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

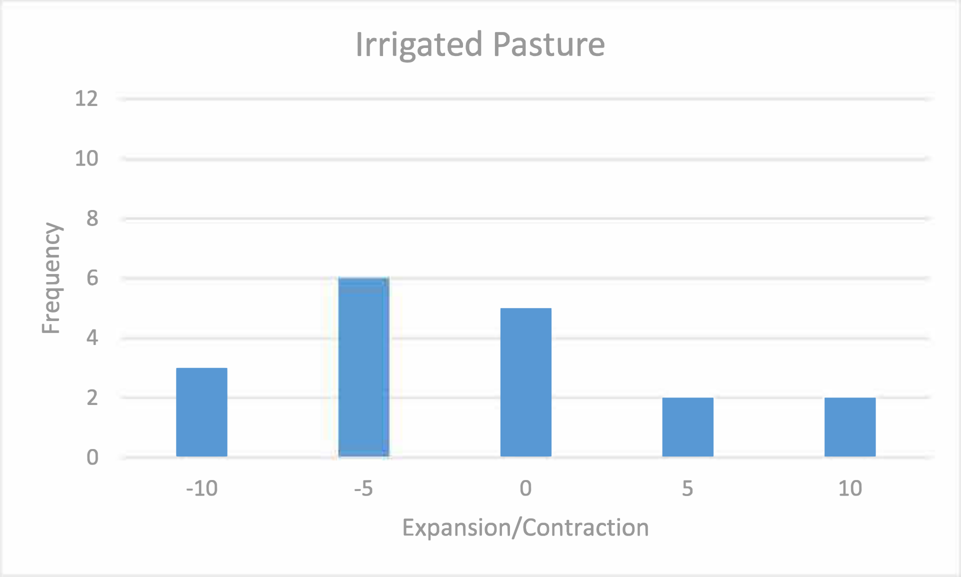
At the June 23rd meeting, work group members estimated that for all crop during the GSP planning horizon, the three subbasins can expect a general reduction of farmed acreage crop types with the exception of vineyards and cannabis/hemp. Work group members did concede that at least in the near term (5-10 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.

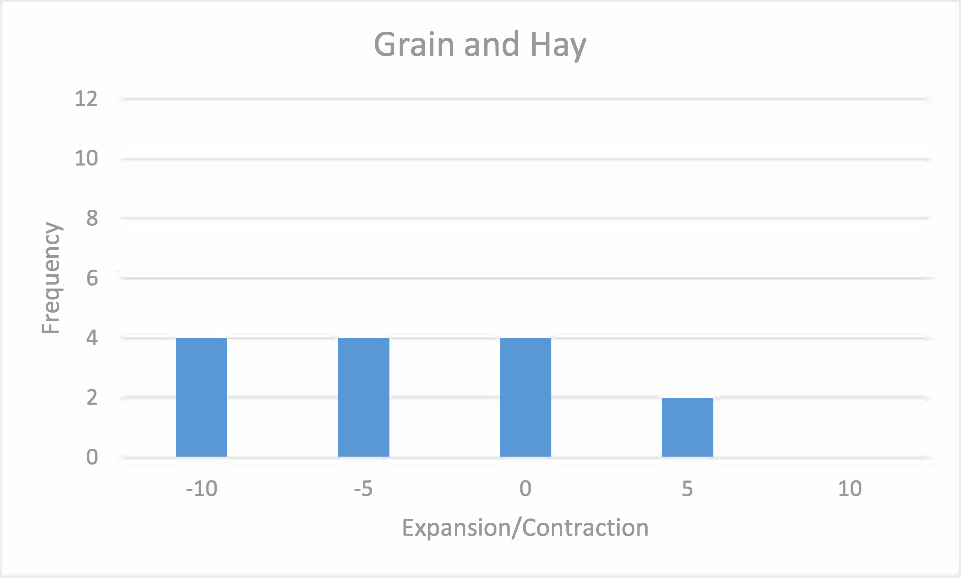
To further evaluate these assumptions, staff developed survey forms, which were sent to the Agricultural Water Demands Practitioner Work Group (7 respondents) and to agricultural land users in the SRP, SV, and PV (28 respondents). The surveys were distributed in late July and early August of 2020. Both 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.

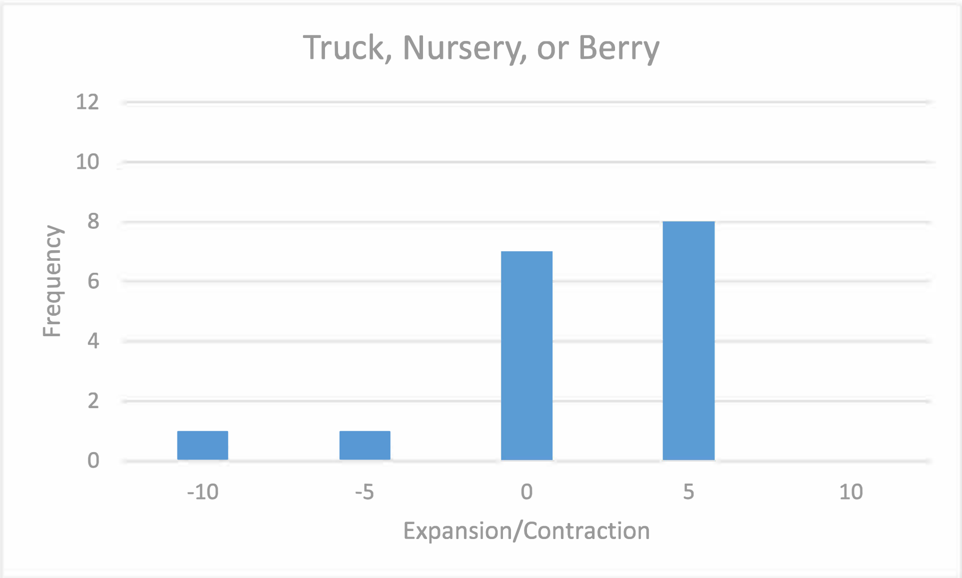
There were differences in the surveys. The agricultural land users were asked about short term (10 years) and long term (50 years) changes in agricultural land use, while the practitioners were asked about only short-term changes. The agricultural land users were asked about dairies while the practitioners 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.

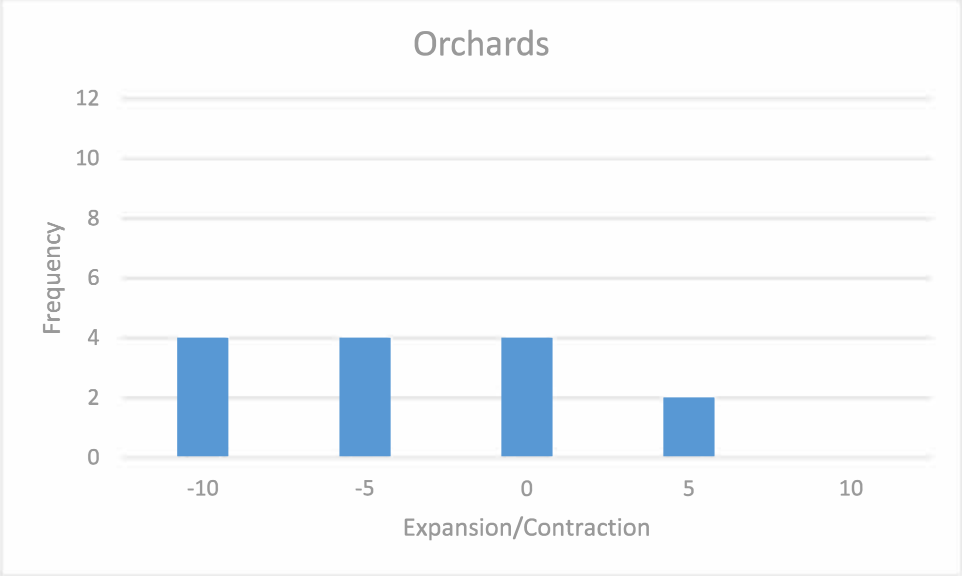
Figures 1 and 2 show the survey results for expected short-term and long-term agricultural land-use changes, respectively. The short-term results combine the practitioner and land user responses with the exception of dairies, which only reflect the land-user responses. The long-term results only reflect 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


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

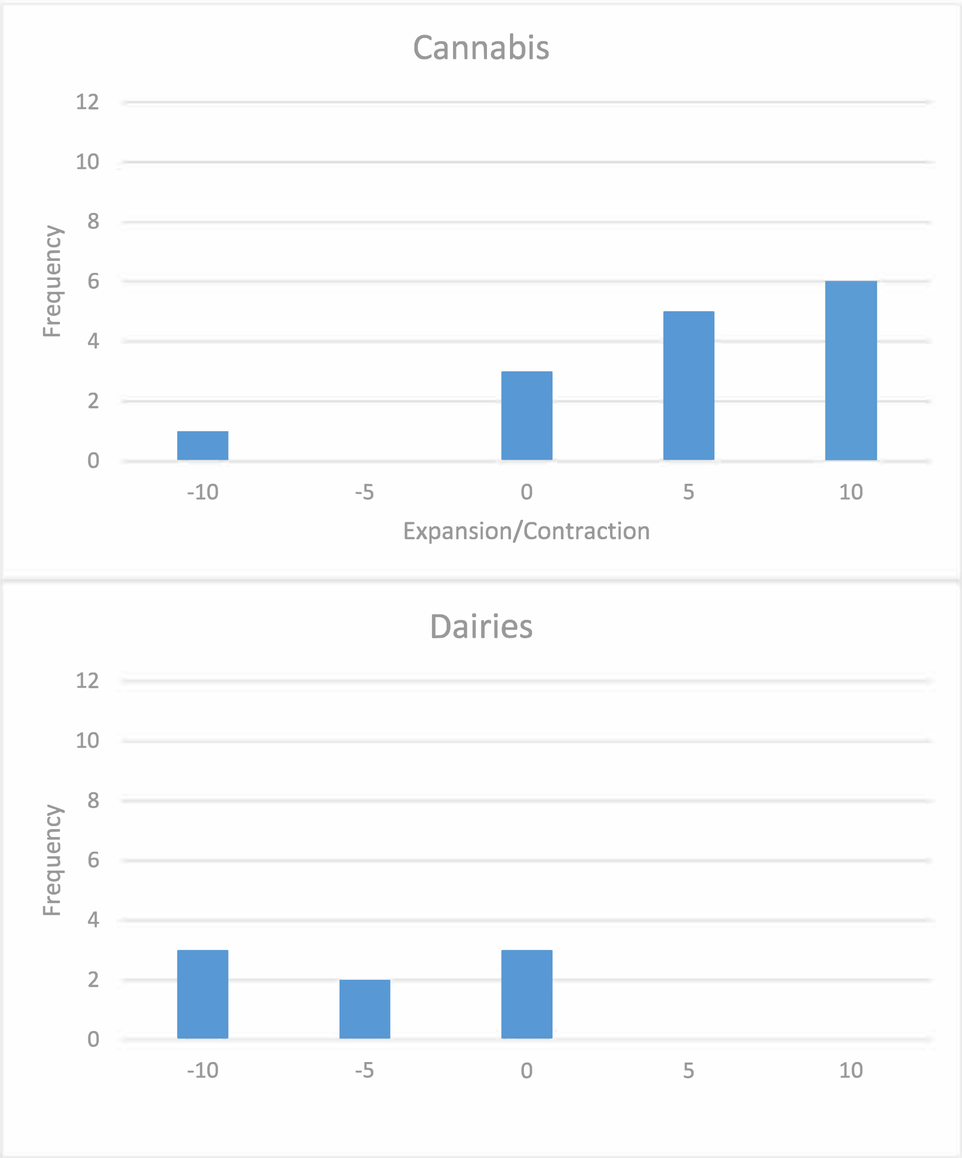
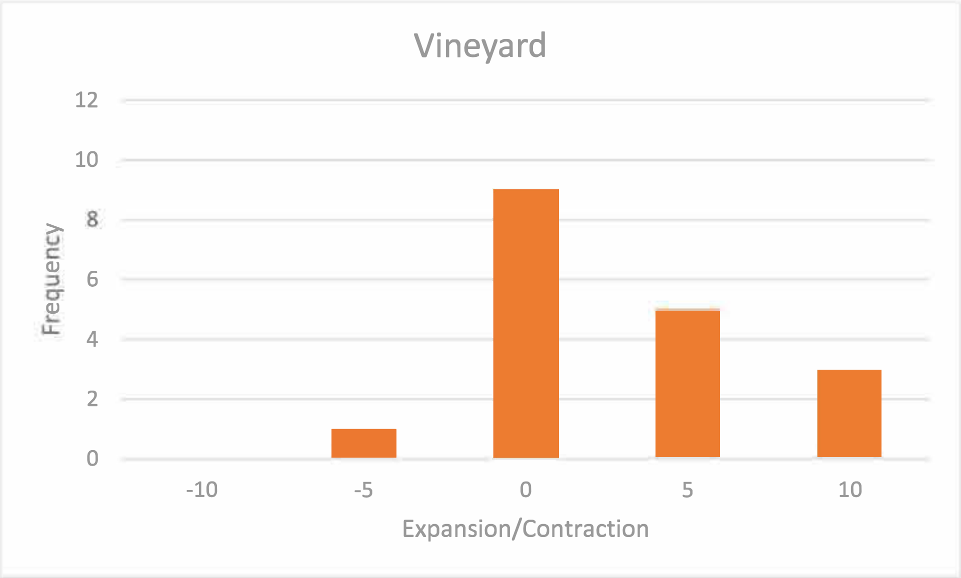
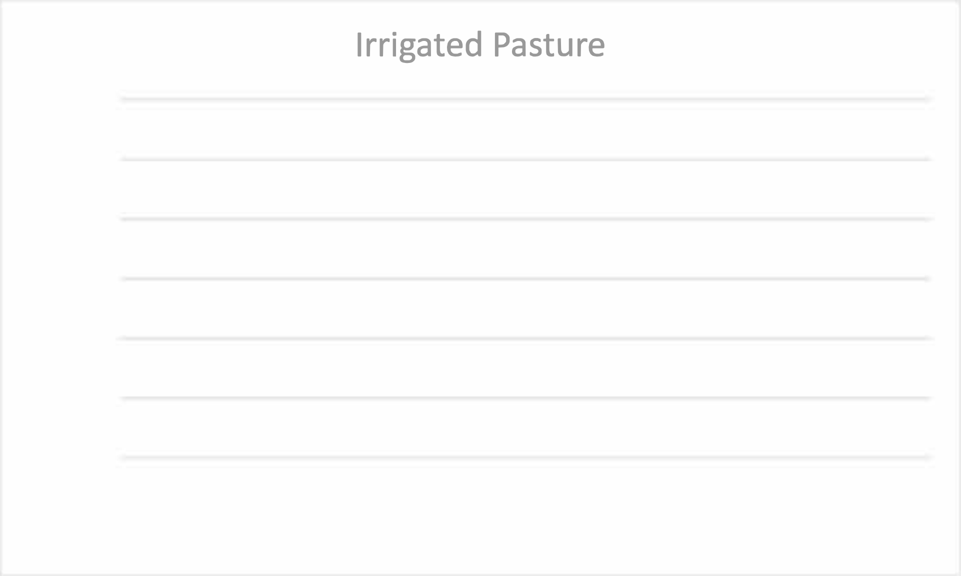
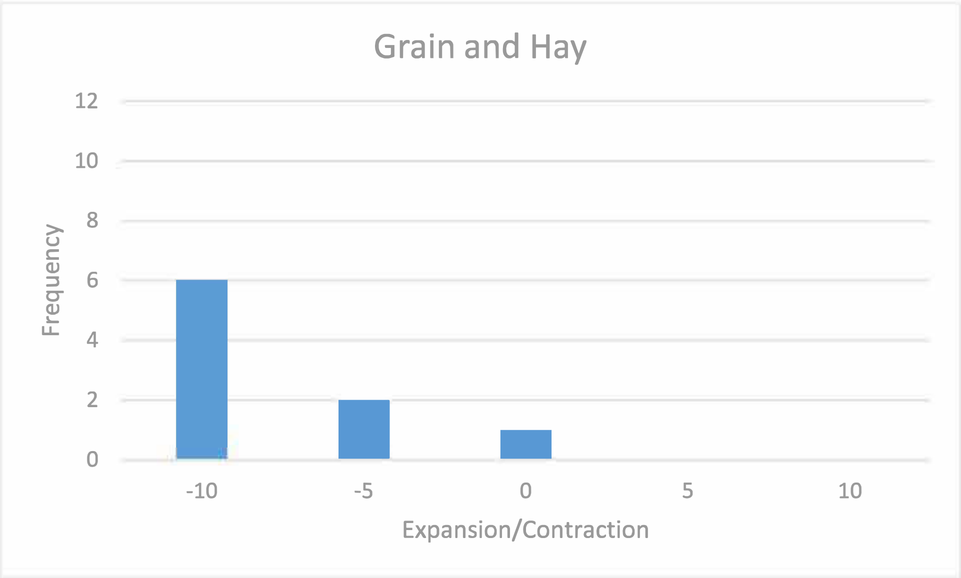


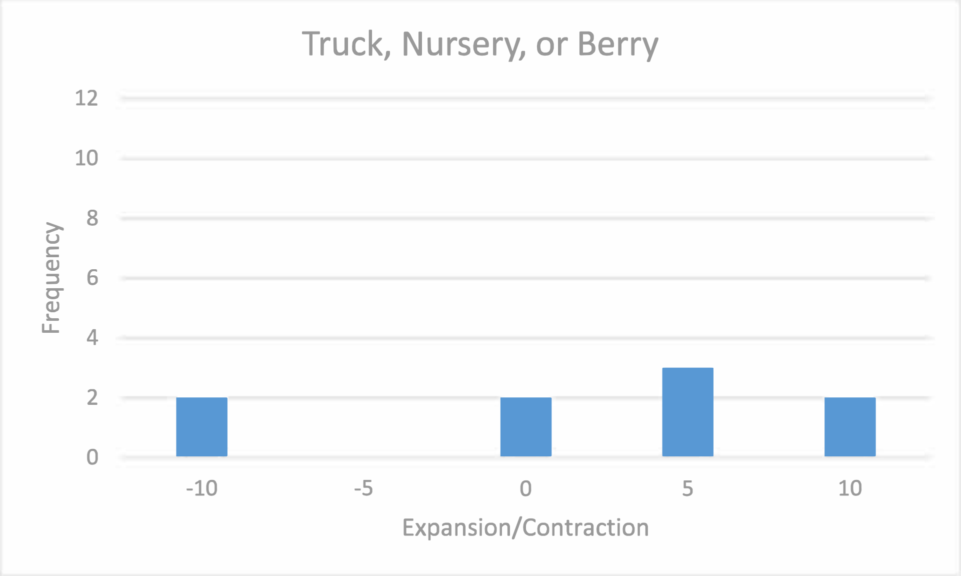
Figure 1. Short-term agricultural land-use changes in the Santa Rosa Plain, Sonoma Valley, and Petaluma Valley.

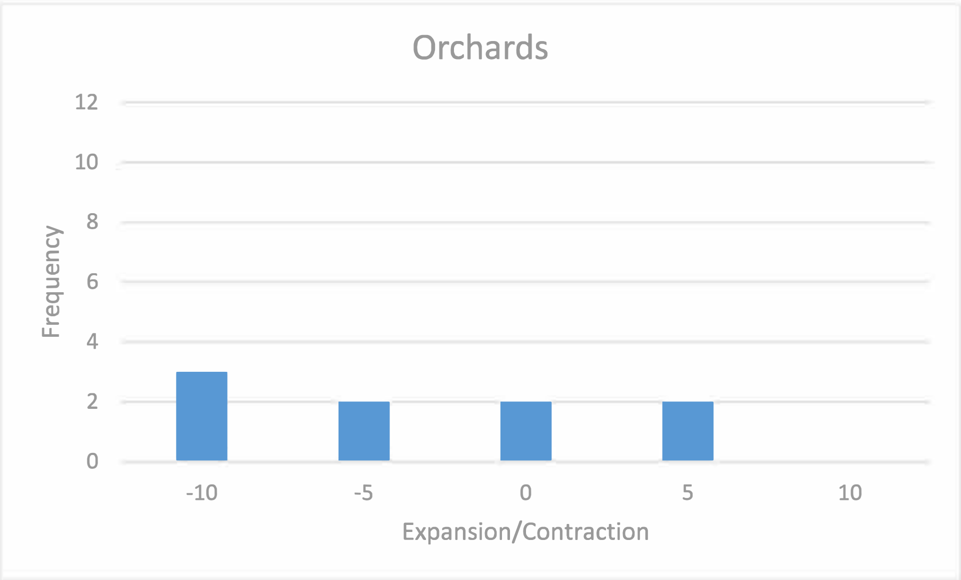
Consider the expected short-term land-use changes (fig. 1). Vineyards, truck crops, and cannabis/hemp are expected to expand (0-5%, 0-5%, and 5-10%, respectively). The other land uses are expected to contract as much as 10% (dairies).

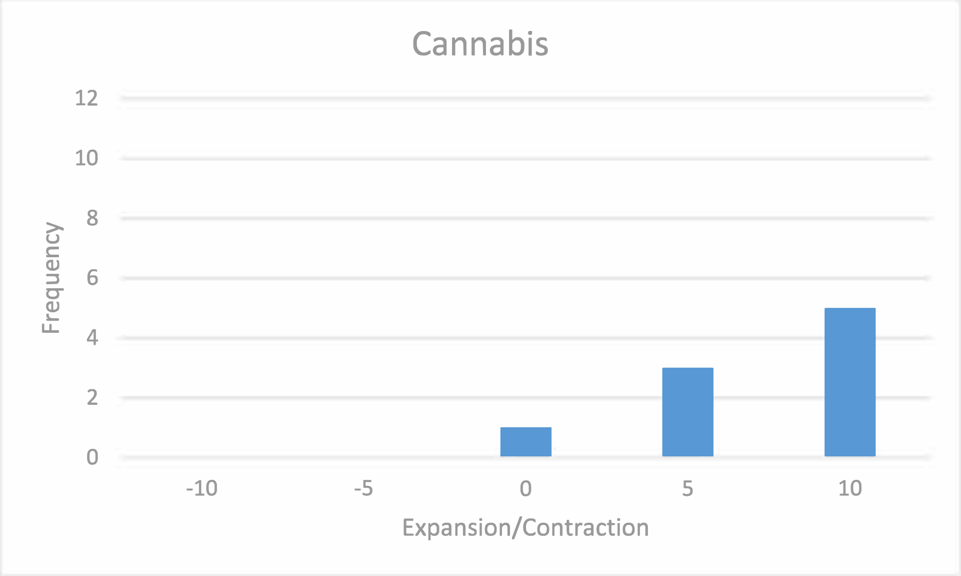

Vineyard
Frequency
12
10
8
6
4
2
0
-10
-5
0
5
10
Expansion/Contraction


Irrigated Pasture


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


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


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

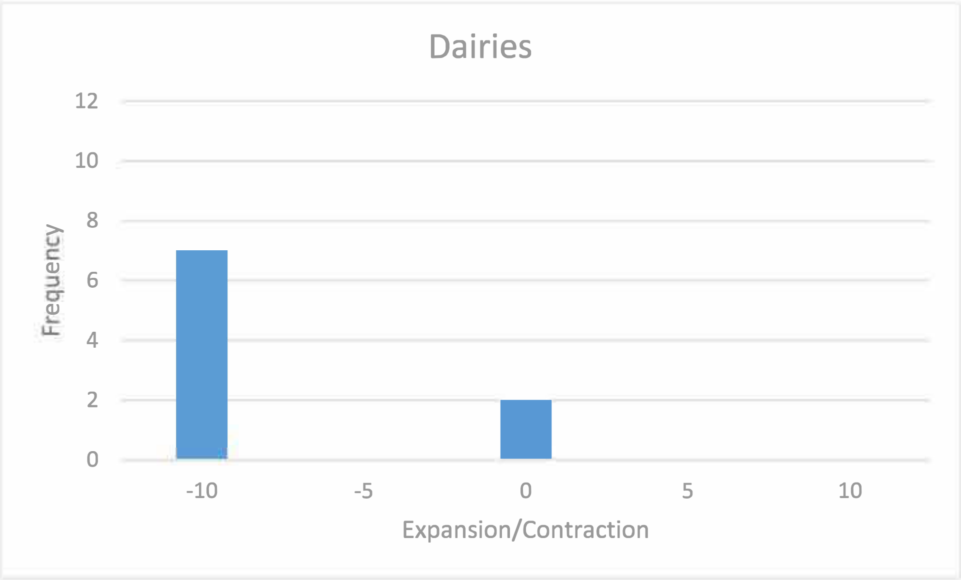


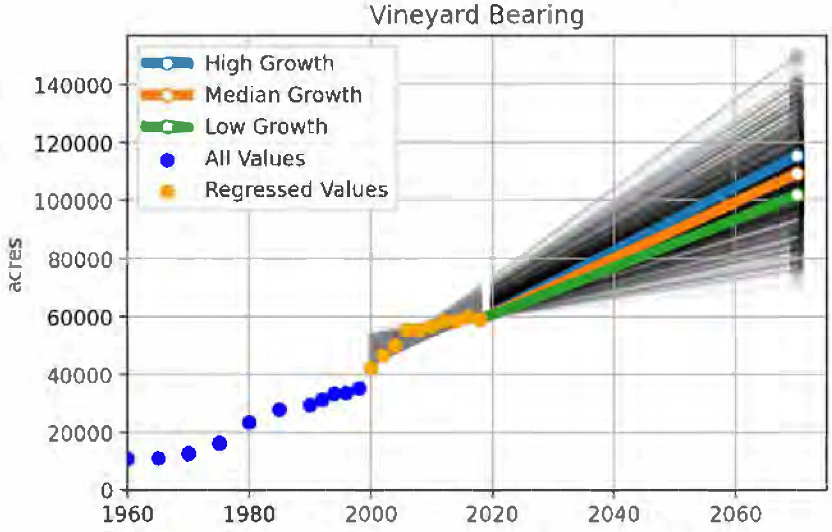
Figure 2. Long-term agricultural land-use changes in the Santa Rosa Plain, Sonoma Valley, and Petaluma Valley.

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

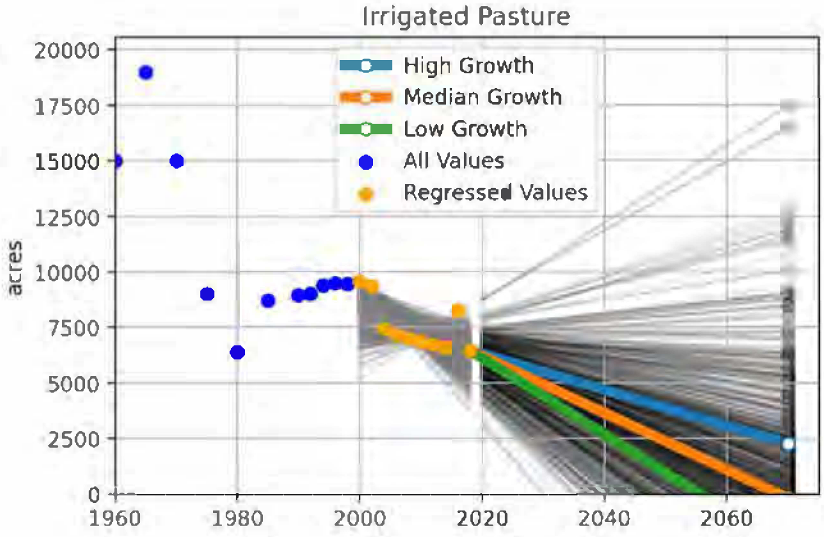

Vineyard Bearing

High Growth 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

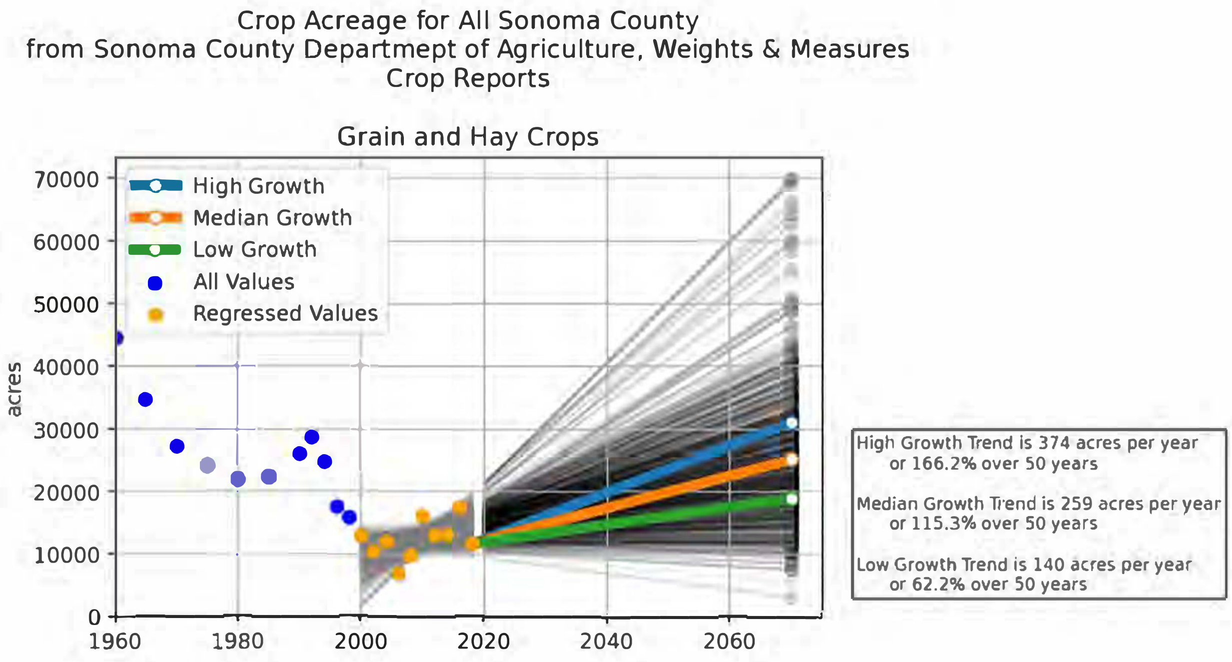
Crop Acreage for All Sonoma County
from Sonoma County Departmept of Agriculture, Weights & Measures
Crop Reports


Irrigated Pasture

High Growth 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

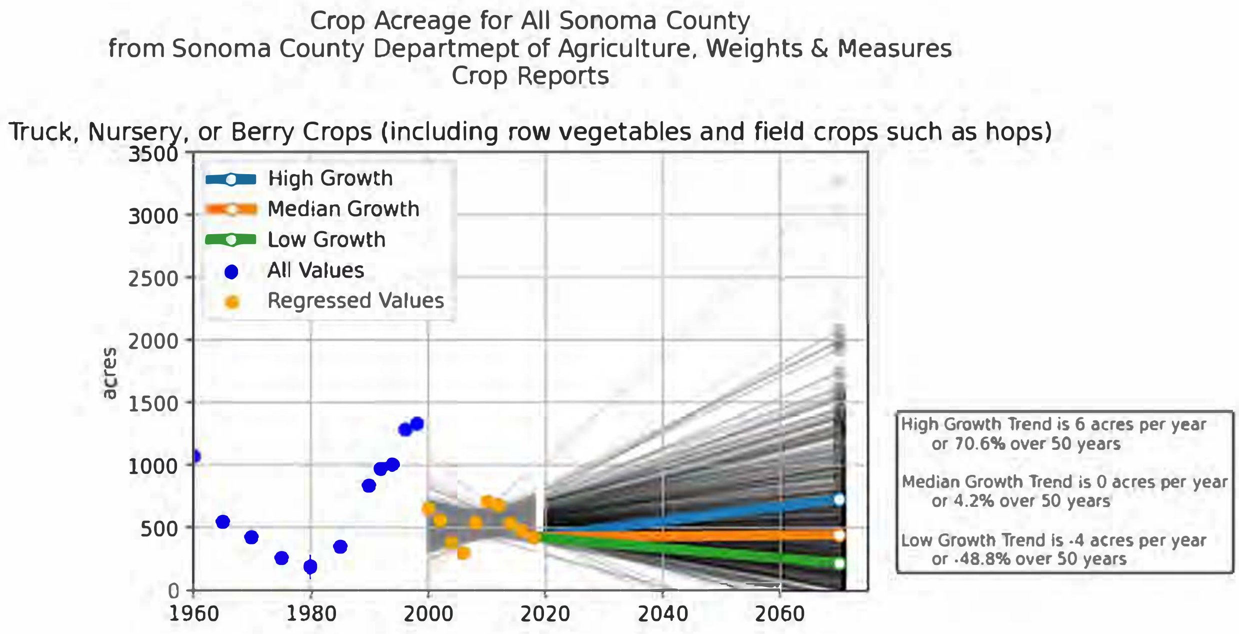

Crop Acreage for All Sonoma County
from Sonoma County Departmept of Agriculture, Weights & Measures
Crop Reports

Grain and Hay Crops

High Growth 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

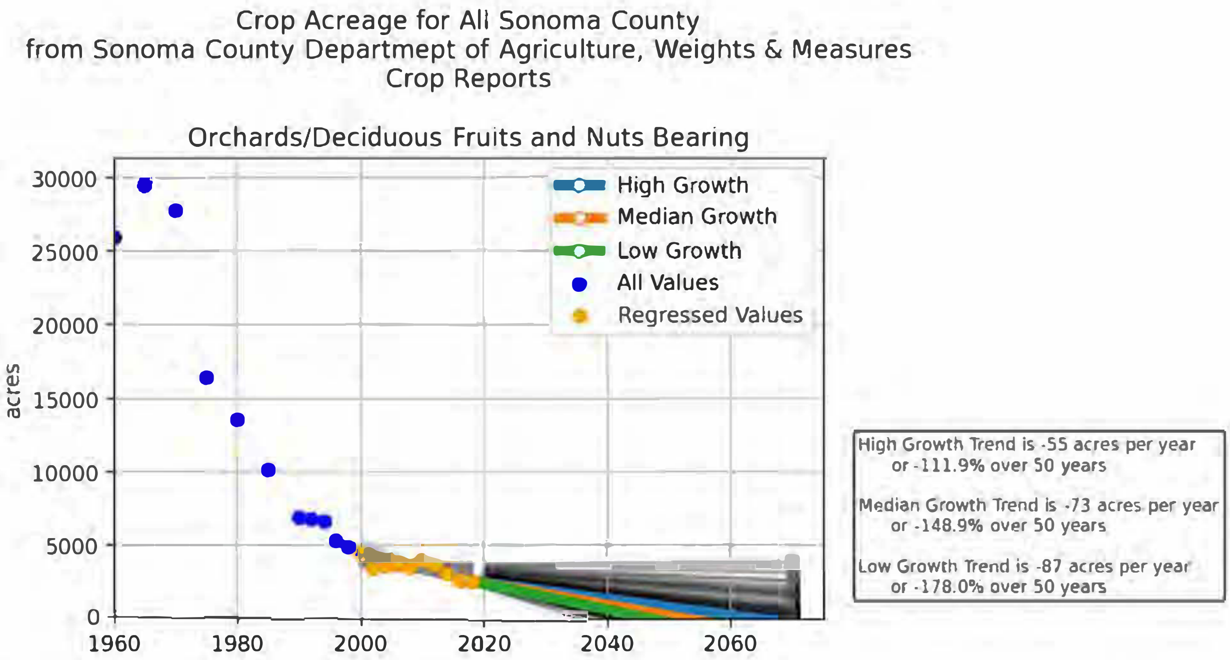

Crop Acreage for All Sonoma County
from Sonoma County Departmept of Agriculture, Weights & Measures
Crop Reports

Truck, Nursery, or Berry Crops (including row vegetables and field crops such as hops)

High Growth 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


Crop Acreage for All Sonoma County
from Sonoma County Departmept of Agriculture, Weights & Measures
Crop Reports

Orchards/Deciduous Fruits and Nuts Bearing

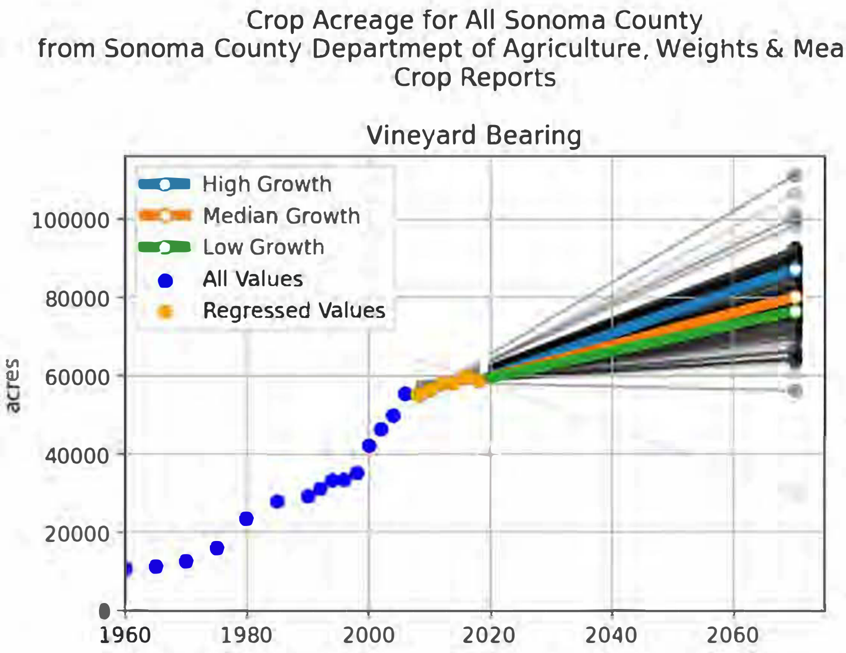
High Growth Trend is -55 acres per year
or -111.9% over 50 years

Median Growth Trend is -73 acres per year
or -148.9% over 50 years

Low Growth Trend is -87 acres per year
or -178.0% 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).


Crop Acreage for All Sonoma County
from Sonoma County Departmept of Agriculture, Weights & Measures
Crop Reports

Vineyard Bearing

High Growth Trend is 548 acres per year
or 48.3% over 50 years

Median Growth Trend is 410 acres per year
or 36.2% over 50 years

Low Growth Trend is 341 acres per year
or 30.1% over 50 years

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.

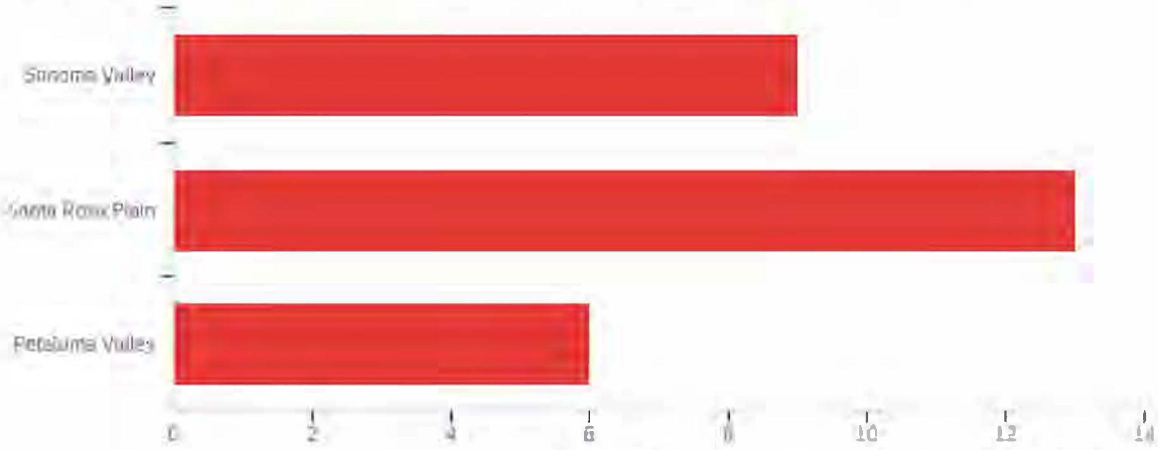


Figure 1: Geographic distribution of survey respondents

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)

---

[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.

---

[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**

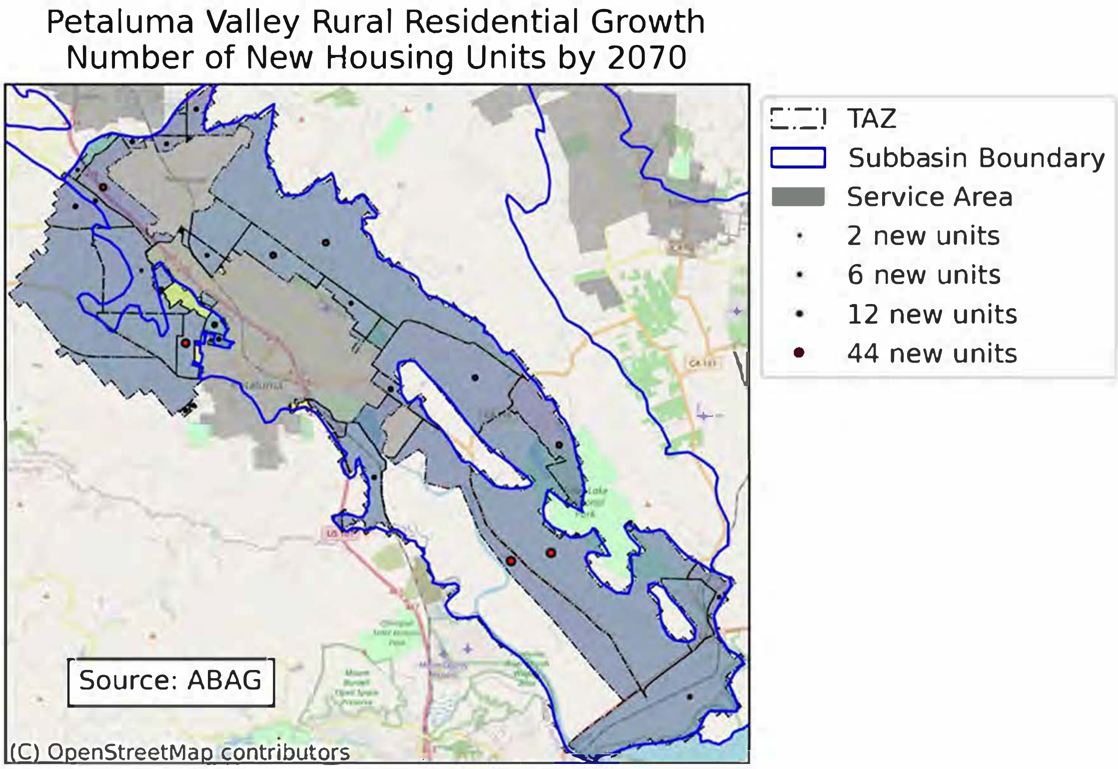


Figure 1 Petaluma Valley Rural Residential Growth Projections

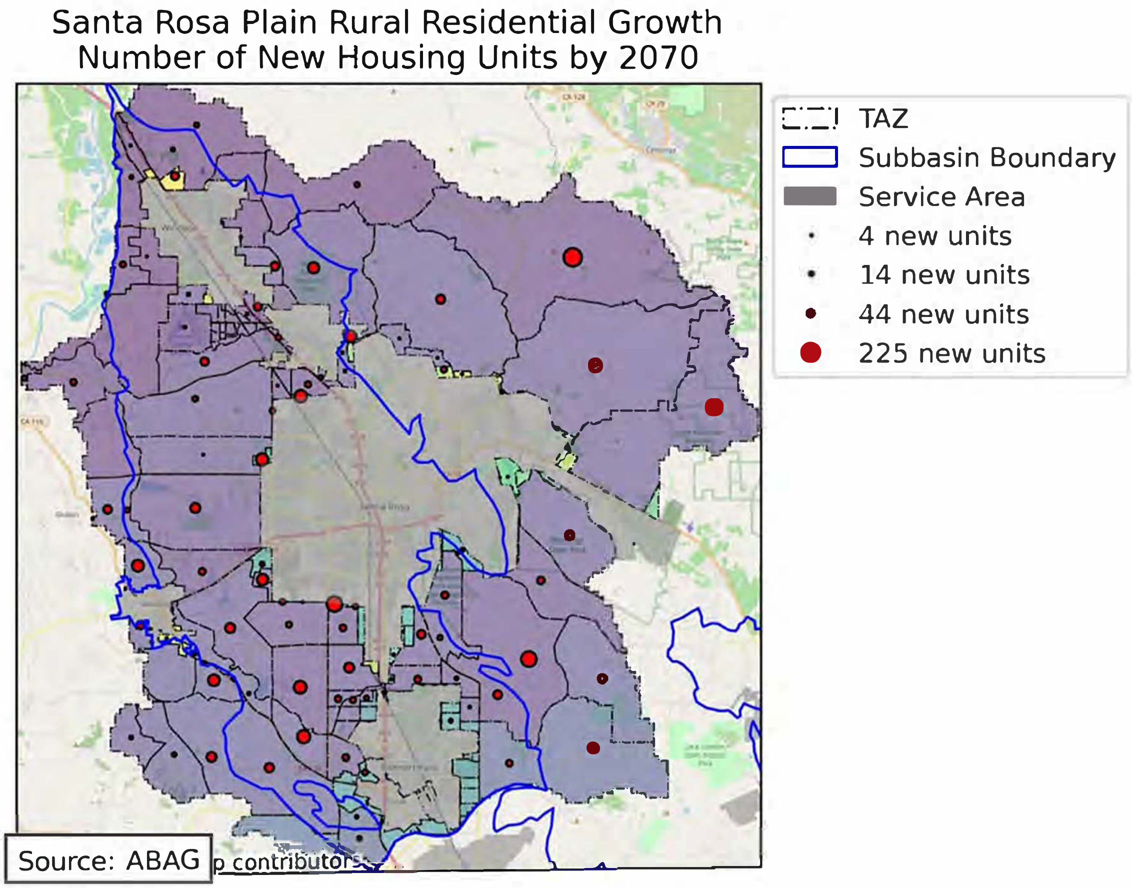


Figure 2 Santa Rosa Plain Rural Residential Growth Projections

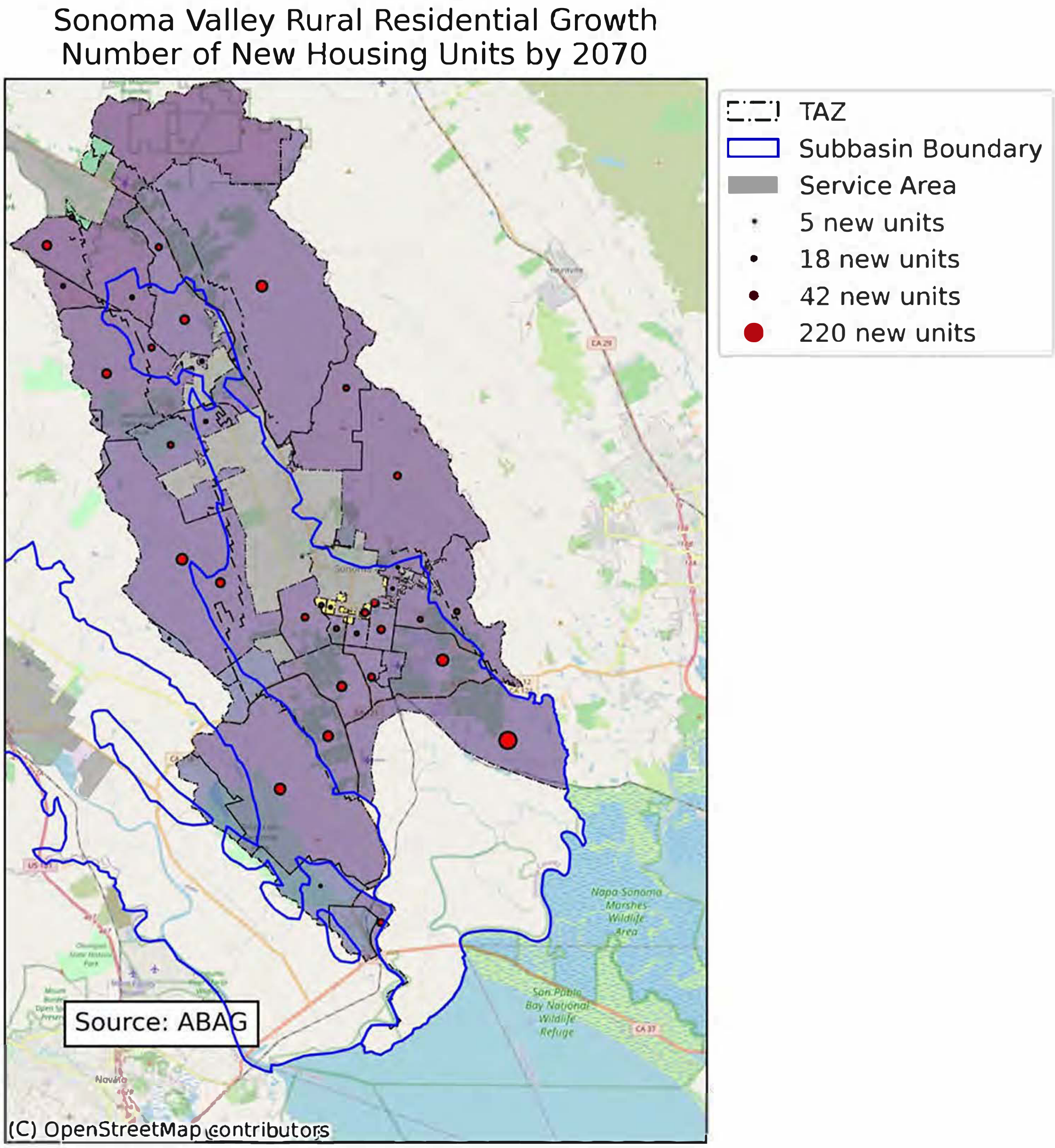


Figure 3 Sonoma Valley Rural Residential Growth Projections

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*

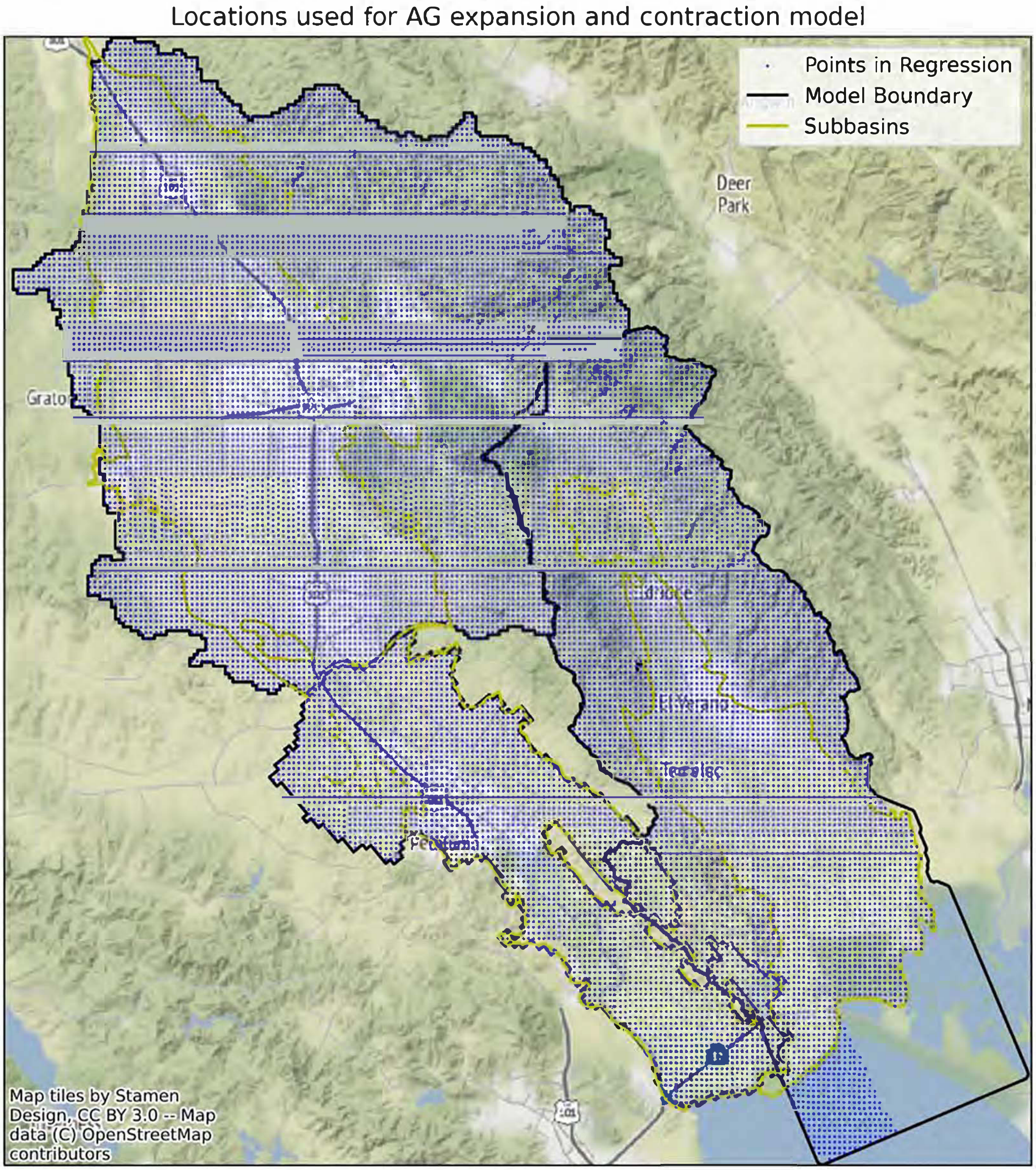


Figure 1 Locations used for AECM

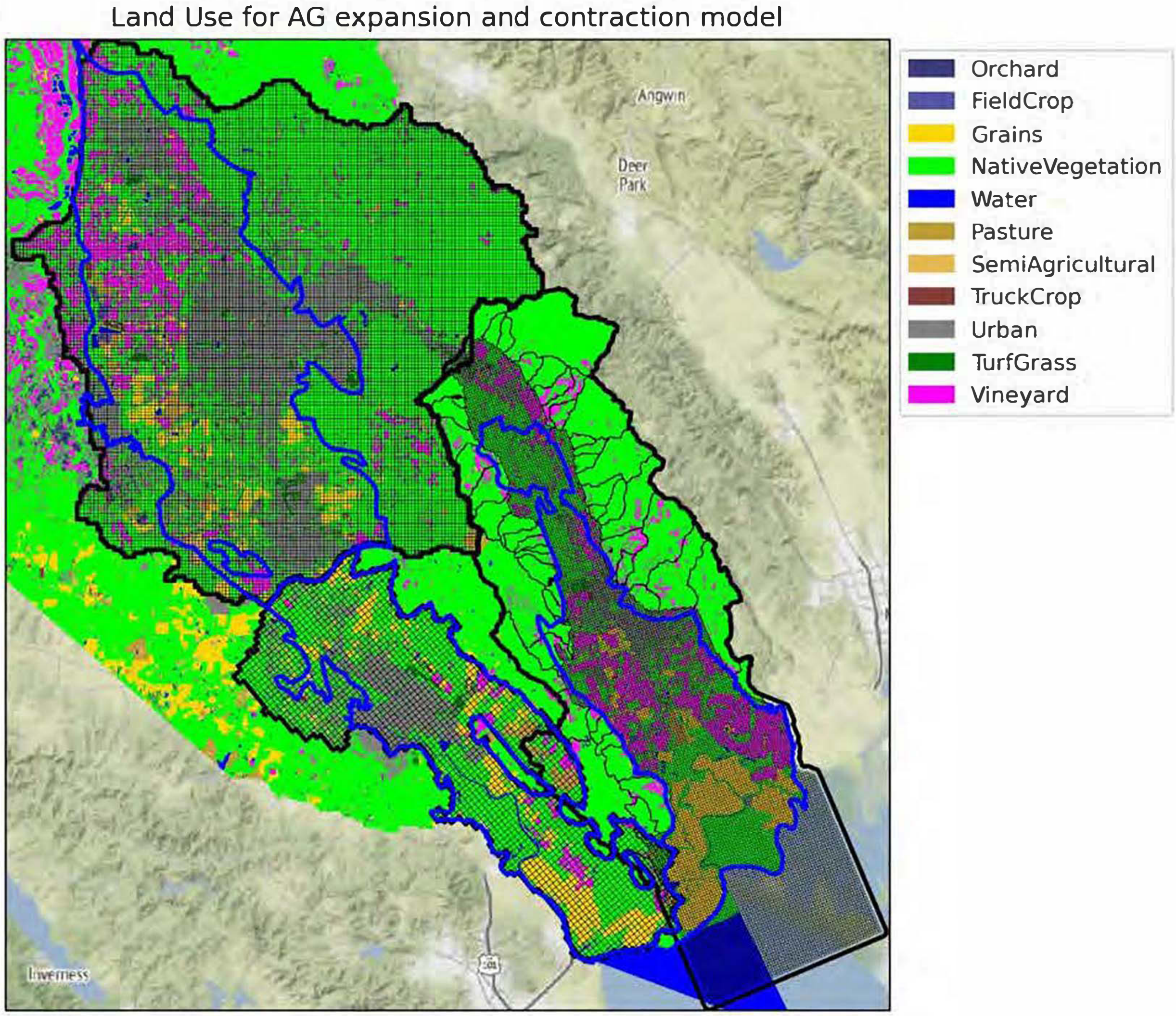


Figure 2 Land Use

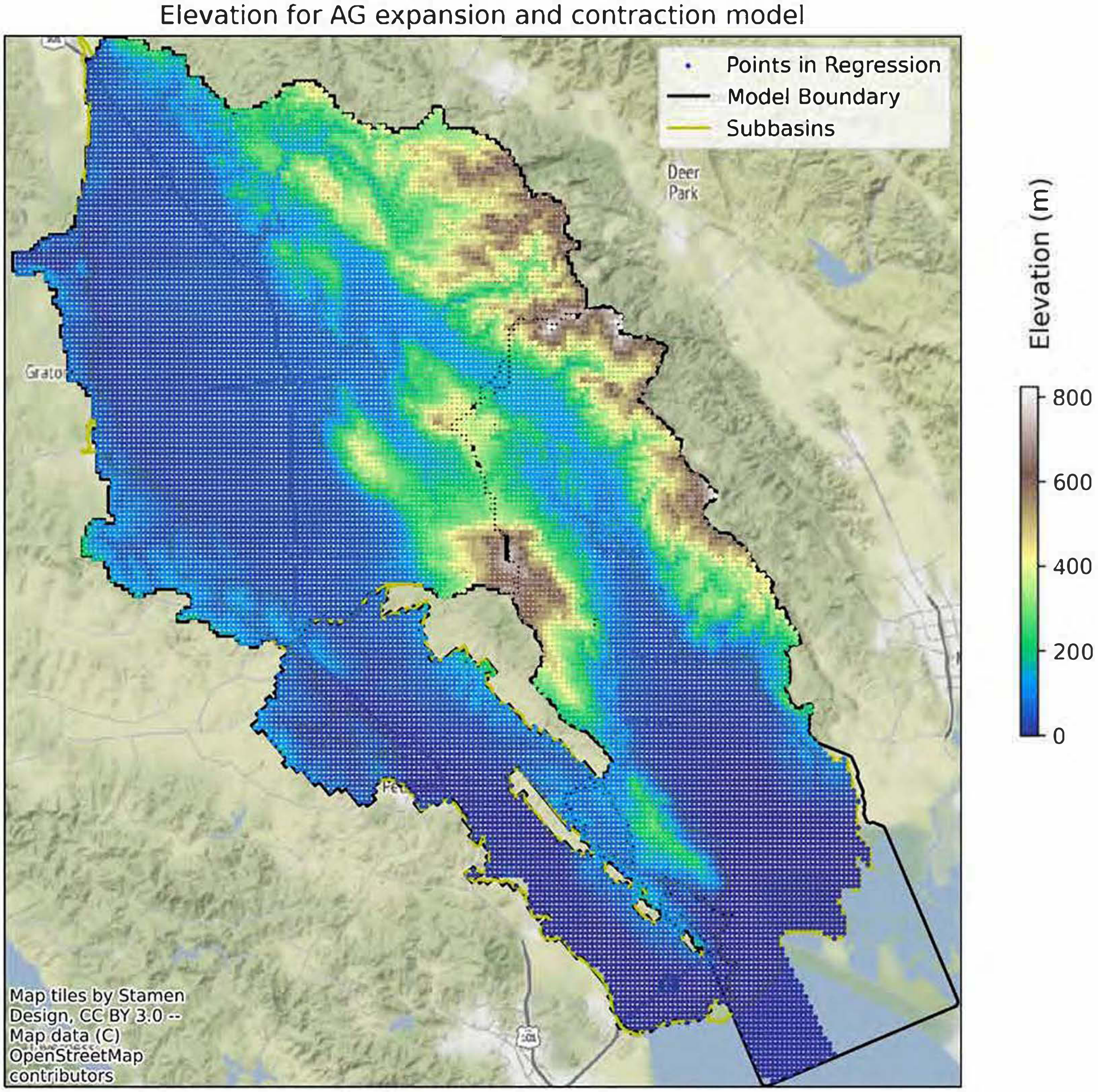


Figure 3 Elevation for AECM

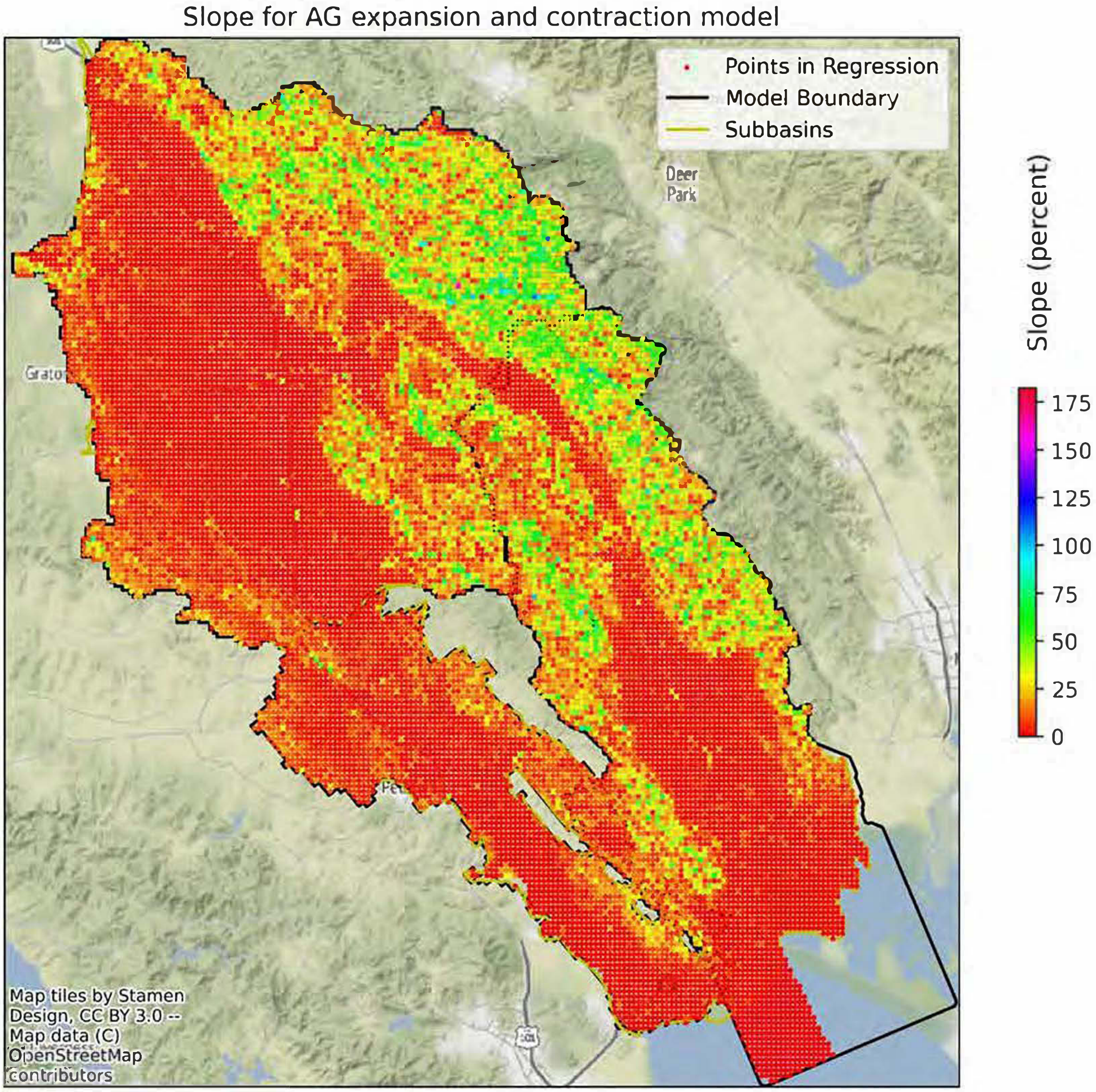


Figure 4 Slope for AECM

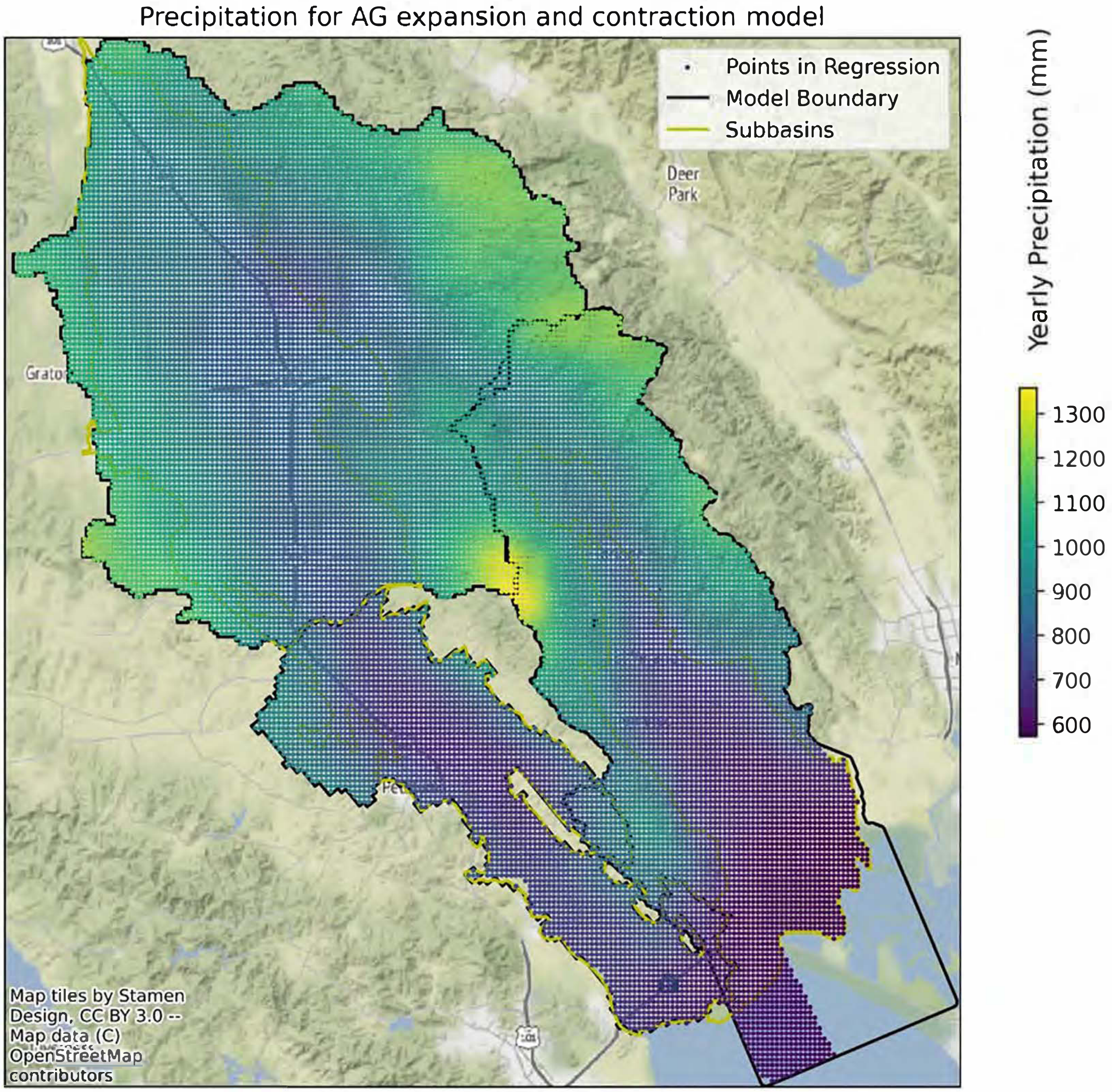


Figure 5 Precipitation for AECM

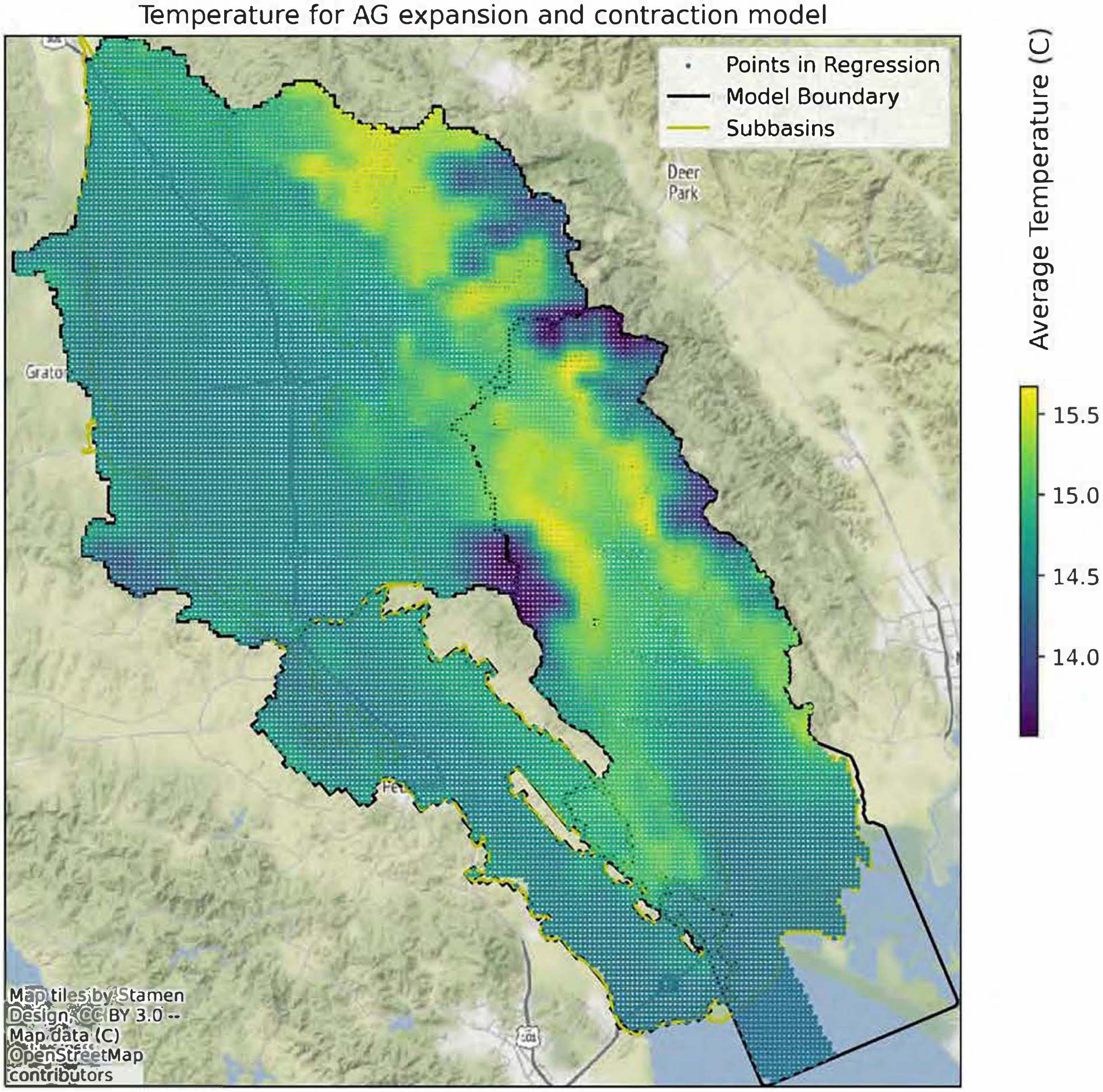


Figure 6 Temperature for AECM

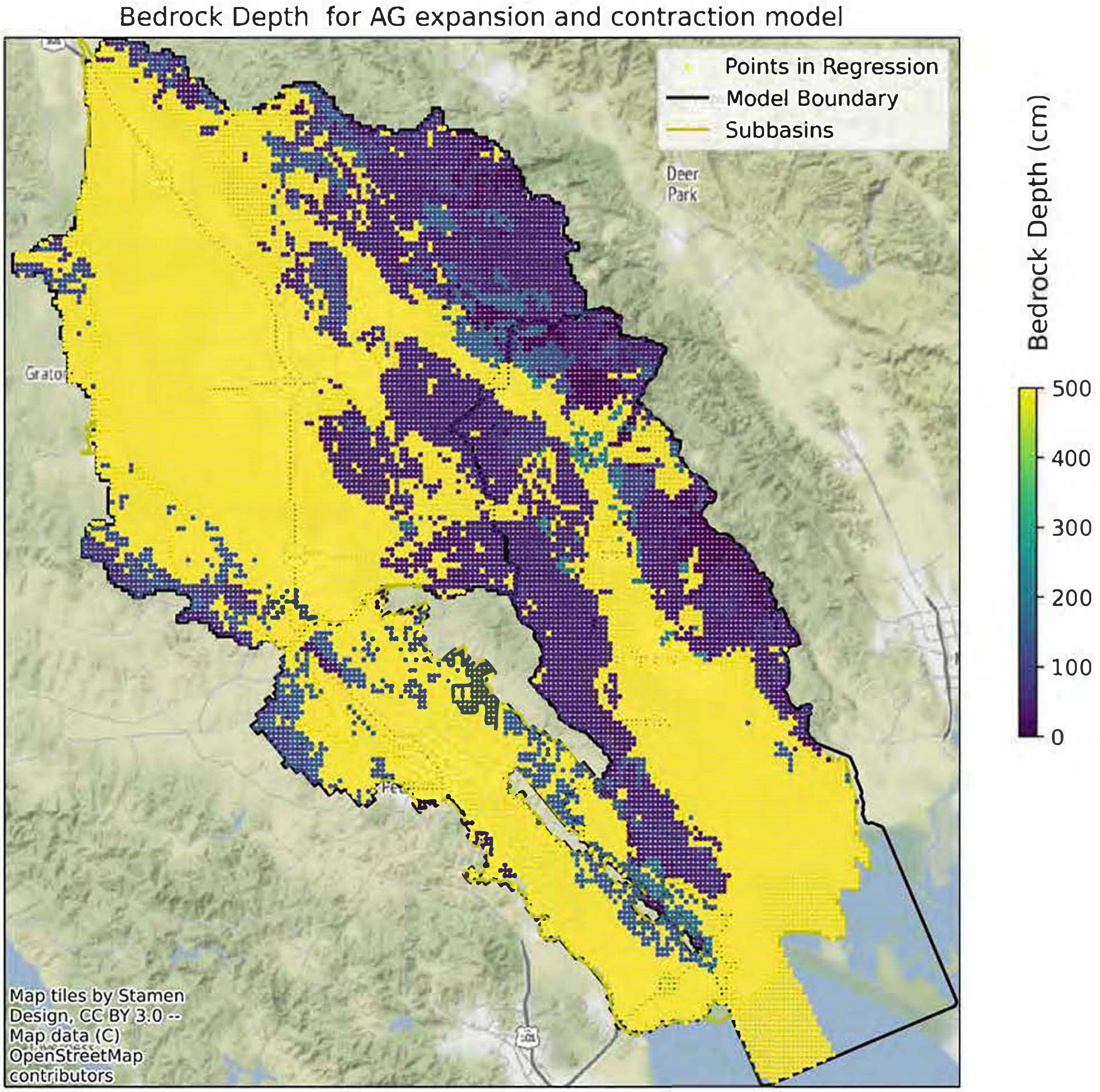


Figure 7 Bedrock Depth for AECM

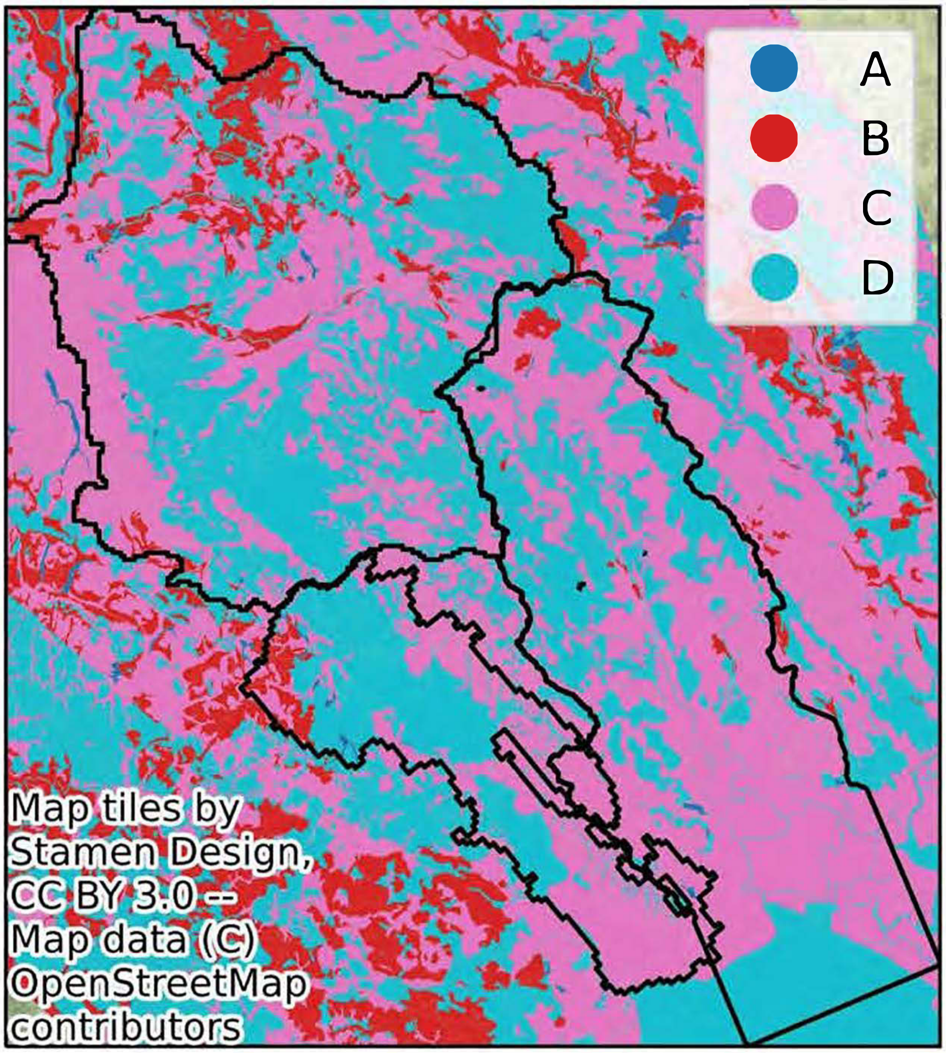


Figure 8 Hydrologic Soil Group

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.

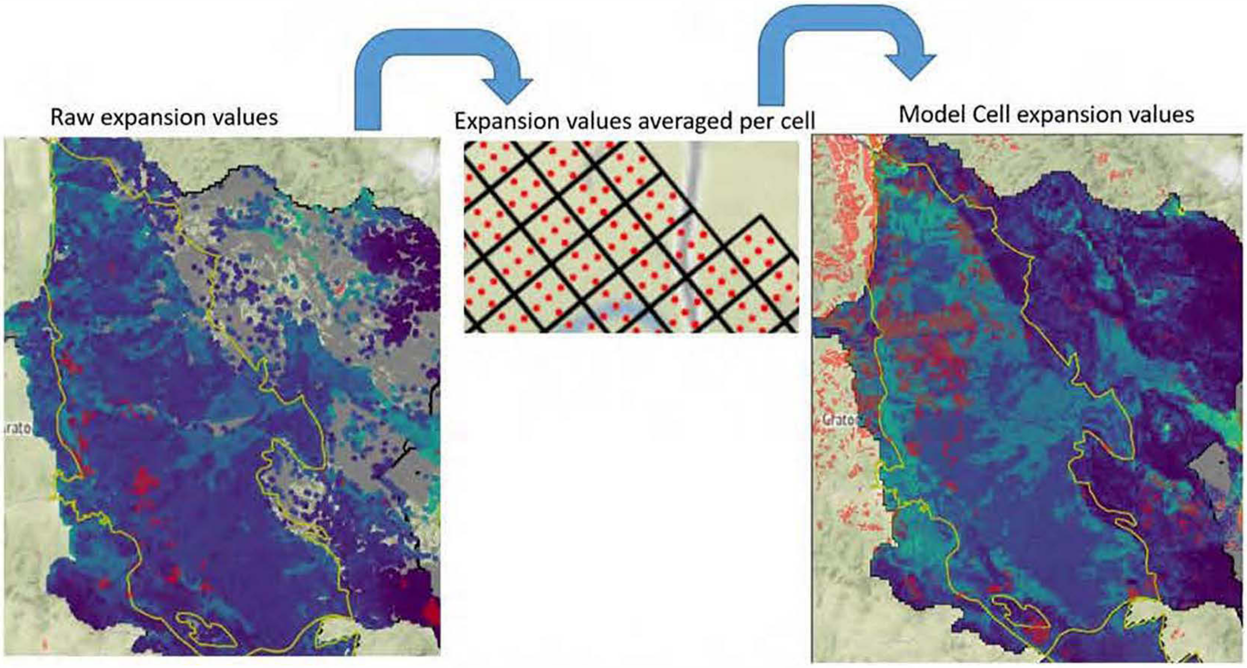


Figure 9 Converting Raw Expansion Values to Model Cell Crop Expansion Rankings

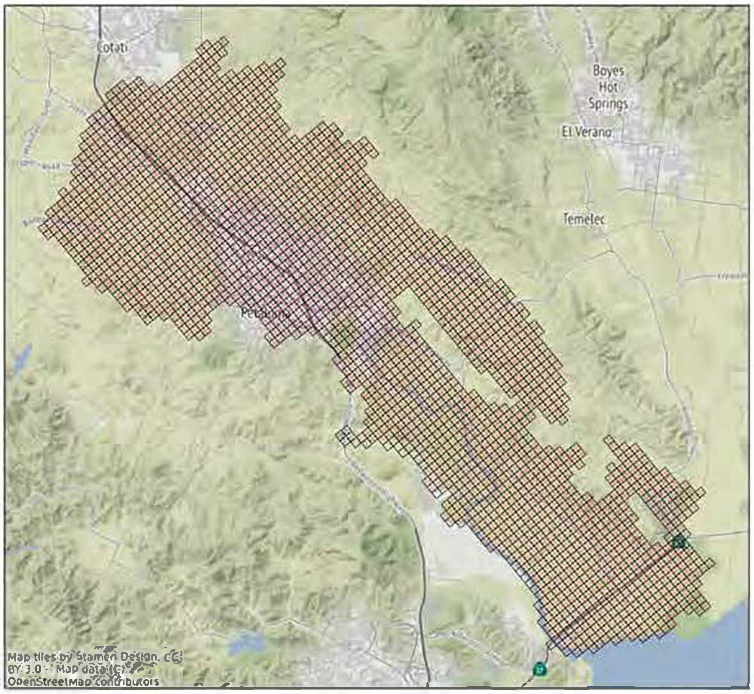


Figure 10 Model Cells Used for AECM predictions, Petaluma Valley Subbasin

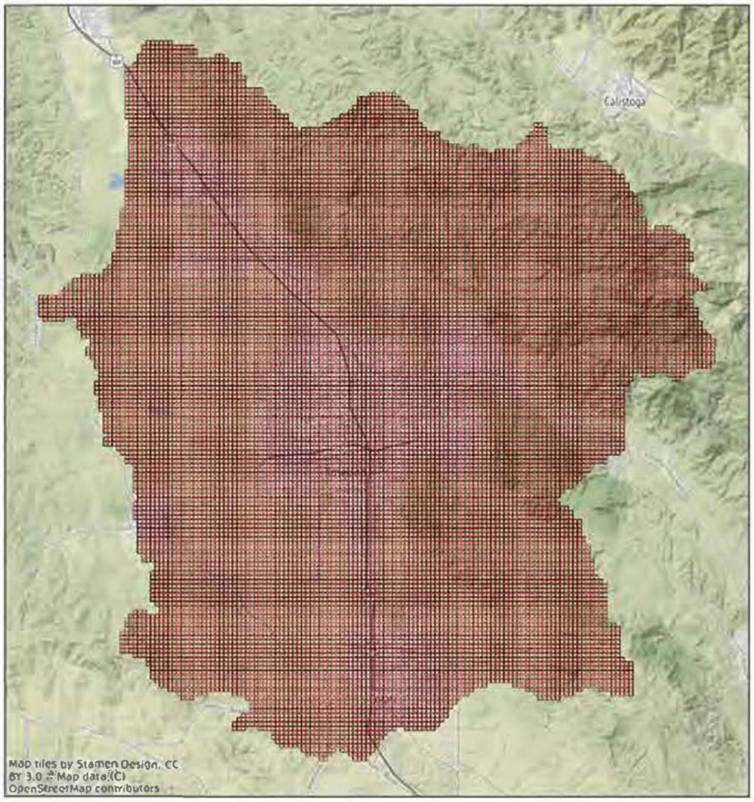


Figure 11 Model Cells Used for AECM predictions, Santa Rosa Plain Subbasin

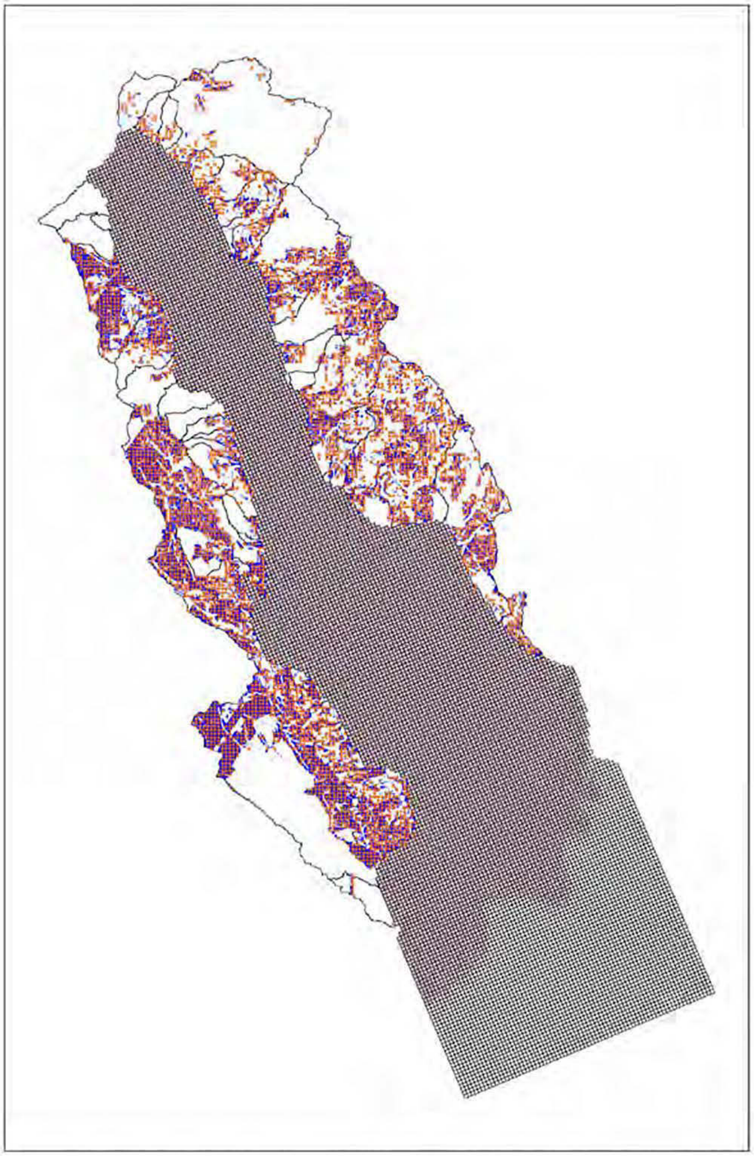


Figure 12 Model Cells Used for AECM predictions, Sonoma Valley Subbasin

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.

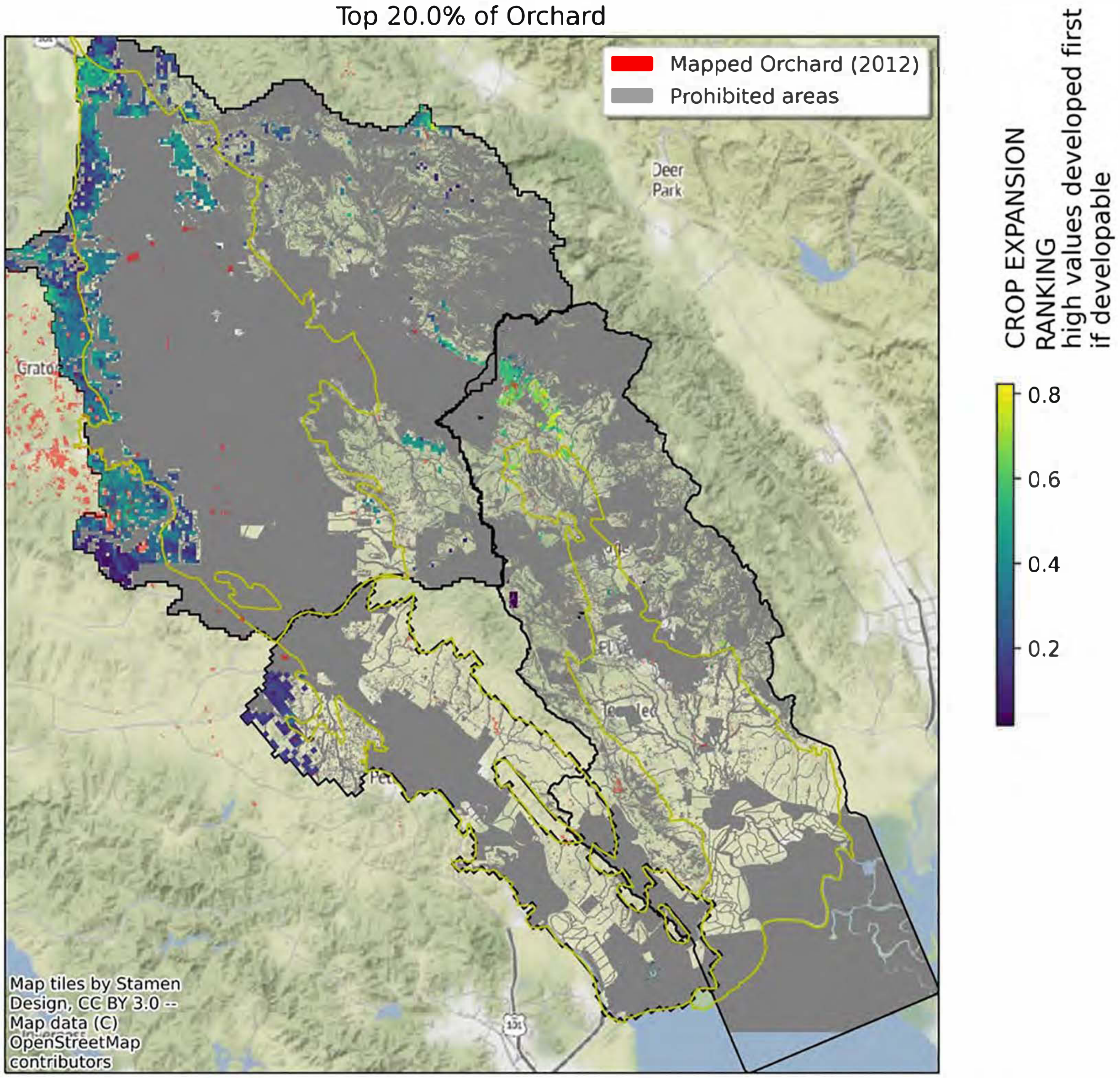


Figure 13 Top 20% Ranked AECM Values for Orchards

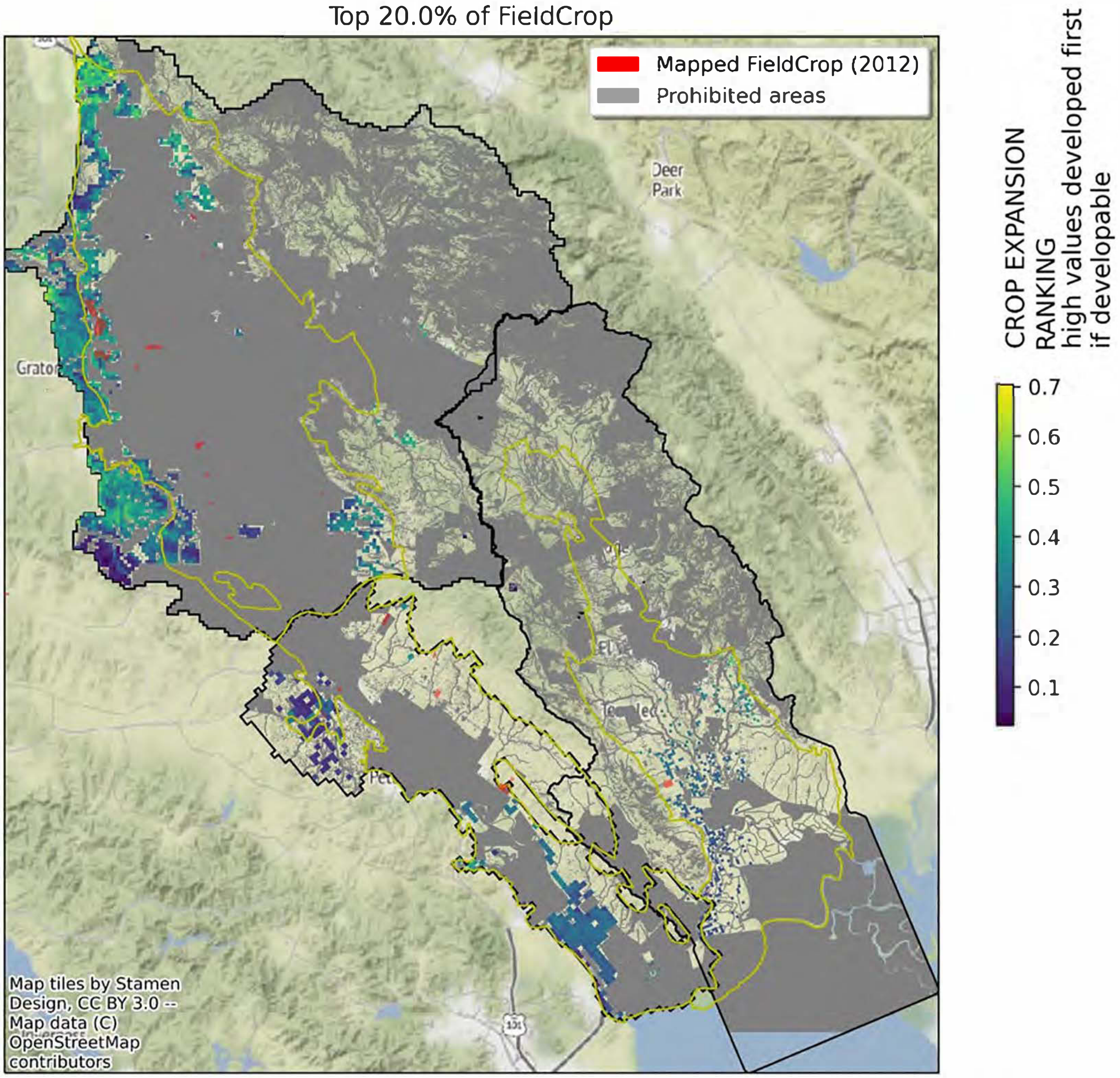


Figure 14 Top 20% Ranked AECM Values for Field Crops

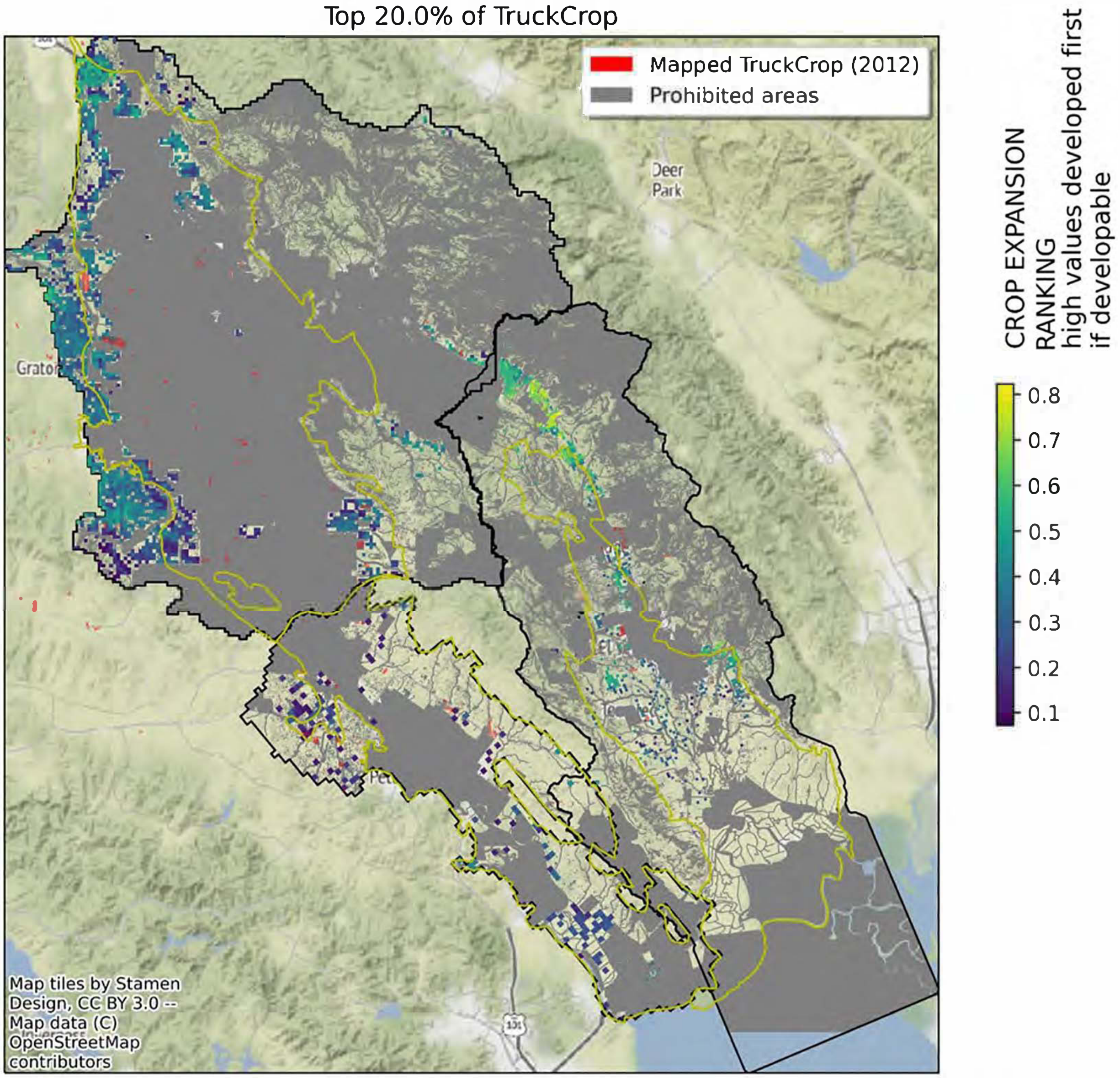


Figure 15 Top 20% Ranked AECM Values for Truck Crops

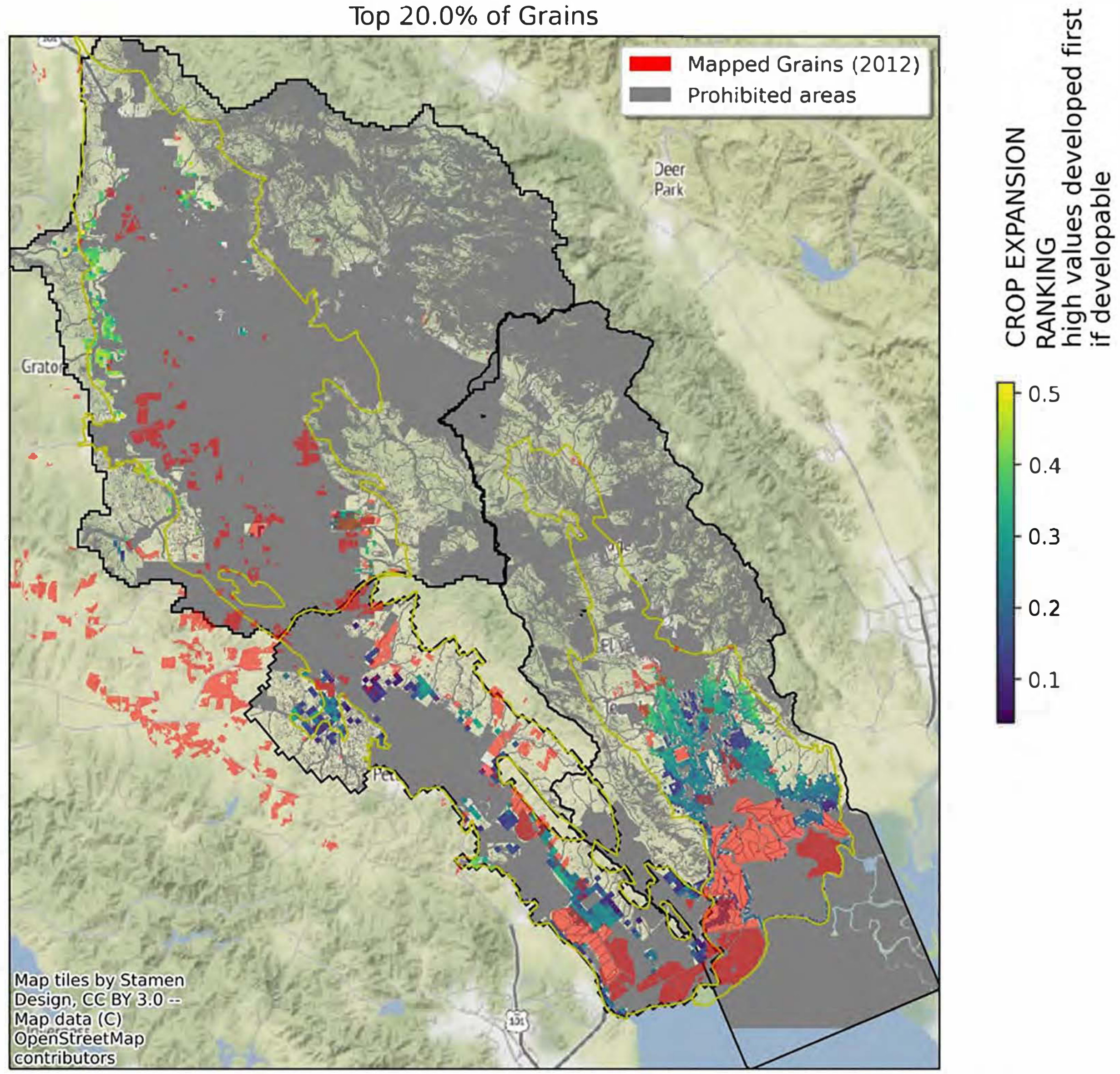


Figure 16 Top 20% Ranked AECM Values for Grains

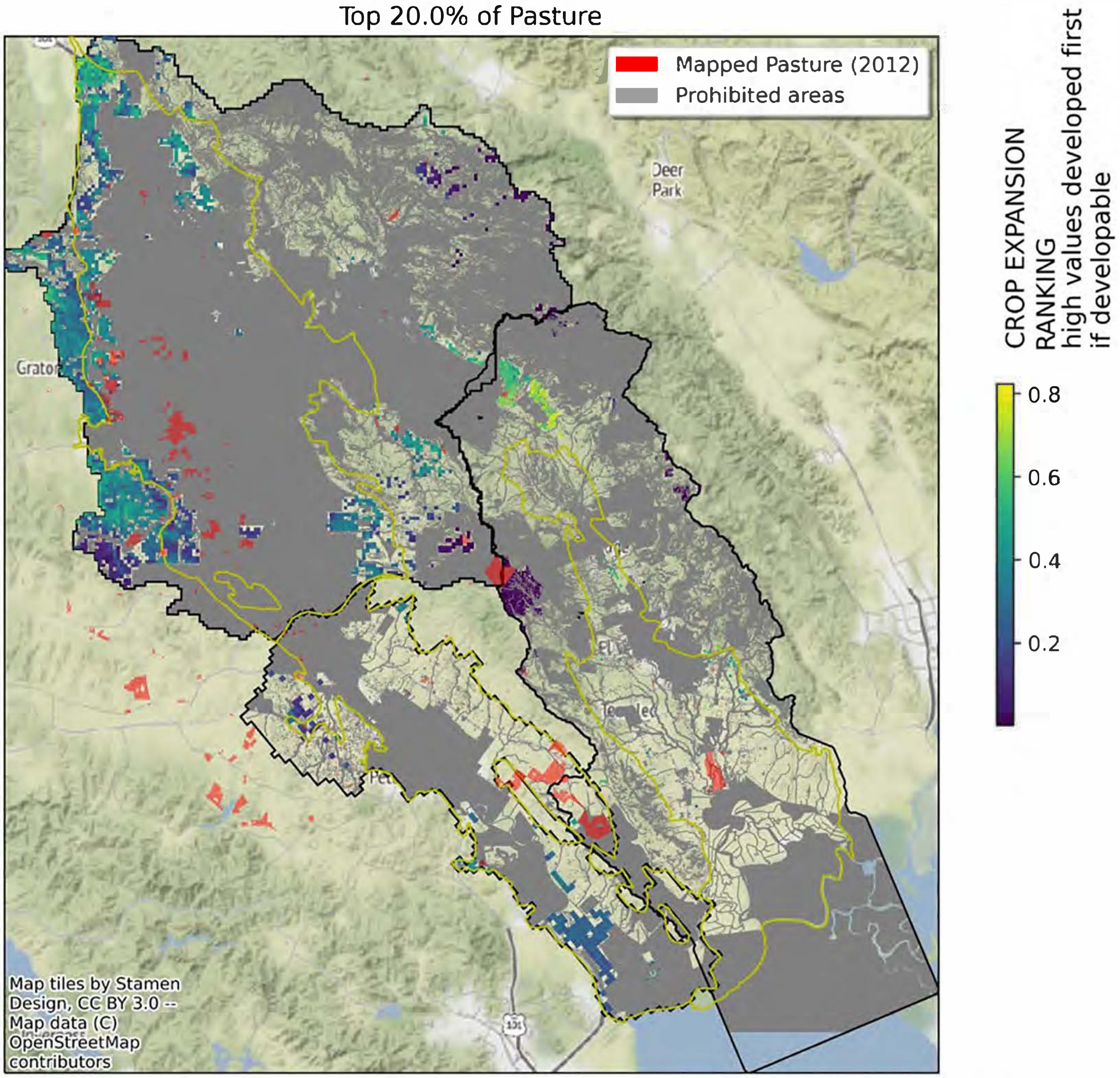


Figure 17 Top 20% Ranked AECM Values for Pasture

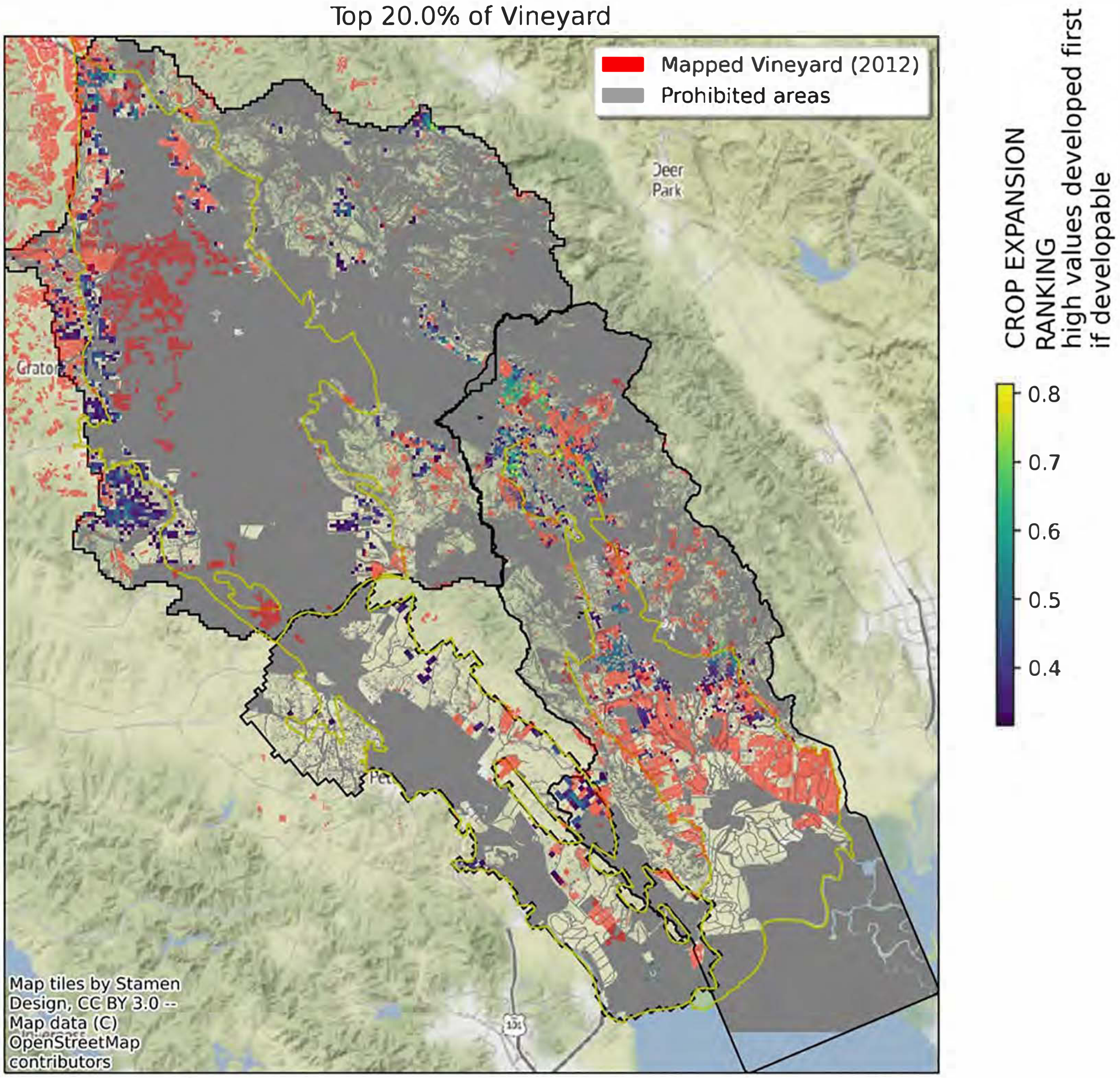


Figure 18 Top 20% Ranked AECM Values for Vineyards

Converting the Model Cell AECM Rankings to Spatial Forecast

With the crop expansion rates and the model cell AECM values now defined, the forecasted spatial locations of the new and removed crops can be assigned. Note that all three basins are treated equally, and if for example, one basin does not have suitable crop areas for a given crop, it may not experience any growth in that subbasin. For each forecast period, the following algorithm is applied on 5-year intervals. The algorithm accounts for growth of crops as well as the contraction of crop areas. When contraction occurs for a crop it is converted to native vegetation, which can then be converted to another crop.

Algorithm steps: loop through all crops, performing steps listed below on each, then proceed to next year

For negative growth:

1. *If no area is remaining for crop, then skip to next crop*
2. *Remove acreage ranked by areas with lowest AECM expansion value. Convert to native vegetation. These areas can be re-developed for other crops.*

For positive growth:

1. *Filter areas that are not developable based on zoning, riparian buffers, etc,*
2. *Filter crops and land uses that cannot be developed (eg vineyards, pastures, etc)*
3. *From remaining areas select cell nodes with highest AECM values until growth is satisfied*

The results of the crop expansion forecasts is summarized in Figure 19. This figure shows only locations that have changed crop type from 2020 to 2075 and does not represent the actual crop types. The figure shows the final crop type at 2075. Figure 20, Figure 21, Figure 22, Figure 23, Figure 24, and Figure 25 display the projected crop distributions from the period from 2020 to 2070.

Table 2 Projected Agricultural Areas for the Petaluma Valley Integrated Hydrologic Model Area

	Field Crop	Grains	Orchard	Pasture	Truck Crop	Vineyard
2020	0	4,563	0	2,203	0	2,025
2025	0	4,563	0	1,914	0	2,025
2030	0	4,563	0	1,692	0	2,048
2035	0	4,563	0	1,469	0	2,070
2040	0	4,585	0	1,246	0	2,070
2045	0	4,607	0	1,002	0	2,070
2050	0	4,630	0	712	0	2,226
2055	0	4,630	0	490	0	2,293
2060	0	4,630	0	267	0	2,315
2065	0	4,674	0	67	0	2,359
2070	0	4,696	0	22	0	2,404

Table 3 Projected Agricultural Areas for the Santa Rosa Plain Hydrologic Model area

	Field Crop	Grains	Orchard	Pasture	Truck Crop	Vineyard
2020	40	360	660	1,420	670	13,270
2025	70	360	570	1,410	710	13,360
2030	100	360	490	1,370	750	13,580
2035	130	360	400	1,360	790	13,780
2040	160	360	310	1,340	830	14,020

2045	190	360	220	1,330	870	14,340
2050	220	360	130	1,320	910	14,550
2055	250	360	40	1,250	950	14,850
2060	280	360	0	1,190	990	15,150
2065	310	360	0	1,110	1,030	15,390
2070	340	360	0	870	1,070	15,700

Table 4 Projected Agricultural Areas for the Sonoma Valley Integrated Hydrologic Model area

	Field Crop	Grains	Orchard	Pasture	Truck Crop	Vineyard
2020	947	7,587	11	195	23	14,426
2025	947	7,656	11	189	23	14,844
2030	947	7,725	0	166	23	15,102
2035	947	7,794	0	109	23	15,385
2040	947	7,840	0	63	23	15,650
2045	947	7,897	0	23	23	15,831
2050	947	7,943	0	23	23	15,973
2055	947	8,010	0	23	23	16,111
2060	947	8,079	0	11	23	16,294
2065	947	8,113	0	6	23	16,516
2070	947	8,177	0	0	23	16,664

Table 5 Projected Agricultural Areas for Areas Inside and Outside Subbasin, Petaluma Valley Integrated Hydrologic Flow Model

	Crop Area, Initial Conditions of Future Projections			Crop Area, End of Future Projections		
	Petaluma Valley	**Wilson Grove**	**Total**	**Petaluma Valley**	**Wilson Grove**	**Total**
Grains	4559	0	4559	4692	0	4692
Orchard	66	0	66	0	0	0
Pasture	2090	400	2490	0	22	22
Semi Agricultural	7516	489	8006	7339	489	7828
Urban	10385	3602	13988	10385	3602	13988
Vineyard	2023	0	2023	2401	0	2401

Table 6 Projected Agricultural Areas for Areas Inside and Outside Subbasin, Santa Rosa Plain Integrated Hydrologic Model

	Crop Area, Initial Conditions of Future Projections			Crop Area, End of Future Projections		
	Outside Basin	**Inside Basin**	**Total**	**Outside Basin**	**Inside Basin**	**Total**

Field Crop	0	10	10	190	150	340
Grains	0	360	360	0	360	360
Orchard	440	230	670	0	0	0
Pasture	530	890	1420	430	440	870
Truck Crop	40	590	630	160	910	1070
Turf Grass	190	560	750	190	560	750
Vineyard	3520	9700	13220	4920	10780	15700

Table 7 Projected Agricultural Areas for Areas Inside and Outside Subbasin, Sonoma Valley Integrated Hydrologic Model

	Crop Area, Initial Conditions of Future Projections			Crop Area, End of Future Projections		
	Outside Basin	**Inside Basin**	**Total**	**Outside Basin**	**Inside Basin**	**Total**
Vineyard	5,301	8,672	13,973	6,632	10,032	16,664
Field Crop	0	947	947	0	947	947
Truck Crop	0	23	23	0	23	23
Orchard	11	17	29	0	0	0
Grains	75	7,444	7,518	136	8,041	8,177
Pasture	23	172	195	0	0	0

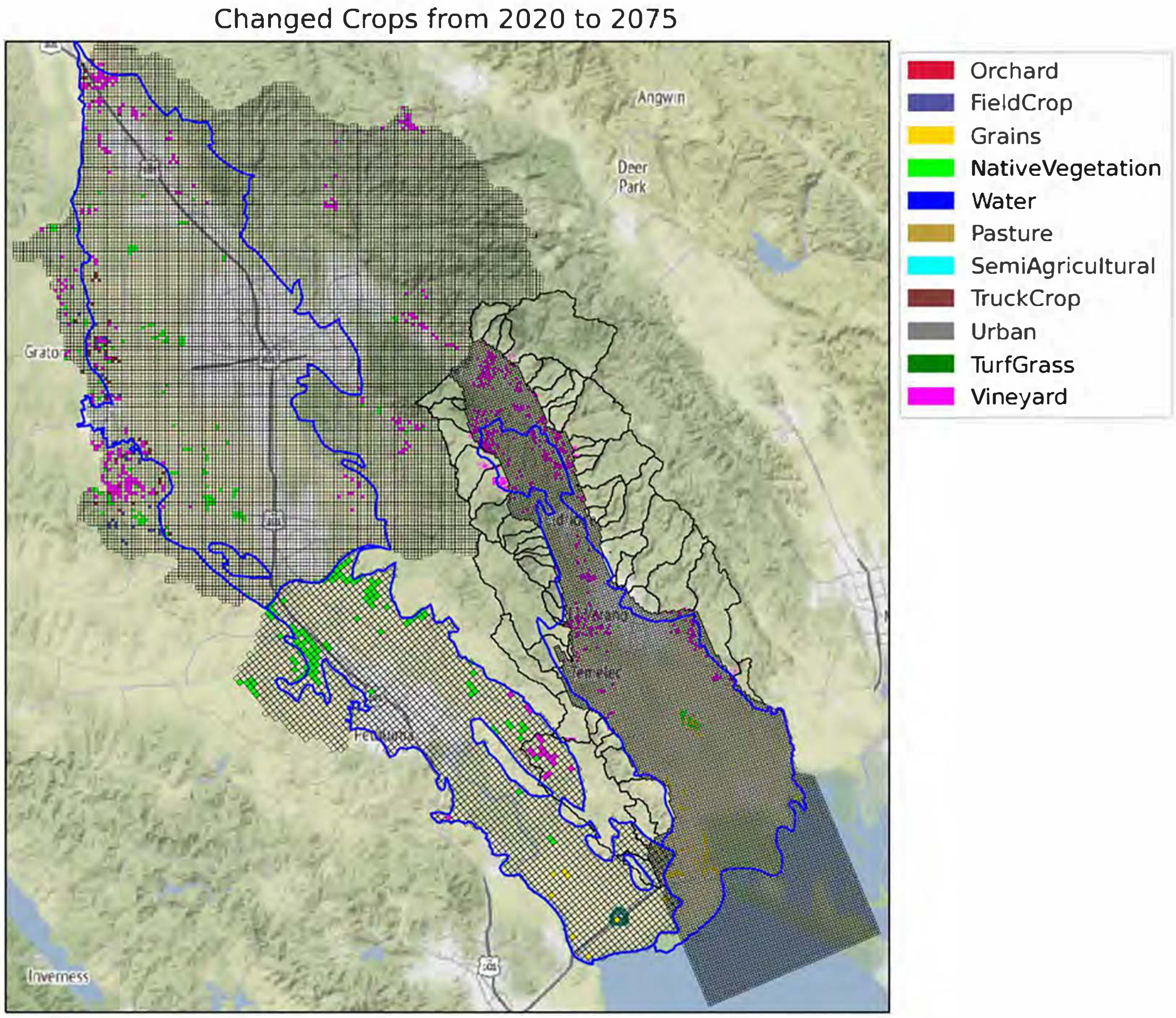


Figure 19 Crop Changes from 2020 to 2075

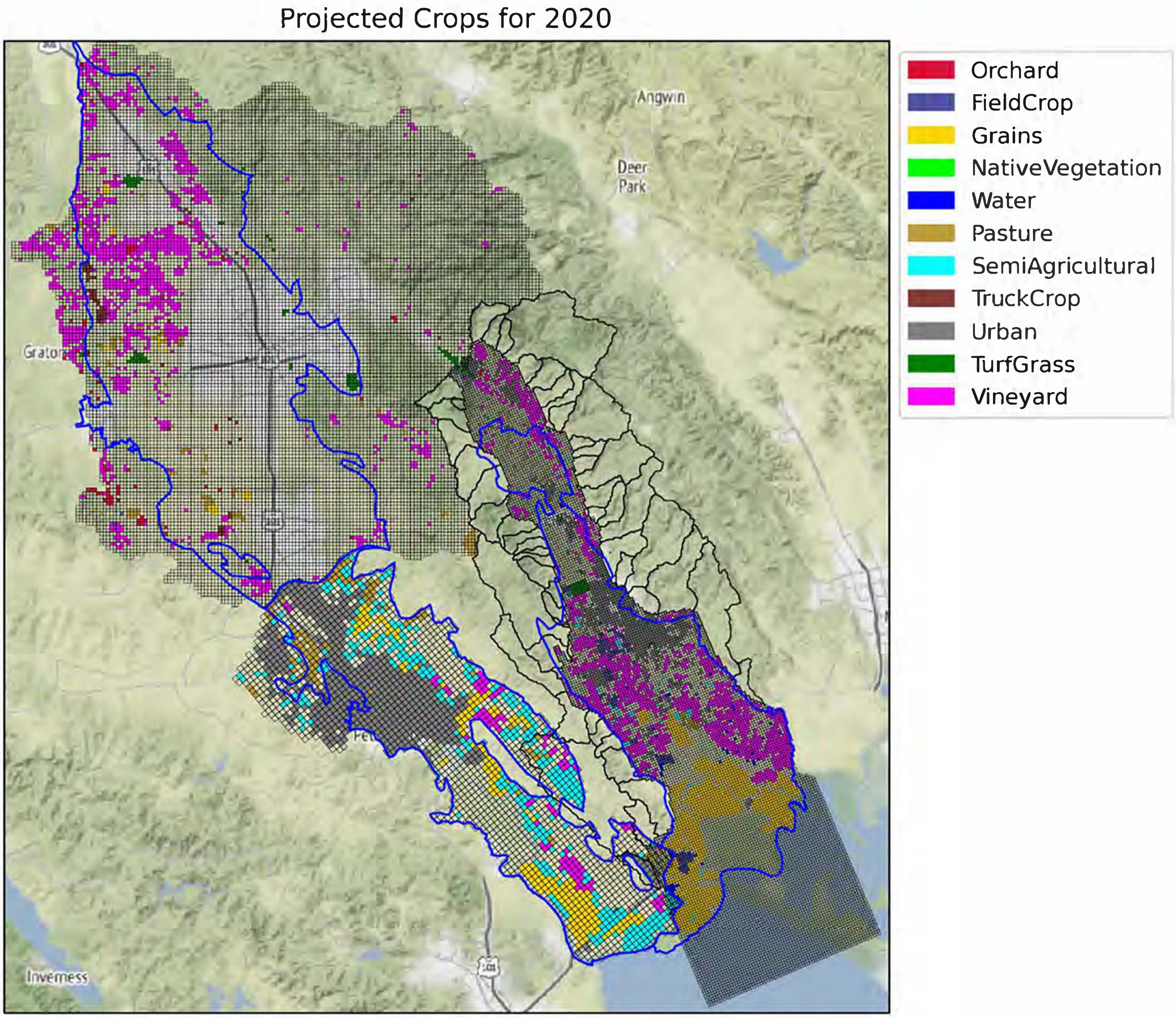


Figure 20 Projected Crops for 2020

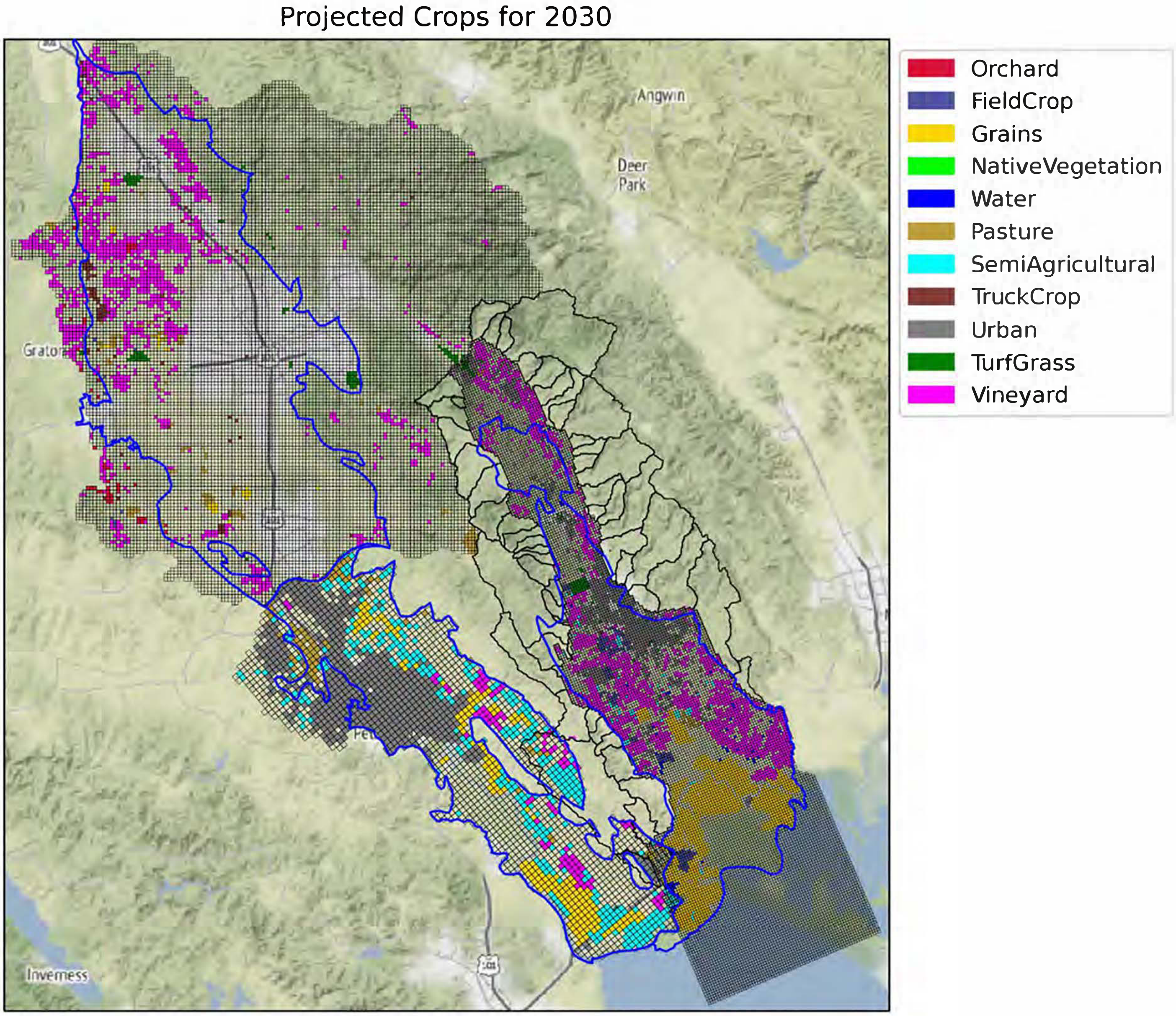


Figure 21 Projected Crops for 2030

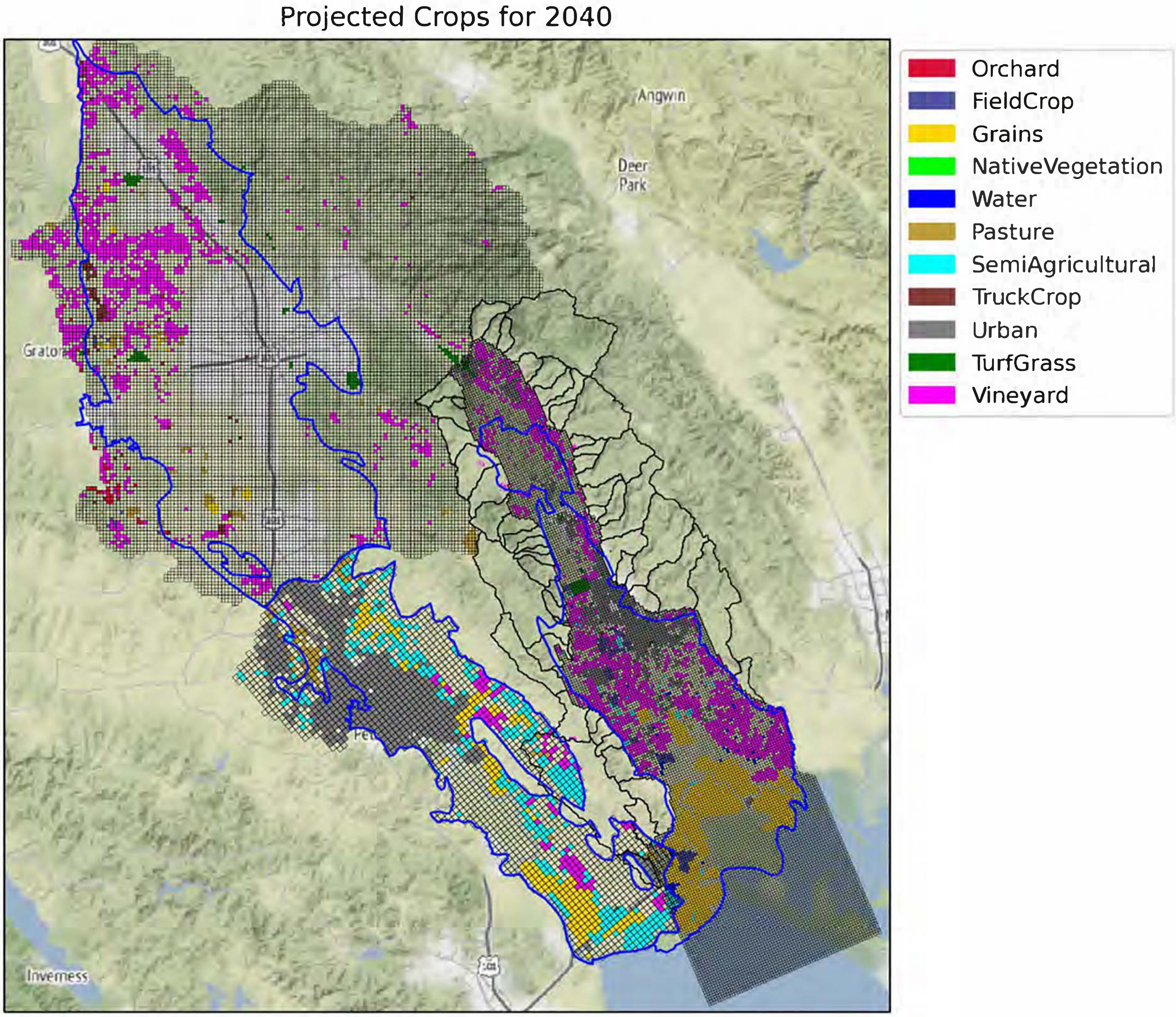


Figure 22 Projected Crops for 2040

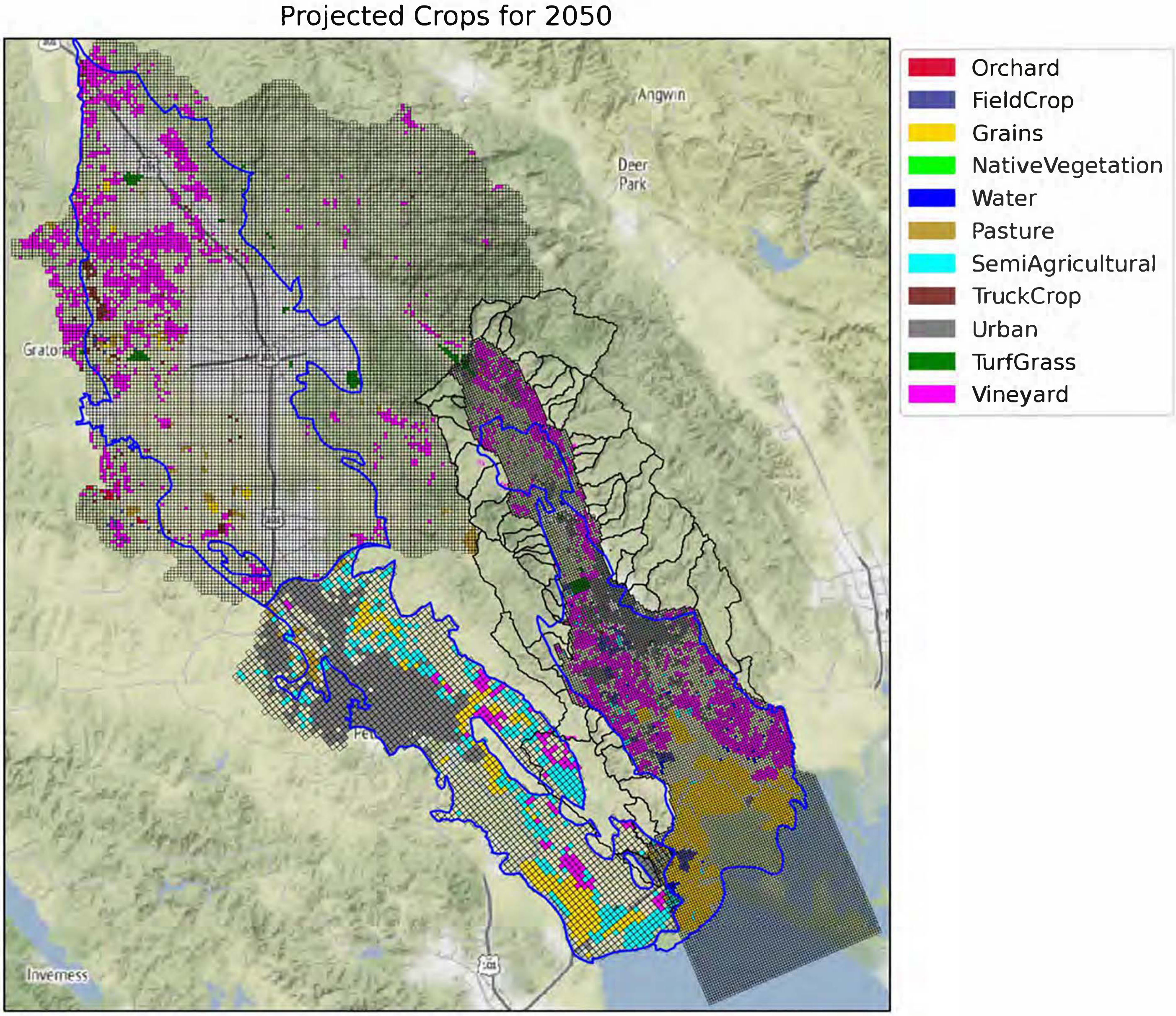


Figure 23 Projected Crops for 2050

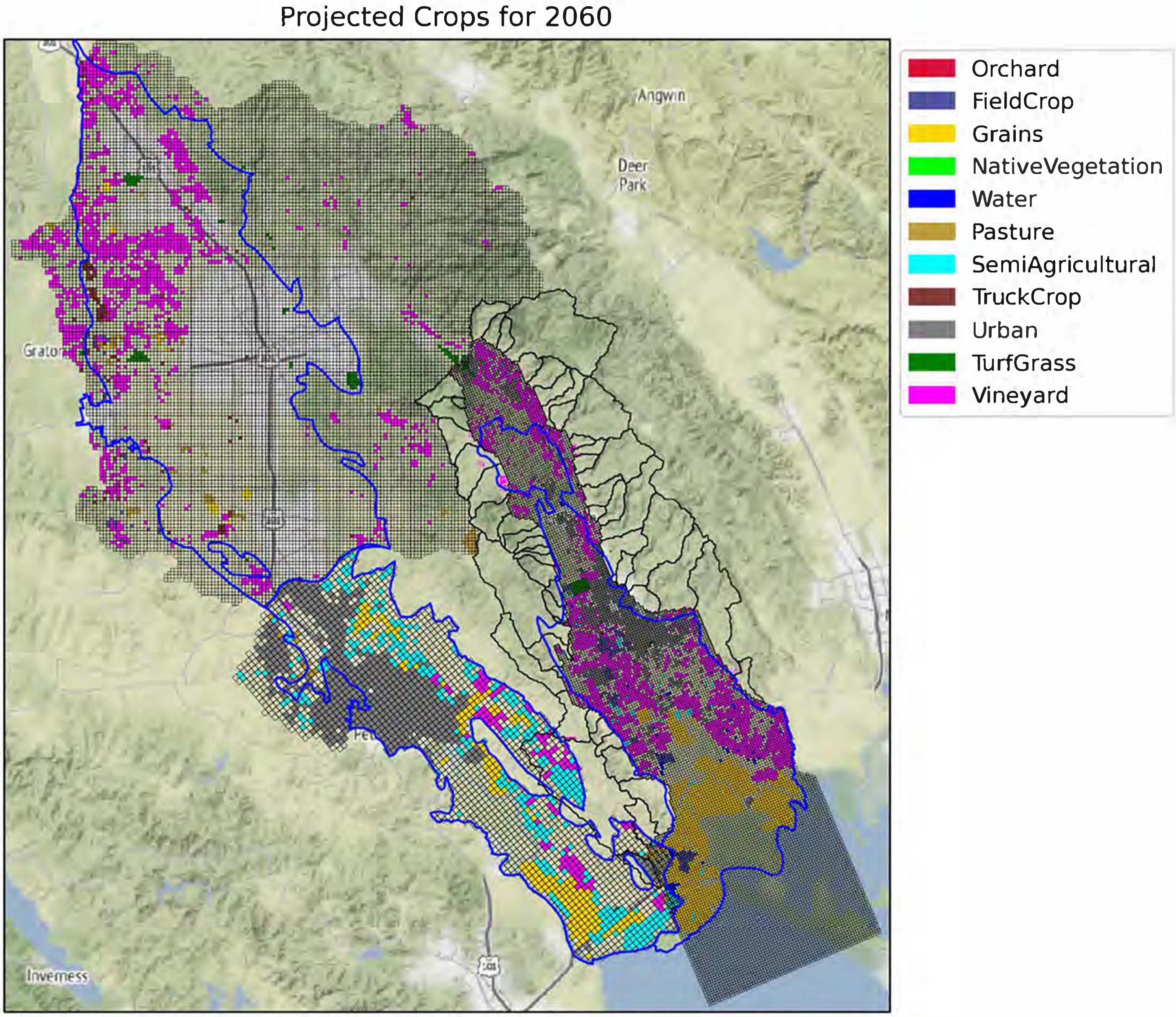


Figure 24 Projected Crops for 2060

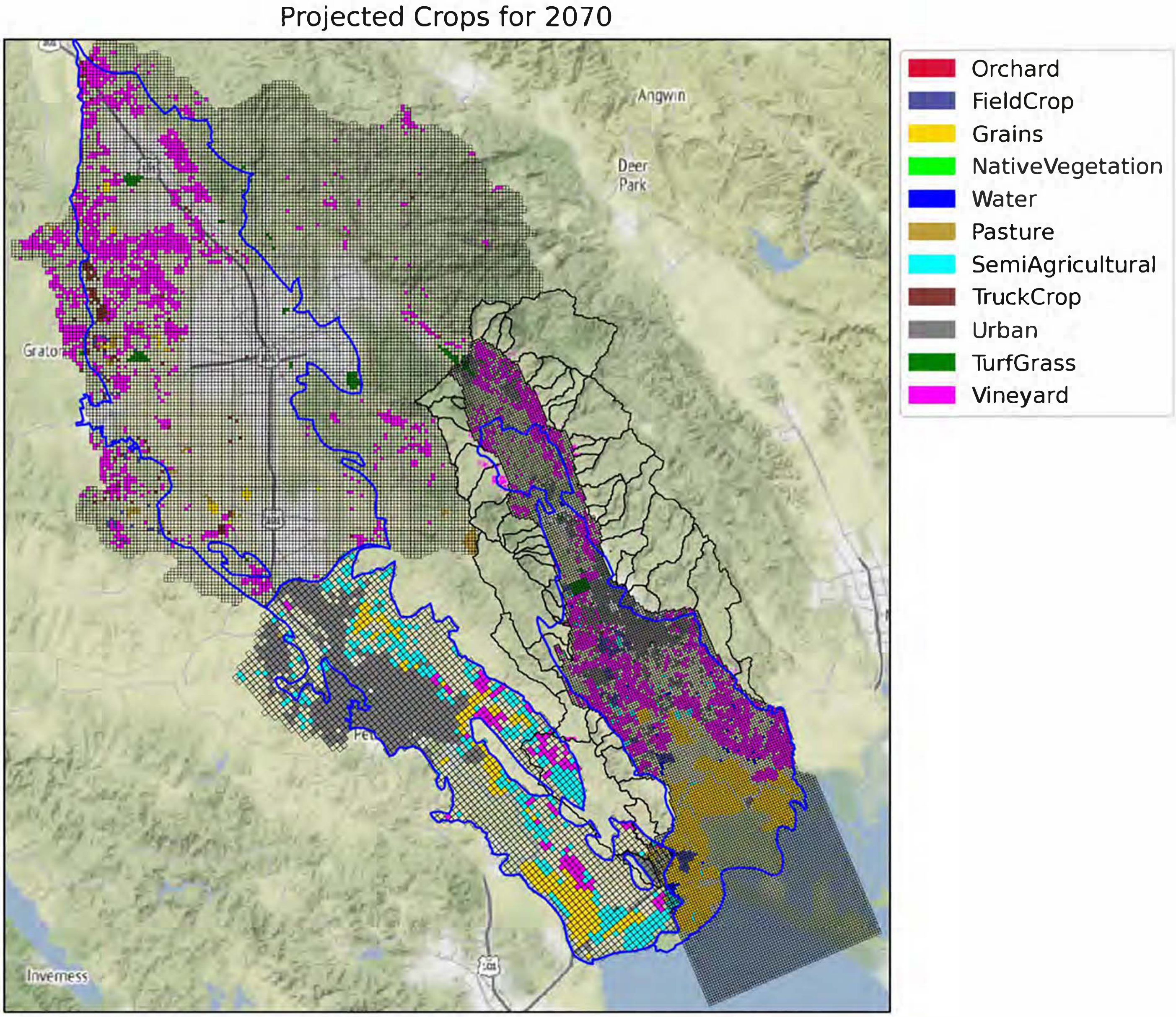


Figure 25 Projected Crops for 2070

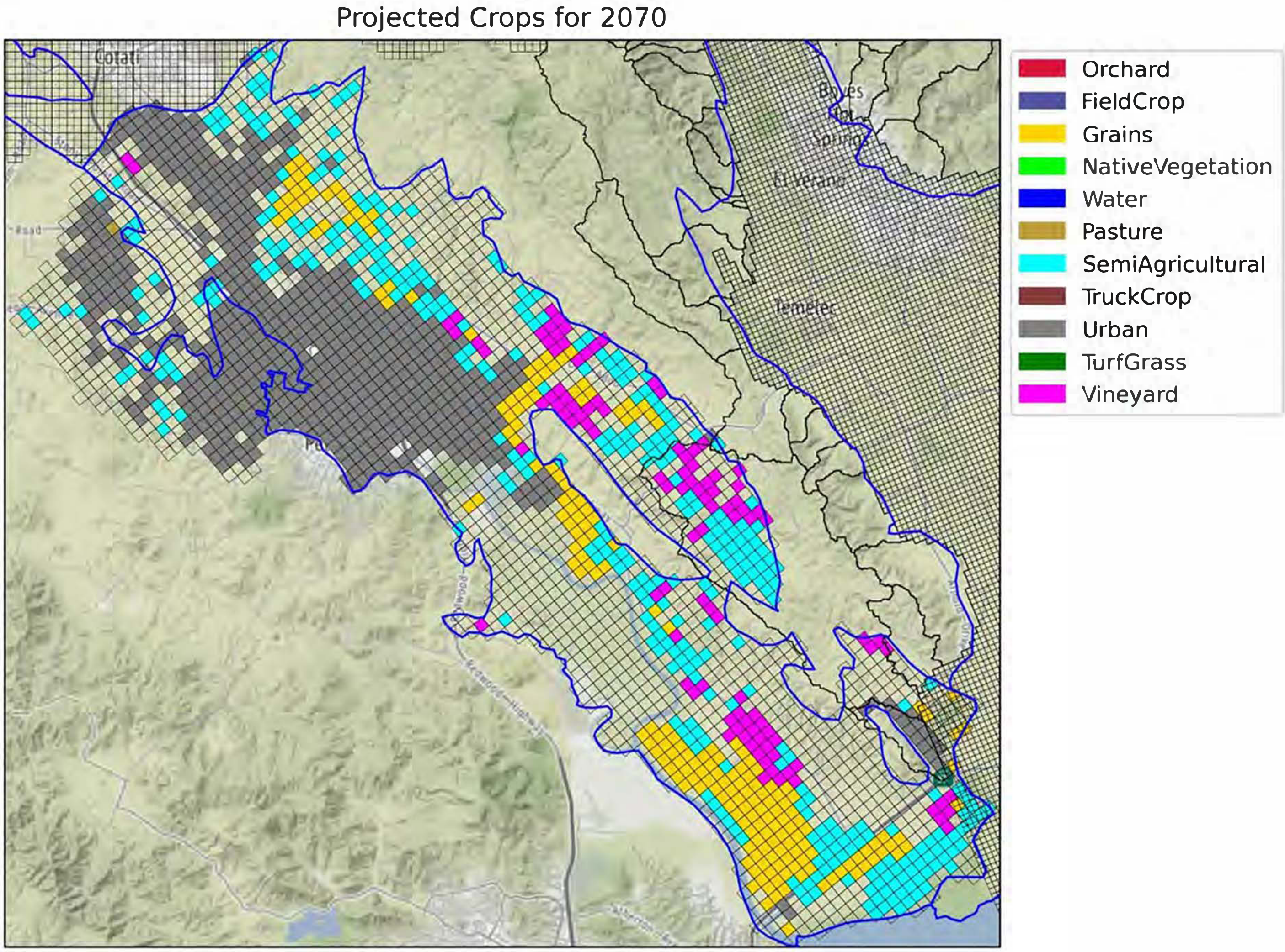


Figure 26 Projected Crops for 2070 for Petaluma Valley

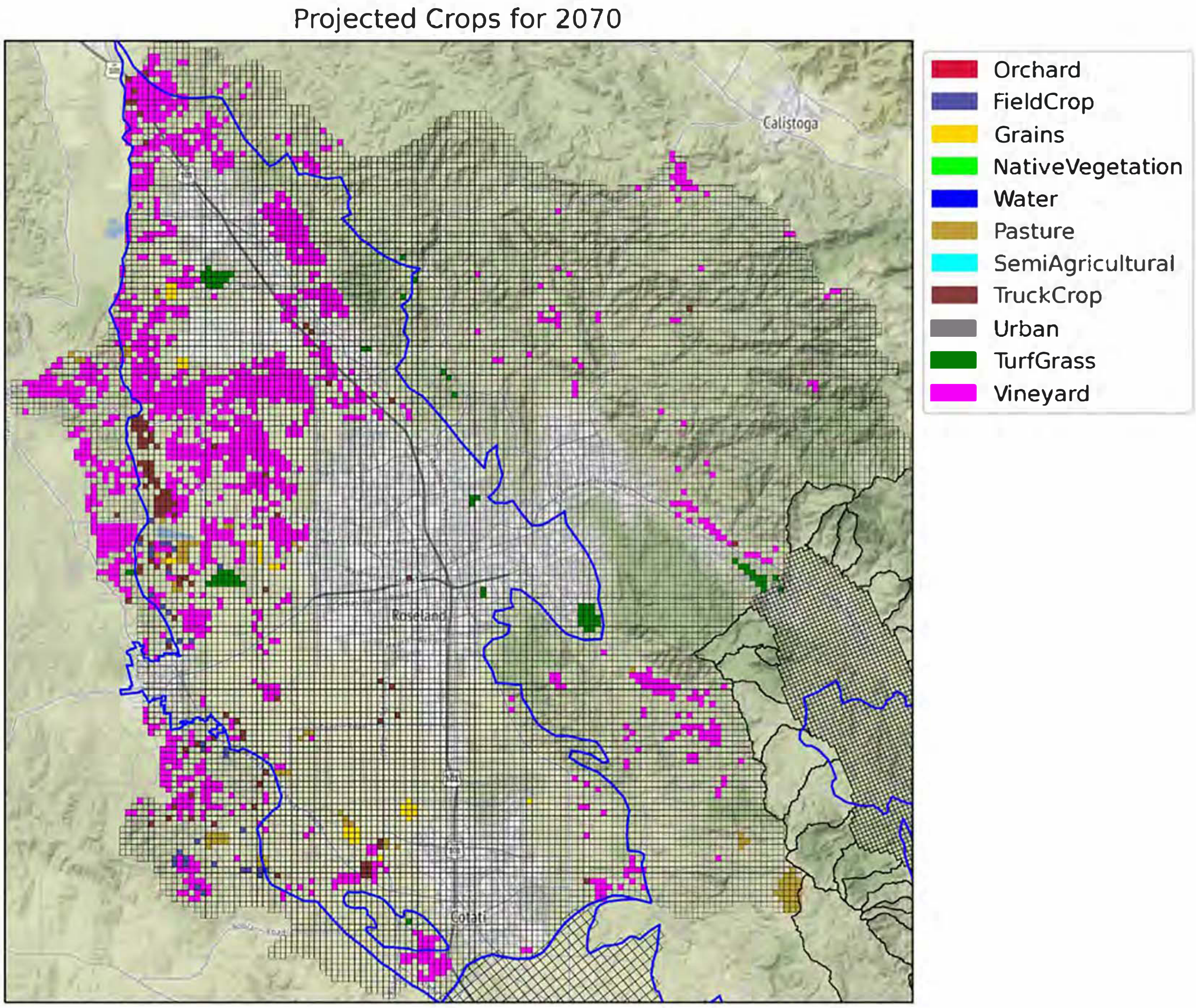


Figure 27 Projected Crops for 2070 for Santa Rosa Plain

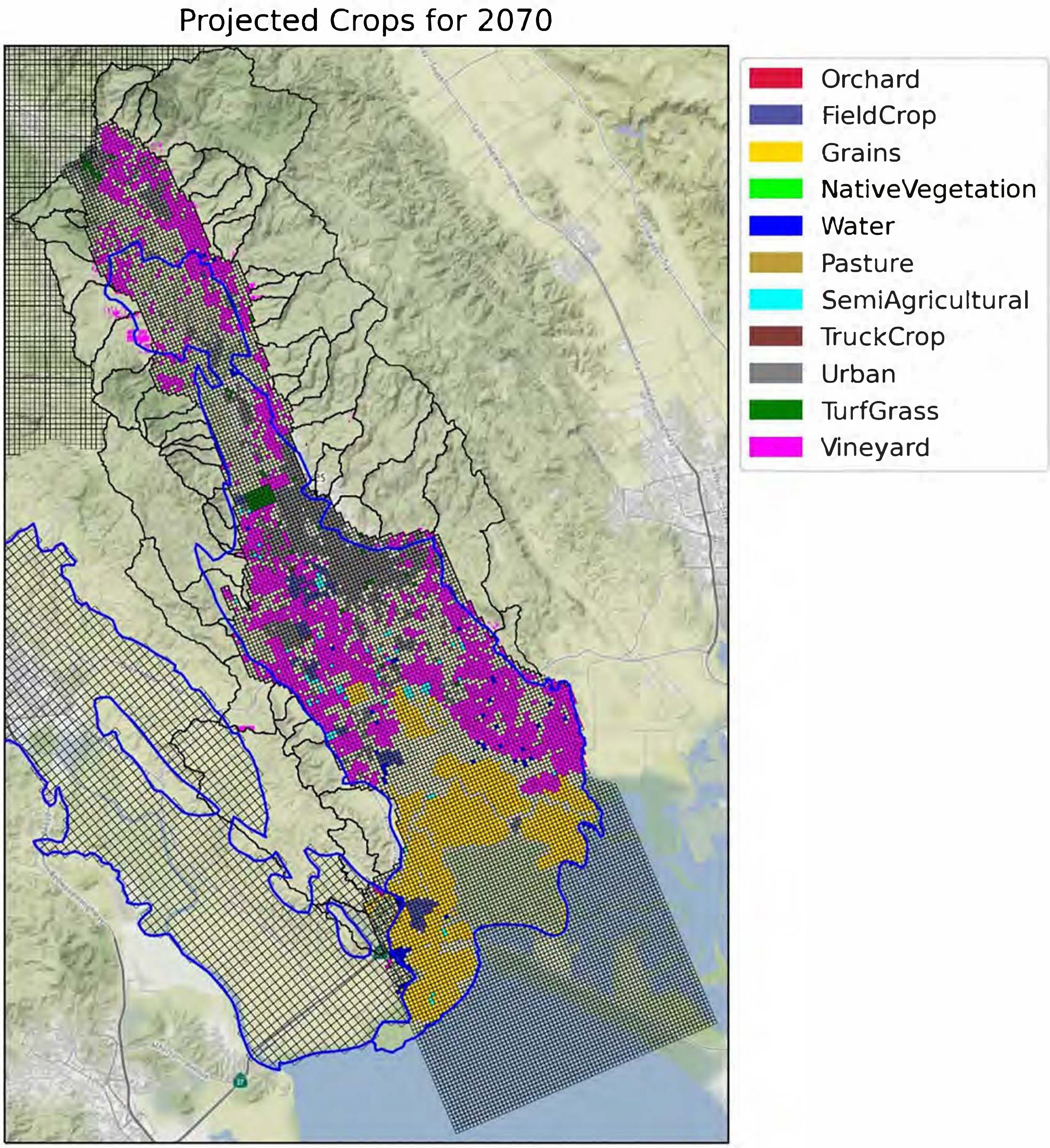


Figure 28 Projected Crops for 2070 for Sonoma Valley

Citations

Boyce, S.E., Hanson, R.T., Ferguson, I., Henson, W., Schmid, W., Reimann, T., Mehl, S.M., 2020, One-Water Hydrologic Flow Model: A MODFLOW Based Conjunctive Use and Integrated Hydrologic Flow Model: U.S. Geological Survey Techniques and Methods 6–A60, v.p.

Hanson, R.T., Boyce, S.E., Schmid, Wolfgang, Hughes, J.D., Mehl, S.M., Leake, S.A., Maddock, Thomas, III, and Niswonger, R.G., 2014, One-Water Hydrologic Flow Model (MODFLOW-OWHM): U.S. Geological Survey Techniques and Methods 6–A51, 120 p., http://dx.doi.org/10.3133/tm6A51.

Heaton E, Merenlender A. 2000. Modeling vineyard expansion, potential habitat fragmentation. Calif Agr 54(3):12-19. https://doi.org/10.3733/ca.v054n03p12.

Niswonger RG (2020) An agricultural water use package for MODFLOW and GSFLOW. Environ Model Softw, 104617

Municipal Water Demand Projections

This memo summarizes the methodology used to develop municipal pumpage projections for use with the required projected water budgets for the three Groundwater Sustainability Plans (GSPs) being developed in Sonoma County. The projections cover the entire 50-year planning horizon in the GSPs (2022 to 2072) and are summarized in the attachment. The municipal pumpers include the following categories:

- Water contractors to Sonoma Water with wells located in the Santa Rosa Plain Subbasin (city of Santa Rosa, Town of Windsor, city of Rohnert Park, city of Cotati), Petaluma Valley Basin (city of Petaluma) and Sonoma Valley Subbasin (city of Sonoma and Valley of the Moon Water District). These water contractors all use groundwater to varying degrees to supplement water deliveries from Sonoma Water (sourced primarily from the Russian River system);
- Sonoma Water which uses groundwater sourced from the Santa Rosa Plain Subbasin as a backup and supplement to its primary source of water from the Russian River system;
- California-American Water – Larkfield Wikiup District (Cal-am) which primarily uses groundwater sourced from the Santa Rosa Plain Subbasin and supplements with water deliveries from Sonoma Water; and
- City of Sebastopol, which is entirely reliant on groundwater pumped from the Santa Rosa Plain Subbasin.

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 the projections were maximum and minimum pumpage estimates for 2022-2072 that were supplied by Sonoma Water and its water contractors. While the ranges of future pumping estimates are generally inclusive of projections currently being developed for 2020 Urban Water Management Plans (UWMP) by each purveyor, in order to account for the significant uncertainty in the future projections and provide for a conservative estimate for the GSP projections, the maximum estimates generally assume higher levels of pumping in comparison with the UWMP projections. In addition, historical pumpage data (2003-19) supplied by municipal pumpers and future climate definitions generated by Sonoma Water were used to develop the projections for Sonoma Water and its water contractors which utilize groundwater as a supplemental or backup source of supply.

For Sonoma Water and its water contractors, the municipal pumpage projections were developed using the following steps:

1. Compile:
    a. historical monthly pumpage for water years (WY) 2003-2019;
    b. estimated future maximum and minimum annual pumpage estimates from Sonoma Water and its contractors for WY2022-2072 (table 1);

    c. and future climate definitions (table 2) developed by Sonoma Water. The future climate definitions are: very wet, wet, normal, dry, and very dry.
2. Calculate:
    a. statistics of historical pumpage including standard deviation (table 3)
    b. and median of future maximum and minimum annual pumpage.
3. Assign future annual pumpage based on future projected climate conditions and water year types with the maximum and minimum estimates from table 1 generally applied to very dry and very wet future periods, respectively. For dry, normal and wet periods, vary the annual pumping within the estimated maximum and minimum ranges using variations of the calculated standard deviations for each purveyor shown on table 3 to reflect higher pumping in drier periods and lower levels of pumping in wetter periods.

There were exceptions to the algorithm as applied to Santa Rosa, Rohnert Park, Cotati, and Sonoma Water. Santa Rosa did not pump groundwater in calendar year (CY) 2018 resulting in the pumpage in WY2018 and 2019 being low. Therefore, the data for WY2018 and 2019 were not used to calculate the standard deviation for the Santa Rosa pumpage data.

Rohnert Park reported that the city would pump 2,577 acre-ft/yr from WY2022-72. In order to apply the algorithm to Rohnert Park, the historical data were used for the maximum, minimum, median, and standard deviation. In addition, Rohnert Park pumped larger volume of groundwater in WY2003 (4,155 acre-ft), which is not representative of the city's more recent annual pumpage; therefore, data for WY2004-19 were used.

Cotati reported a maximum estimated pumpage of 322 acre-ft/yr. This rate is much less than the WY2003-19 maximum rate of 513 acre-ft/yr; therefore, a maximum rate of 513 acre-ft/yr was assigned.

Sonoma Water's strategy in use of groundwater has changed beginning in Water Year 2010 when its wells in the Subbasin were shifted to serve as supplemental and backup supplies resulting in significantly lower groundwater pumping during the current water budget period of 2012 through 2018 in comparison with the previous time period. Therefore, data for WY2012-18 were used for Sonoma Water.

City	Year	Minimum (afy)	Maximum (afy)
Santa Rosa	2020-2025	1300	3500
Windsor	2020-2025	25	400
	2026-2072	50	750
Rohnert Park*	2022-2072	340	2330
Cotati**	2022-2072	90	513
Petaluma	2020-2025	0	300
	2026-2072	0	600
Sonoma	2022-2072	50	238
Valley of the Moon	2020-2032	100	500
	2033-2052	100	750
	2053-2072	100	1000
Sonoma Water	2022-2072	0	1272

Table 1. Estimated future minimum and maximum projected pumpage rates, except where noted.
(* based on 2003-19 Rohnert Park pumpage and **used historic maximum rate)

Water year	Very Dry	Dry	Normal	Wet	Very Wet
2019	1	0	0	0	0
2020	1	0	0	0	0
2021	1	0	0	0	0
2022	1	0	0	0	0
2023	0	0	1	0	0
2024	0	0	0	1	0
2025	0	0	0	1	0
2026	0	0	1	0	0
2027	0	0	1	0	0
2028	0	1	0	0	0
2029	0	0	1	0	0
2030	0	0	0	1	0
2031	0	0	1	0	0
2032	0	0	1	0	0
2033	0	0	1	0	0
2034	0	0	1	0	0
2035	0	0	0	1	0
2036	0	0	0	0	1
2037	0	0	0	1	0
2038	0	0	0	1	0
2039	0	0	1	0	0
2040	0	0	1	0	0
2041	0	0	1	0	0
2042	0	0	1	0	0
2043	1	0	0	0	0
2044	0	0	1	0	0
2045	0	0	0	1	0
2046	0	0	0	1	0
2047	0	0	1	0	0
2048	0	0	1	0	0
2049	0	0	1	0	0
2050	0	0	0	1	0
2051	0	0	1	0	0
2052	0	0	1	0	0
2053	0	1	0	0	0
2054	0	1	0	0	0
2055	0	1	0	0	0
2056	0	1	0	0	0
2057	0	1	0	0	0
2058	0	0	1	0	0

2059	0	0	1	0	0
2060	0	1	0	0	0
2061	0	1	0	0	0
2062	0	1	0	0	0
2063	0	1	0	0	0
2064	0	1	0	0	0
2065	0	0	1	0	0
2066	0	0	1	0	0
2067	0	1	0	0	0
2068	0	0	1	0	0
2069	0	1	0	0	0
2070	0	1	0	0	0
2071	0	0	1	0	0
2072	0	0	1	0	0
2073	1	0	0	0	0

Table 2. Future climate definitions as defined by Sonoma Water.

City	Mean	Standard Deviation	Minimum	25% quartile	Median	75% quartile	Maximum
Santa Rosa*	827.26	588.53	0.00	234.65	1125.76	1252.43	1638.29
Windsor**	89.29	70.82	29.92	45.33	68.95	112.91	189.34
Rohnert Park***	1356.68	557.99	338.88	880.94	1314.40	1764.26	2327.27
Cotati	285.93	121.66	53.42	258.06	298.53	363.86	513.08
Petaluma	290.27	346.55	0.00	0.00	156.12	383.99	1137.70
Sonoma	116.91	69.56	21.90	70.00	86.59	164.30	247.81
Valley of the Moon	480.59	88.35	343.86	410.95	480.84	534.40	668.74
Sonoma Water	453	499.0	2	27.15	208.00	829.13	1272

Table 3. Statistics of historic WY2003-19 pumpage data by city except where noted. (*used WY2003-17 data for Santa Rosa, **used WY2003-06 data for Windsor, ***used WY2004-19 data for Rohnert Park, ****used 2012-2018 data for Sonoma Water)

Future groundwater pumpage for CalAm and Sebastopol were assumed to increase annually without variations based on projected water year types, as both pumpers use groundwater as a primary source of supply and have less flexibility to conjunctively use both surface water and groundwater for water supply, (i.e., future groundwater demand is anticipated to be more influenced by future growth).

CalAm pumpage was assumed to increase 0.5% annually from the WY2019 pumpage of 637 acre-ft based on consultation with CalAm staff. The value of 0.5% was selected based on the medium range estimate of future growth developed for the rural residential projections. The growth was assumed as a straight-line increase in demand for the 5-year period, resulting in a 2072 projected pumpage of 826 acre-feet.

For the city of Sebastopol, the following methodology was developed in consultation with city of Sebastopol planning department staff:

1. For 2035, the stated assumptions on page 3.14-15 of the City of Sebastopol Draft EIR for its General Plan Update for buildout within the City limits were used:
    a. 1,324 acre-feet per year (AFY) based on projected 2035 population of 9,165 x 129 gallons per capita per day (gpcd)x 365 days
    b. Assume a straight-line increase from the City's average recent baseline pumping of 1,000 AFY in 2020 to 1,320 in 2035
2. For 2035 – 2072, given far greater uncertainty in growth during this period an annual projected growth of 0.5% (medium value assumed for rural residential growth projections) was applied and yielded:
    a. A 2072 projected population of ~10,860 (increase of 1,695 over the 37-year period between 2035 and 2072)
    b. A 2072 demand of 1,570 AFY by applying the same 129 gpcd assumptions as above

Sebastopol pumpage was assumed to increase linearly between WY2019 and 2035 and between WY2035 and 2073.

.

Appendix 3-E
Sonoma Water Climate Scenario Assessment for Groundwater Sustainability Planning

Sonoma Water Climate Scenario Assessment for Groundwater Sustainability Planning

Technical Assessment of Climate Scenarios for Sonoma Water Groundwater Sustainability Planning

February 24, 2020

Sonoma Water

Contents

1. Introduction

Sonoma Water is utilizing climate information for a number of regional water planning, sustainability, and resiliency efforts. As part of regional efforts to develop Groundwater Sustainability Plans (GSPs), future climate information is required to assess the sustainability of groundwater management over conditions that may be different than historical climate. This technical memorandum provides information on an evaluation of twenty individual climate model projections of simulated key metrics related to regional climate and hydrology that can be used to support identification of a subset of scenarios for use in water planning efforts. Figure 1 shows Russian River watershed and the 3 Groundwater sub-basins.

Figure 1. Russian River Hydrologic Basin and Santa Rosa Valley, Petaluma Valley, and Napa-Sonoma Groundwater Sub-Basins

2. Approach and Methods

Over the past several decades, air temperatures have increased globally and throughout the western United States, including California. While the Sonoma County region is complex with several microclimates, historical patterns of warming have occurred in near all monitoring stations in the region (Erkstrom and Moser 2012). Precipitation over most of California, including the Sonoma County region, is dominated by extreme variability, both seasonally, annually, and over decadal time scales.

Projections of future climate conditions are generally performed through general circulation models (GCMs) forced with specific global greenhouse gas (GHG) emission scenarios (IPCC 2013). The projections included in this summary rely upon available climate projections using the models and emissions scenarios included in the Coupled Model Intercomparison Project 5 (CMIP5). Twenty individual downscaled GCM projections were selected from ten different GCMs and two different Representative Concentration Pathways (RCPs), RCP4.5 and RCP8.5. The ten GCMs were chosen by the DWR Climate Change Technical Advisory Group (CCTAG) based on a regional evaluation of climate model ability to reproduce a range of historical climate conditions (DWR CCTAG, 2015). The 20 climate projections were downscaled using a statistical downscaling method called LOCA at 1/16th degree (~6 km) (~3.75 miles) spatial resolution by Scripps Institution of Oceanography (Pierce et al., 2014) and subsequently further downscaled to a 270-meter resolution by the USGS as part of the Basin Characterization Model (BCM) data set. These data form the basis for this assessment.

As part of California's Fourth Climate Change Assessment, four of the GCMs were identified as "cool/wet", "middle", "warm/dry", and "diversity" based on an evaluation of climate metrics for northern California coast region (Pierce et al. 2018). The individual GCMs, RCPs, and Fourth Climate Change Assessment identifiers are shown in Table 1.

Table 1. GCMs Selected by DWR CCTAG and Used in this Assessment

GCM	RCP 4.5	RCP 8.5	CA Fourth Climate Change Assessment "Northern CA Coast" Identifier
ACCESS1-0	X	X	
CCSM4	X	X	
CESM1-BGC	X	X	
HadGEM2-CC	X	X	
CMCC-CMS	X	X	
CNRM-CM5	X	X	Cool/Wet
CanESM2	X	X	Middle
GFDL-CM3	X	X	
HadGEM2-ES	X	X	Warm/Dry
MIROC5	X	X	Diversity

Since modeling efforts for the Sonoma GSPs may not be able to support the characterization of groundwater basin outcomes based on all 20 projections, a subset of climate projections may be needed to provide a representation of the future climate conditions. Two possible approaches are recommended: (1) selection of an individual climate projection such as HadGEM2-ES to represent a scenario of future climate or (2) use of a sub-ensemble of projections to map projected changes in temperature and precipitation to an underlying historical time series. The individual projection approach has advantages in that it will present one outcome of the climate model projections and will contain internally-consistent variability and change. Dry and wet periods (seasonal, annual, and inter-annual) of differing durations and severity can be explored. The second approach is termed an ensemble-informed process and adjusts historical time series to reflect the projected changes associated with the sub-ensemble. The ensemble-informed process is included in the climate change data documented in Guidance Document for the Sustainable Management of Groundwater by California Department of Water Resources (CA DWR, 2018). This process provides a stable depiction of the central tendency of the ensemble of climate models and is capable of capturing seasonal and annual changes, but significant changes in interannual variability are not captured due to its reliance on an underlying historical time series. This technical report focuses on the evaluation of individual climate projections.

In addition, for GSP planning purposes, it is desirable to identify projected climate scenarios that more specifically represent the climate and hydrologic conditions within the Russian River watershed and Sonoma County. Based on the discussions with regional water managers, we have identified five major climate, hydrologic, and water supply metrics that could support assessment of specific climate scenarios. These metrics are listed below:

- Mean change in annual temperature and precipitation
- Mean annual Russian River streamflow
- 1- and 3-yr Russian River streamflow variability
- Lake Sonoma annual minimum reservoir storage conditions
- Sonoma Water delivery capability

For each future climate projection, each of the resulting metrics was assessed. Climate information was averaged for the Russian River watershed area. Naturalized streamflow was derived from BCM simulations and subsequently corrected for historical biases. Reservoir and water delivery outcomes were derived from HEC-ResSim simulations using the future climate and naturalized streamflow inputs.

Climate projection outcomes were assessed for two future periods. In order to capture variability in precipitation and streamflow a period of sufficient length was required. For this assessment, the mid-century period is defined as the period of 2006-2060 and late century is the period of 2045-2099 and results are compared to the historical period of 1951-2005. Each of these periods includes 55-years of variability, and the historical period represents the same period for which BCM streamflow results were bias-corrected. For climate information (temperature and precipitation change), we also present changes for shorter 30-year periods in addition to the longer 55-year periods for comparison. These additional periods are 2035-2065 for mid-century and 2070-2099 for late century compared to the historical period of 1976-2005 and are those presented in Pierce et al. (2018), a report prepared for the California Fourth Climate Change Assessment.

3. Results

The sections that follow present the results for projected changes in precipitation, temperature, streamflow, storage, and Sonoma Water diversion for mid-century conditions.

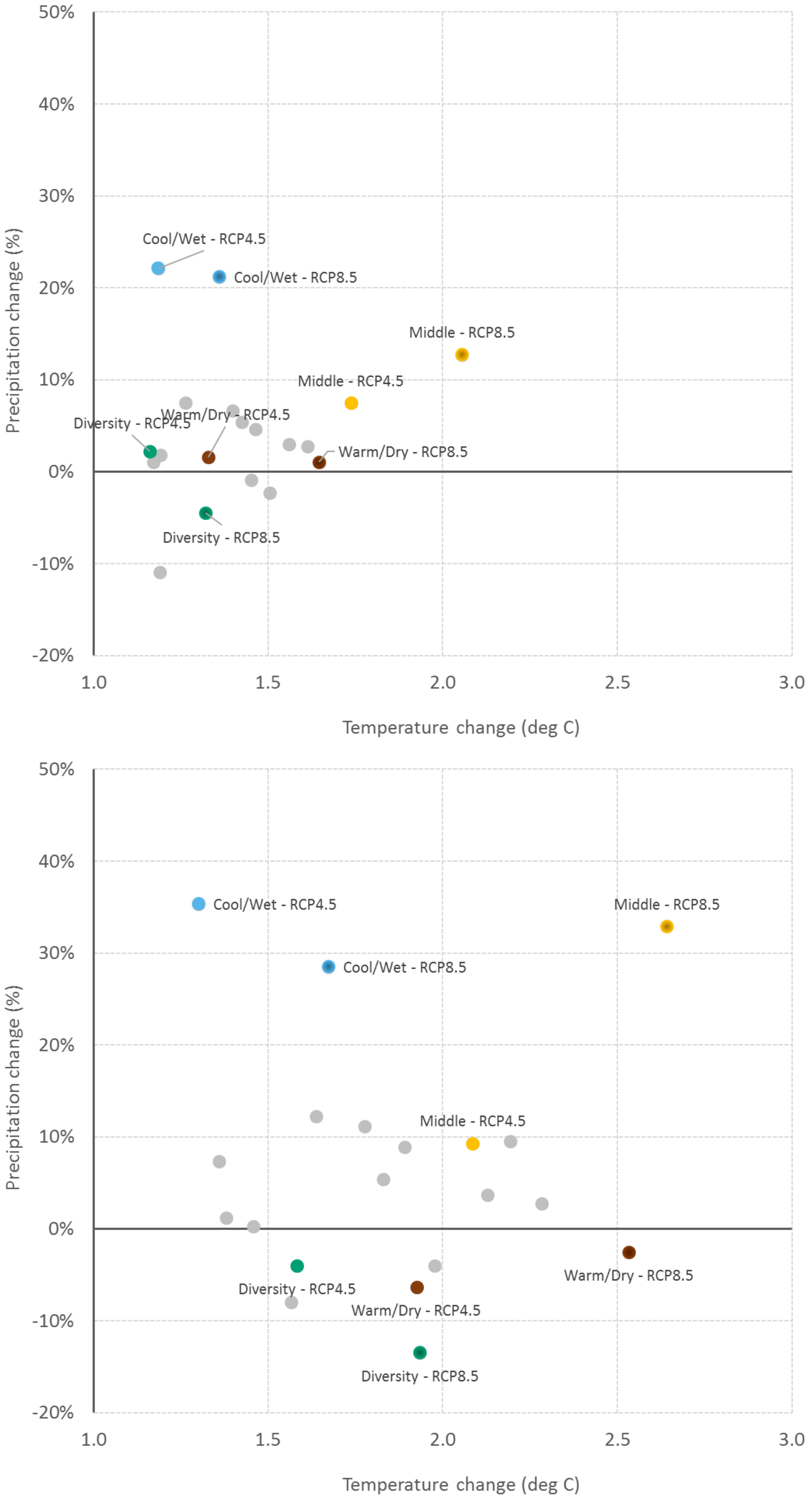
3.1 Projected Changes in Precipitation and Temperature

Figure 2 shows the temperature and precipitation changes projected by ten different GCMs for both RCP 4.5 and 8.5 scenarios for mid-century. The GCMs with a “Northern CA Coast” identifiers are colored and labeled with other GCMs shown in grey. The top panel shows the changes using the 55-year period of 2006-2060, while the bottom panel shows the changes for the 30-year period of 2035-2065. All models project temperature to increase between 1.2 and 2.6 degree Celsius. HadGEM2-ES (Warm/Dry model) and CanESM2 (Middle model) project the highest temperature increase, while CNRM-CM5 (Cool/Wet model) projects the lowest increase with about 1.2 degree Celsius among all model projections. In addition, most of the model projections (16 out of 20) suggest a slightly wetter future for the region. CNRM-CM5 and CanESM2 show the largest increases among all model projections. On the other hand, MIROC5 (Diversity model) suggests reduction in precipitation by mid-century.

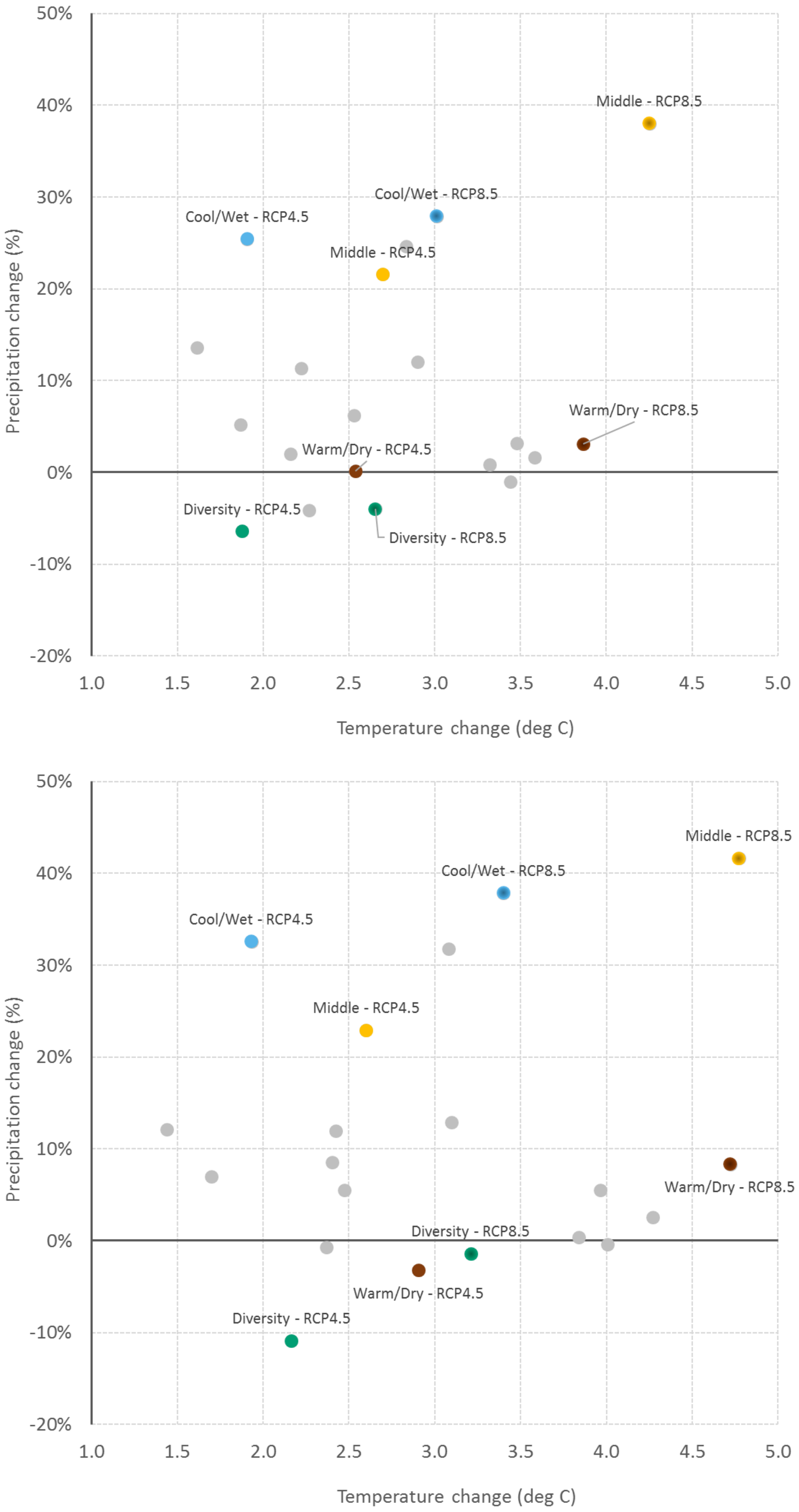
Figure 3 shows the same information for late century. The top panel shows the changes using the 55-year period of 2045-2099, while the bottom panel shows the changes for the 30-year period of 2070-2099. All models project temperature to increase between 1.4 and 4.7 degree Celsius. HadGEM2-ES (Warm/Dry model) and CanESM2 (Middle model) project the highest temperature increase, while CNRM-CM5 (Cool/Wet model) projects the lowest increase. In addition, most of the model projections suggest a wetter future for the region. CNRM-CM5 and CanESM2 show larger increases among all model projections. On the other hand, MIROC5 (Diversity model) suggests reductions in precipitation starting in mid-century and becoming more pronounced by late-century.

Based on this assessment, the CanESM2 model, which was labeled as “middle” in DWR’s Fourth Climate Change Assessment, can only be considered as “warm/wet” for the Russian River domain. The “warm/dry” HadGEM2-ES model tends more to the middle, and the “diversity” MIROC5 continues to be the driest model. The CNRM-CM5 model appears consistent with “cool/wet” identifier.

Figure 2. Projected Changes in Mean Annual Temperature and Precipitation (top panel: 2006-2060 and lower panel: 2035-2065)



igure 3. Projected Changes in Mean Annual Temperature and Precipitation (top panel: 2045-2099 and lower panel: 2070-2099)



3.2 Projected Changes in Annual Streamflow

Figure 4 shows the annual natural streamflow exceedance probability curves for historical and future scenarios at the Russian River downstream of the Dry Creek confluence for the period of 2006-2060. The results indicate the potential for streamflow reductions, particularly during the drier years (lower percentiles) and potential increases during wetter years (higher percentiles). The “cool/wet” and “middle” projections show much higher increases in streamflow increases than the “diversity” and “warm/dry” projections. It appears that the so-called “warm/dry” projections fall more towards the center of the ensemble of results and produce wetter wet years and drier dry years as compared to the historical distribution.

Figure 5 shows the annual natural streamflow exceedance probability curves for historical and future scenarios at the Russian River downstream of the Dry Creek confluence for the period of 2045-2099. Under this later future period, the differences between scenarios is magnified but shows similar relative ordering as the earlier period. The so-called “middle” projections exhibit the greatest change in streamflow, while the “warm/dry” once again tends toward the actual middle of the distribution.

Figure 4. Projected Changes in Annual Russian River Streamflow for Period of 2006-2060.

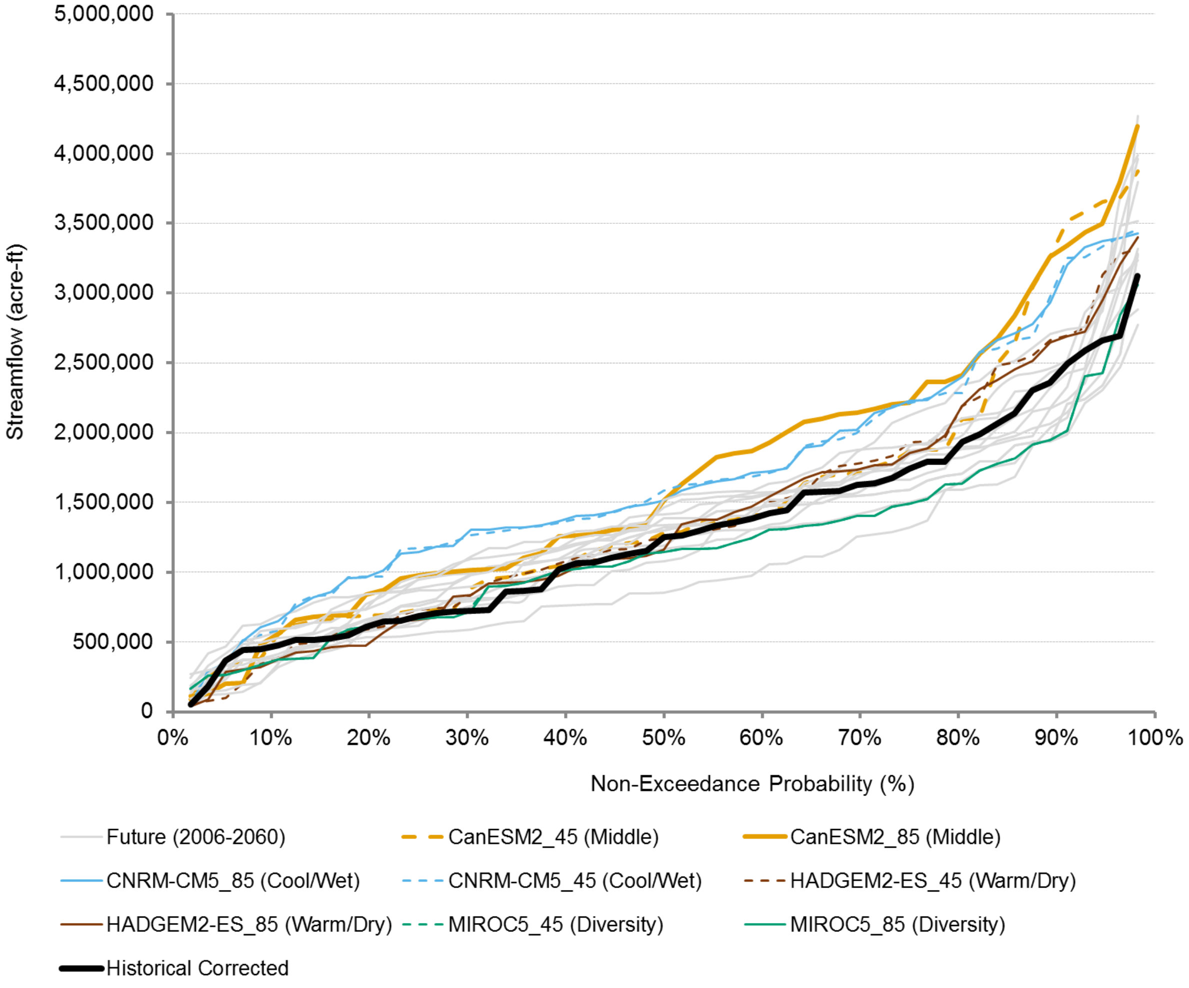
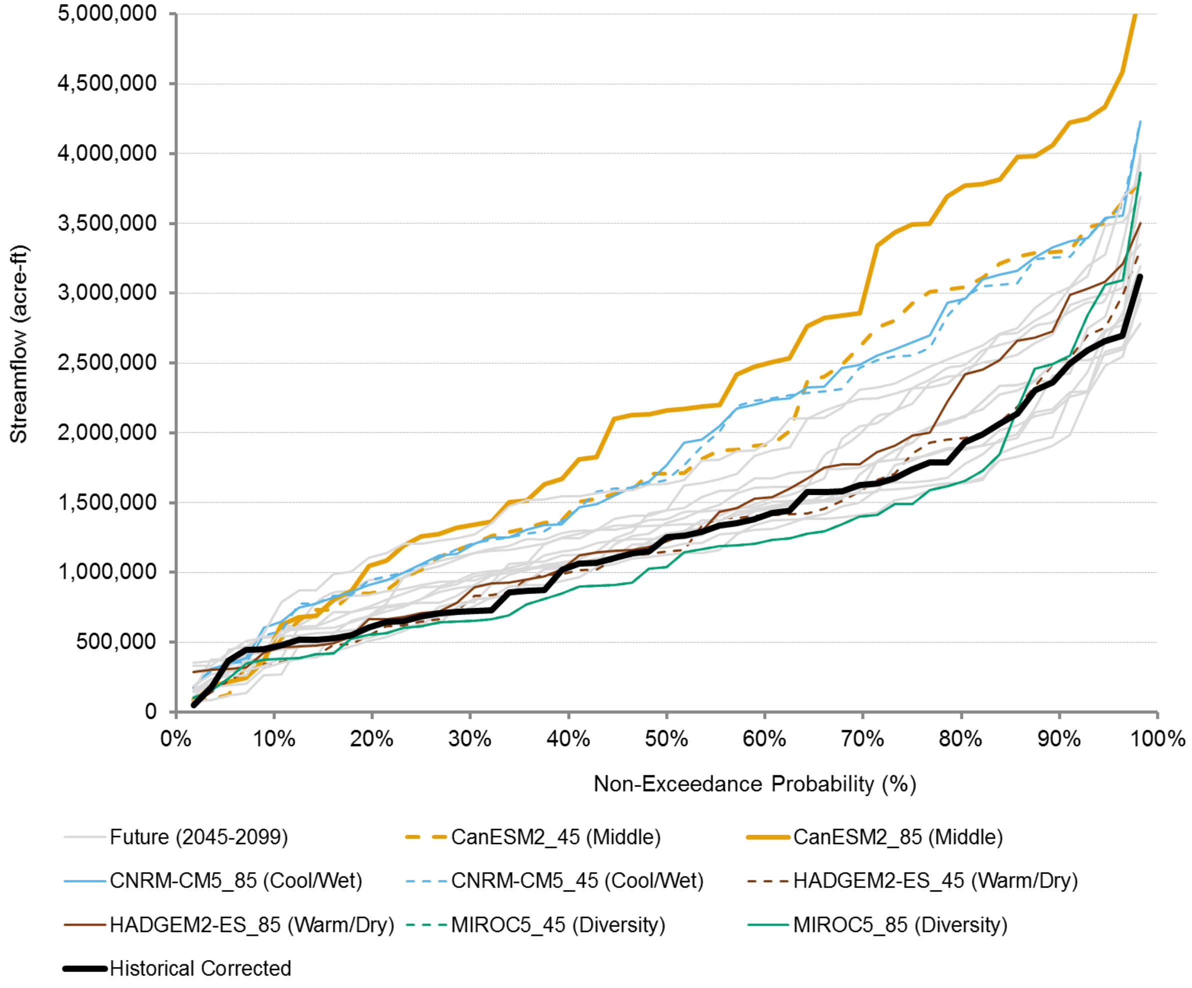


Figure 5. Projected Changes in Annual Russian River Streamflow for Period of 2045-2099.



3.3 Projected Changes in 3-Year Annual Streamflow

Figure 6 shows the 3-year annual natural streamflow exceedance probability curves for historical and future scenarios at the Russian River downstream of the Dry Creek confluence for the period of 2006-2060. The results indicate an expansion in variability for the moderate to wet periods but only modest changes in variability for the driest periods. The “cool/wet” and “middle” projections show the largest increases in 3-year streamflow, while the “diversity” and “warm/dry” projections indicate the greatest reductions in 3-year streamflow. Similar to annual streamflow, the so-called “warm/dry” projections fall more towards the center of the ensemble of results and produce wetter wet years and some drier dry years as compared to the historical distribution. The “diversity” projection continues to exhibit the lowest 3-year annual streamflow.

Figure 7 shows the 3-year annual natural streamflow exceedance probability curves for historical and future scenarios at the Russian River downstream of the Dry Creek confluence for the period of 2045-2099. Under this later future period, the differences between scenarios is magnified but shows similar relative ordering as the earlier period. The so-called “middle” projections exhibit the greatest change in streamflow, while the “warm/dry” once again tends toward the actual middle of the distribution.

Figure 6. Projected Changes in 3-Year Annual Russian River Streamflow for Period of 2006-2060.

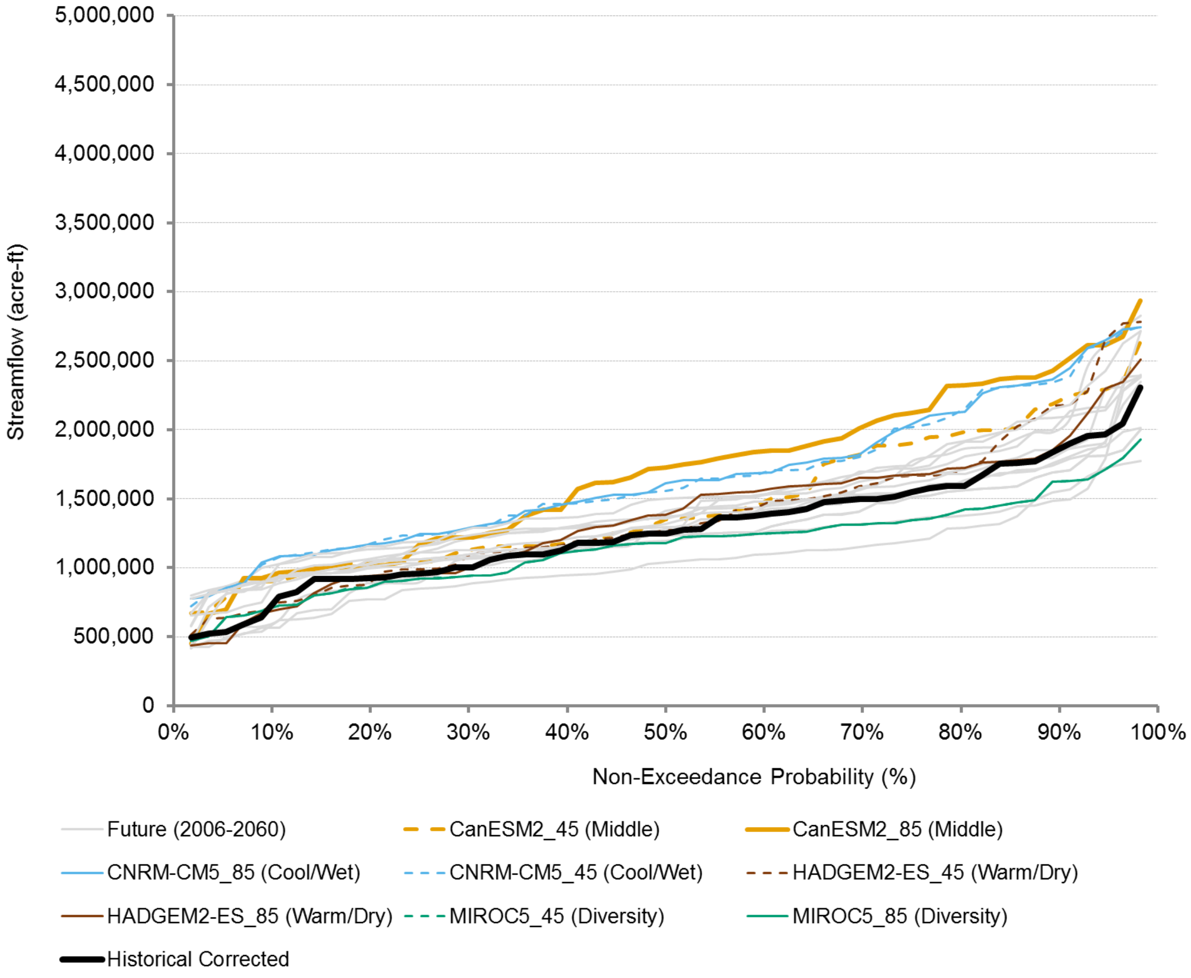
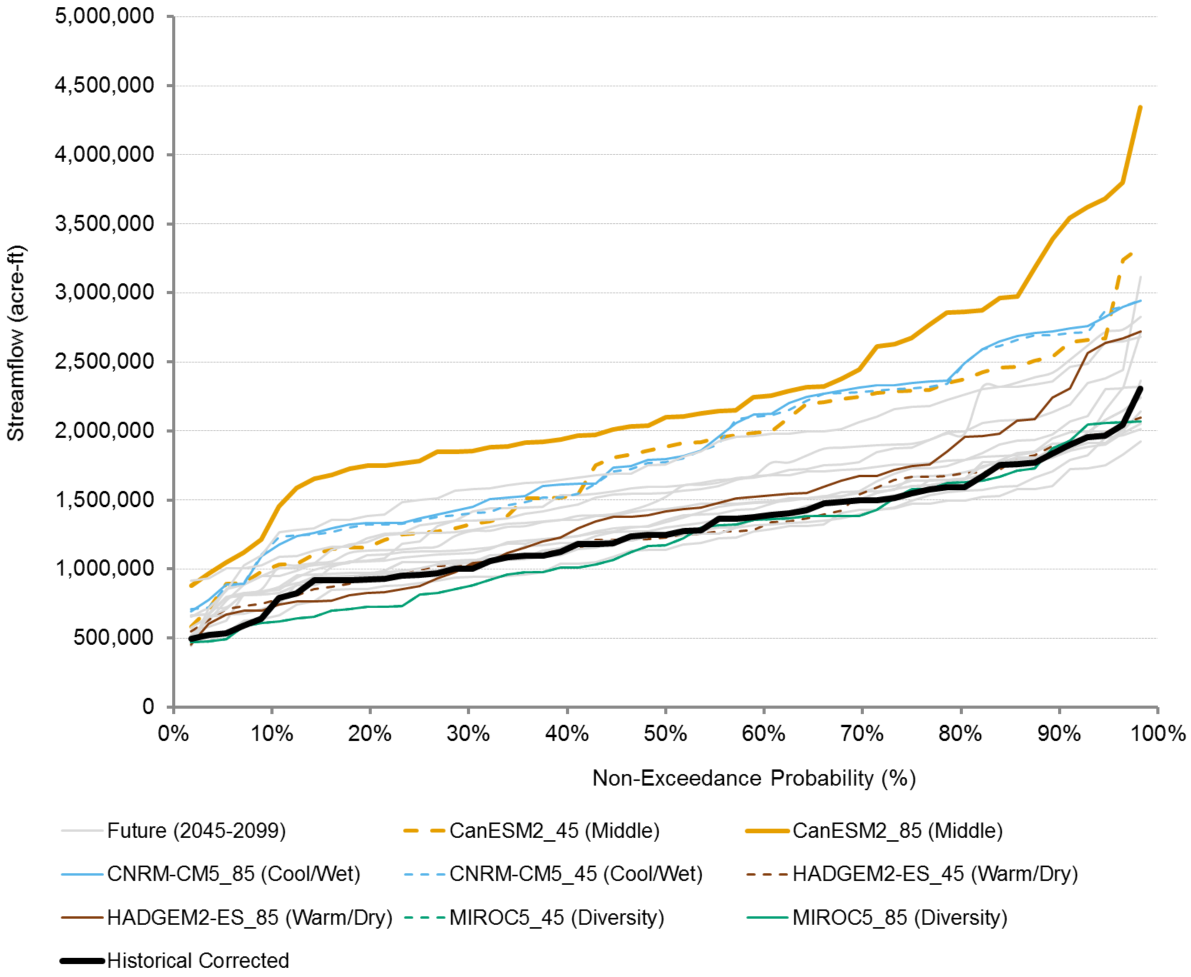


Figure 7. Projected Changes in 3-Year Annual Russian River Streamflow for Period of 2045-2099.



3.4 Projected Changes in Lake Sonoma Storage

Figure 8 shows the end of September storage exceedance probability curves for baseline and future scenarios at Lake Sonoma for the period of 2006-2060. Most future projections project decreases in storage across all exceedance values due to the projected increase in water demand in the basin and by Sonoma Water contractors. Note that the historical projections and “current operations” assume historical water demands. The range of outcomes for the lowest 30-40% of years is driven by the climate projections. Some projections suggest lower storage conditions than that projected under historical operations and indicate a few extreme challenging years.

Figure 9 shows the end of September storage exceedance probability curves for baseline and future scenarios at Lake Sonoma for the period of 2045-2099. Most future projections show decreases in storage across all exceedance values due to the projected increase in water demand in the basin and by Sonoma Water contractors. During this period, most of the projections suggest lower storage conditions than that projected under historical operations and indicate at least 10% of years lower than historical low levels.

Figure 8. Projected End of September Lake Sonoma Storage for Period of 2006-2060.

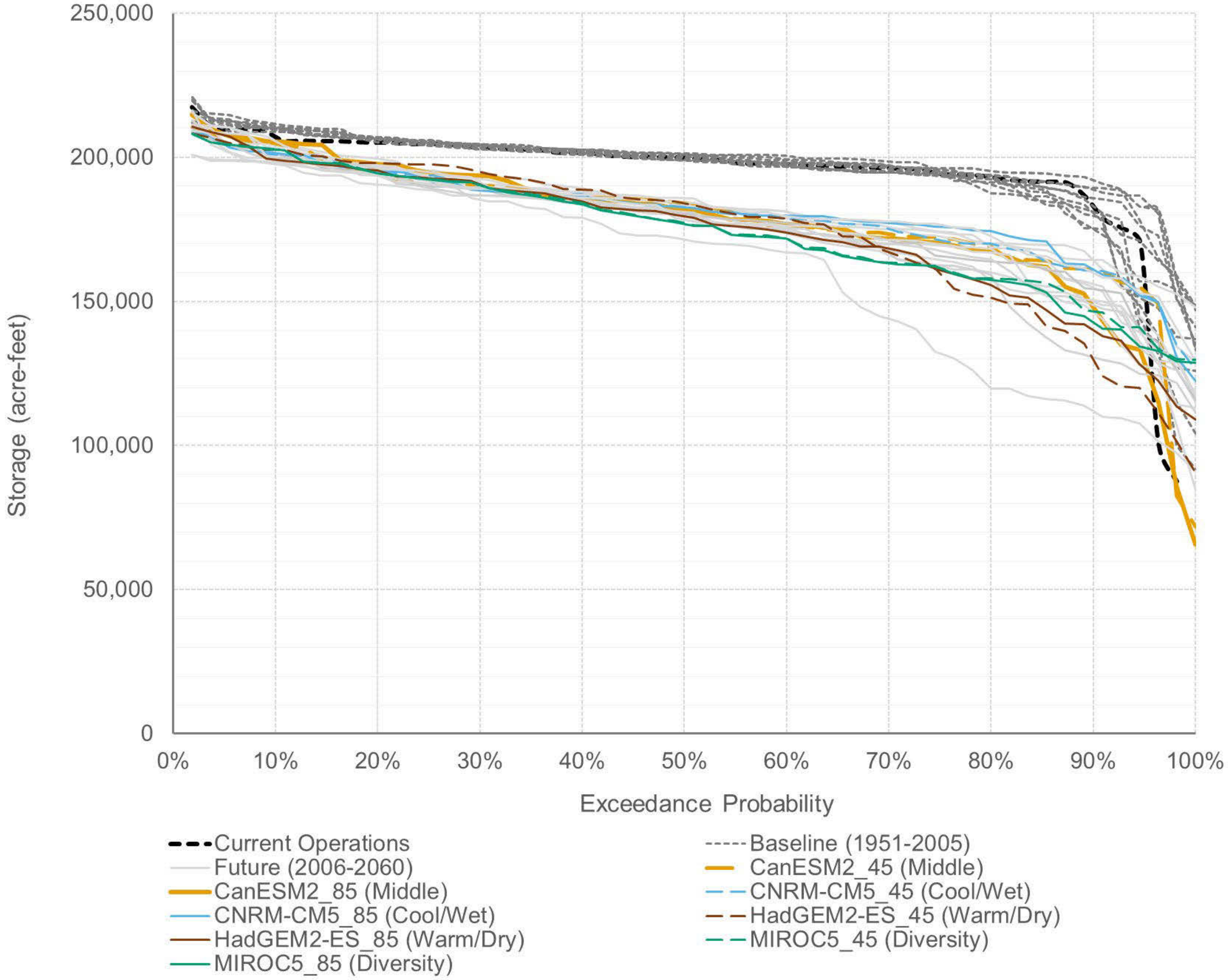
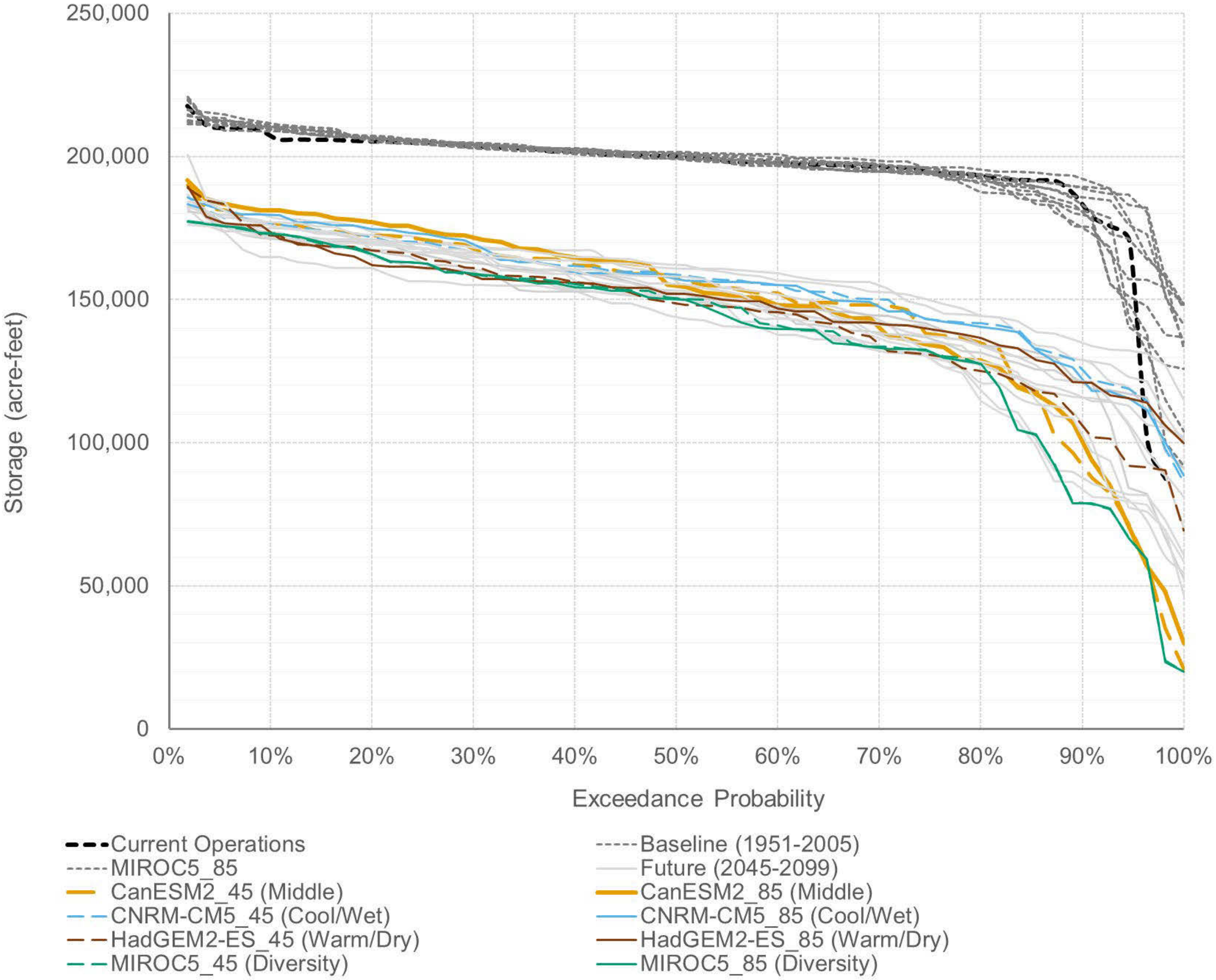


Figure 9. Projected End of September Lake Sonoma Storage for Period of 2045-2099.



3.5 Projected Changes in Sonoma Water Diversion Capability

Figures 10 and 11 show the exceedance probability curves for annual Sonoma Water diversion (acre-feet) under both baseline and future conditions. Due to increase in water demand, the Sonoma Water diversion is increased in all simulations. In general, HEC-ResSim simulations suggest nearly identical results for all GCM model projections which indicates similar delivery capability. The Sonoma Water system appears to be able to adapt to the climate and hydrologic changes projected in the scenarios.

Figure 10. Projected Sonoma Water Annual Diversion Capability for Period of 2006-2060.

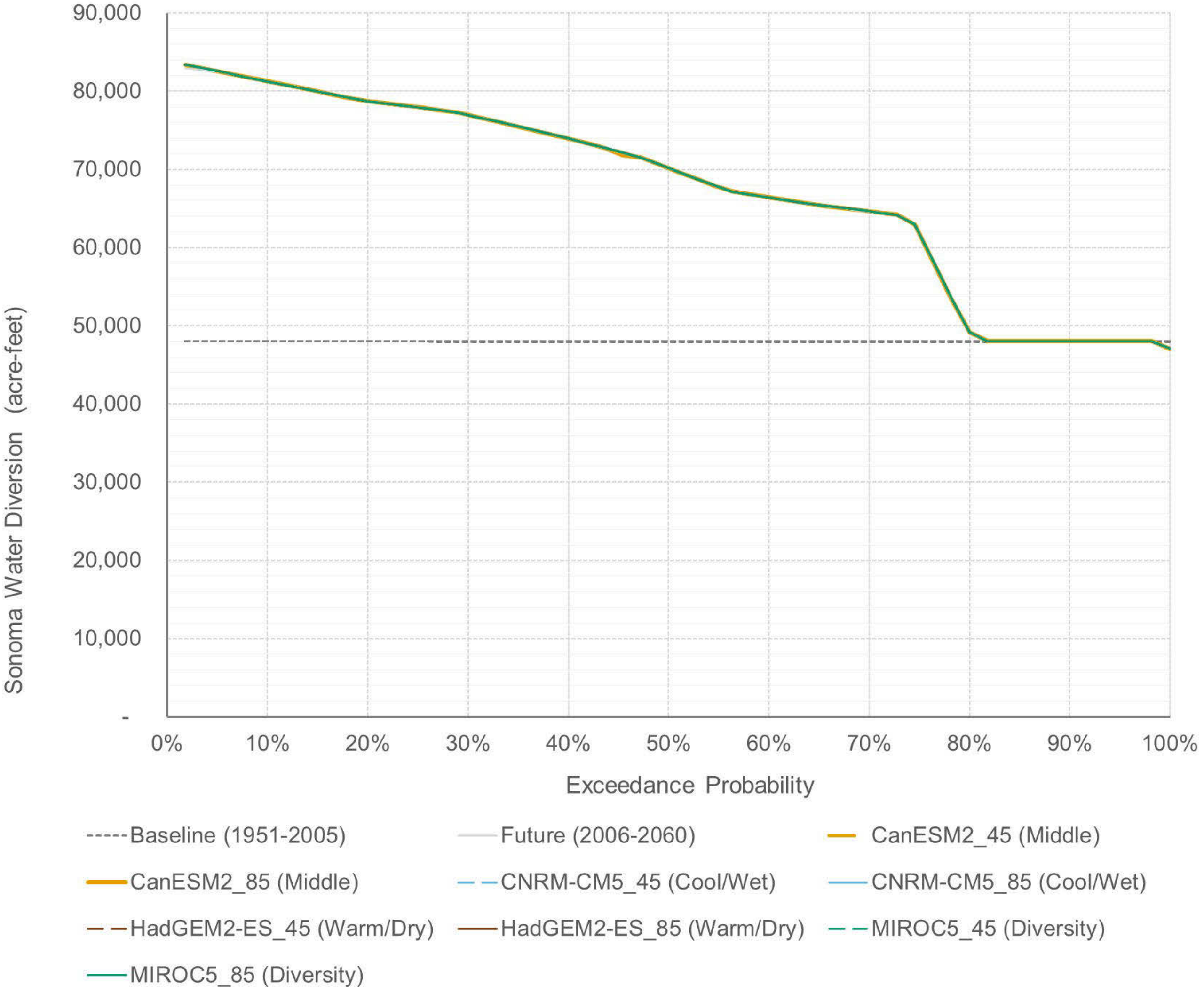
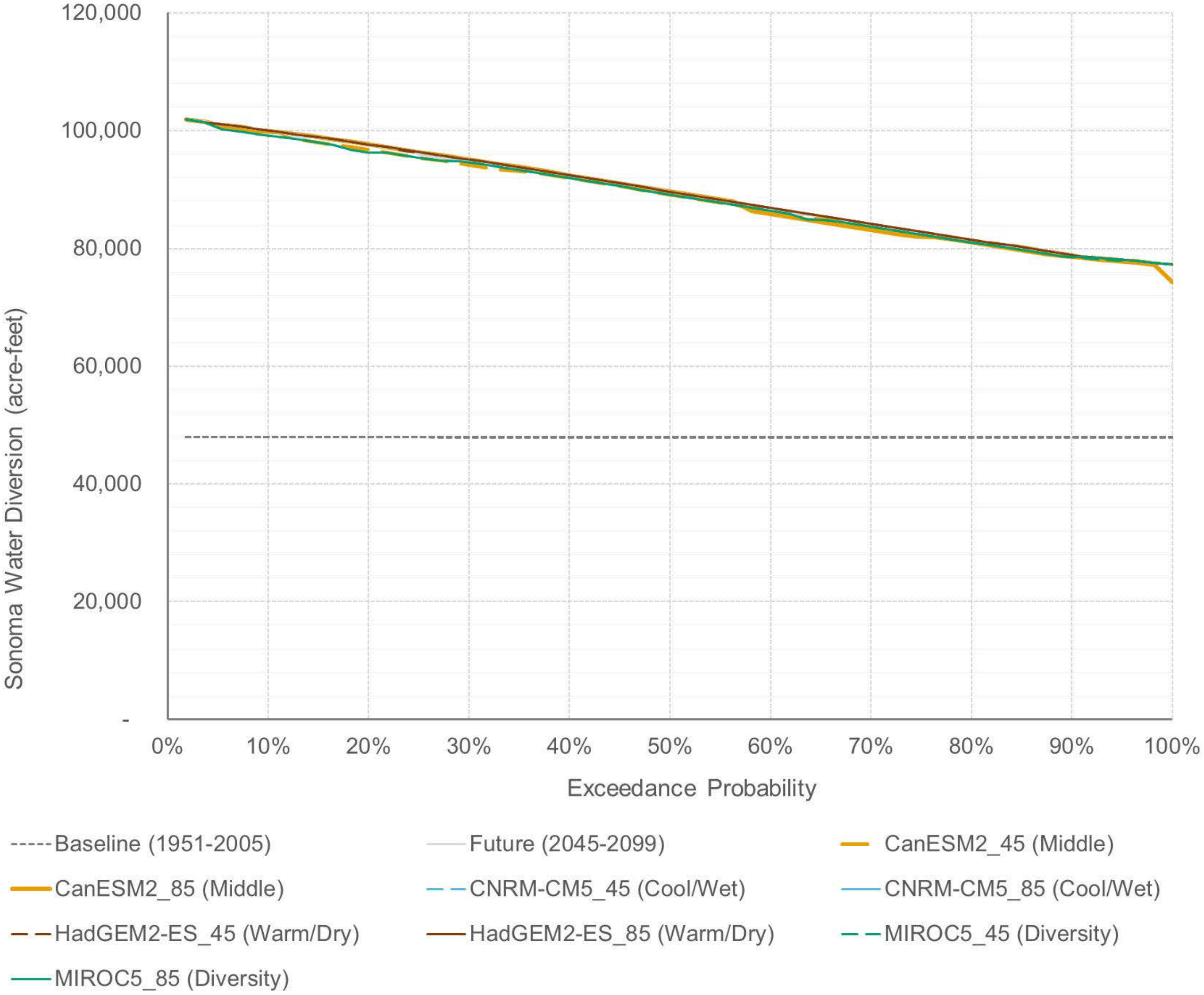


Figure 11. Projected Sonoma Water Annual Diversion Capability for Period of 2045-2099.



4. Scenario Rankings

For each of the climate, hydrologic, and water supply metrics, the model projection rank was determined by ordering the resulting metric values for the 2006-2060 period. A projection that had the largest increase amongst the 20 projections would indicate rank equal to 1, while the largest decrease/smallest increase projection would indicate rank equal to 20. The middle-most projections would indicate rank equal to 9, 10, or 11.

Table 2 shows the resulting rank of each GCM for each metric. Since each GCM includes simulations for both RCP 4.5 and 8.5, two rank values are shown.

The CanESM2 model, indicated by the CA Fourth Climate Change Assessment as “middle”, ranks among the warmest, wettest, and highest annual streamflow projections. Similarly, the CNRM-CM5 model ranks among the wettest with high annual streamflow projections compared to the ensemble. Conversely, the CMCC-CMS, HadGEM2-CC, and MIROC5 models rank among the driest of the models when comparing streamflow. The CCSM4, GFDL-CM3, and HadGEM2-ES models rank closest to the middle when comparing the mean climate and hydrologic metrics.

Streamflow variability and storage metrics did not present substantial differentiation between scenarios, and since water diversion was essentially the same for all projections, no rank was assigned for this metric.

Table 2. Rank of GCM (RCP 4.5/8.5) for Metrics Used in this Assessment Based on 2006-2060 Period

GCM	**T**	**P**	**Q mean** (average streamflow)	**Q var 1-yr** (coefficient of variation of annual streamflow)	**Q var 3-yr** (coefficient of variation of 3-year annual streamflow)	**Lake Sonoma Storage**	**Sonoma Water Diversion**
ACCESS1-0	18/7	14/8	14/5	3/8	1/7	2/9	N/A
CCSM4	15/5	12/9	10/13	1/11	2/9	20/12	N/A
CESM1-BGC	10/14	6/5	6/7	12/17	14/16	1/6	N/A
HadGEM2-CC	20/8	19/16	15/16	15/14	19/18	13/11	N/A
CMCC-CMS	16/6	20/17	20/17	6/13	8/17	18/8	N/A
CNRM-CM5 (Cool/Wet)	17/11	1/2	3/1	19/18	11/10	5/4	N/A
CanESM2 (Middle)	2/1	4/3	4/2	2/7	6/5	7/10	N/A
GFDL-CM3	9/4	7/10	9/11	20/17	20/15	3/19	N/A
HadGEM2-ES (Warm/Dry)	12/3	13/15	15/12	5/4	3/4	16/17	N/A
MIROC5 (Diversity)	19/13	11/18	18/19	10/9	13/12	14/15	N/A

5. Summary and Recommendations

This assessment of projected climate scenarios reviewed important climatic, hydrologic, and water supply metrics that would be used to evaluate the relative performance of individual GCM projections within the Russian River watershed. For basin-wide planning projects and programs, such as the GSPs, for which the use of dozens of individual climate scenarios is not practical, this assessment was intended to inform which scenarios may be used to represent the 20-scenario ensemble and provide realistic climate change evaluations for (groundwater) planning purposes.

Through this assessment, we found that the CanESM2 model, indicated by the CA Fourth Climate Change Assessment as “middle” for the North Coast, ranks among the warmest, wettest, and highest streamflow projections for the Russian River watershed area. Use of this projection to represent the middle of the ensemble is not recommended for the Sonoma County GSPs. The CNRM-CM5 model also ranks among the wettest with high streamflow projections compared to the ensemble.

Conversely, the CMCC-CMS, HadGEM2-CC, and MIROC5 models rank among the driest of the models when comparing streamflow. The MIROC5 model was identified as a “diversity” model in the CA Fourth Climate Change Assessment, and we concur that this GCM includes projections that will likely test water supply and water management the most. This GCM could be considered for providing a “stress test” for Sonoma Water and regional water resource systems.

The CCSM4, GFDL-CM3, and HadGEM2-ES models rank closest to the middle of the ensemble when comparing the mean climate and hydrologic metrics. While the HadGEM2-ES model was identified as a “warm/dry” model in the CA Fourth Climate Change Assessment report, it likely best represents the middle of the ensemble for mean climate and hydrologic metrics for the Russian River watershed. While somewhat arbitrary to select this model from the other middle models, the HadGEM2-ES model did not stray to any of the extremes for other metric rankings. For example, the CCSM4 indicated the highest annual coefficient of variation for streamflow, while the GFDL-CM3 indicated the lowest. The HadGEM2-ES results may suggest that it was “more in the middle” than others, and thus may be appropriate for use in Sonoma County GSP development.

6. References

Brekke et al. 2013. Downscaled CMIP3 and CMIP5 Climate Projections Release of Downscaled CMIP5 Climate Projections, Comparison with Preceding Information, and Summary of User Needs

California Department of Water Resources Climate Change Technical Advisory Group (CCTAG). 2015. Perspectives and guidance for climate change analysis. California Department of Water Resources Technical Information Record. p. 142.

California Department of Water Resources Sustainable Groundwater Management Program. 2018. Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development.

Ekstrom, Julia A., and Susanne C. Moser. 2012. Climate Change Impacts, Vulnerabilities, and Adaptation in the San Francisco Bay Area: A Synthesis of PIER Program Reports and Other Relevant Research. California Energy Commission. Publication number: CEC-500-2012-071.

Flint, L.E, and Flint, A.L. 2012a. Downscaling future climate scenarios to fine scales for hydrologic and ecological modeling and analysis: Ecological Processes, v. 1, no. 1.

Flint, L.E., and Flint, A.L. 2012b. Simulation of climate change in San Francisco Bay Basins, California: Case studies in the Russian River Valley and Santa Cruz Mountains: U.S. Geological Survey Scientific Investigations Report 2012–5132, 55 p.

Flint et al. 2013. Fine-scale hydrologic modeling for regional landscape applications: the California Basin Characterization Model development and performance. Ecological Processes, 2:25

Intergovernmental Panel on Climate Change (IPCC). 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley, eds. Cambridge, United Kingdom and New York, New York: Cambridge University Press. p. 1535.

Pierce, D. W., T. P. Barnett, B. D. Santer, and P. J. Gleckler, 2009: Selecting global climate models for regional climate change studies. Proceedings of the National Academy of Sciences, doi:10.1073/pnas.0900094106.

Pierce, David W., Daniel R. Cayan, and Bridget L. Thrasher. 2014. “Statistical Downscaling Using Localized Constructed Analogs (LOCA).” J. Hydrometeor. 15, 2558–2585.

Pierce D. W., D. R. Cayan, and L. Dehann, (Scripps Institution of Oceanography). 2016. Creating Climate projections to support the 4th California Climate Assessment.

Pierce, D. W., J. F. Kalansky, and D. R. Cayan, (Scripps Institution of Oceanography). 2018. Climate, Drought, and Sea Level Rise Scenarios for the Fourth California Climate Assessment. California’s Fourth Climate Change Assessment, California Energy Commission. Publication Number: CNRA-CEC-2018-006.

Taylor, Karl E., Ronald J. Stouffer, Gerald A. Meehl. 2012. An Overview of CMIP5 and the Experiment Design. Bull. Amer. Meteor. Soc., 93, 485–498.

Appendix 4-A
Hydrographs of Representative Monitoring Points

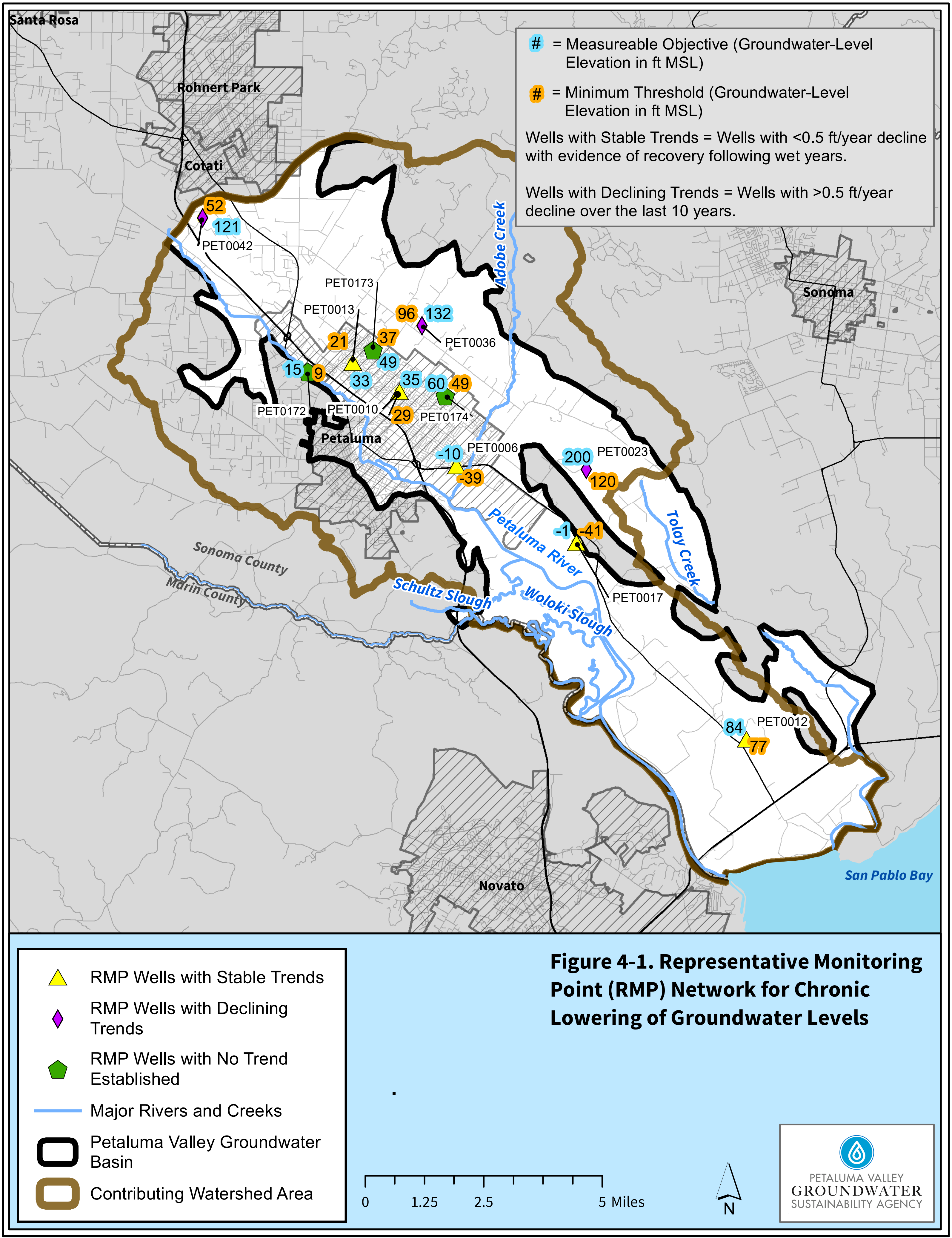
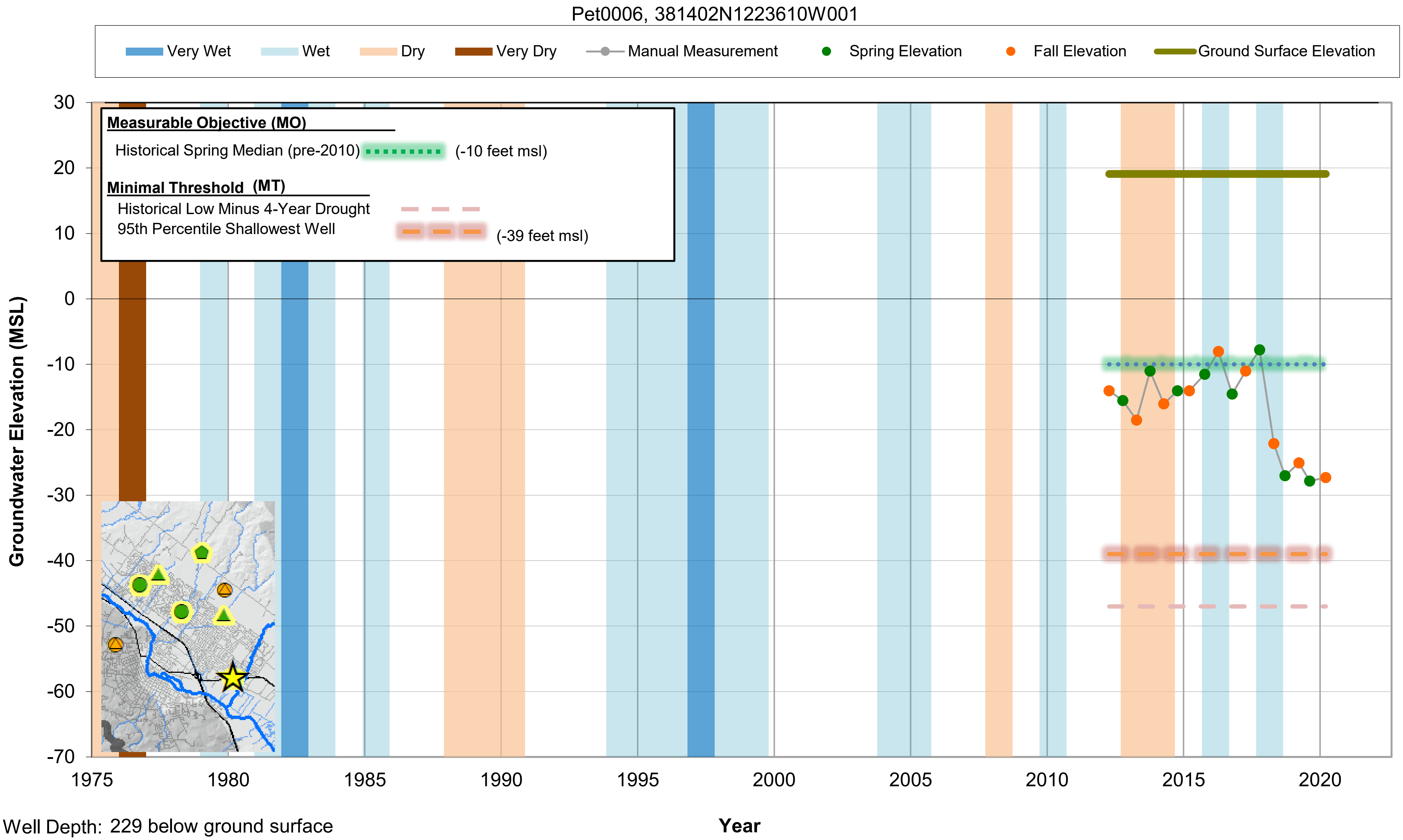
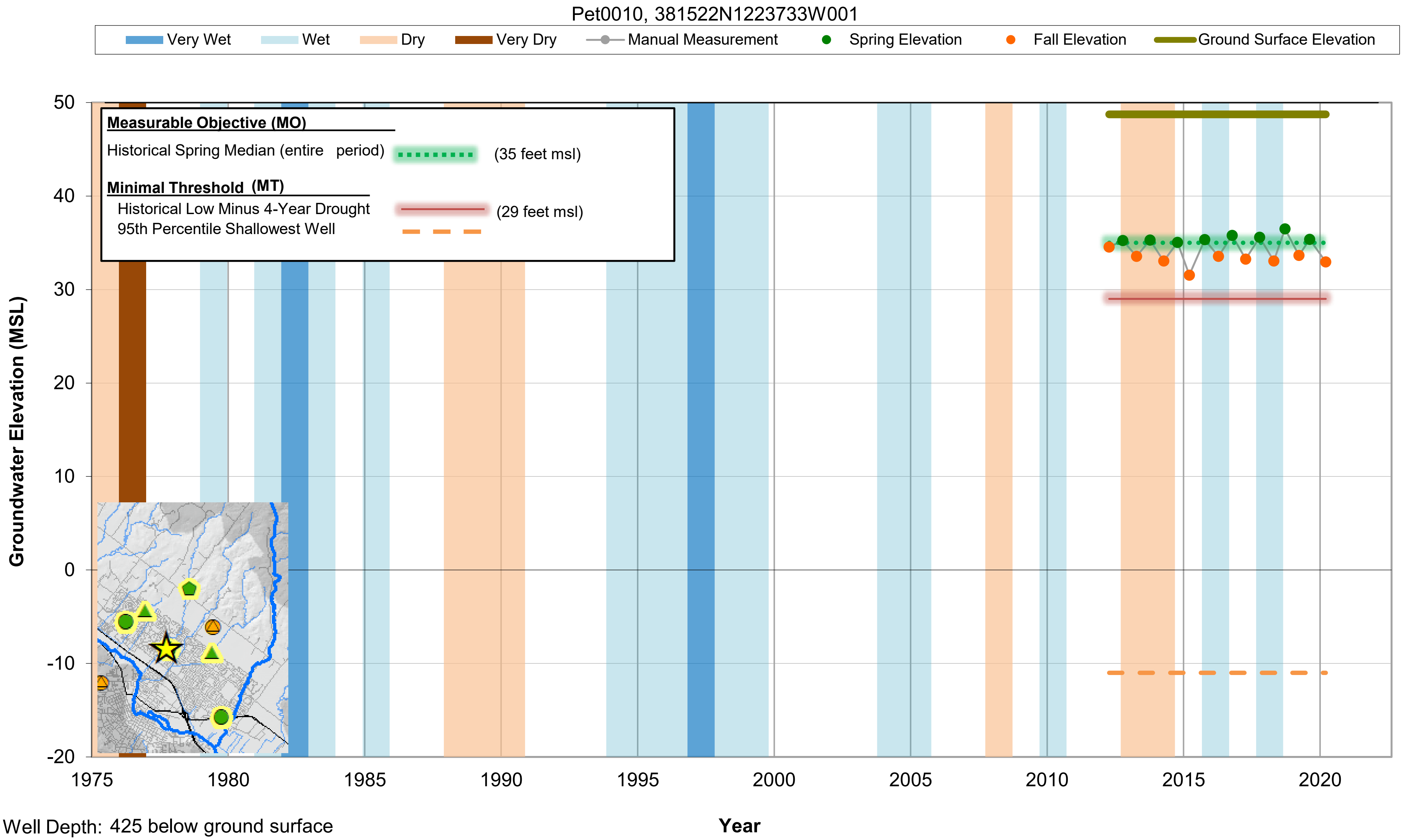


Figure 4-1. Representative Monitoring Point (RMP) Network for Chronic Lowering of Groundwater Levels

Filepath: T:\SGMA\GSAs\Petaluma Valley\MXDs\Fig4_1_PET_Potential_RMPs_SMCs1_10_4.mxd Date prepared: 11/8/2021

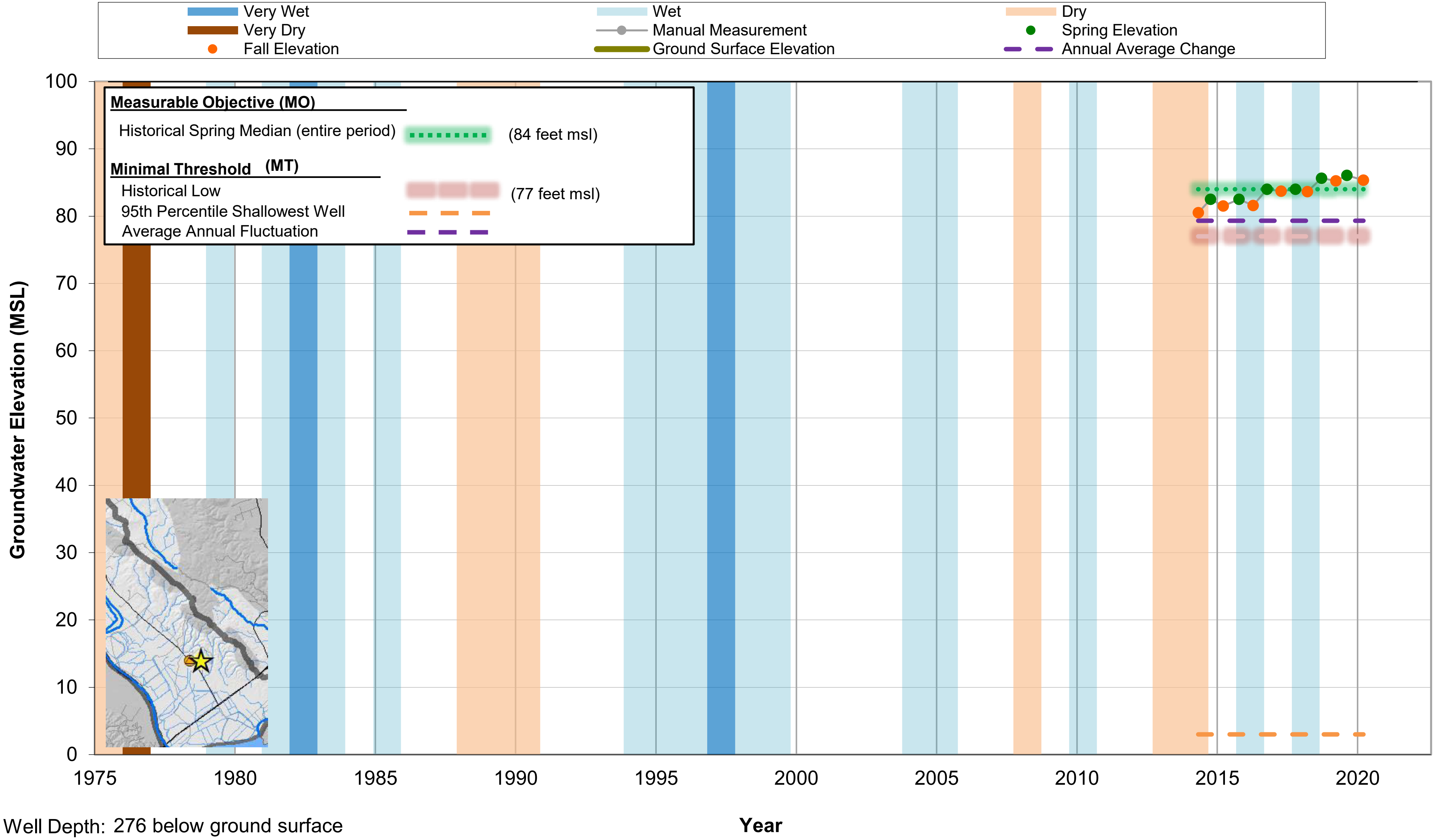


Well Depth: 229 below ground surface
Screened Intervals: 89-229 below ground surface
Type of Well: Municipal
Ground Surface Elevation: 19 feet msl



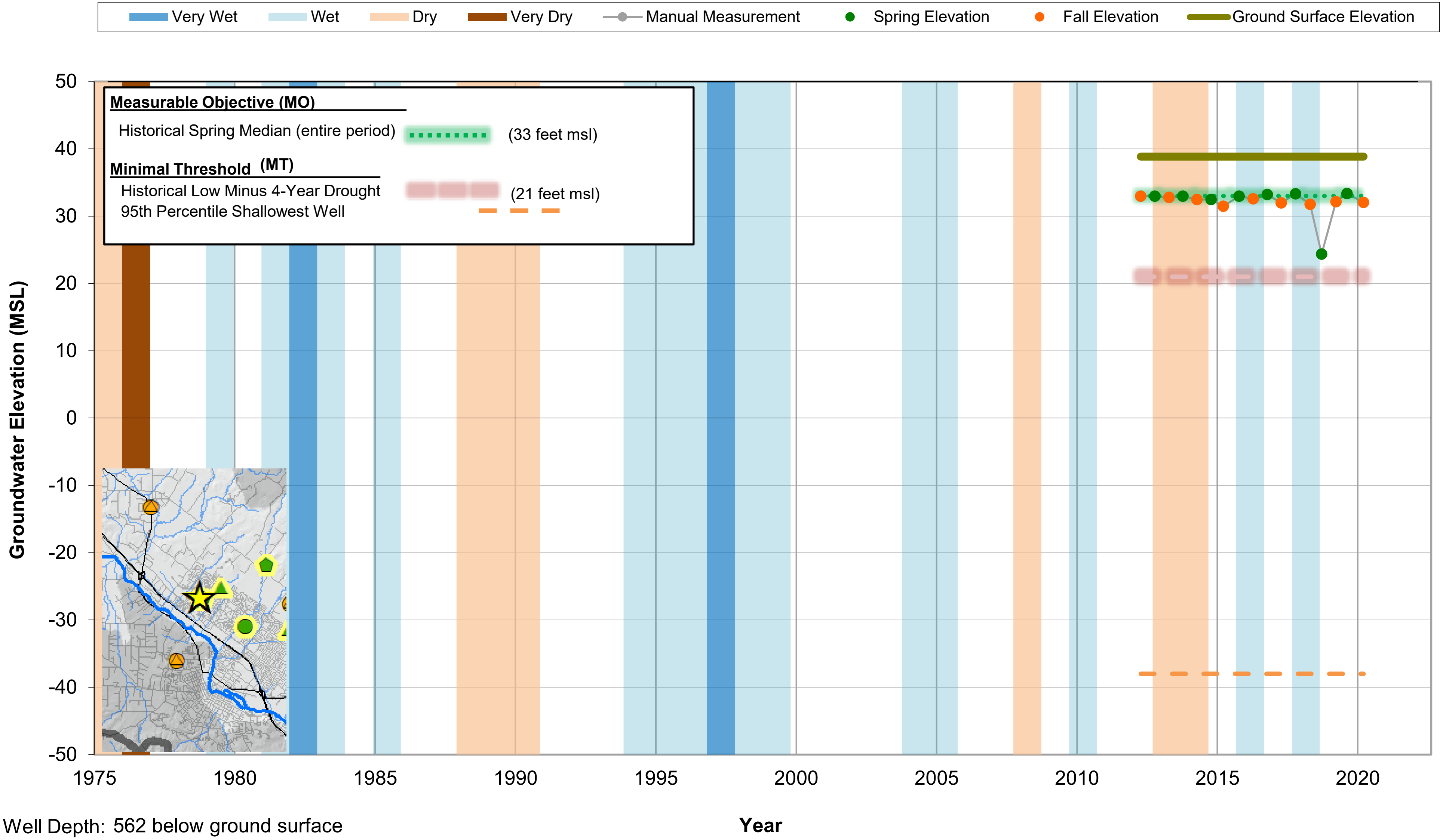
Well Depth: 425 below ground surface
Screened Intervals: 305-382 below ground surface
Type of Well: Municipal
Ground Surface Elevation: 49 feet msl

Pet0012, 381531N1224876W001

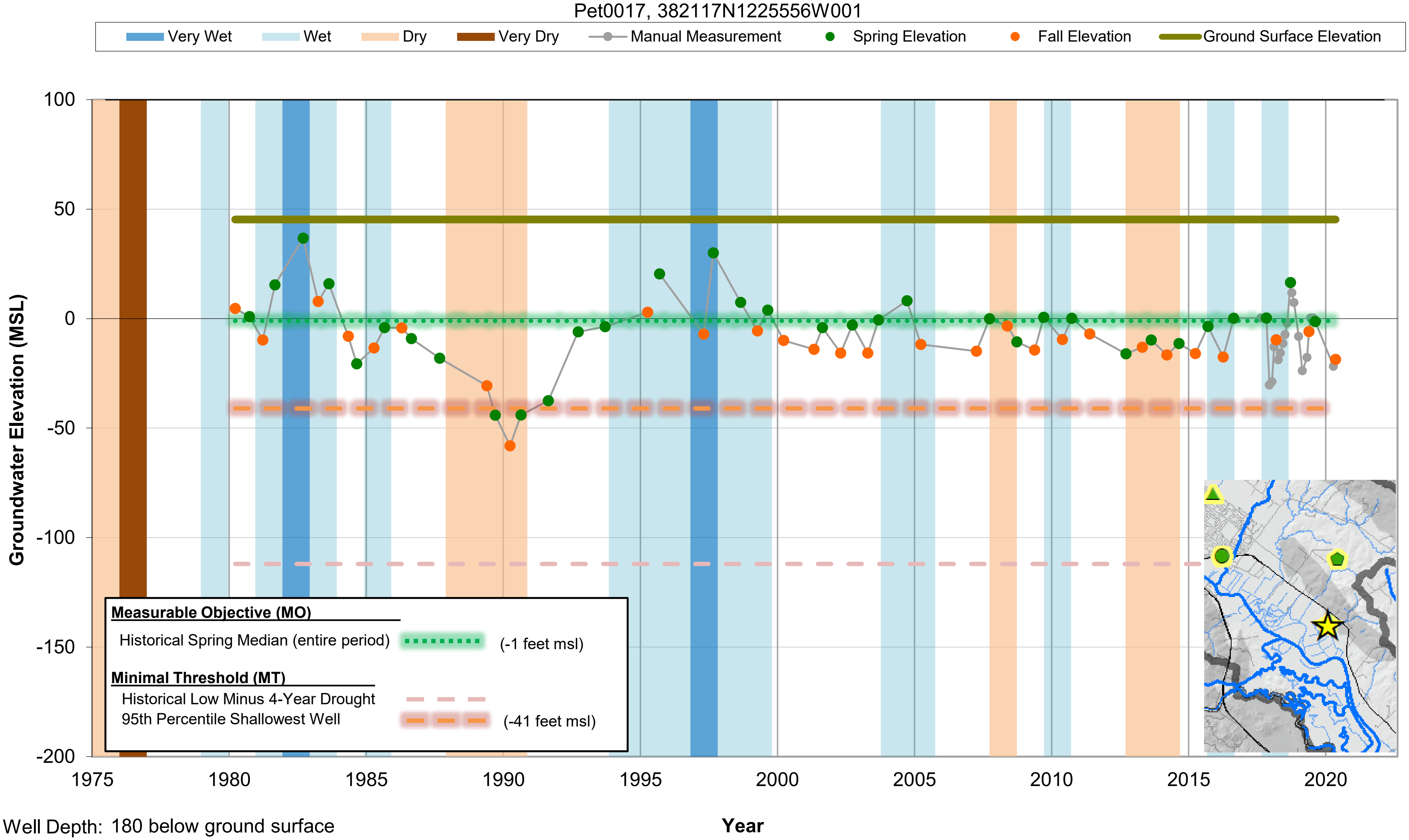


Well Depth: 276 below ground surface
Screened Intervals: 75-275 below ground surface
Type of Well: Observation
Ground Surface Elevation: 128 feet msl

Pet0013, 381553N1223839W001

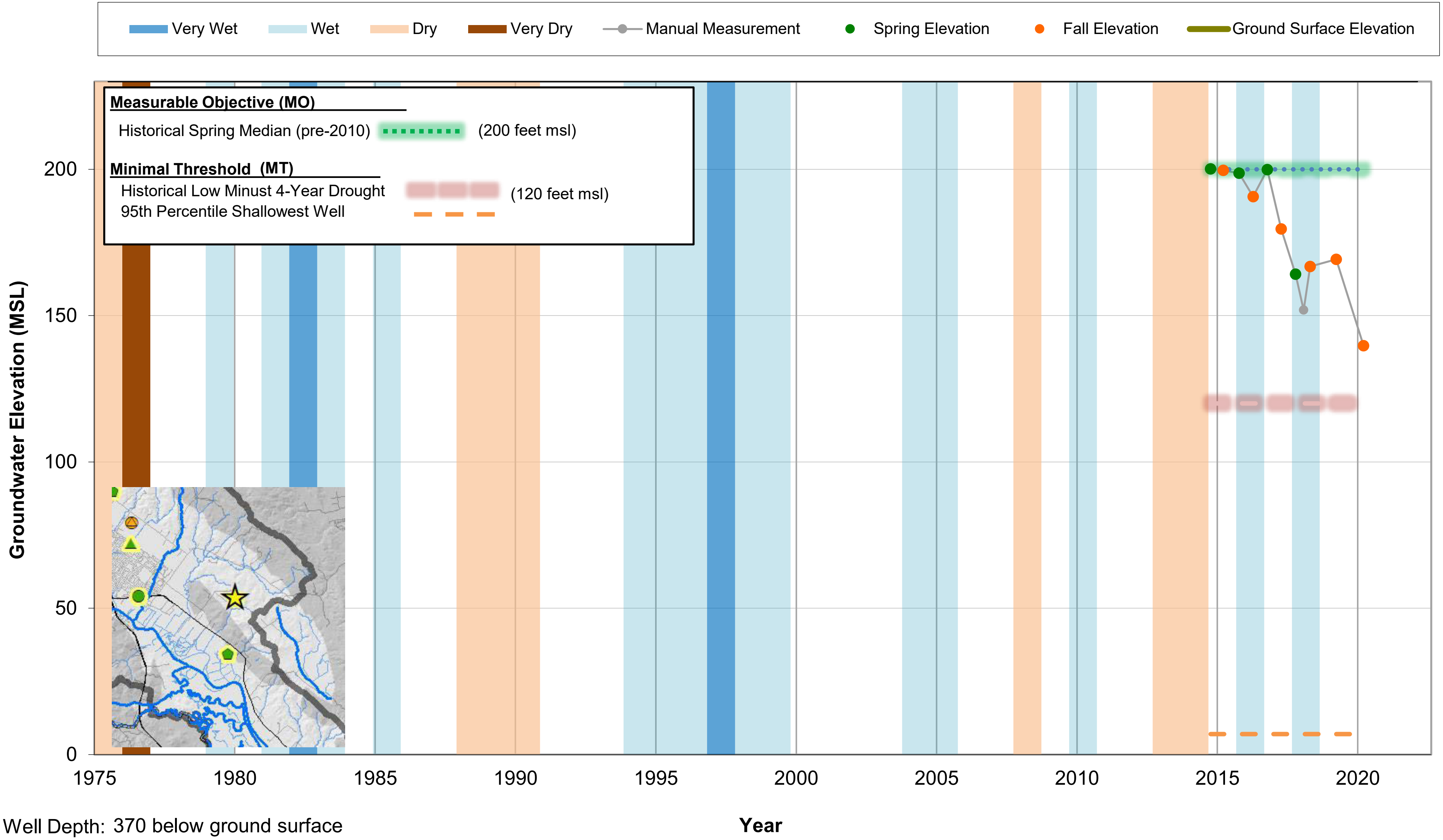


Well Depth: 562 below ground surface
Screened Intervals: 52-538 below ground surface
Type of Well: Municipal
Ground Surface Elevation: 39 feet msl

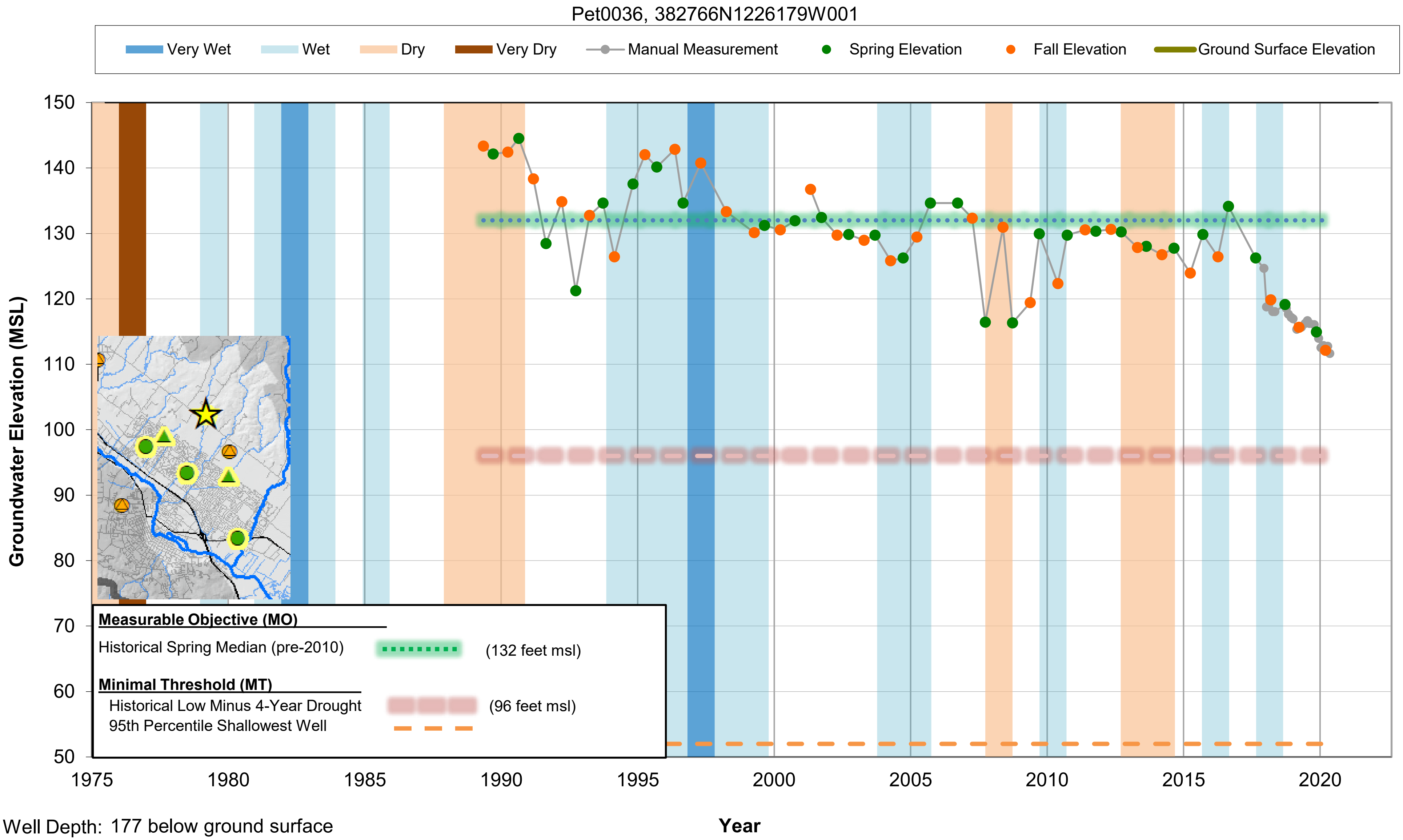


Well Depth: 180 below ground surface
Screened Intervals: 140-180 below ground surface
Type of Well: Supply
Ground Surface Elevation: 45 feet msl

Pet0023, 382342N1225525W001

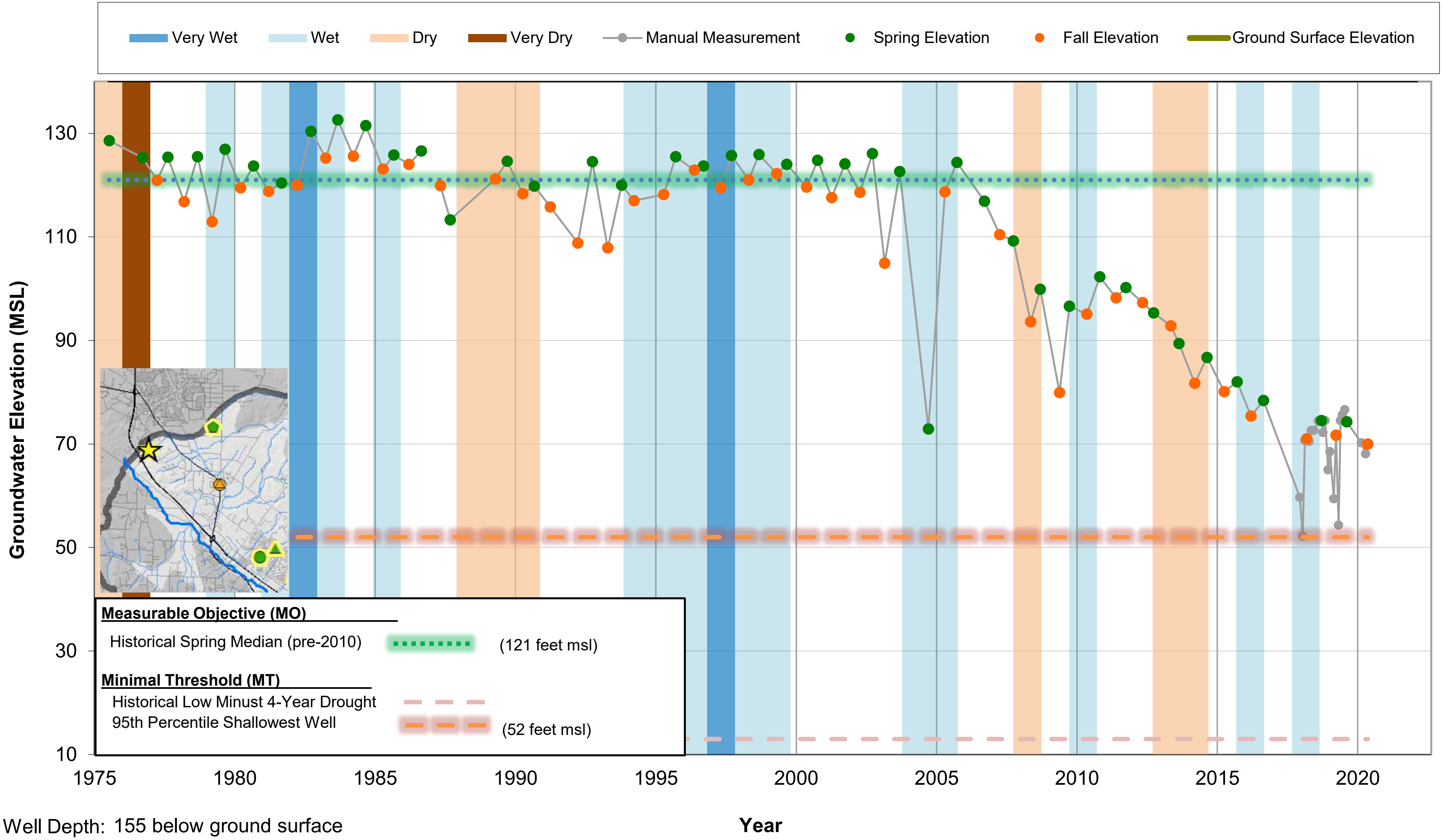


Well Depth: 370 below ground surface
Screened Intervals: 30-370 below ground surface
Type of Well: Supply
Ground Surface Elevation: 245 feet msl

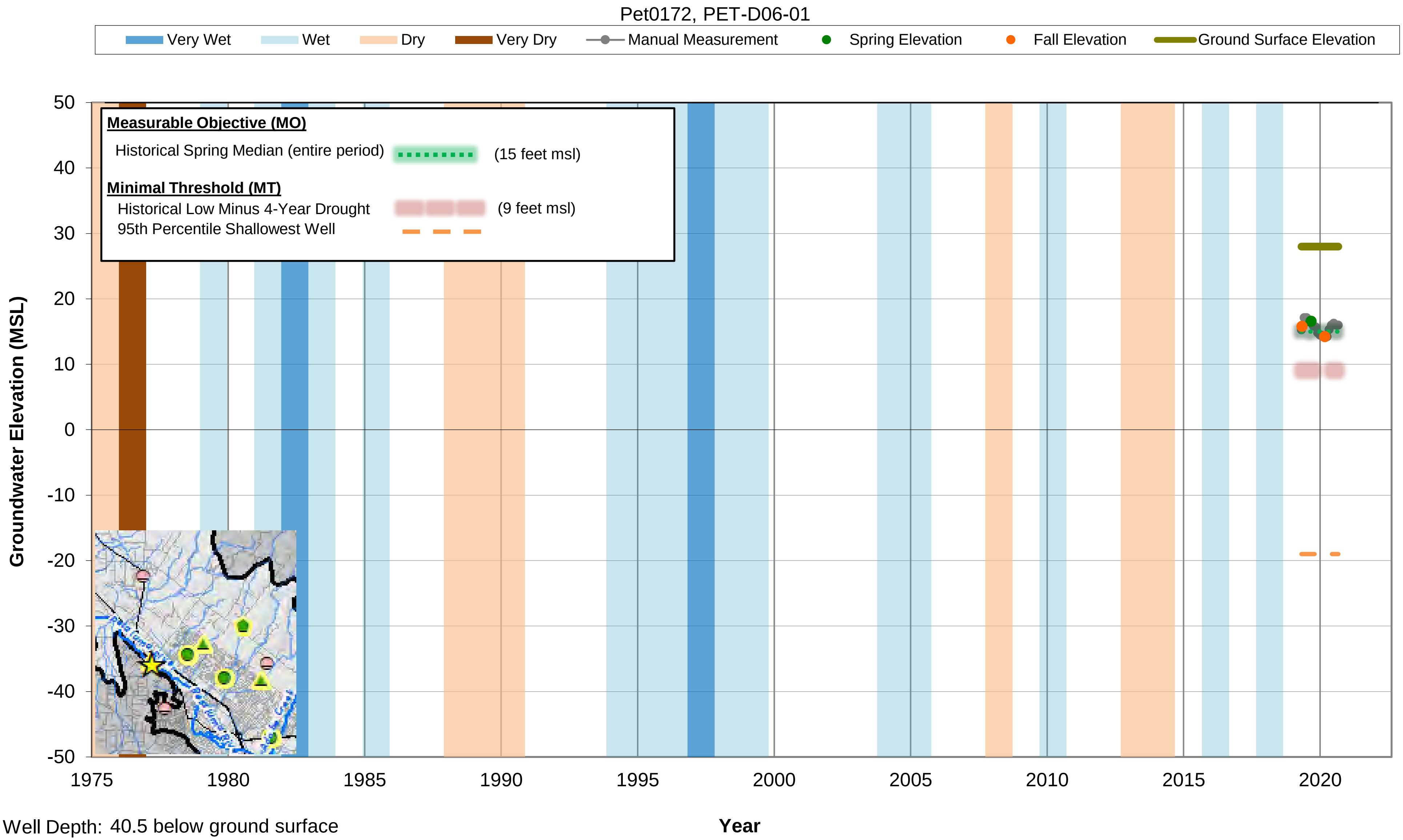


Well Depth: 177 below ground surface
Screened Intervals: 158-177 below ground surface
Type of Well: Supply
Ground Surface Elevation: 163 feet msl

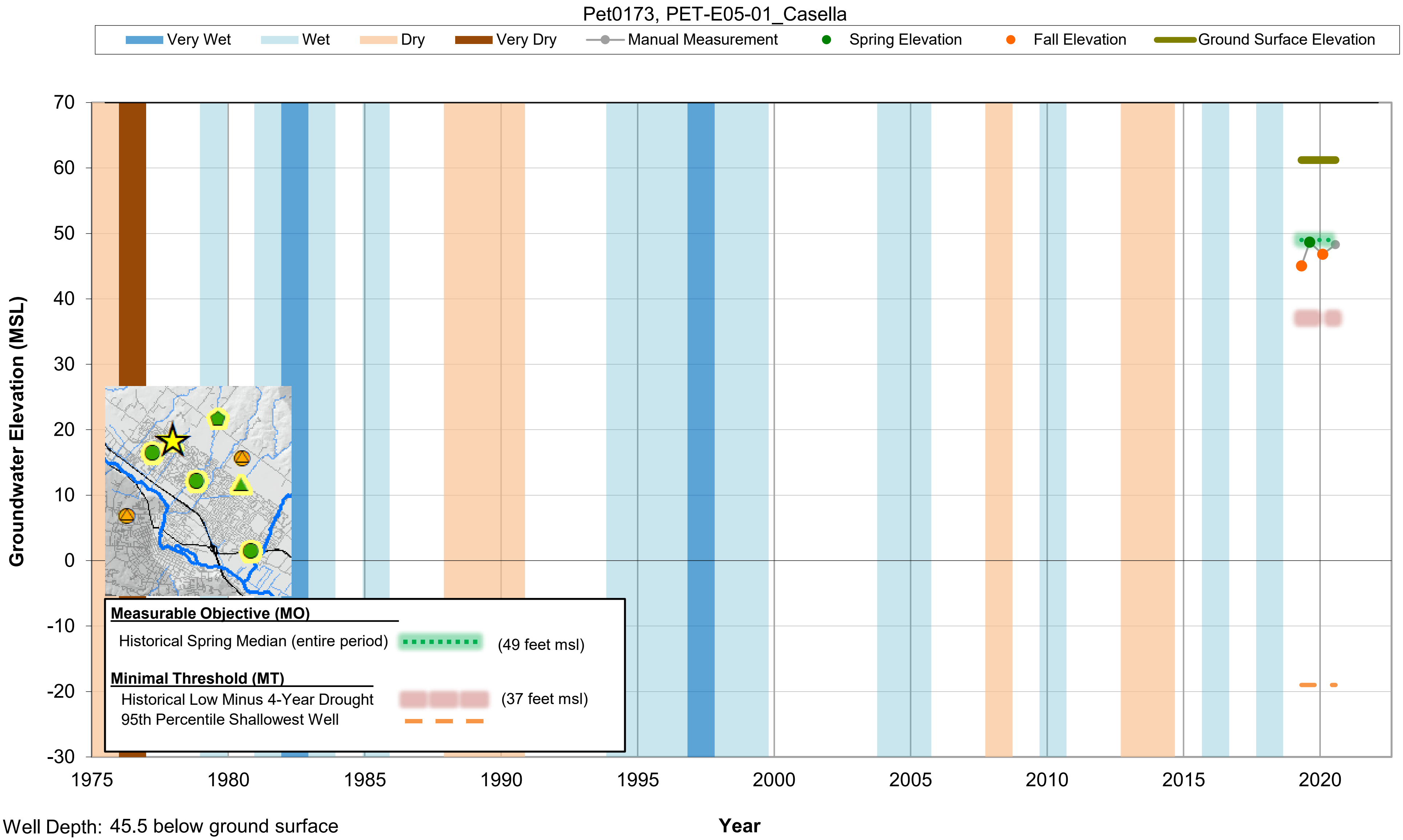
Pet0042, 383076N1227041W001



Well Depth: 155 below ground surface
Screened Intervals: 30-150 below ground surface
Type of Well: Supply
Ground Surface Elevation: 158 feet msl

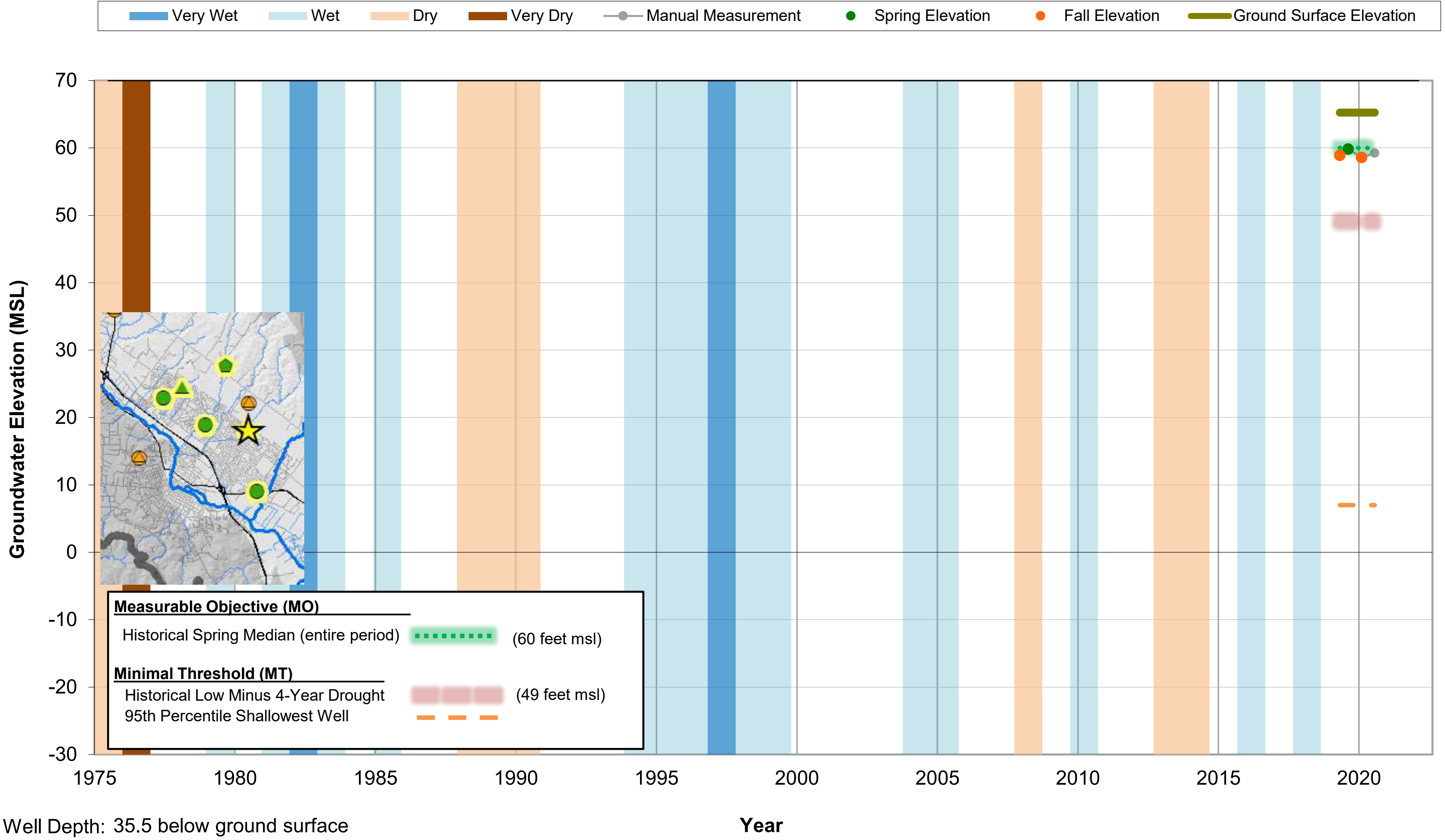


Well Depth: 40.5 below ground surface
Screened Intervals: 20-40 below ground surface
Type of Well: Monitoring
Ground Surface Elevation: 28 feet msl



Well Depth: 45.5 below ground surface
Screened Intervals: 35-45 below ground surface
Type of Well: Observation
Ground Surface Elevation: 61 feet msl

Pet0174, PET-F06-01_Garfield



Well Depth: 35.5 below ground surface
Screened Intervals: 15-35 below ground surface
Type of Well: Observation
Ground Surface Elevation: 65 feet msl

.

Appendix 4-B
Definition of Drought for Sonoma County Groundwater Sustainability Plans

Definition of Drought for
Sonoma County Groundwater Sustainability Plans

Summary

During the planning and implementation phases of the Groundwater Sustainability Plan (GSP) it will be necessary to make the determination if a water year qualifies as a droughtor does not. For the groundwater level sustainability indicator the occurrence of a drought may allow for overdraft to occur without qualifying as undesirable results. The Drought Monitor Long Term Drought Indicator Blend (LTDIB) will be used to assess for drought conditions. A drought is considered to occur when the LTDIB water-year averaged value meets or exceeds that of the D1, or moderate, drought.

Background

During periods of drought, the groundwater sustainability plans allow for minimum threshold exceedances that under normal conditions would constitute undesirable results. For the groundwater level sustainability indicator, if minimum threshold exceedances are caused by droughts that extend for longer than the 4-year drought factor already incorporated into the calculated minimum thresholds, it is not considered an undesirable result unless the groundwater levels do not rebound to above the thresholds during future normal and wet years following long-term droughts. This is consistent with GSP regulations which state that, “overdraft during a period of drought is not sufficient to establish a chronic lower of groundwater levels” (California Water Code 10721). Additionally, for the interconnected surface water sustainability indicator the percentage of minimum threshold exceedances that constitute undesirable results is higher during drought years and lower during non-drought years. Here the definition of a drought is detailed for use in the planning and implementation phases of the Sonoma County GSPs.

The US Drought Monitor is a map of drought conditions in the United States that is developed and updated by experts of National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Agriculture (USDA). The map is updated every week and incorporates a number of meteorological, hydrologic, and agricultural inputs to assess conditions. Drought conditions are described by severity through the use of the following codes: abnormally dry (D0), showing areas that may be going into or are coming out of drought, and four levels of drought: moderate (D1), severe (D2), extreme (D3) and exceptional (D4). The effects of each drought category on California are shown in Table 1 and Figure 1 shows a snapshot view of the LTDIB values for April 2021 for the continental US.

A variety of maps are developed by the Drought Monitor. For the SGMA subbasins the Long-Term Drought Indicator Blend (LTDIB) will be used as the metric for establishing drought and non-drought conditions. This is an objective metric that utilizes a scoring system with inputs from the Palmer Drought Severity Index (PDSI), the Z-index, CPC soil moisture storage, and a 180 day, 1-year, 2-year, and 5-year observations of the Standardized Precipitation Index (Guttman, 1998). The PDSI is a standardized index that uses both precipitation and evapotranspiration in a hydrologic accounting system (Palmer, 1965). The Z-index measures short-term drought on a monthly scale. The Climate Prediction Center Soil moisture storage[1] is a mechanistic model that simulates soil storage for the continental US. The SPI is a meteorological index that calculates the precipitation deficit for a given period, with respect to the observed precipitation variance. A limitation of the SPI is that it does not account for the effect evapotranspiration has on the presence or severity of drought. Under warming climate conditions this effect will become more important. The PDSI, Z-index, and CPC soils moisture storage do account for the effect of increased temperatures and should counteract the limitations of the SPI indices.

Table 1 Impacts on California By Drought Category[2]

Category	Historically observed impacts
D0 – Abnormally Dry	Soil is dry; irrigation delivery begins early
	Dryland crop germination is stunted
	Active fire season begins
	Winter resort visitation is low; snowpack is minimal
D1 – Moderate Drought	Dryland pasture growth is stunted; producers give supplemental feed to cattle
	Landscaping and gardens need irrigation earlier; wildlife patterns begin to change
	Stock ponds and creeks are lower than usual
D2 – Severe Drought	Grazing land is inadequate
	Producers increase water efficiency methods and drought-resistant crops
	Fire season is longer, with high burn intensity, dry fuels, and large fire spatial extent; more fire crews are on staff
	Wine country tourism increases; lake- and river-based tourism declines; boat ramps close
	Trees are stressed; plants increase reproductive mechanisms; wildlife diseases increase
	Water temperature increases; programs to divert water to protect fish begin

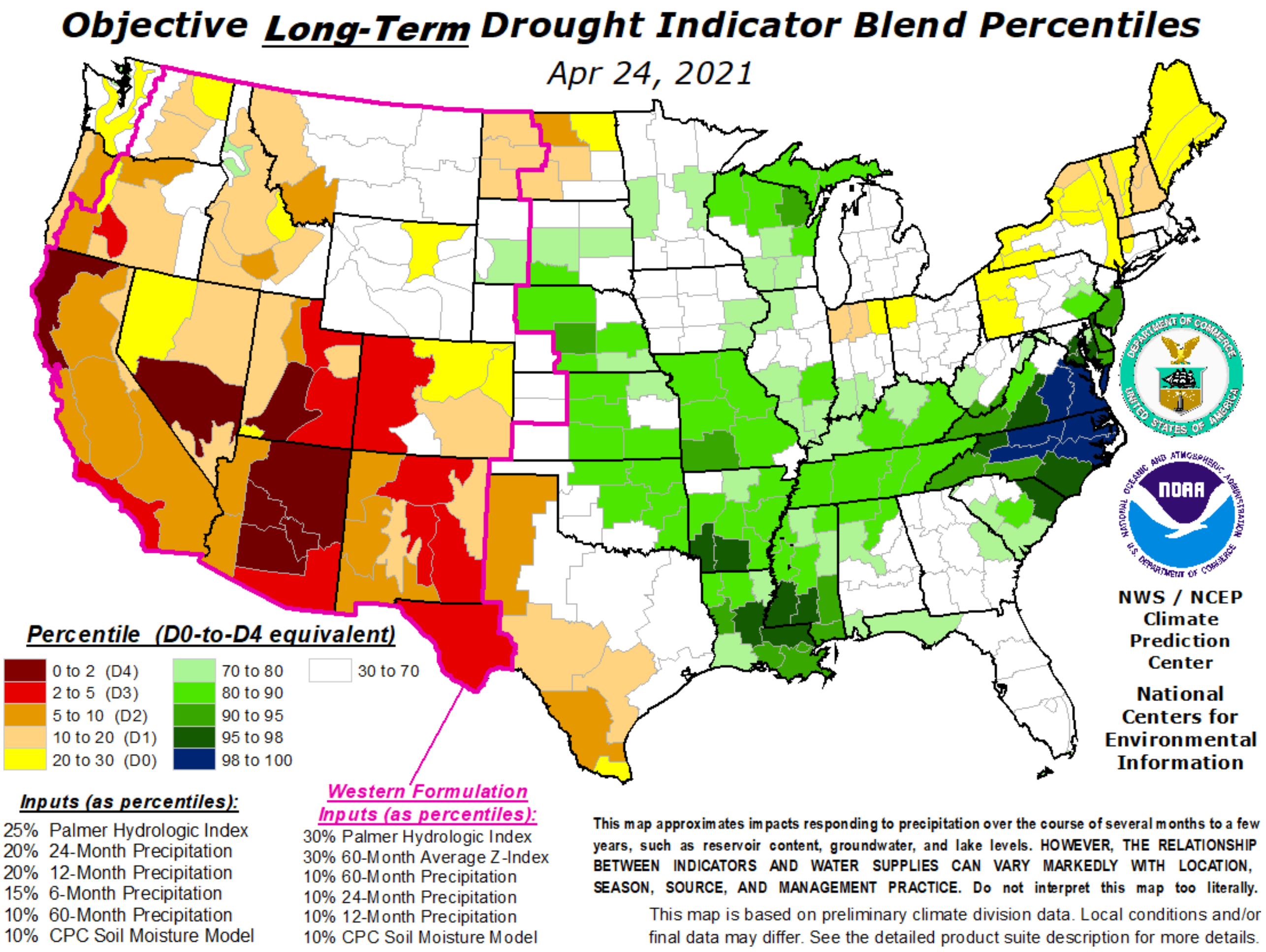
---

[1] https://www.cpc.ncep.noaa.gov/soilmst/w.shtml

[2] https://droughtmonitor.unl.edu/About/AbouttheData/DroughtClassification.aspx

	River flows decrease; reservoir levels are low and banks are exposed
D3 – Extreme Drought	Livestock need expensive supplemental feed, cattle and horses are sold; little pasture remains, producers find it difficult to maintain organic meat requirements
	Fruit trees bud early; producers begin irrigating in the winter
	Federal water is not adequate to meet irrigation contracts; extracting supplemental groundwater is expensive
	Dairy operations close
	Fire season lasts year-round; fires occur in typically wet parts of state; burn bans are implemented
	Ski and rafting business ar low, mountain communities suffer
	Orchard removal and well drilling company business increase; panning for gold increases
	Low river levels impede fish migration and cause lower survival rates
	Wildlife encroaches on developed areas; little native food and water is available for bears, which hibernate less
	Water sanitation is a concern, reservoir levels drop significantly, surface water is nearly dry, flows are very low; water theft occurs
	Wells and aquifer levels decrease; homeowners drill new wells
	Water conservation rebate programs increase; water use restrictions are implemented; water transfers increase
	Water is inadequate for agriculture, wildlife, and urban needs; reservoirs are extremely low; hydropower is restricted
	Fields are left fallow; orchards are removed; vegetable yields are low; honey harvest is small

D4 – Exceptional Drought	Fire season is very costly; number of fires and area burned are extensive
	Many recreational activities are affected
	Fish rescue and relocation begins; pine beetle infestation occurs; forest mortality is high; wetlands dry up; survival of native plants and animals is low; fewer wildflowers bloom; wildlife death is widespread; algae blooms appear
	Policy change; agriculture unemployment is high, food aid is needed
	Poor air quality affects health; greenhouse gas emissions increase as hydropower production decreases; West Nile Virus outbreaks rise
	Water shortages are widespread; surface water is depleted; federal irrigation water deliveries are extremely low; junior water rights are curtailed; water prices are extremely high; wells are dry, more and deeper wells are drilled; water quality is poor;



Inputs (as percentiles):

- 25% Palmer Hydrologic Index
- 20% 24-Month Precipitation
- 20% 12-Month Precipitation
- 15% 6-Month Precipitation
- 10% 60-Month Precipitation
- 10% CPC Soil Moisture Model

Western Formulation Inputs (as percentiles):

- 30% Palmer Hydrologic Index
- 30% 60-Month Average Z-Index
- 10% 60-Month Precipitation
- 10% 24-Month Precipitation
- 10% 12-Month Precipitation
- 10% CPC Soil Moisture Model

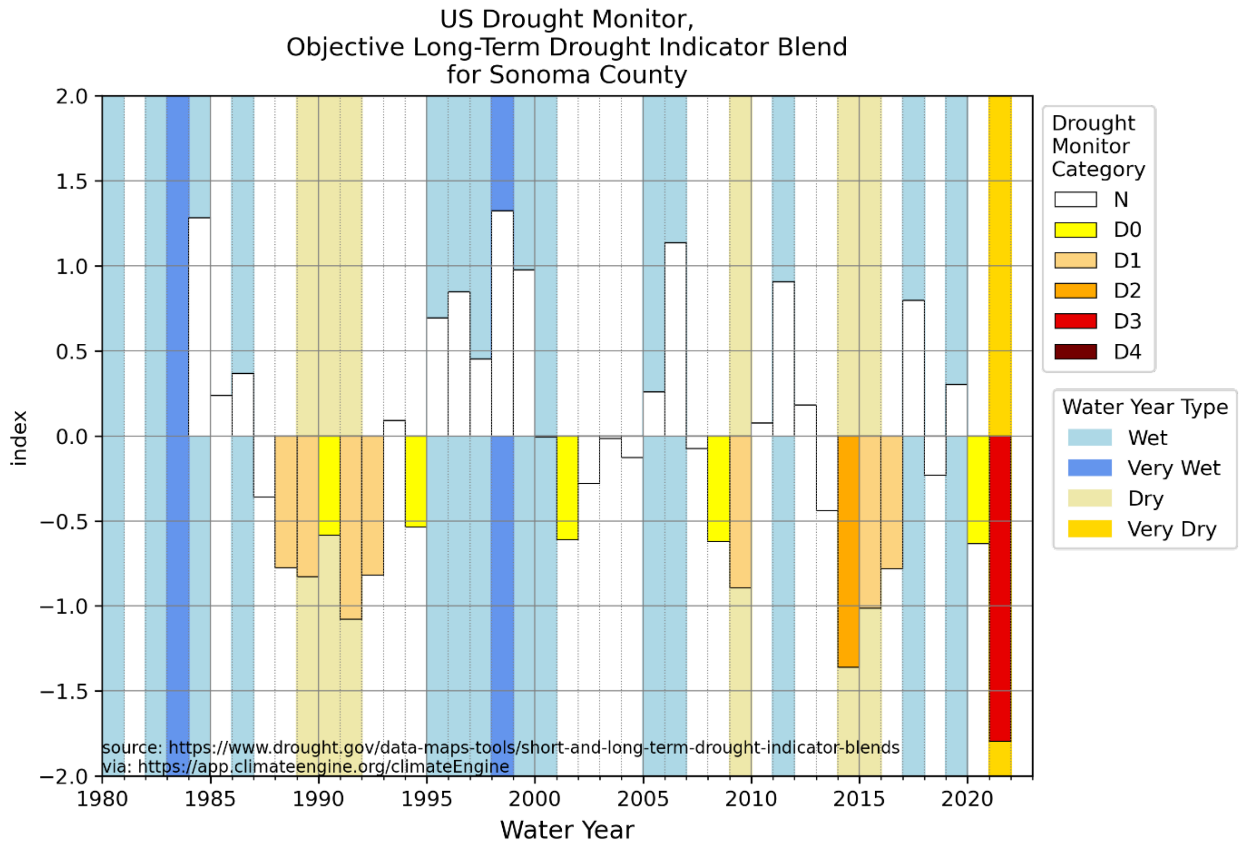
This map approximates impacts responding to precipitation over the course of several months to a few years, such as reservoir content, groundwater, and lake levels. HOWEVER, THE RELATIONSHIP BETWEEN INDICATORS AND WATER SUPPLIES CAN VARY MARKEDLY WITH LOCATION, SEASON, SOURCE, AND MANAGEMENT PRACTICE. Do not interpret this map too literally.

This map is based on preliminary climate division data. Local conditions and/or final data may differ. See the detailed product suite description for more details.

Figure 1 Snapshot of the Objective Long-Term Drought Indicator Blend for April 24, 2021

Approach for Future Drought Conditions

The LTDIB for all of Sonoma County is shown in Figure 2. The values represent the spatially averaged value for the entire county averaged for the entire water year. It should be emphasized that this value is averaged over the entire water year, so that, for example, water year 2021 ends in a D4 drought, but the water year is categorized only as D3 due to yearly averaging. The Water Year types for the three subbasins are also shown for comparison on Figure 2. Years classified as Moderate Drought (D1) will be used as the definition of Drought for the Subbasins. Given this definition there are nine years in the period spanning Water Year 1984 to the end of Water Year 2021 that qualify as drought conditions. In the same period there are 7 years classified as dry or very dry based on the water year type classifications developed by the GSA's. Four of these years are categorized as D1 drought conditions, one of the dry years is classified as D2, and water year 2021 is classified as an extreme dry year. There is good correspondence between the GSA water year type classifications and the LTDIB classifications. It should be noted that these years have not officially been classified as drought or non-drought years by the Drought Monitor.



source: https://www.drought.gov/data-maps-tools/short-and-long-term-drought-indicator-blends
via: https://app.climateengine.org/climateEngine

Figure 2 US Drought Monitor, Objective Long-Term Drought Indicator Blend for Sonoma County

Method of Calculation

The Earth Engine website (https://app.climateengine.org/climateEngine) stores the raw data and also calculates the LTDIB values. The sub-weekly values are averaged over the water year and then categorized based on the LTDIB value. The cutoffs for each classification are detailed in Table 2.

Table 2 Drought categories by LTDIB value

Range	Category
(-2.5, -2.0]	D4
(-2.0, -1.5]	D3
(-1.5, -1.2]	D2
(-1.2, -0.7]	D1
(-0.7, -0.5]	D0
(-0.5, 10.0]	N

Appendix 4-C
Key Themes and Outcomes from Interconnected Surface Water Practitioners Work Group

Sustainable Management Criteria (SMC)
for the Depletion of Interconnected Surface Water (ISW)

Background, Proposed Adaptive Approach, and Key Themes and Outcomes from March 22 Practitioner Work Group Meeting

March 23, 2021

ISW SMC Background

Groundwater Sustainability Agency (GSA) Administrators for the Santa Rosa Plain, Petaluma Valley, and Sonoma Valley Subbasins convened a practitioner work group of experts to assist in the development of the ISW SMC. This document provides a brief overview of ISW SMC components and a recap of key outcomes from the work group's final meeting held on March 22, 2021.

As with other SMCs for Groundwater Sustainability Plans (GSPs) in the three subbasins discussed above, the ISW SMC consists of four *primary* components:

- A Significant and Unreasonable Conditions Statement (S&U) for the Subbasin, which provides the overall goal for the sustainability indicator in terms of conditions which must be avoided to achieve sustainability.
- Minimum Thresholds (MT) at each representative monitoring point which provide numerical targets for unreasonable conditions .
- Measurable Objectives (MO) at each representative monitoring point which provide numerical targets for the desirable conditions to be achieved with implementation of the GSP.
- Undesirable Results (UR), which provide a quantitative description of the combination of MT exceedances that cause significant and unreasonable effects in each subbasin. Avoiding URs is how sustainability is achieved in a subbasin.

Combined, these four components define how groundwater sustainability is achieved in relation to surface water depletion. However, the ISW SMC is unique in that information in the historical record linking surface water depletion directly to groundwater usage under the jurisdiction of the GSAs is very limited. In fact, at a majority of representative monitoring points in the subbasins, only one year of groundwater level data is available. Variable levels of correlation between simulated streamflow depletion and groundwater levels, a lack of existing instream flow targets, and limited data for assessing the presence of any *historically* significant and unreasonable conditions complicate the development of this SMC.[1] To address these data gaps, the GSA technical team propose a tiered adaptive management approach that will provide the information needed to update the SMC during the implementation phase of each of the GSPs, as summarized below.

---

[1] While it is recognized that low summer baseflows in certain years can impact aquatic species, until we know how much water they need to survive and thrive (via instream flow targets), a MT is difficult to determine. The current approach requires using historical data and avoiding conditions lower than historical surface water depletion amounts.

ISW SMC Proposed Adaptive Approach

In recognition of the significant information and data limitations and the importance of interconnected surface water to beneficial users within the Subbasin, potential future studies and activities have been identified and prioritized in coordination with the work group according to relative importance and potential costs. These studies and activities will be further developed and considered for the early implementation phase of the GSP based on available funding sources and future funding and partnership opportunities.

Group 1 (Improves characterization of causes and effects of depletion, lower cost studies, outside funding or leveraged funding opportunities with partners):

- Improve data/information on existing water wells and stream diversions
- Model improvements – focused calibration of surface water and groundwater interaction
- Improve GDE mapping/remote sensing for vegetation health (e.g., NVDI, GDE pulse, etc.)
- Compile and evaluate existing and relevant habitat field surveys
- Evaluate future airborne geophysical data (DWR funded)

Group 2 (Monitoring network improvements, higher cost studies, etc.):

- Additional shallow monitoring wells and stream gauges
- Focused geophysical studies
- Geomorphic and streambed conductivity assessments
- Additional focused habitat field mapping, as needed

In the meantime, an initial SMC must be developed and include the components above based on simulated data and the best available historical information that will be updated and, where appropriate, refined with actual observed data during the implementation phase. The general procedure for developing the initial SMC involves:

1. Use of groundwater-levels measured at shallow monitoring wells near streams (representative monitoring points [RMPS]) as a proxy for surface water depletion[2]
2. Use model to estimate years with highest levels of simulated streamflow depletion (20th percentile) between 2004 and 2018
3. Calculate percentile ranking of simulated dry-season groundwater levels associated with these years
4. Set initial MTs at this percentile ranking using available datasets for wells measured near RMPs
5. Set initial MO as mean of dry season measured groundwater-levels from historical record

The initial proposed S&U, MT, MO, and UR are as follows and will be refined through discussions with Advisory Committees in each of the three subbasins:

---

[2] Use of groundwater-levels as a proxy for surface water depletion focuses the SMC on conditions the GSA has authority to manage (i.e., groundwater conditions within the Subbasin)

- S&U Statement[3]: Significant and unreasonable depletion of surface water from interconnected streams occurs when surface water depletion, caused by groundwater pumping within the Basin/Subbasin, exceeds historical depletion or adversely impacts the viability of groundwater dependent ecosystems (GDEs) or other beneficial users of surface water.
- MT: The equivalent groundwater-level, representing the three years (2014-2016) during which the most surface water depletion due to groundwater pumping was estimated between 2004-2018. This is the number that serves as an indicator for the potential presence of undesirable results.
- MO: The mean groundwater level for any available dry-season observations during 2004–2020.
- UR: Options for consideration in determining undesirable results include:
    - 25% of RMPs (2 wells)
    - 25% of RMPs (2 wells) for 2 consecutive years
    - 25% of RMPs (2 wells) during drought years and 10% of RMPs (1 well) during non-drought years
    - 40% of RMPs (3 wells) during drought years and 10% of RMPs (1 well) during non-drought years

Prior to determining if undesirable results are occurring based on MT exceedances, the GSA would need to assess whether potential causes of exceedances are related to depletions associated with groundwater pumping or other activities not under the jurisdiction of the GSA

---

[3] Important definitions related to the S&U statement include:
- "groundwater pumping" excludes any diversions by surface water rights holders
- "historical depletion" estimated as simulated surface water depletion caused by groundwater pumping as informed by available historical measured data (2004-2018 for the Santa Rosa Plain)
- "groundwater dependent ecosystems" includes aquatic species and vegetation, as defined in Basin Setting
- "other beneficial users of surface water" include surface water rights holders and recreational uses (where applicable)

Key Themes and Outcomes from March 22 Work Group Meeting

Practitioner Work Group Members:

- Sam Boland-Brien, State Water Resources Control Board (SWRCB)
- Maurice Hall, Environmental Defense Fund (EDF)
- Jessie Maxfield, CA Department of Fish and Wildlife (CDFW)
- Andrew Renshaw, CA Department of Water Resources (DWR)
- Rick Rogers, National Marine Fisheries Service (NMFS)
- Melissa Rohde, The Nature Conservancy (TNC)
- Natalie Stork, SWRCB
- Val Zimmer, SWRCB

Data Gaps and Adaptive Management Approach (from March 22 Work Group meeting):

- Staff acknowledge a range of data gaps for the ISW SMC and recommend an adaptive management approach based on further study and increased monitoring during the implementation phase of GSPs for the Santa Rosa Plain, Petaluma Valley, and Sonoma Valley Subbasins.
- Practitioner Work Group members were highly supportive of the proposed adaptive management approach and recognized the significant data gaps due to a short period of record for RMPs in the Subbasins. Multiple participants acknowledged Sonoma Water is at the forefront of developing science around the ISW SMC.
- Suggested opportunities for future studies and partnerships to fill data gaps include:
    - CDFW Fisheries Restoration and Habitat Restoration Grant Programs may provide opportunities for future monitoring or studies.
    - GSAs will not be able to fund all necessary studies during the first 5 year update to the GSPs. Developing more information and monitoring on wells and surface water diversions should be the first priority.
    - Partnership with local academia, neighboring GSAs, and groups such as the Association of California Water Agencies (ACWA) could provide additional resources for studies, projects, and increased monitoring.
    - CDFW recommends increased analysis on the potential impact of cannabis cultivation for surface and groundwater levels as part of the Sonoma County Cannabis Land Use Ordinance Update and General Plan Amendment (Update). Partnership opportunities with CDFW and local jurisdictions may be available in relation to the Update.

Comments on approach and setting of MTs, MO, and URs (from March 22 Work Group meeting):

- Staff presented proposed MT/MO and UR options for consideration.
- Practitioner Work Group members generally agreed with the approach for developing the SMC, based on a thorough modeling analysis.
- Two primary suggestions were provided by Work Group members:
    - Using water years from 2014-2016 to set MTs could be problematic as these occurred during a historic drought. MTs based on these water years may not be protective of beneficial uses, most notably the health of aquatic species.

    - For additional context on general streamflows, staff could consider providing the actual magnitude (in cfs) of flows *in addition* to the current relative percentages of depletion. Additionally, URs could be linked to the severity of MT exceedances to provide a sliding scale [for project/action implementation]

Materials from
Practitioner Working Group Meetings for Interconnected Surface Water and Groundwater Dependent Ecosystems

SMC for Depletion of Interconnected Surface Water

Wednesday, October 7, 2020

Meeting Notes

Contact: Sam Magill, Practitioner Work Group Facilitator

Welcome and Work Group Purpose

Jay Jasperse, Sonoma Water welcomed the attendees and thanked them for their time and willingness to participate in the work group. Jasperse provided a brief overview of the work group structure.

Agenda Review and Work Group Introductions

Sam Magill, Work Group Facilitator walked through the agenda and meeting protocol before suggesting a round of introductions.

Work Group Background

Jay Jasperse presented the focus of the workgroup meetings. This group will assess options for developing Sustainable Management Criteria (SMC) for depletion of interconnected surface water due to groundwater pumping. The GSA technical staff will use the input from this subgroup to develop a recommended SMC methodology. Jasperse then provided a quick overview of Sustainable Management Criteria including the six indicators and key terms, followed by the role of the workgroup, Advisory Committee and Board. He covered key challenges (technical complexities, data and information limitations, surface water rights) for surface water depletion Sustainable Management Criteria.

Marcus Trotta, Sonoma Water gave an overview of the basin setting and groundwater conditions in the three basins followed by and integrated model overview for each basin.

Questions/Comments

Maurice Hall (chat) – Are there any areas where issues have or are arising from groundwater levels that are too high, e.g. flooding basements, saturated soils, etc.?

> Trotta – I am not aware of reported serious problems with shallow groundwater conditions. I know there are areas of shallow groundwater that can cause problems for construction. There are reports of agricultural drains in some of the basins, but we don't have good mapping/documentation of where they are in the basins.

Sam Boland-Brien – I am wondering – at the GSA Board level, what is their appetite for this topic and their interest level, and where does it fit in their priorities?

> Jasperse – It is a mixed bag. The three GSA Boards are made up of different interests and there are a variety of perspectives. We haven't discussed this topic too much with the Board yet so there hasn't been a great opportunity to provide detailed comments yet.