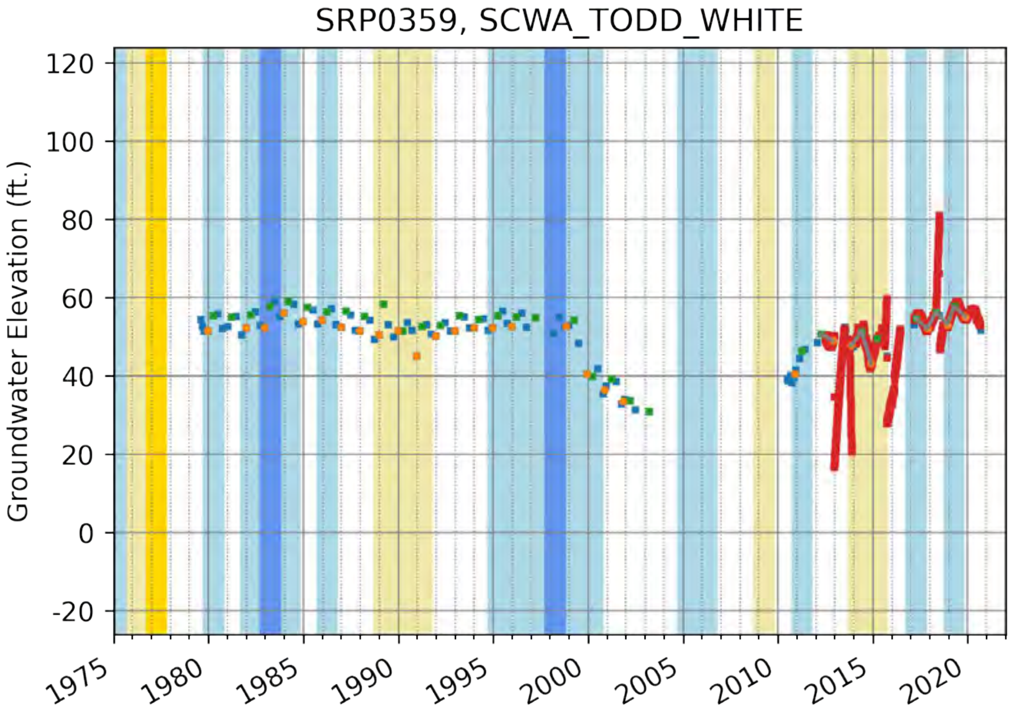
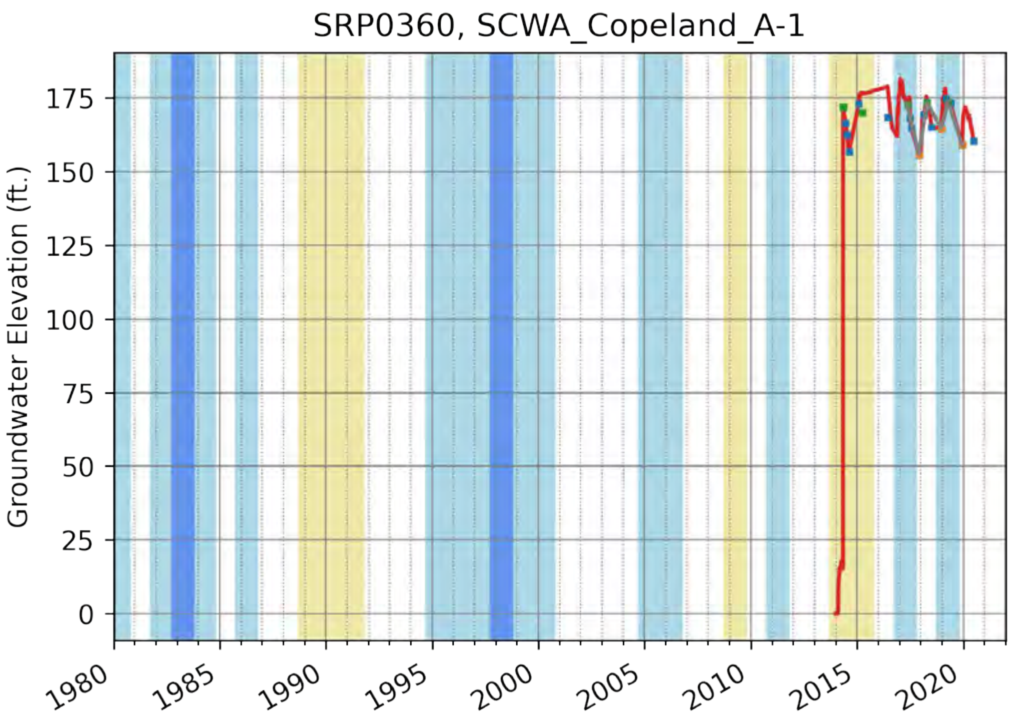
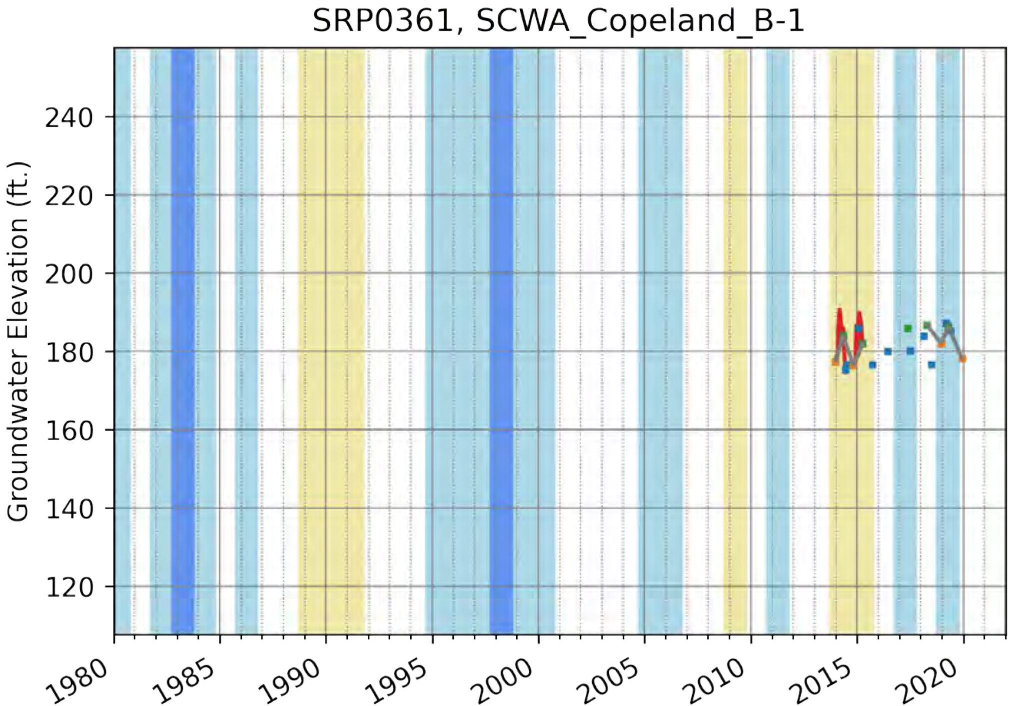


SRP0358, SCWA_TODD_BLUE
Groundwater Elevation (ft.)
200
150
100
50
0
-50
-100
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

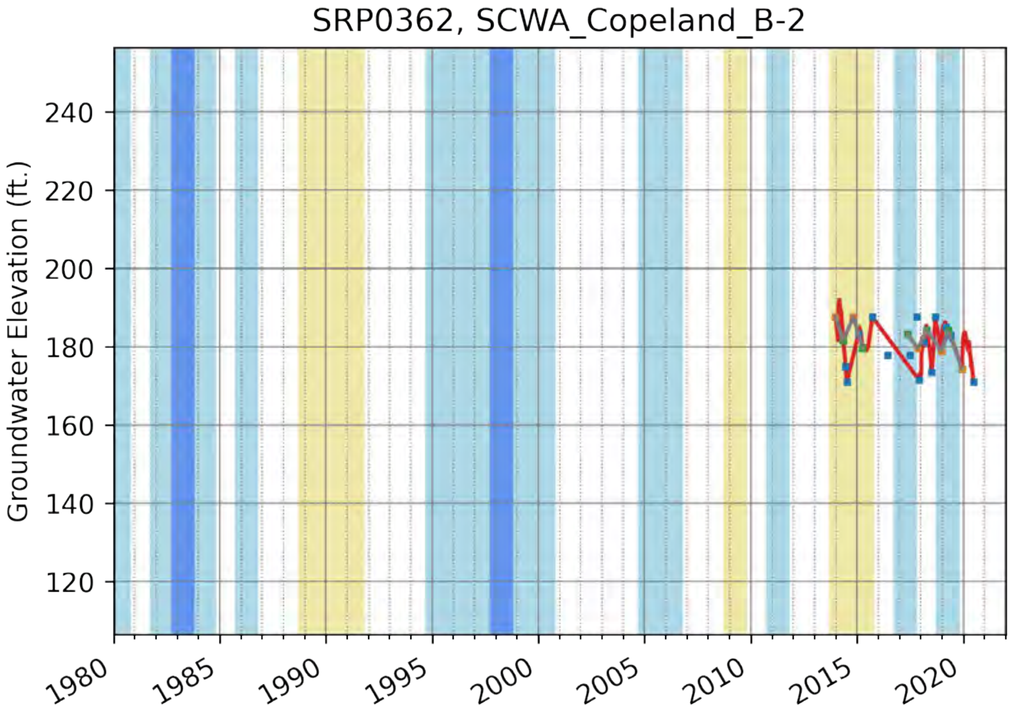

SRP0359, SCWA_TODD_WHITE
Groundwater Elevation (ft.)
120
100
80
60
40
20
0
-20
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

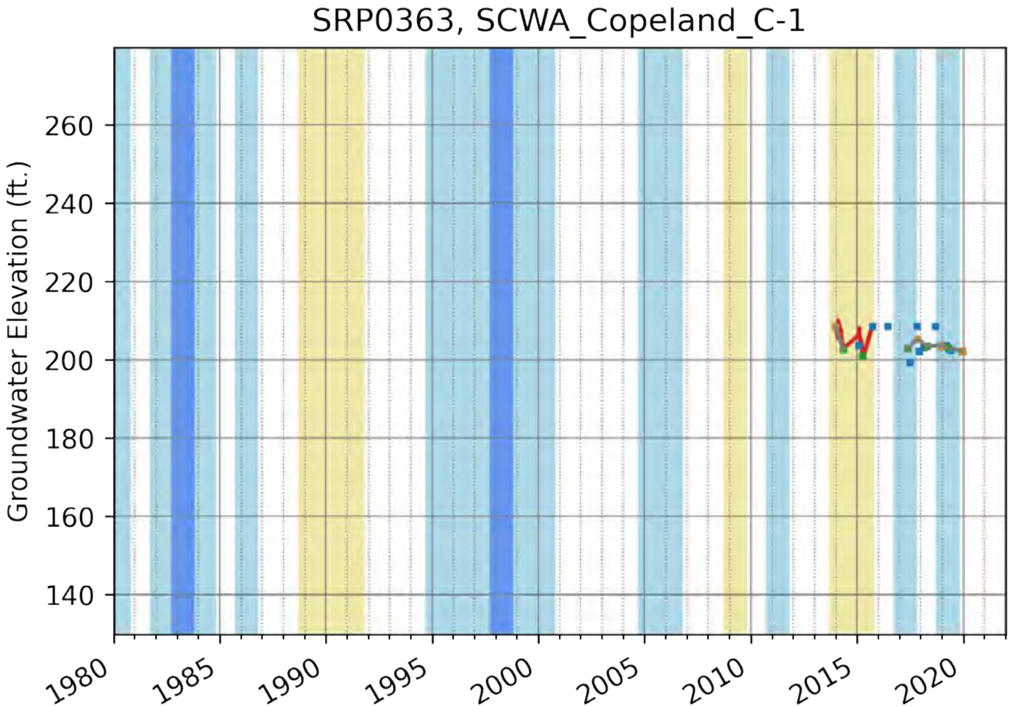


SRP0360, SCWA_Copeland_A-1
Groundwater Elevation (ft.)
175
150
125
100
75
50
25
0
1980
1985
1990
1995
2000
2005
2010
2015
2020

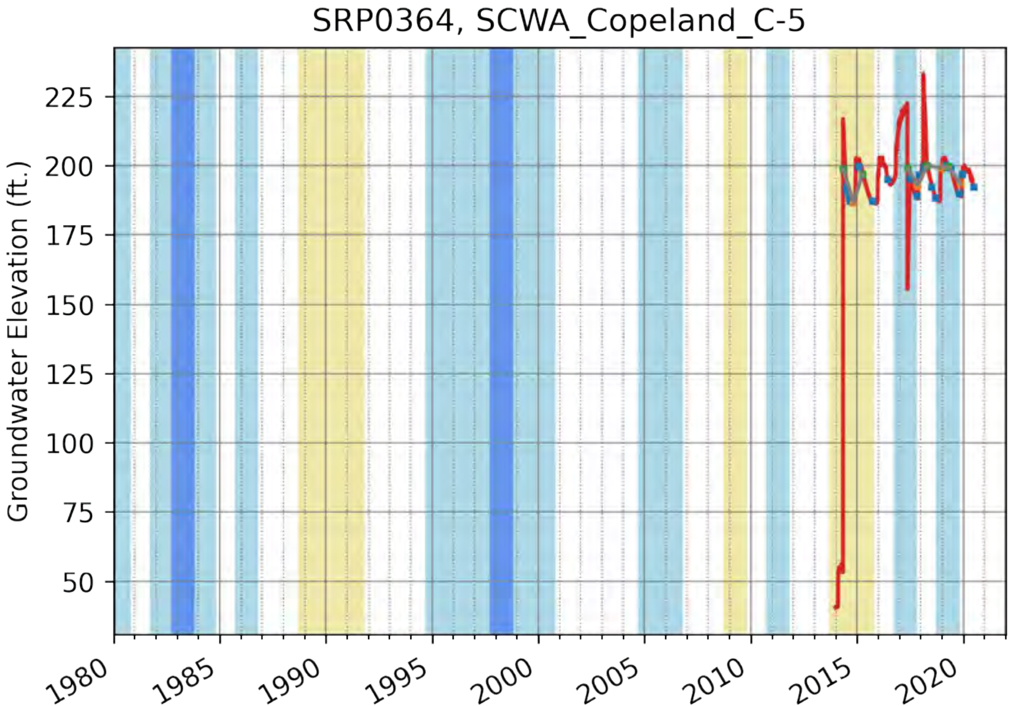


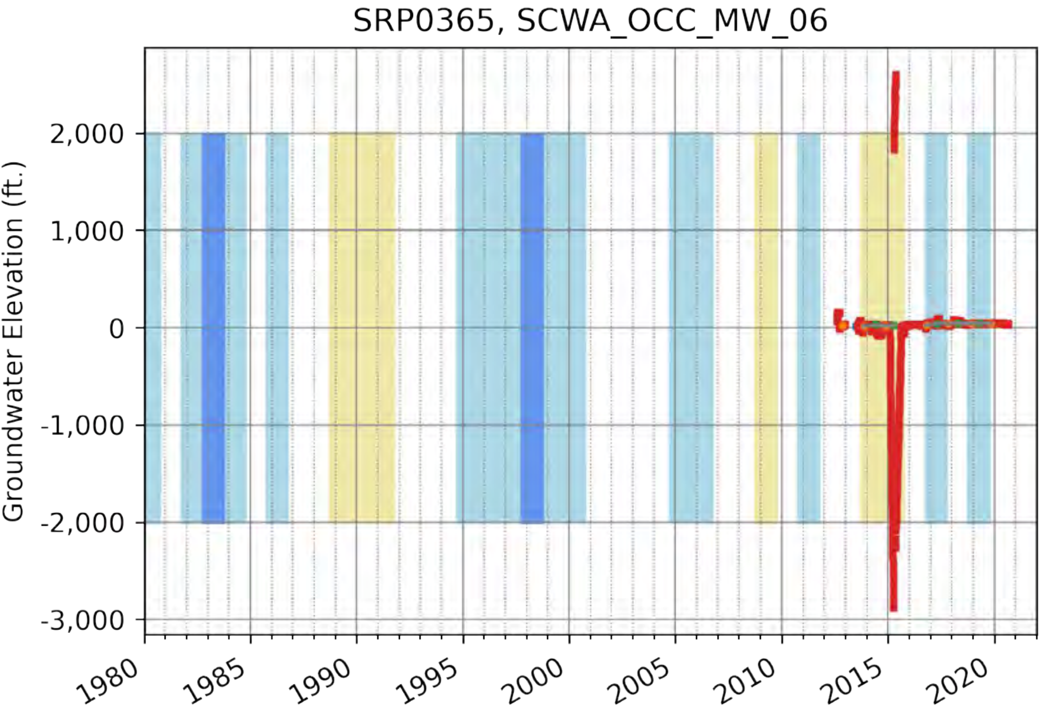
SRP0361, SCWA_Copeland_B-1
Groundwater Elevation (ft.)
240
220
200
180
160
140
120
1980
1985
1990
1995
2000
2005
2010
2015
2020


SRP0362, SCWA_Copeland_B-2
Groundwater Elevation (ft.)
240
220
200
180
160
140
120
1980
1985
1990
1995
2000
2005
2010
2015
2020



SRP0363, SCWA_Copeland_C-1
Groundwater Elevation (ft.)
260
240
220
200
180
160
140
1980
1985
1990
1995
2000
2005
2010
2015
2020


SRP0364, SCWA_Copeland_C-5
Groundwater Elevation (ft.)
225
200
175
150
125
100
75
50
1980
1985
1990
1995
2000
2005
2010
2015
2020



SRP0365, SCWA_OCC_MW_06
Groundwater Elevation (ft.)
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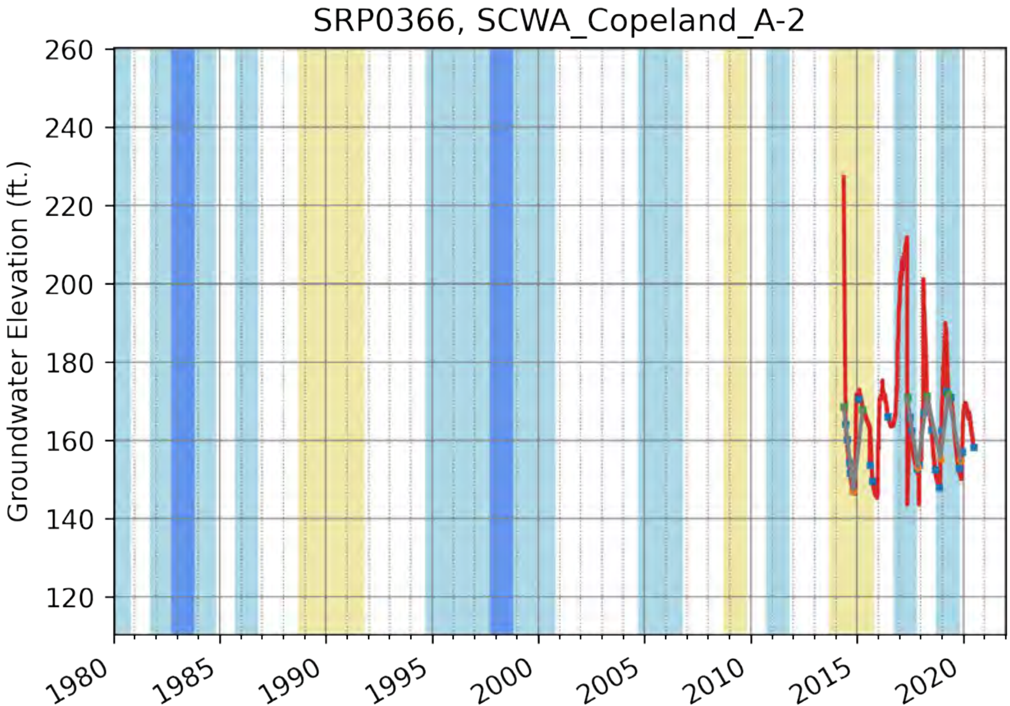
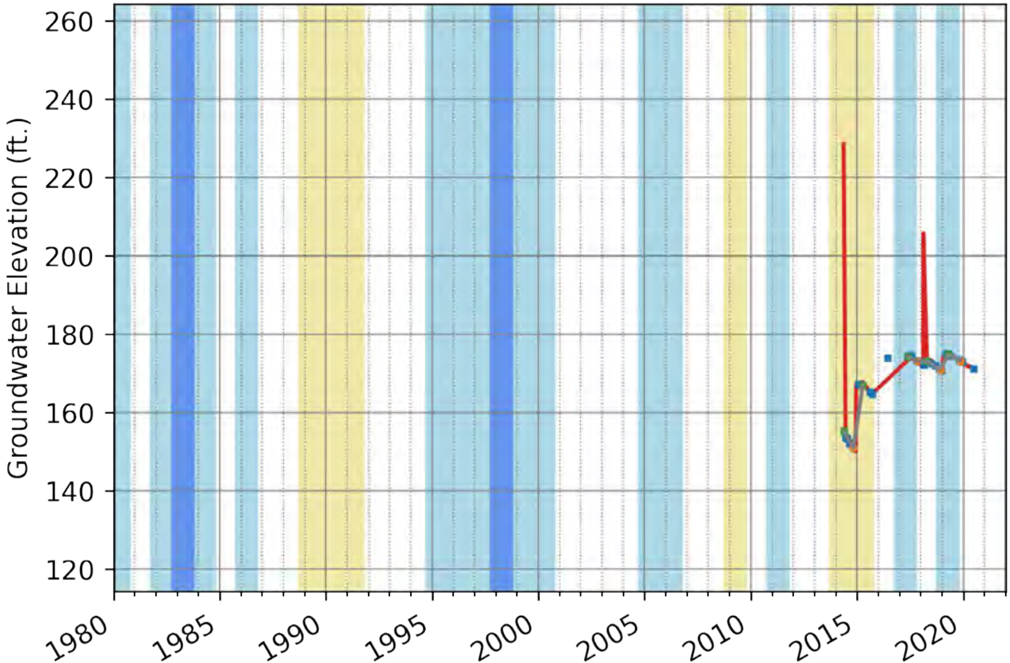
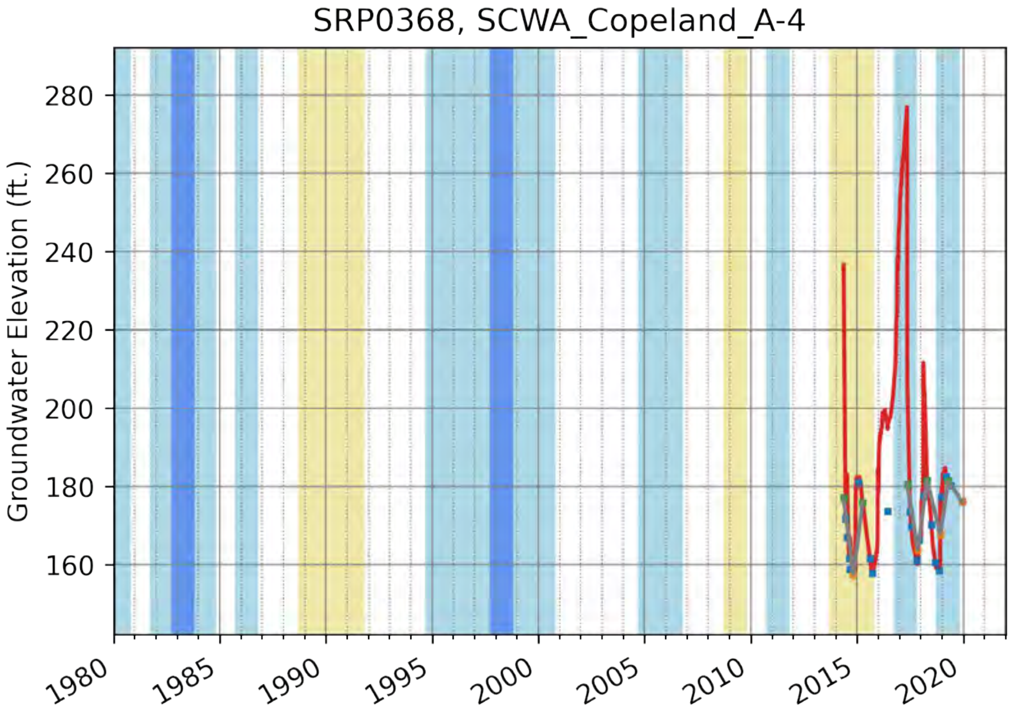
1,000
0
-1,000
-2,000
-3,000
1980
1985
1990
1995
2000
2005
2010
2015
2020

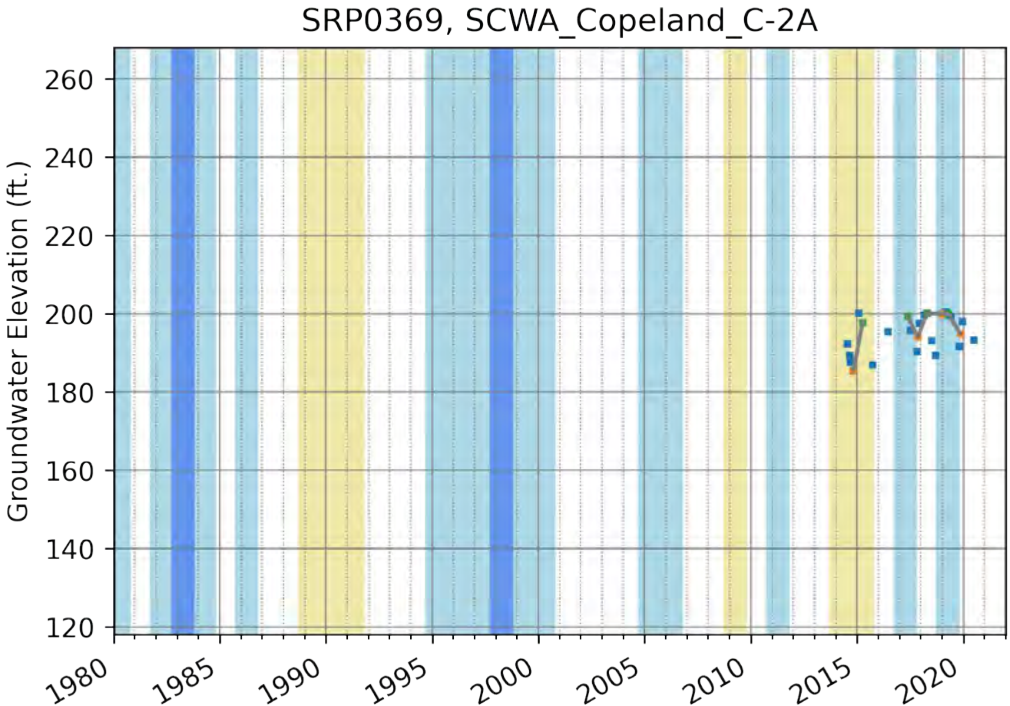


SRP0366, SCWA_Copeland_A-2
Groundwater Elevation (ft.)
260
240
220
200
180
160
140
120
1980
1985
1990
1995
2000
2005
2010
2015
2020

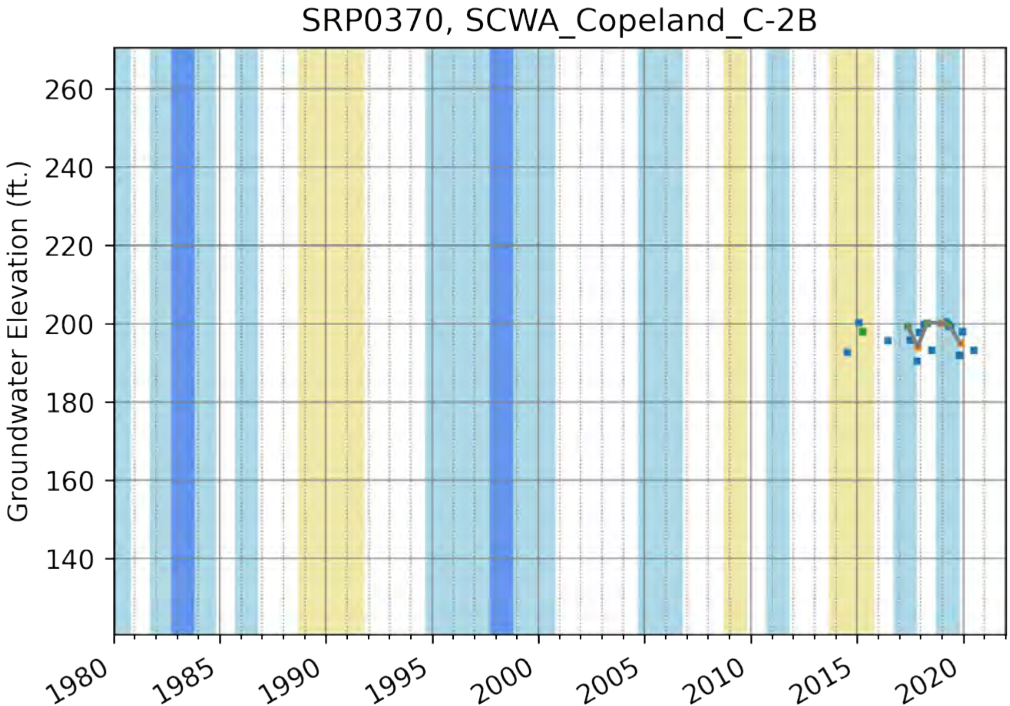
SRP0367, SCWA_Copeland_A-3



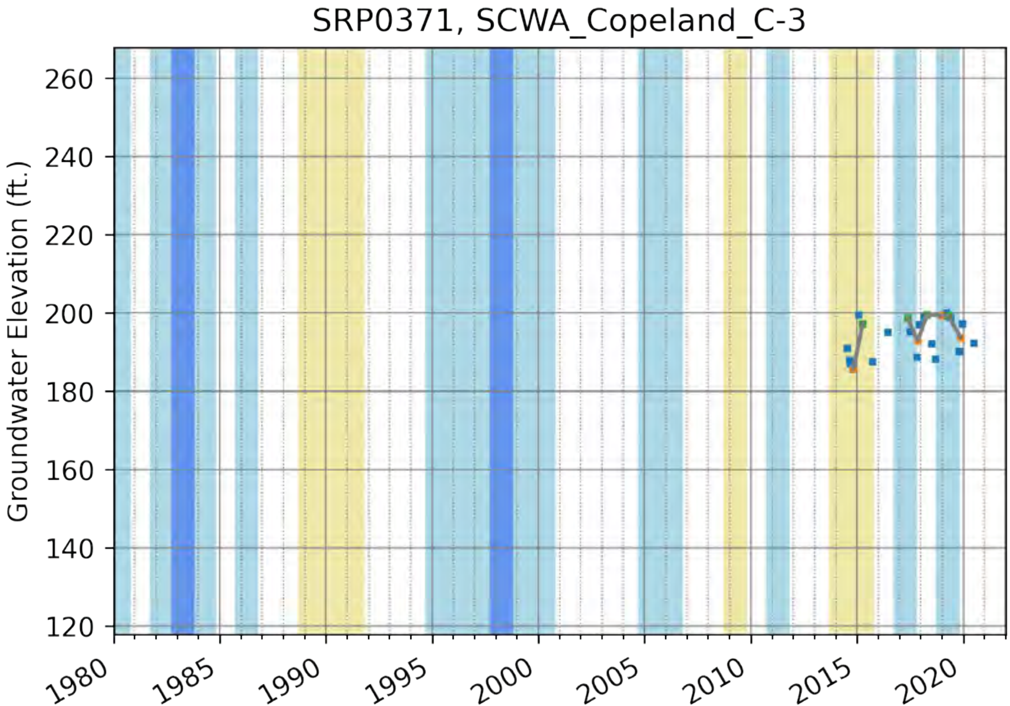

SRP0368, SCWA_Copeland_A-4
Groundwater Elevation (ft.)
280
260
240
220
200
180
160
1980
1985
1990
1995
2000
2005
2010
2015
2020



SRP0369, SCWA_Copeland_C-2A
Groundwater Elevation (ft.)
260
240
220
200
180
160
140
120
1980
1985
1990
1995
2000
2005
2010
2015
2020

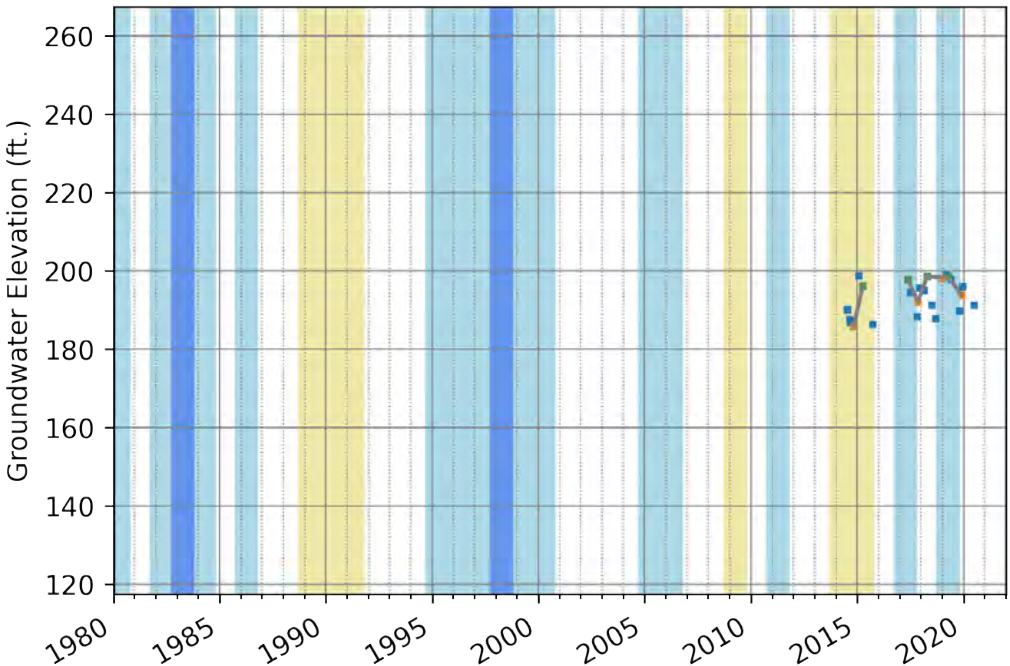


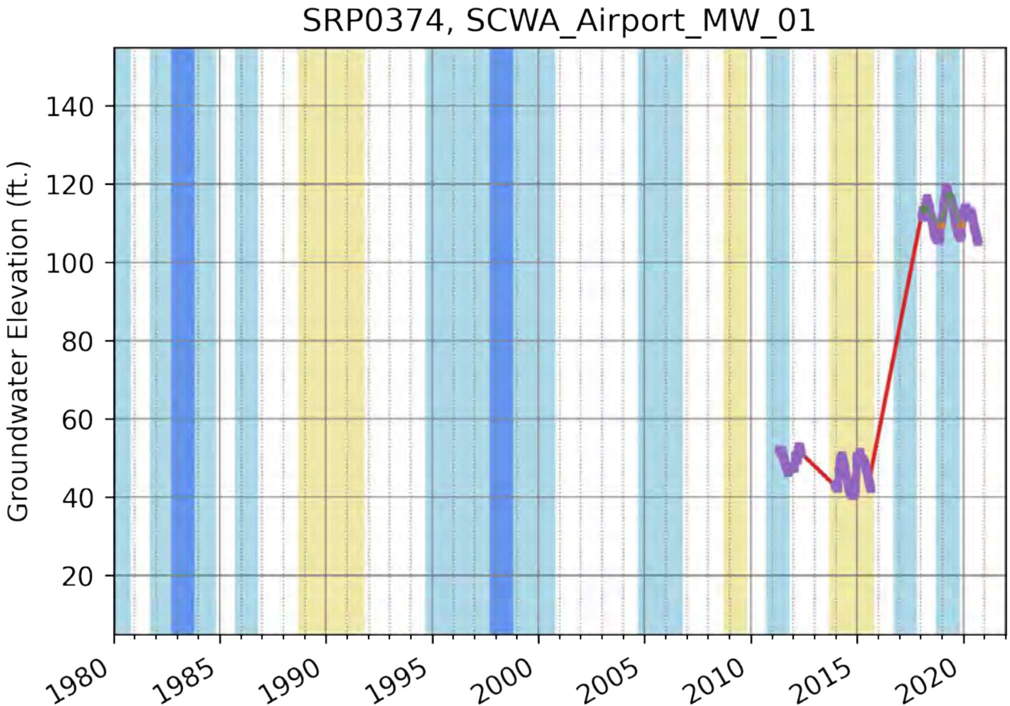
SRP0370, SCWA_Copeland_C-2B
Groundwater Elevation (ft.)
260
240
220
200
180
160
140
1980
1985
1990
1995
2000
2005
2010
2015
2020

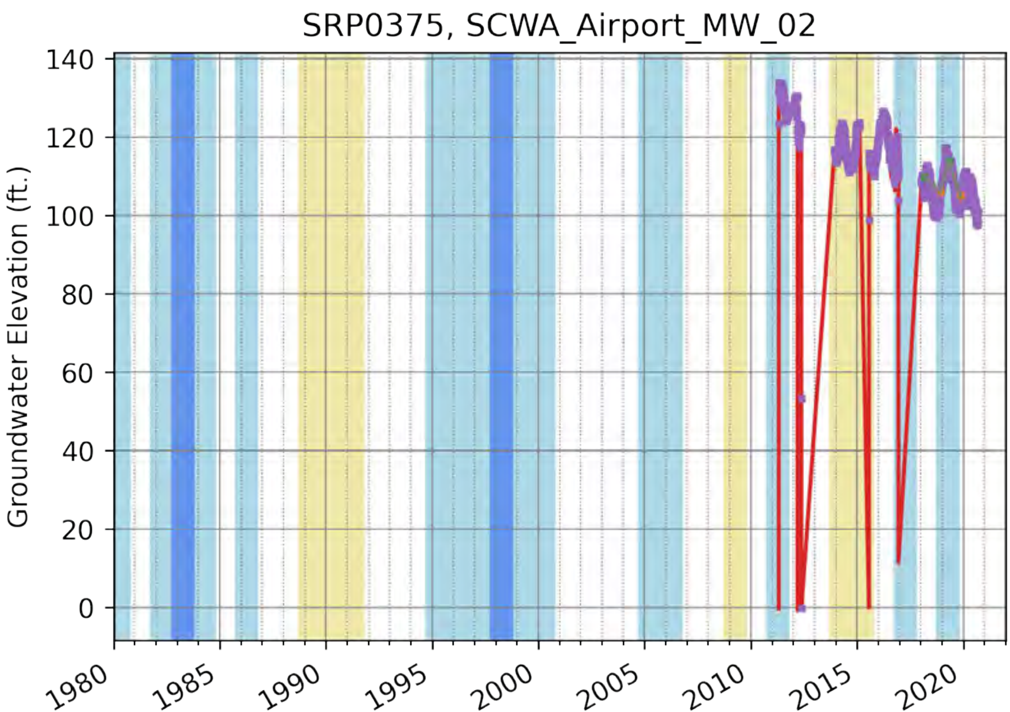


SRP0371, SCWA_Copeland_C-3
Groundwater Elevation (ft.)
260
240
220
200
180
160
140
120
1980
1985
1990
1995
2000
2005
2010
2015
2020

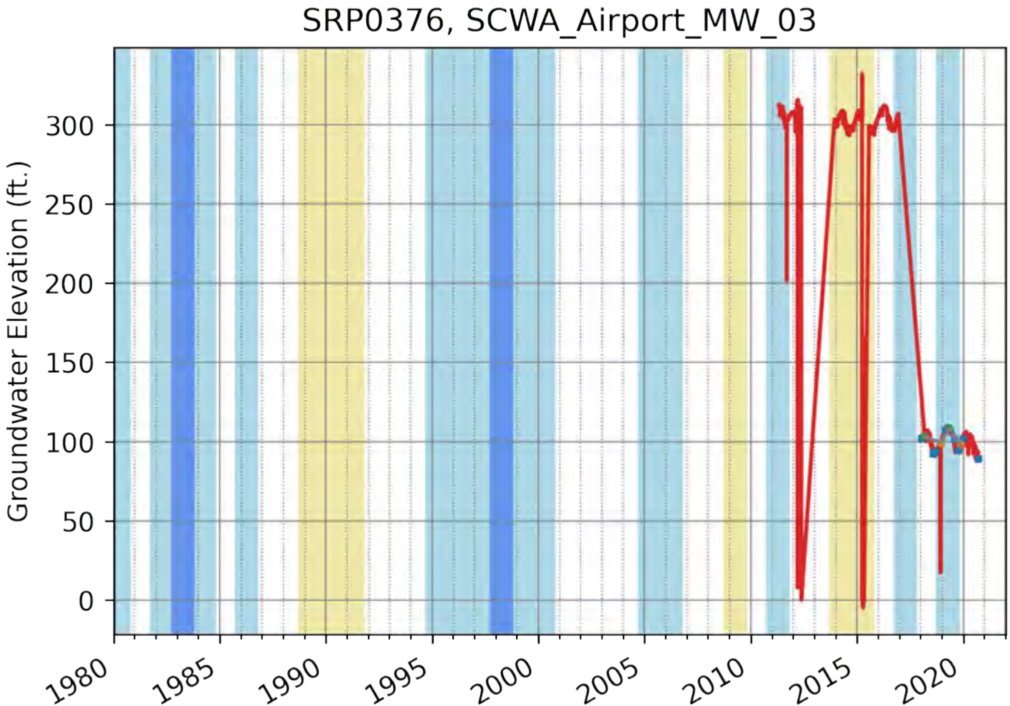
SRP0372, SCWA_Copeland_C-4

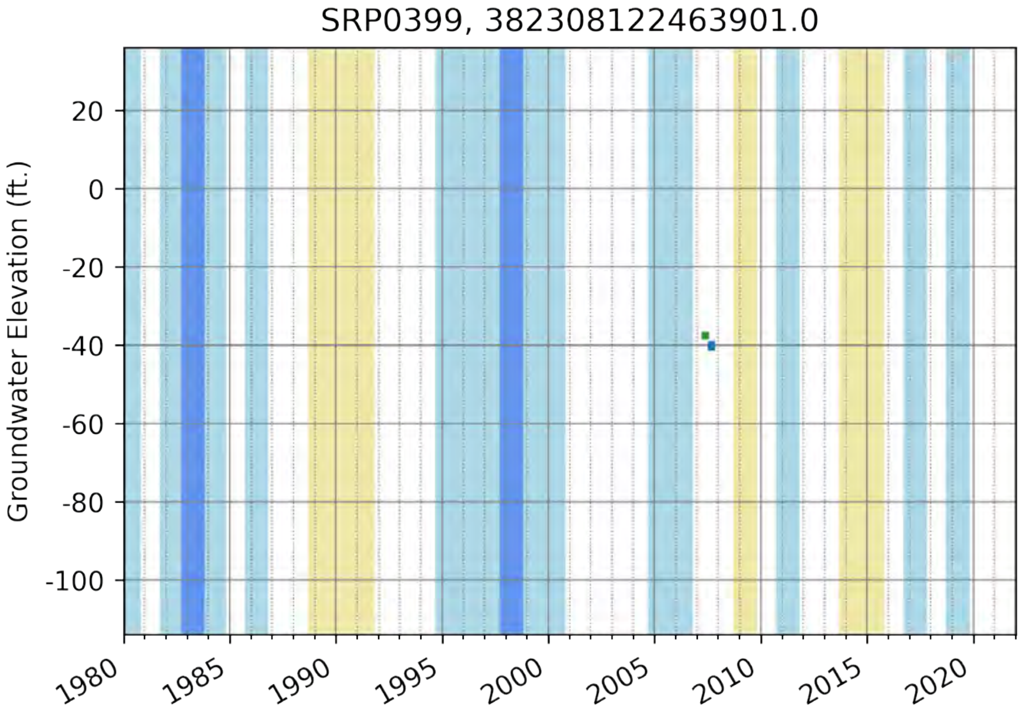



SRP0374, SCWA_Airport_MW_01
Groundwater Elevation (ft.)
20
40
60
80
100
120
140
1980
1985
1990
1995
2000
2005
2010
2015
2020

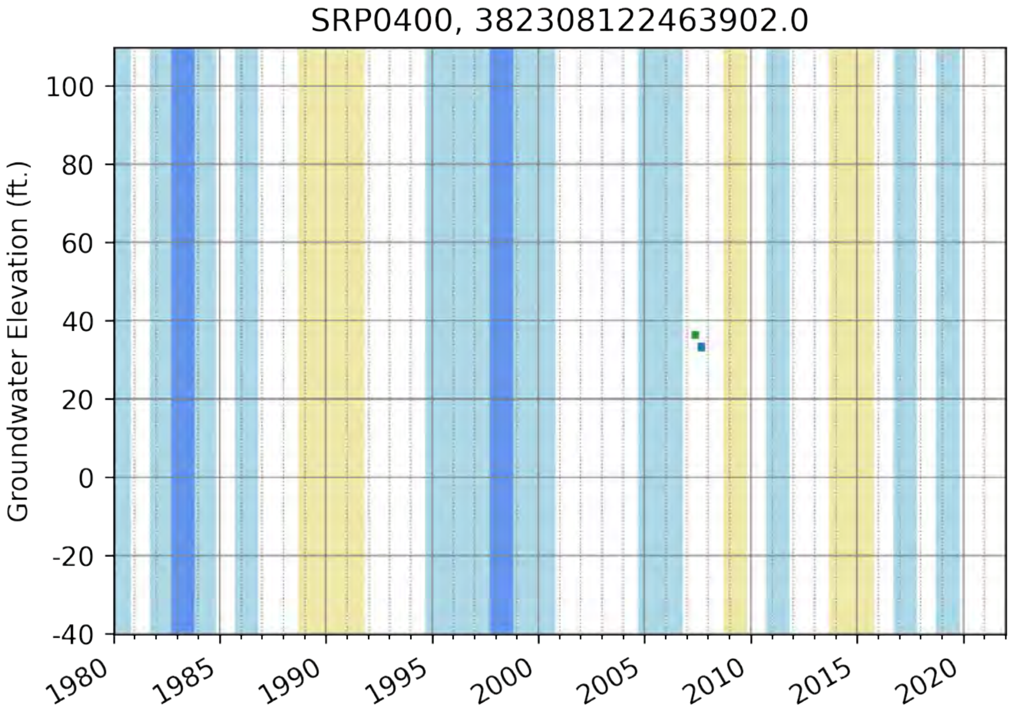


SRP0375, SCWA_Airport_MW_02
Groundwater Elevation (ft.)
140
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
2020

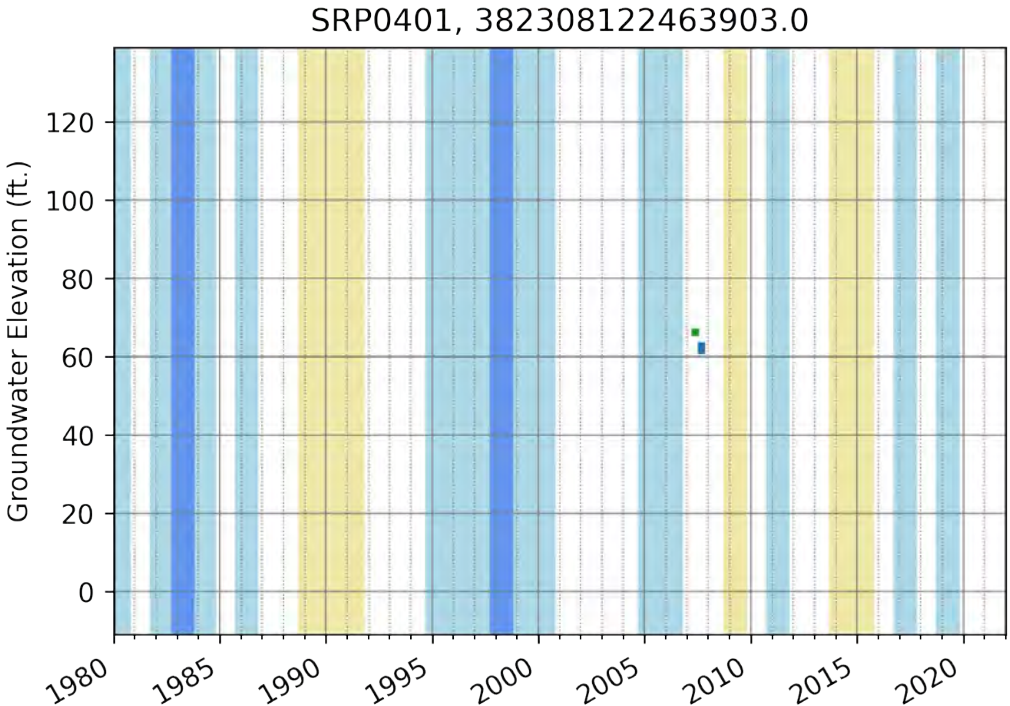

SRP0376, SCWA_Airport_MW_03
Groundwater Elevation (ft.)
300
250
200
150
100
50
0
1980
1985
1990
1995
2000
2005
2010
2015
2020



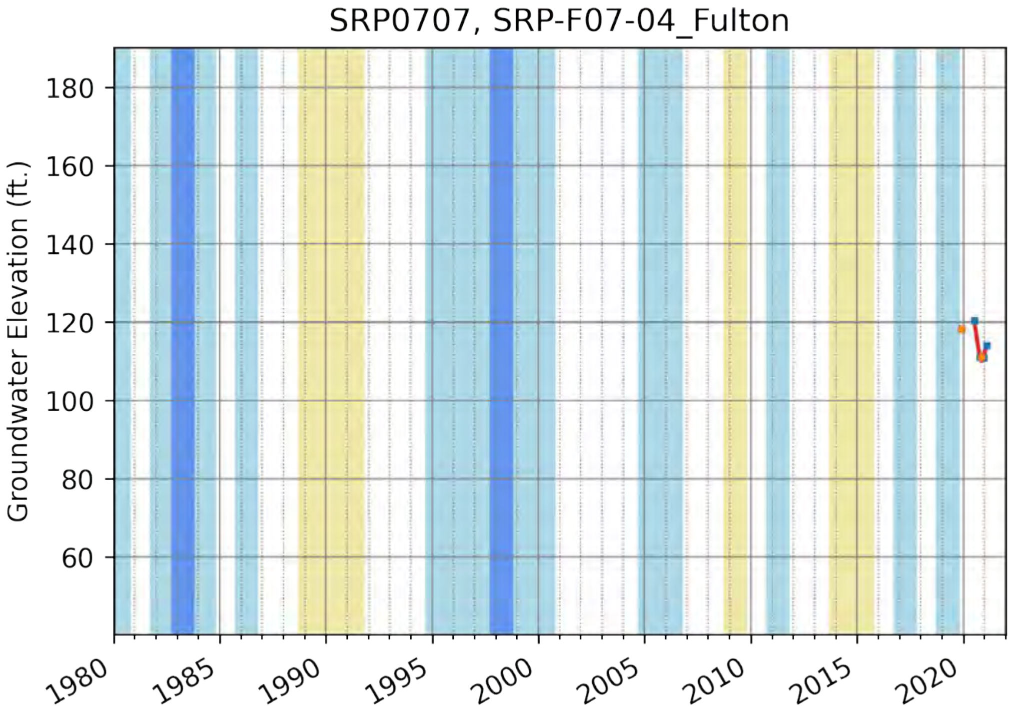
SRP0399, 382308122463901.0
Groundwater Elevation (ft.)
20
0
-20
-40
-60
-80
-100
1980
1985
1990
1995
2000
2005
2010
2015
2020

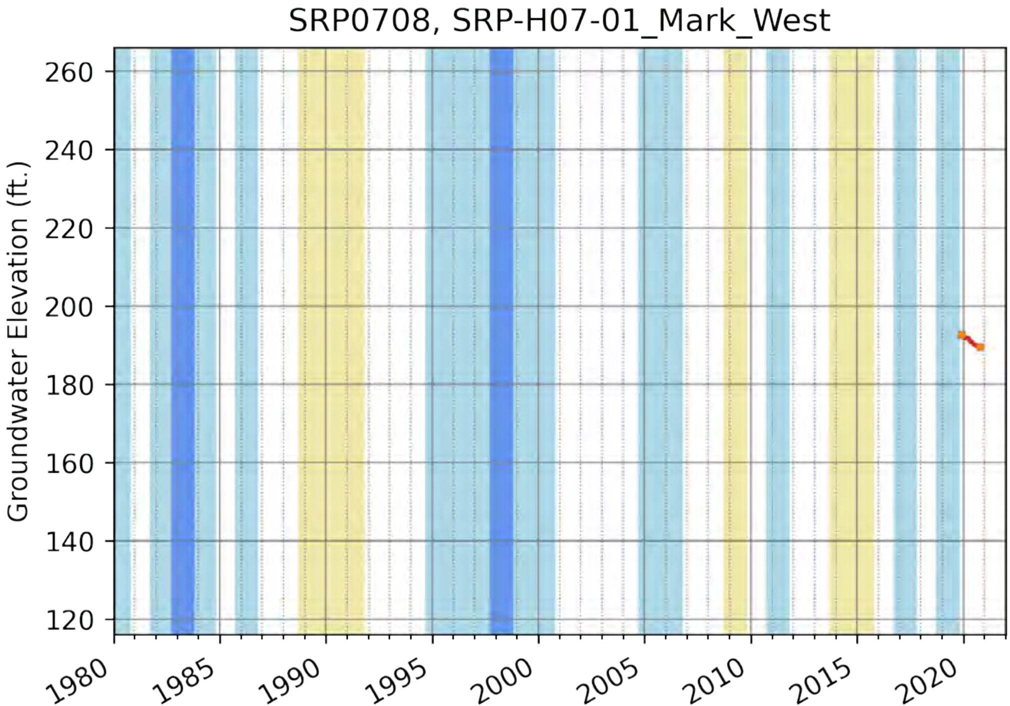


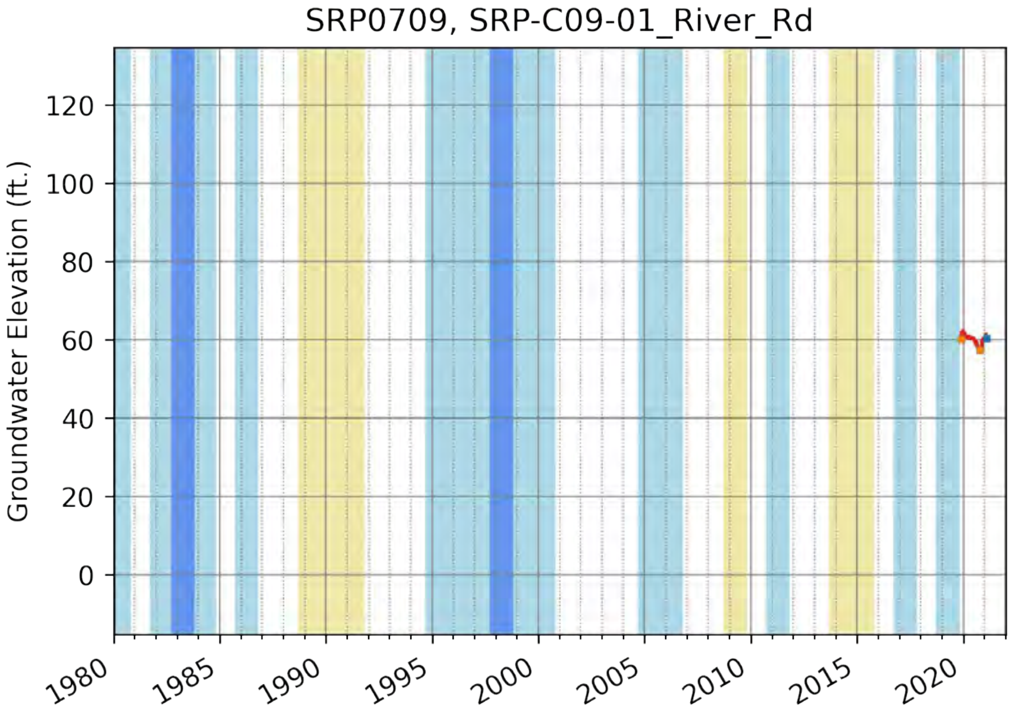
SRP0400, 382308122463902.0
Groundwater Elevation (ft.)
100
80
60
40
20
0
-20
-40
1980
1985
1990
1995
2000
2005
2010
2015
2020



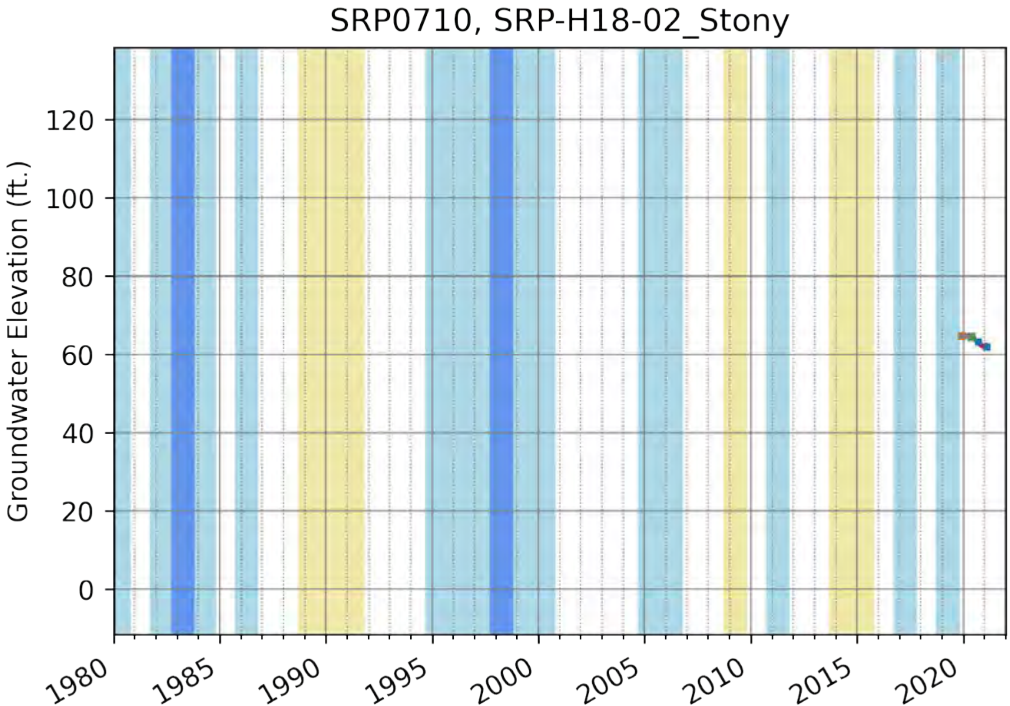
SRP0401, 382308122463903.0
Groundwater Elevation (ft.)
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
2020


SRP0707, SRP-F07-04_Fulton
Groundwater Elevation (ft.)
180
160
140
120
100
80
60
1980
1985
1990
1995
2000
2005
2010
2015
2020

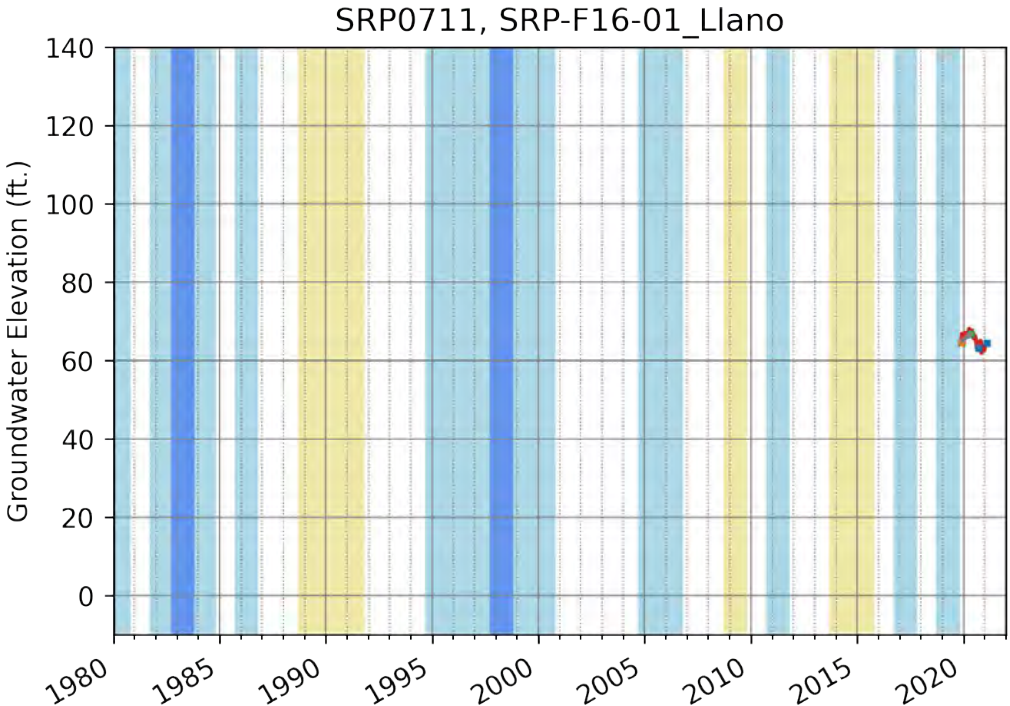

SRP0708, SRP-H07-01_Mark_West
Groundwater Elevation (ft.)
260
240
220
200
180
160
140
120
1980
1985
1990
1995
2000
2005
2010
2015
2020



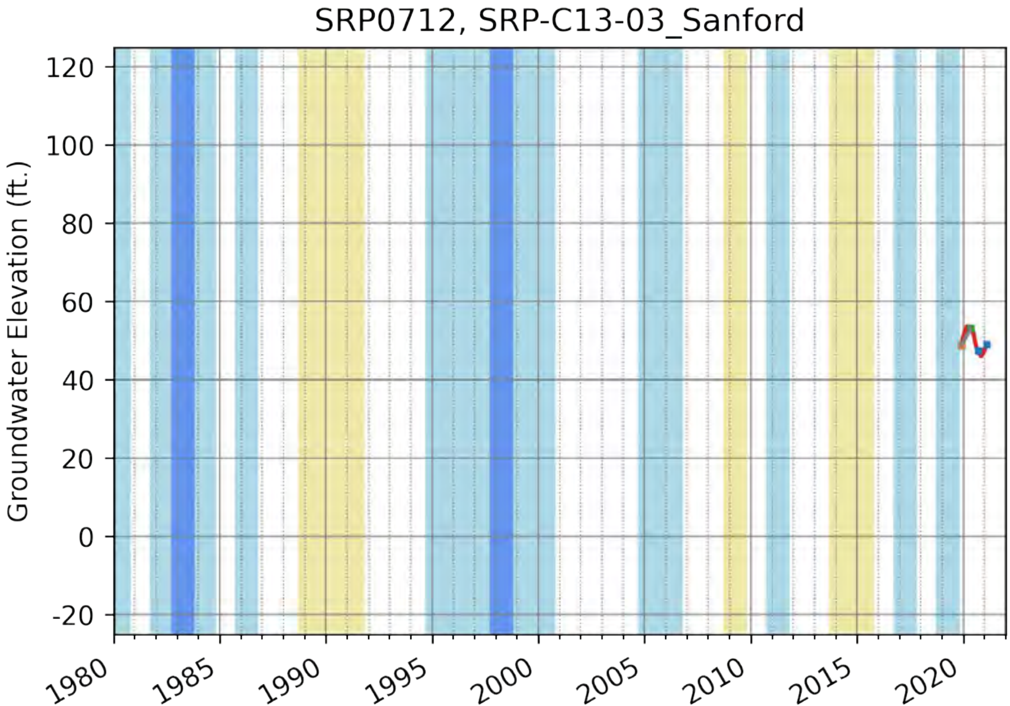
SRP0709, SRP-C09-01_River_Rd
Groundwater Elevation (ft.)
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
2020

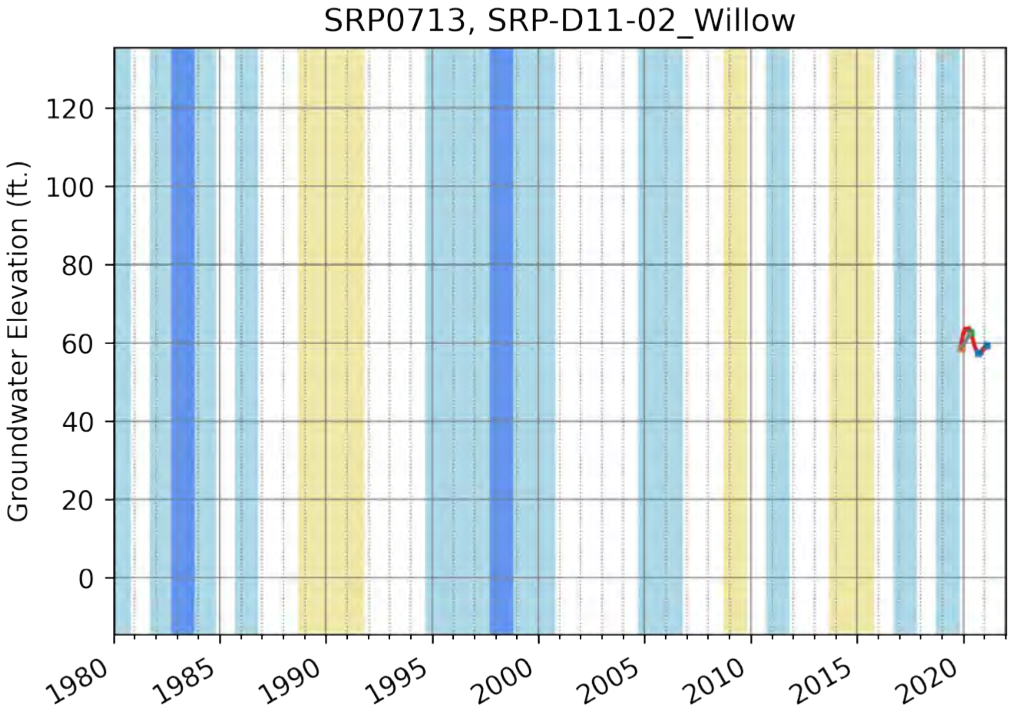


SRP0710, SRP-H18-02_Stony
Groundwater Elevation (ft.)
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
2020

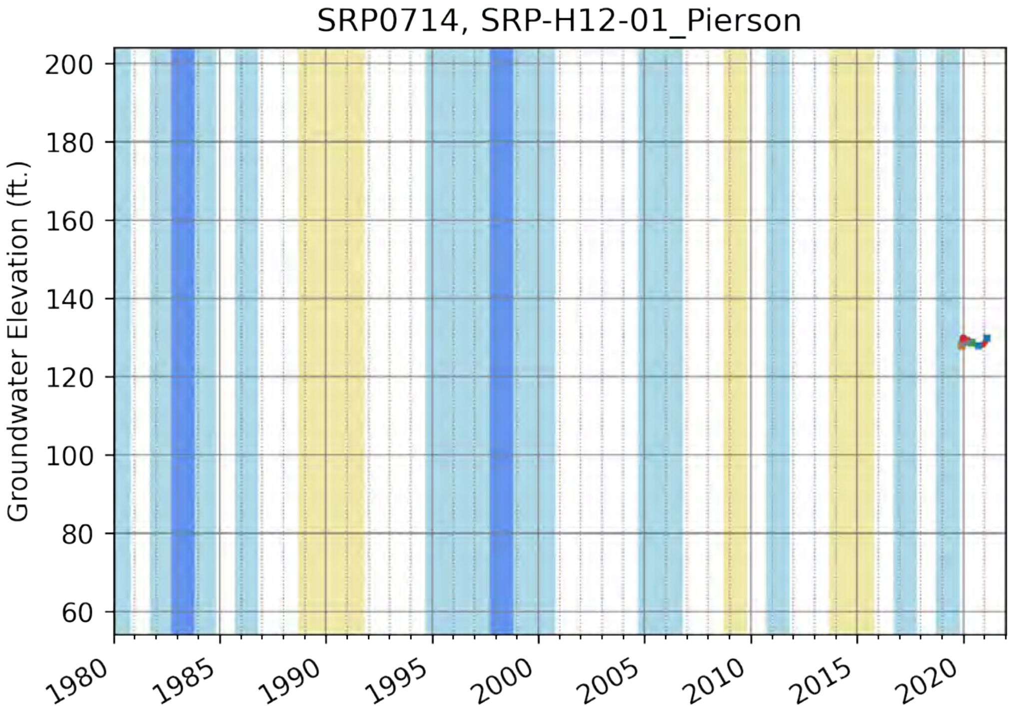


SRP0711, SRP-F16-01_Llano
Groundwater Elevation (ft.)
140
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
2020

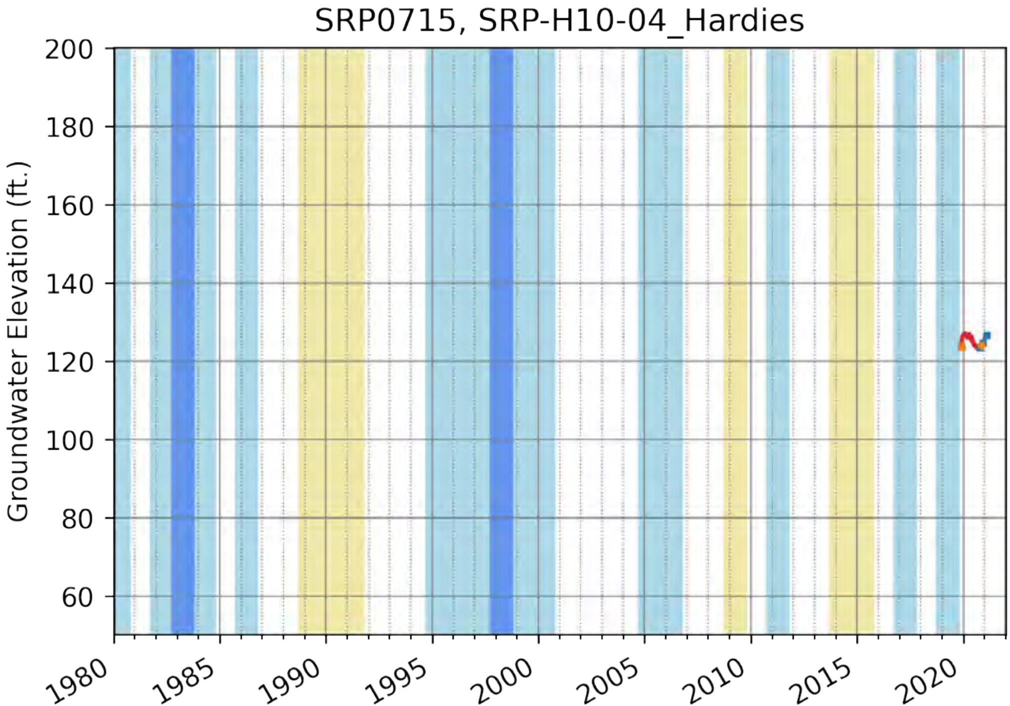

SRP0712, SRP-C13-03_Sanford
Groundwater Elevation (ft.)
120
100
80
60
40
20
0
-20
1980
1985
1990
1995
2000
2005
2010
2015
2020

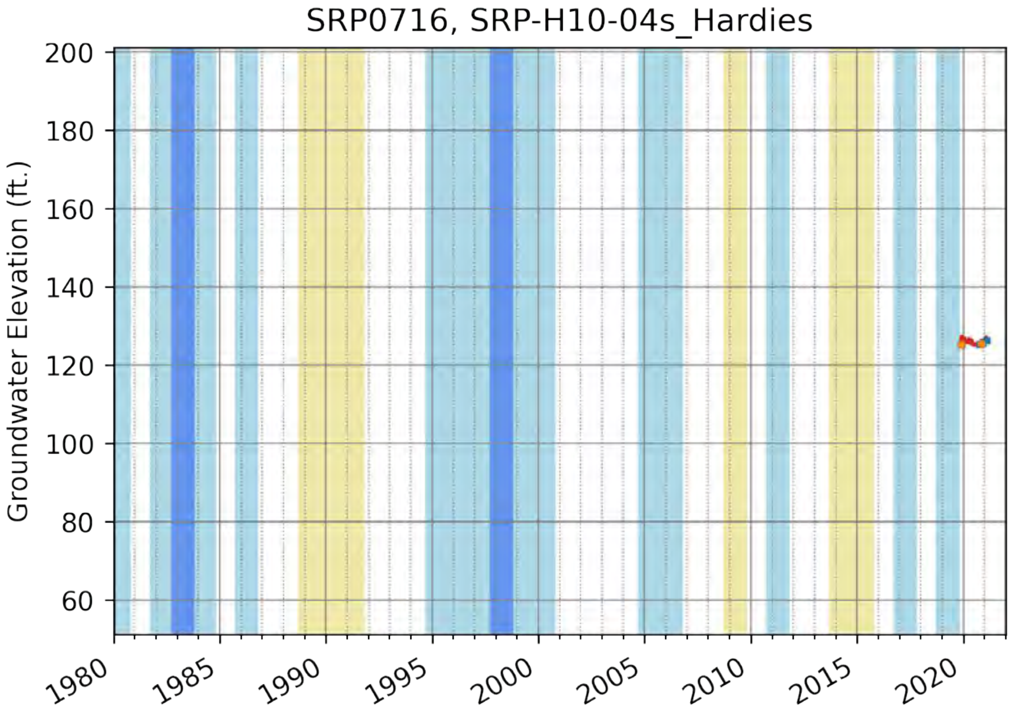


SRP0713, SRP-D11-02_Willow
Groundwater Elevation (ft.)
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
2020



SRP0714, SRP-H12-01_Pierson
Groundwater Elevation (ft.)
200
180
160
140
120
100
80
60
1980
1985
1990
1995
2000
2005
2010
2015
2020


SRP0715, SRP-H10-04_Hardies
Groundwater Elevation (ft.)
200
180
160
140
120
100
80
60
1980
1985
1990
1995
2000
2005
2010
2015
2020


SRP0716, SRP-H10-04s_Hardies
Groundwater Elevation (ft.)
200
180
160
140
120
100
80
60
1980
1985
1990
1995
2000
2005
2010
2015
2020

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Appendix 3-C
Santa Rosa Plain Hydrologic Model (SRPHM) Updates

Figures

Tables

1. Introduction

The Groundwater Sustainability Plan (GSP) development includes the use of a groundwater flow model to compute a basin wide groundwater and surface water budget, to support sustainable management criteria (SMC) development, and to assess the effects of proposed projects and management actions on overall basin sustainability.
The U.S. Geological Survey (USGS) has developed an integrated surface water/groundwater flow model that encompasses the Santa Rosa Plain watershed and the groundwater basin. The Santa Rosa Plain Hydrologic Model (SRPHM) was released in 2014 and included a simulation period from 1975 through 2010. The USGS performed further revisions to the model in 2019 that were provided to the GSP model team. These revisions included a temporal update through 2015 and modification of input file structure (SRPHM 1.0). Further revisions to the model made by the GSP model team are documented herein as version SRPHM 1.0+. These revisions include:

- further temporal extension of the model through December, 2018;
- changes to agricultural pumping estimates;
- changes to rural domestic pumping estimates;
- updates to public water supply well pumping
- revisions to the representation of climate and recycled water; and
- incorporation of septic return flows

1.1 General Description of Model

The SRPHM is an integrated groundwater-surface water hydrologic and watershed model of the Santa Rosa Plain Watershed (262 square miles), inclusive of the entire Santa Rosa Plain[1] and Rincon Valley groundwater subbasins, and portions of the Kenwood Valley, Wilson Grove Formations Highlands, Healdsburg area, and Alexander area groundwater subbasins. The watershed, groundwater basin, and model domain boundary are show in Figure 1. SRPHM was developed using the USGS groundwater and surface water model, GSFLOW (McLaughlin et al., 2008), which consists of two integrated model components: (1) a watershed hydrology model based on the Precipitation Runoff Modeling System (PRMS) (Leavesly et al, 1983, 2005) and (2) a groundwater-surface water model developed using MODFLOW-NWT (MF-NWT) (Niswonger et al., 2011). Additionally, a decoupled soil-moisture balance model, the Crop Water Demand Model (CWDM), was used with the original USGS model to estimate crop irrigation pumping demands; this has been replaced with the recently developed Ag Package (Niswonger, 2020), as further described in Section 1.2.2 below. Figure 2 shows a schematic representation of the interaction between the different model components for the current updated version of the model (SRPHM 1.0+). For a detailed description of the conceptualization, parameterization, calibration and development of the original USGS model, the reader is referred to USGS Scientific Investigation Report 2014-5052 (Wolfenden and Nishikawa, 2014).

[1] Two slivers of the recently modified (expanded) DWR Bulletin 118 Santa Rosa Plain basin boundary are not covered by the model domain (154 acres near Sebastopol and 113 acres south of Healdsburg). Combined, these excluded slivers make up only 0.3% of the total Subbasin area of 81,284 acres.

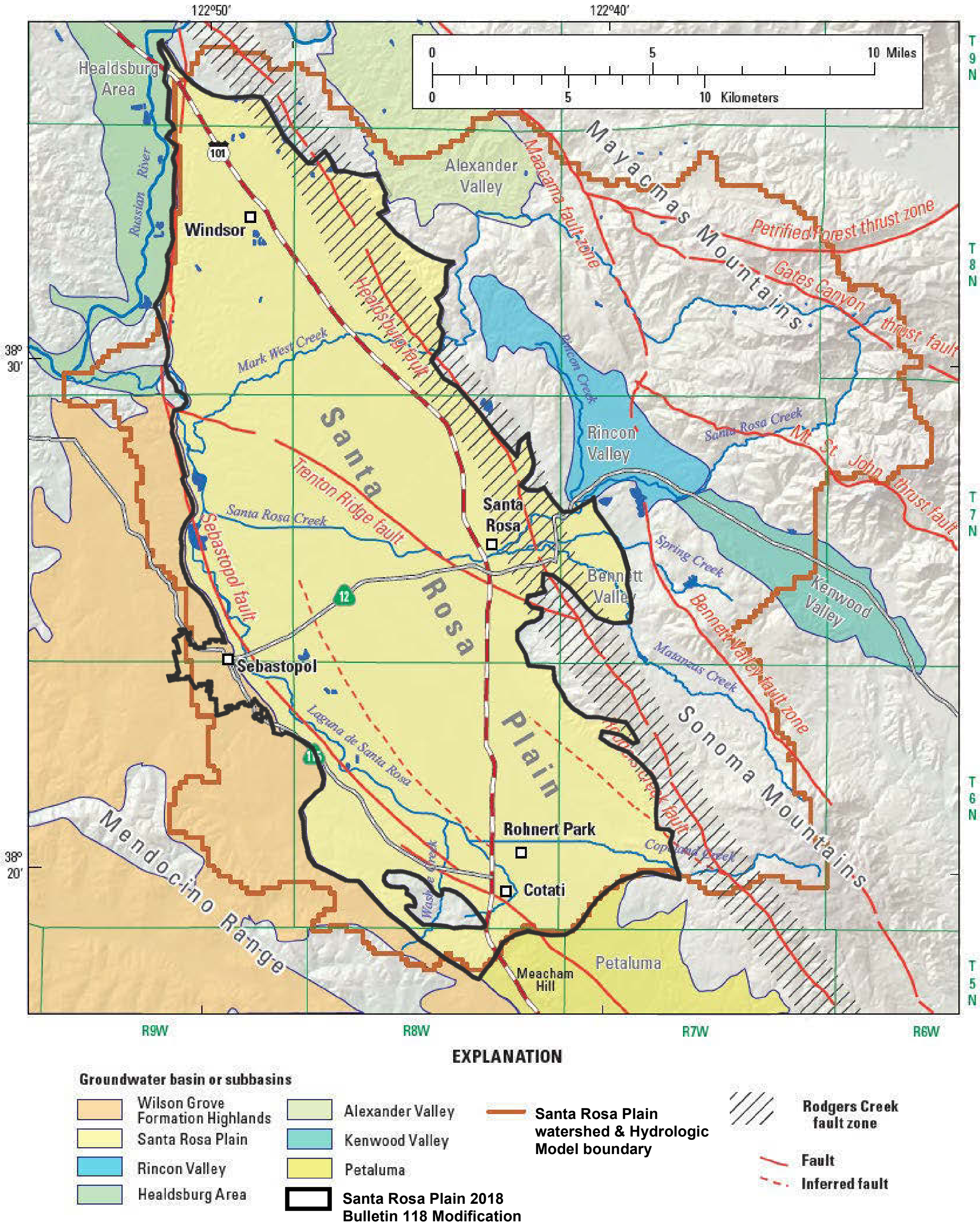


Figure 1. Santa Rosa Plain Hydrologic Model (SRPHM) Area (modified from USGS, 2013)

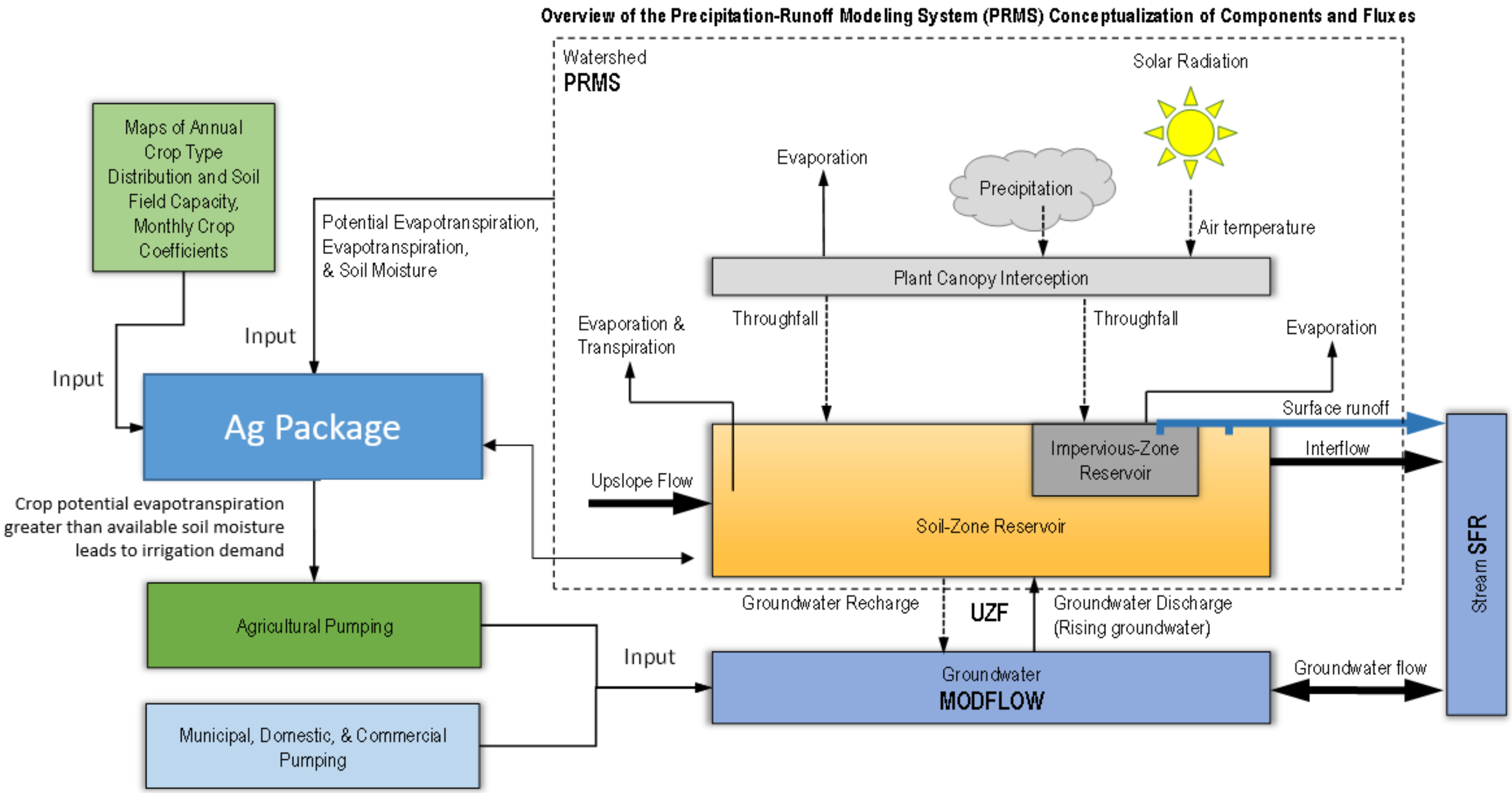


Figure 2. SRPHM conceptual model of interactions between Ag Package, PRMS, and MODFLOW

1.2 Rural Pumping Updates

The groundwater demand for rural pumping (rural pumpage) consists of the combined total of pumping to meet rural residential supply and unmet agricultural irrigation demand. As neither rural residential or agricultural pumping are commonly measured or reported, the USGS estimated these groundwater demands on the basis of estimates of rural population density and an average per-capita water usage, and by using the CWDM soil moisture balance model to estimate crop-specific irrigation demand.

1.2.1 Rural Residential Water Demand

1.2.1.1 Original USGS approach

The model assumed that rural residents outside the city limits of Santa Rosa, Rohnert Park, Cotati, Sebastopol, California American Water Company, and Town of Windsor rely entirely on groundwater. Census tract polygons and population density data were used to estimate the areas and population not serviced by public supply wells. By definition, the census tracts report a single population number which results in an assumption of homogeneous spatial population density within each tract. This caused an overestimate of the population density at the interface of the urban and rural areas within a census tract, which would result in an overestimation of pumping. An annual water demand of 0.19 acre-feet per capita per year (170 gallons per capita per day, gpcd) was assumed. The source of this value was referenced as being based on data from the 1994 California Water Plan Update (DWR, 1994).

1.2.1.2 Updated approach

Rural residential parcels identified in the Rate Study were used to locate parcels in the Santa Rosa Plain utilizing groundwater for domestic purposes (Raftelis, 2019). These include some parcels within city limits identified by their respective water service providers. The Sonoma County parcel database was filtered to locate rural residential parcels outside of the groundwater basin but within the groundwater model domain. The locations of parcels incorporated into the model are shown in Figure 3, as well as the indoor and outdoor water use by parcel. A total of 11,943 parcels are included within the entire model domain and 7,482 parcels are within the Subbasin, of which 1,282 wells are urban users in the Subbasin (Table 1). The 2019 Rate Study (Raftelis, 2019) cited a lower number of total residential groundwater users of 6,627 parcels. The discrepancy appears to be due to the Rate Study database being updated following the publication of the report to account for urban well users.

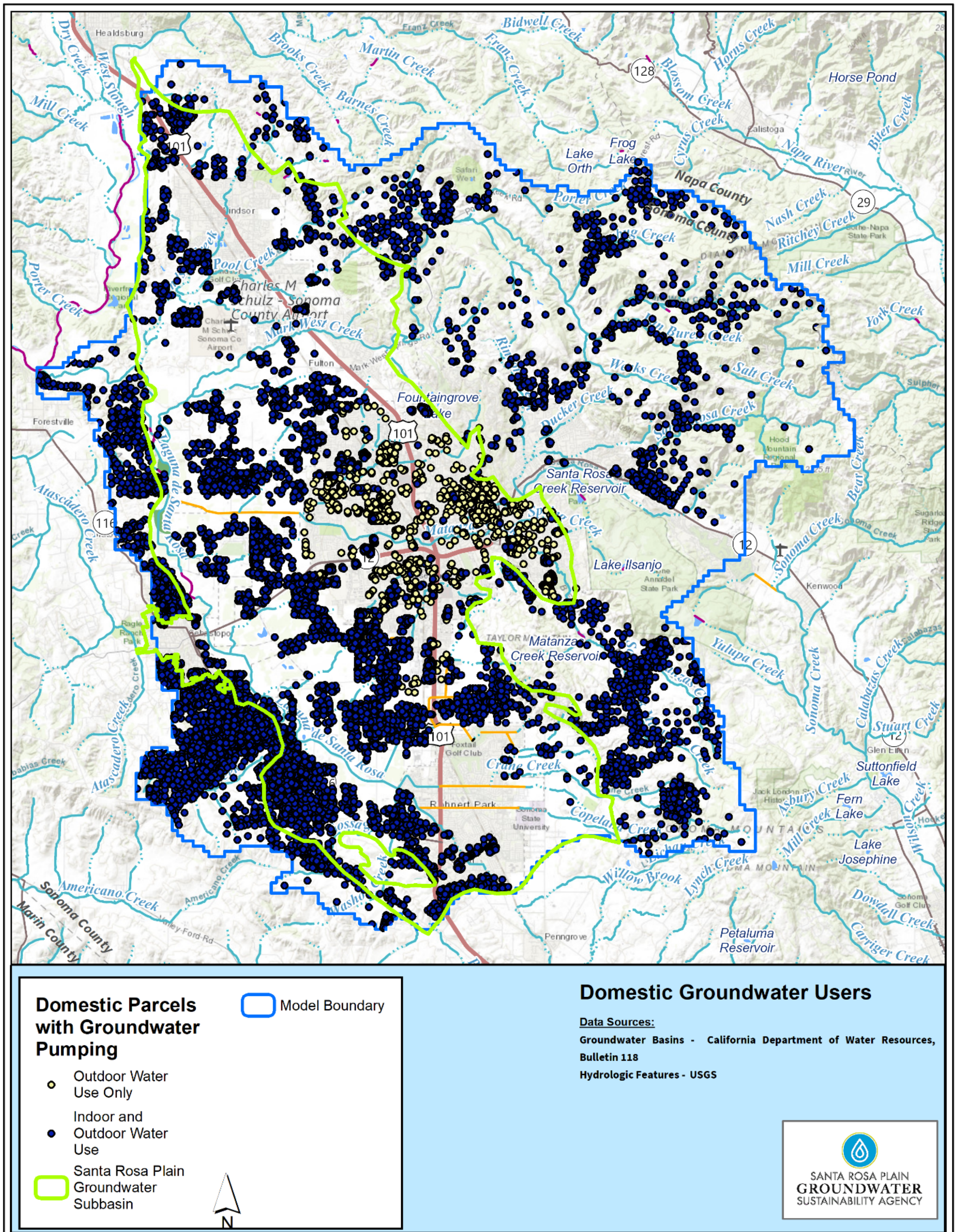


Figure 3 Domestic groundwater users in the SRPHM

The yearly groundwater usage applied to each parcel was determined by the size of the parcel and the parcel type. The groundwater demand was estimated by:

$$\mathbf{Q_{parcel} = Q_{indoor} + \%\ Irrigated \times I_d \times P_{av(i)}}$$

% Irrigated = 2.80%

I_d = 2.9 ft/year; Turf Irrigation Depth

$P_{av(i)}$= Parcel area (acres)

Q_{indoor} (In home use) = 0.24 AF/year

Parcel zoning use codes were used to determine if a parcel uses groundwater for indoor and outdoor, indoor only, or outdoor only. Parcels with outdoor and indoor uses are typically common residences, whereas indoor only parcels are those with a mixed residential and agricultural zoning use code description. The assumption is that the agricultural demands will be satisfied by Ag Package (see below) for that parcel. Parcels with outdoor only use were identified in the rate study and the information was provided by the water service providers. These parcels are assumed to only use groundwater pumping for outdoor use only.

Table 1 Number of Domestic Wells Inside and Outside Subbasin, and by Domestic Use-Type

Demand Type	Inside Subbasin	Outside Subbasin	Total
Outdoor and Indoor	6,185	4,102	10,287
Indoor Only	15	353	368
Outdoor Only	1,282	6	1,288
Total	7,482	4,461	11,943

The start of pumping for a given parcel was determined from the year that the parcel database indicated the parcel was developed. The updated timeseries of rural domestic groundwater pumping applied in the entire model domain is shown in Figure 4. As indicated by Figure 4, the rural domestic pumping incorporated into the revised SRPHM 1.0+ is several times lower than estimates from the original SRPHM and reflect a smoother transition over time. The smoother transition is due to the use of the development dates from the parcel database rather than the use of periodic census surveys, which cause the more abrupt changes in the original SRPHM. The lower overall estimates of rural domestic pumping are also more consistent with estimates from the Rate Study. For the Subbasin, total pumping by rural domestic users totaled 3,664 acre-feet per year in the Rate Study whereas the total estimate derived by SRPHM 1.0+ is 2,900 acre-feet per year. The difference is due to the use of separate indoor and outdoor water use in the SRPHM 1.0+, which required independent water-use estimates. The Rate Study identified a group of estimates and chose a central representative value of 0.5 acre-feet per year per parcel, whereas, the average per parcel water use calculated by SRPHM 1.0+, excluding urban water users, is 0.42 acre-feet per year. The Rate Study also accounted for secondary units on domestic parcels which were not accounted for in the SRPHM 1.0+.

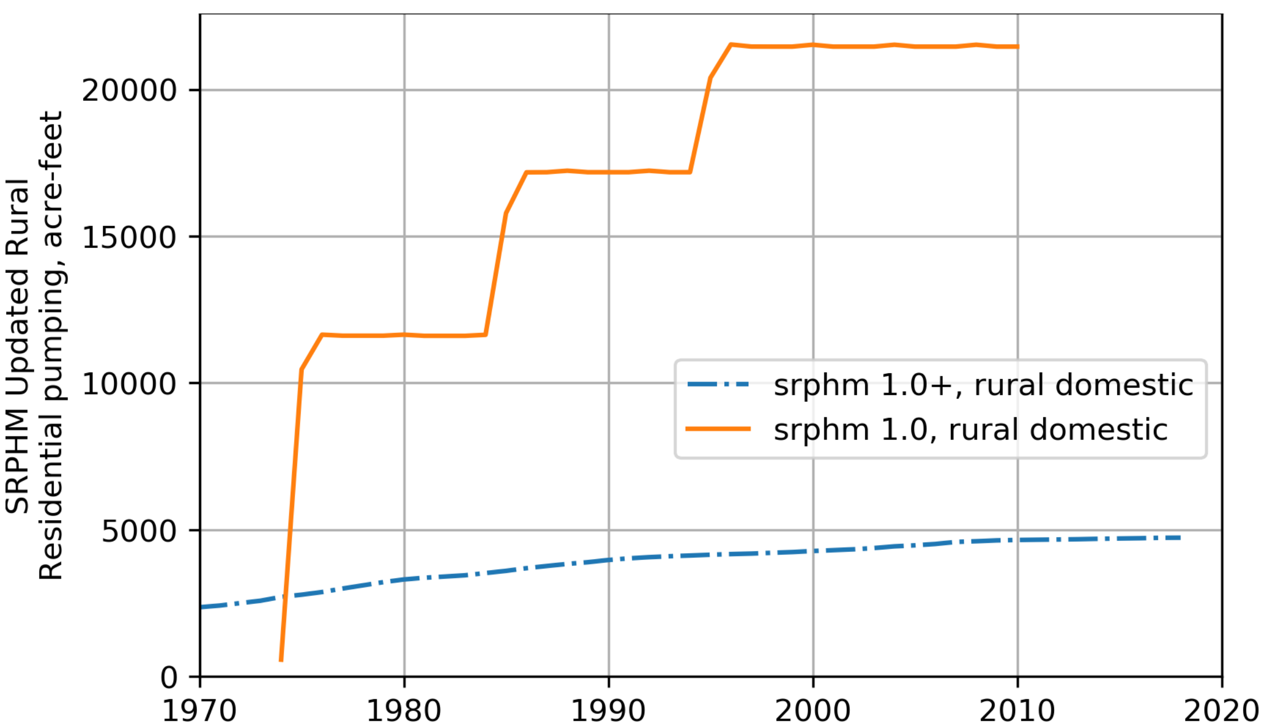


Figure 4 Rural domestic pumping in the Santa Rosa Plain Hydrologic Model for the entire model area. SRPHM 1.0+ refers to this update and SRPHM1.0 is the original USGS model.

Parcels are aggregated spatially by model cell for every stress period. The layers from which the parcels pump groundwater is determined from the reported domestic well depths. The reported well depths are provided by DWR's Well Completion Report Map which describes the number, maximum, minimum and average depths for wells by township, range, and section. The layer assigned to a given parcel was selected based on the minimum, maximum and mean defined in the DWR dataset for that well's township, range and section

1.2.2 Agricultural Irrigation Pumping

1.2.2.1 Original USGS approach

There is no comprehensive metering on agricultural pumping in the Subbasin, and therefore, agricultural groundwater pumping demands must be estimated through other means. Agricultural irrigation demand was estimated by the USGS for Water Year 1975-2015 using the daily Crop Water Demand Model (CWDM) in conjunction with the calibrated watershed model used in PRMS-only mode. The CWDM is decoupled from the calibrated watershed model. This means the CWDM uses information from the calibrated watershed model to calculate irrigation demand and simulate pumping in the SRHM but does not apply the water to the watershed in the SRHM.

1.2.2.2 Updated approach

Due to limitations of the CWDM, a new but conceptually similar approach was taken in the model update to estimate agricultural pumping. The Ag Package is coupled with GSFLOW and dynamically computes crop water demand and irrigation pumping and irrigation return flows. Irrigation demands are calculated as the potential evapotranspiration that remains after evaporation and transpiration utilize all available water in the soil zone (Niswonger, 2020). The Ag Package performs this calculation through PRMS and, therefore, processes such as Hortonian overland flow, Dunnian runoff, and a suite of other soil moisture processes are incorporated into the calculation of applied irrigation. Recycled water is indirectly incorporated through the external link file that acts to apply the recycled water directly into the soil zone. This water should act to limit groundwater pumping where it is applied by satisfying the potential evapotranspiration before irrigation is required.

1.2.2.3 Land Use Processing and Ag Package Inputs

Many of the original USGS model input files used to run the CWDM were used as inputs for the Ag Package. The datasets included the crop land use datasets for 1974, 1986, 1999 and 2008. Newly available land use datasets from DWR for 2012, 2014 and 2016 were used to update the agricultural land use to 2018. The Sonoma County Vegmap dataset was assessed for use in the crop updates; however, because its land use classifications are inconsistent with DWR's, the DWR datasets were chosen. As seen in Table 2, the total acreage of vineyards mapped by the VEGMAP is only 100 acres (1%) greater than that mapped in the DWR 2012 land use dataset. Pastures and grains show the greatest variance between the two datasets, though this is potentially because of the classifications used in VEGMAP are different than the DWR classifications. The DWR 2012 land use dataset contains an array of information on crop type, water source, irrigation types, and other information, whereas the 2014 and 2016 datasets only map the crop type identified through aerial imagery. The crop types used in the original CWDM model were retained in SRPHM 1.0+, and include: Field Crop, Grains, Orchard, Pasture, Truck Crop, Turf Grass, and Vineyard. The land use type that makes up the majority area of a cell is assigned to those model cells and only cells in the above list are included in the Ag Package. A majority of model cells are not simulated by the Ag Package because they do not have active crops. Additionally, crops indicated as non-irrigated were not included in the Ag Package inputs.

Table 2 Comparison of Acres of Crops in the DWR 2012 Land Use dataset and the VEGMAP dataset. These are not the same values used in the AG package as some crops were removed depending on irrigation source or non-irrigation. Only crops with comparable classifications are shown.

Crop Type	DWR 2012	VEGMAP 2014
Field Crop	490	810
Grains	3350	1830
Orchard	260	220
Pasture	3420	2360
Vineyard	9960	10060

Pastures are prevalent within the Subbasin and can can be a water intensive crop. In the 2019 Rate Study (Raftelis, 2019) it was assumed that pastures in the subbasin were not irrigated, whereas the 2012 DWR land use map by DWR indicates an irrigated land use for pasture areas. In order to assess whether pastures are irrigated, we mapped irrigated pastures identified in DWR's land use dataset with the remote sensing-based normalized difference vegetation index (NDVI). NDVI is a common tool to assess vegetation health (Anderson et al, 2012), with values ranging from -1 to 1. Greater NDVI values indicate the increasing presence of chlorophyll content in plant matter, and thus a healthier non-stressed crop which is interpreted to be an indicator of irrigated agriculture. Figure 5 shows the irrigated pasture locations from DWR 2012 as input into the groundwater model with the 2012 Fall NDVI average values. The pastures identified in the model occur in areas with high NDVI values indicating vigorous growth late in the season, and therefore a high likelihood that these pastures are irrigated.

The DWR 2012 land use datasets are based off field-level reconnaissance mapping and aerial photo interpretation and are regarded as high-quality data. The DWR 2012 land use map indicates the source of irrigation for all fields, including pastures. It is assumed that if groundwater is the listed source of water for a pasture, then that field would be included as a pasture. Data from the recycled water providers indicates that many of the pastures that have groundwater as their irrigation source (as determined by DWR (2012)) also receive recycled water. For water year 2012, 74% of the simulated pasture model cells in the subbasin received recycled water. Pastures were not included in the simulation where sworn affidavits attesting to no groundwater use exist. There are 28 such parcels with sworn affidavits. The locations of simulated pastures, simulated pastures that receive recycled water, water source, and parcels with affidavits are show in Figure 6. For those model cells that receive it, recycled water is applied to the soil zone by PRMS, and if there is unmet evapotranspiration for that cell, then groundwater is pumped and applied to the soil zone.

The land use derived crop datasets for 1974, 1986, 1999, 2008, 2012, and 2018 were used to define the crops for the model simulation from 1974 to 2018. For every AG Package model cell, the crop type for a given year was defined by the crop map nearest in time for that cell. For example, to define the crops for 1995, the crop map from 1999 was used, whereas the crop map from 1986 was used for the model simulation year of 1990. Figure 7 and Table 3 show the area simulated by the AG Package within the entire model domain, and Figure 8 and Table 4 shows the crops within the Subbasin only. The pasture land use crop inputs derived from the

2012 dataset were applied for the 1986 to 2018 period because of the reliance on data only available within the 2012 dataset. Figure 9 depicts the spatial distribution of crops for calendar Year 2012.

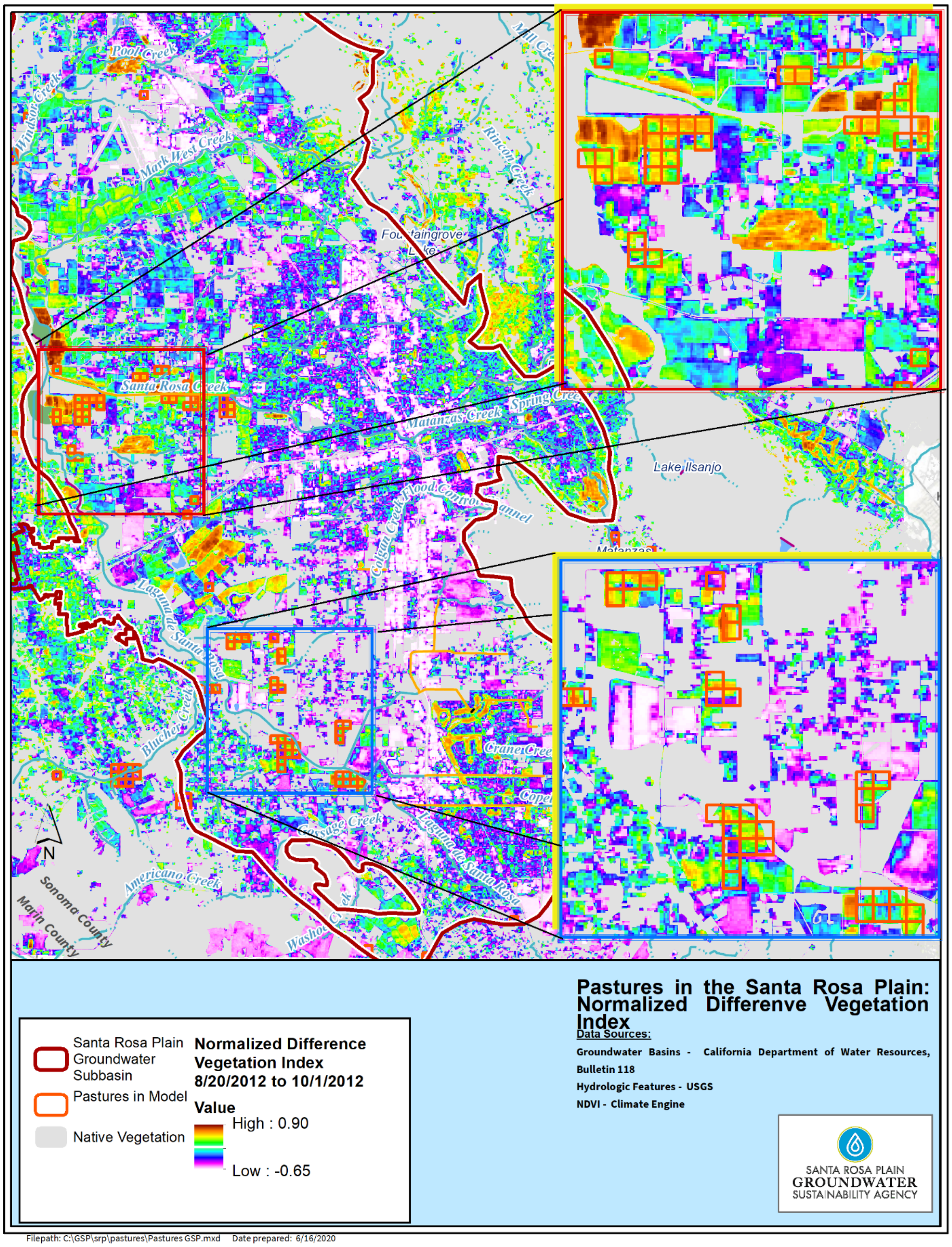


Figure 5 Pastures in the Santa Rosa Plain: Normalized Difference Vegetation Index

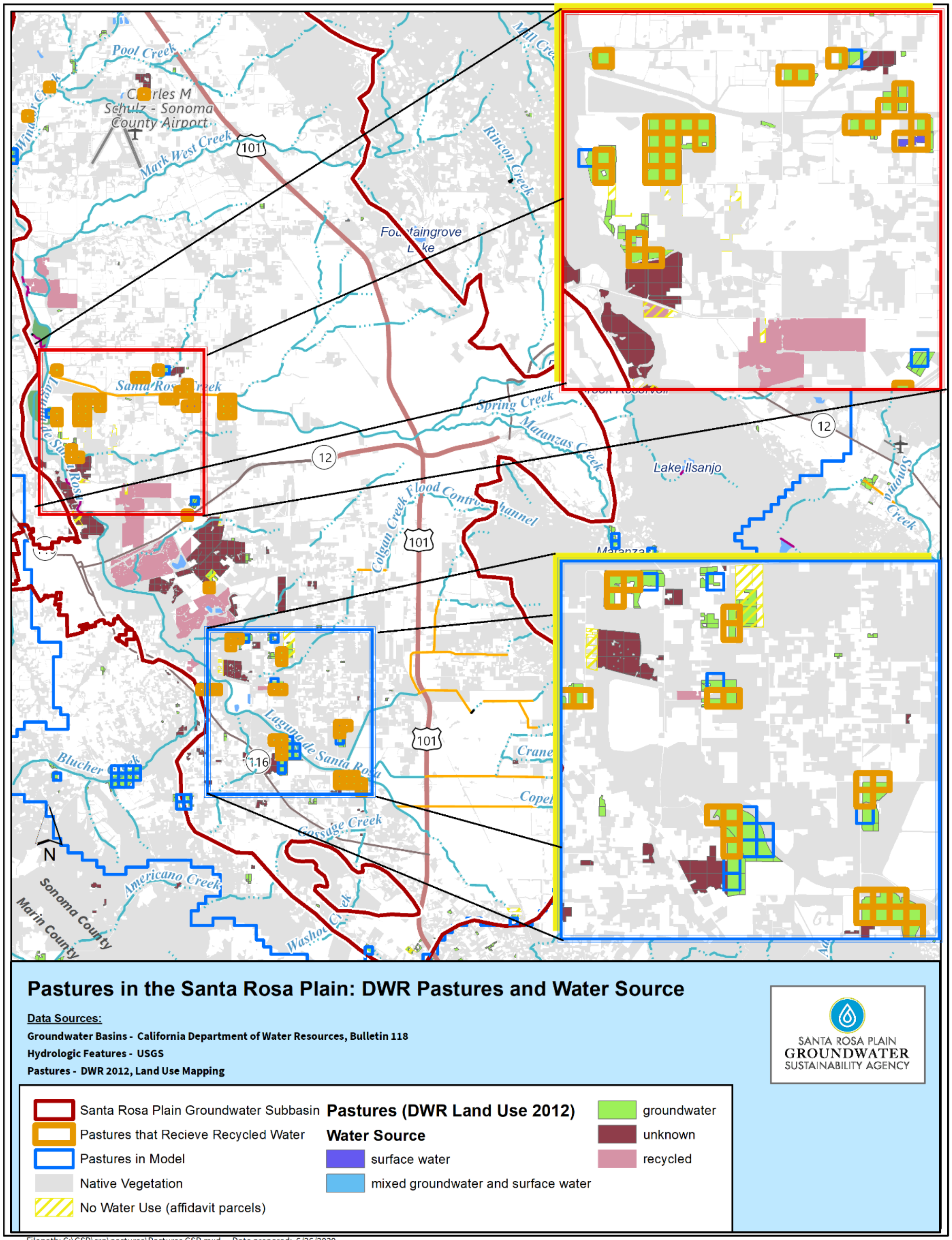


Figure 6 Pastures in the Santa Rosa Plain: DWR Pastures and Water Source

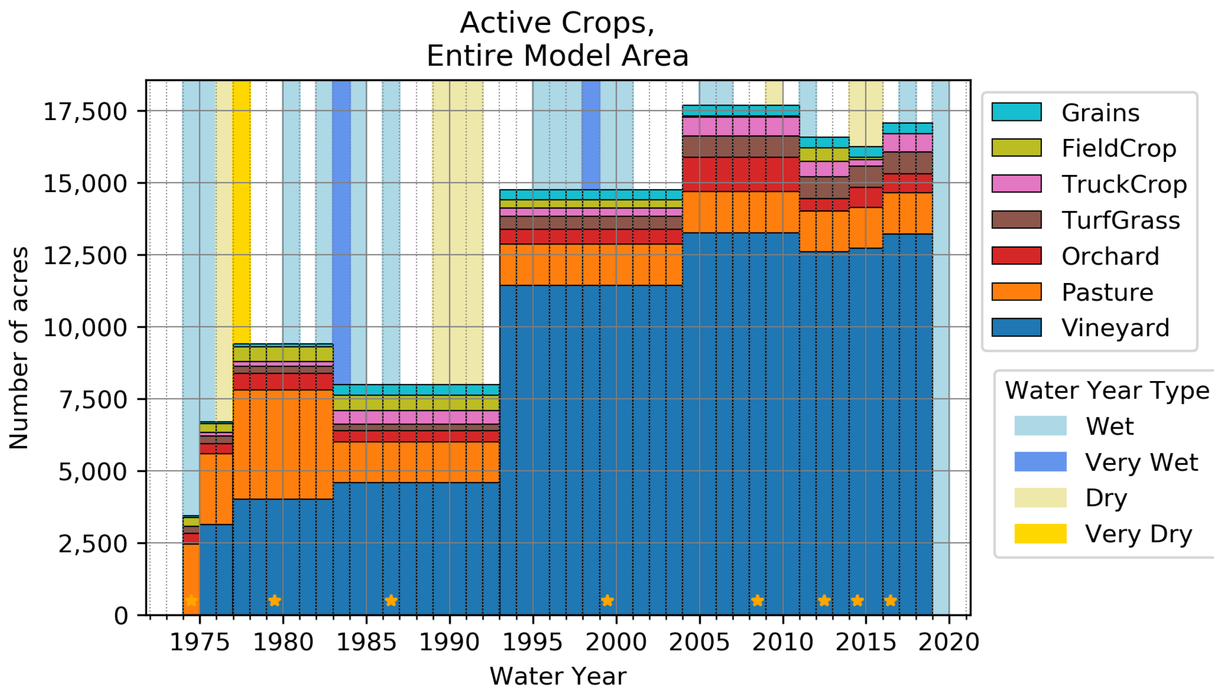


Figure 7 Total Crop Area for the Entire SRPHM Area. Orange stars at base of graph indicate years where land use data was available to create crop input dataset. Years without recorded data were assigned by the nearest year with available data.

Table 3 Number of Acres per Crop for the Entire SRPHM Area. These values were determined from the land use datasets and were used to assign intervening years not listed.

Year	Field Crop	Grains	Orchard	Pasture	Truck Crop	Turf Grass	Vineyard
1974	310	60	350	2,470	120	260	3,130
1979	520	100	560	3,790	160	260	4,020
1986	550	360	390	1,420	460	220	4,590
1999	280	360	510	1,420	290	450	11,440
2008	50	360	1,190	1,420	640	750	13,260
2012	480	360	440	1,420	530	750	12,590
2014	80	360	680	1,420	230	750	12,720
2016	10	360	670	1,420	630	750	13,220

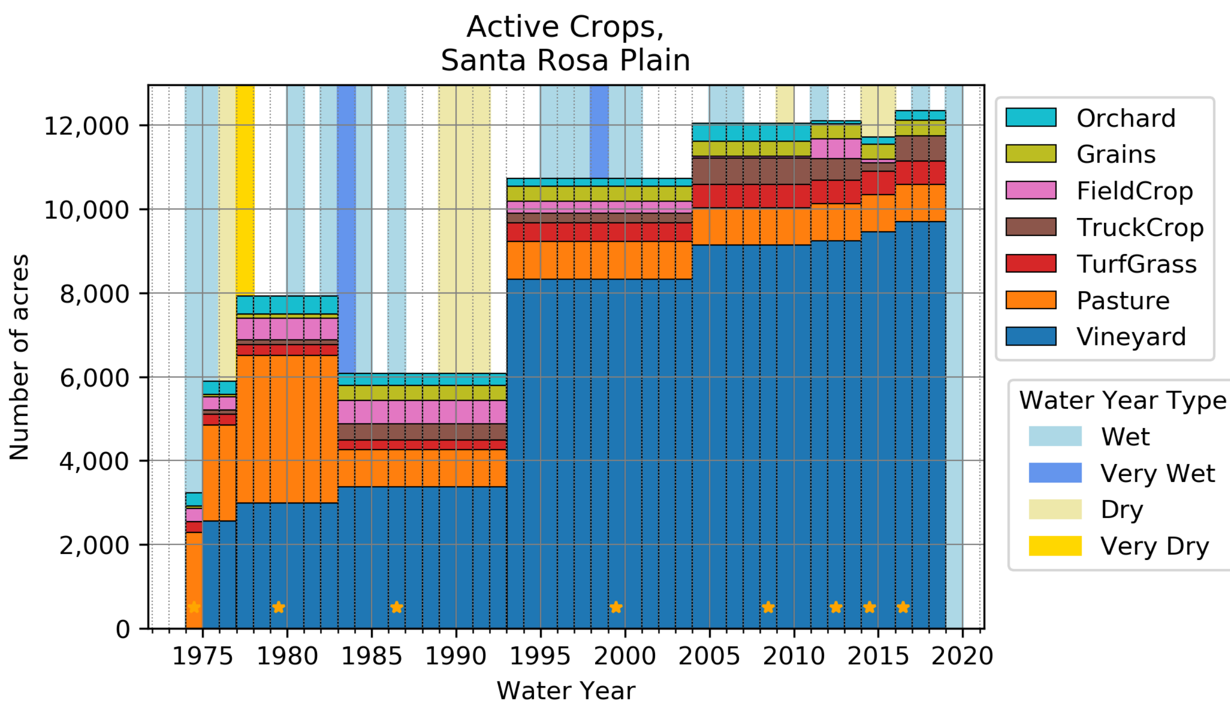


Figure 8 Active Crop Area within the Santa Rosa Plain Subbasin. Orange stars at base of graph indicate years where land use data was available to create crop input dataset. Years without recorded data were assigned by the nearest year with available data.

Table 4 Number of Acres per Crop for the Subbasin. These values were determined from the land use datasets and were used to assign intervening years not listed.

Year	Field Crop	Grains	Orchard	Pasture	Truck Crop	Turf Grass	Vineyard
1974	310	60	320	2,290	100	260	2,560
1979	510	100	430	3,520	110	260	2,990
1986	550	360	290	890	390	220	3,380
1999	280	360	190	890	230	450	8,330
2008	50	360	420	890	620	560	9,140
2012	470	360	70	890	510	560	9,240
2014	80	360	180	890	200	560	9,450
2016	10	360	230	890	590	560	9,700

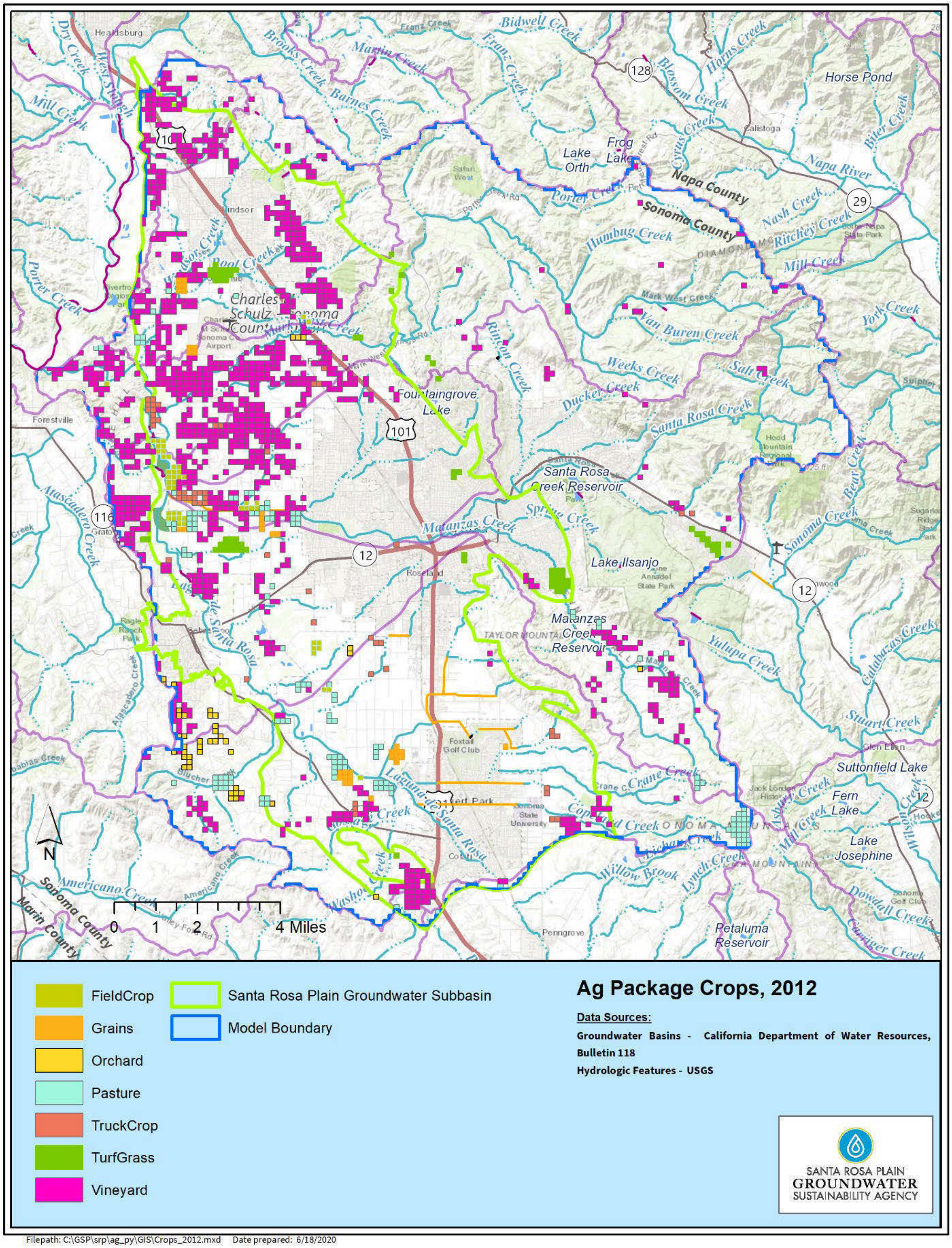


Figure 9 Ag package Crop, 2012

Crop coefficients are used to simulate the variation in crop evapotranspiration demands as a function of potential evapotranspiration. Potential evapotranspiration is calculated by PRMS using the Jensen-Haise formulation. Crop specific crop coefficients and monthly crop-irrigation schedules are shown in Figure 10 and Figure 11. The crop coefficients for vineyards are based on values derived for the Russian River region (Davids Engineering, 2013). The other crop coefficients are from Allen et al (1998), Gibeault et al (1989), Snyder et al (1987a, 1987b), and Brush et al (2004).

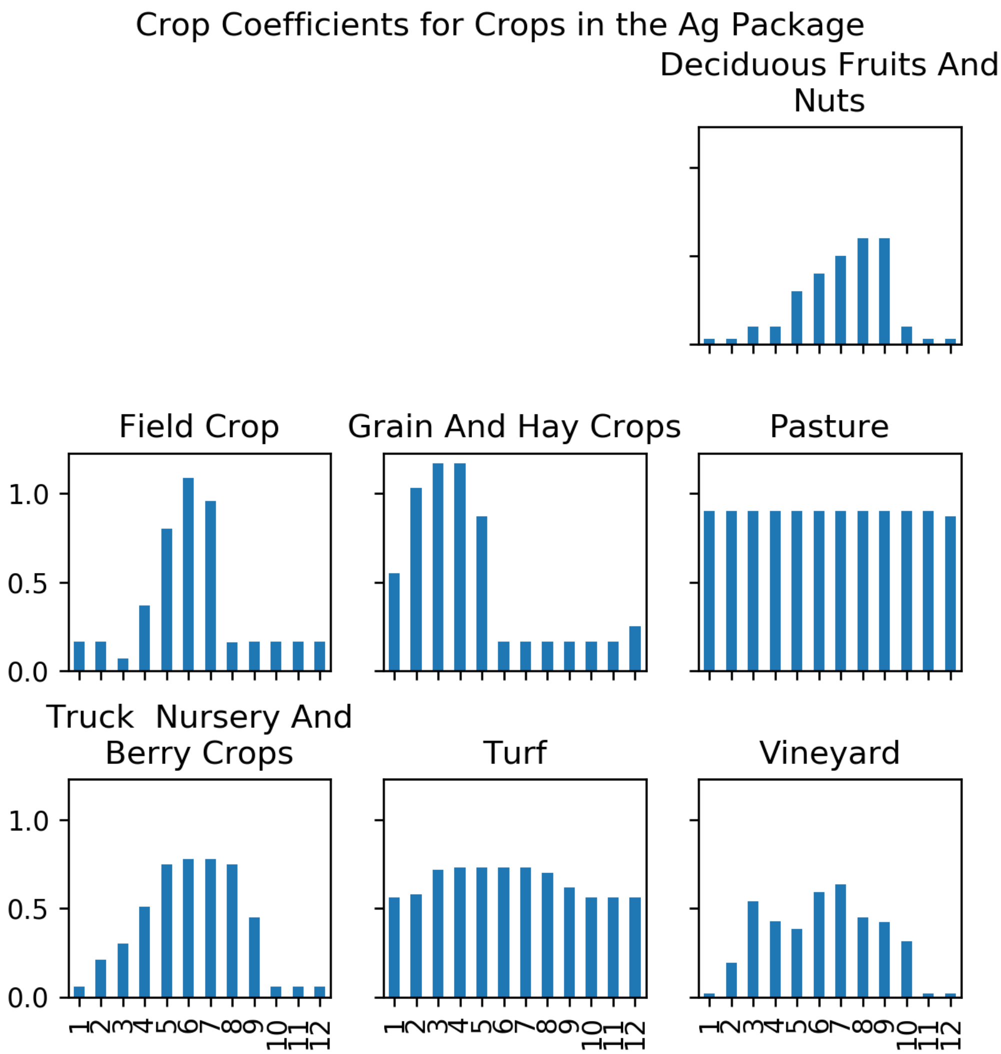


Figure 10 Monthly Crop Coefficients

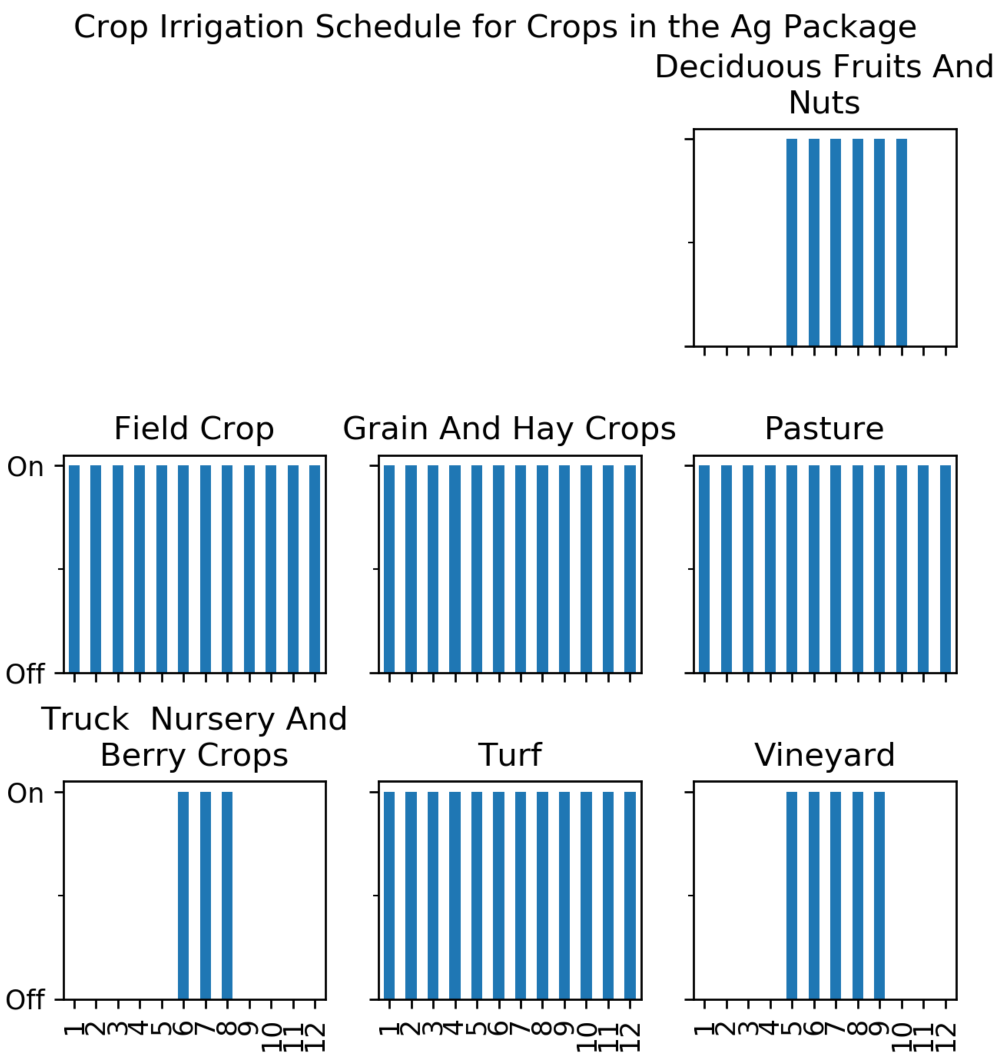


Figure 11 Monthly irrigation schedules

Adjustments were made to the PRMS soil parameters in order to incorporate agricultural practices such as drip irrigation for vineyards. For vineyard cells the impervious area was set to 30% to incorporate bare soils (Table 5), and summer rain interception value (srain_intcp) was set to zero so that no irrigation is intercepted by vegetation in order to simulate drip irrigation. soil2gw_max was also set to zero so that no water directly recharges from soil capillary zone to groundwater in order to simulate high efficiency irrigation for vineyards. All crops were assigned a value of 2 inches for the water holding capacity of the soil zone as defined by soil_moist_max and sat_threshold.

Table 5 Changes to PRMS parameters in SRPHM 1.0+

PRMS Parameter	PRMS Parameter Description	Crop Type	Updated Parameter	Rationale
srain_intcp	Summer rain interception	Vineyard	0%	drip irrigation
imperviousness	Percent of cell causing runoff	Vineyard	30%	estimate of bare soils and area where no ET occurs
soil2gw_max	Maximum amount of gravity reservoir that flows to groundwater	Vineyard	0 inch	used to simulate high efficiency irrigation
soil_moist_max	Maximum available water holding capacity of capillary reservoir	Vineyard	2 inch	calibrated value
sat_threshold	Water holding capacity of the gravity and preferential-flow reservoirs	Vineyard	2 inch	calibrated value
srain_intcp	Summer rain interception	All other Crops Besides Vineyards	Unchanged from original	NA
imperviousness	Percent of cell causing runoff	All other Crops Besides Vineyards	Unchanged from original	NA
soil2gw_max	Maximum amount of gravity reservoir that flows to groundwater	All other Crops Besides Vineyards	Unchanged from original	NA
soil_moist_max	Maximum available water holding capacity of capillary reservoir	All other Crops Besides Vineyards	2 inch	calibrated value
sat_threshold	Water holding capacity of the gravity and preferential-flow reservoirs	All other Crops Besides Vineyards	2 inch	calibrated value

The simulated pumpage per crop for the Santa Rosa Plain Subbasin is shown in Figure 12 and a summary of groundwater pumpage per crop for the period from water year 2012 to 2018 is shown in Table 6. Pastures were the dominant use of irrigation until 1983, after which vineyard irrigation has been the largest total use of groundwater irrigation in the subbasin. The total yearly average irrigation depth in feet per crop is shown in Table 7 and monthly average irrigation depth for all crops is shown in Figure 13. Pastures have the highest irrigation depth per crop and vineyards are the lowest irrigation depth on average. Most irrigation occurs in the summer months, although pastures and turfgrass have simulated irrigation periods that extend into the spring and fall.

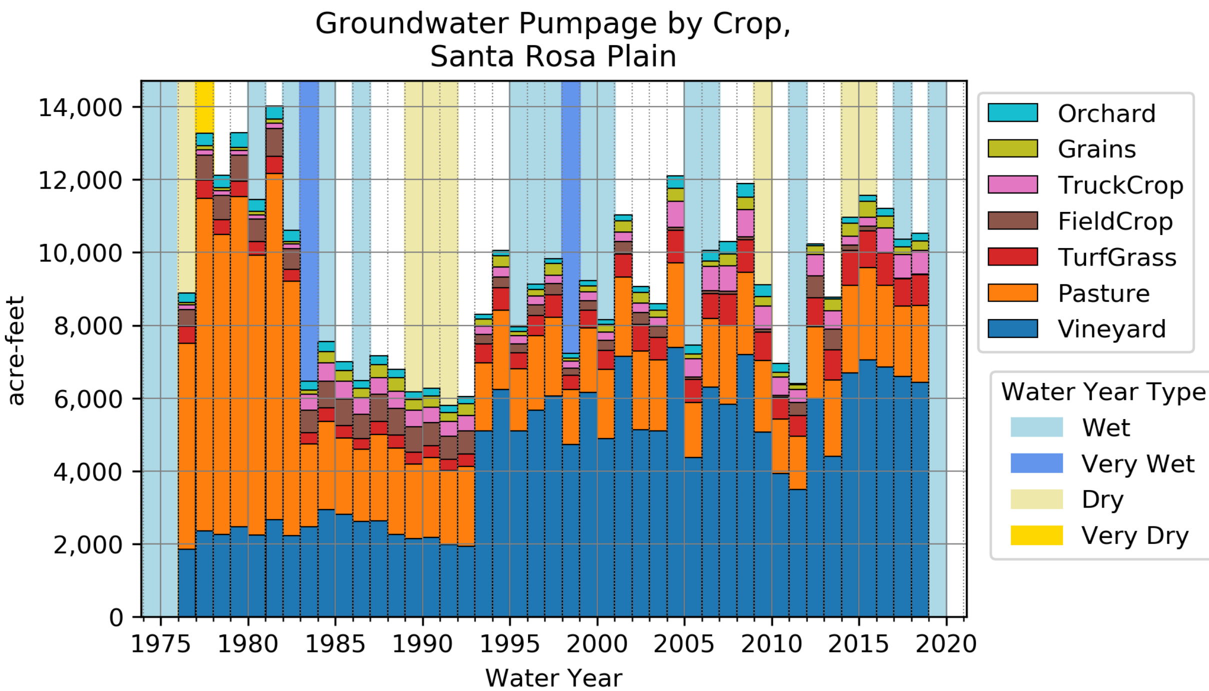


Figure 12 Simulated groundwater pumpage by crop for the Subbasin

Table 6 Groundwater pumpage per crop for the Subbasin from Water 2012 to 2018

	Field Crop	Grains	Orchard	Pasture	Truck Crop	Turf Grass	Vineyard
Mean	200	300	100	2,200	500	900	6,300
Minimum	0	200	0	1,900	200	800	4,400
Maximum	600	400	200	2,500	700	1,000	7,000
Median	100	300	200	2,100	600	800	6,600

Table 7 Average simulated irrigation depth by crop, pre-recycled water deliveries from 1975 to 1990

Crop Type	Irrigation depth (feet)
Vineyards	0.76
Orchard	0.78
Truck Nursery	1.25
Pastures	2.25
Grain	0.86
Turf Grass	1.55
Field Crop	1.29

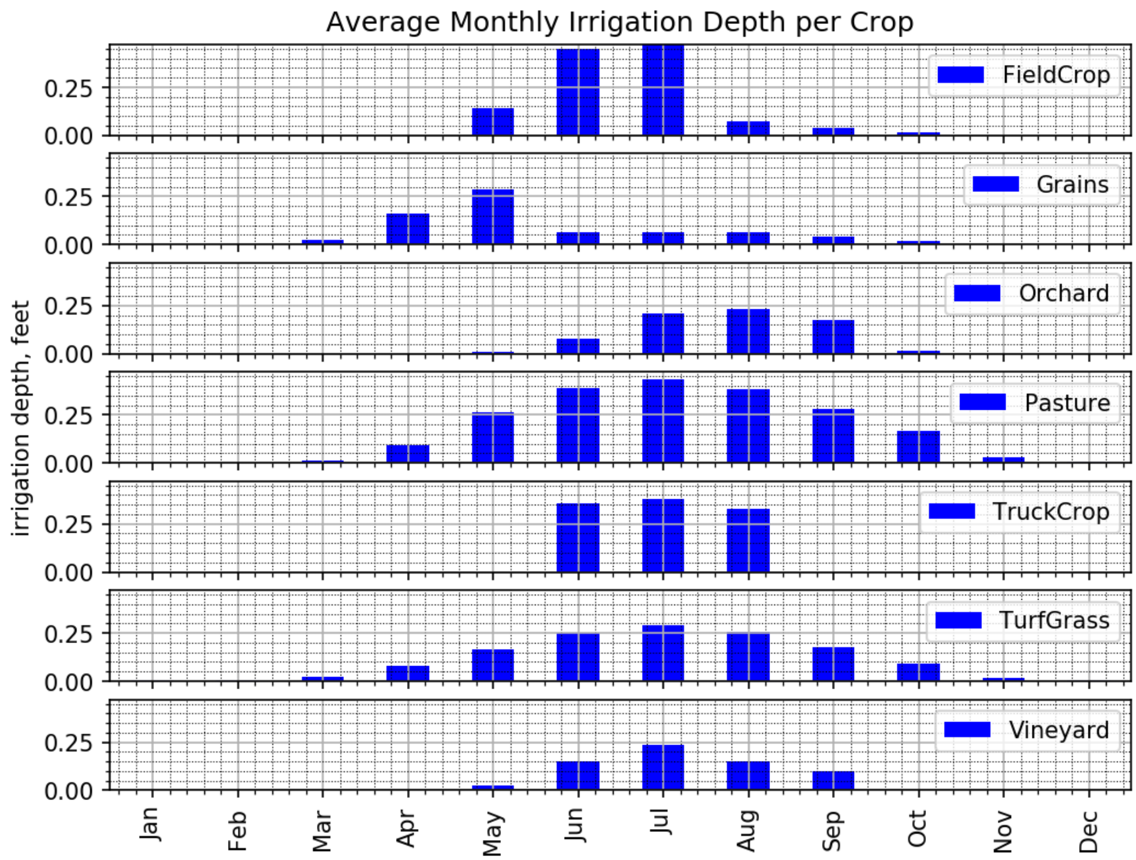


Figure 13 Model Results: Average monthly irrigation depth per crop

1.2.3 Public Water Supply Pumping

Large and small water service providers pump groundwater to serve to their customers. Large water suppliers include Cotati, Rohnert Park, Santa Rosa, Sebastopol, Windsor, Sonoma Water, Sonoma State University, and California-American Larkfield. Small water suppliers include Canon Manor Water System, Cloverleaf Ranch Summer Camp and many others including wineries, schools, mutual water companies, RV parks, restaurants, and parks. Other sources of groundwater extraction, such as pumping for urban landscape irrigation are not included in the model. Pumpage data from the large and small water suppliers were included in the original USGS model and have been updated here. The large water suppliers generally provided pumpage records for each of their extraction wells. These pumpage records were summed by month and then used to extend the pumping records to December 2018 (shown annually in Figure 14). Pumpage data for small water suppliers were provided by CA DWR Division of Drinking Water (DDW). If monthly data were not available for certain periods, then they were estimated based on data from previous years[2]. If total pumpage was given for a supplier, then it was divided among all active wells managed by that supplier.

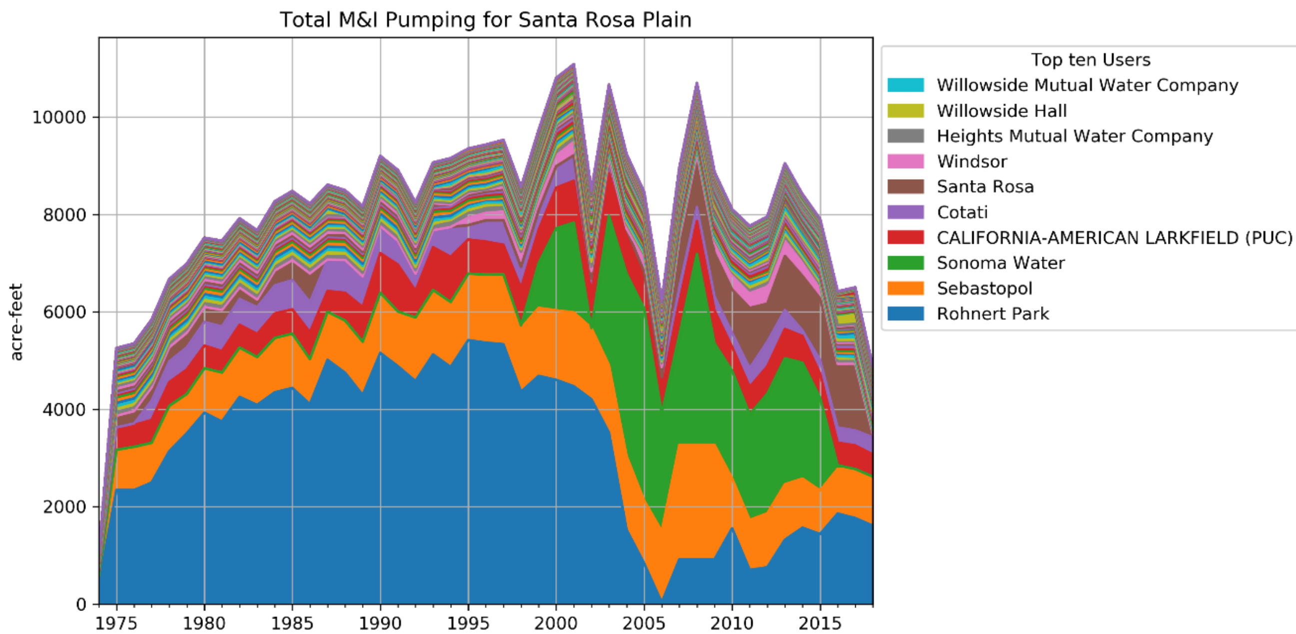


Figure 14 Total Monthly Pumpage by Munipical and Industrial water service providers for the Santa Rosa Plain Subbasin with Top 10 Users labeled

1.3 Additional Completed Model Updates

1.3.1 Climate Representation

The representation of climate stresses in the model has been changed from the original approach of the SRPHM 1.0 of using daily grids of precipitation and minimum and maximum temperature, to an approach based on time series input for individual weather stations which are then interpolated spatially onto the model grid by PRMS subroutines. This change resulted in a reduction in model input file size, although not a reduction in model run time. The updated

[2] Exceptions to this were for small water suppliers located in areas affected by 2017 Tubbs fire that were missing data for 2017 and 2018 because they were not operational after the fire.

model climate input files for 1975-2015 are currently only available in the new climate station format.

The PRMS watershed model requires input of daily precipitation and minimum and maximum daily air temperatures. The original SRPHM v1.0 used a gridded climate data set of daily precipitation and daily minimum and maximum air temperatures as input to GSFLOW. The gridded daily climate data set was developed externally to SRPHM as part of the model development by pre-processing and integration of climate data from a combination of monthly Parameter-elevation Regressions on Independent Slopes Model (PRISM) gridded data (monthly normal; Daly et al, 2002; PRISM Climate Group., 2016) and daily data from 109 climate stations centered on the watershed. The PRISM data were used to develop a spatial interpolation model that allowed for filling in many data gaps both spatially and temporally. This method was used to develop daily climate data for water years 1948-2010.

In contrast, the new USGS SRPHM v1.0 (which extended the model period through end of 2015) uses a station based climate input approach, where daily precipitation and minimum and maximum air temperature are provided at the locations of two climate stations within the basin, and then a spatial interpolation model is applied to these inputs directly within PRMS to define daily climate inputs at each model cell. The two station locations are at the Santa Rosa and Windsor California Irrigation Management Information System (CIMIS) stations (Table 8).

Although SRPHM v1.0+ uses station data time series as its input, the version of the updated input time series that the USGS extended through 2015 were actually derived from an extended gridded daily climate set developed in the same manner as for the SRPHM 1.0 model. Interpolated time series for these two station locations were extracted from this extended gridded data set. To update the climate input through 2018 (or for future updates) with this approach requires acquiring updated data through 2018 for all 109 climate stations used by the USGS and performing the data-processing steps to generate the full gridded daily data set. This would have been time consuming for a short period of the model update; therefore, a more simplified approach was implemented. The USGS SRPHM 1.0 input data time series for the two stations were compared with time series derived from the gridded PRISM daily data (interpolated to the coordinates of each station) for the 2010-2015 time period and showed good agreement. On this basis, the updated time series for the two station locations are based on interpolation to the station locations directly from daily PRISM gridded data. Though the 109 stations are not explicitly used as climate inputs here, observed climate data within and around the model domain are incorporated into the development of the PRISM model. The PRISM daily data sets only extend to January 1, 1981; therefore, the original USGS SRPHM v1.0 time series values are used for 1974-1980. The updated climate inputs used in the model update are shown in Figure 15, with the resulting water year 2015 to 2018 precipitation updated for SRPHM 1.0+ shown in Figure 16, Figure 17, Figure 18, and Figure 19.

Table 8 CIMIS Climate Stations in SRPHM

CIMIS Station #	DWR Regional Office	Station Name	County	Latitude	Longitude	Elev (ft)	Status	Connect Date	Disconnect Date
83	NCRO	Santa Rosa	Sonoma	38.40355	-122.799931	80	Active	1/1/1990	Active
103	NCRO	Windsor	Sonoma	38.526822	-122.813886	90	Active	12/14/1990	Active

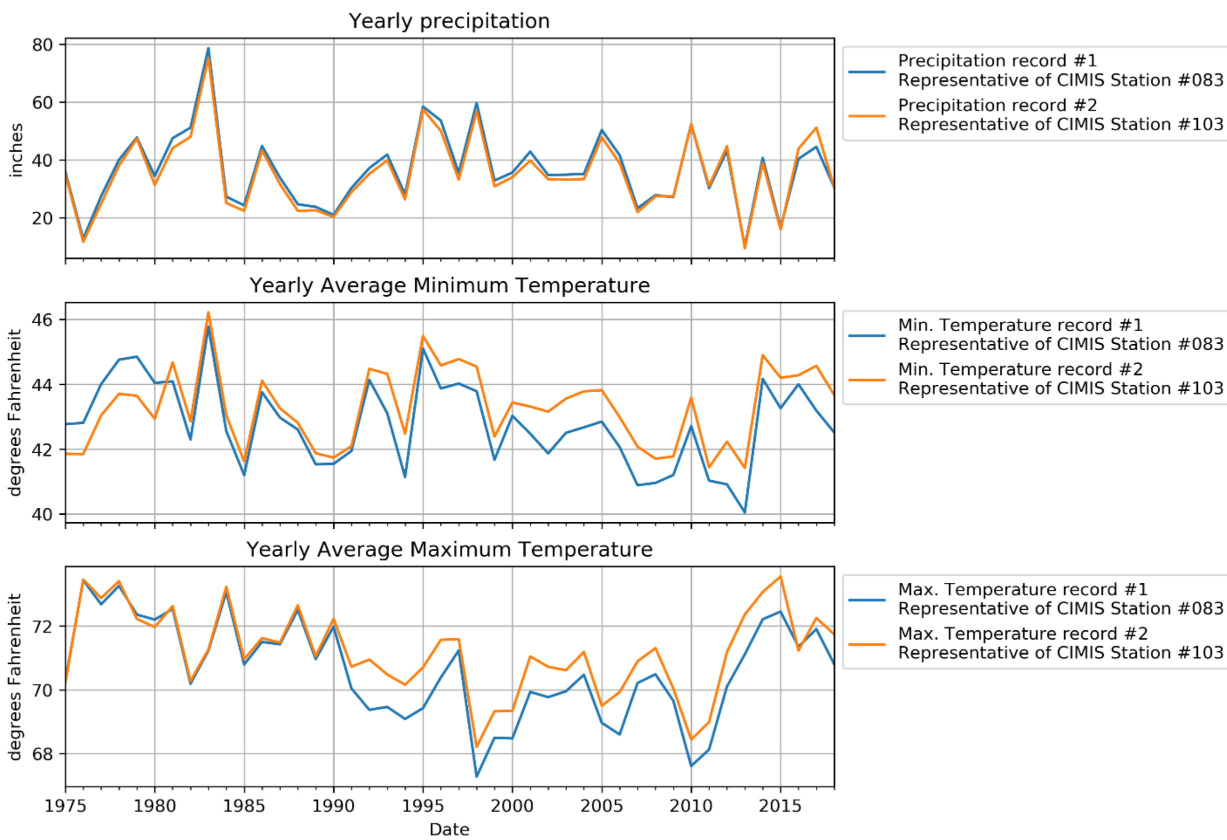


Figure 15 Updated Climate Inputs for the SRPHM v1.0+

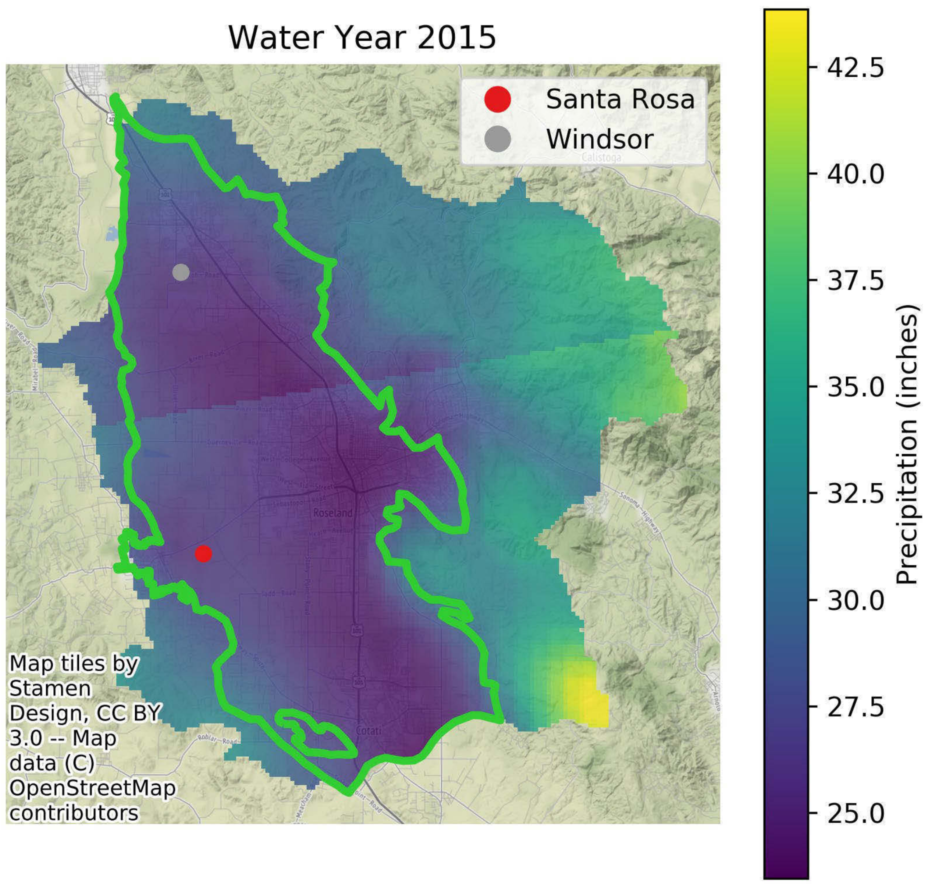


Figure 16 Water Year 2015 Precipitation for the SRPHM 1.0+

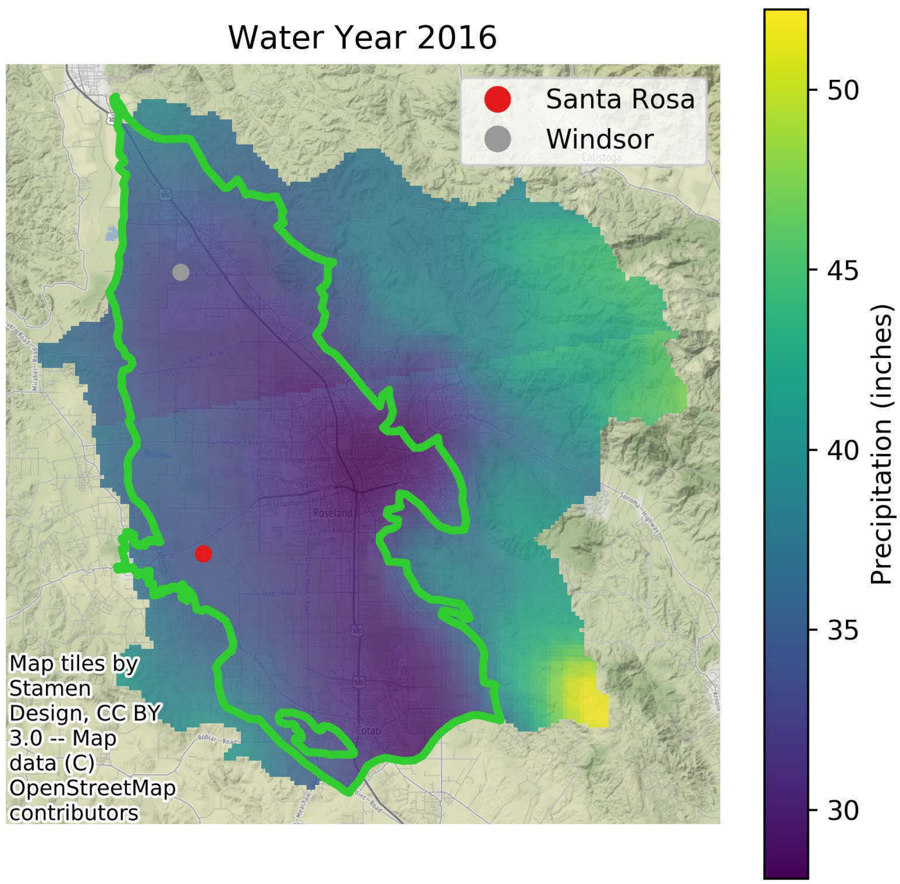


Figure 17 Water Year 2016 Precipitation for the SRPHM 1.0+

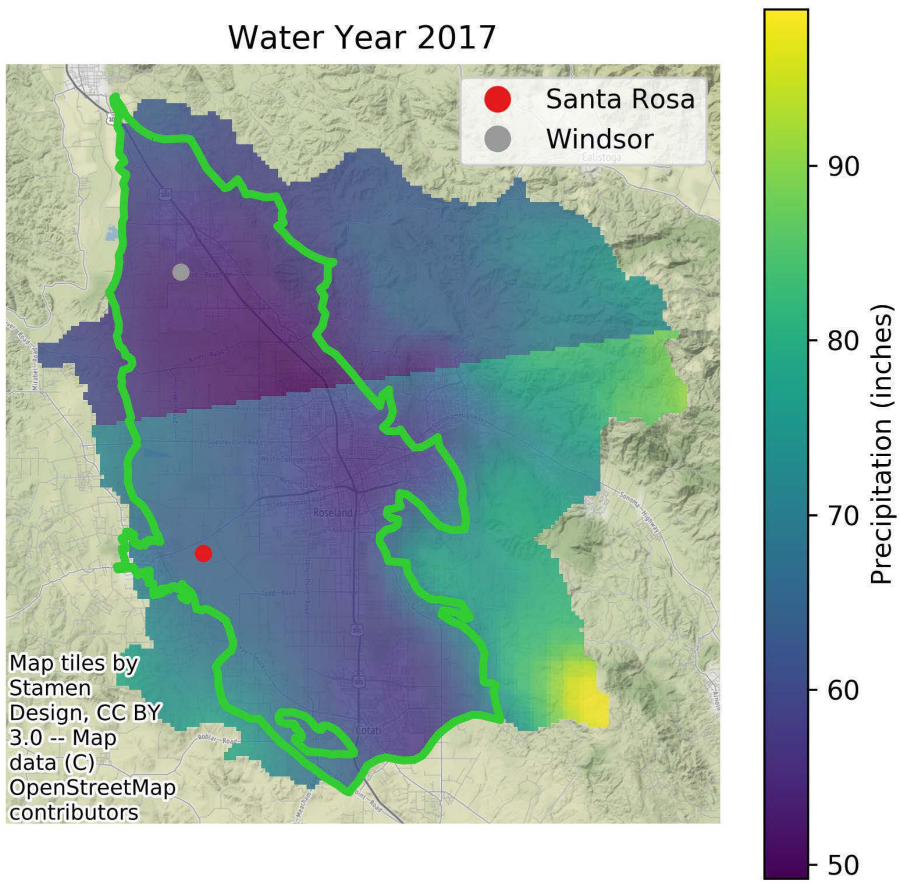


Figure 18 Water Year 2017 Precipitation for the SRPHM 1.0+

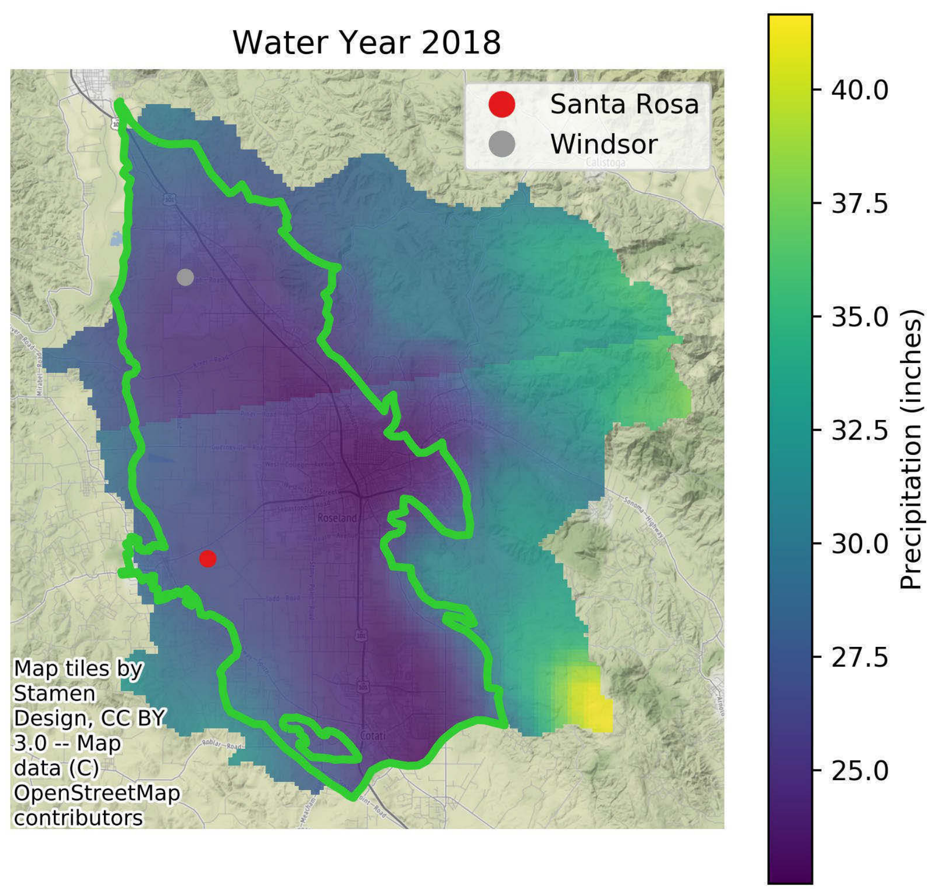


Figure 19 Water Year 2018 Precipitation for the SRPHM 1.0+

1.3.2 Recycled Water Deliveries

Recycled water deliveries applied as irrigation were previously simulated in SRPHM v1.0 by adding the delivered water to the daily precipitation grids. Recycled water use has now been separated and is represented by adding recycled water volumes to the soil zone through a new input file using the PRMS Water Use Input Module. The use of this module also accounts for irrigation with recycled water when estimating rural pumpage with the Ag Package.
Monthly records on the application of treated wastewater from the Town of Windsor and the city of Santa Rosa used for irrigation, also referred to as recycled or reclaimed water, were compiled by the USGS for water-years 1990 through 2017 for use in the SRPHM 1.0. Data for 2018 were estimated based on using monthly averages of the data from the previous three years. The SRPHM 1.0 data do not include recycled water deliveries from the Airport-Larkfield-

Wikiup Sanitation Zone and these were not updated in SRPHM 1.0+. For the most part, land irrigated with recycled water was within the Laguna de Santa Rosa 100-year flood-plain area, and is used for both landscape and agricultural irrigation (as seen on Figure 21 of USGS, 2013). The annual volume of recycled water used for irrigation averaged about 10,200 acre-ft.

1.3.3 Septic Return Flows

The original USGS SRPHM does not include septic return flows. The model was updated here to include septic return flows by recharging 80% of indoor water use to the first model layer (O'Conner Environmental, Inc. 2018) using the Flow and Head Boundary (FHB) package. The FHB package assumes that recharge occurs immediately and by utilizing this approach the delay of infiltrated septic water as it moves through the unsaturated zone is not simulated. This delay could be important for when a parcel is newly developed and there is a delay as the infiltrated water moves through the unsaturated zone. After a period of time, likely a year or less, depending on the rate of flow and the hydraulic conductivity of the unsaturated zone, recharge from septic infiltration becomes nearly continuous. The growth, locations and timing of the septic return flows mimic indoor rural domestic groundwater use described earlier. See Figure 3 for locations where groundwater pumping supplies water for indoor water use.

Calibration Results

After changing groundwater pumping, PRMS parameters, and other properties mentioned in this report, it is expected that the model will have different simulated results than SRPHM 1.0. Simulated groundwater levels are compared with observed groundwater levels to determine if the model remains relatively well-calibrated, or if model properties need to be adjusted to improve simulation capabilities. The two types of calibration observations are groundwater levels and streamflows. There are 111 groundwater wells for which the model simulates groundwater levels, and here we emphasize a subset of the key observation wells identified by Wolfenden and Nishikawa (2014) and the representative monitoring points used in the GSP. The key wells along with the other groundwater level hydrographs were updated in SRPHM 1.0+ through 2018.

Groundwater level hydrographs

The shallow groundwater level hydrograph in Figure 20 (SRP0357) near the town of Sebastopol shows a reasonable representation of the shallow groundwater levels. This well was not part of the original USGS study and therefore is a good representation of the updated model's ability to simulate groundwater levels in areas where it was not part of the calibration assessment. Figure 21 shows the hydrograph for SRP0359 and is located within the same borehole as SRP0357 as part of a nested well. This well is a medium depth well and also indicates that the model is capable of simulating groundwater levels in a location for which the model was not originally assessed for calibration. Because the shallow and deeper groundwater levels at this location are both reasonably simulated, the hydraulic gradient between these depths should be well represented in the model. Groundwater movement is controlled by gradients, so this is an important consideration and a favorable model result.

Figure 22 displays the groundwater level hydrograph for a well located southeast of Rohnert Park. Both the observed and simulated hydrographs display a groundwater level rebound following the decrease in groundwater pumping in the area. The rebound in groundwater levels is very well represented by the simulated hydrograph, as well as the seasonal variations that occur in addition to the long-term changes.

Finally, Figure 23 depicts a model bias for well SRP0117 located in southeastern Santa Rosa. Here groundwater levels are about 25 feet too low, compared to the observed data for that location.

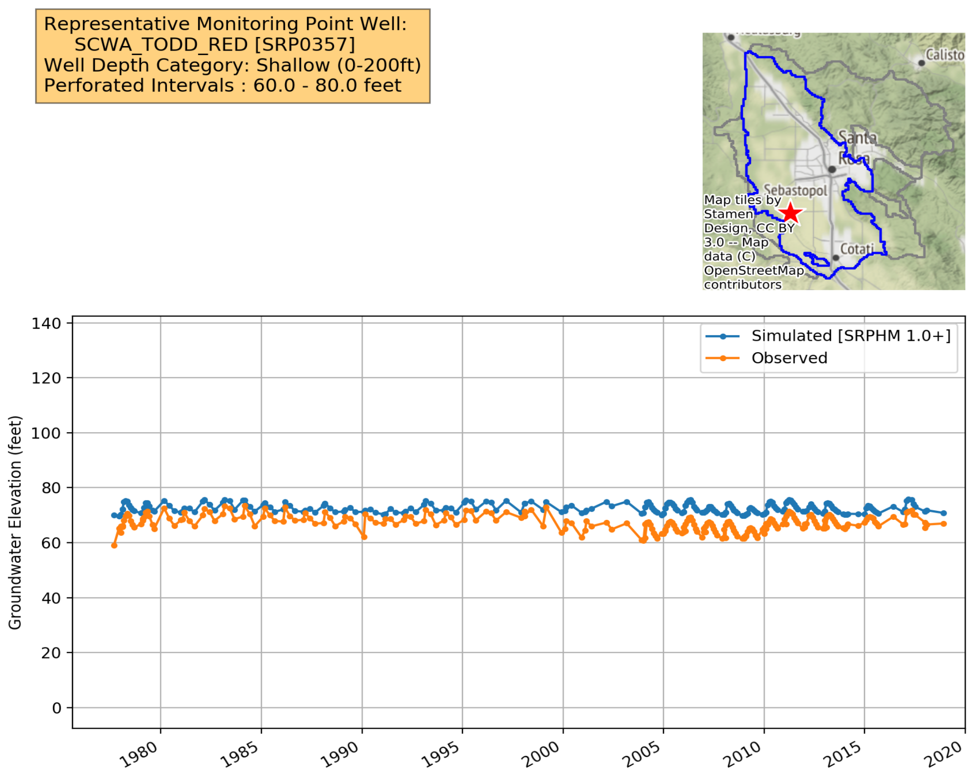
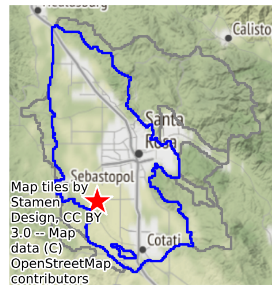


Figure 20 Groundwater level hydrograph simulated by SRPHM 1.0 and SRPHM 1.0+, and observed groundwater levels for SRP0357, Representative Monitoring Point

Representative Monitoring Point Well:
SCWA_TODD_WHITE [SRP0359]
Well Depth Category: Medium (200-500ft)
Perforated Intervals : 237.0 - 257.0 feet



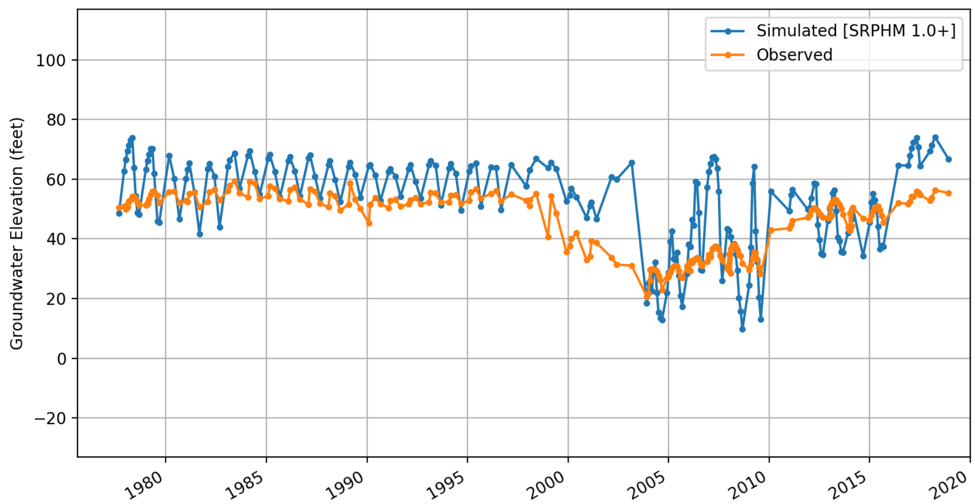


Figure 21 Groundwater level hydrograph simulated by SRPHM 1.0 and SRPHM 1.0+, and observed groundwater levels for SRP0359, Representative Monitoring Point

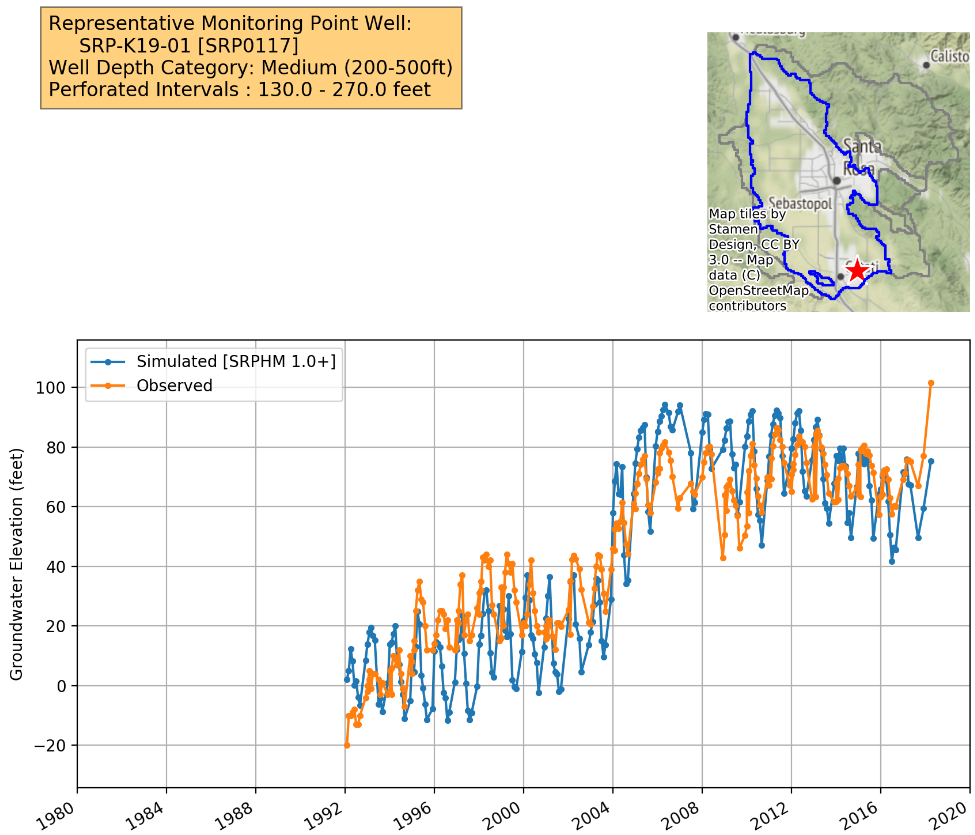


Figure 22 Groundwater level hydrograph simulated by SRPHM 1.0 and SRPHM 1.0+, and observed groundwater levels for SRP0117, Representative Monitoring Point

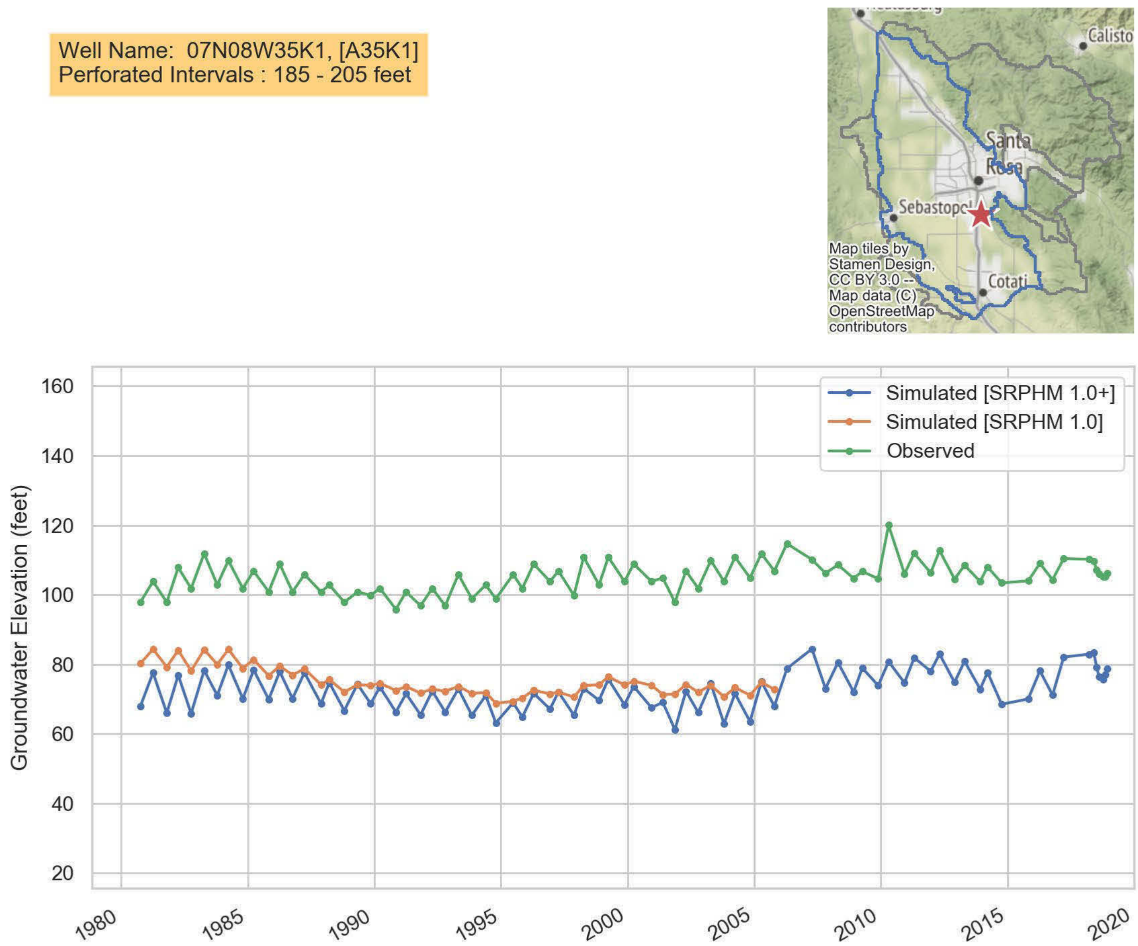


Figure 23 Groundwater level hydrograph simulated by SRPHM 1.0 and SRPHM 1.0+, and observed groundwater levels for State Well ID 07N08W35K1 , Key Well

One way to display groundwater level results is to plot the observed versus the simulated groundwater levels. If an observed groundwater level matches its simulated value, then the point will plot on the 1:1 line, whereas simulated values that are too high will plot above the 1:1 line, and simulated values that are too low will plot below the 1:1 line. Overall the errors should be distributed symmetrically about the 1:1 line reflecting a lack of bias in the simulation results. Figure 24 depicts the observed versus simulated groundwater levels for wells located within the Subbasin along with the 1:1 line in red. Additionally the figure shows that the Root Mean Square error for these results increased from 20.91 feet in SRPHM 1.0 to 21.84 ft in SRPHM 1.0+. The median residual did not change between SRPHM 1.0 to SRPHM 1.0+, though the average residual became slightly more negative. These results are reflected in Figure 24 which shows little difference between the density of residuals about the 1:1 line, reflecting a model that has a small but reasonable bias in overestimating groundwater levels. The small increase in the bias is likely a result of the decreased groundwater pumping from SRPHM 1.0 and SRPHM 1.0+, which would cause groundwater levels to increase.

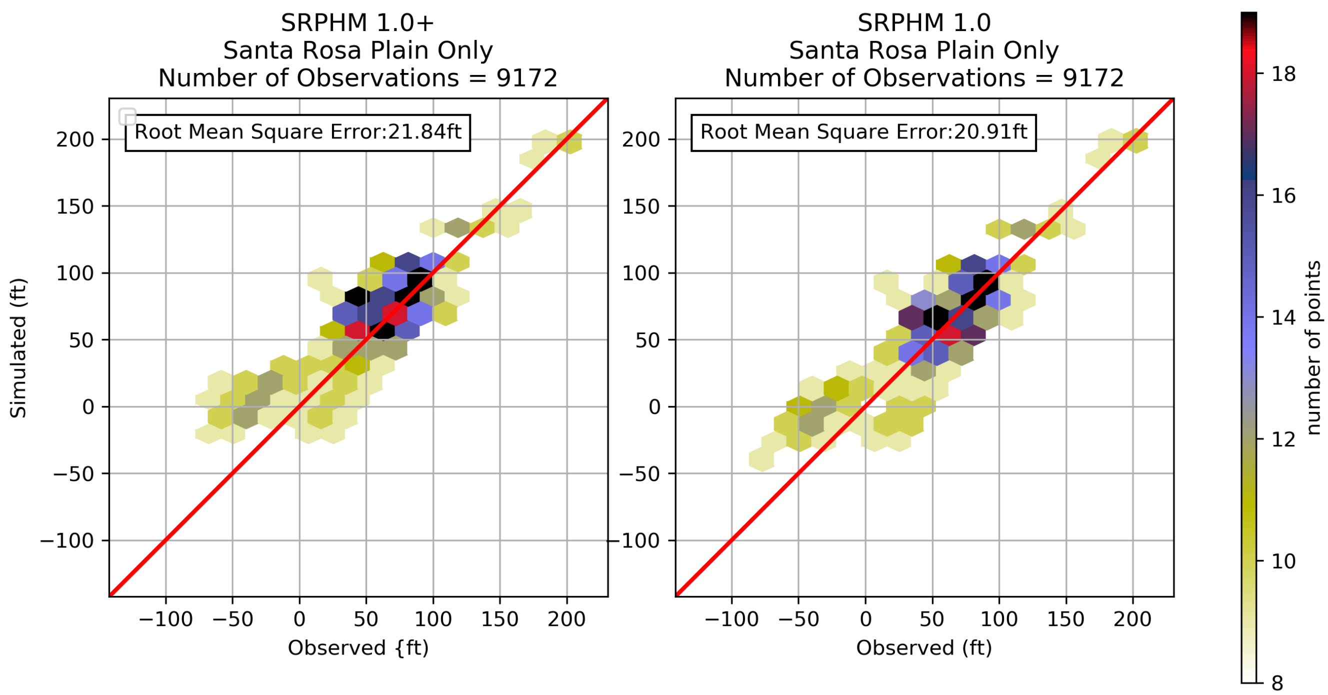


Figure 24 Observed versus simulated groundwater levels for the SRPHM 1.0 and SRPHM 1.0+

The difference between a simulated and observed value is known as the residual. The average residuals for all wells is shown in Figure 25, with the key calibration wells emphasized with grey boxes. A perfect simulation would have small residuals for all wells, and if any residuals were large, they would be randomly spatially distributed and not clustered in zones. At 18 of 38 of the key well locations the absolute groundwater level residual is less than 10 feet. As seen in the map, there are not any clusters of wells with correlated biases that cover large areas of the Subbasin model domain, indicating there is not significant spatial bias in the model. There is one small cluster in the southern area west of Rohnert Park and another cluster of three wells east of the Santa Rosa Airport. These clusters are small and could potentially reflect too much pumping in the Airport area (positive residual) and too little pumping west of Rohnert Park (negative residual).

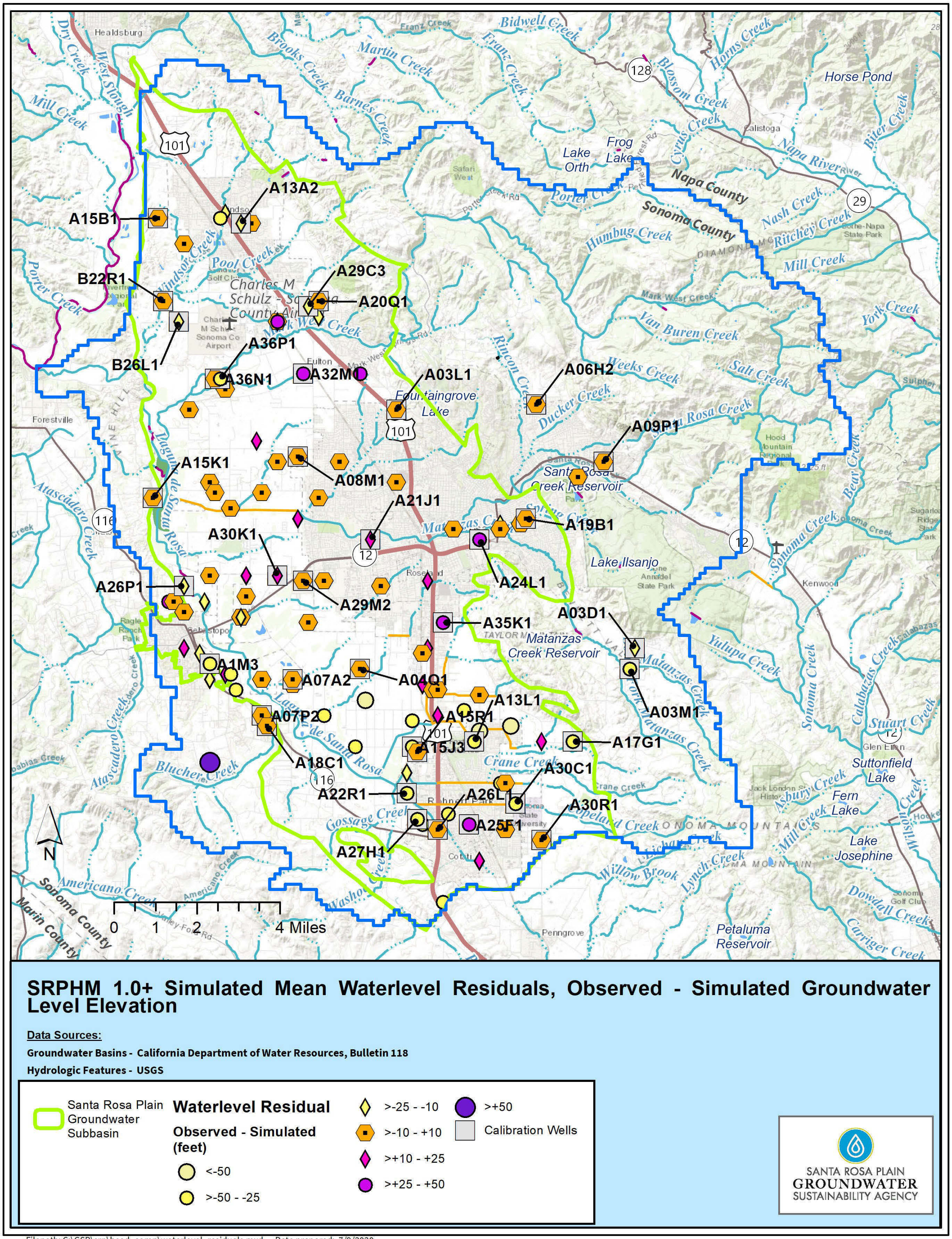


Figure 25 SRPHM 1.0+ Mean Groundwater level Residuals, 1974 to 2018

DRAFT

Stream Calibration

Streamflow is an important component for the GSP. It is also an important calibration metric because it incorporates a number of hydrologic processes that the model must simulate. Streamflow integrates precipitation volumes and distribution, actual evapotranspiration, aquifer hydraulic properties, and groundwater pumpage, amongst other processes. Fortunately for the Subbassin there are a large number of USGS stream gages that are, or have historically, operated within or just outside of the Subbasin. A map of the stream gage locations is shown on Figure 26. The calibration assessments for each of the gages is shown on Figure 26, Figure 28, Figure 28, Figure 29, Figure 30, Figure 31, Figure 32, Figure 33, Figure 34, Figure 35, for Brush Creek At Santa Rosa (11466065), Colgan Creek Near Santa Rosa (11465690), Colgan Creek Sebastopol (11465700), Copeland Creek at Rohnert Park (11465660), Laguna de Santa Rosa at Stony Point Roadd Nearr Cotati (11465680), Laguna de Santa Rosa Creek Near Sebastopol (11465750), Mark West Creek Near Mirabel Heights (11466800), Mark West Creek Near Windsor (11465500), Matanzas Creek at Santa Rosa (11466170), and Santa Rosa Creek at Willowside Road Near Santa Rosa (11466320), respectively. Brush Creek discharge reflects inflows from outside of the subbasin, and as seen in Figure 27, the simulated discharge data matches the observed very well, including the flow duration curve, the observed versus simulated, and the monthly flows. Colgan Creek near Santa Rosa, Colgan Creek near Sebastopol, and Copeland Creek near Rohnert Park all simulate both the low flows and high flows very well, with only the Colgan Creek near Sebastopol displaying a small divergence of flows at low flows around the 90% flow exceedance value. At that location the SRPHM 1.0+ performs better than the SRPHM 1.0. At the Laguna de Santa Rosa near Cotati both the SRPHM 1.0 and SRPHM 1.0+ display discharge values greater than the observed for the top 30% of flow exceedance, though they display similar trends for much of the remaining curves. Importantly, at both Laguna de Santa Rosa gages, the SRPHM 1.0+ displays comparable discharges in the June through September period when groundwater dependent ecosystems are likely heavily reliant on groundwater discharge to streams.

The Mark West Creek and the Matanzas Creek gages do not record summer low flows and therefore their calibrations are not as important here as other gages that do. Nonetheless, for the one year when the gages recorded summer flows, there is good agreement between the observed and simulated for those periods. The Santa Rosa Creek at Willowside Road near Santa Rosa streamgage record is very well reproduced at all but the lowest of flows. At flows below the 70% exceedance, the SRPHM 1.0+ has very similar exceedance, whereas at flows below 10 cfs (90% exceedance) there is some divergence. This divergence is either a result of too high of groundwater discharge to streams during the summer within the groundwater basin, or too high of discharge from the upstream locations outside of the Subbasin.

When considering all of the streamflow gage records, the updated SRPHM 1.0+ is generally well suited at simulating the monthly flow duration curves and the monthly average flow rates for summer and fall discharge. There is a slight tendency to over simulate pumping during these low flow periods, and bias may need to be accounted for when using the SRPHM for assessments of surface water depletion and other surface water processes.

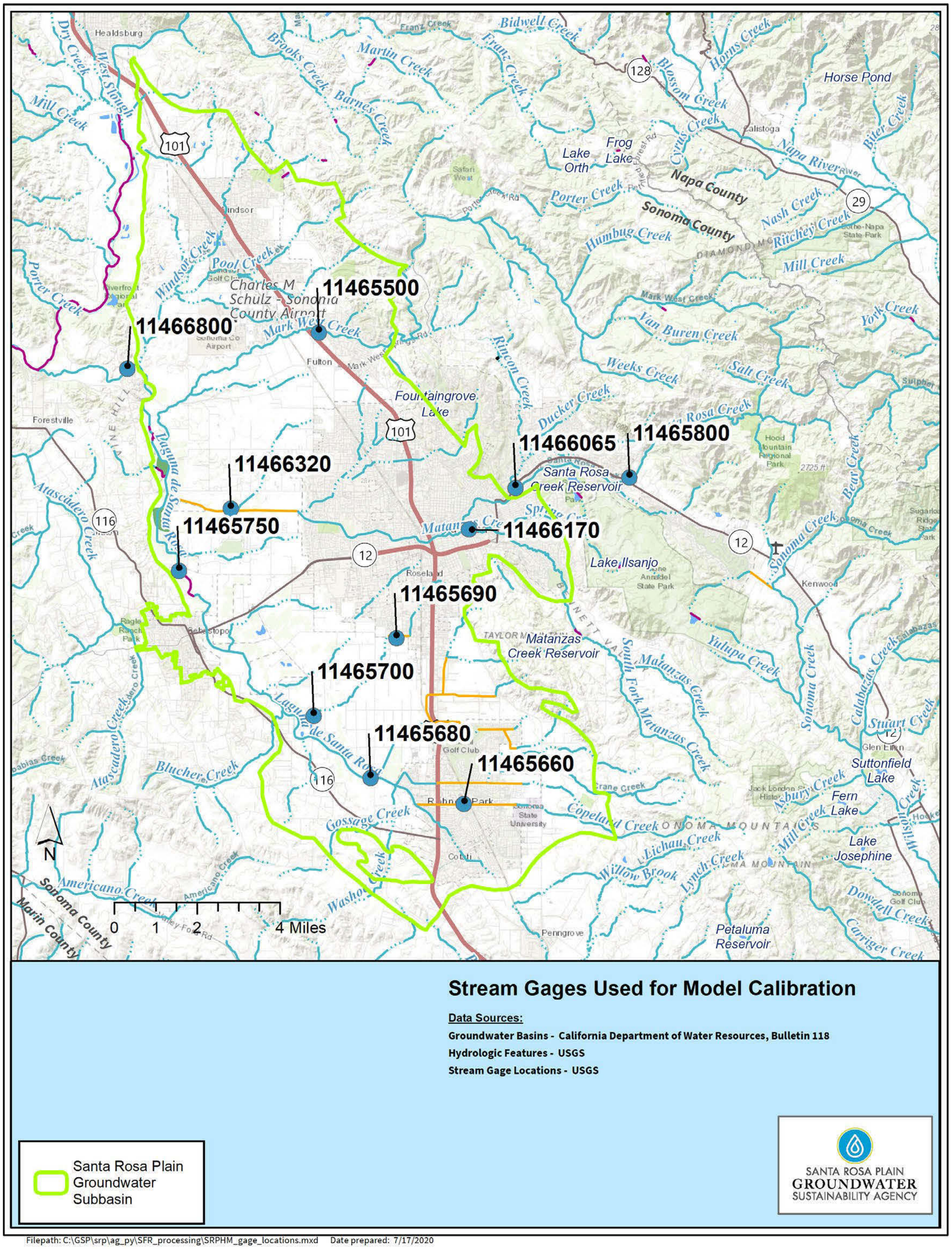


Figure 26 USGS stream gage locations and their site identifiers

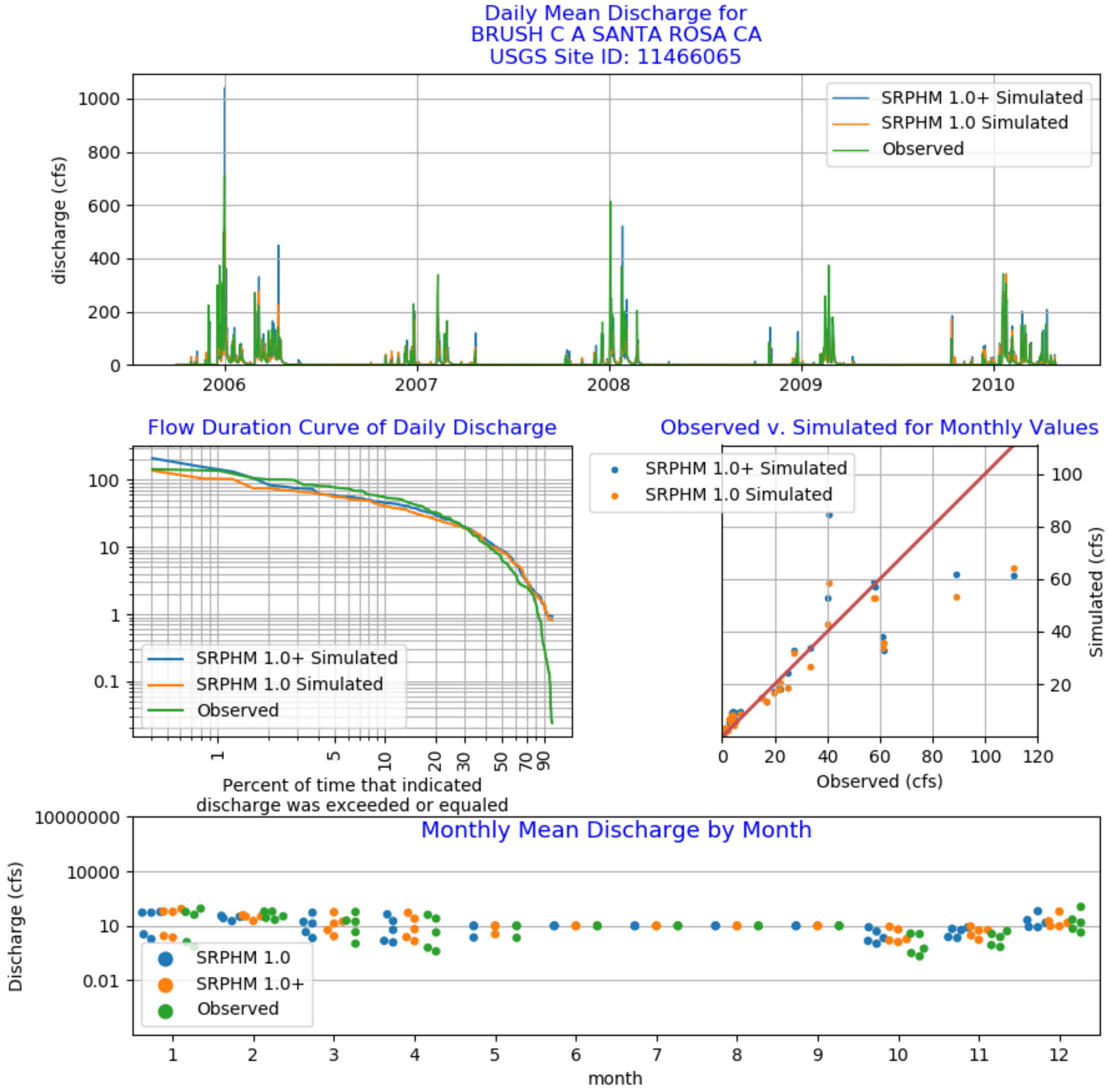


Figure 27 Simulated SRPHM 1.0, SRPHM 1.0+ and observed daily discharge, flow duration, observed versus simulated discharge, and monthly mean discharge for Brush Creek at Santa Rosa

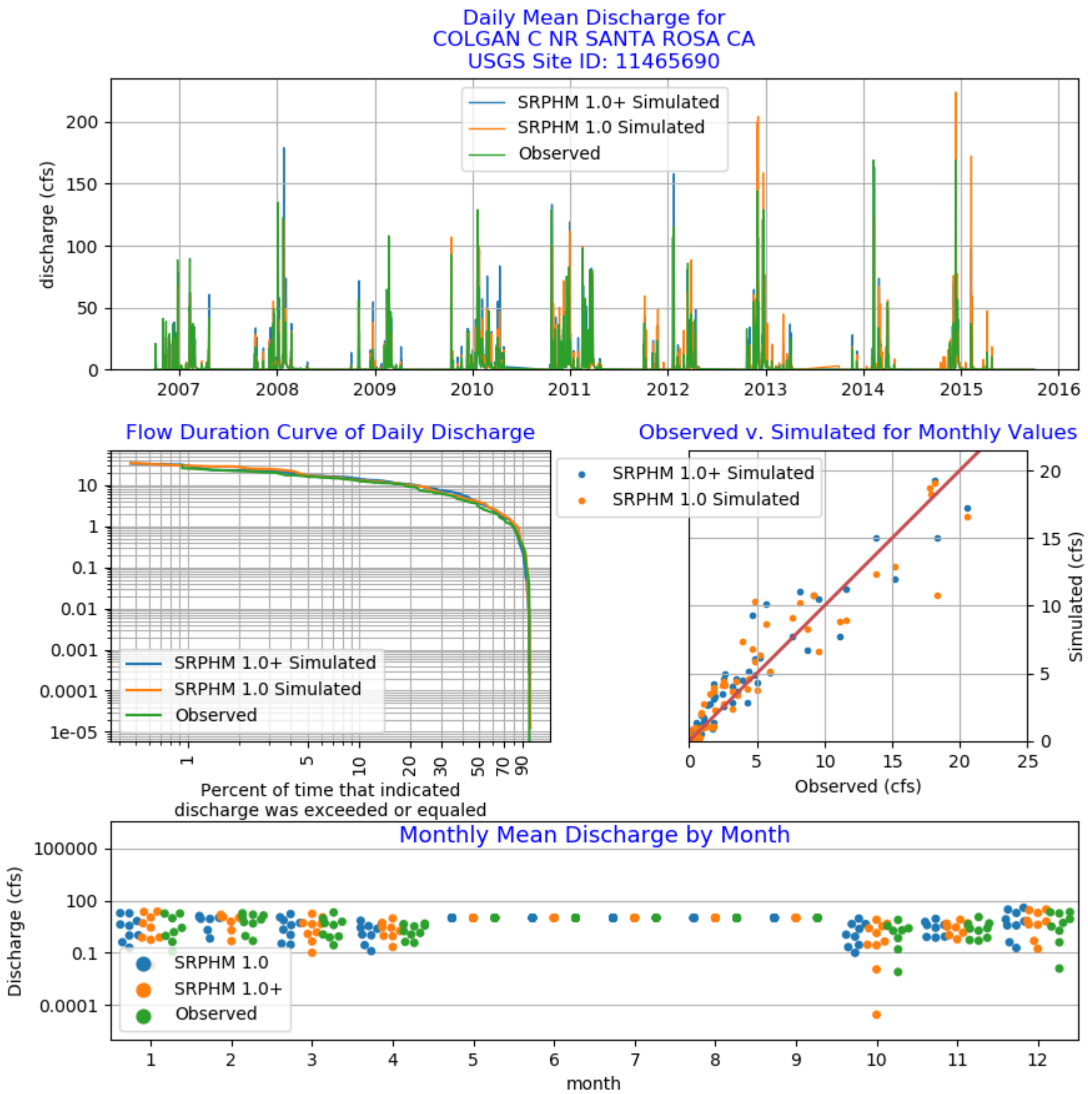


Figure 28 Simulated SRPHM 1.0, SRPHM 1.0+ and observed daily discharge, flow duration, observed versus simulated discharge, and monthly mean discharge for Colgan Creek near Santa Rosa

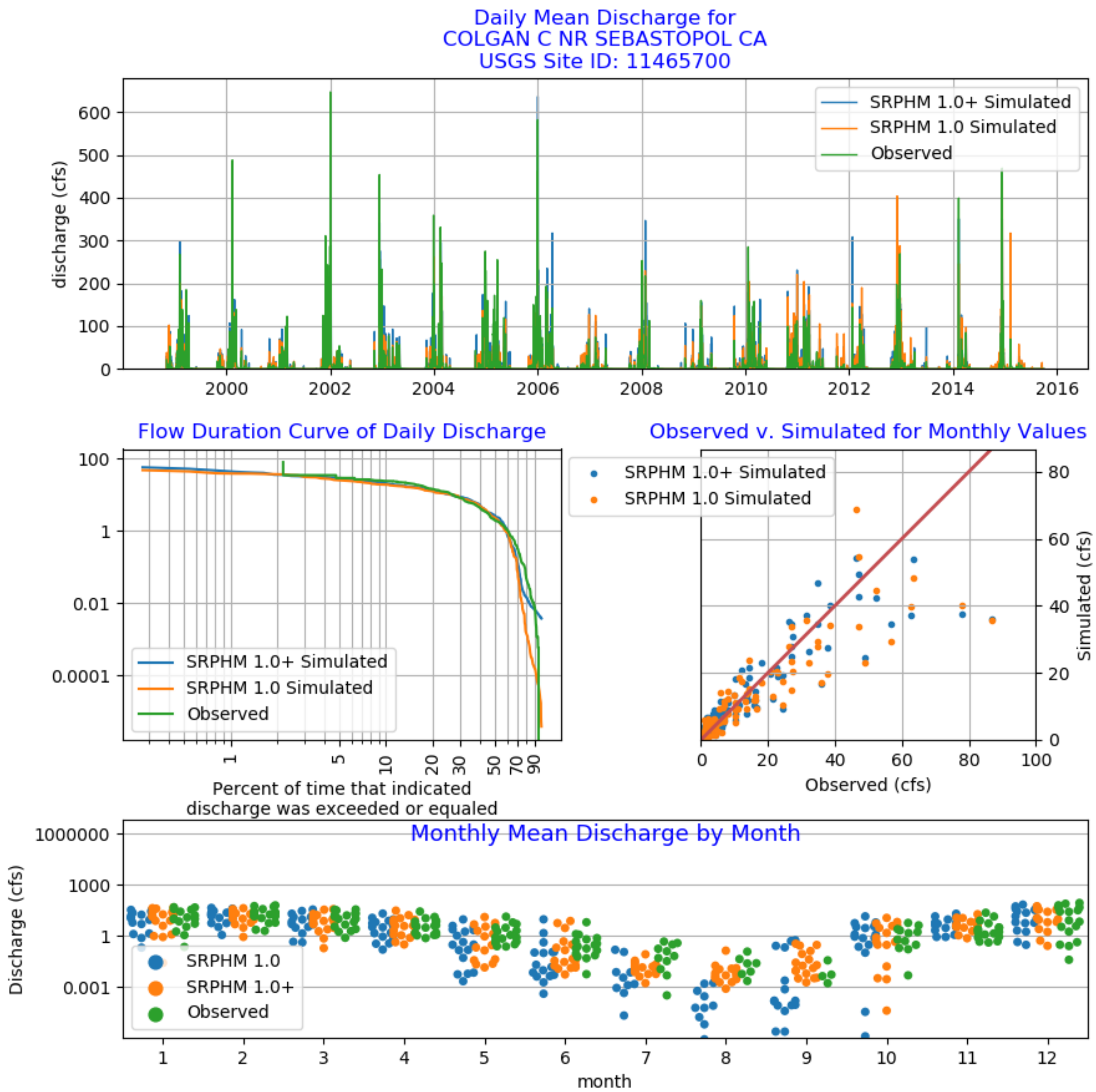


Figure 29 Simulated SRPHM 1.0, SRPHM 1.0+ and observed daily discharge, flow duration, observed versus simulated discharge, and monthly mean discharge for Colgan Creek near Sebastopol

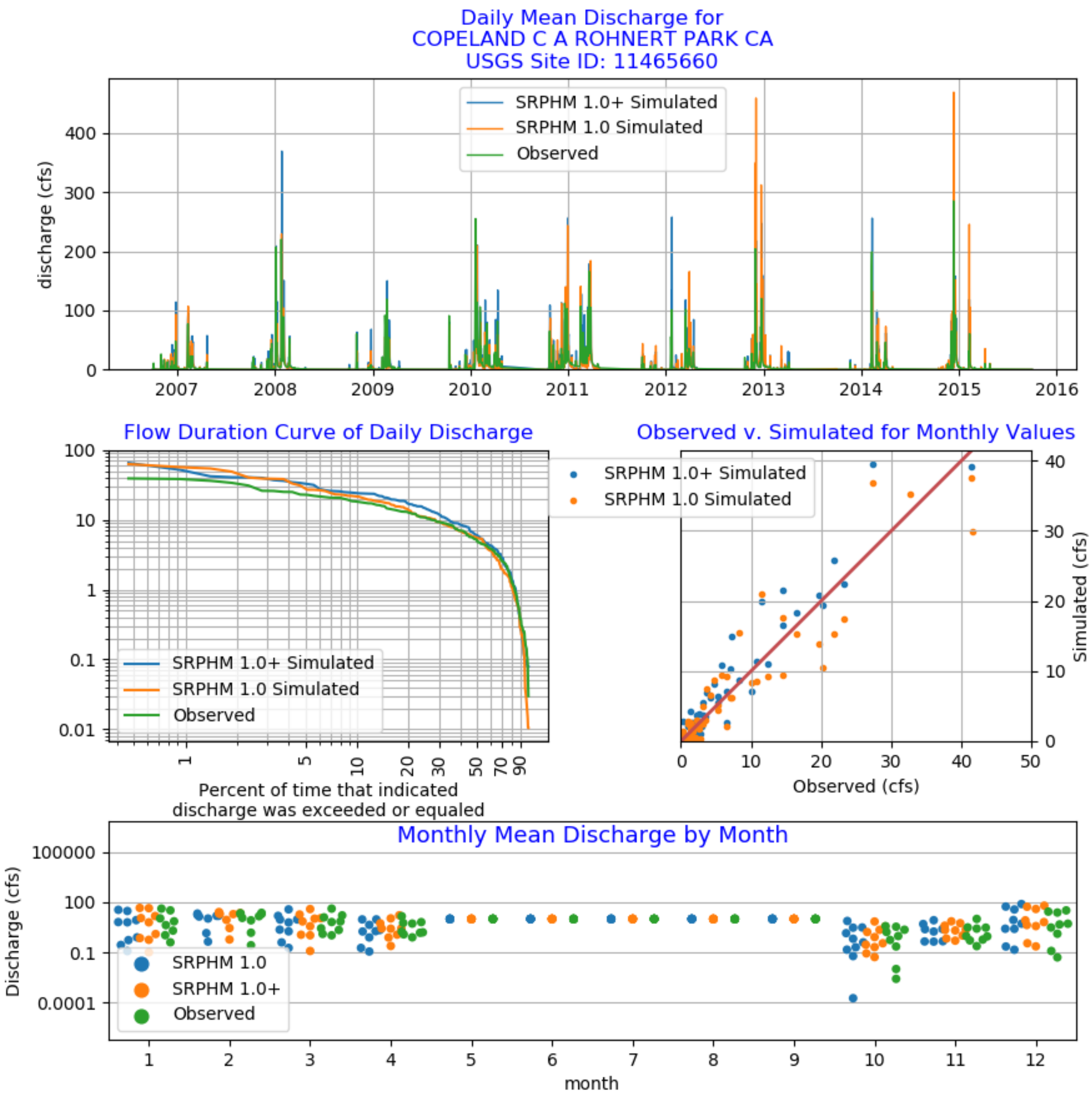


Figure 30 Simulated SRPHM 1.0, SRPHM 1.0+ and observed daily discharge, flow duration, observed versus simulated discharge, and monthly mean discharge for Copeland Creek at Rohnert Park

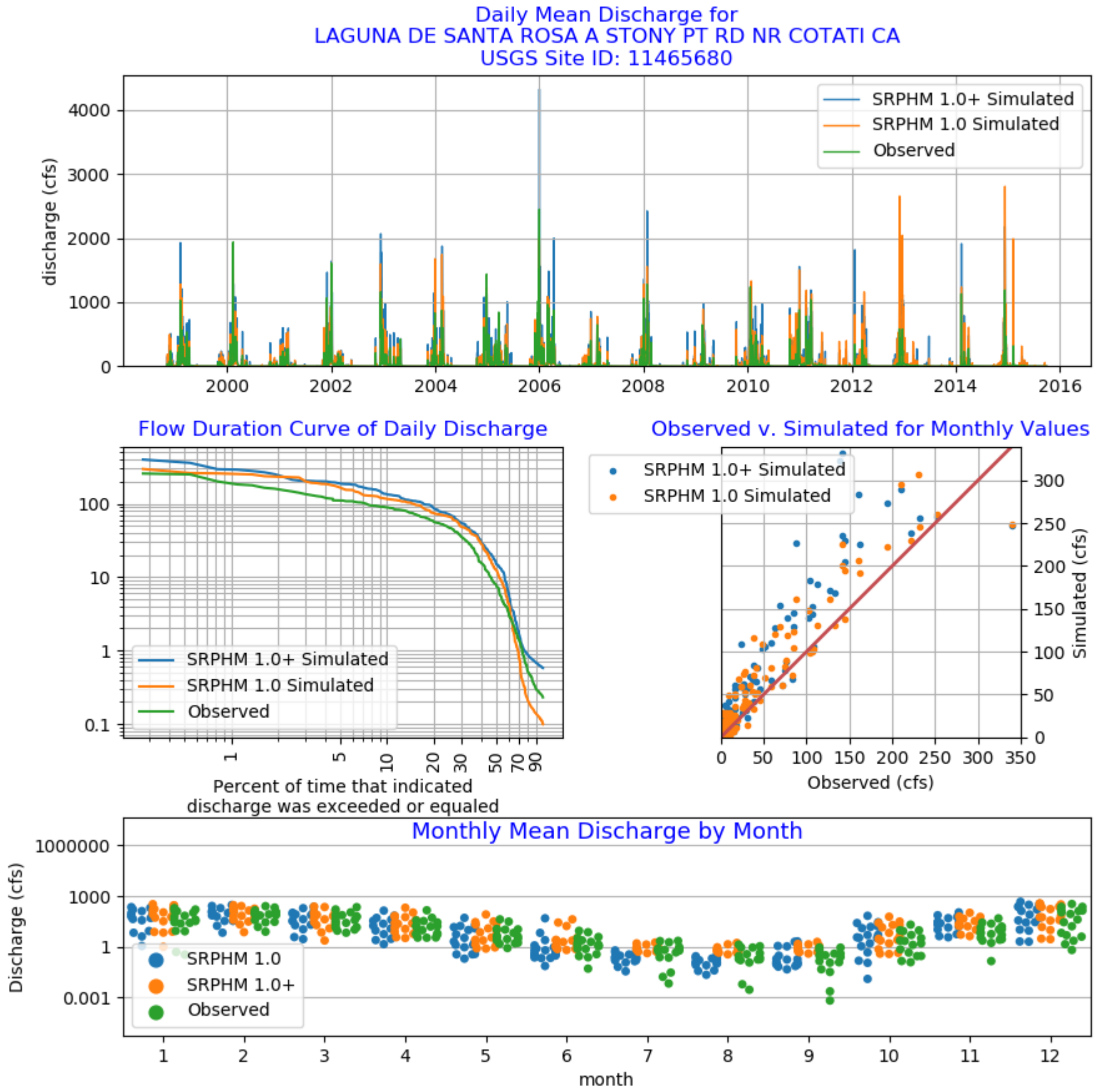


Figure 31 Simulated SRPHM 1.0, SRPHM 1.0+ and observed daily discharge, flow duration, observed versus simulated discharge, and monthly mean discharge for Laguna de Santa Rosa at Stony Point Road Near Cotati

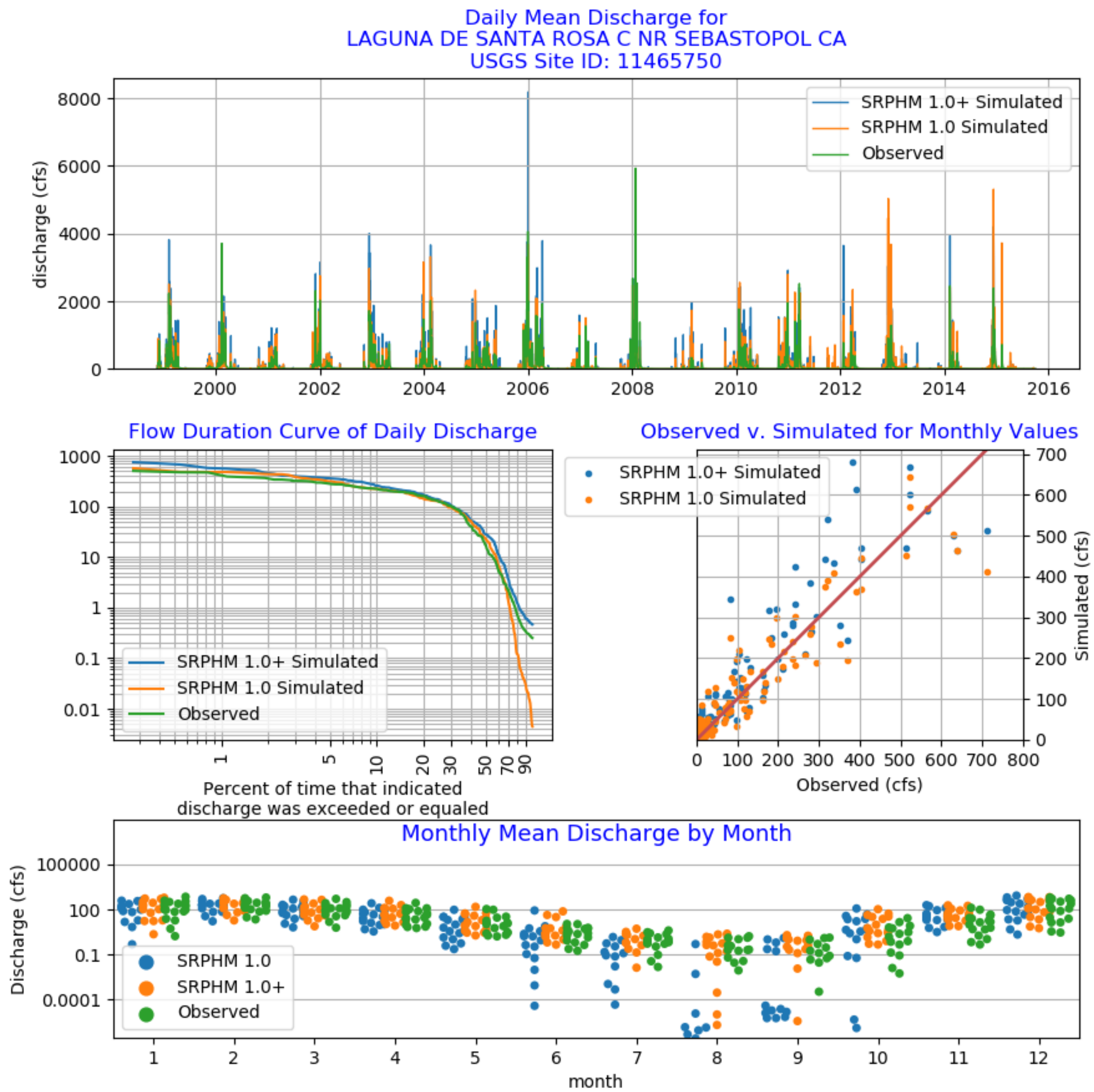


Figure 32 Simulated SRPHM 1.0, SRPHM 1.0+ and observed daily discharge, flow duration, observed versus simulated discharge, and monthly mean discharge for Laguna de Santa Rosa Creek Near Sebastopol

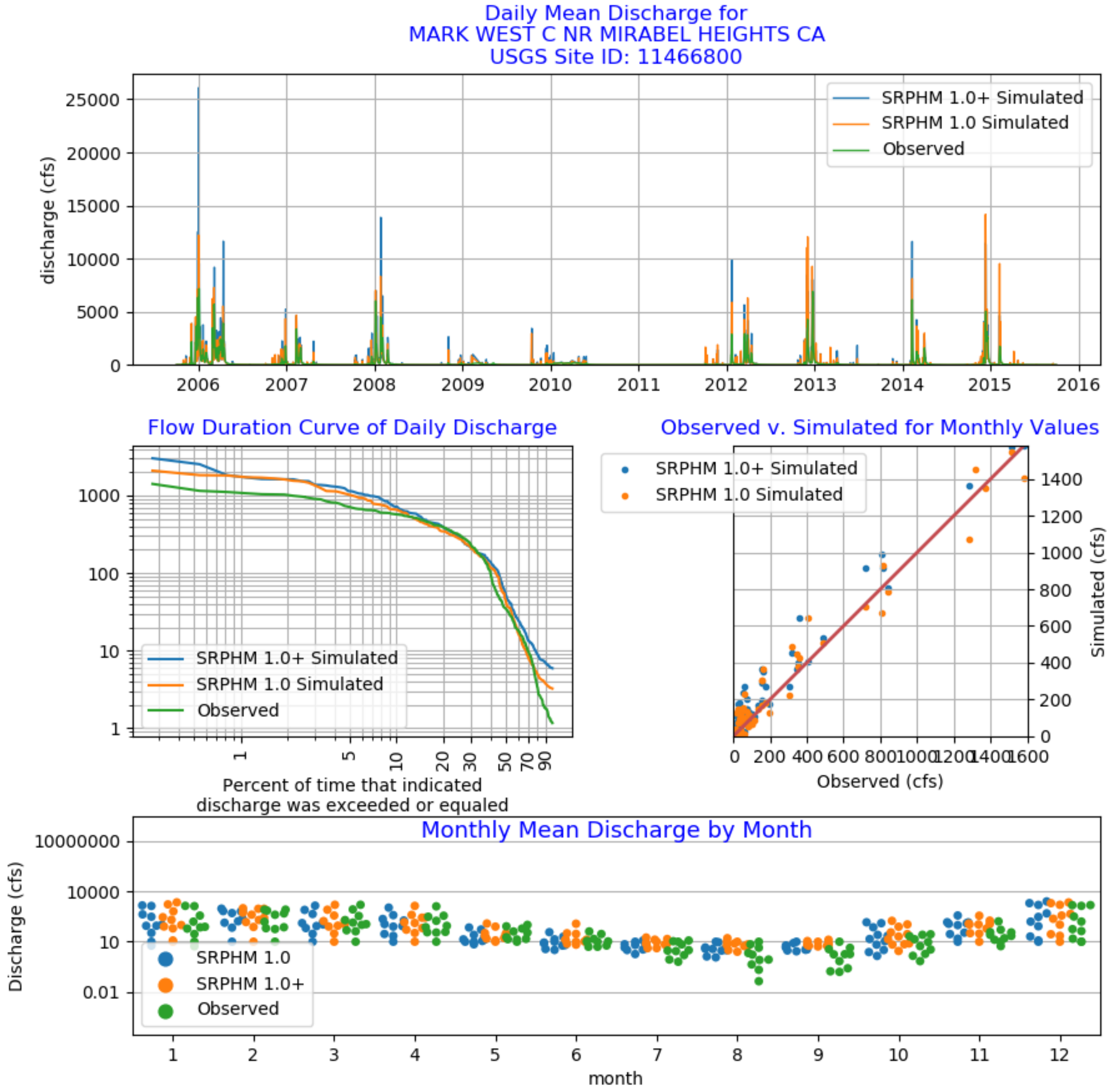


Figure 33 Simulated SRPHM 1.0, SRPHM 1.0+ and observed daily discharge, flow duration, observed versus simulated discharge, and monthly mean discharge for Mark West Creek Near Mirabel Heights

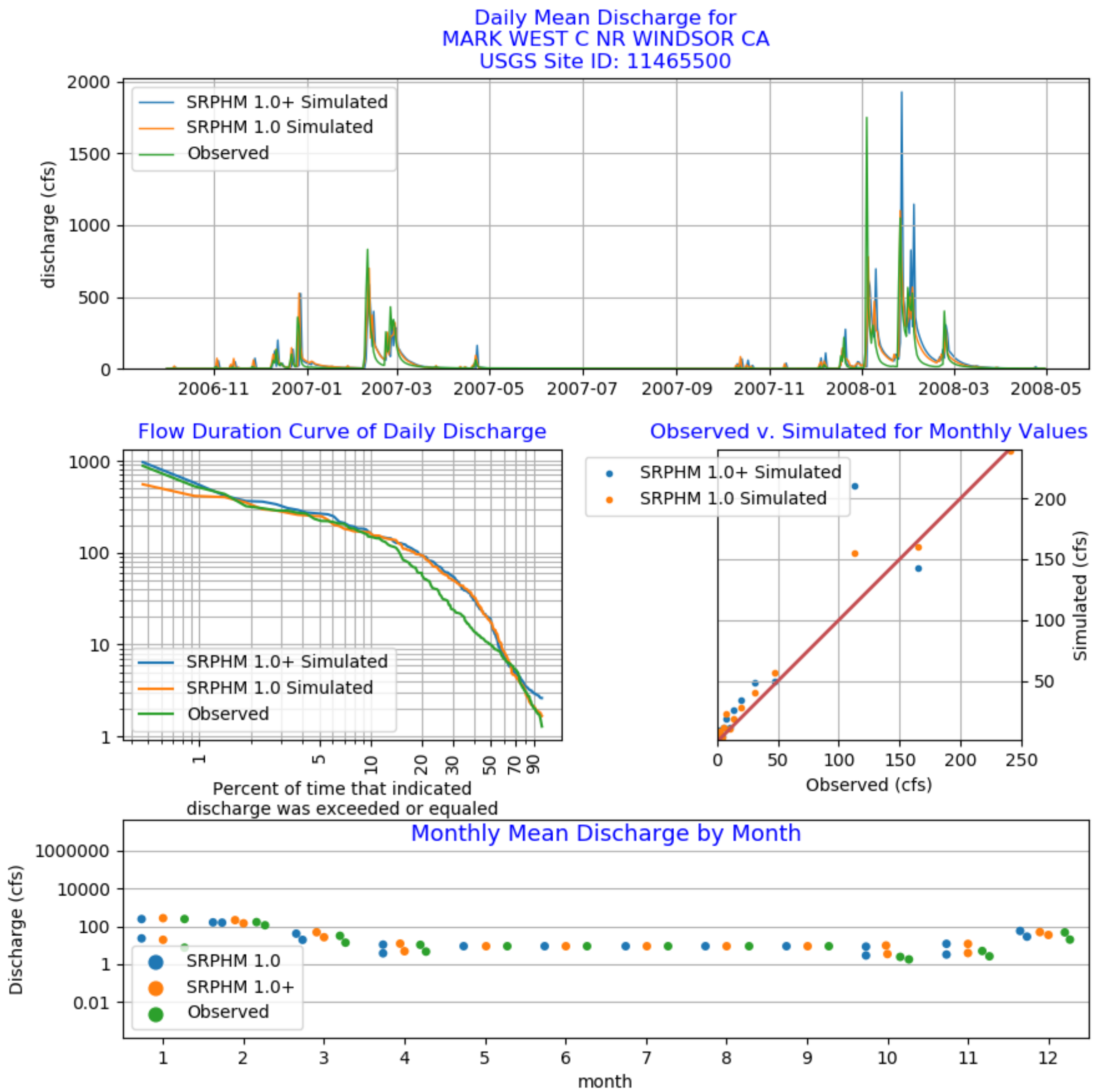


Figure 34 Simulated SRPHM 1.0, SRPHM 1.0+ and observed daily discharge, flow duration, observed versus simulated discharge, and monthly mean discharge for Mark West Creek Near Windsor

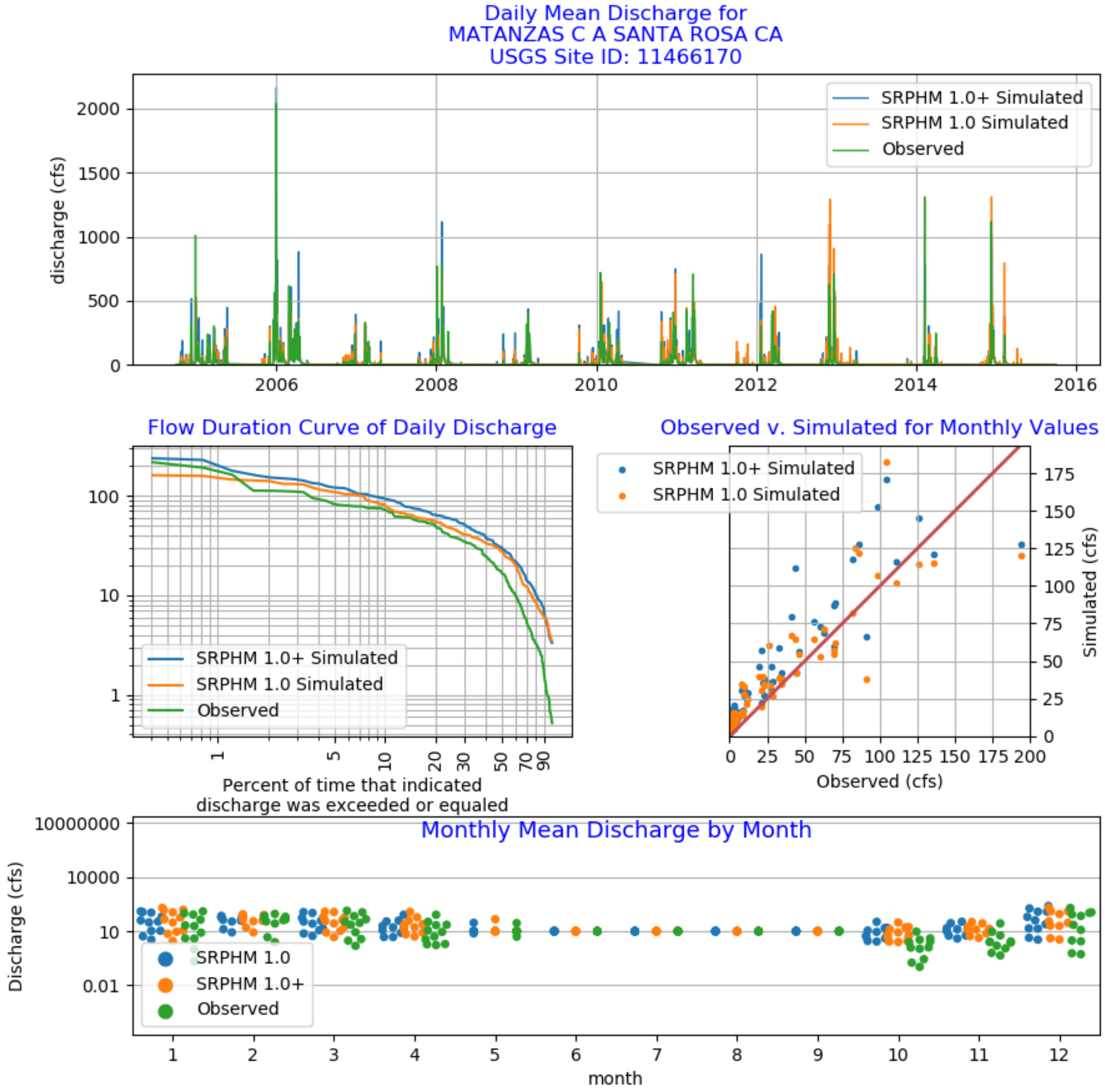


Figure 35 Simulated SRPHM 1.0, SRPHM 1.0+ and observed daily discharge, flow duration, observed versus simulated discharge, and monthly mean discharge for Mayacamas Creek at Santa Rosa

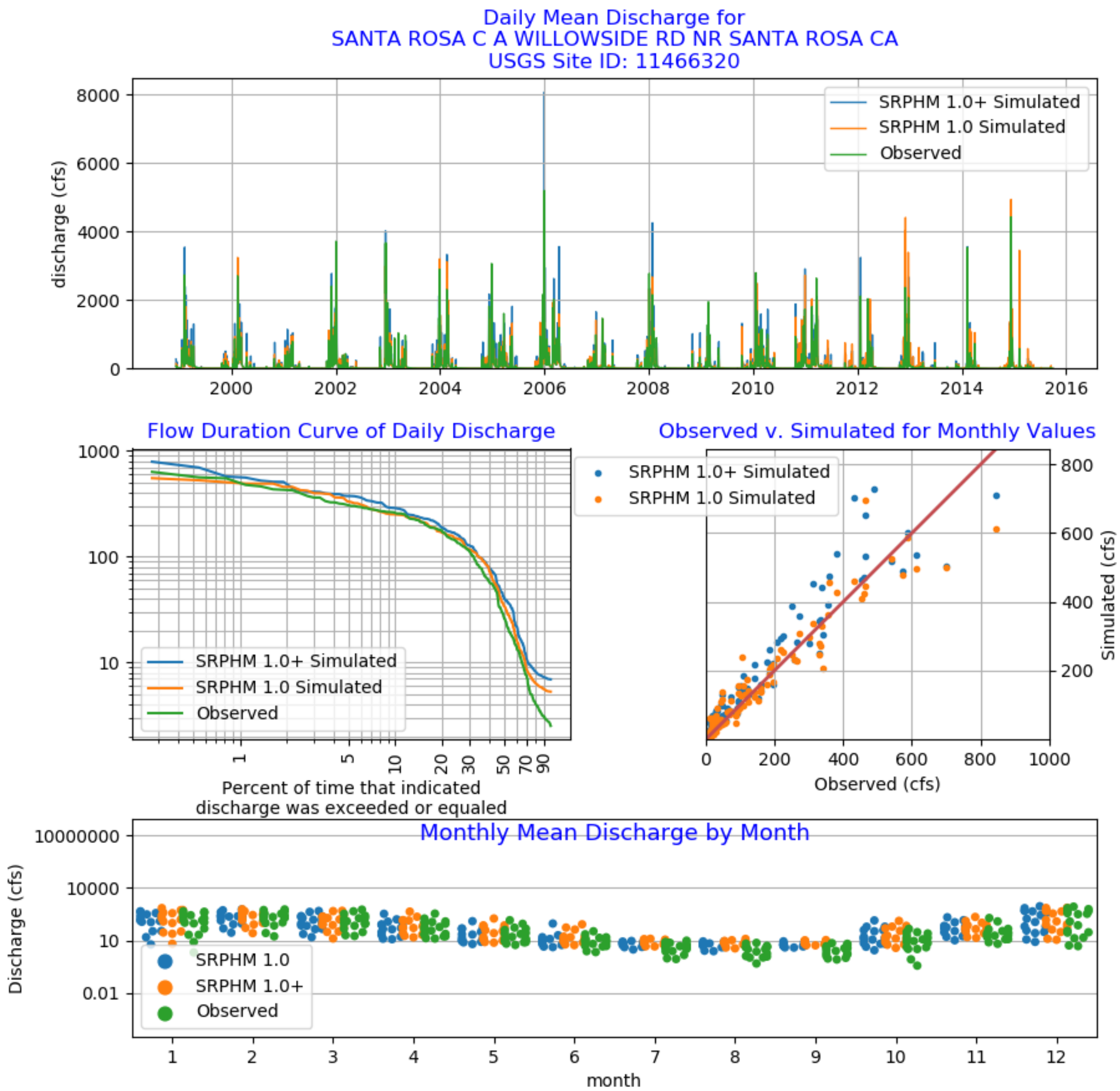


Figure 36 Simulated SRPHM 1.0, SRPHM 1.0+ and observed daily discharge, flow duration, observed versus simulated discharge, and monthly mean discharge for Santa Rosa Creek at Willowside Road Near Santa Rosa

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Appendix 3-D
Future Groundwater Demands and Land Use Changes

Projection of Future Water Demands for Rural Residential and Municipal Water Users, and Changes in Agricultural Land Use for the Groundwater Sustainability Plans of the Santa Rosa Plain, Sonoma Valley, and the Petaluma Valley Subbasin

Future Groundwater Demands and Land Use Change

Santa Rosa Plain GSA, Sonoma Valley GSA, and Petaluma Valley GSA

The Petaluma Valley, Santa Rosa Plain, and the Sonoma Valley Groundwater Sustainability Agencies are required to incorporate projections of future groundwater use as part of their groundwater sustainability plan (GSP) development. This document details the methods and data used to make such projections. The documents contained herein were presented to the Advisory Committee for each GSA during the development of the GSP. The documents detail the projected changes in 1) land use for agriculture, 2) new housing units requiring groundwater for supply, and 3) municipal groundwater demand projections. The outputs from these projections are incorporated into the groundwater model for each groundwater subbasin,. The simulations cover the time period from October 2020 to September 2071.

Agricultural Water Demand Projections

Agricultural Water Demand Projections

Land-Use Surveys

This memo provides an overview of *preliminary* outcomes from the Agricultural Water Demand workgroup to date. The outcomes described below do not represent final work products; they are intended to offer an update for discussion purpose during October 2020 Advisory Committee meetings for the Sonoma Valley, Petaluma Valley, and Santa Rosa Plain subbasins. A complete summary of all practitioner work group outcomes will be provided to all Advisory Committees at the conclusion of discussions in the fall of 2020.

The primary focus of the Ag Demands work group has been providing estimates of agricultural contraction or expansion over the 50-year planning horizon of the GSP for major crop types in the three subbasins, including:

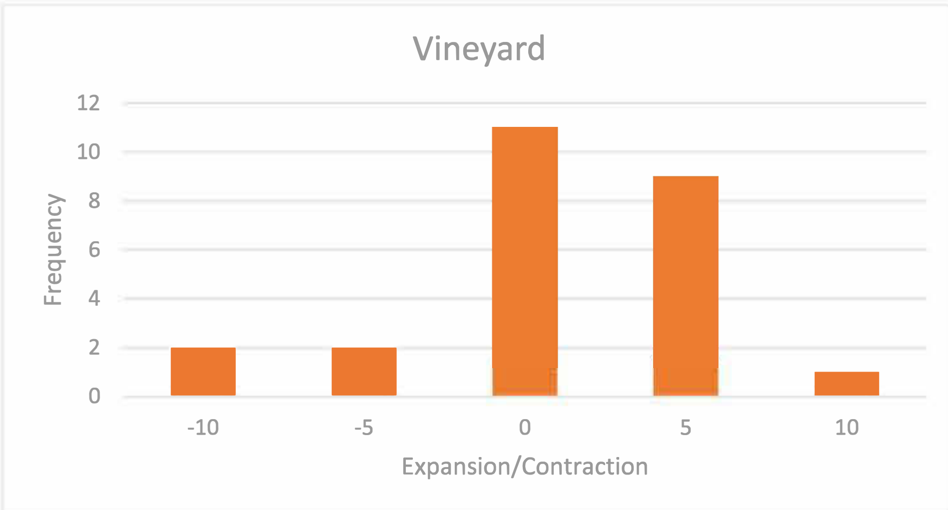
- Vineyards
- Irrigated pasture
- Dairies
- Grain and hay crops
- Truck, nursery, or berry crops (including row vegetables and field crops such as hops)
- Orchards/deciduous fruits and nuts
- Cannabis/hemp

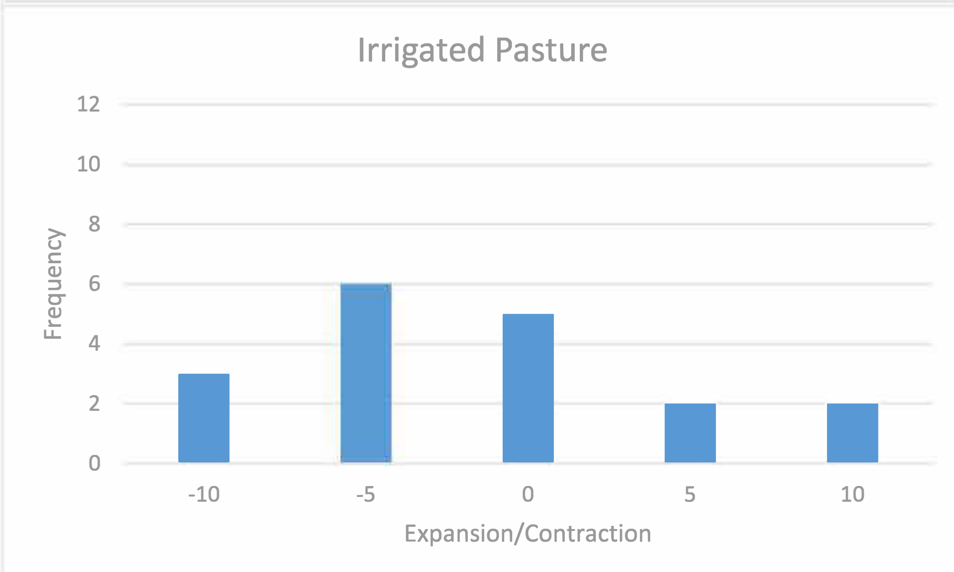
At the June 23rd meeting, work group members estimated that for all crop during the GSP planning horizon, the three subbasins can expect a general reduction of farmed acreage crop types with the exception of vineyards and cannabis/hemp. Work group members did concede that at least in the near term (5-10 years) vineyard production is also likely to contract, primarily due to market forces and an oversupply of grapes. Water supply availability, population growth/land conversion for residential use, and land prices in general were cited as the primary causes for contraction of other agricultural uses.

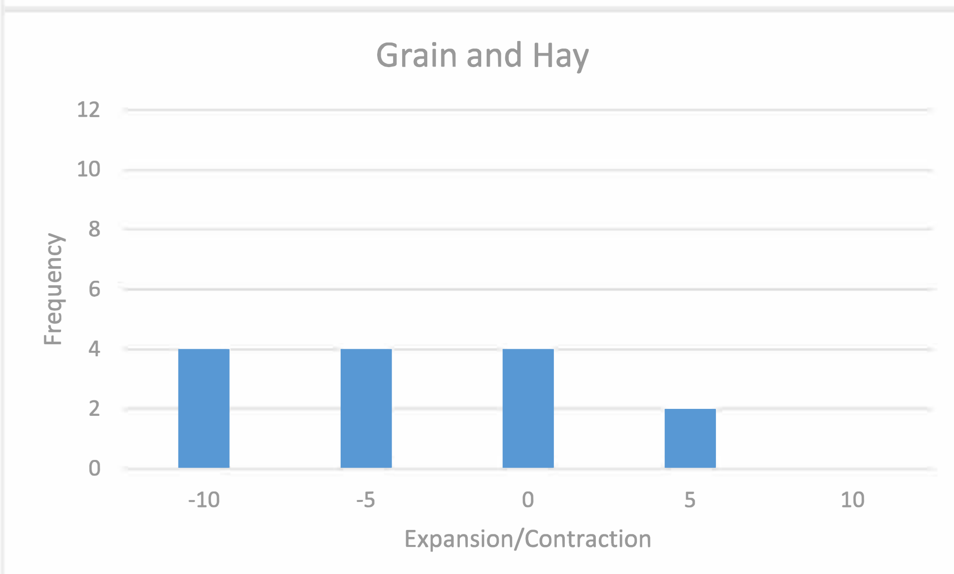
To further evaluate these assumptions, staff developed survey forms, which were sent to the Agricultural Water Demands Practitioner Work Group (7 respondents) and to agricultural land users in the SRP, SV, and PV (28 respondents). The surveys were distributed in late July and early August of 2020. Both surveys asked respondents about expected expansion or contraction of the following agricultural land uses: vineyards; irrigated pasture; grain and hay; truck, nursery, or berry crops (truck crops); orchards/deciduous fruits and nuts; cannabis/hemp; and other. Note that no respondent described “other”; therefore, this land use will not be addressed here.

There were differences in the surveys. The agricultural land users were asked about short term (10 years) and long term (50 years) changes in agricultural land use, while the practitioners were asked about only short-term changes. The agricultural land users were asked about dairies while the practitioners were not. The agricultural land users were asked if their answers were specific to one of the three groundwater basins and a plurality (13/28) indicated the SRP. It should be noted that some of the practitioners indicated that preserving Tiger Salamander habitat in the SRP will be a constraint to agricultural expansion in that basin.

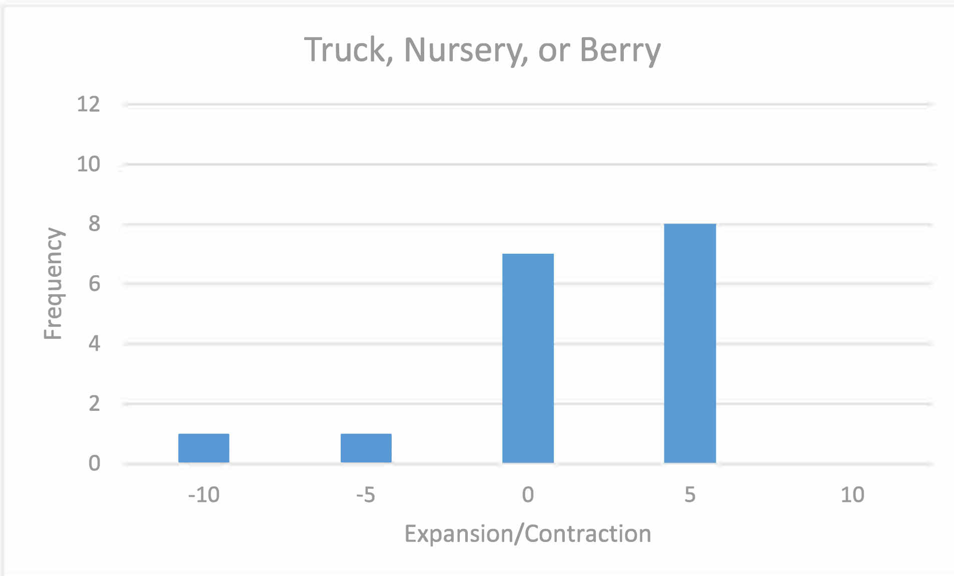
Figures 1 and 2 show the survey results for expected short-term and long-term agricultural land-use changes, respectively. The short-term results combine the practitioner and land user responses with the exception of dairies, which only reflect the land-user responses. The long-term results only reflect the land-user responses. The X-axis shows the expected expansion or contraction, where -10, -5, 0, 5 and 10 are the percentage change in land use; where a negative value indicates contraction, zero indicates no change, and a positive value indicates expansion. The Y-axis shows the total count or frequency for each land-use change category.

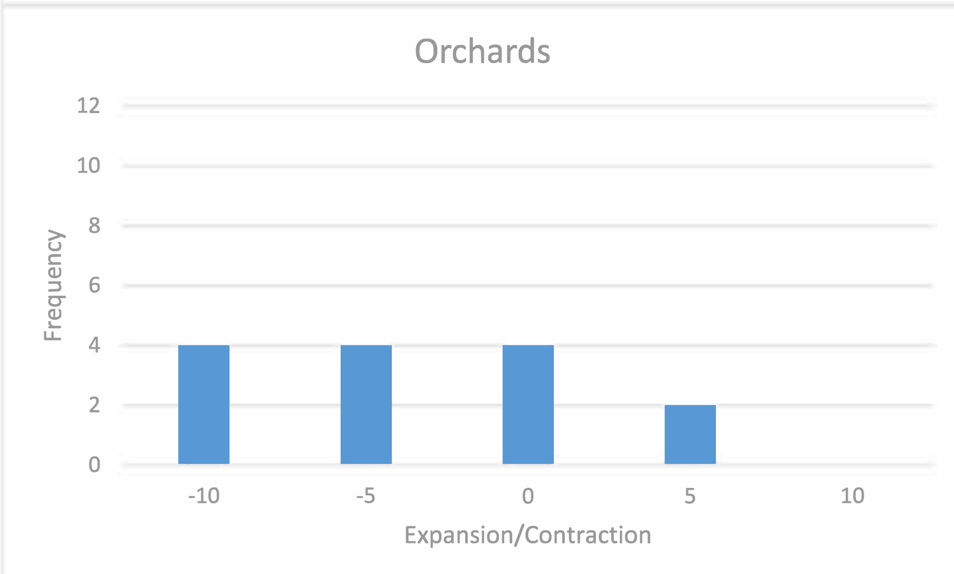

Vineyard
Frequency
12
10
8
6
4
2
0
-10
-5
0
5
10
Expansion/Contraction


Irrigated Pasture
Frequency
12
10
8
6
4
2
0
-10
-5
0
5
10
Expansion/Contraction


Grain and Hay
Frequency
12
10
8
6
4
2
0
-10
-5
0
5
10
Expansion/Contraction

3


Truck, Nursery, or Berry
12
10
8
6
4
2
0
Frequency
-10
-5
0
5
10
Expansion/Contraction


Orchards
12
10
8
6
4
2
0
Frequency
-10
-5
0
5
10
Expansion/Contraction

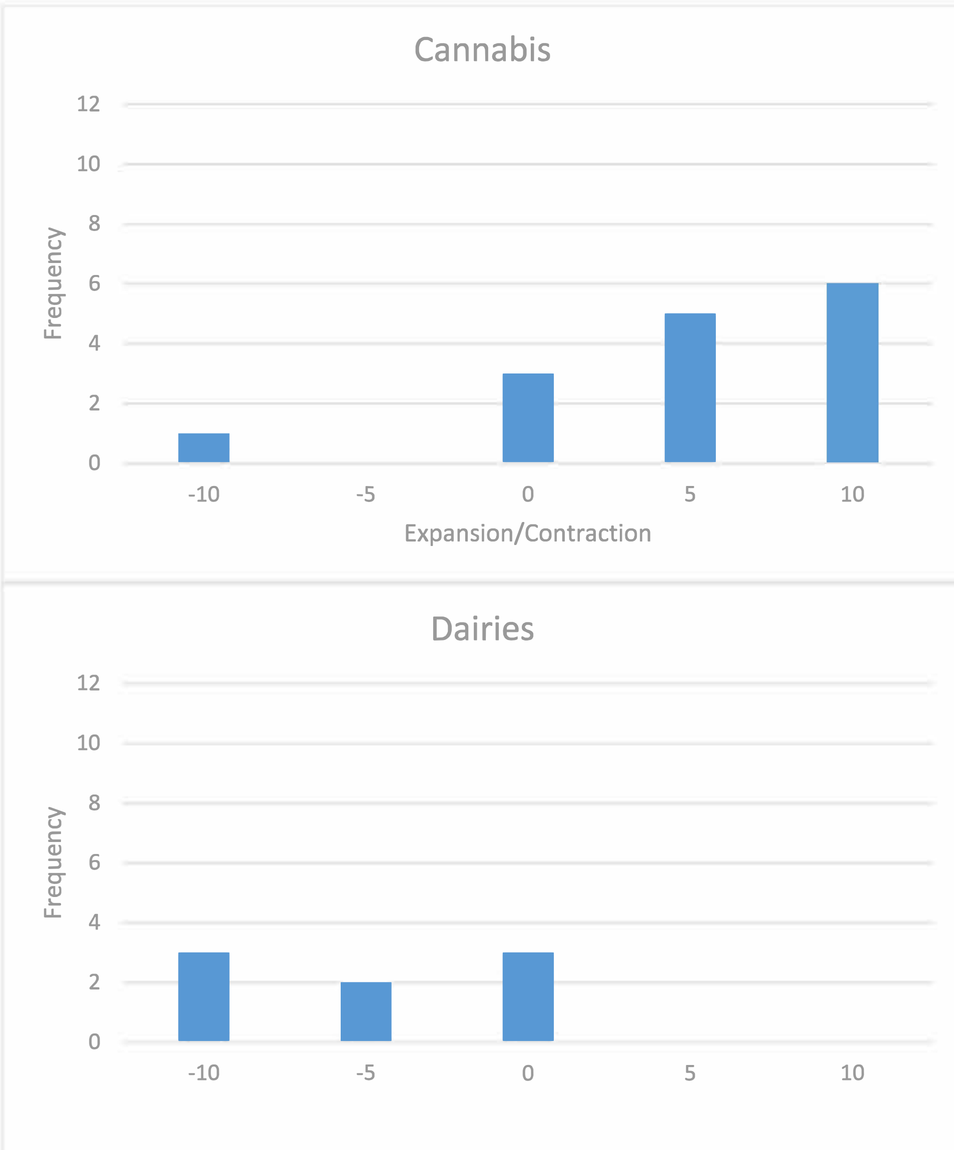
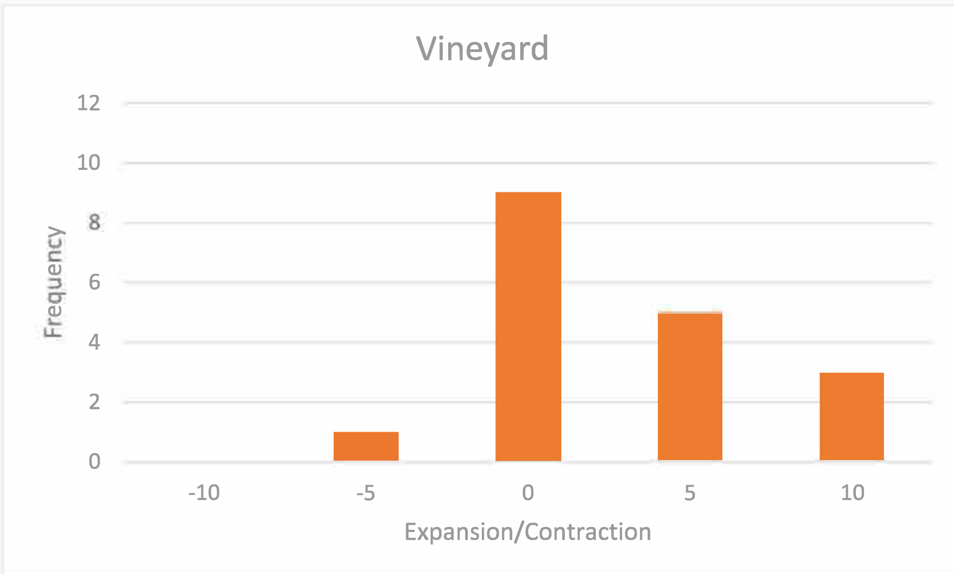
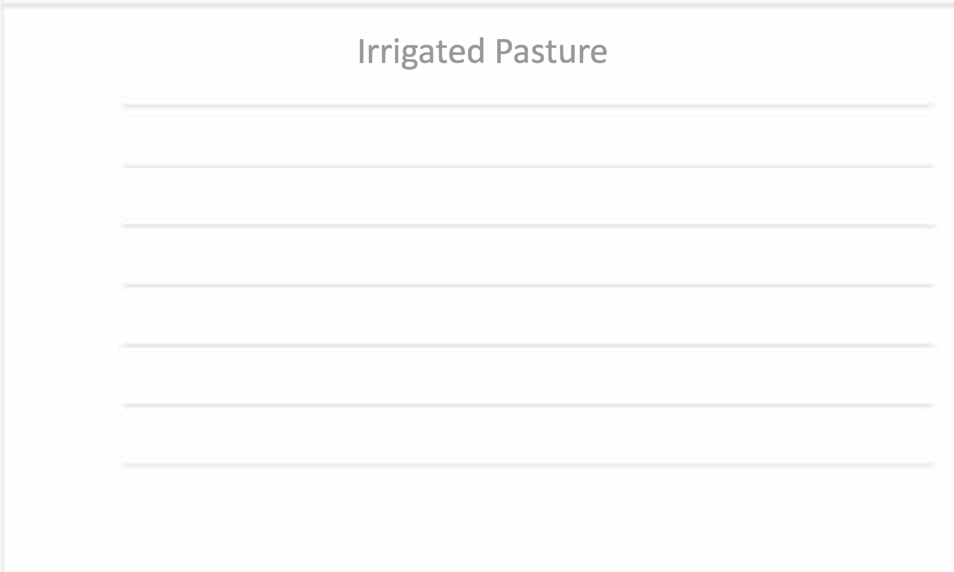


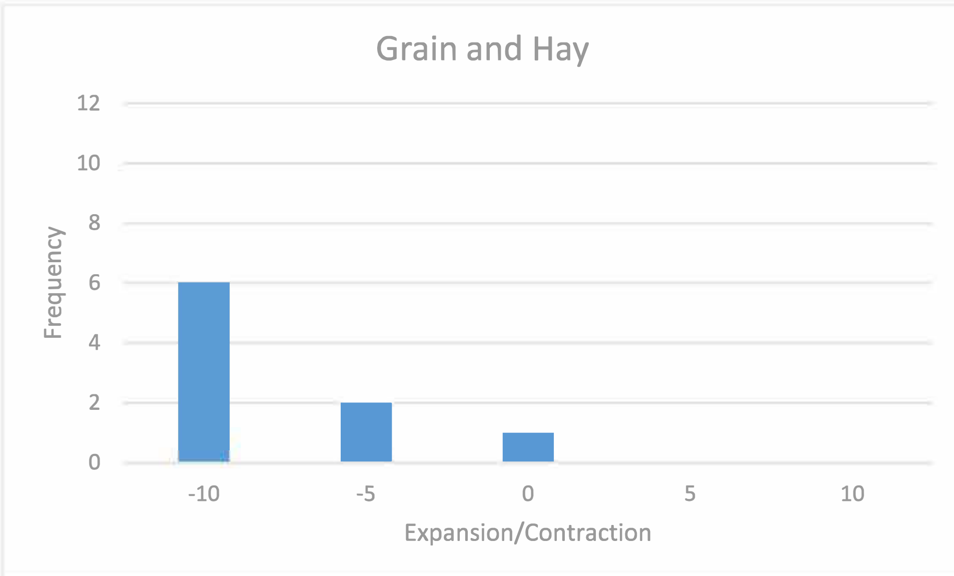
Figure 1. Short-term agricultural land-use changes in the Santa Rosa Plain, Sonoma Valley, and Petaluma Valley.

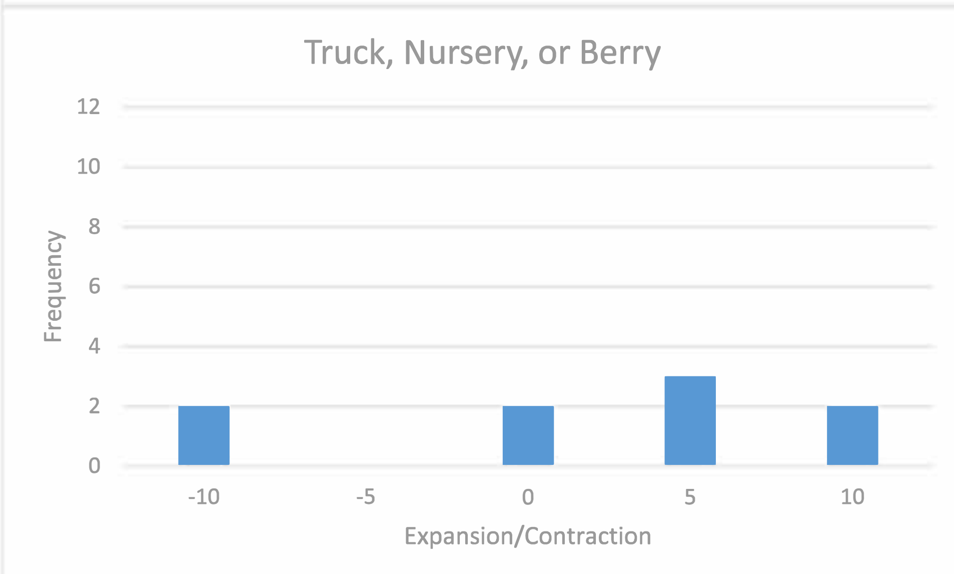
Consider the expected short-term land-use changes (fig. 1). Vineyards, truck crops, and cannabis/hemp are expected to expand (0-5%, 0-5%, and 5-10%, respectively). The other land uses are expected to contract as much as 10% (dairies).

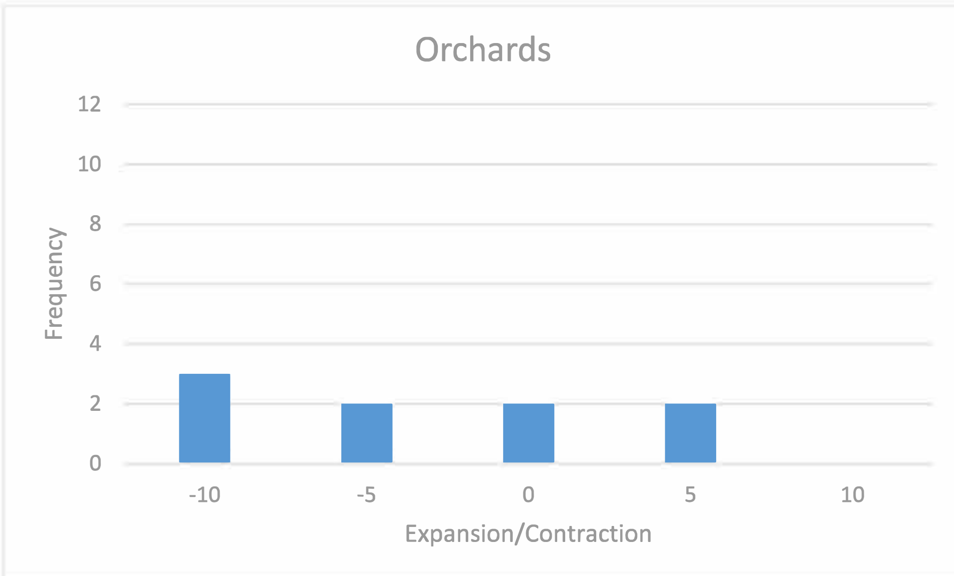

Vineyard
12
10
8
6
4
2
0
Frequency
-10
-5
0
5
10
Expansion/Contraction

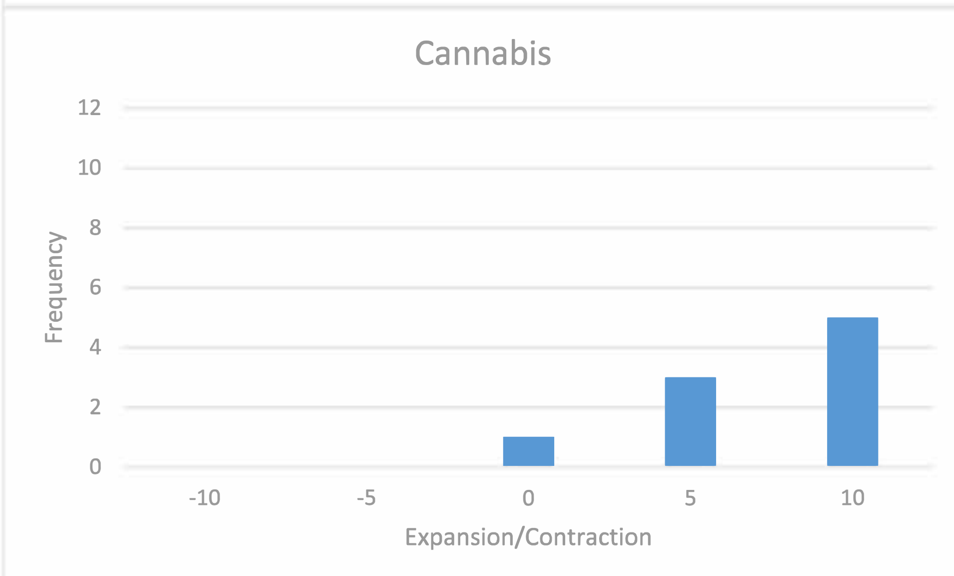

Irrigated Pasture

6


Grain and Hay
Frequency
12
10
8
6
4
2
0
-10
-5
0
5
10
Expansion/Contraction


Truck, Nursery, or Berry
Frequency
12
10
8
6
4
2
0
-10
-5
0
5
10
Expansion/Contraction


Orchards
Frequency
12
10
8
6
4
2
0
-10
-5
0
5
10
Expansion/Contraction


Cannabis
Frequency
12
10
8
6
4
2
0
-10
-5
0
5
10
Expansion/Contraction

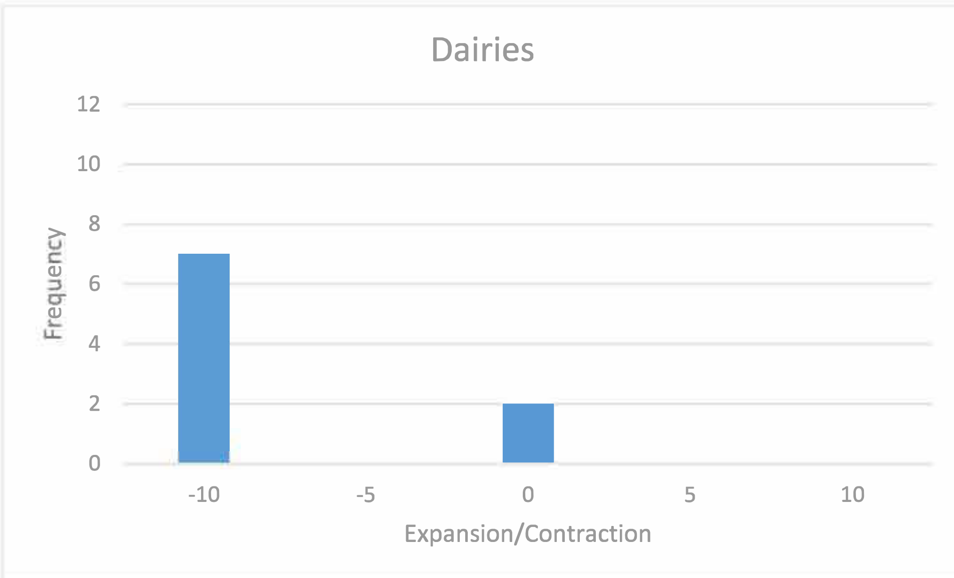
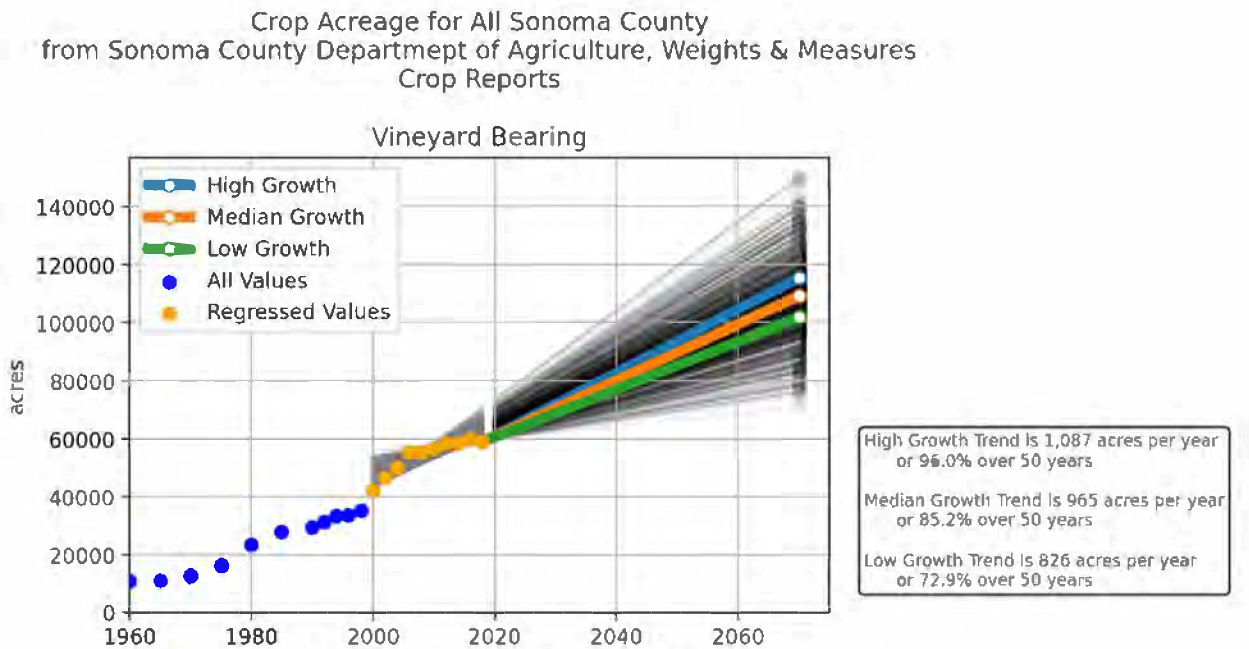


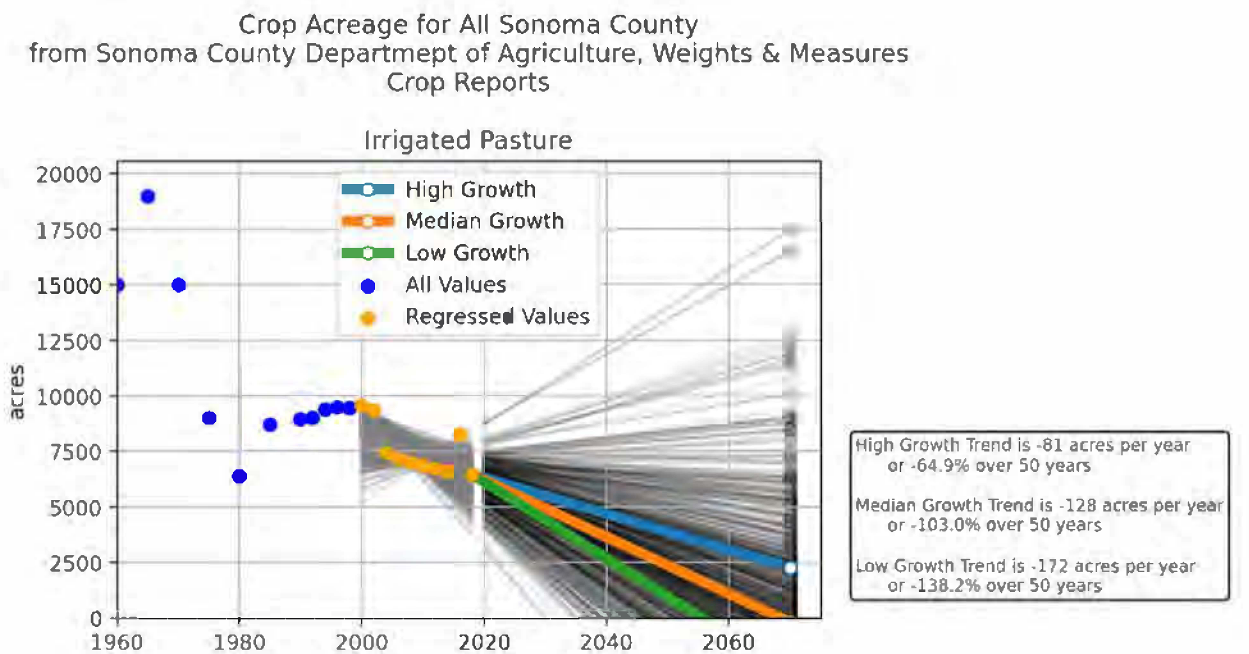
Figure 2. Long-term agricultural land-use changes in the Santa Rosa Plain, Sonoma Valley, and Petaluma Valley.

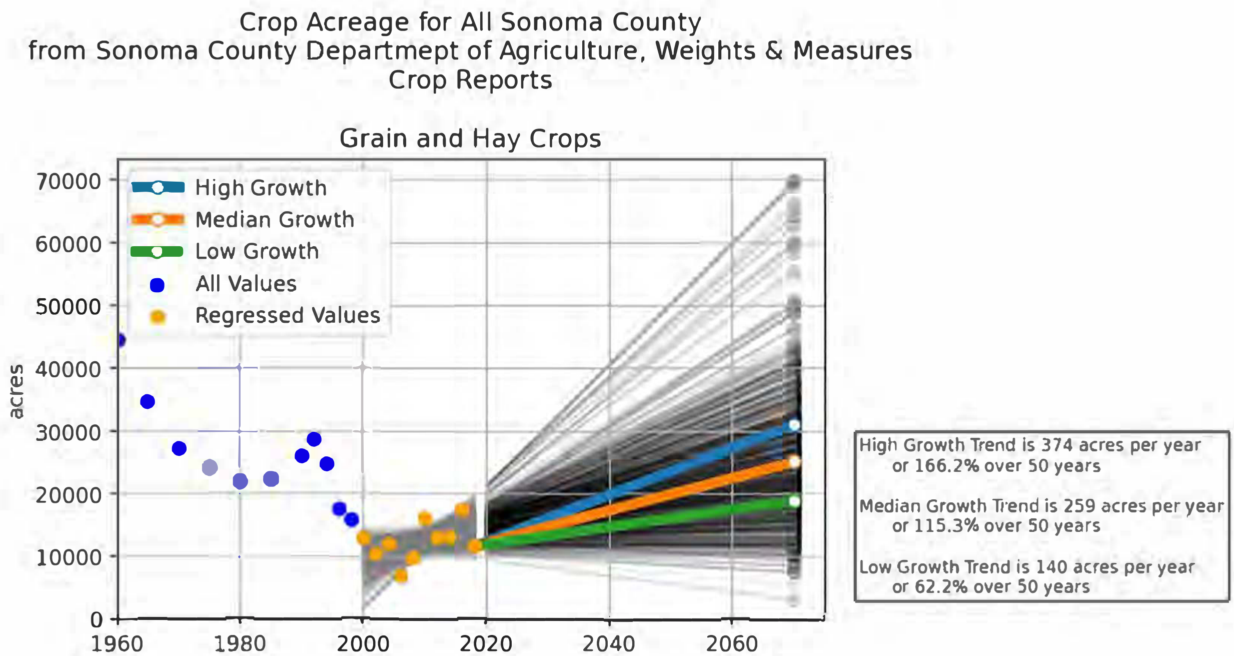
Consider the expected long-term land-use changes (fig. 2). Vineyards, truck crops, and cannabis/hemp again are expected to expand (0-10%, 0-10%, and 5-10%, respectively); however, a fairly large number of respondents expected truck crops to contract 10%. All the other land uses are expected to contract as much as 10%.

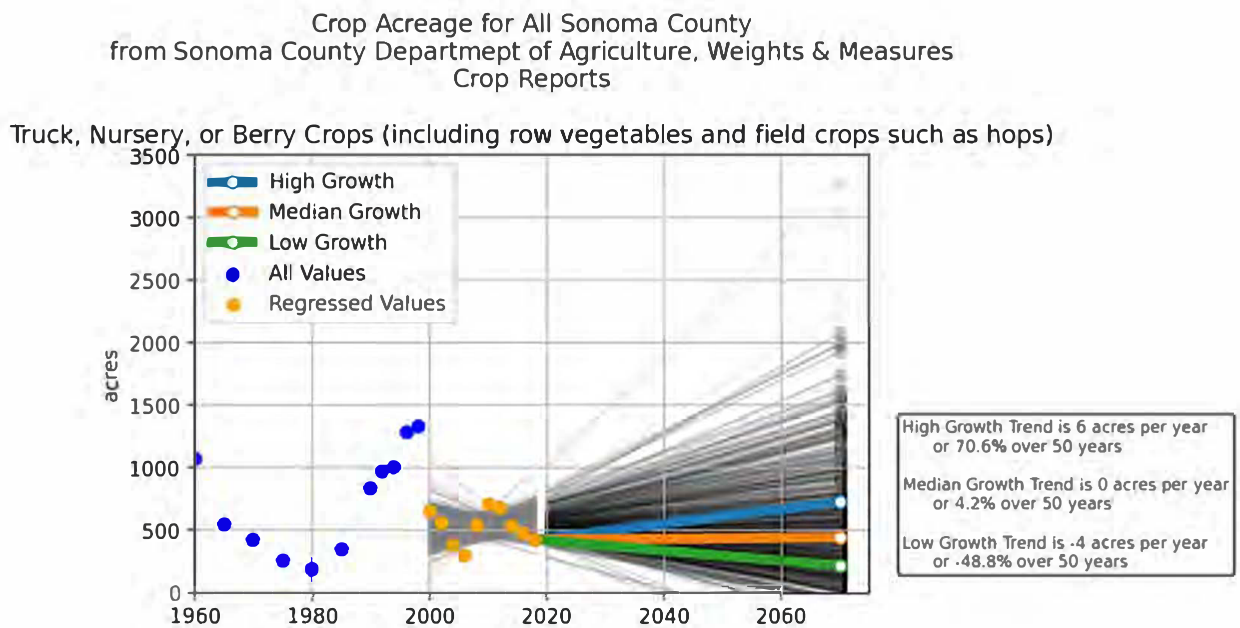
Reported Land-Use Data

In order to provide a comparison of survey results with historical changes in cropping patterns, land-use data from 1960 to 2018 (every 5 years until 1990, then every 2 years thereafter) for vineyards; irrigated pasture; grain and hay; truck crops; and orchards/deciduous fruits and nuts were compiled using Sonoma County crop reports (https://sonomacounty.ca.gov/Agriculture-Weights-and-Measures/Crop-Reports/) and are shown in figure 3. Note that the data compiled from the crop reports and displayed here represent all of Sonoma County. The crop reports reported bearing, nonbearing, and total acreage for vineyards and occasionally for orchards/deciduous fruits and nuts. In addition, the reports reported harvested acreage for the other land uses; it was assumed that harvested acreage was equivalent to bearing acreage. Therefore, bearing acreage is shown in figure 3.


Crop Acreage for All Sonoma County
from Sonoma County Departmept of Agriculture, Weights & Measures
Crop Reports
Vineyard Bearing
High Growth
Median Growth
Low Growth
All Values
Regressed Values
acres
High Growth Trend is 1,087 acres per year
or 96.0% over 50 years
Median Growth Trend is 965 acres per year
or 85.2% over 50 years
Low Growth Trend is 826 acres per year
or 72.9% over 50 years


Crop Acreage for All Sonoma County
from Sonoma County Departmept of Agriculture, Weights & Measures
Crop Reports
Irrigated Pasture
High Growth
Median Growth
Low Growth
All Values
Regressed Values
acres
High Growth Trend is -81 acres per year
or -64.9% over 50 years
Median Growth Trend is -128 acres per year
or -103.0% over 50 years
Low Growth Trend is -172 acres per year
or -138.2% over 50 years


Crop Acreage for All Sonoma County
from Sonoma County Departmept of Agriculture, Weights & Measures
Crop Reports
Grain and Hay Crops
High Growth
Median Growth
Low Growth
All Values
Regressed Values
acres
70000
60000
50000
40000
30000
20000
10000
0
1960
1980
2000
2020
2040
2060
High Growth Trend is 374 acres per year or 166.2% over 50 years
Median Growth Trend is 259 acres per year or 115.3% over 50 years
Low Growth Trend is 140 acres per year or 62.2% over 50 years


Crop Acreage for All Sonoma County
from Sonoma County Departmept of Agriculture, Weights & Measures
Crop Reports
Truck, Nursery, or Berry Crops (including row vegetables and field crops such as hops)
High Growth
Median Growth
Low Growth
All Values
Regressed Values
acres
3500
3000
2500
2000
1500
1000
500
0
1960
1980
2000
2020
2040
2060
High Growth Trend is 6 acres per year or 70.6% over 50 years
Median Growth Trend is 0 acres per year or 4.2% over 50 years
Low Growth Trend is -4 acres per year or -48.8% over 50 years

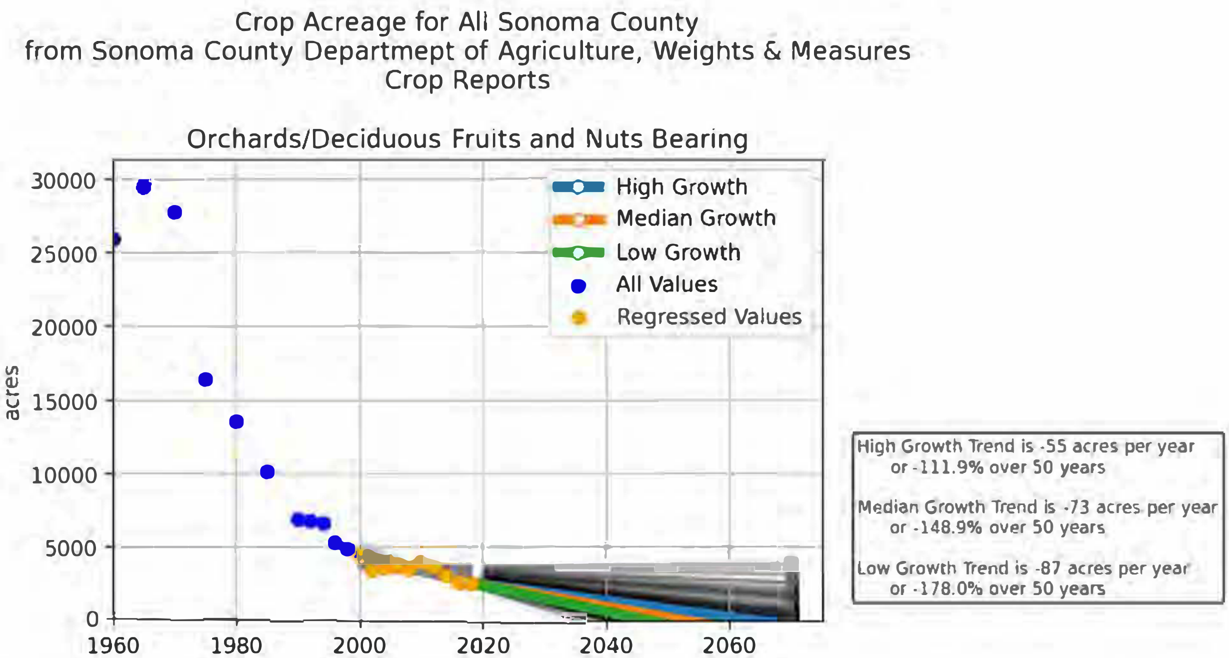


Figure 3: Agricultural land use for vineyards; irrigated pasture; grain and hay; truck crops; and orchards/deciduous fruits and nuts, 1960-2018. Future land use contraction or expansion based on 2000-2018 data.

In addition to the historic land use, the data were extrapolated from 2020 to 2070 based on regressions of the 2000 - 2018 data (fig. 3). An additional regression of the 2008-2018 data was performed for vineyards, as the growth pattern exhibited a more moderate rate during this more recent time period (fig. 4). The regressions include high, median, and low growth trends. Qualitatively, the results indicate that vineyards; grain and hay; and truck crops may expand while irrigated pastures and orchards contract (fig. 3). With the exception of grain and hay, these results generally agree with the survey results. However, the scale of expansion/contraction differ. For example, the regression indicates that vineyard acreage may expand 20% in 10 years and almost 100% in 50 years based on the 2000-2018 data and 10% in 10 years and 48% in 50 years based on the 2008-2018 data (figs. 3 and 4). On the other hand, the regression indicates that irrigated pastures may contract 50% in 10 years and almost 140% in 50 years (fig. 3). The survey results indicated an expected 0-10% expansion of vineyards and an expected 5-10% contraction of irrigated pastures within 50 years (fig. 2).

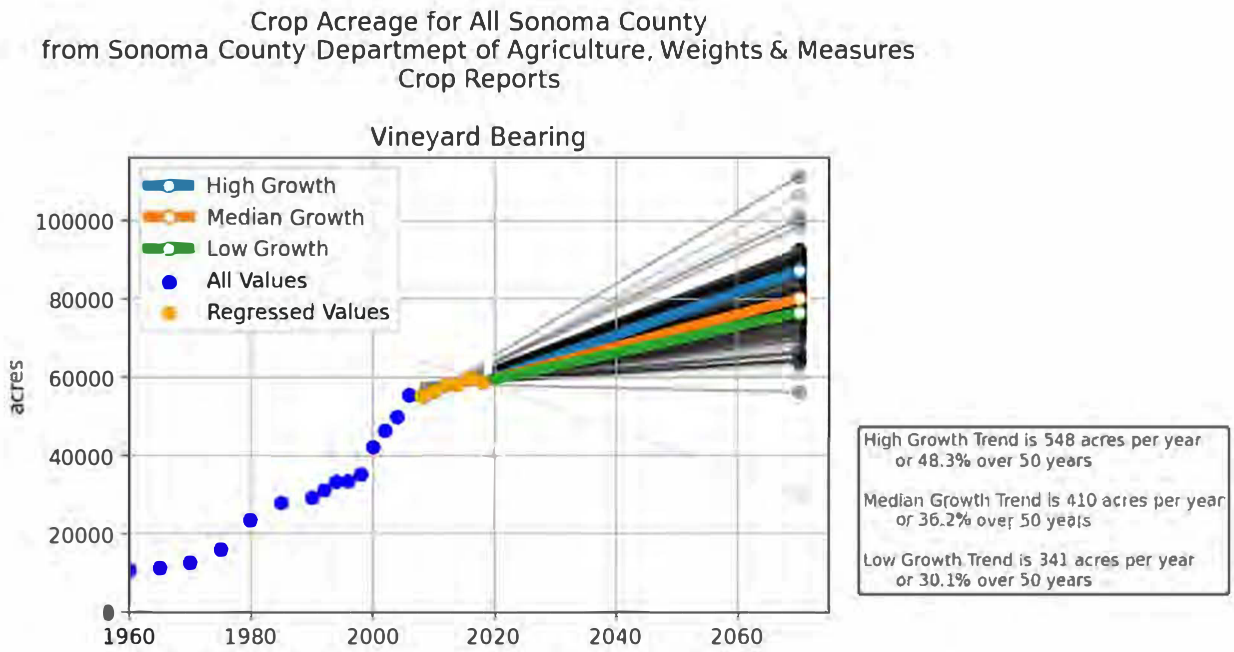


Figure 4. : Agricultural land use for vineyards, 1960-2018. Future land use contraction or expansion

Simulating Land-Use Change

The survey results must be incorporated into quantitative land-use projections for use in the GSPs. Sonoma Water, as part of its efforts to develop a groundwater-flow model of the Sonoma Valley, has developed an algorithm to estimate the change in vineyard acreage in the Sonoma Valley (Andrew Rich, Sonoma Water, personal communication, 2020). The algorithm uses changes in vineyard acreage between 1999 and 2012 to estimate growth rates and the probability that a parcel will be converted to a vineyard based on physical characteristics (e.g. slope, elevation, aspect, soil type, etc.), as well as possible constraints, such as conservation easements, and zoning of the parcel. The algorithm will be modified to address additional crops and the conversion of crops expected to contract in the area to crops expected to expand.

Specifically, the algorithm will be modified to include truck crops and, possibly, grain and hay. Although cannabis is expected to expand in the short and long term, the current acreage is so small (e.g., currently about 40 acres in the SRP) that even a 10% increase in acreage will result in a small total area (and relatively small projected water use at the basin-wide scale); therefore, cannabis will not be addressed here. Additionally, although the potential for future projected development of hemp as a crop in the basin was raised by several practitioners and land-user responders, hemp crops are not being simulated for the initial GSPs due to uncertainties related to any potential future cultivation of hemp and associated farming practices. Should cultivation of hemp occur at a significant scale during the early stages of GSP implementation, hemp can be included when updating future projections during 5-year GSP updates.

The projected growth rates can be defined by the survey or regression results. Staff will discuss options for simulating the growth rates at the practitioner workgroup's next meeting on October 15, 2020. The conversion probabilities will be modified to address vineyards and truck crops (and possibly grain and hay) and the physical characteristics of available, unused land as well as land being cultivated by crops expected to contract will be addressed. The land will assumed to be converted based on the conversion probabilities with the lands with the highest probabilities being converted first.

Agricultural Water Demands Practitioner Work Group; Summary Report/Update to Sonoma County GSA Advisory Committees

Agricultural Water Demands Practitioner Work Group

Summary Report/Update to Sonoma County GSA Advisory Committees

January 4, 2021

Work Group Overview

The Agricultural Water Demand Projections Practitioner Work Group was assembled to help develop estimates of future changes in crop acreage to inform water demand projections in three Sonoma County groundwater basins/subbasins (Sonoma Valley, Petaluma Valley, and Santa Rosa Plain) over the 50-year planning horizon for Groundwater Sustainability Plans (GSPs). Specifically, work group members were asked to consider whether acreage for the following major crop types are likely to contract, stay the same, or expand over the 50-year planning horizon:

- Vineyards
- Irrigated pasture
- Dairies
- Grain and hay crops
- Truck, nursery, or berry crops (including row vegetables and field crops such as hops)
- Orchards/deciduous fruits and nuts
- Cannabis/hemp

The work group met on June 23rd, August 6th, and October 15th; members include:

- Keith Abeles, Sonoma County Resources Conservation District
- Andy Casarez, Sonoma County Agricultural Commissioner
- Nick Frey, representing vineyard interests
- Brittany Heck, representing non-vineyard agriculture
- Rhonda Smith, UC Cooperative Extension
- Tawny Tesconi, Sonoma County Farm Bureau

At the June 23rd meeting, work group members estimated that for all crops during the GSP planning horizon, the three subbasins can expect a general reduction of farmed acreage crop types with the exception of vineyards and cannabis/hemp. Many work group members further indicated that in the near term (5-10 years) vineyard production could contract, primarily due to market forces and an oversupply of grapes. Water supply availability, population growth/land conversion for residential use, and land prices in general were cited as the primary causes for contraction of other agricultural uses.

To further vet these assumptions, staff developed a survey for work group consideration in advance of the August 6th work group meeting. In responding to the survey, a majority of work group participants said that a significant contraction of farmed acreage (defined as at least 5% of total acreage per year) should be expected for the following crop types:

- Dairies
- Grain and hay crops
- Orchards/deciduous fruits and nuts

- Irrigated pasture

Likewise, a majority of work group participants felt that the following crops types would experience either a continuation of existing farmed acreage or expansion:

- Vineyards
- Truck, nursery, or berry crops (including row vegetables and field crops such as hops)
- Cannabis/hemp

During the August 6th meeting, work group members generally confirmed these results, but noted that projections are highly uncertain due to a number of unforeseeable factors. That said, they agreed that common assumptions such as rising land value and cost of production will be determinative factors in overall agricultural production (and the corresponding water usage by crop type). They requested a similar survey be distributed to a larger group of growers in the subbasins to confirm these assumptions. Sonoma Farm Bureau offered to distribute the survey to its members, the Community Alliance with Family Farmers (CAFF), and the California Winegrape Commission on August 18th.

Public Survey Results

As noted, a survey was developed to poll agricultural practitioners in the three subbasins. 43 practitioners provided response; geographic distribution of respondents is provided in figure 1 below. Additionally, 19 or 43 respondents owned or operated vineyards, 7 indicated non-vineyard, unspecified agricultural operations, and the remaining 17 declined to state their business or organization.

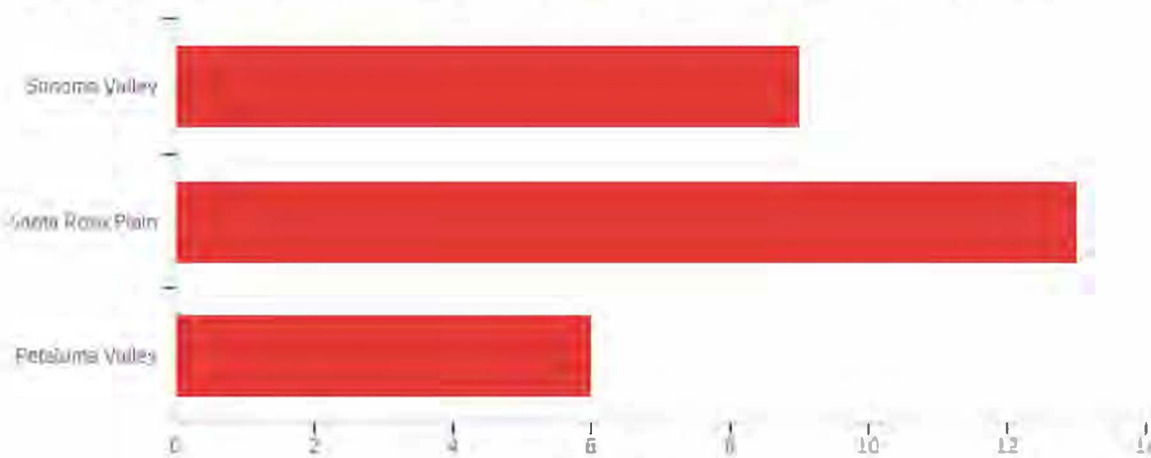


Figure 1: Geographic distribution of survey respondents

Public survey responses were generally in line with feedback received from work group members, and included the following key takeaways:

- General continuation or reduction of farmed acreage for all crop types except truck, nursery, or berry crops and cannabis/hemp.
- Water supply availability, population growth, land conversion and prices and market forces were cited as the primary reasons for the agricultural contractions.
- Responses on vineyard acreage ranged from substantial contraction to moderate expansion.

Extrapolated Historical Crop Data

In order to place the survey results within the frame of reference of historical changes in cropping patterns, land-use data from 1960 to 2018 (every 5 years until 1990, then every 2 years thereafter) for vineyards; irrigated pasture; grain and hay; truck crops; and orchards/deciduous fruits and nuts were compiled using Sonoma County crop reports (https://sonomacounty.ca.gov/Agriculture-Weights-and-Measures/Crop-Reports/).

The historical trends for each crop group were then extrapolated from 2020 to 2070 based on statistical regressions of the 2000 - 2018 county-wide crop report data. The regressions include high, median, and low growth trends correlating with the 75%, 50% and 25% percentiles. **Attachment 1** includes a memorandum with all survey results and analysis of trends in historical crop acreage, which was provided to work group members, Advisory Committee and Boards at their October meetings.

During the October 15th meeting, work group members noted that the relatively high historical growth trends for vineyards from 2000 – 2018 are likely not indicative of future trends. One work group member suggested further evaluating potential changes to vineyards by researching available market information from industry information sources, such as the Wine Market Council; Wine Institute; Turrentine, Gomberg & Frederickson; and Ciatti Global Wine and Grape Market reports. Research into available information from these sources, which are primarily focused on near-term markets for bulk wine and grapes, generally indicated that the underlying driver for wine demand--alcohol consumption generally and wine specifically--has been flat, and wineries & wine marketing organizations are working to grow that demand (with many sources noting the substantial uncertainty surrounding the future). However, no quantified future projections were identified through this additional research.

In order to help account for this information and work group member input, the historical cropping trends for vineyard projections were scaled downward by utilizing only the more recent (2008-2018) historical crop trends. Evaluation of the historical growth pattern for vineyards indicates this time period exhibits a more moderate increase in acreage in comparison with the longer-range 2000-2018 time period used for other crops and better reflects more recent trends for this crop (fig. 4 of Attachment 1).

Proposed Approach

At the October 15th work group meeting, staff provided a suggested approach for 50-year crop projections, consisting of:

- Calculating a range of projections for each crop type based on survey results and historical land use with data extrapolated through 2070;
- Utilizing the calculated mid-range of these high/low projections for the 50-year projected water budget.

Staff then used a combination of the survey results and historical extrapolated data to develop the proposed cumulative projection ranges for each crop type across all three basins. The higher (more positive/less negative) of the growth rates from the opinion polls and the historical extrapolated data is used for the high growth projections and the lower (less positive/more negative) is used for the low growth projections. In order to balance and help reconcile the practitioners input on projected cropping changes with the historical extrapolated data, the following procedure was followed:

- Where the most frequent survey responses indicated expansion (positive growth), the high historical extrapolated trend was used for the ranges;
- Where the most frequent survey responses indicated no or negligible growth, the median historical extrapolated trend was used for the ranges;
- Where the most frequent survey responses indicated contraction (negative growth), the low historical extrapolated trend was used for the ranges.

. The calculated proposed high, mid-range, and low growth trends, are as follows:[1]

Vineyards

- High growth: 36% increase over 50 years or 199 acres per year (based on the median historical extrapolated trend)
- Low growth: 0% over 50 years or 0 acres per year (most frequent survey response)

Proposed 50-year GSP projections (mid-range): increase of 100 acres per year or a 18% increase over 50 years (total 4,978 acre increase over 50-years across the three basins/subbasins)

Irrigated pasture

- High growth: 10% decrease over 50 years or -9 acres per year (based on most frequent survey response)
- Low growth: 138% decrease over 50 years or -122 acres per year (based on the low historical extrapolated trend)

Proposed 50-year GSP projections (mid-range): decrease of 57 acres per year or a 65% decrease over 50 years (total 2,872 acre decrease over 50-years across the three basins/subbasins)

Grain and hay crops

- High growth: 62% increase over 50 years or 31 acres per year (based on the low historical extrapolated trend)
- Low growth: 10% decrease over 50 years or -5 acres per year (most frequent survey response)

Proposed 50-year GSP projections (mid-range): increase of 13 acres per year or a 26% increase over 50 years (total 654 acre increase over 50-years across the three basins/subbasins)

Truck, nursery, or berry crops (including row vegetables and field crops such as hops)

- High growth: 70% increase over 50 years or 23 acres per year (based on the high historical extrapolated trend)
- Low growth: 5% over 50 years or 2 acres per year (most frequent survey response)

Proposed 50-year GSP projections (mid-range): increase of 12 acres per year or a 38% increase over 50 years (total 611 acre increase over 50-years across the three basins/subbasins)

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[1] Cannabis and hemp projections were not included at this time, as total farmed acreage is currently negligible and limited historical data is available to extrapolate projections. Staff will re-evaluate inclusion of cannabis/hemp projections in the 5-year update to the GSP.

Orchards, deciduous fruits and nuts

- High growth: 10% decrease over 50 years or -2 acres per year (based on most frequent survey response)
- Low growth: 178% decrease over 50 years or -34 acres per year (based on the median historical extrapolated trend)

  Proposed 50-year GSP projections (mid-range): decrease of 18 acres per year or a 94% decrease over 50 years (total 893 acre decrease over 50-years across the three basins/subbasins)

Application of Projections into 50-Year Water Budgets

Based on the proposed projections above and subsequent input from the Advisory Committees in all three subbasins and work group members, staff will develop the projected 50-year water budgets using the mid-range growth trends for each crop. The procedures for geographically distributing the changes in cropping patterns for the 50-year model simulations are described in the following section, titled Converting Agricultural Projections to Spatial Projections Using the Agricultural Expansion and Contraction Model. The projections take into account physical characteristics (e.g. slope, elevation, aspect, soil type, etc.), as well as possible constraints, such as conservation easements, and parcel zoning. The projected land use changes detailed in the report will then be used as input datasets for each groundwater flow model which calculate the associated groundwater demands for each crop after taking into account available information on irrigation practices and availability of recycled water or surface water sources.

Rural Residential Housing Unit Projections

TO: Sonoma County Groundwater Sustainability Agencies

FROM: Pete Parkinson, AICP

DATE: December 22, 2020

SUBJECT: Rural Residential Housing Unit Projections

This memo summarizes the methodology used to develop a range of rural residential housing unit projections for use with the required projected water budgets for the three Groundwater Sustainability Plans (GSPs). These projections include rural residential growth anticipated to rely on groundwater in the three basins, including water from individual domestic wells and from independent water systems that rely on groundwater (e.g., mutual water companies and similar entities). The projections do not include development where water is provided by a large public water system[1]. The projections cover the entire 50-year planning horizon in the GSPs (2022 to 2072) and are summarized in the attachment.

Public agencies typically do not generate 50-year projections, mainly because of the considerable uncertainty associated with future land use and economic conditions. The starting point for most projections is the local general plan, in this case Sonoma County's *General Plan 2020*. However, the projections in General Plan 2020 only extend to the Plan's horizon year of 2020, so another source for data and projections is needed. It is noted that the California Department of Finance projects a 15 percent decline in Sonoma County's population by 2060, but this projection is not useful for estimating the rural residential subset of Sonoma County's land use future.[2]

Despite the lack of projections beyond the General Plan horizon year, this analysis assumes that the foundational planning policies adopted by the County and the incorporated cities will remain in place for the duration of the GSP. These adopted planning policies focus most residential growth into the cities and designated unincorporated urban service areas. All nine cities in Sonoma County have voter-adopted urban growth boundaries, which are assumed to remain in effect throughout the GSP planning period. As a result of these policies, residential growth in the rural areas has historically been low and is expected to remain that way into the foreseeable future.

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[1] For analysis purposes, large public water systems include municipal purveyors and other public water systems serving over 500 connections. Most of these large public water system service areas are included in water demand projections through 2045 that are currently under development for 2020 Urban Water Management Plans (UWMPs). These UWMP projections will help inform the development of future groundwater projections in service areas for large public water systems.

[2] California Department of Finance. Demographic Research Unit. Report P-2A: Total Population Projections, California Counties, 2010-2060 (Baseline 2019 Population Projections; Vintage 2019 Release). Sacramento: California. January 2020.

While the local land use plan does not provide useful projections, the Sonoma County Transportation Authority (SCTA) develops and maintains a countywide transportation model as part of the Comprehensive Transportation Plan (CTP) to forecast future traffic volumes and patterns. The current CTP has a horizon year of 2040. The transportation model includes projections of land use changes (residential and non-residential) in approximately 900 Traffic Analysis Zones (TAZs) throughout the County. These land use projections at the TAZ level are based on the projections in PlanBayArea 2040,[3] supplemented with a finer-grained analysis of local development activity and consideration of general plan buildout capacity, based on input from local planning agencies. In addition to the 2040 land use projections, the SCTA model has the added advantage of providing a geographic distribution of the projected housing unit growth.

Using SCTA's TAZ data, we have developed rural residential growth projections for three scenarios that provide a high, medium, and low range of growth rates, as shown in the attachment. The "low" scenario corresponds to general plan buildout, which is low mainly because of the short time horizon for the current general plan but relies on the geographic distribution from the SCTA model. The "medium" scenario is based on PlanBayArea 2040 and the "high" scenario is 25 percent above PlanBayArea 2040. Separate projections were made for areas within each groundwater basin and for areas in the contributing watershed for each basin which are also included in the domains of the models which will be used to estimate the projected water budgets. These are shown as "in-basin" and "watershed," respectively, on the attachment. The geographic distribution of future growth is the same for each scenario and is based on the land use projections in SCTA's model.

The following paragraphs describe how these projections were developed to ensure that we are only looking at rural residential growth that affects groundwater demand.

- The analysis excludes any portion of a TAZ that is either outside the basin or watershed (as the case may be), or within a large public water system.[4] Areas within a large public water system service boundary will be accounted for in the groundwater model by taking into account data projections from 2020 UWMPs or other water system projections currently being developed. GIS data was used to calculate the percentage of land area in each TAZ that is relevant to this analysis (i.e., within a basin but outside a municipal boundary). That percentage was then applied to the SCTA model's housing

[3] The regional planning agency for the Bay Area, ABAG/MTC, develops population and housing projections for each city and county in the region as part of the Regional Transportation Plan and Sustainable Communities Strategy. The current version of this plan, PlanBayArea 2040, includes projections to the year 2040.

[4] Large public water systems include the Town of Windsor; Cal-Am (California-American Larkfield PUC service area); the cities of Santa Rosa, Rohnert Park, Cotati, Petaluma, Sonoma and Sebastopol; Penngrove (used geographic extent of Penngrove detailed in the US Census TIGER database); and the Valley of the Moon Water district.

unit projections to arrive at an adjusted projection for each TAZ. The resulting data and projections were further analyzed for anomalous situations.

- Most anomalies occurred where a TAZ straddles a municipal boundary, but the projected housing unit growth will occur within the municipality, not in the rural portion of the TAZ. Since growth in the rural areas is expected to be relatively low, these anomalies were identified by scanning for TAZs that showed a high growth rate (e.g., more than a 25% increase over 25 years). These TAZs were then checked on a map to determine whether growth would likely occur within the municipal boundary or in the rural area. In nearly every situation where this was checked, the likely growth was determined to be within the municipal boundary, not in the rural area, so the projections for that TAZ were adjusted downward.

- In the community of Penngrove (part of the Petaluma Valley Subbasin), domestic water is provided by the privately owned Penngrove Water Company. Within this portion of its service area, the PWC uses water from the Sonoma Water aqueduct rather than groundwater, so this usage should not be included in groundwater demand projections. However, the PWC service area map does not correspond to the location of actual connections (actual connections are in a much smaller area). Considering this, the Penngrove area defined by the TIGER Census database was used as the service area instead of the published service area as it reflects the likely extent of the service area. The portion of the PWC service area outside of Penngrove relies on groundwater (most notably the Canon Manor West area in the Santa Rosa Plain Basin) and is included in the rural residential projections.

- The numerous mutual water companies in the three basins create an additional issue because geographically dispersed rural residential parcels draw water from a single shared well (or well field). For these areas, the projected growth will be distributed throughout the relevant TAZs as described above, but the current baseline groundwater pumping for the mutual water company will be assigned to the known location of the water company well(s), where data is available. Projections of housing unit growth in TAZs encompassing mutual water companies should not be interpreted as projections for those water providers; no attempt was made to project housing unit growth or future water demand for mutual water companies but additional housing unit development is accounted for at the TAZ level. It is noted that the areas served by most mutual water companies are largely built out and substantial additional residential development is not anticipated.

- Since the low-growth TAZ level projections based on SCTA's model only went to 2040, these figures were extrapolated out to 2072. This was a straight-line extrapolation based on the growth rates calculated in each TAZ from 2015 to 2040 (the period covered in SCTA's model). Consideration was given to decreasing the growth rate after 2040 as the County's rural areas approach buildout, but a straight-line extrapolation was chosen due to the considerable uncertainty with long-range projections. The projected growth was divided evenly into 5-year increments to correspond to the time frames in the groundwater model.

- The figures in the attachment do not include Accessory Dwelling Unit (ADU) development in the rural areas. However, ADUs will be accounted for in the groundwater model by including a water use factor based on new ADUs as a percentage of new dwelling units. Data from 2014 to 2018 shows that, on average, the number of new ADUs was 25 percent of the number of new dwellings (with a low of 15% and a high of 35% per year). The water use factor assumes that ADUs do not result in additional outdoor water use, so the per-unit water use factor for new ADUs is a fraction of that used for new dwellings.

- While these projections were in development, the ABAG and MTC were (and remain) in the process of updating PlanBayArea to a 2050 horizon year. A key feature of this regional planning process is the Regional Housing Needs Allocation process, or RHNA. The RHNA process provides the number of new housing units that each city and county must plan for over the next eight-year planning period (2022-2030). Although the RHNA process is not finalized, preliminary information indicates jurisdictions throughout the Bay Area are likely to receive a substantially larger housing allocation in this upcoming cycle. Substantial uncertainty remains about the final RHNA numbers. The RHNA process and the planning necessary to distribute these additional housing units at the jurisdictional level will not be completed in time to be integrated into the initial GSPs. Given this timing and the substantial uncertainty surrounding the RHNA numbers themselves, no attempt was made in this analysis to forecast future housing based on new RHNA numbers.

As shown in the attachment, the growth rates in the three groundwater basins are projected to be quite low under the low, medium, and high growth scenarios. Even the "high" growth scenario shows less than 1 percent growth annually. As discussed above, this is to be expected in the rural areas of the County. Nonetheless, the three scenarios provide a reasonable range of projected rural residential housing unit growth.

These projections will be revisited and updated for each 5-year update of the GSP. The projections contained in the SCTA traffic model will remain a useful tool for medium-term projections (i.e., 20 years) and the TAZs will remain useful for projecting the geographic distribution of rural residential growth. In the first 5-year GSP interval, the upcoming round of RHNA allocations will be finalized and local planning agencies will complete the planning necessary to distribute those additional housing units throughout their respective communities. In addition, the County will likely make substantial progress and perhaps even complete its General Plan update, which will provide useful insights and updated population and housing forecasts.

In addition to using the adopted planning documents for each update of rural residential growth, it is recommended that permitting activity be tracked in each basin and watershed, at the TAZ level if possible. This will help validate the results obtained using the SCTA model data and improve the accuracy of projections over time as implementation of the GSPs occurs.

Attachments:

Table 1 Rural Residential Housing Projections

		Low		Medium		High	
	2015 Baseline Housing Units	**Annual Rate**	**Total New Housing Units**	**Annual Rate**	**Total New Housing Units**	**Annual Rate**	
Sonoma Valley, In Basin	2987	**0.2%**	**340**	**0.6%**	**986**		
Sonoma Valley, Watershed	2843	**0.1%**	**98**	**0.4%**	**630**		
Petaluma Valley, In Basin	1021	**0.1%**	**67**	**0.5%**	**286**		
Petaluma Valley, Watershed	1399	**0.1%**	**44**	**0.1%**	**101**		
SRP, In Basin	7116	**0.2%**	**612**	**0.5%**	**2077**		
SRP, Watershed	5649						**2170**

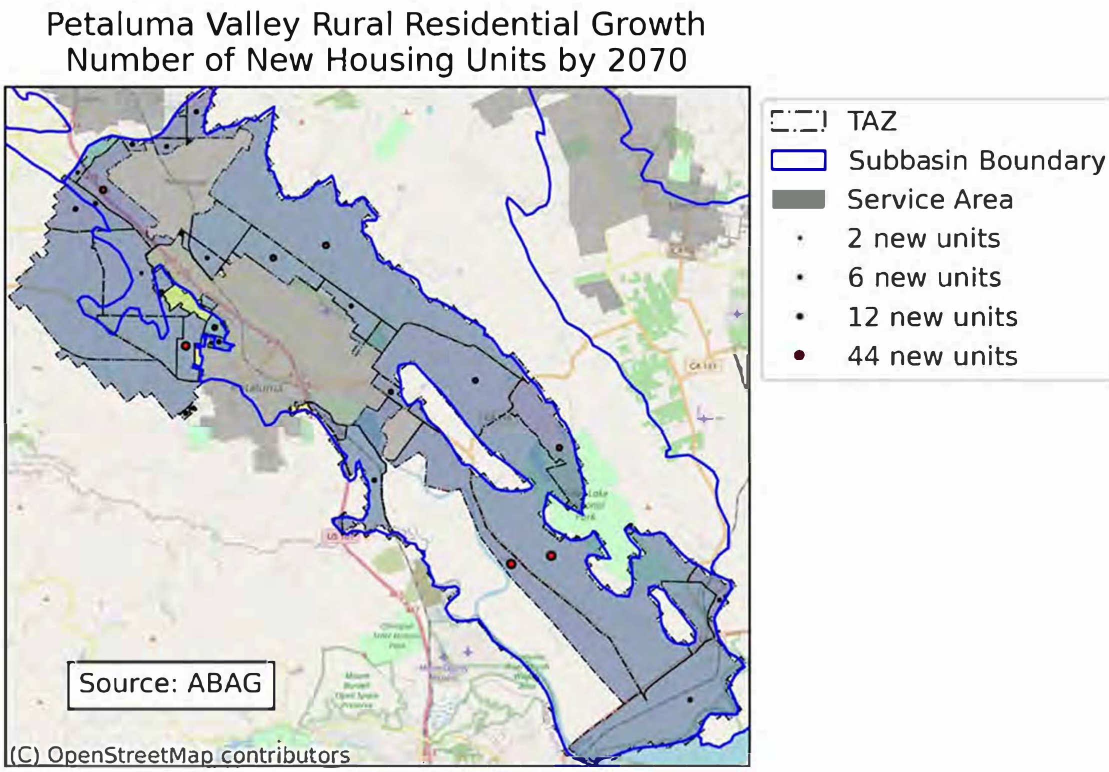

Figure 1 Petaluma Valley Rural Residential Growth Projections

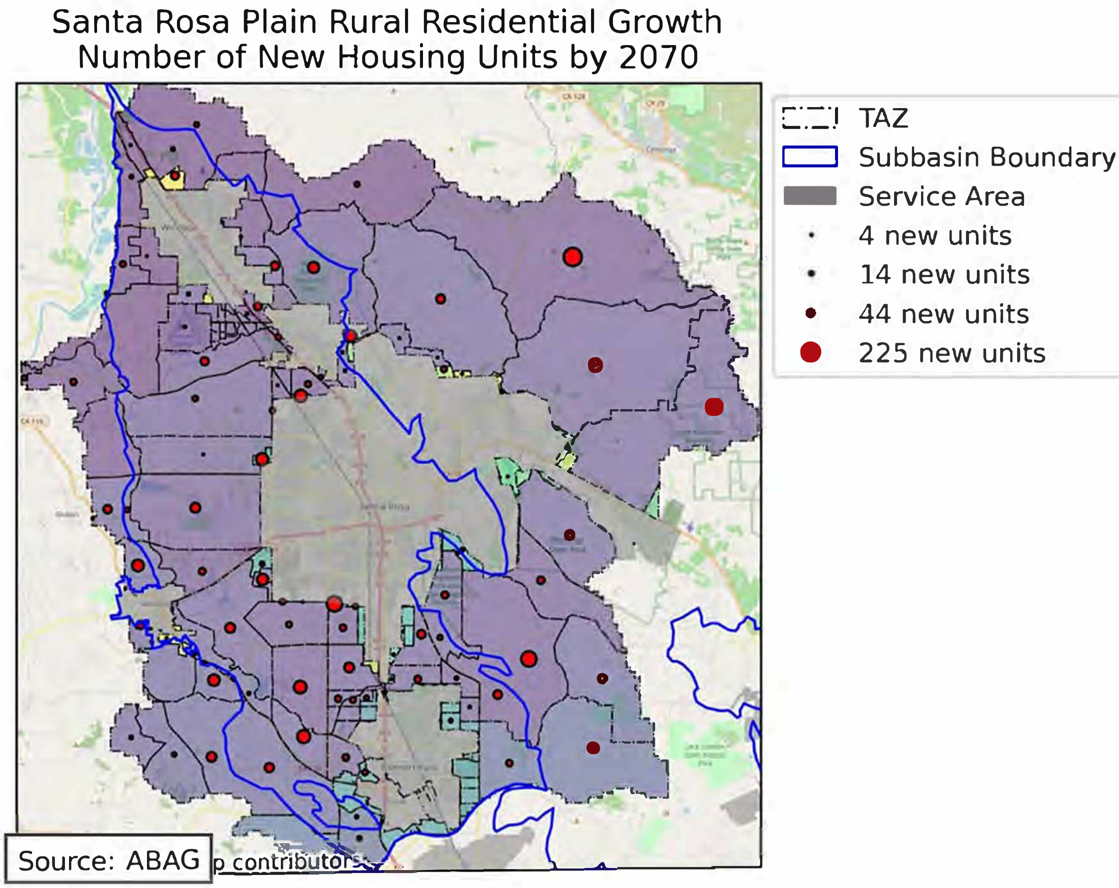

Figure 2 Santa Rosa Plain Rural Residential Growth Projections

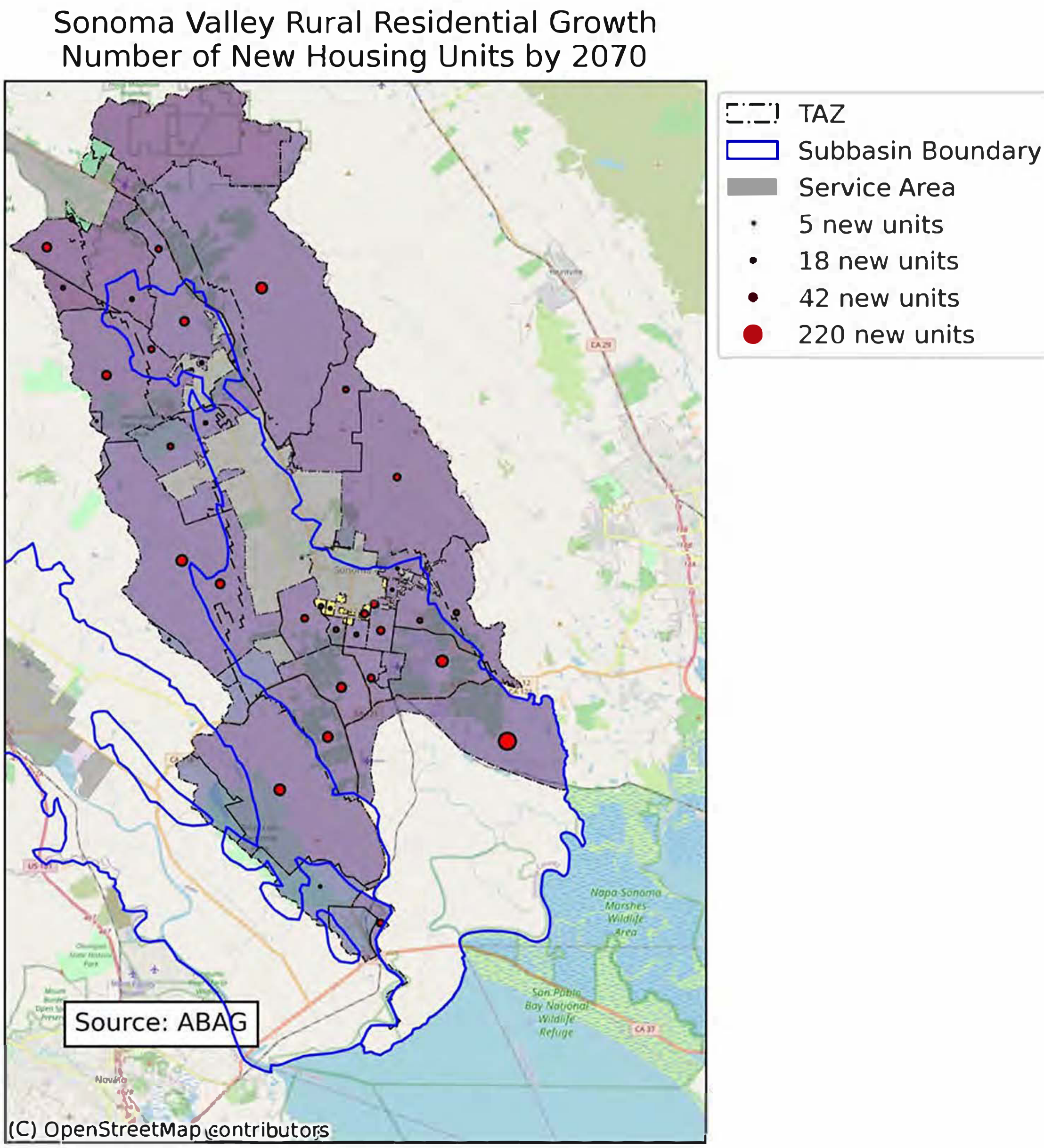

Figure 3 Sonoma Valley Rural Residential Growth Projections

Converting Agricultural Projections to Spatial Projections Using the Agricultural Expansion and Contraction Model (AECM)

Sonoma Water

Andrew Rich

April 13, 2021

Introduction

This report summarizes the methods used to develop the spatial datasets of future agricultural land uses in the three Sonoma County groundwater subbasins/basins required to comply with the Sustainable Groundwater Management Act (SGMA). For these subbasins/basins projected 50-year future groundwater budgets are required as part of their groundwater sustainability plans (GSPs). The agricultural land use projections detailed here will serve as inputs into the groundwater flow models that were developed for each subbasin/basin. The groundwater flow models will then calculate groundwater demands based on the climate, crop types and other factors. For the Santa Rosa Plain, the AG Package (Niswonger, 2020) uses the outputs from the outputs developed here to calculate projected groundwater demands. The Sonoma Valley and Petaluma Valley models use MODFLOW-One Water Hydrologic Model (OWHM; Hanson et al, 2014, Boyce et al, 2020).

Projections of future agricultural land use expansion and contractions developed through the Agricultural Water Demand Projections Practitioner Work Group (work group) serve as the basis for this work. These projections detail the rate of growth or contraction in acres per year for vineyards, field crops, truck crops, orchards, grains and hay, and pastures. Some of the crops exhibit contractions whereas others are nearly stable or show expansion. The AECM developed here is used to spatially project the desired changes in land use based upon a statistical representation of the affinity for each crop for physiographic (eg topography, slope) properties. The work by Heaton and Merenlander (2000) demonstrated that a logistical regression model is suitable for predicting the conversion to vineyards in Sonoma County. The authors used a number of parameters such as slope, aspect, distance to streams, and others to predict locations more likely to be converted to vineyards in Sonoma County. Here we are adapting and generalizing the methods to be used for the 8 crops listed above.

Methods

For each crop a logistical regression model is fitted with the observed independent and observed dependent variables. A logistical regression is a statistical expression of the probability of a binary output conditioned on the independent variables. The locations for which all of the independent and dependent variables are extracted is shown in Figure 1. There are 17,407 points used in developing the AECM models for each crop. The dependent variable for each crop is the presence or absence of that crop. The presence or absence of a crop is extracted from the mapped land use as of 2012, shown in Figure 2. The independent variables for all crops are shown in Table 1. The maps for each of the independent variables are shown in Figure 3, Figure 4, Figure 5, Figure 6, Figure 7, and Figure 8.

Table 1 Independent AECM parameters

	Variable name	Type	Source
1	ppt	Average Precipitation	PRISM
2	tmean	Average Temperate	PRISM
3	slope	Slope	DEM

4	elev	Slope	DEM
5	asp	Aspect	DEM
6	BdrkDep	Bedrock Depth	NRCS Soil Data
7	HydSol	Hydrologic Soil Group	NRCS Soil Data

Summary of the Methods for Applying the Agricultural Expansion and Contraction Model

- *Use mapped crop distribution of the crop types [dependent variables]*
- *Create GIS datasets of soils, climate, and topographic properties expected to impact distribution of crops [independent variables]*
- *For each crop type create fit model that expresses ranking of a site based on independent variables*
- *Use fit model to assign ranking to all cells for each crop based on average ranking for cell*
- *Apply growth/contraction on 5-year intervals using crop rankings and GIS of areas where growth may occur*

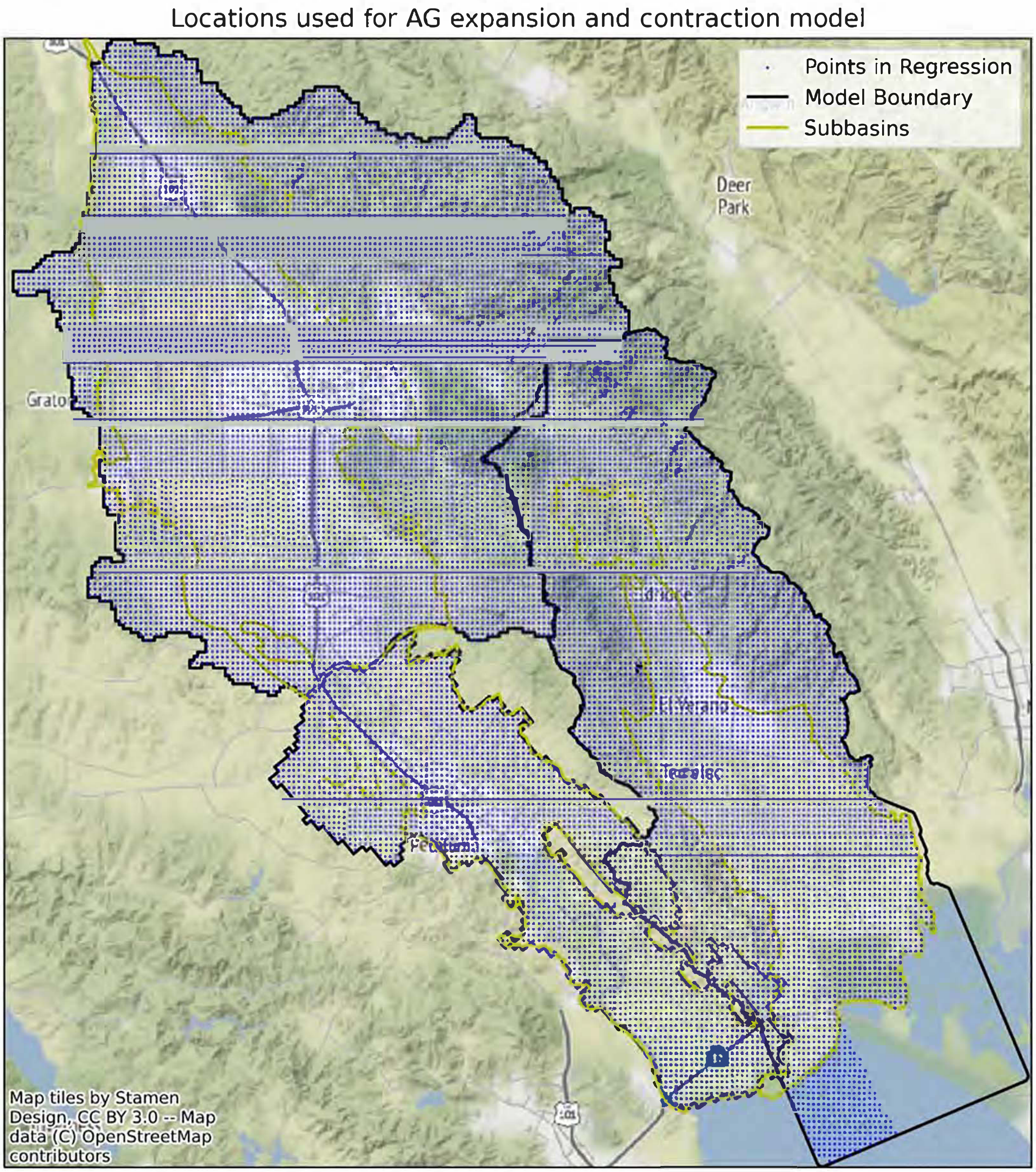

Figure 1 Locations used for AECM

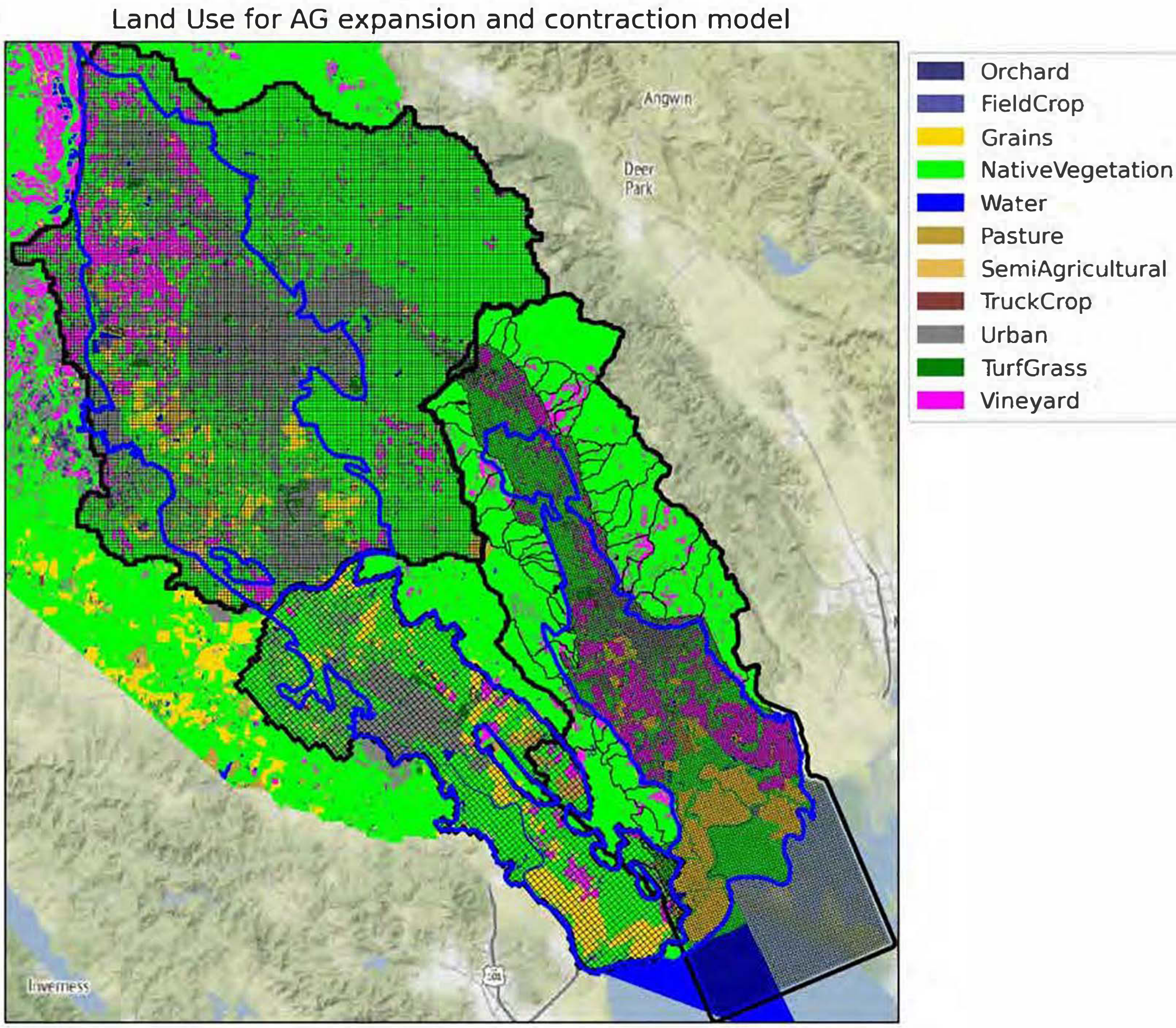

Figure 2 Land Use

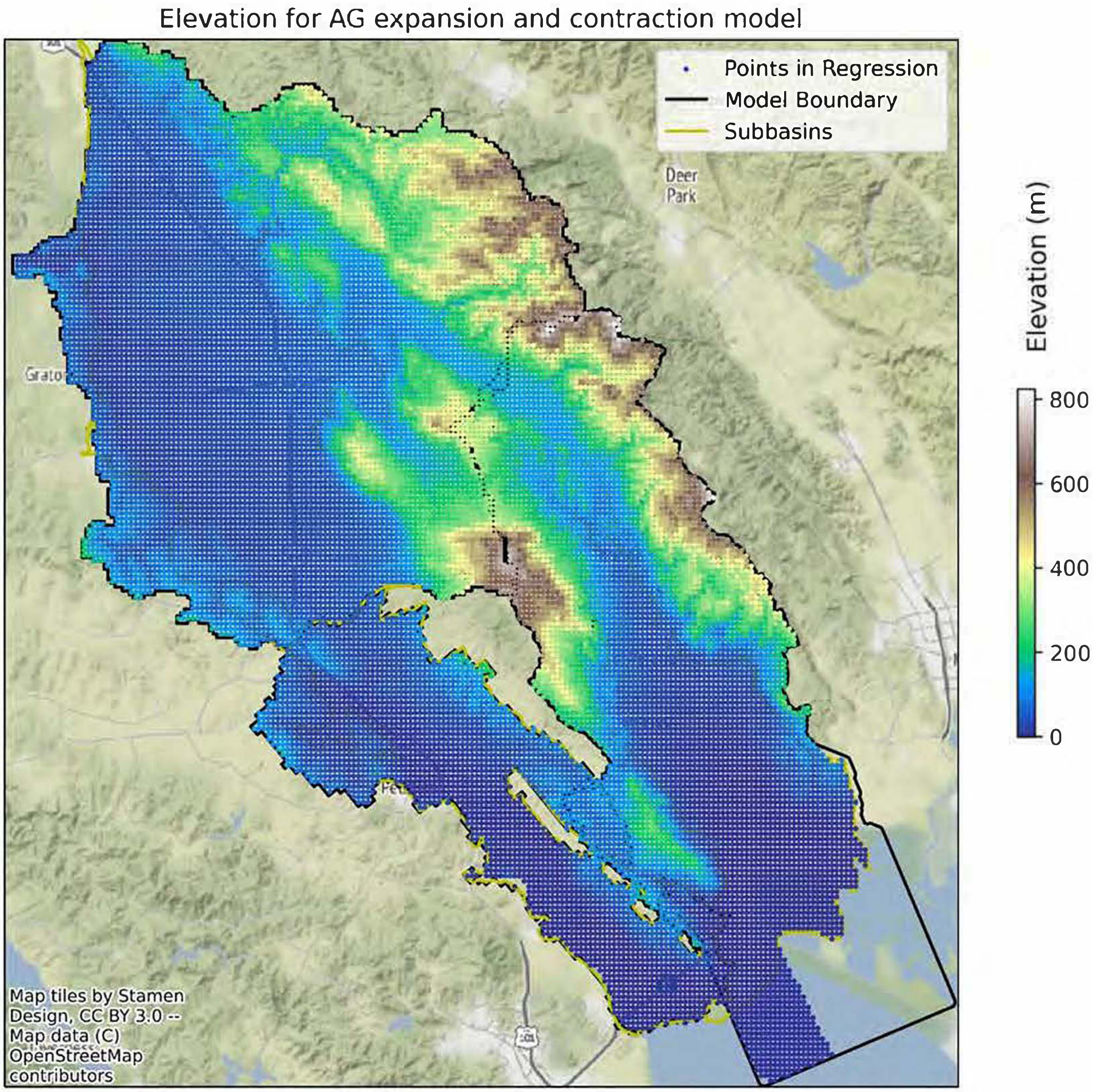

Figure 3 Elevation for AECM

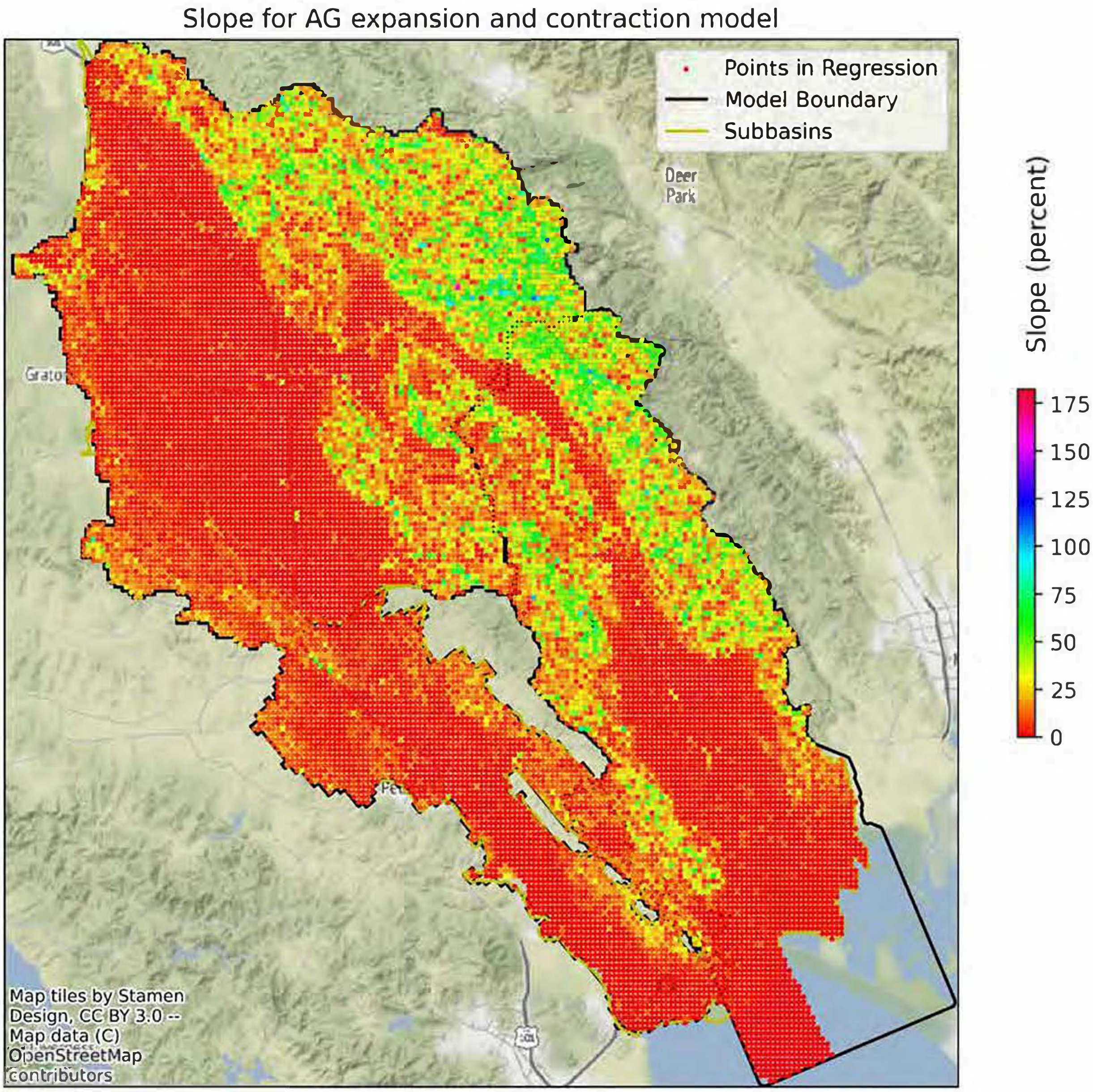

Figure 4 Slope for AECM

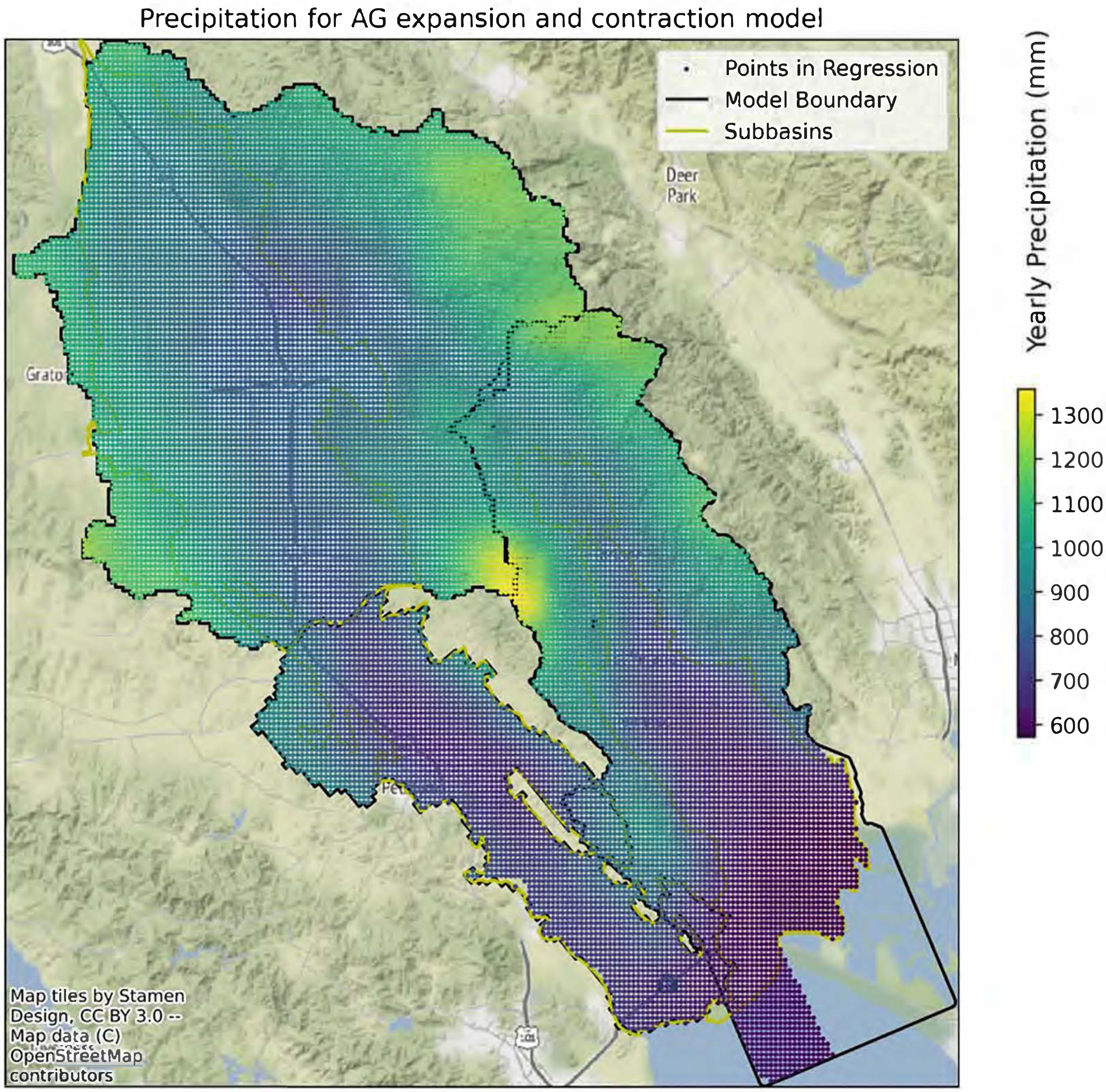

Figure 5 Precipitation for AECM

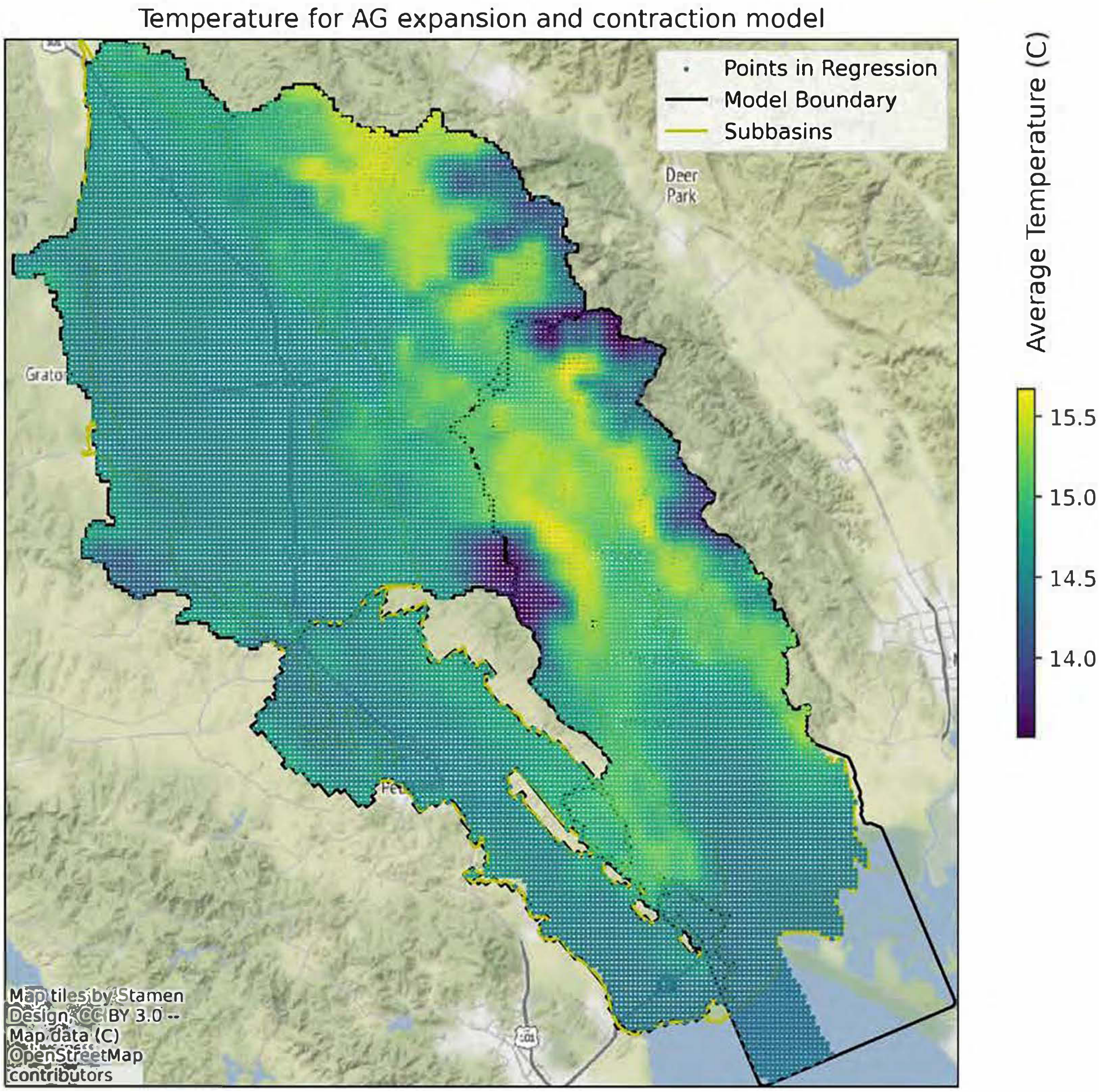

Figure 6 Temperature for AECM

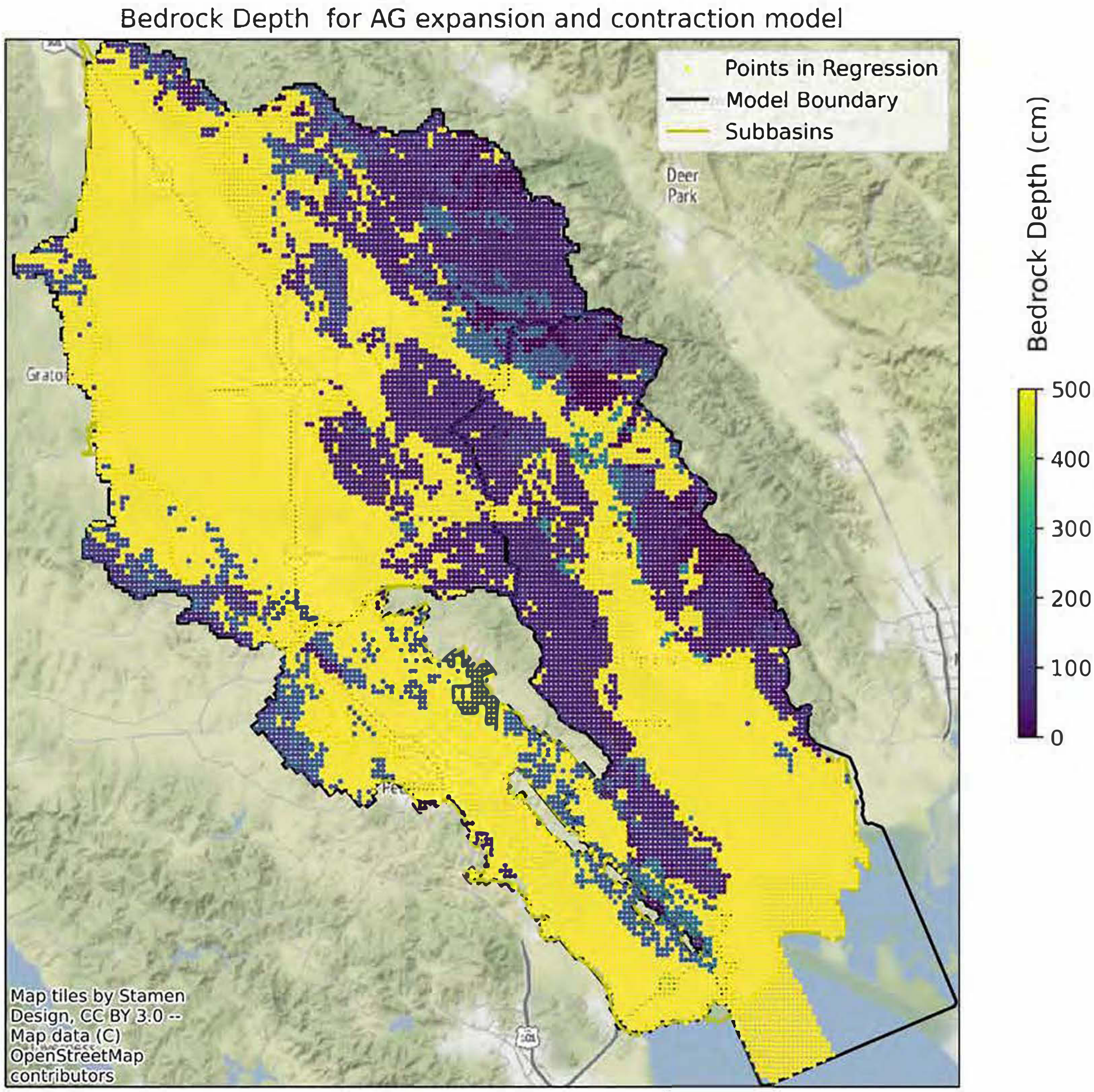

Figure 7 Bedrock Depth for AECM

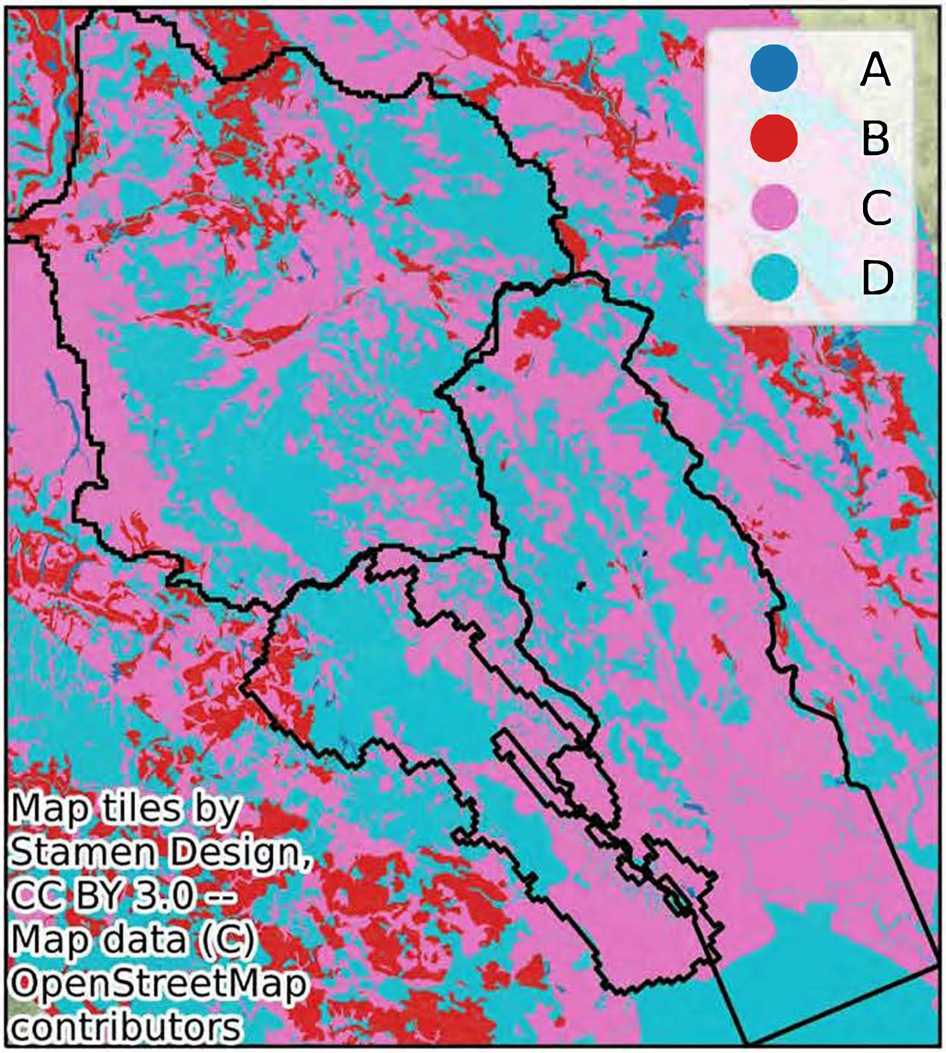

Figure 8 Hydrologic Soil Group

Logistical Regression Values to Crop Expansion Rankings

After developing the logistical regression statistical models for each crop, they are now used to estimate the ranking for all locations. To do so, five points were added to each model cell. Then for each point the fitted crop expansion regression probability was calculated and the mean value was assigned to each cell. These steps are shown in Figure 8. The model cells for which the five points were extracted and averaged are shown in Figure 9, Figure 10, and Figure 11.

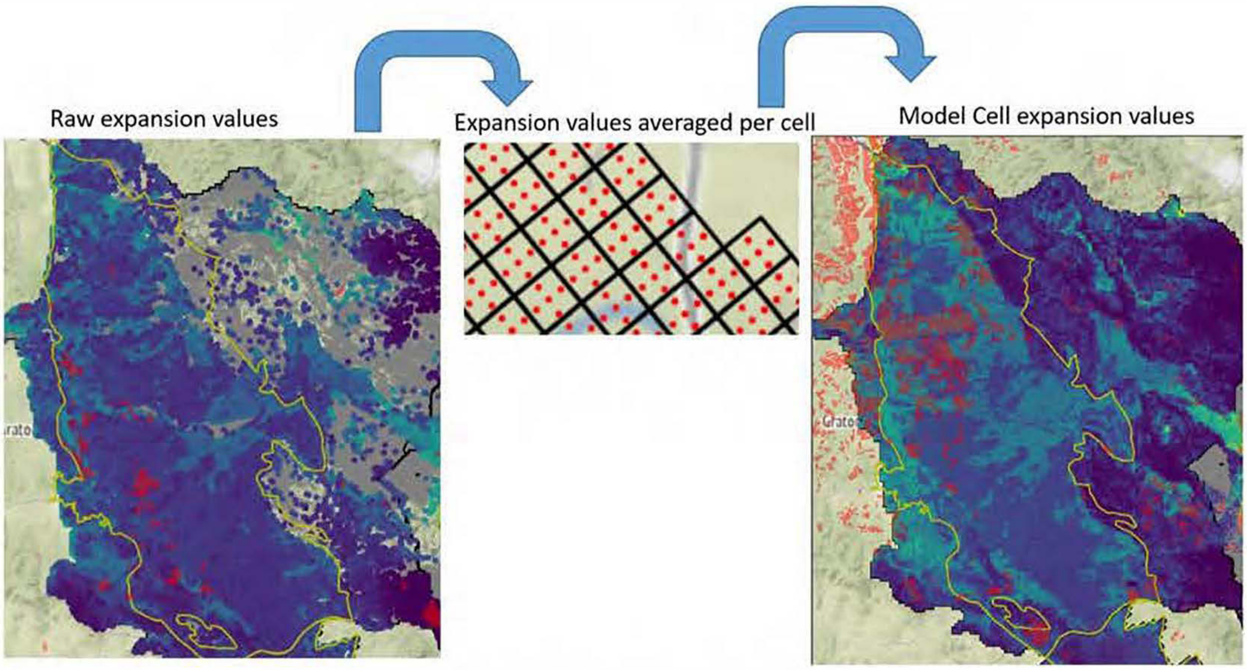

Figure 9 Converting Raw Expansion Values to Model Cell Crop Expansion Rankings

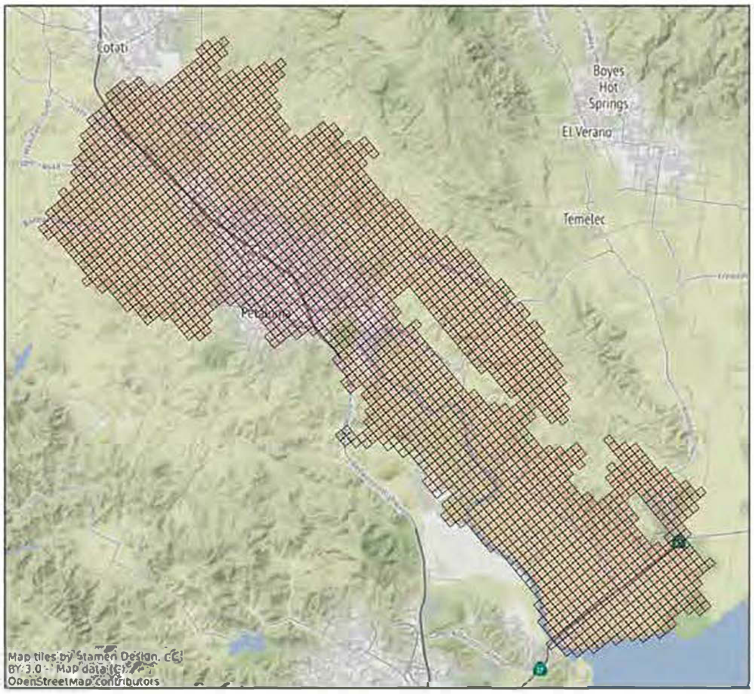

Figure 10 Model Cells Used for AECM predictions, Petaluma Valley Subbasin

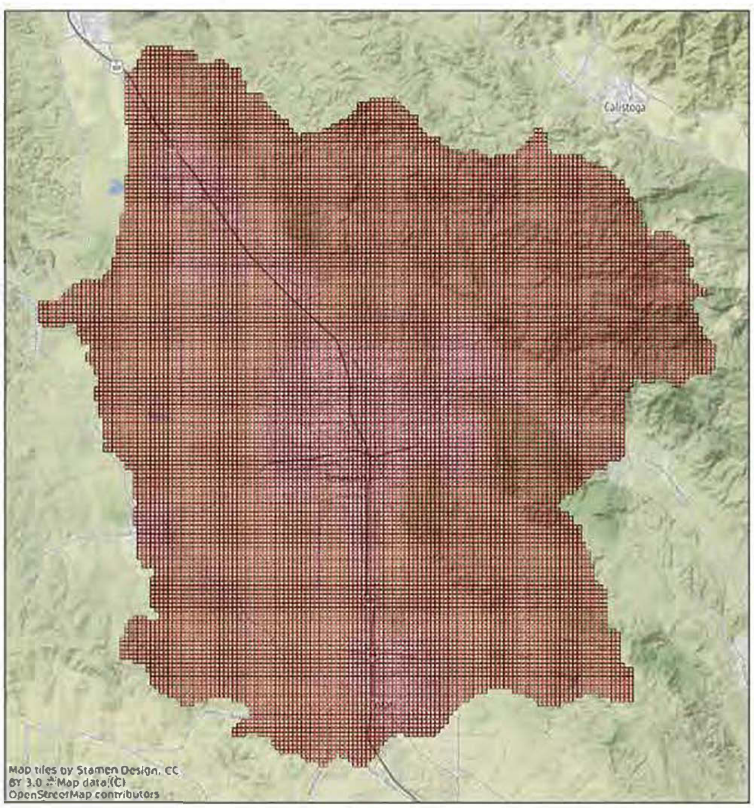

Figure 11 Model Cells Used for AECM predictions, Santa Rosa Plain Subbasin

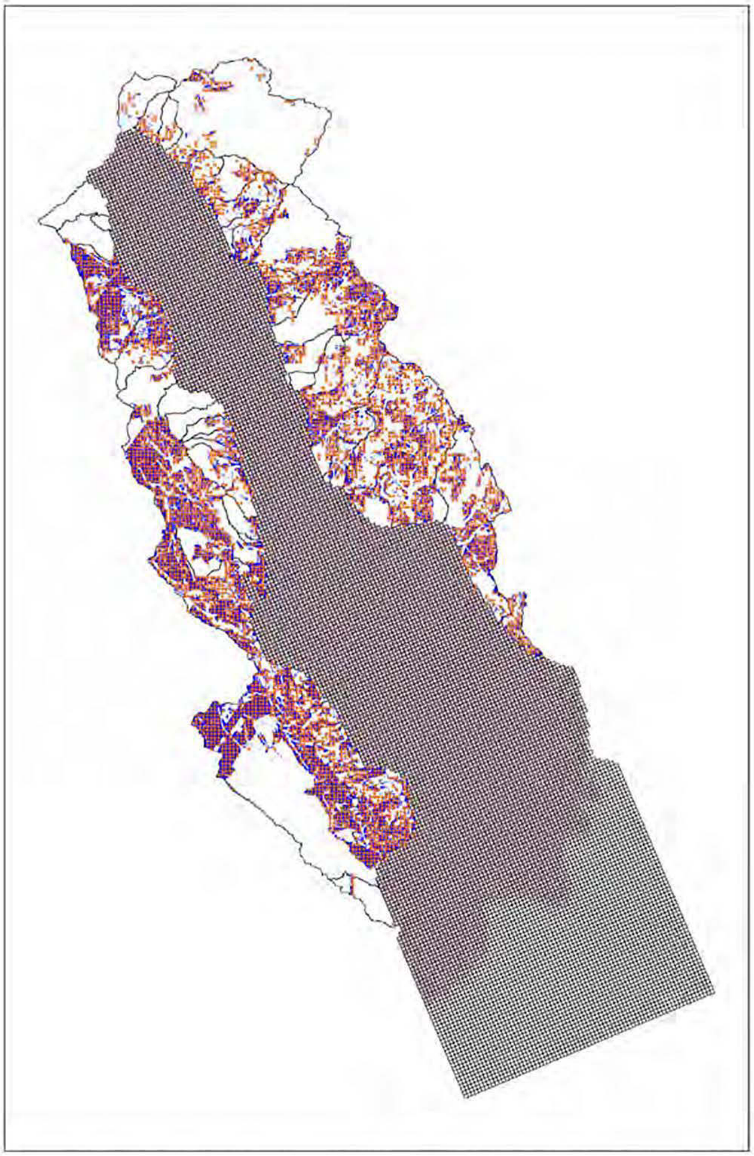

Figure 12 Model Cells Used for AECM predictions, Sonoma Valley Subbasin

Agricultural Expansion Model Values for Each Crop

The final AECM values for each crop are shown in Figure 12, Figure 13, Figure 14, Figure 15, Figure 16, Figure 17 for orchards, field crops, truck crops, grains and hay, pastures, and vineyards, respectively. The figures show the top 20% of locations (based on model cells) after removing locations that cannot be converted to a vineyard. The prohibited areas dataset consists of locations that cannot be developed due to zoning restrictions, public ownership, agricultural exclusion areas such as VESCO or stream buffers, and other datasets.

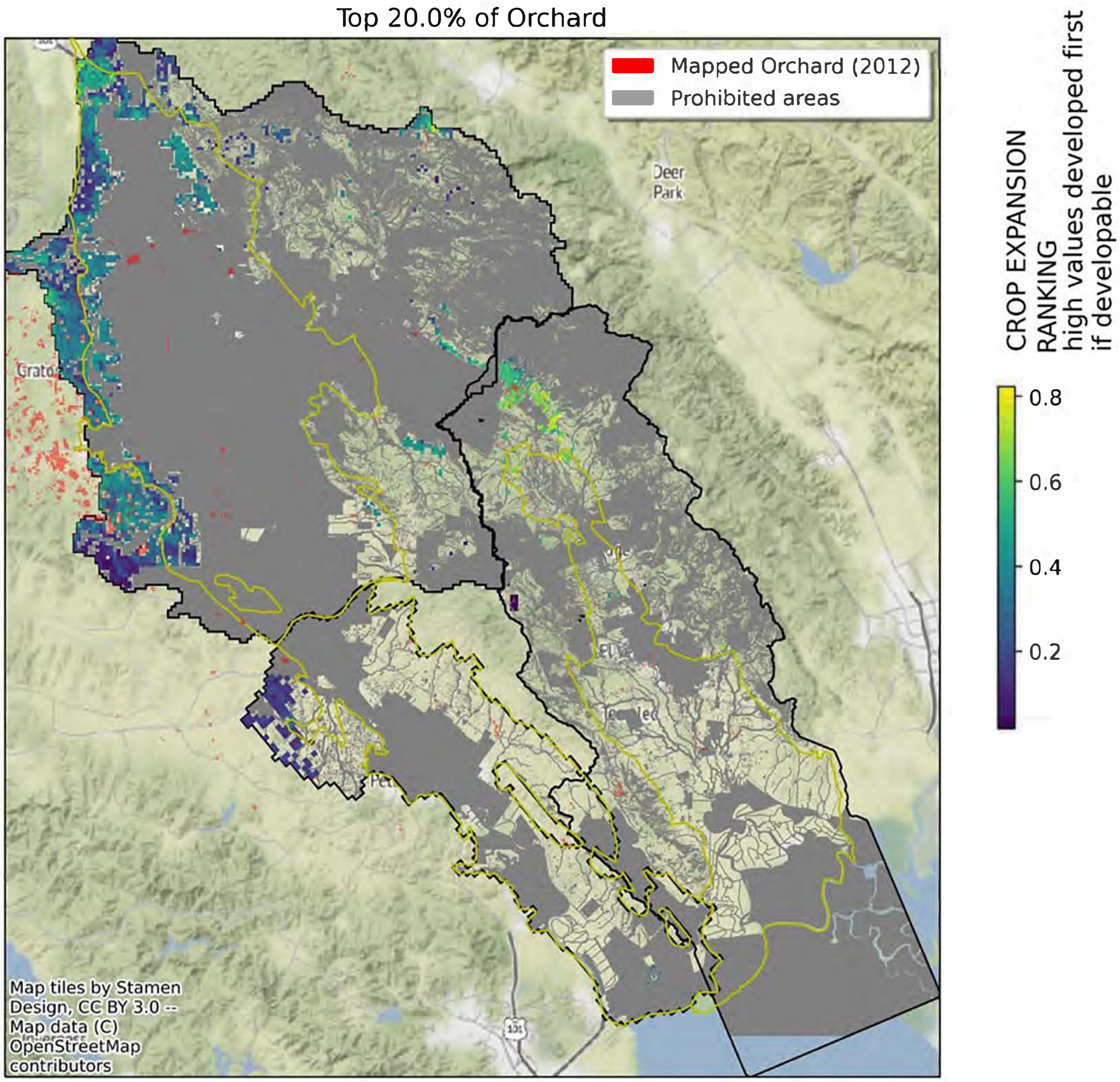

Figure 13 Top 20% Ranked AECM Values for Orchards

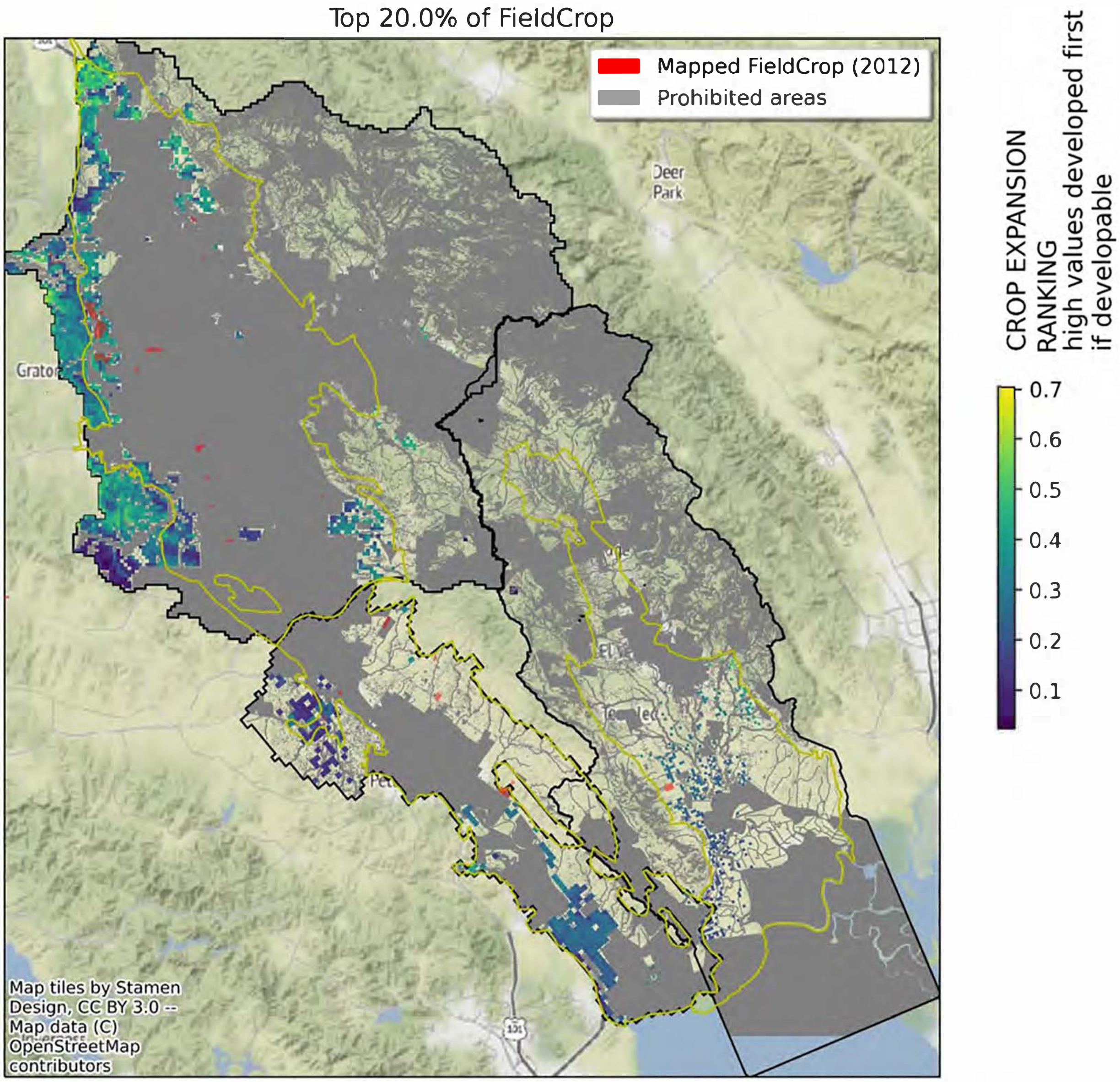

Figure 14 Top 20% Ranked AECM Values for Field Crops

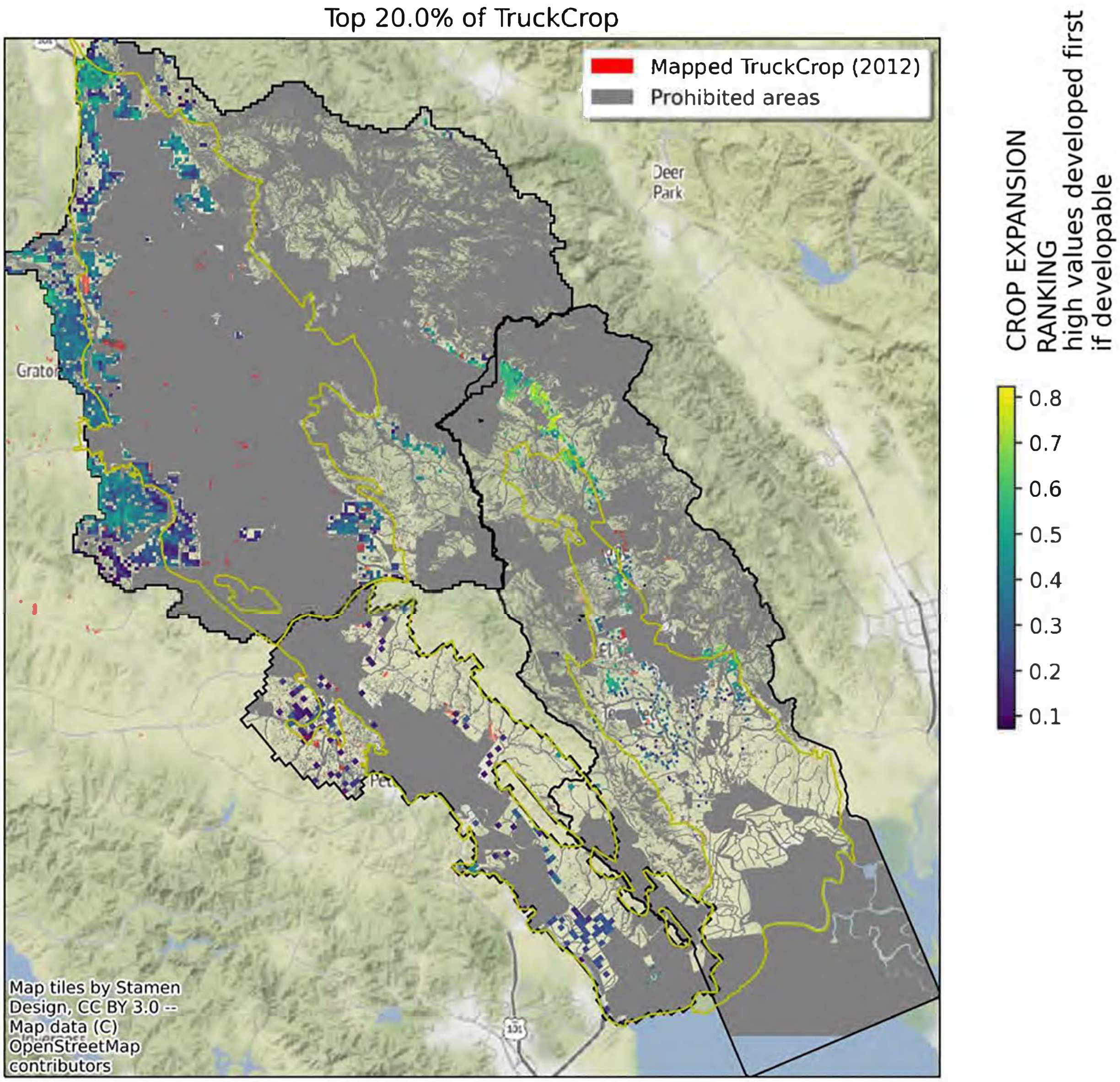

Figure 15 Top 20% Ranked AECM Values for Truck Crops