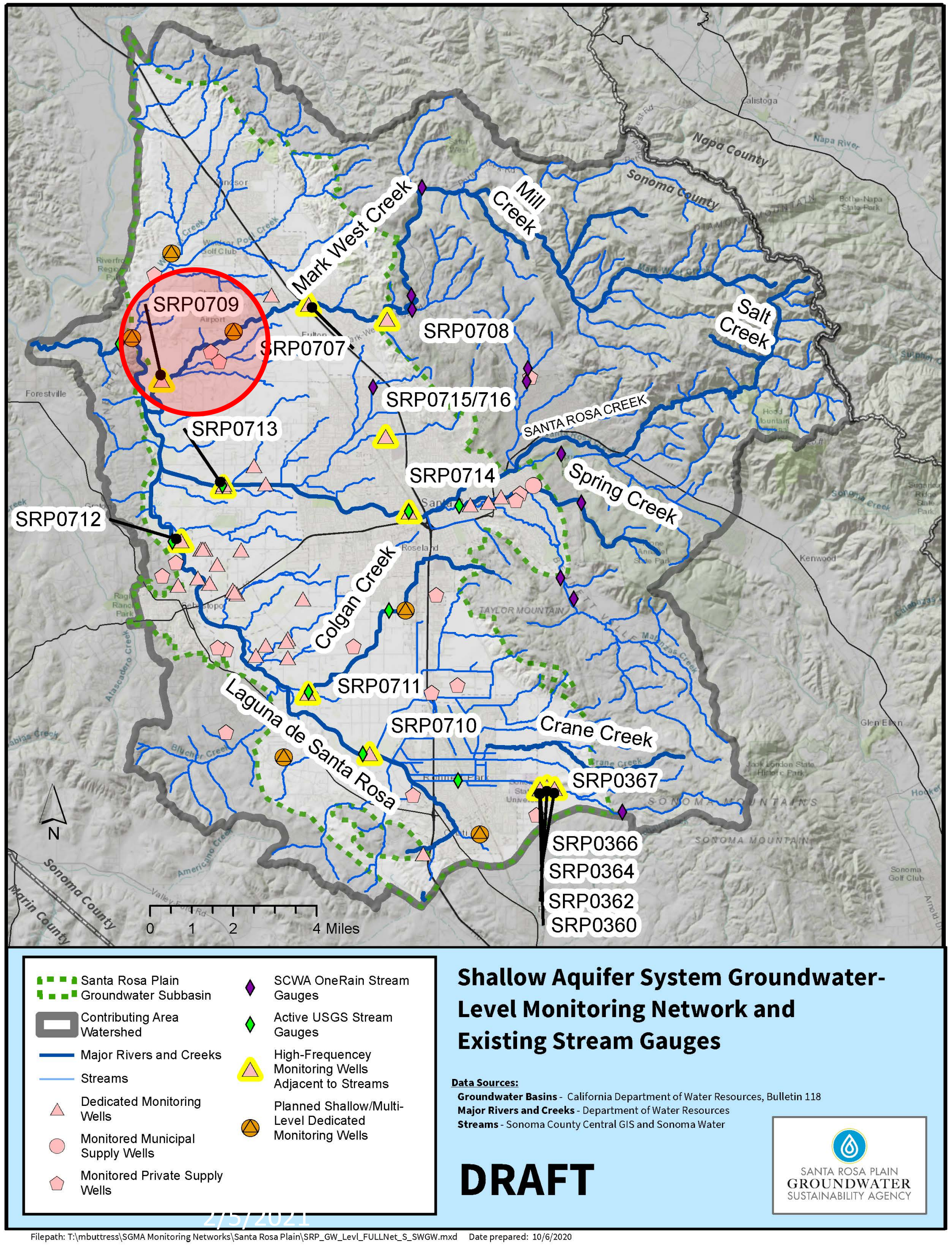
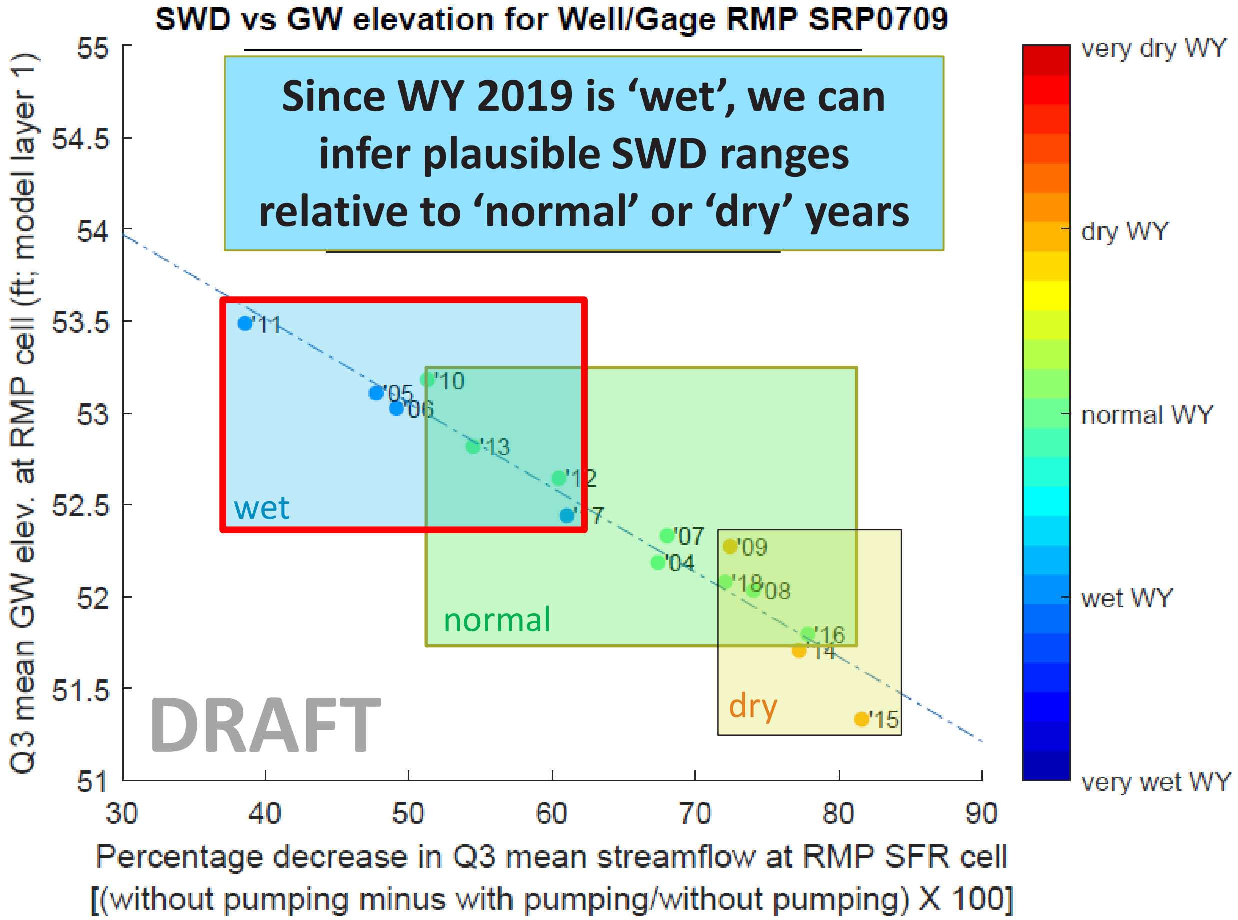
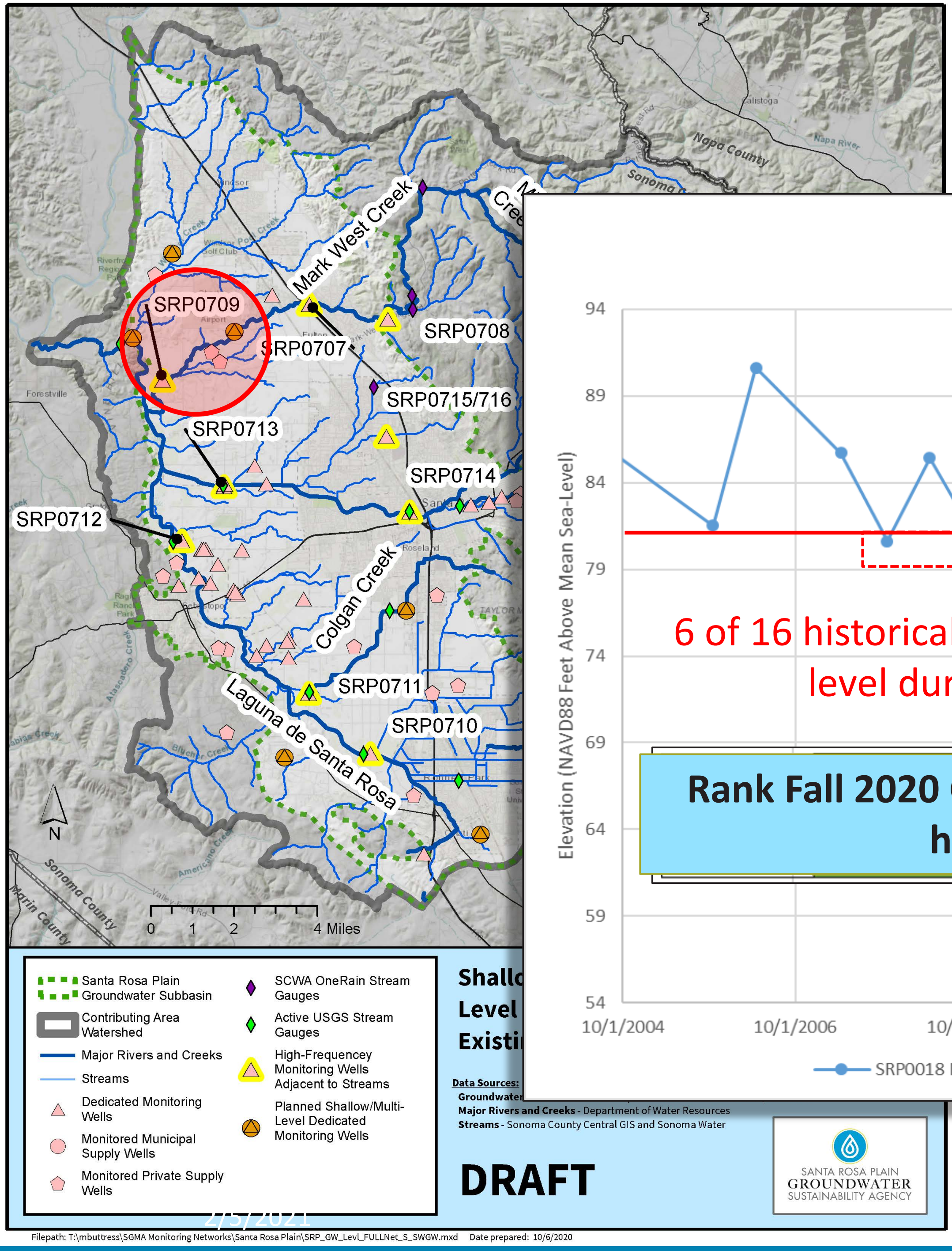
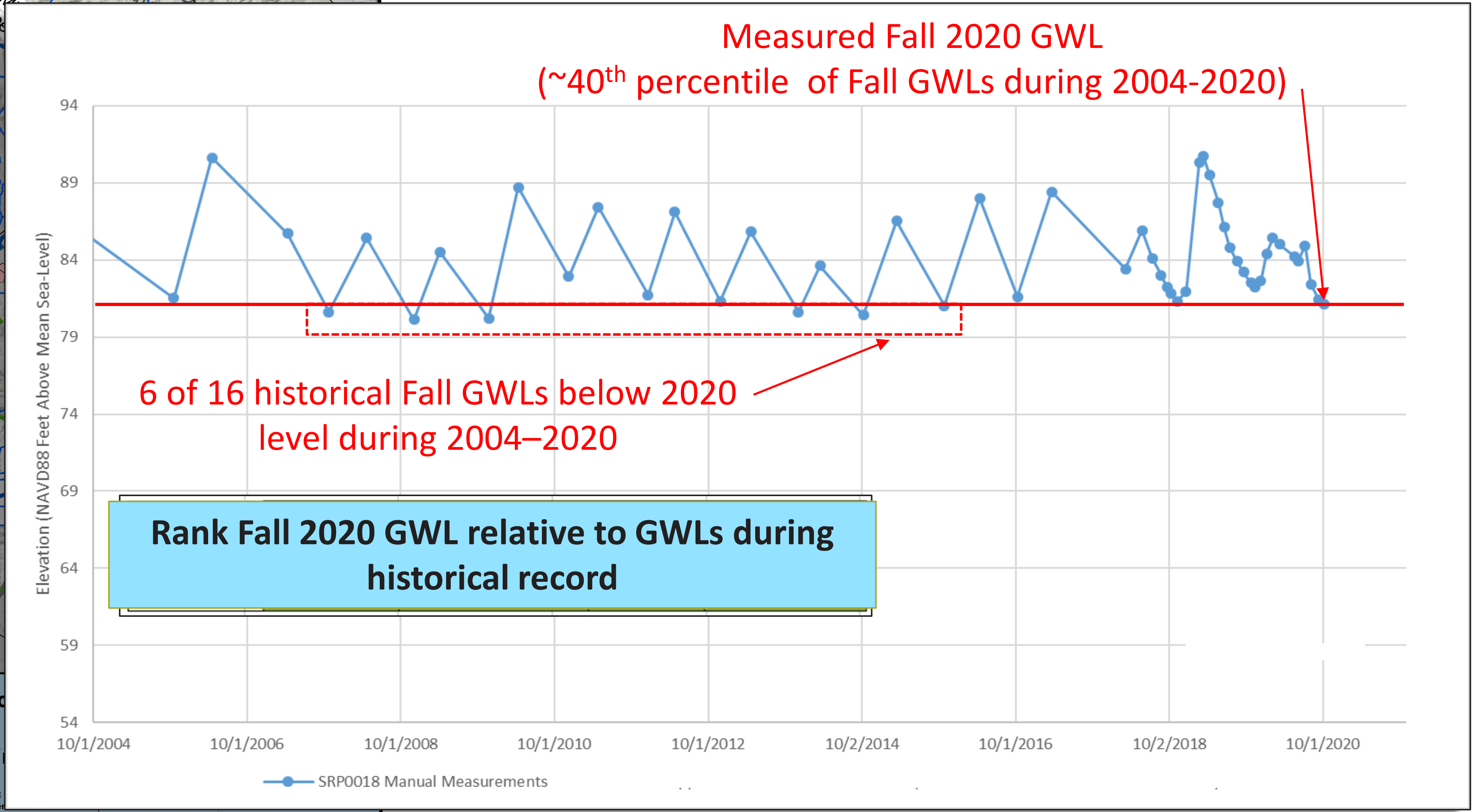
# How do we use model results to characterize SWD from measurements? — Example: WY 2019



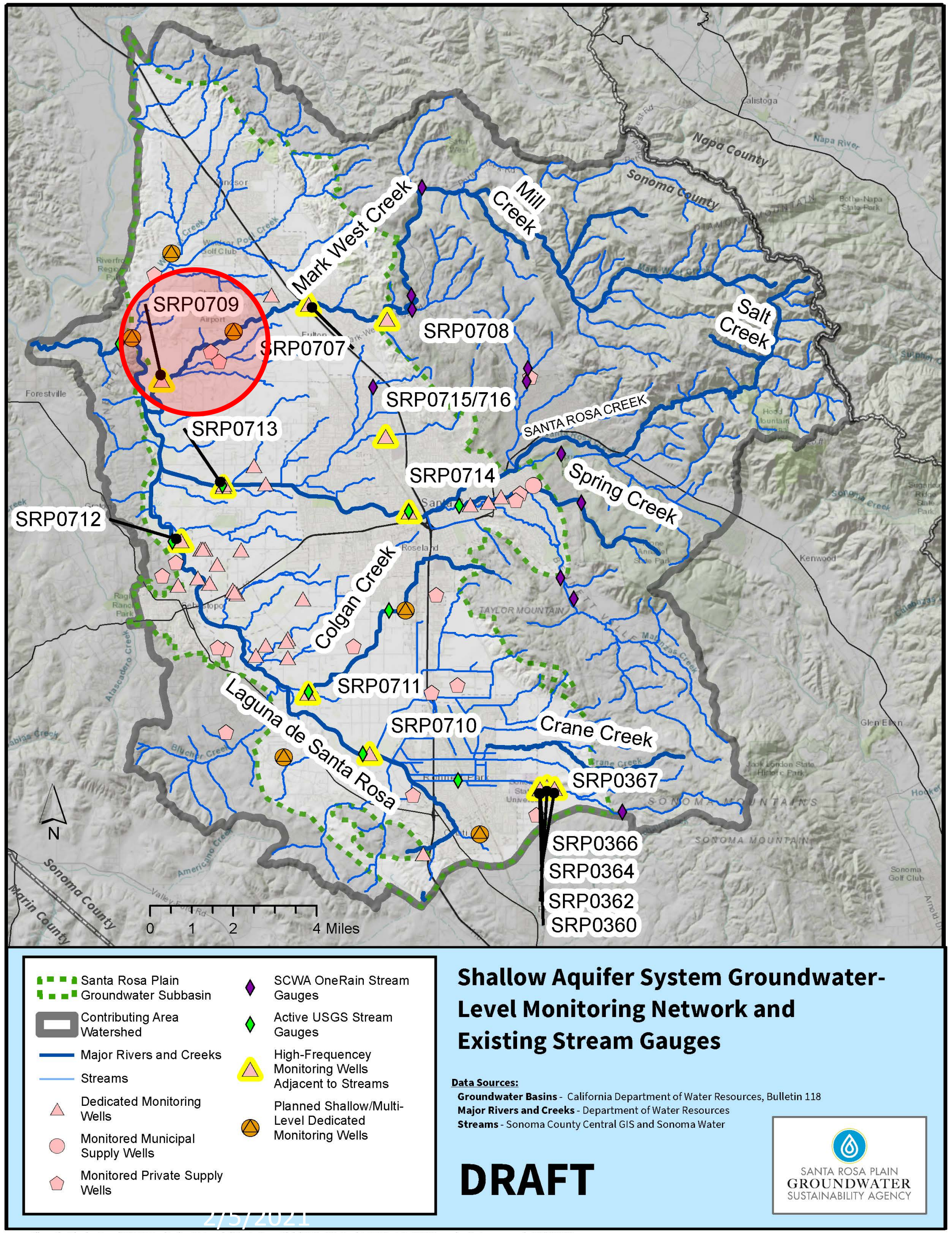



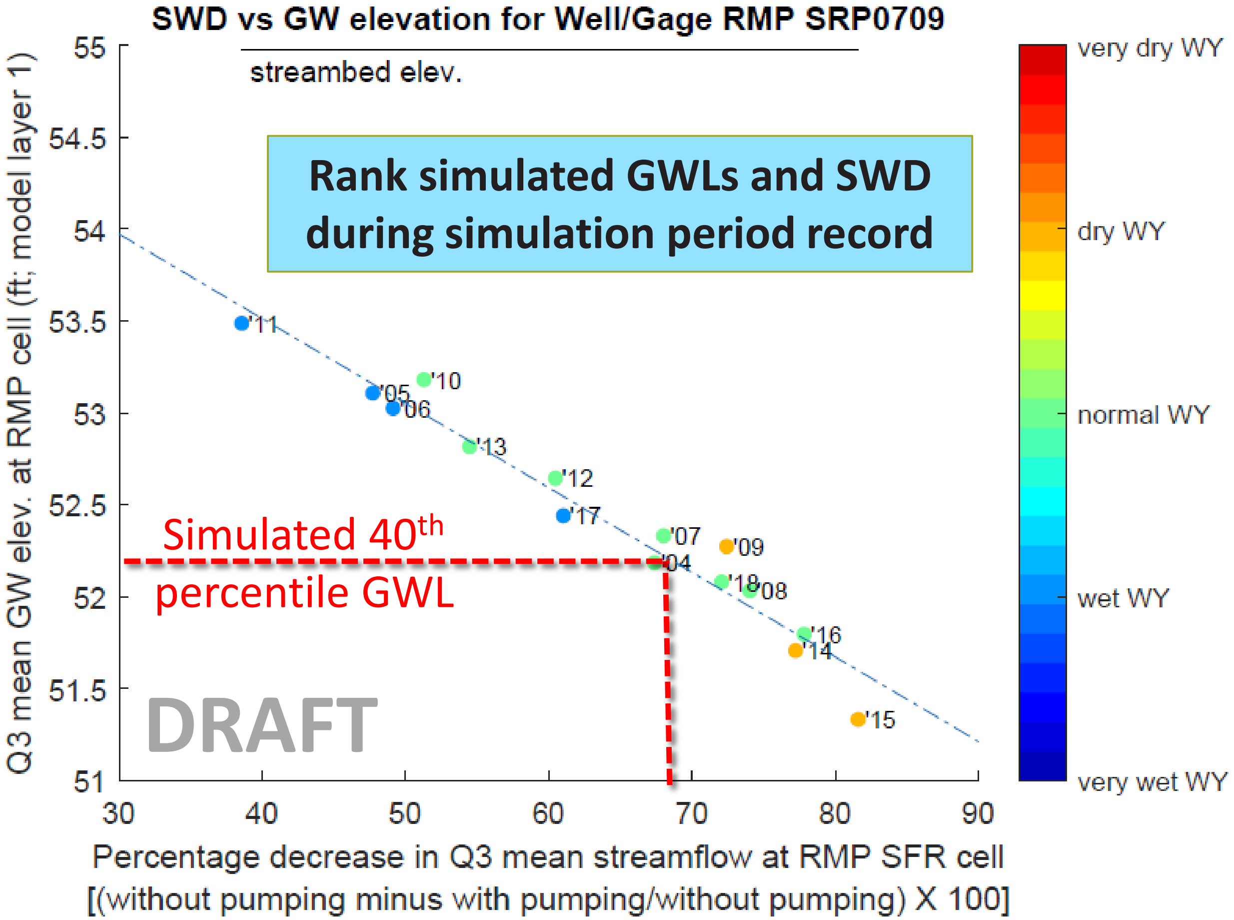
# How do we use model results to characterize SWD from measurements? — Example: Fall 2020 GWL

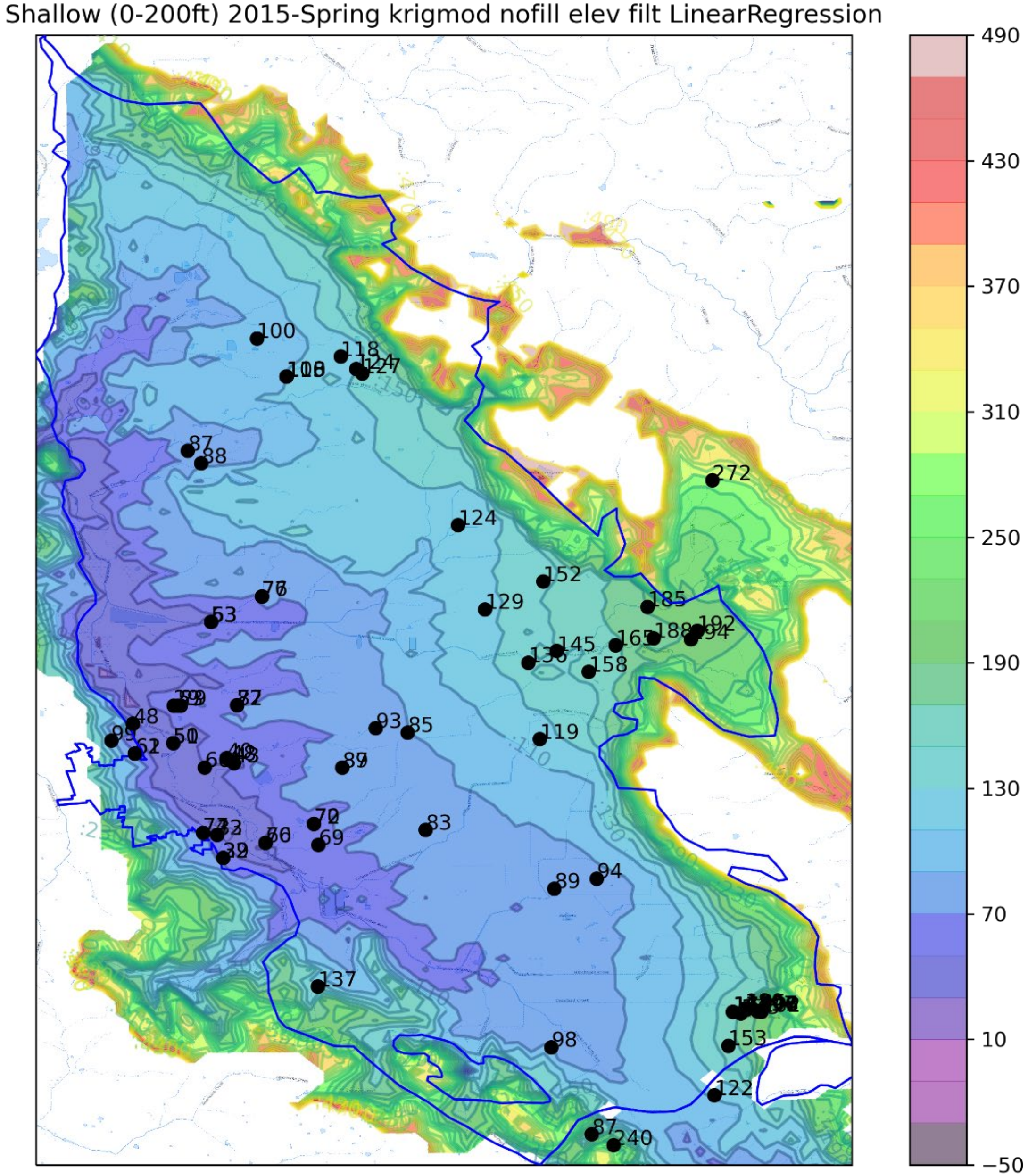


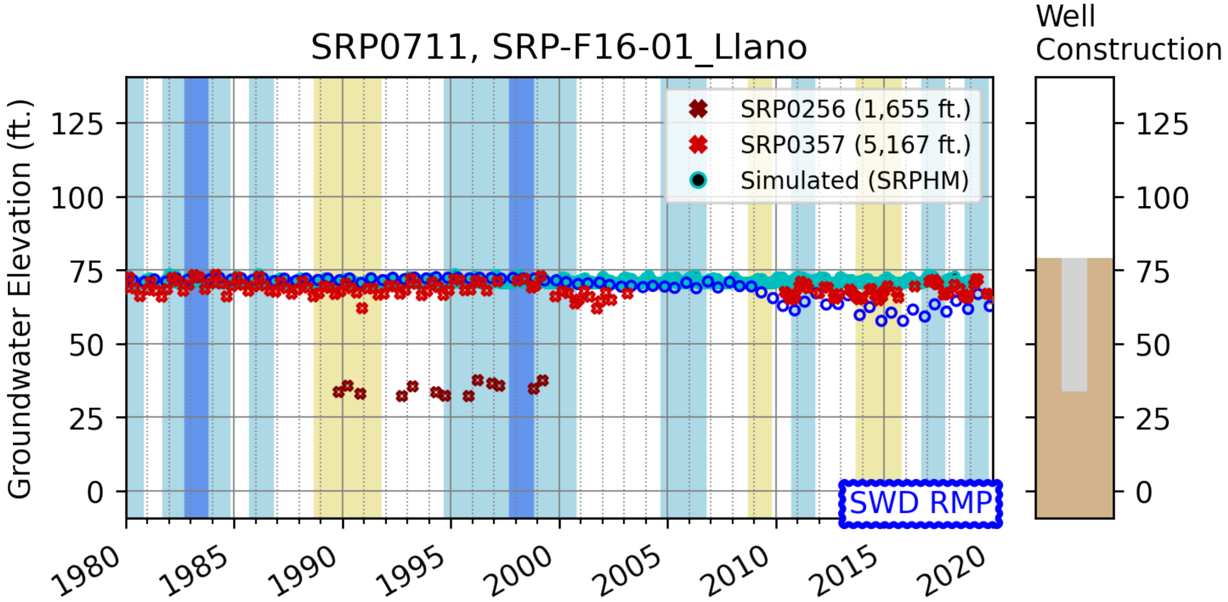
# How do we use model results to characterize SWD from measurements? — Example: Fall 2020 GWL



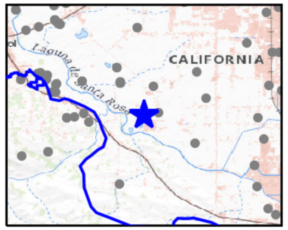






# Machine learning techniques can leverage historical GWLs to generate historical GWL hydrographs at RMP locations

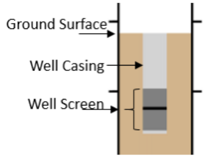



Location




Well Depth: 45.5 ft
Well Depth Category: Other
Groundwater Basin: SANTA ROSA VALLEY - SANTA ROSA PLAIN
Screened Intervals:
Elevation: 79 ft
Vertical Coordinates: Survey_ElevNAD88

Well Construction Legend



# Surface Water Depletion Methodology Options

Technical staff evaluated a number of different options:

- Historical method (eg, 2015 or other historical conditions)
- Straight Surface water depletions thresholds (percentage discharge)
- Surface water depletions thresholds based on summertime threshold (discharge)
- Surface depletion impacts on streamflow (discharge)

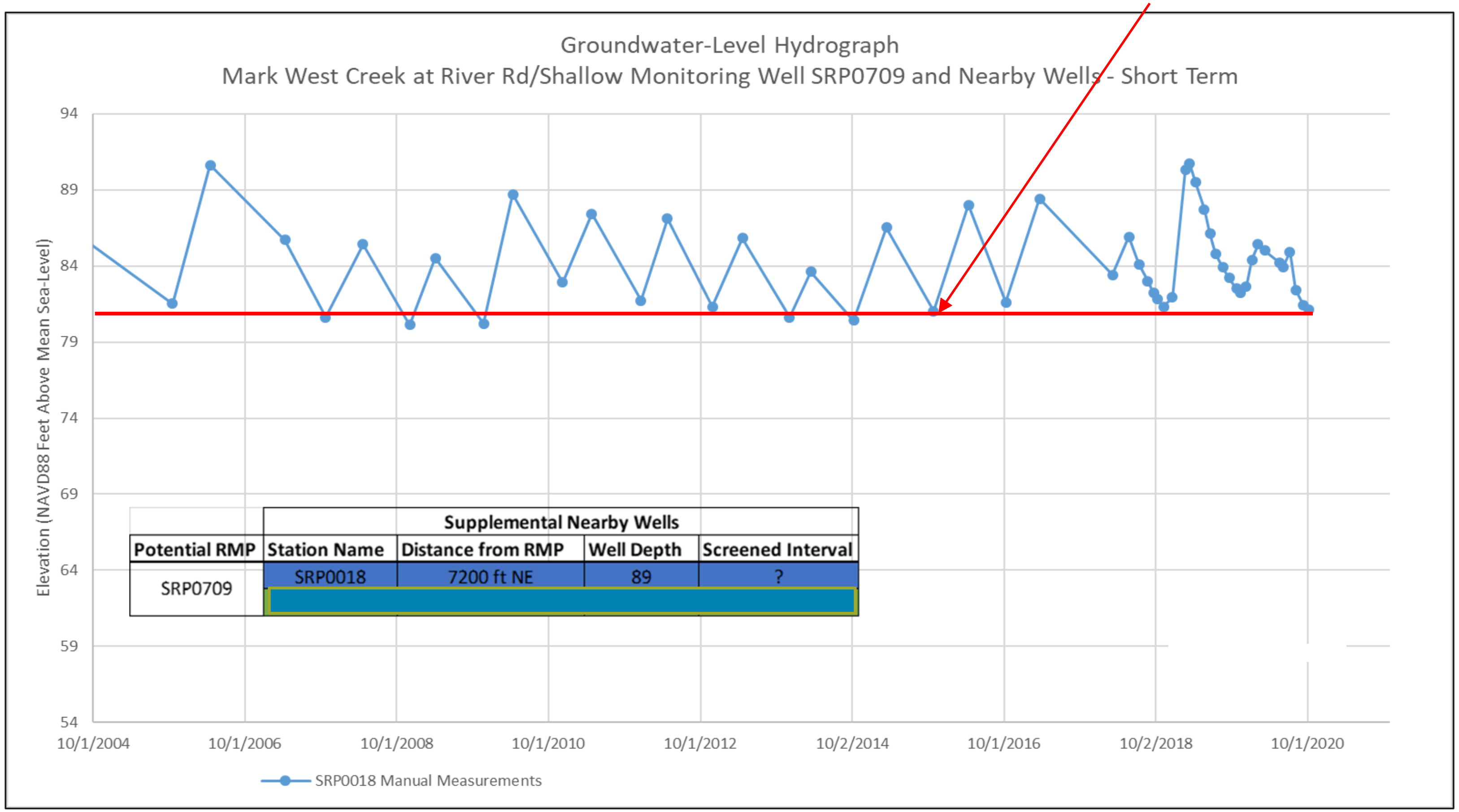
Paired down to two options for consideration today:

1. Fall 2015 GWL as Minimum Threshold
2. SWD Threshold (percentage of discharge) as Minimum Threshold

# Surface Water Depletion SMC Strawman Options

1. Fall 2015 GWLs as Minimum Threshold

Measured 2015 Fall GWL



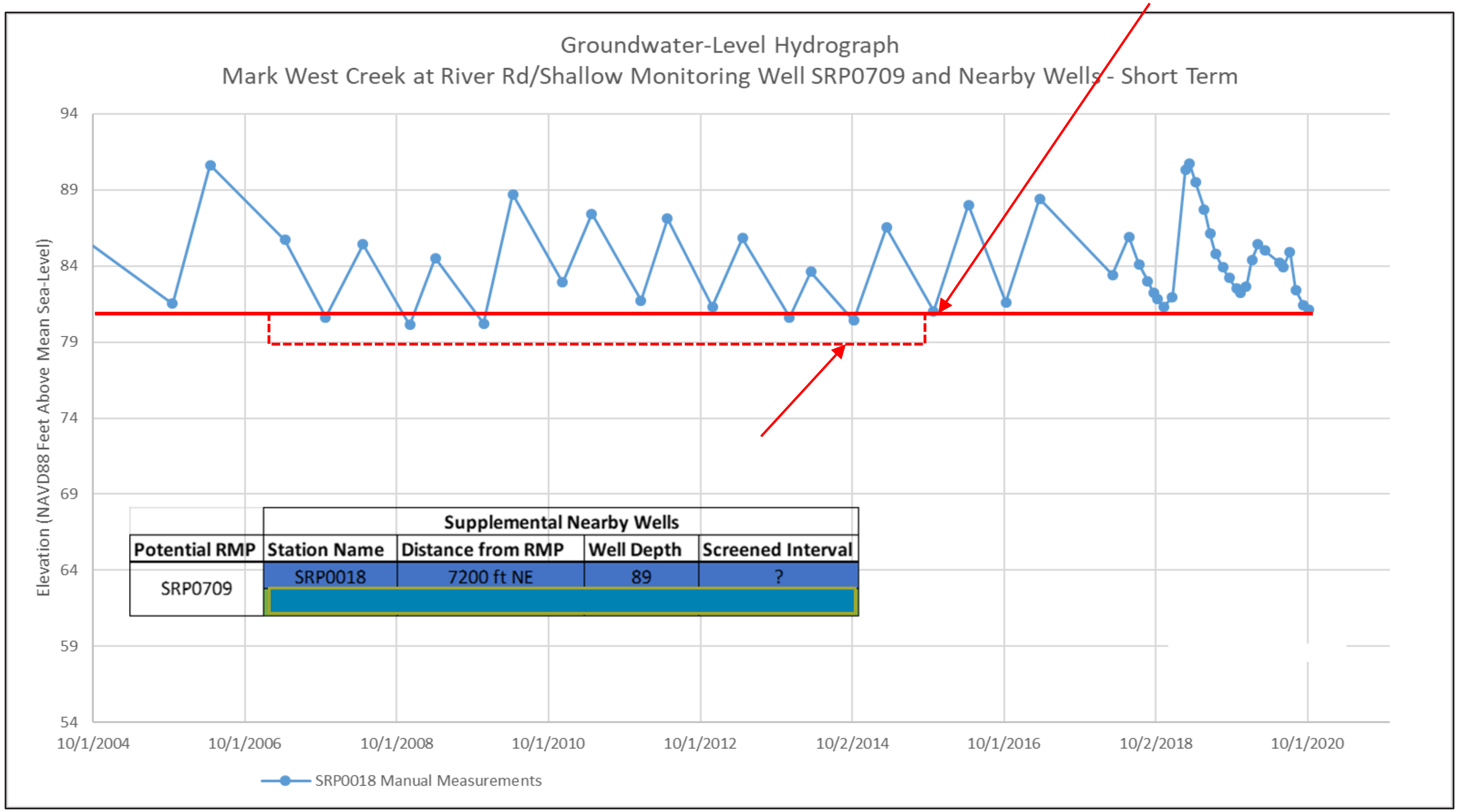

| | Supplemental Nearby Wells | | | |
|---|---|---|---|---|
| Potential RMP | Station Name | Distance from RMP | Well Depth | Screened Interval |
| SRP0709 | SRP0018 | 7200 ft NE | 89 | ? |

# Surface Water Depletion SMC Strawman Options

## 1. Fall 2015 GWLs as Minimum Threshold

**Set SMC based on GWL, use relationship to infer SWD impact**

Measured 2015 Fall GWL (~30th percentile during 2004-2020)




| | Supplemental Nearby Wells | | | |
|---|---|---|---|---|
| Potential RMP | Station Name | Distance from RMP | Well Depth | Screened Interval |
| SRP0709 | SRP0018 | 7200 ft NE | 89 | ? |

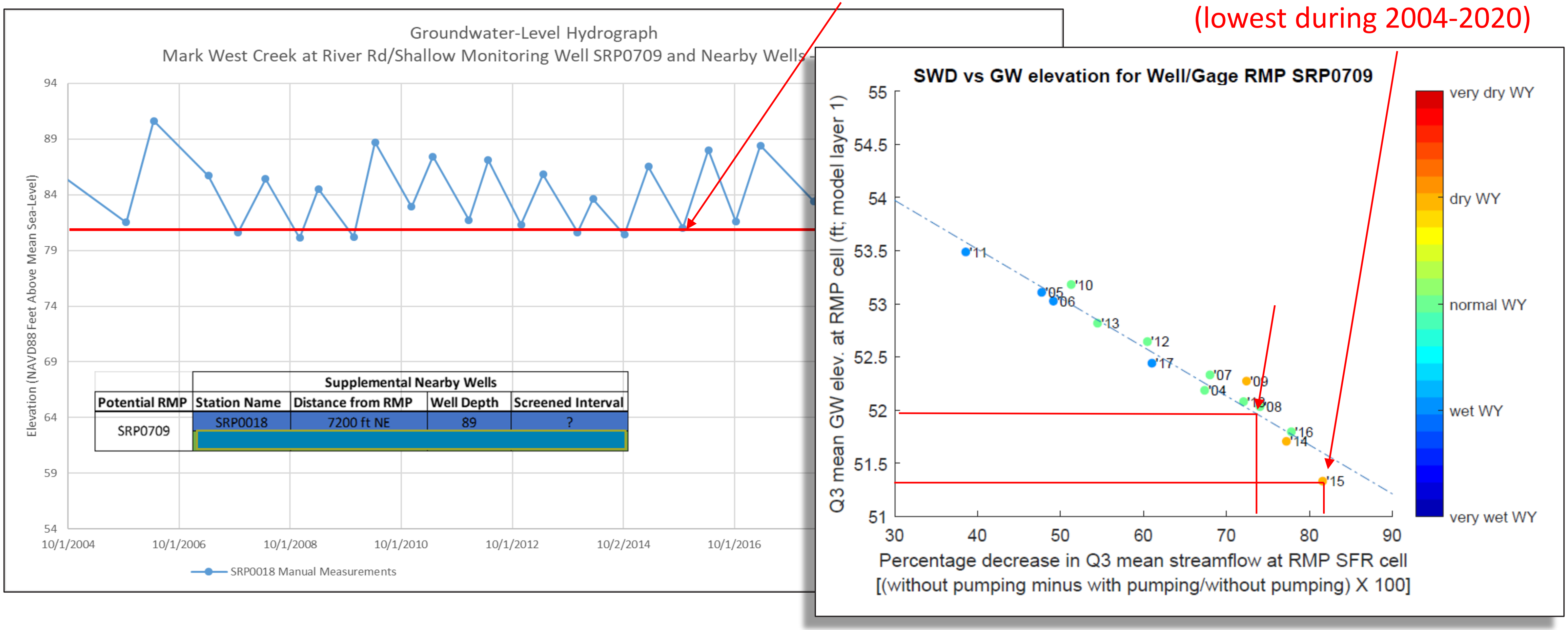
# Surface Water Depletion SMC Strawman Options

## 1. Fall 2015 GWLs as Minimum Threshold

**Set SMC based on GWL, use relationship to infer SWD impact**

Measured 2015 Fall GWL (~30th percentile during 2004-2020)

Simulated 2015 Q3 GWL (lowest during 2004-2020)




| Potential RMP | Supplemental Nearby Wells | | | |
|---|---|---|---|---|
| | Station Name | Distance from RMP | Well Depth | Screened Interval |
| SRP0709 | SRP0018 | 7200 ft NE | 89 | ? |

# Surface Water Depletion SMC Strawman Options … Pros/Cons

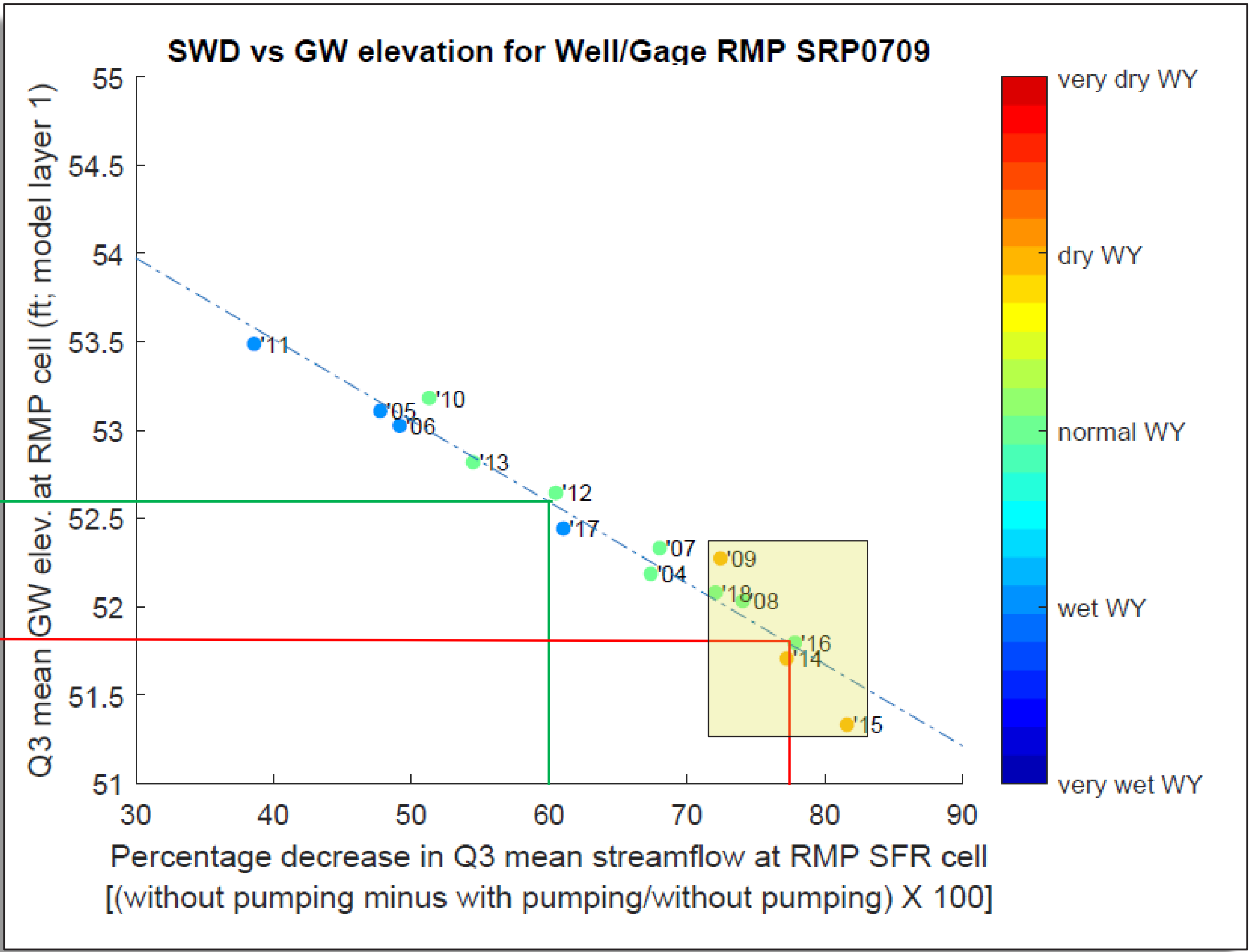
## 2. SWD Threshold (percentage of discharge) as Minimum Threshold

**Use relationship to determine GWL proxy for SWD threshold.**

**… Requires very high confidence in model results**

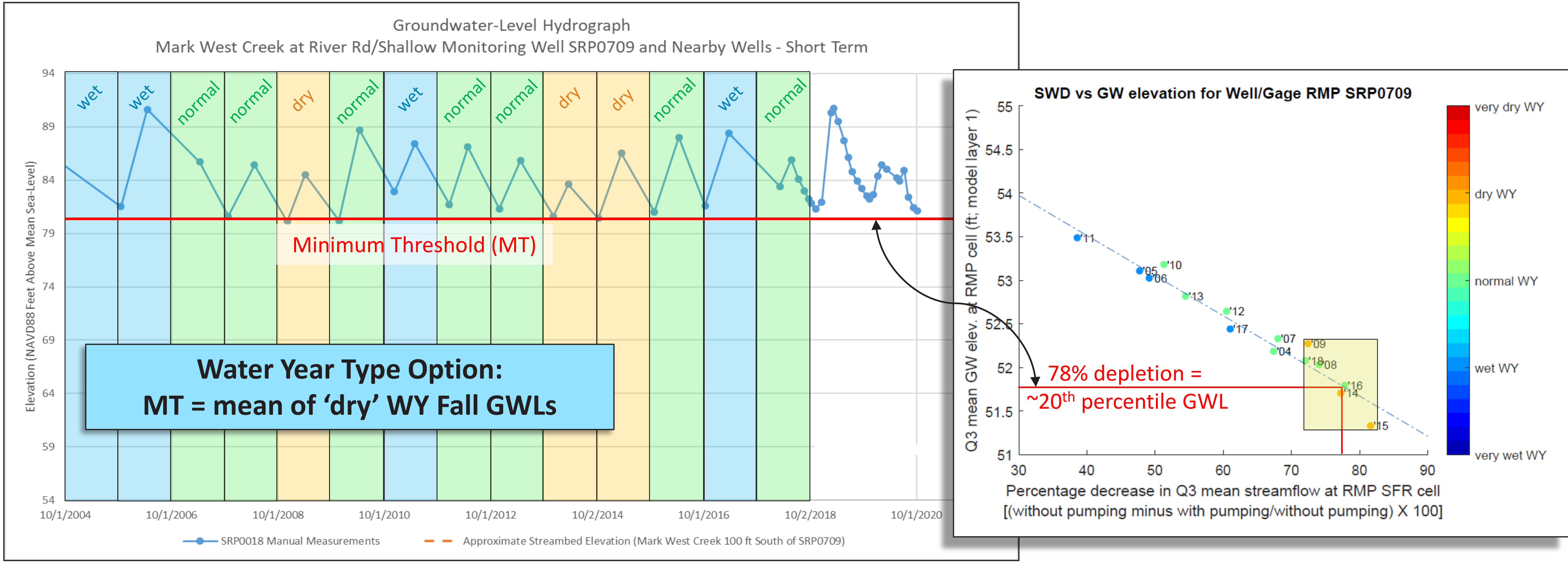
**Example measurable objective (MO) =**
No more than mean depletion during ’04–’18
i.e., 60% during Jul/Aug/Sep (Q3)

**Example minimum threshold (MT) =**
Goal of no more than ~78% depletion during Jul/Aug/Sep (Q3): Mean depletion during dry years.



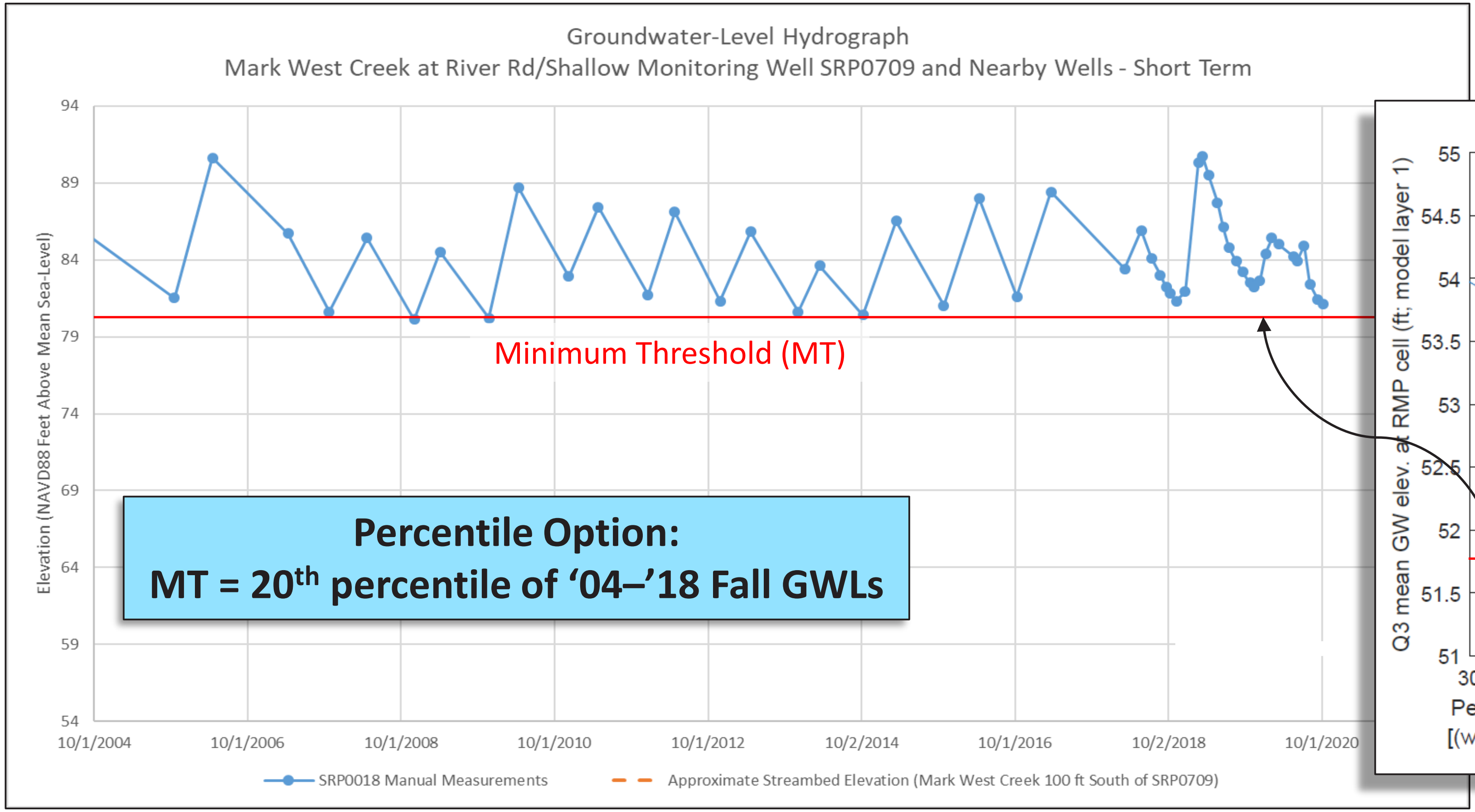
# Surface Water Depletion SMC Strawman Options … Pros/Cons

## 2. SWD Threshold (percentage of discharge) as Minimum Threshold

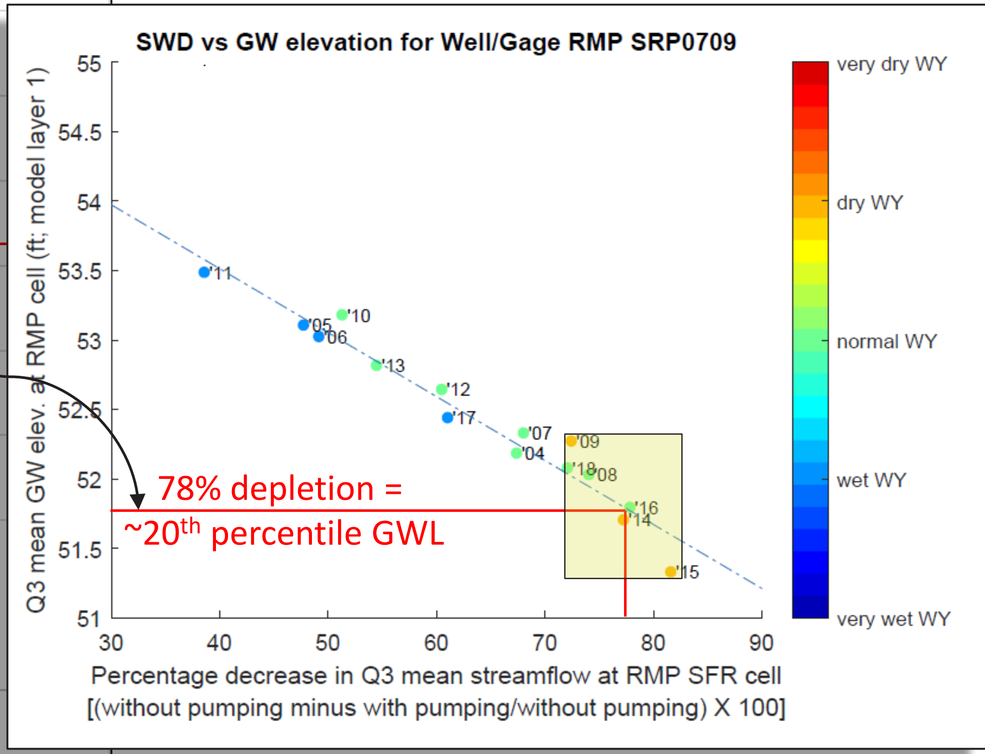


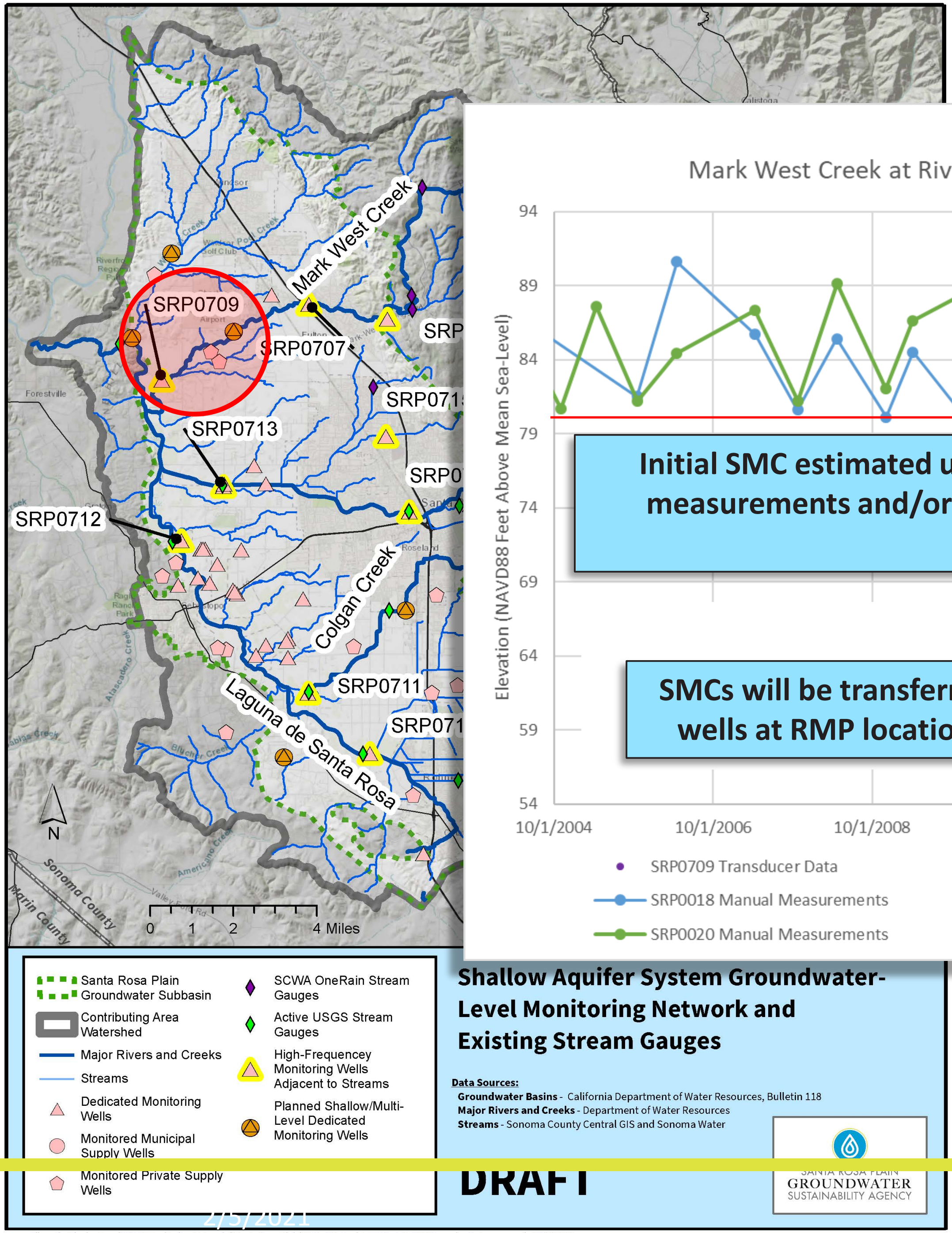
# Surface Water Depletion SMC Strawman Options … Pros/Cons

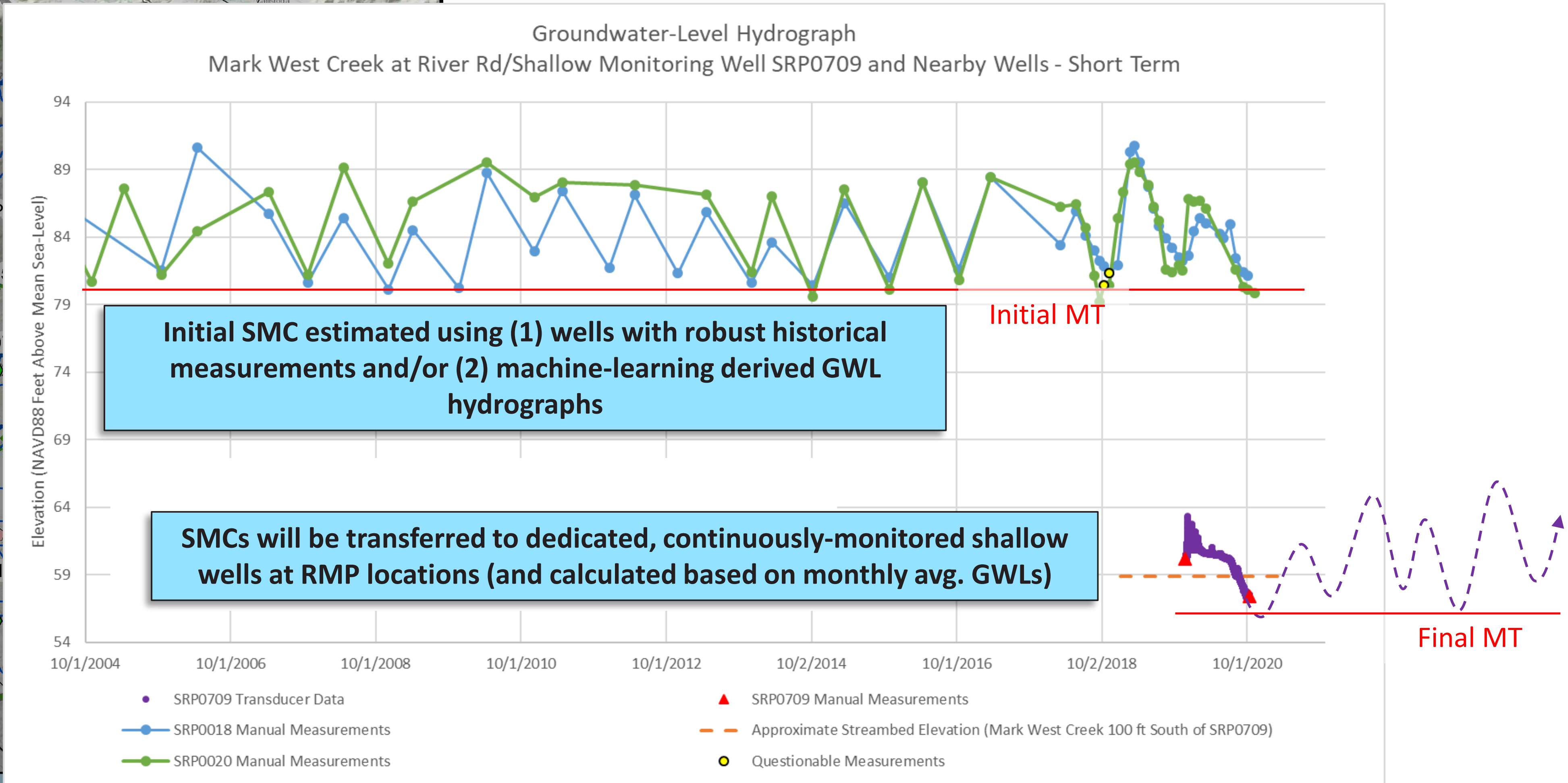
## 2. SWD Threshold (percentage of discharge) as Minimum Threshold




**Percentile Option:**
**MT = 20th percentile of '04–'18 Fall GWLs**






**Initial SMC estimated using (1) wells with robust historical measurements and/or (2) machine-learning derived GWL hydrographs**

**SMCs will be transferred to dedicated, continuously-monitored shallow wells at RMP locations (and calculated based on monthly avg. GWLs)**

# Surface Water Depletion SMC Strawman … Two Examples … Pros/Cons

1. Fall 2015 GWL as Minimum Threshold
2. SWD Threshold (percentage of discharge) as Minimum Threshold

| Criteria | Fall 2015 GWLs | SWD Thresholds (percentage of discharge) |
|---|---|---|
| **Reliance on simulated data** | Medium/Low | High (simulated depletion + discharge) |
| **Relevance to Potential Beneficial User Impacts** | Low | Medium/High |
| **Pros** | Indirectly supported by regulations | Emphasizes lower flows, good correlation w/ modeled heads in SRPHM. More easily tied to Undesirable Results |
| **Cons** | No established relationship with SWD, inflexible, some locations with no data | No established relationship with GDEs; not a depletion volume |
| **Adaptable to future knowledge, instream flow thresholds** | No | Yes |
| **Simplicity/Communication** | Easy to communicate/Estimate | Moderately easy to communicate/Estimate |
| **Arbitrary?** | Low | Currently High |

# Questions/Discussion/Work Group Input

# Initial Discussion of Possible Options for Undesirable Results

**Undesirable Result**: *Quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the Basin/Subbasin.*

Goal is to provide options for the GSA Board to consider for determining Undesirable Results:

1. Some percentage of MT exceedances (eg, 25% of RMPs, etc.)
2. Multiple years of MT exceedances (eg, 2 consecutive years)
3. Some combination of 1 and 2
4. Other ideas?

*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 related to surface water rights. Developing a description of this assessment in coordination with SWRCB.*

# Data Gaps and Future Recommended Activities

# Initial List of Data Gaps and Future Recommended Activities

- Informational Data Gaps:
  - Location, completion details and pumping estimates for existing water wells (particularly near streams)
  - Type, location and rates of permitted surface water diversions (including any diversions made through wells)
- Monitoring Needs:
  - Additional shallow monitoring wells in data gap areas and near existing RMPs to better assess hydraulic gradients and potential causes of depletion
  - Additional streamflow gauges and/or routine seepage measurements to better evaluate spatial and temporal gaining/losing conditions
- Modeling Improvements:
  - Improve ability of models to accurately simulate shallow aquifer system groundwater levels and surface water/groundwater interaction: incorporate data that will be collected from new shallow monitoring wells and other studies/monitoring conducted during initial GSP implementation period
- Others?

# Next Steps in Developing SMC for Depletion of Interconnected Surface Water

1. Complete GDE and ISW mapping
2. Further evaluate potential RMP networks
3. Develop draft SMC at each proposed RMP for all three basins based on potential methodology
4. Develop options for Undesirable Result determination
5. Develop narrative for GSP SMC section

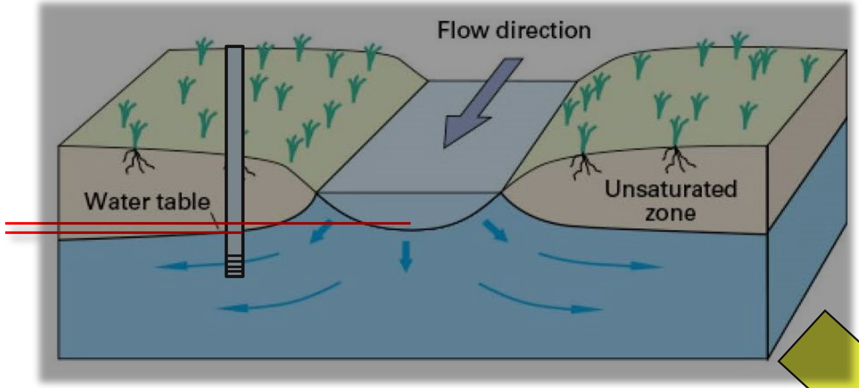
SANTA ROSA PLAIN
GROUNDWATER
SUSTAINABILITY AGENCY

# SW Depletion SMC Development

STEPHEN MAPLES

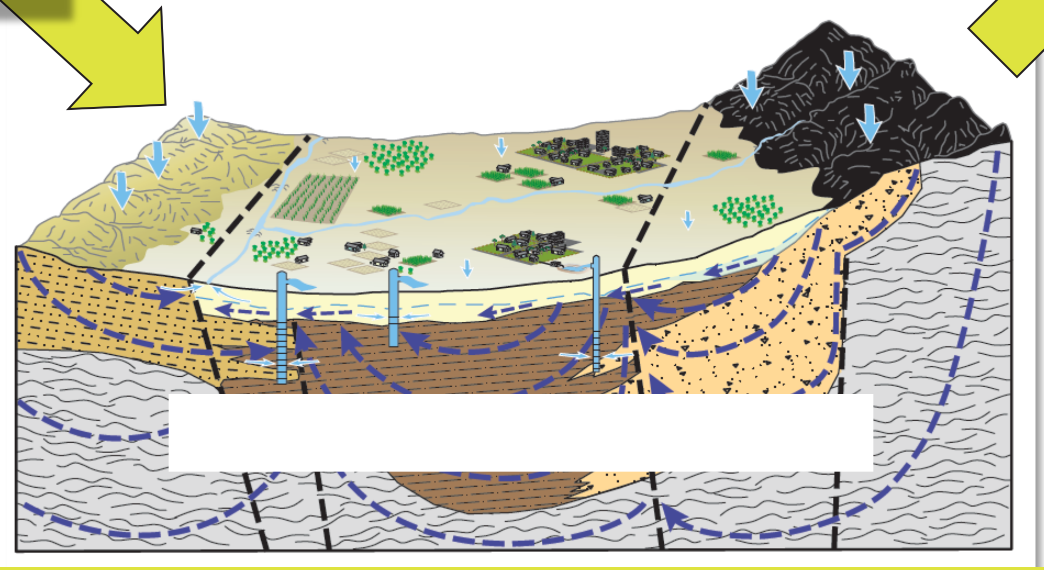
12/09/2020 UPDATE

# How can we leverage measurements and models to characterize GW/SW interactions and SW depletion?

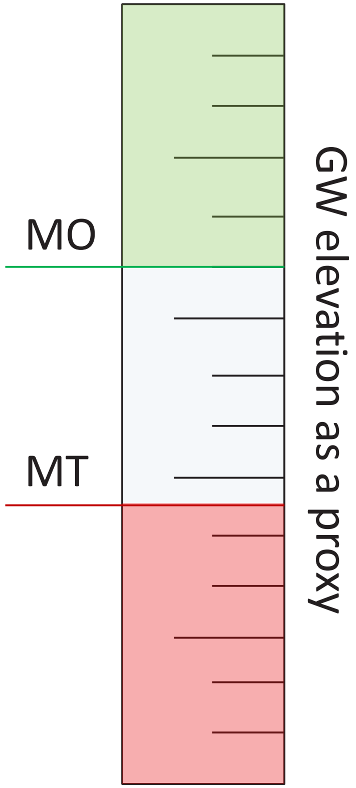



**Local** GW elevation
(measured/simulated)

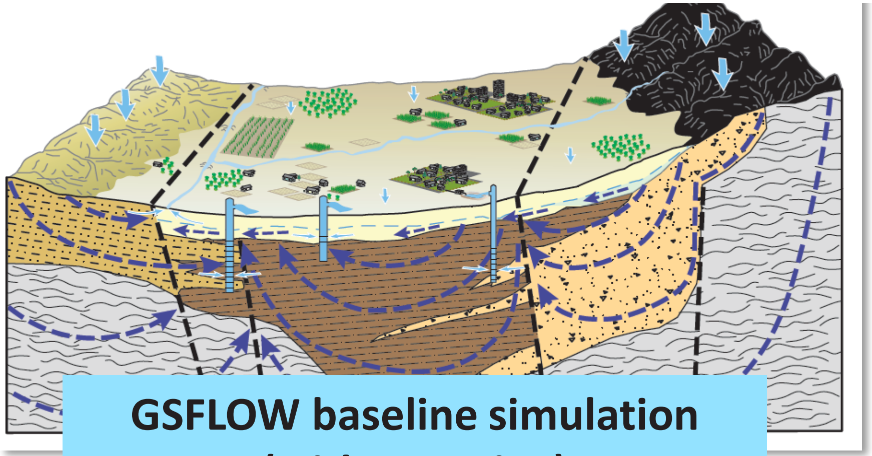
**Regional** SW depletion
characterization (simulated)



**SMCs are tied to GW elevations and informed by simulation results**

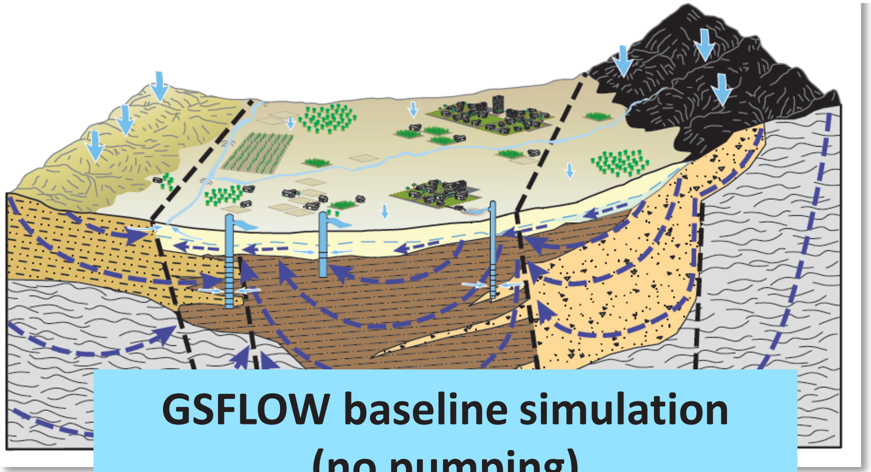


# Isolate GW pumping impacts by "differencing" a historical baseline simulation (with pumping) from a identical simulation without pumping



**GSFLOW baseline simulation (<u>with</u> pumping)**

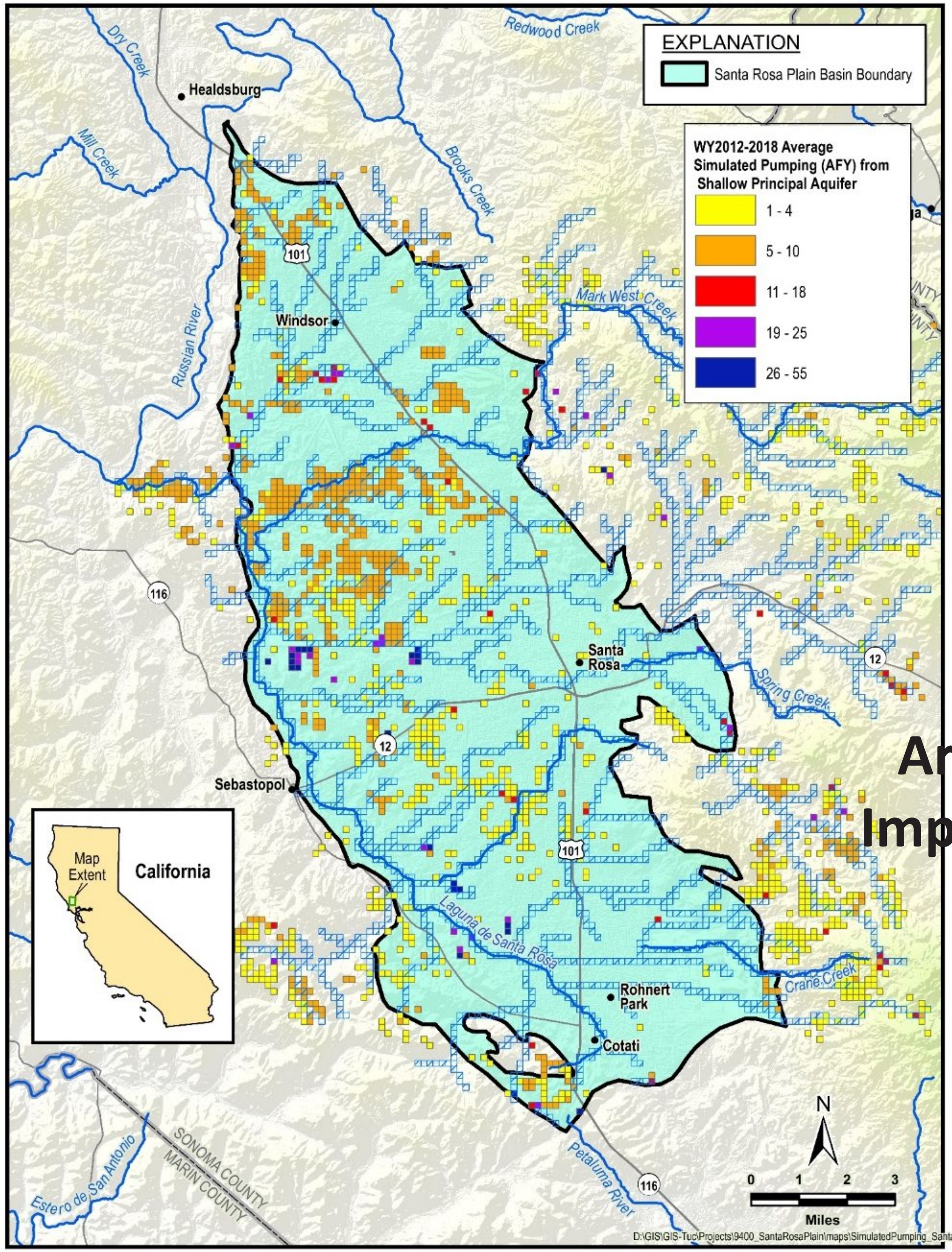
minus



**GSFLOW baseline simulation (<u>no</u> pumping)**

**Isolate Surface Water Depletion (SWD) from groundwater pumping**

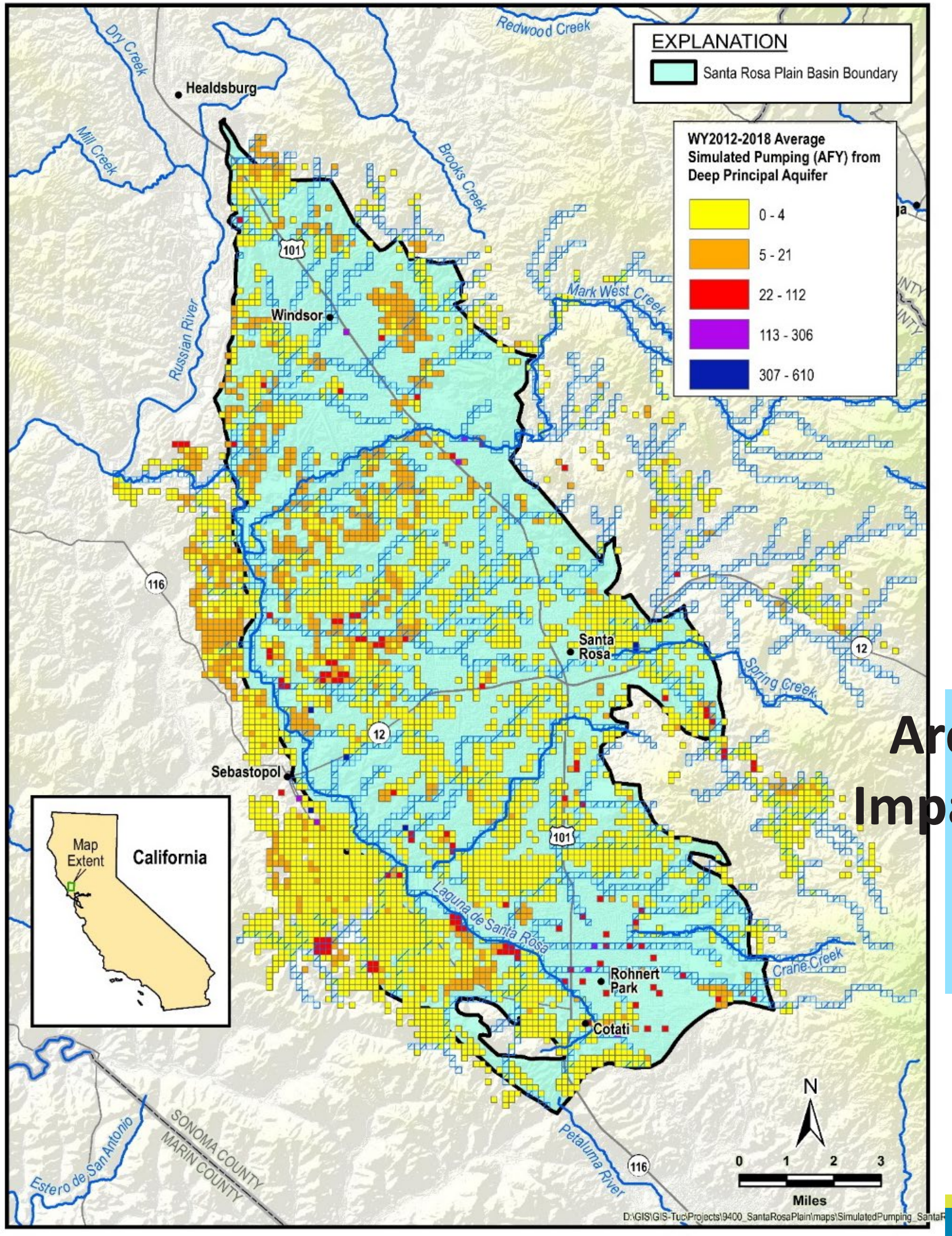
# Where does pumping occur within the basin?




**Areal Extent of Pumping Impacts in Santa Rosa Plain**

**Layer 1**

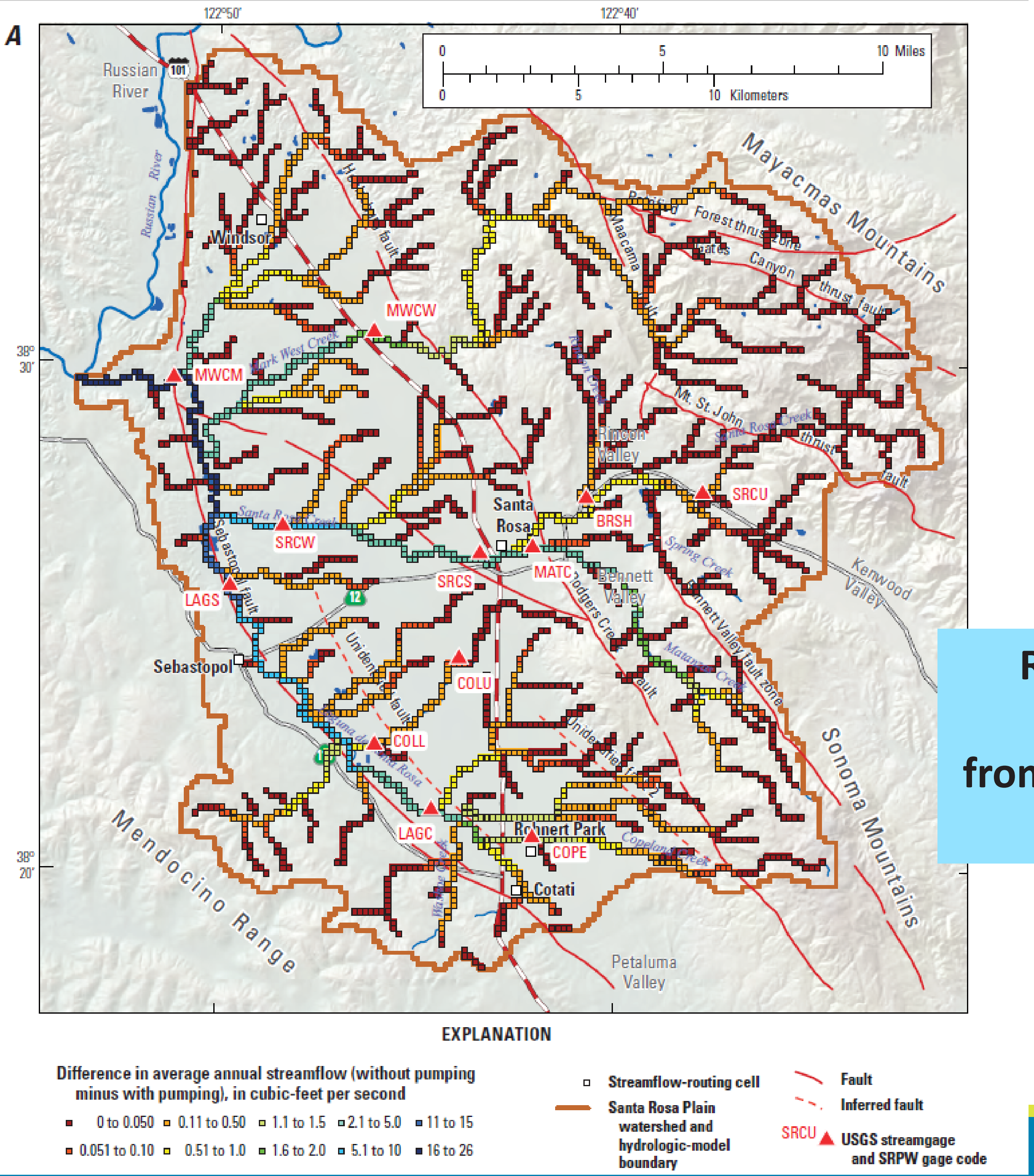
# Where does pumping occur within the basin?




**Areal Extent of Pumping Impacts in Santa Rosa Plain**

**Layers 2–8**

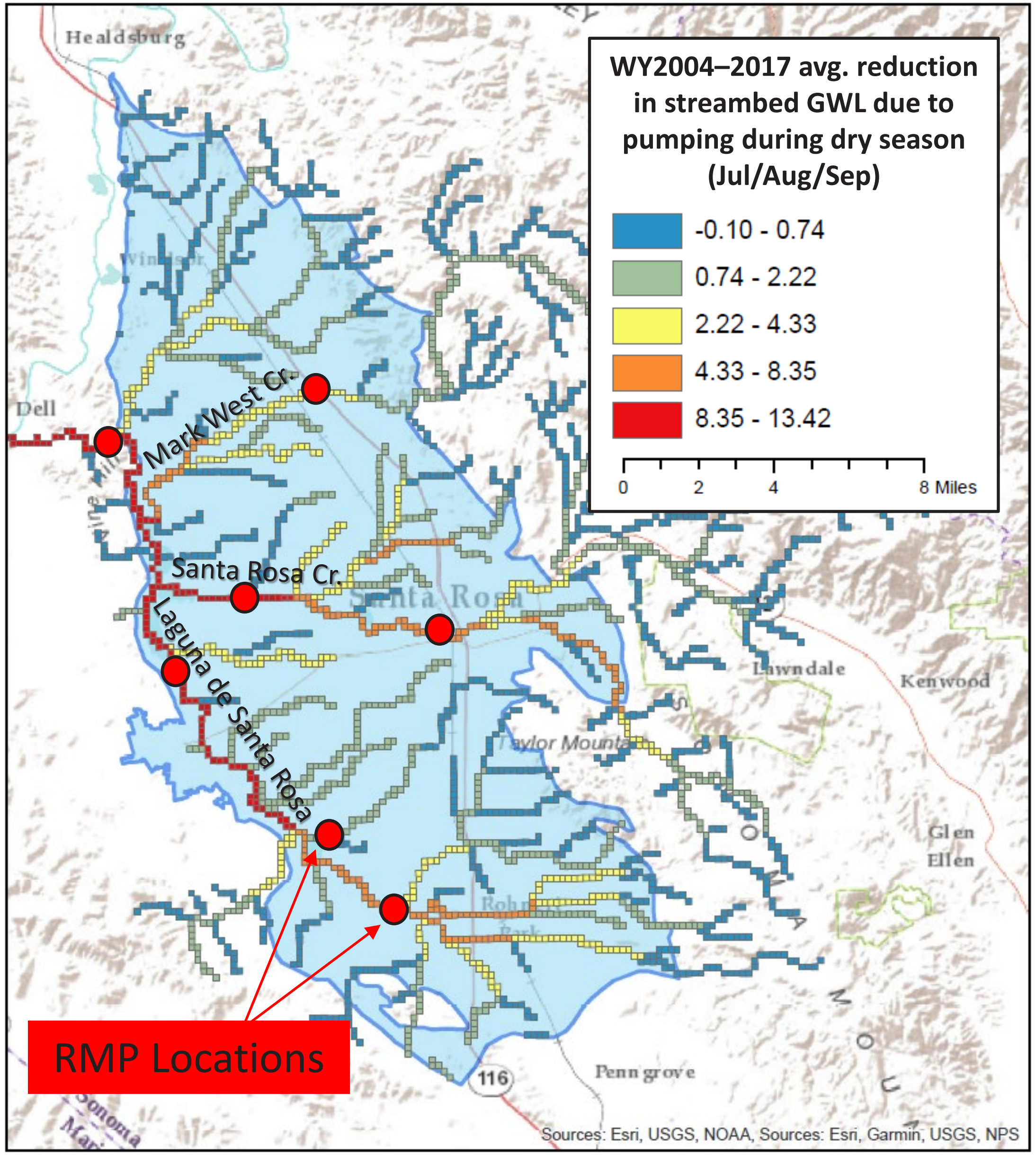
# Where does pumping have greater potential to impact streamflows?




**Reductions in streamflow due to pumping.**

**from: Woolfenden and Nishikawa, 2014, Chapter E Figure 9A**

# Where does pumping have greater potential to impact streamflows?



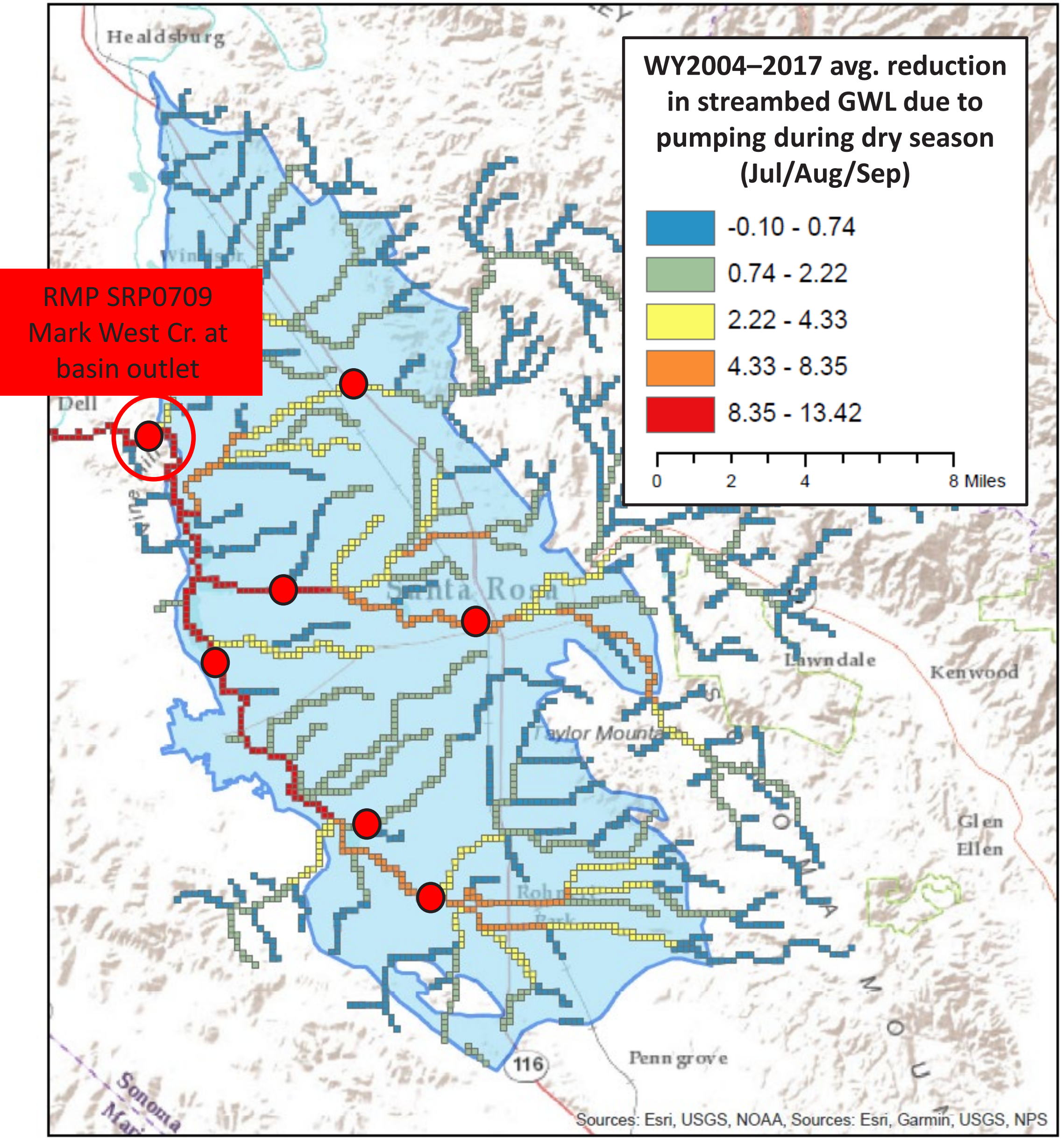

**Modeling suggests that pumping has greater potential to impact streamflows on:**

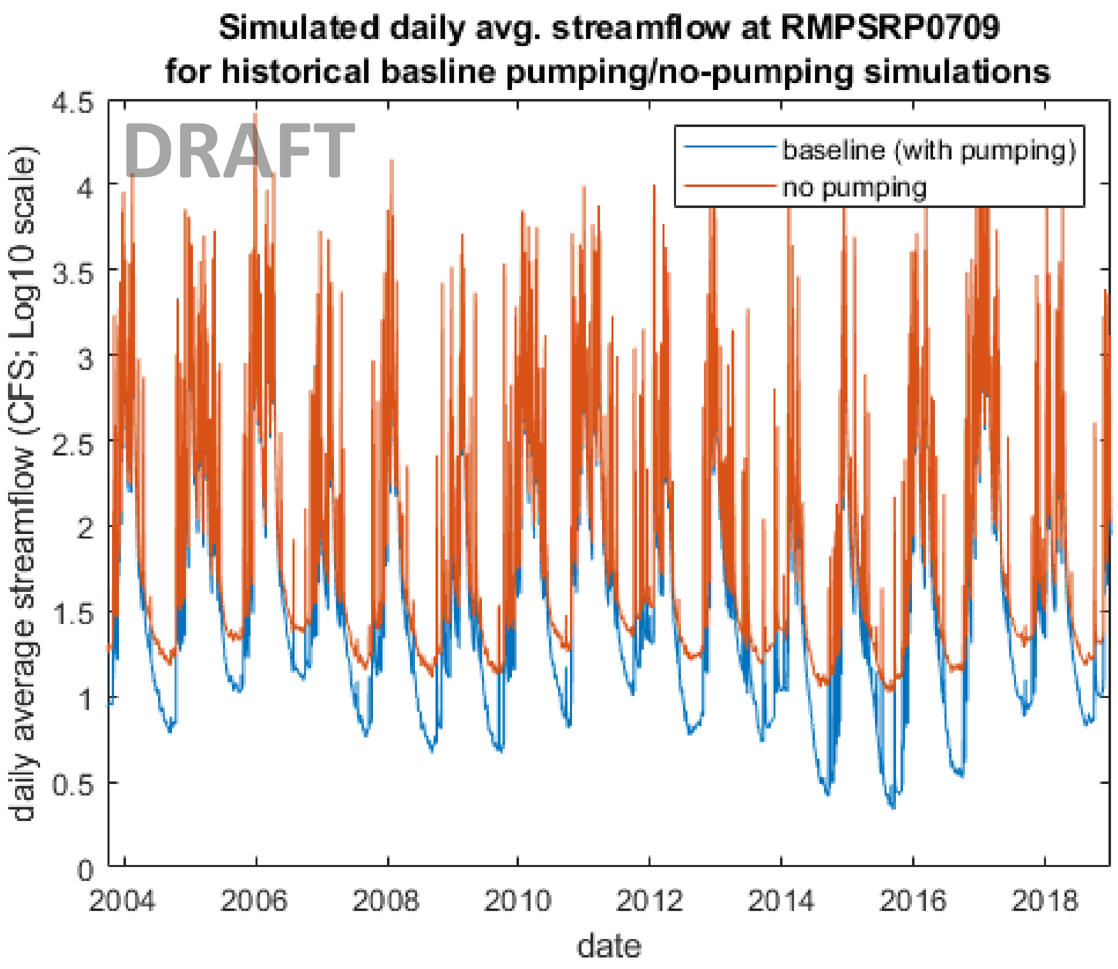
Laguna de Santa Rosa
Santa Rosa Cr.
Mark West Cr.

**Actual impacts are very dependent upon:**

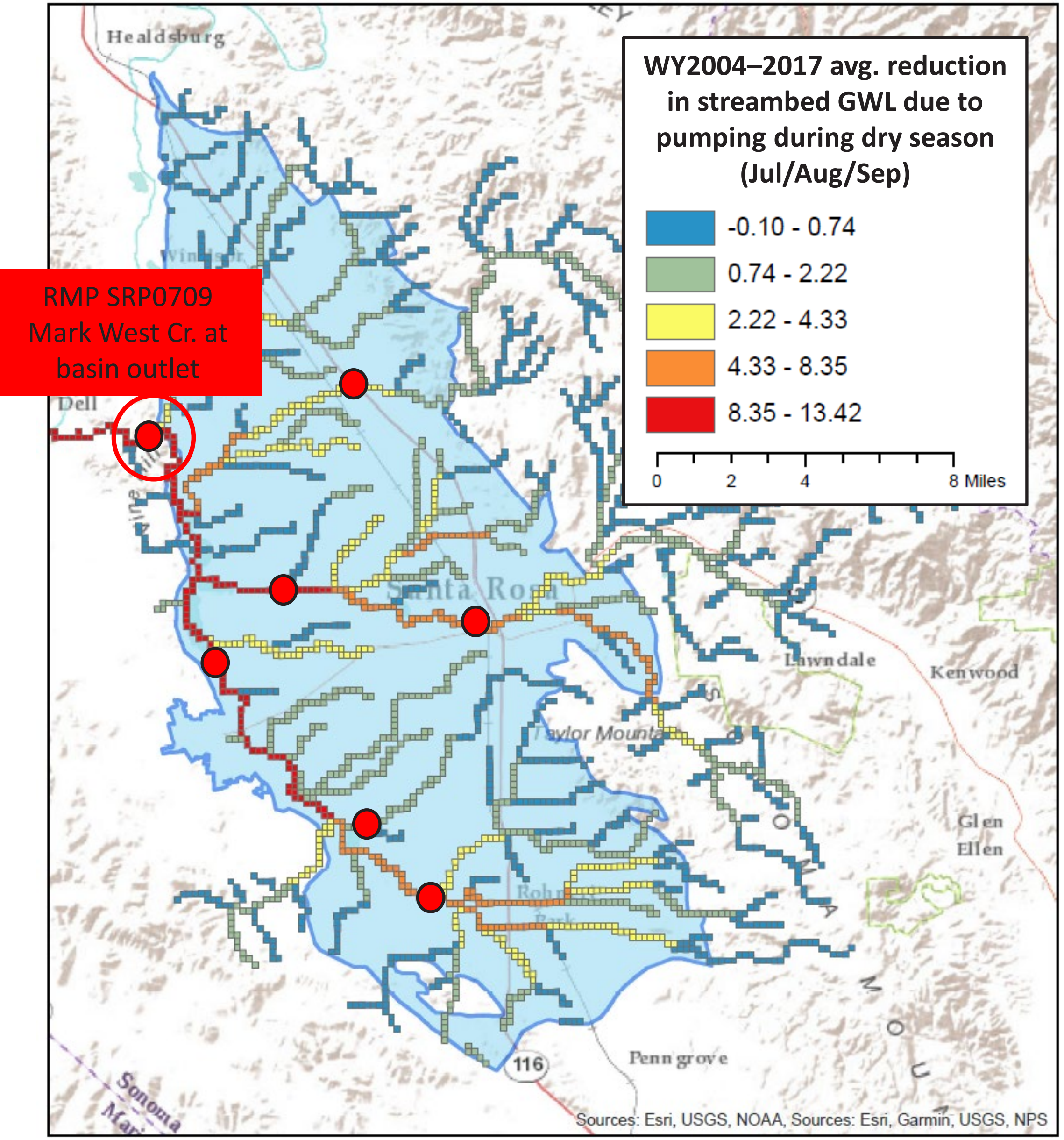
(1) streambed/shallow aquifer hydraulic conductivity
(2) stream/aquifer configuration

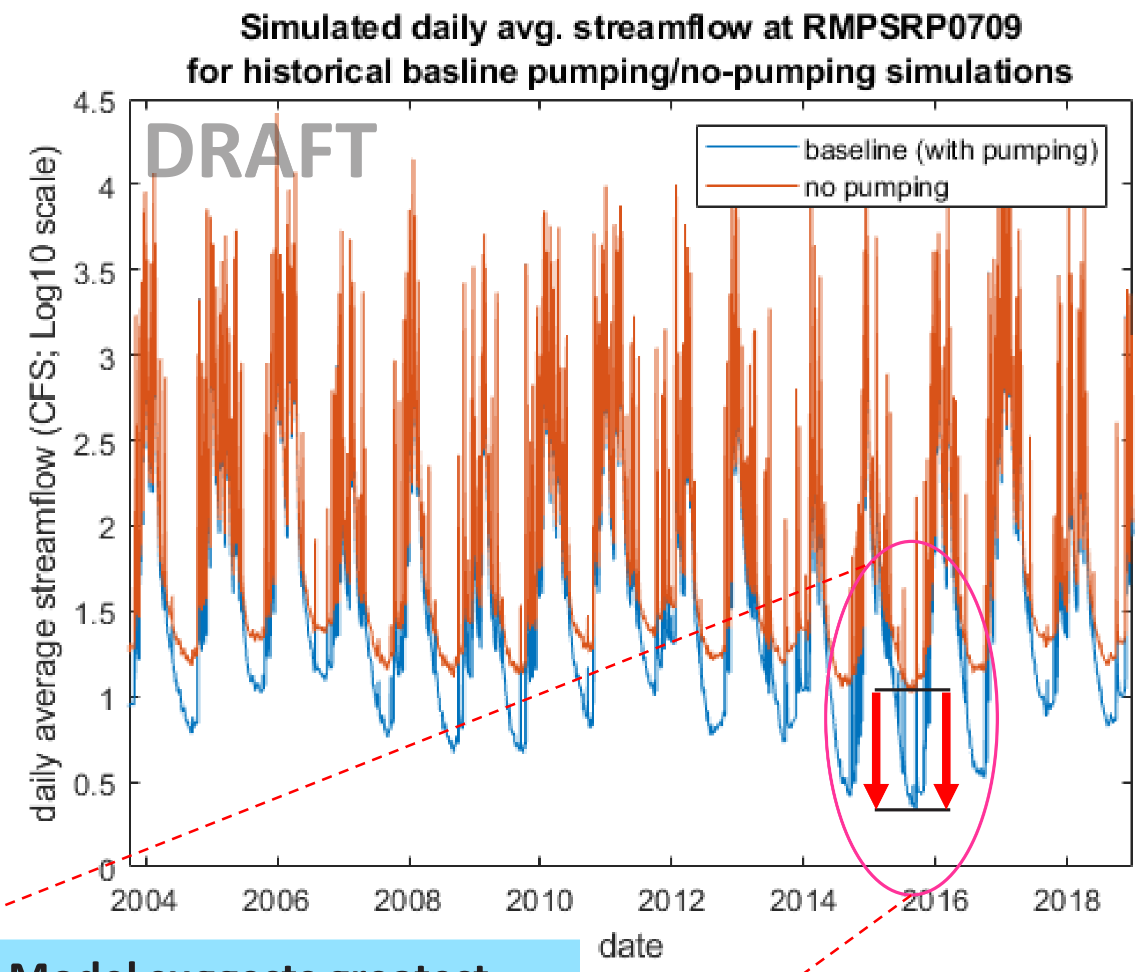
# What is the impact of pumping on outflows from the basin?



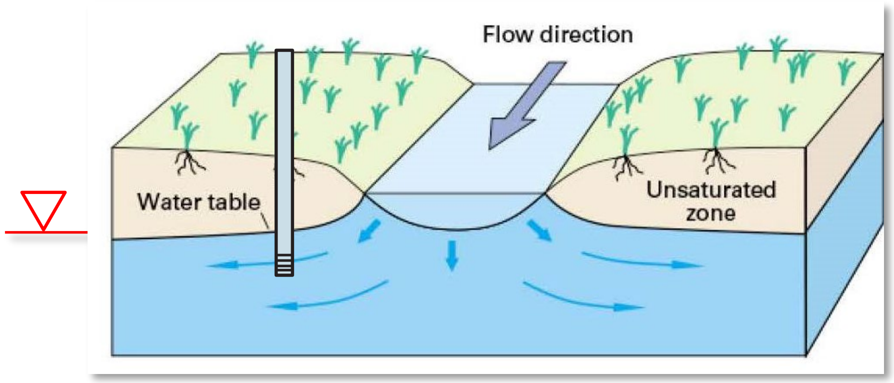
# What is the impact of pumping on outflows from the basin?

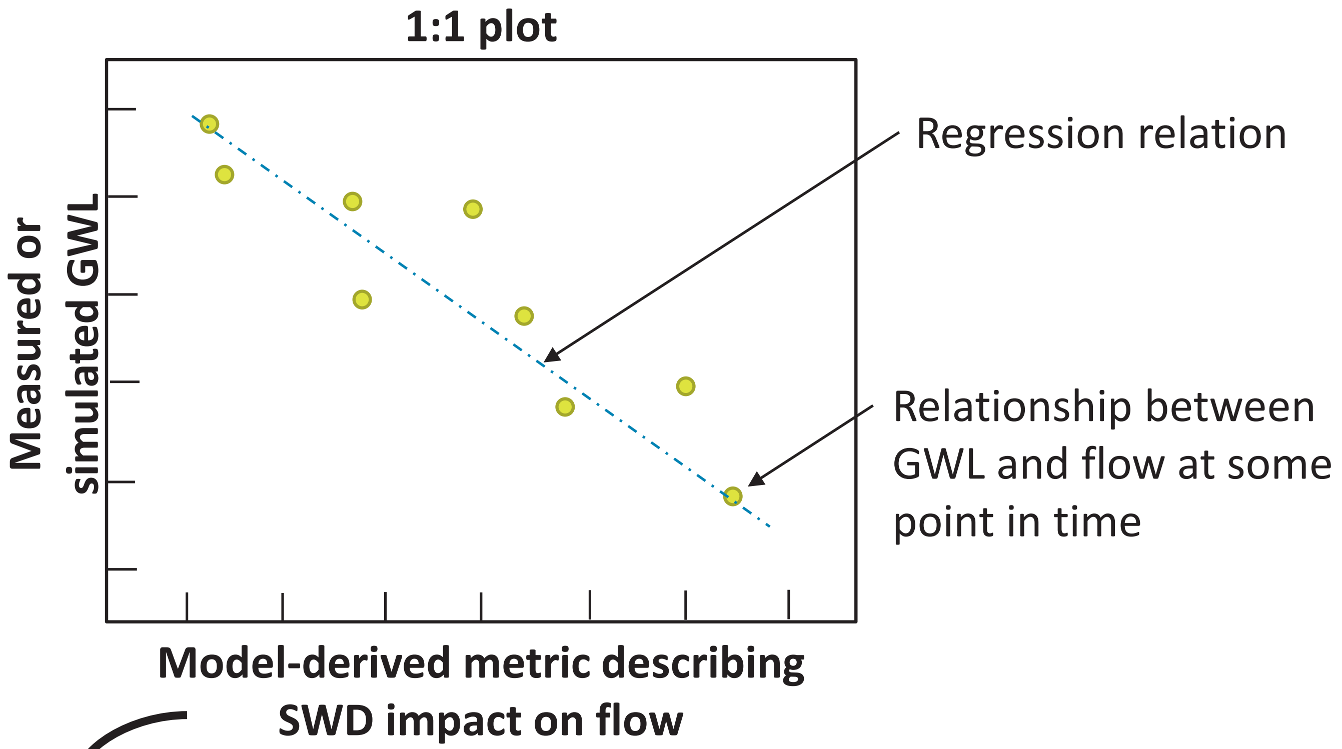



**Model suggests greatest reduction in dry-season flows due to pumping during 2015**

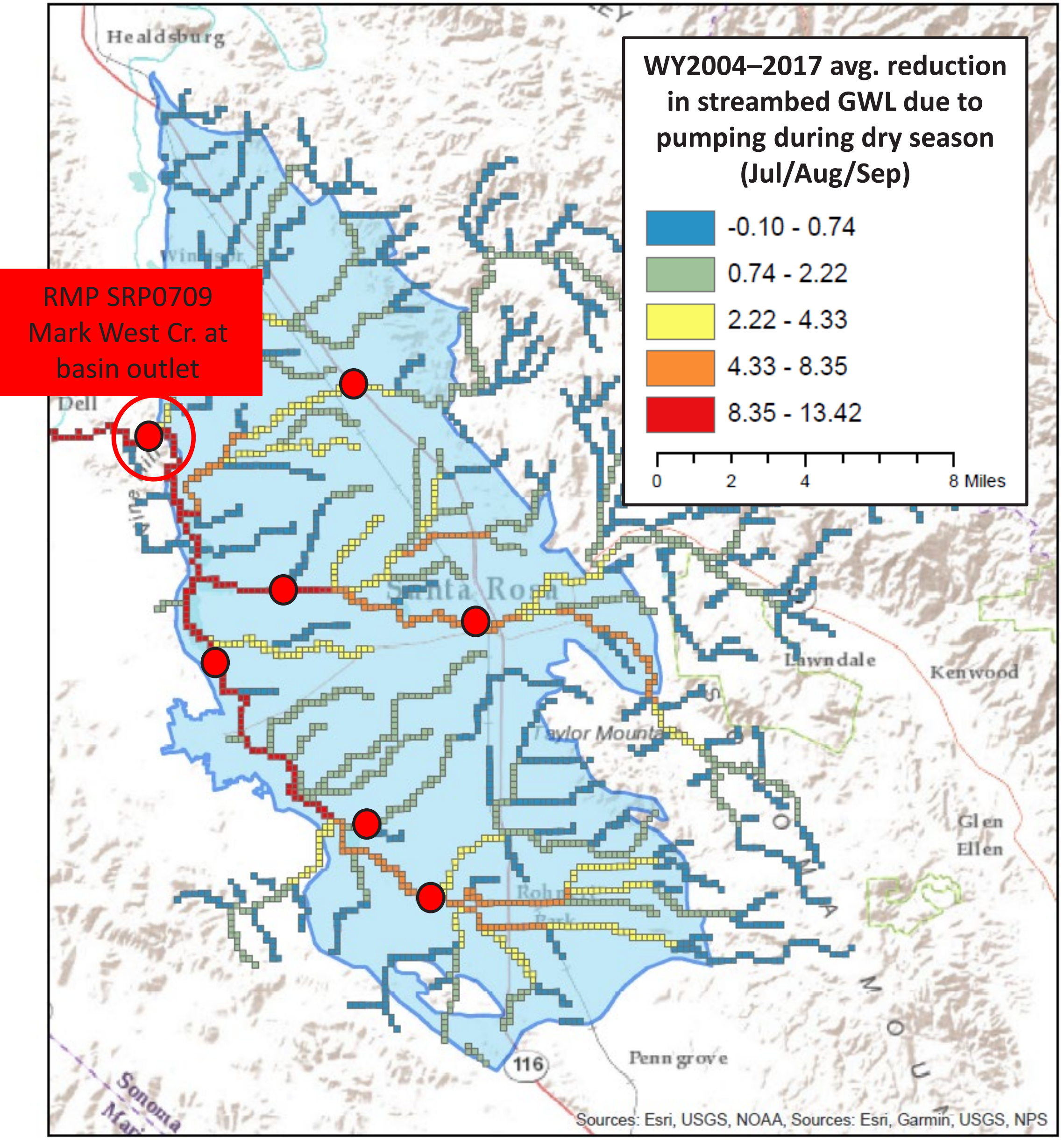
# How can GWL be used as a proxy for surface water depletion?



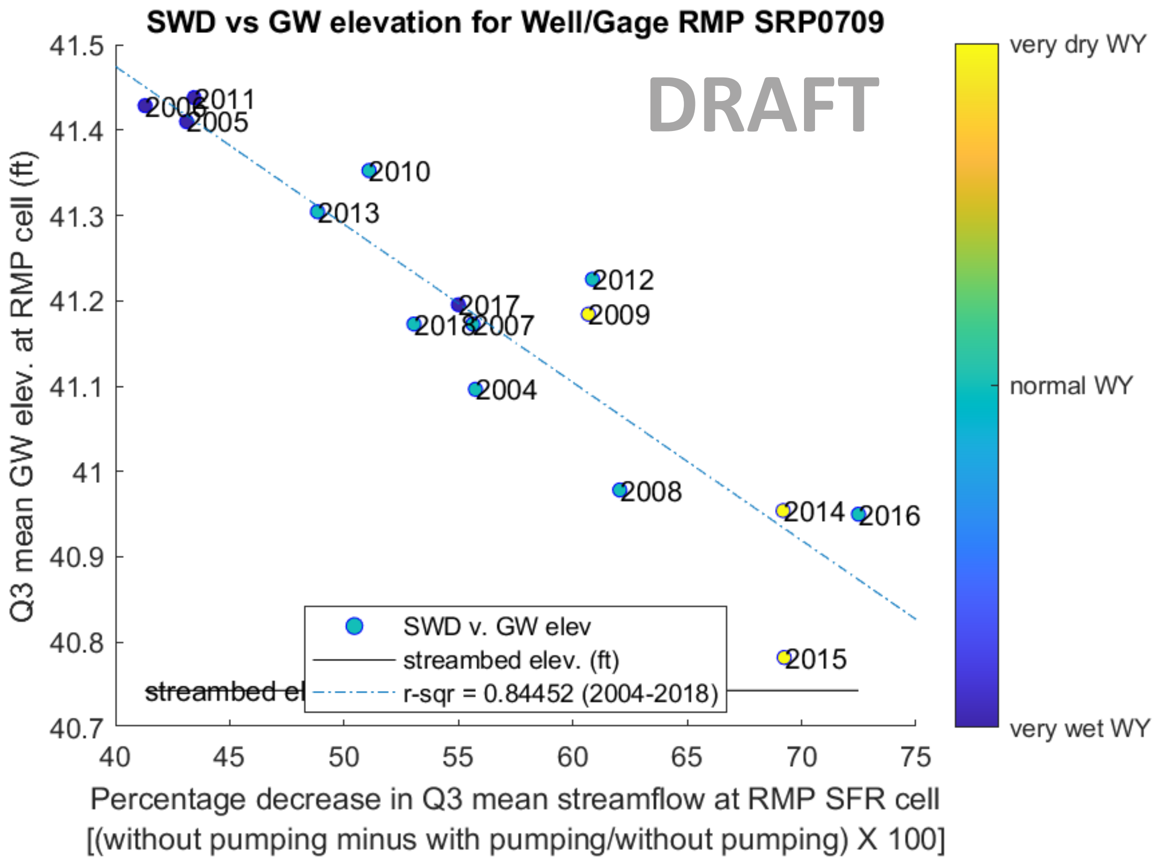




1. **Percent reduction in streamflow due to pumping (over entire WY)**
2. **Percent reduction in streamflow due to pumping (during low-flow periods)**
3. **Number of days that SWD exceeds threshold value**

# Can we use GW levels as a proxy for SWD?




**Good correlation … for simulated GW levels and SWD at some RMPs**



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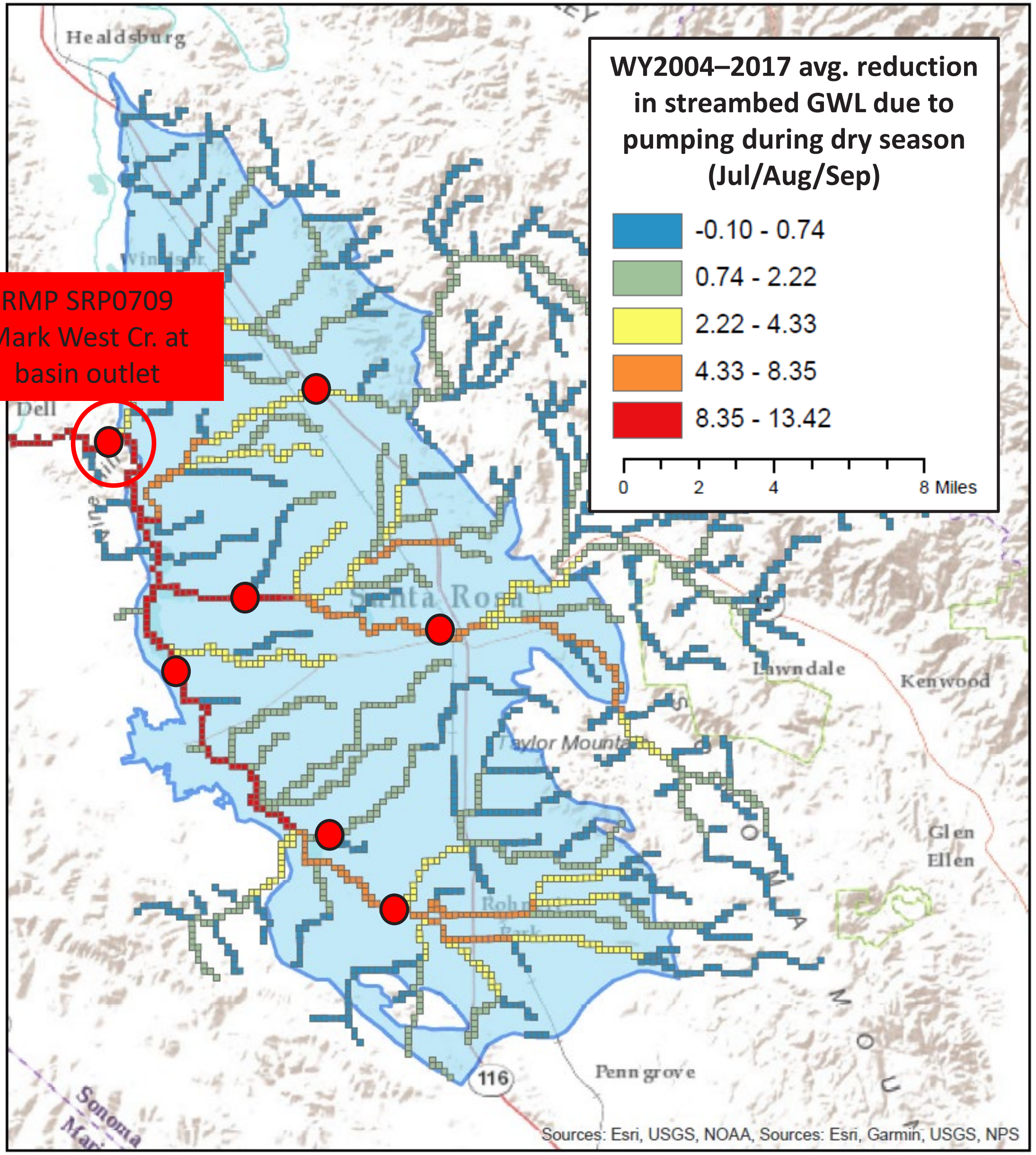


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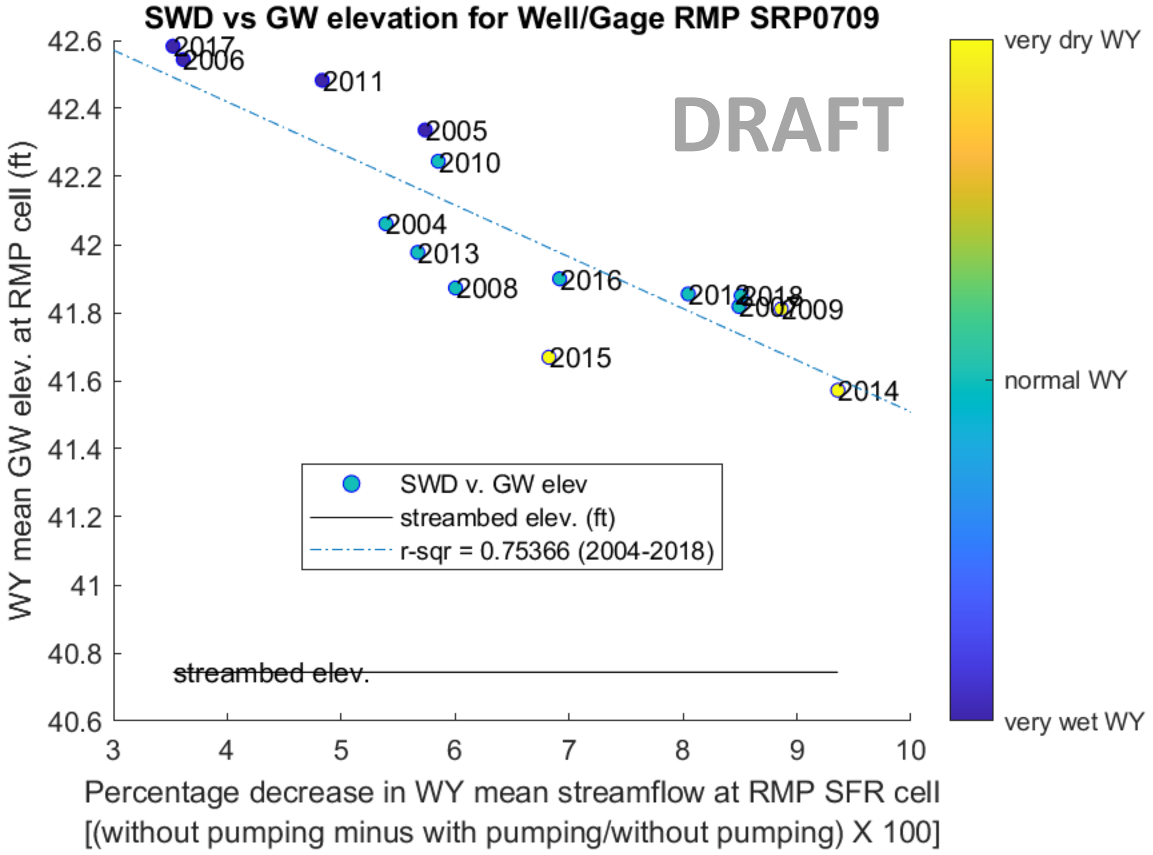
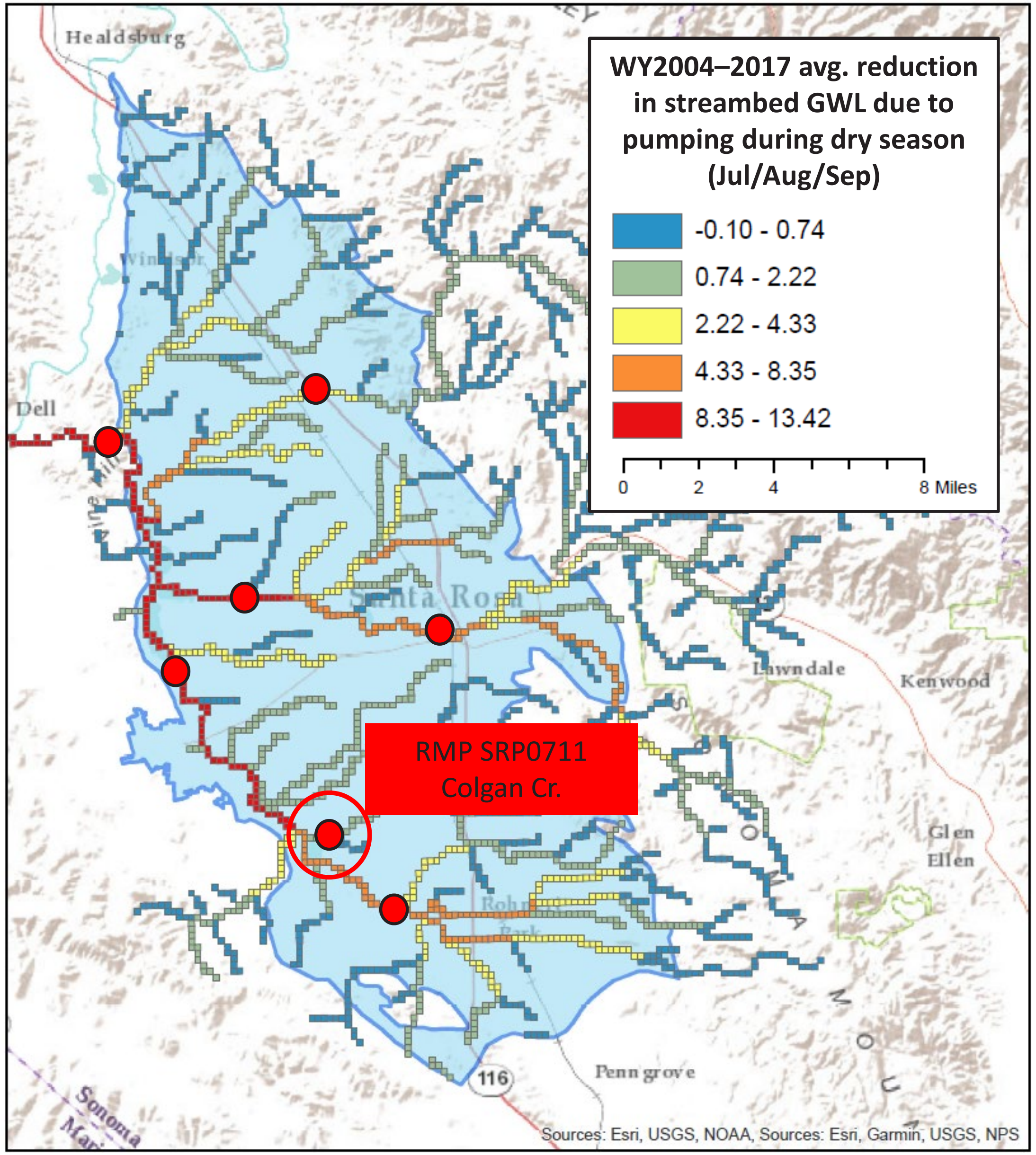
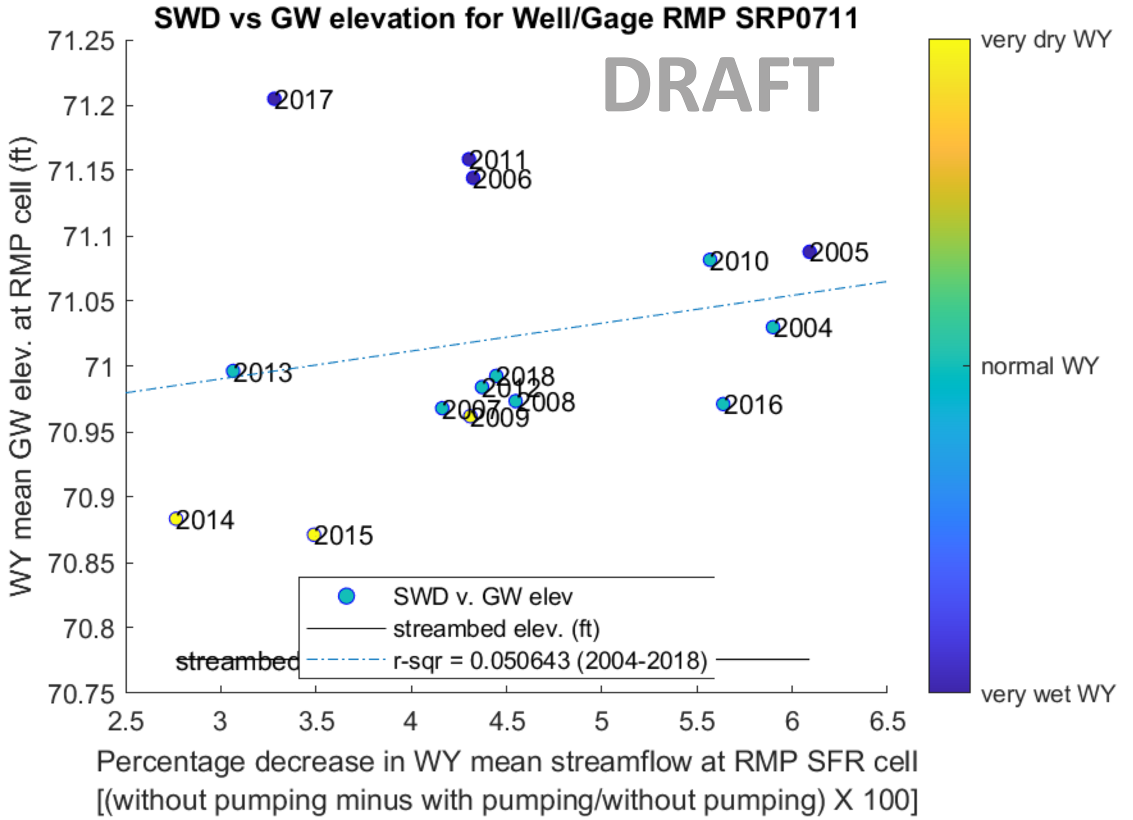


# Can we use GW levels as a proxy for SWD?

**Poor correlation … for some RMPs where little SWD is occurring**



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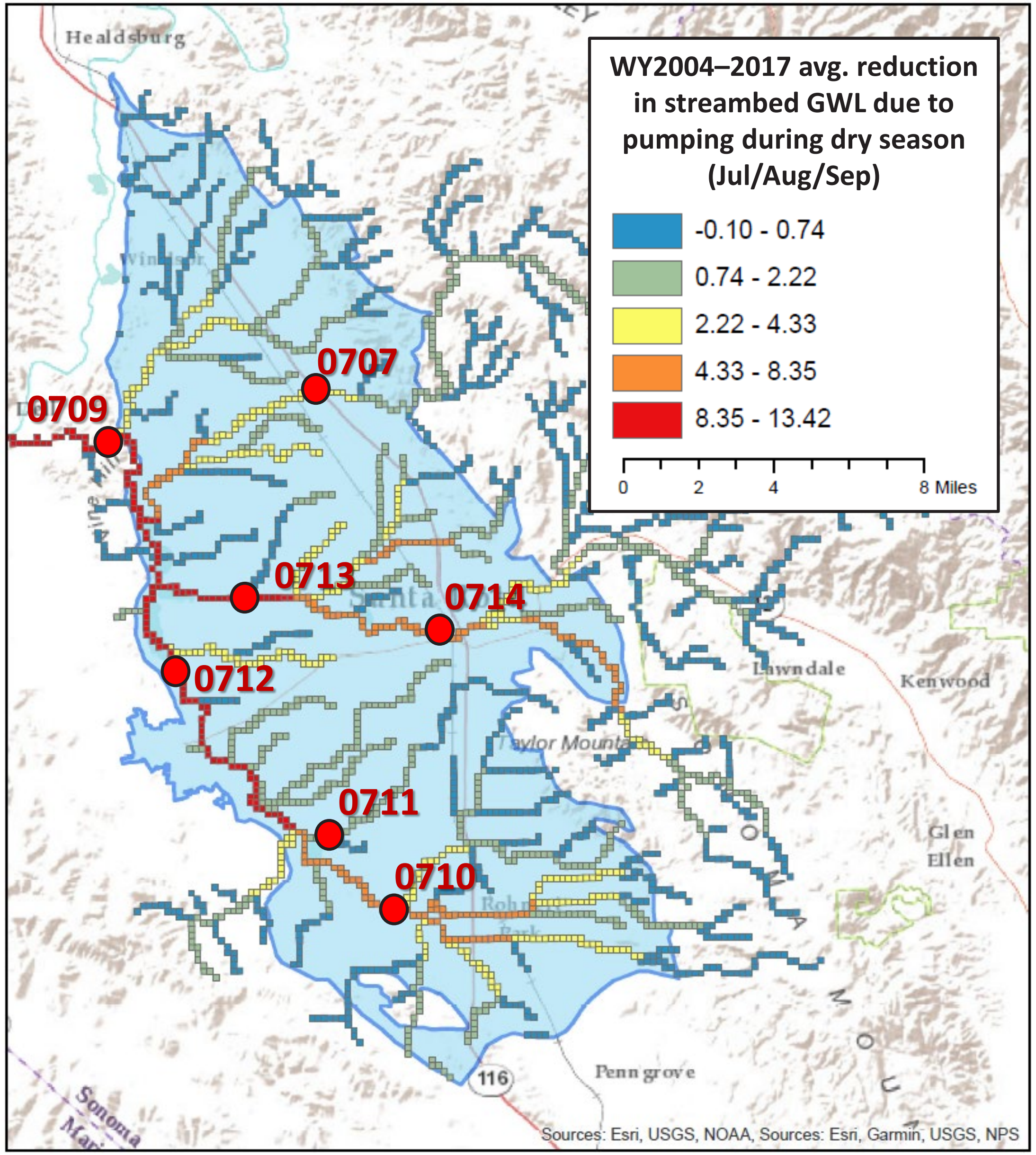
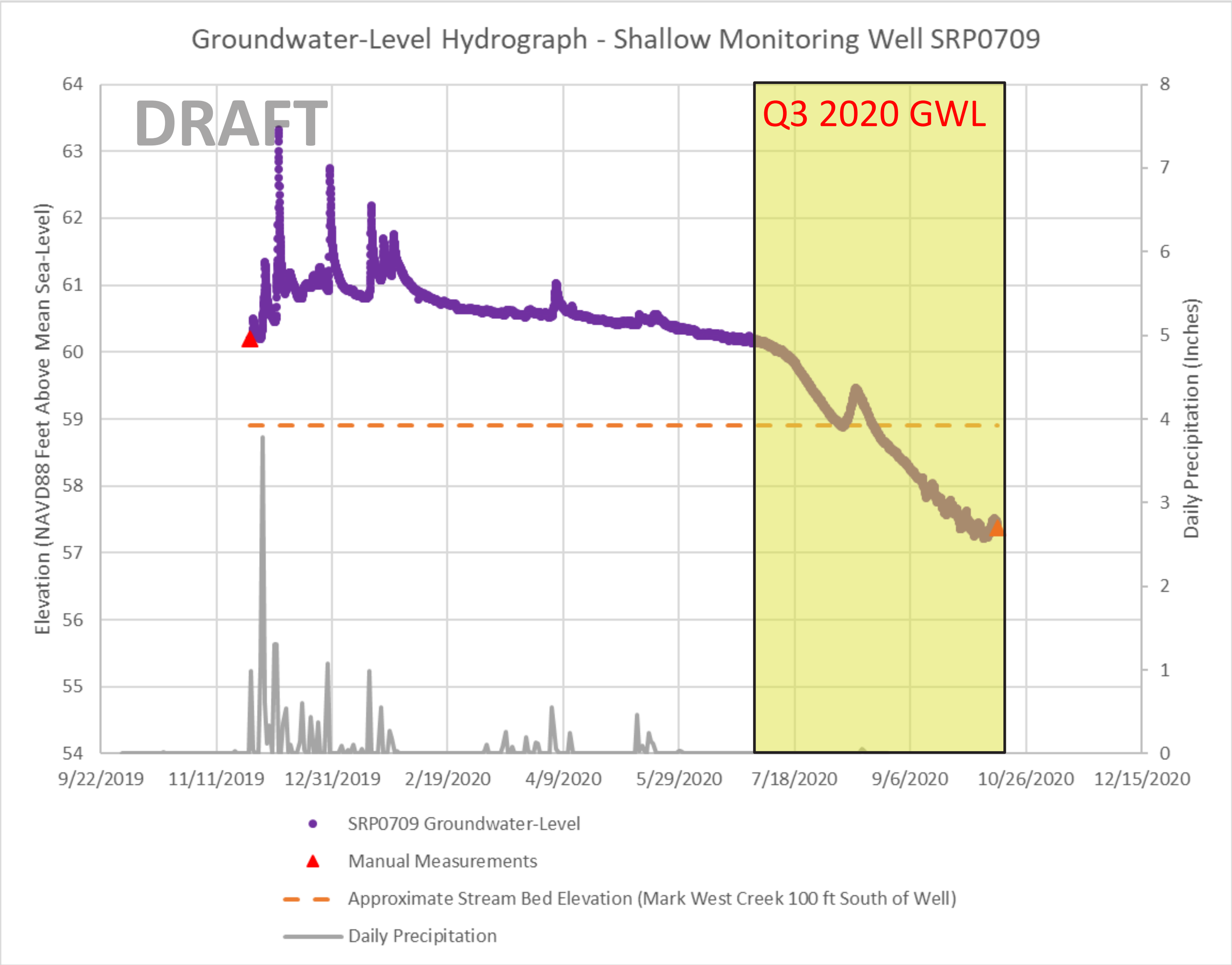



**Good correlation between modeled GWL and SWD is noted at several monitoring locations.**

| RMP | r-squared agreement between GWL and SWD | |
|---|---|---|
| | Full Water Year (WY) | Q3 dry period (Jul/Aug/Sep) |
| SRP0707 | 0.72 | 0.78 |
| SRP0709 | 0.75 | 0.84 |
| SRP0710 | 0.49 | 0.03 |
| SRP0711 | 0.05 | 0.16 |
| SRP0712 | 0.28 | 0.74 |
| SRP0713 | 0.54 | 0.13 |
| SRP0714 | 0.71 | 0.27 |




# Model results show promise … How do they compare with measured data?

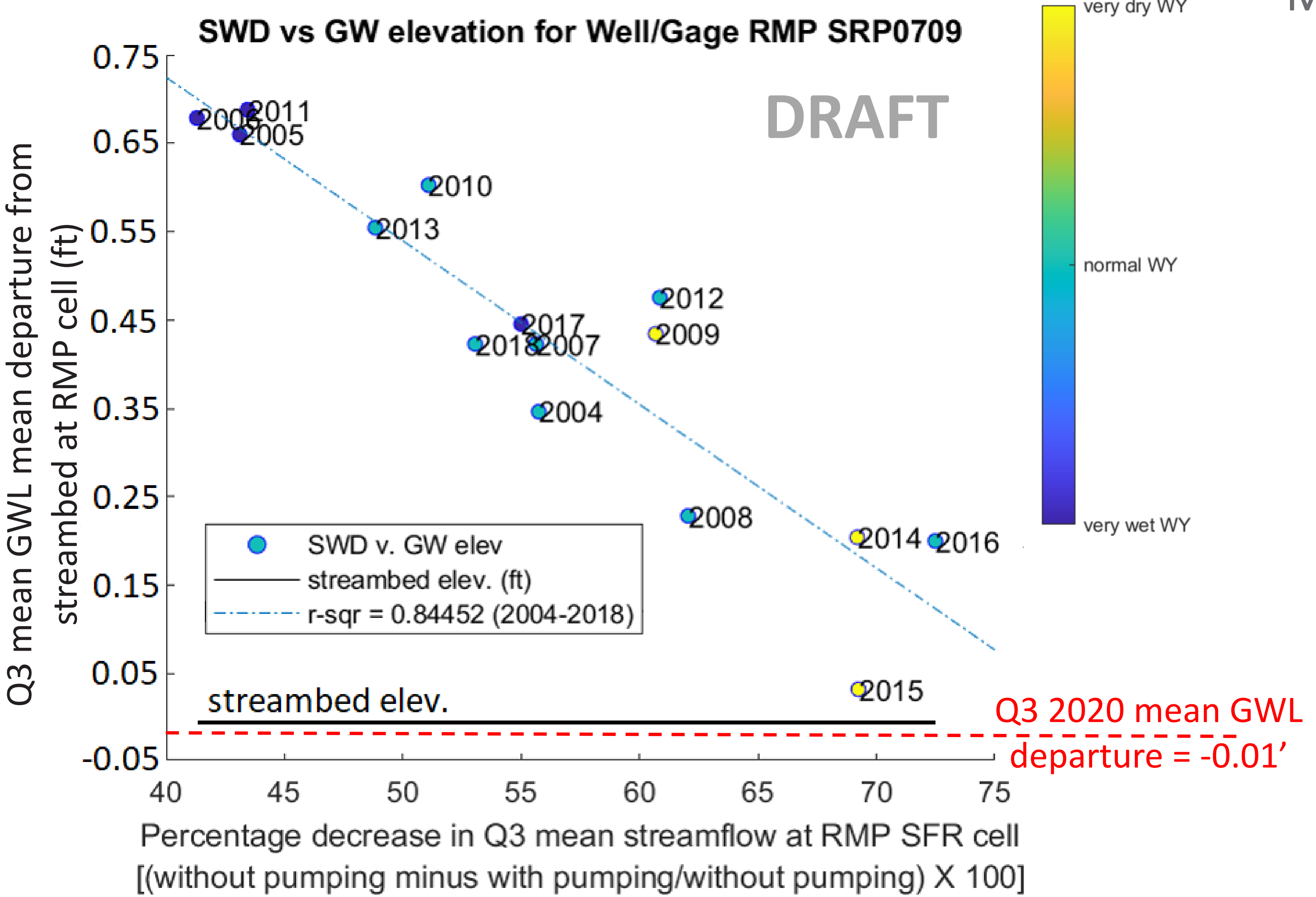
## Problem:

**Model simulation period (WY1974–2018) does not overlap with RMP data collection (2019–present)**

**Reliance on model results assumes well calibrated model, esp. at RMP locations.**

## Potential Solution:

**Compare measured/modeled behavior for similar WY type.**
**(WY2020 = dry year)**

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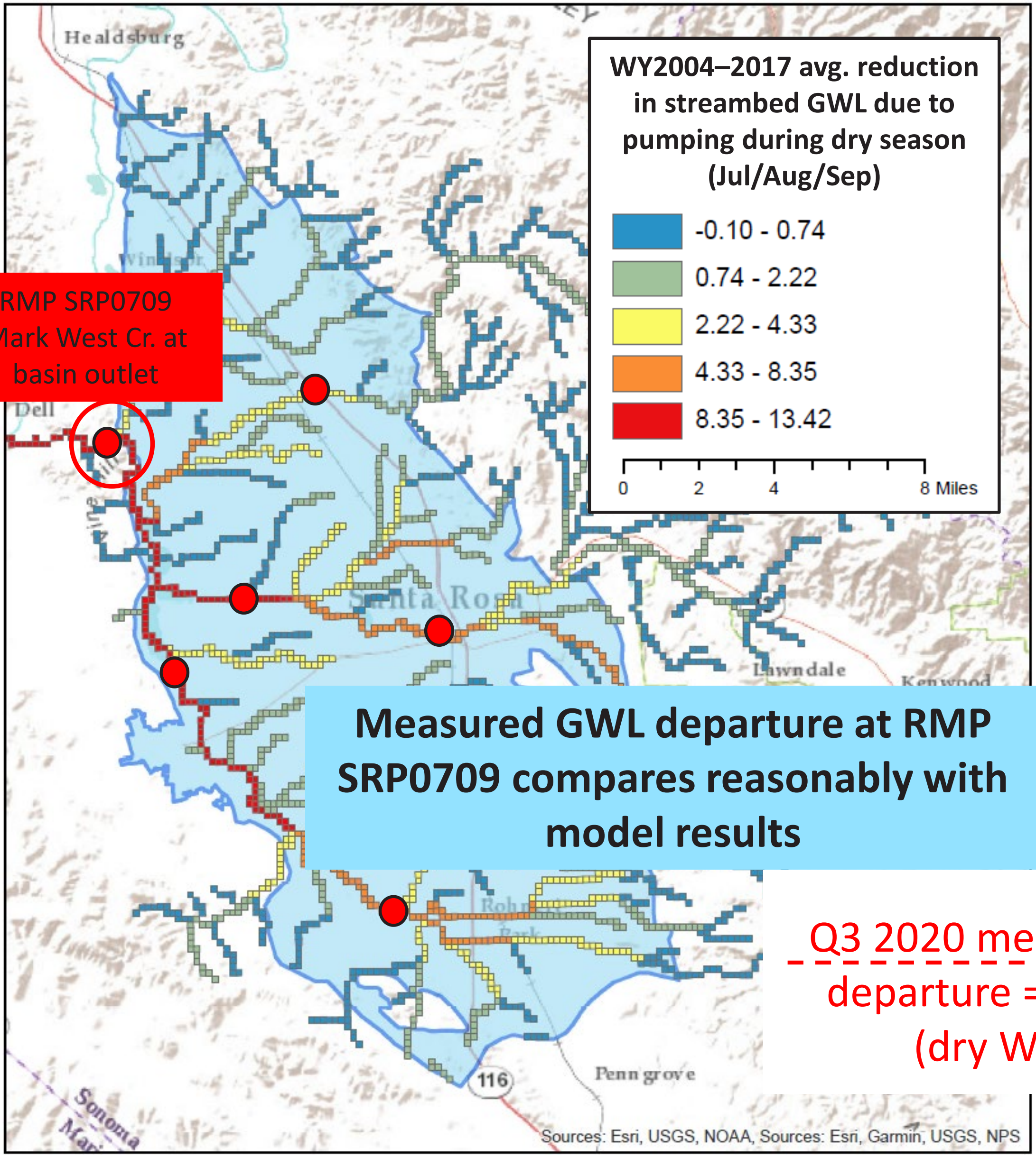
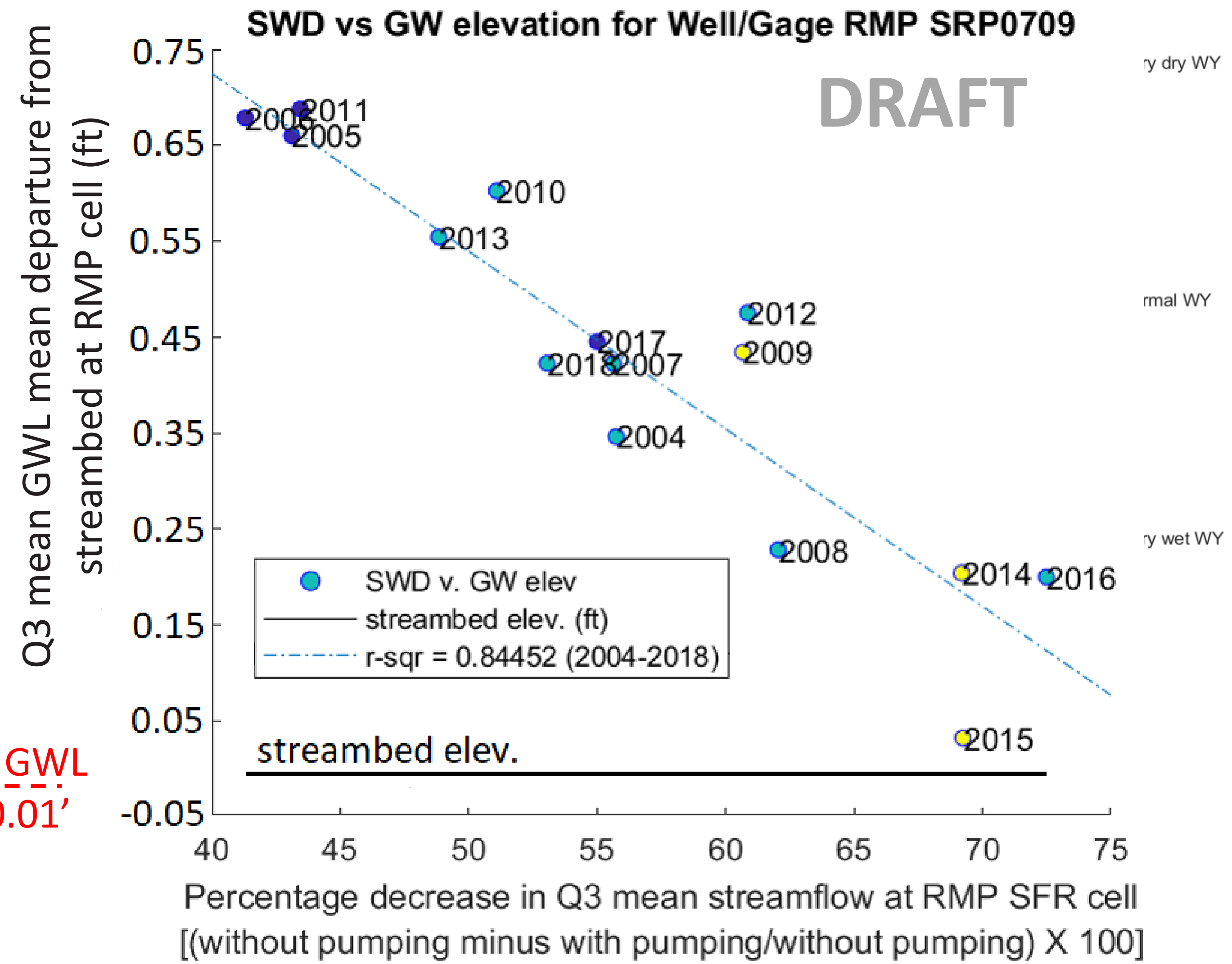
**(WY2020 = dry year)**

# Model results show promise …
# How do they compare with measured data?

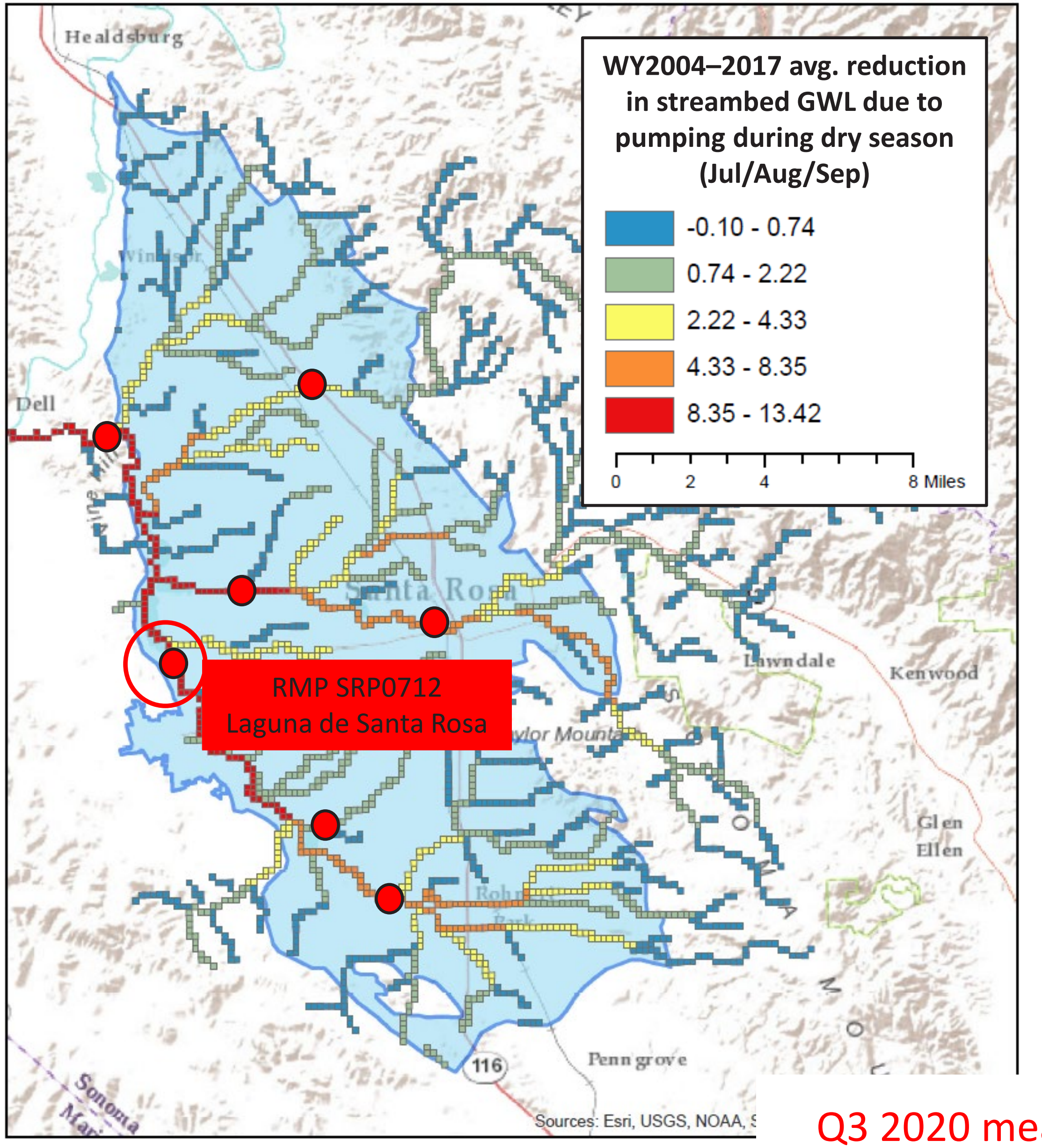


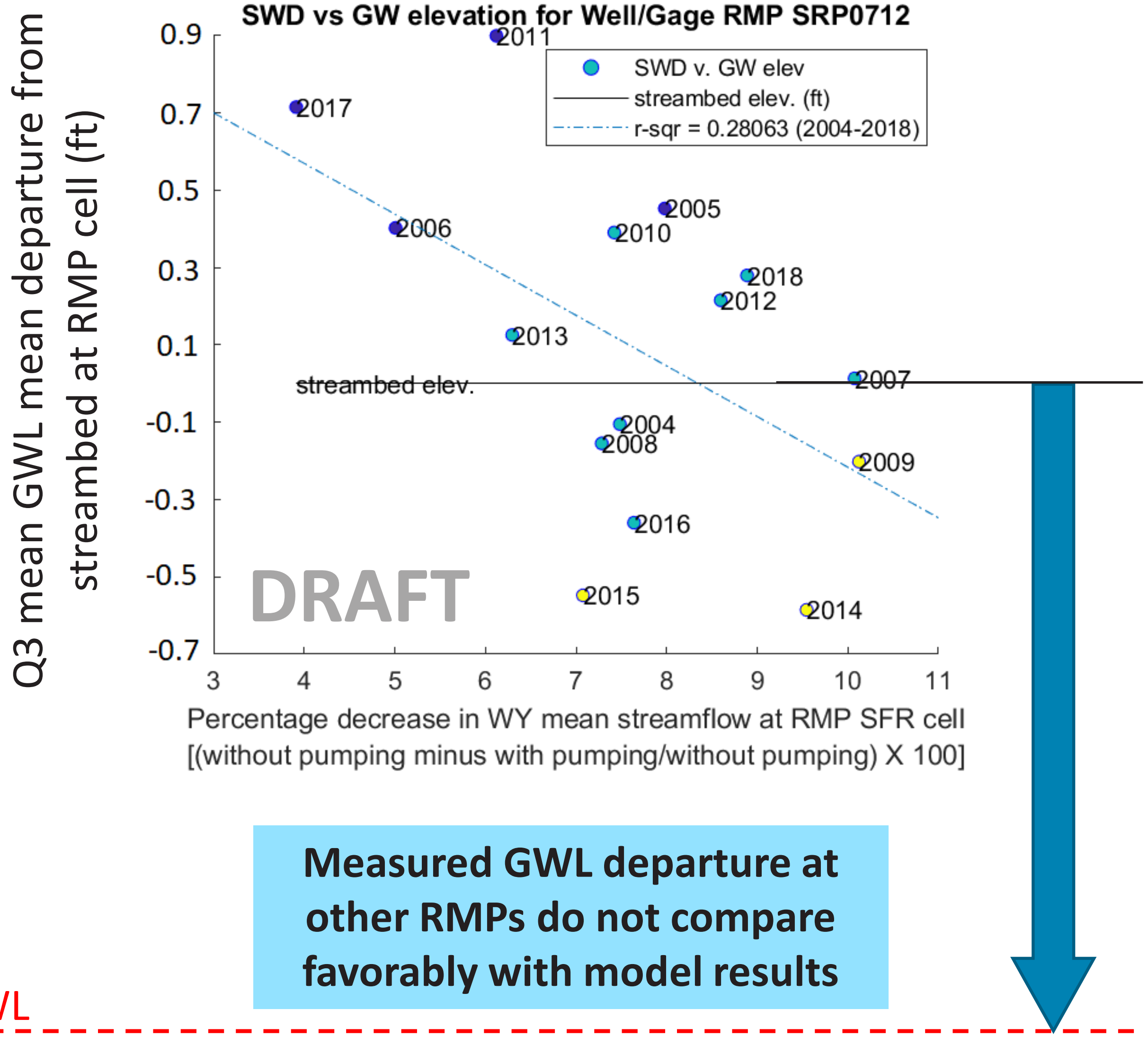

**Measured GWL departure at RMP SRP0709 compares reasonably with model results**

Q3 2020 mean GWL departure = -0.01' (dry WY)



# Model results show promise …
# How do they compare with measured data?



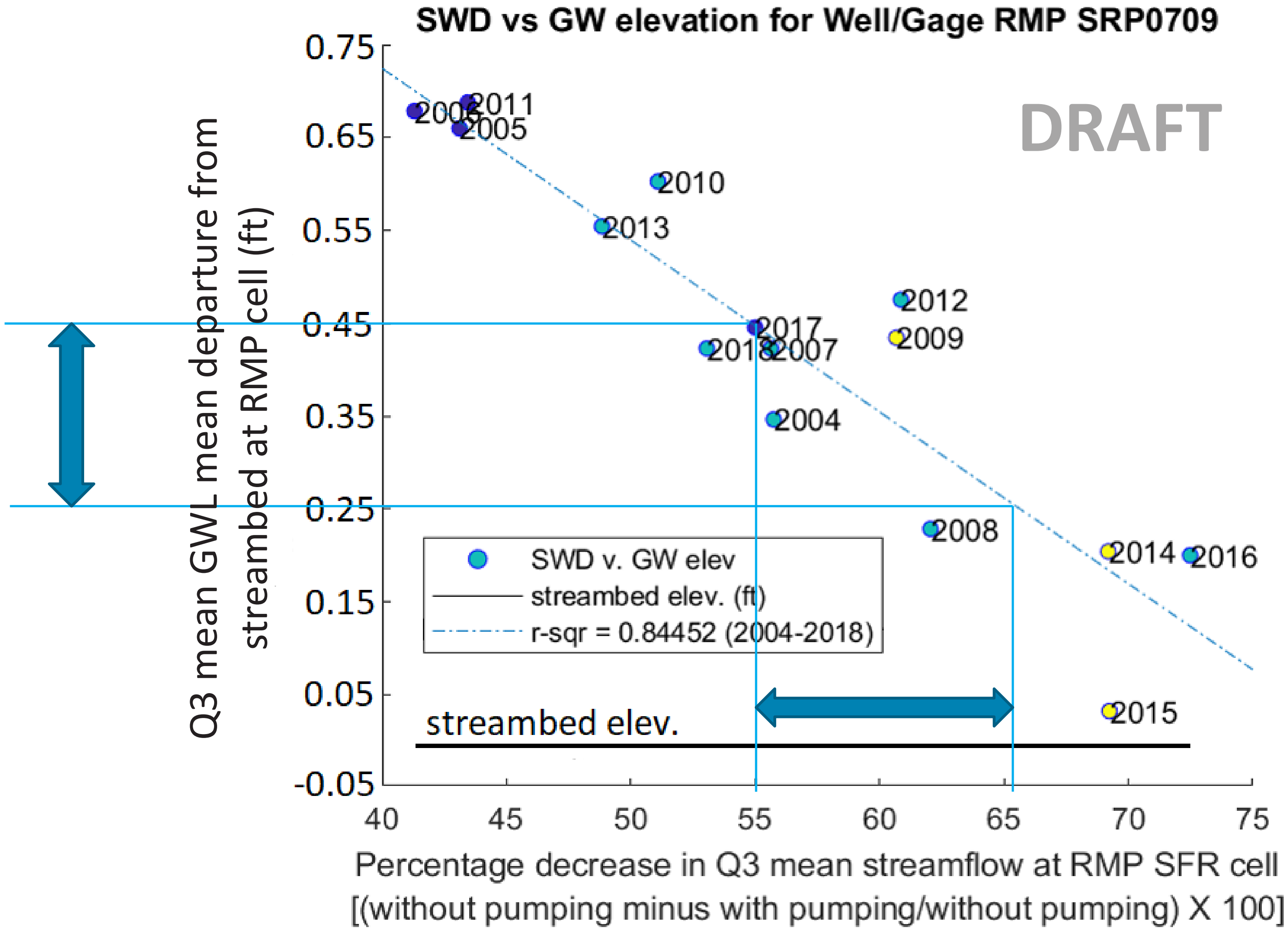




**Measured GWL departure at other RMPs do not compare favorably with model results**

Q3 2020 mean GWL departure = -4.5’ (dry WY)

# How can GWL – SWD relationship be used to inform SMC choice?
# … Assuming good agreement between measured data and model results

**Relationship suggests 0.1 ft reduction in mean Q3 GWL corresponds with ~10% increase in SWD.**



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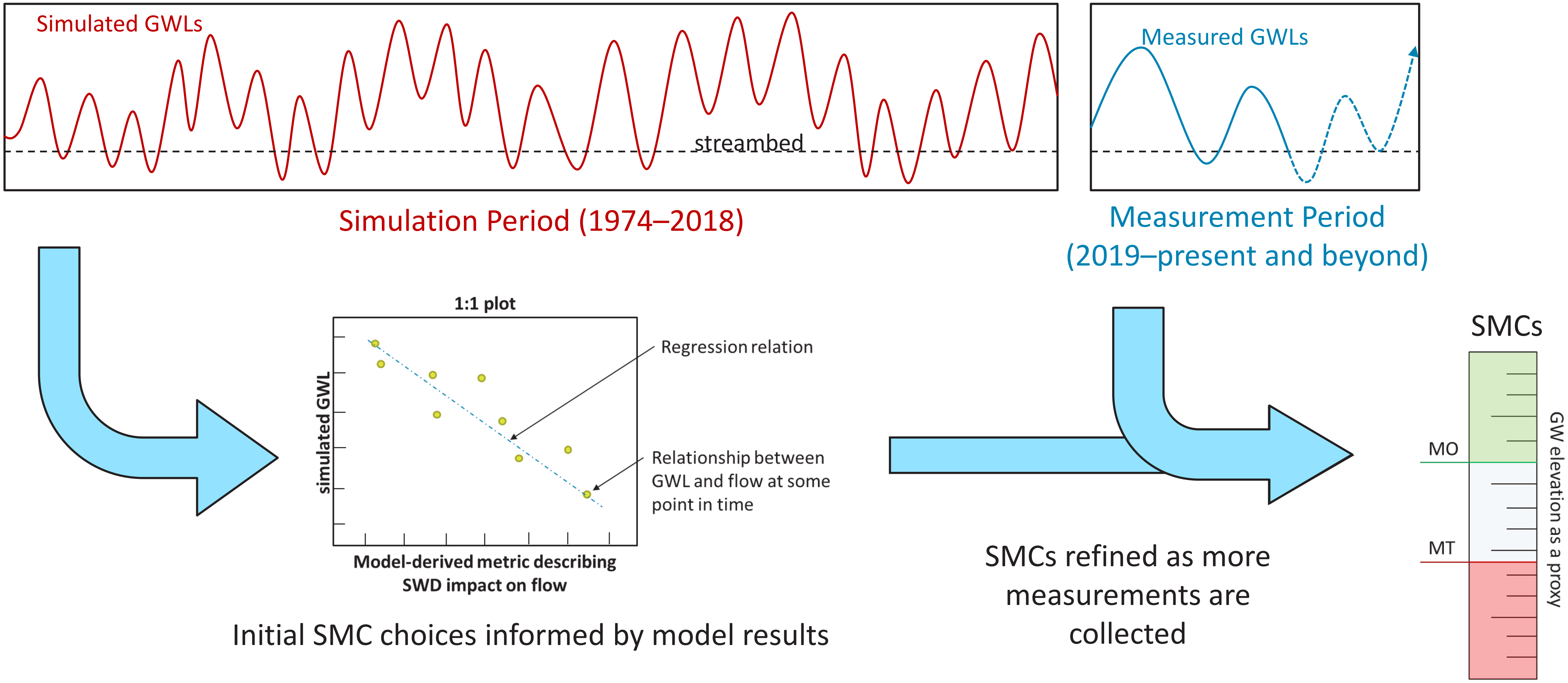


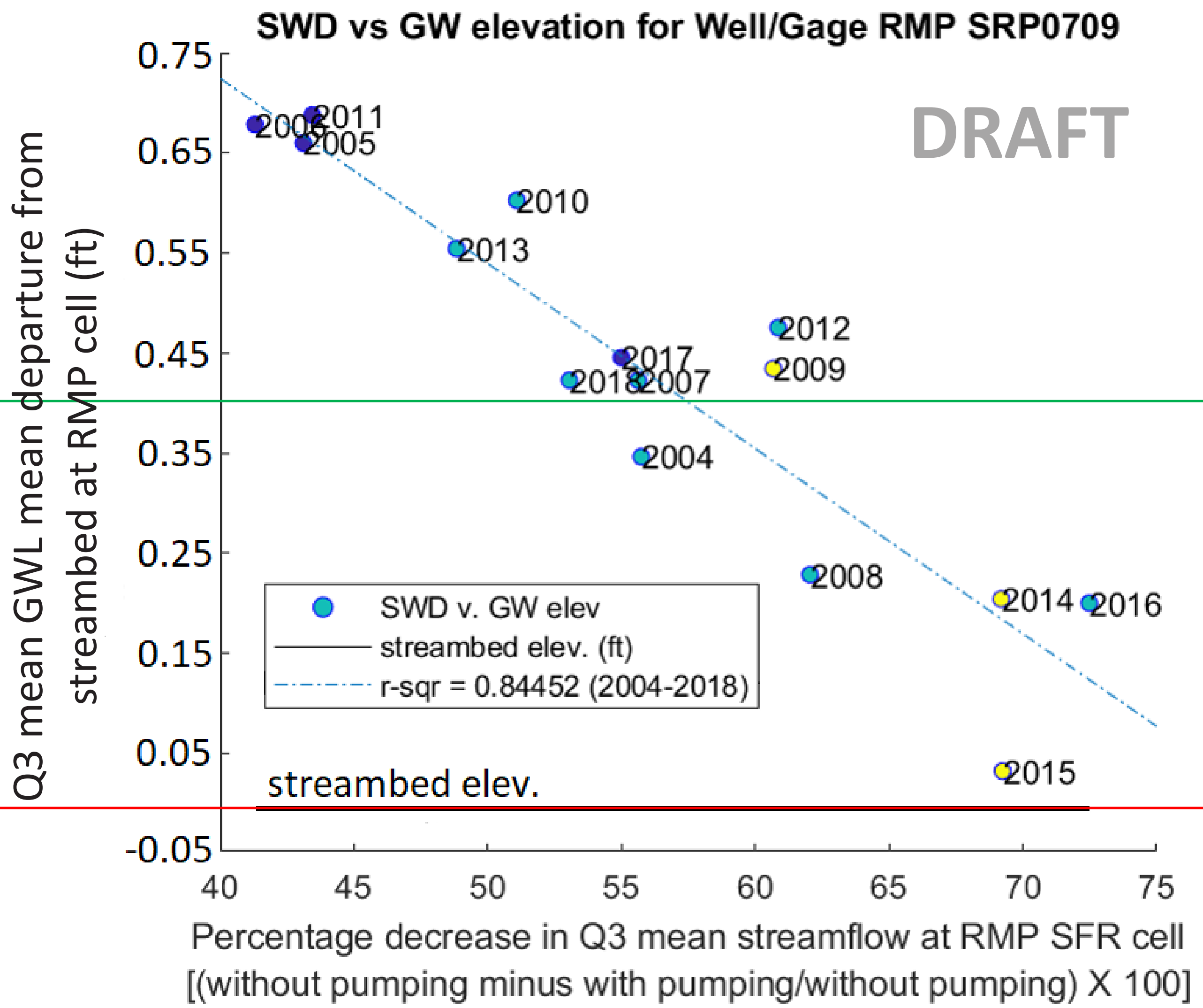
# How can GWL – SWD relationship be used to inform SMC choice?
# … Assuming good agreement between measured data and model results

**Potential Approach:**

**Set SMC based on GWL, use relationship to infer SWD impact**

Example measurable objective (MO) =
Q3 GWL > mean Q3 GWL during 2004–2018
= ~55-60% avg. decrease in Q3 streamflow

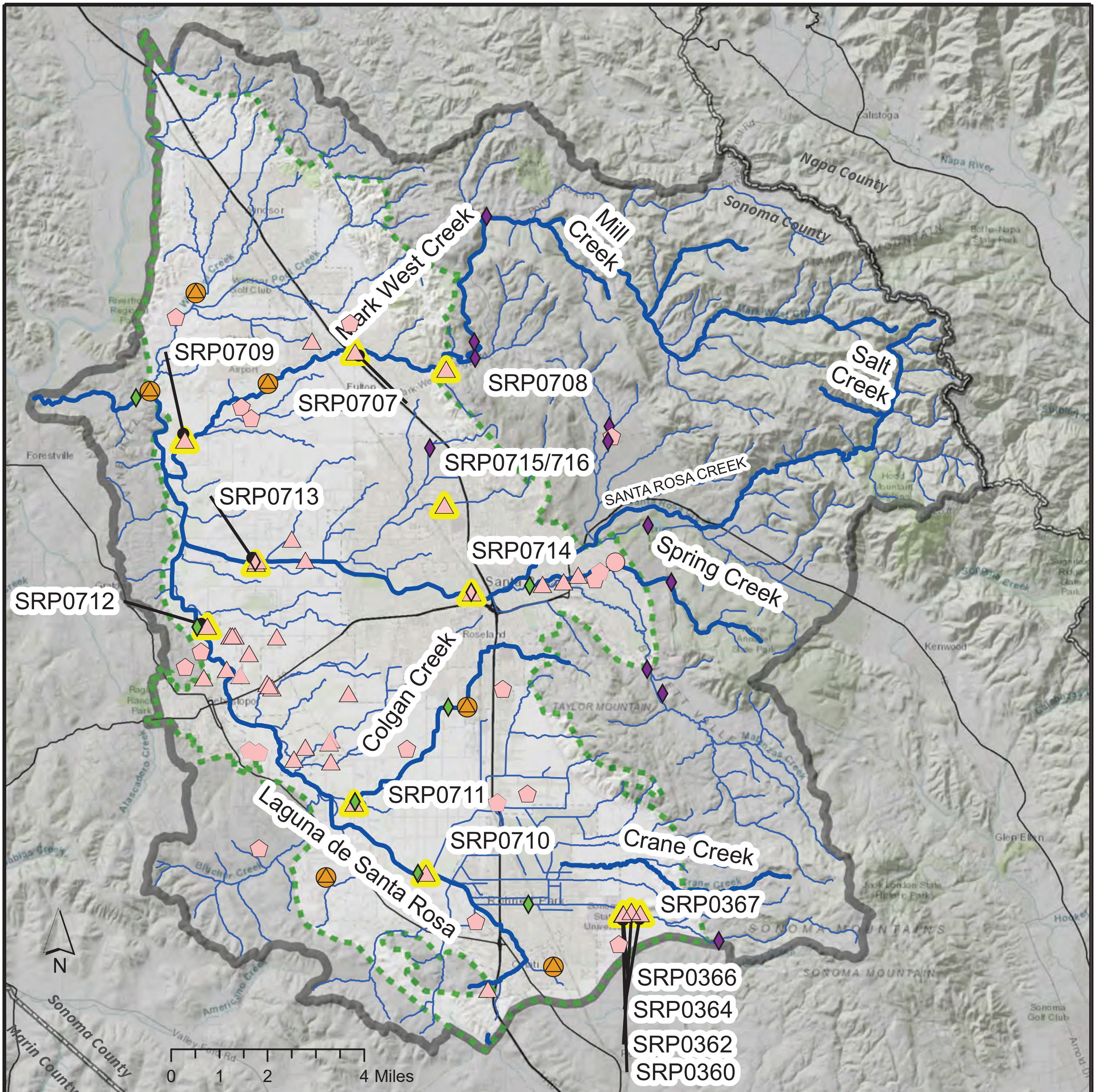
Example minimum threshold (MT) =
Q3 GWL > streambed elev.
= >75% avg. decrease in Q3 streamflow



**Shallow TSS Monitoring Well Details**
**Santa Rosa Plain Groundwater Subbasin**

| Station Name | Station Number | Location Description | Well Depth (ft BGS) | Screened Interval (ft BGS) | Well TOC Elevation (ft MSL) | Approximate Distance from Well to Creek (ft) | Direction of Well from Creek |
|---|---|---|---|---|---|---|---|
| SRP0707 | SRP-F07-04_Fulton | Mark West Creek at Fulton Rd | 50.5 | 30-50 | 143.92 | 200 | S |
| SRP0708 | SRP-H07-01_Mark West | Mark West Creek at Mark West Springs Rd. | 25.5 | 15-25 | 196.18 | 275 | SE |
| SRP0710 | SRP-H18-02_Stony | Laguna de Santa Rosa at Stony Point Rd. | 45.5 | 35-45 | 89.67 | 75 | N |
| SRP0709 | SRP-C09-01_River Rd | Mark West Creek at River Rd | 33.5 | 23-33 | 71.86 | 100 | N |
| SRP0711 | SRP-F16-01_Llano | Colgan Creek at Llano Rd. | 45.5 | 35-45 | 79.26 | 110 | S |
| SRP0712 | SRP-C13-03_Sanford | Laguna de Santa Rosa at Occidental Rd. | 48.5 | 28-48 | 69.28 | 1135 | E |
| SRP0713 | SRP-D11-02_Willow | Santa Rosa Creek at Willowside Rd. | 45.5 | 25-45 | 78.77 | 115 | S |
| SRP0714 | SRP-H12-01_Pierson | Santa Rosa Creek at Pierson St. | 51.5 | 41-51 | 150.34 | 65 | S |
| SRP0715 | SRP-H10-04_Hardies | Paulin Creek at Hardies Ln. | 40.5 | 30-40 | 135.45 | 35 | S |
| SRP0716 | SRP-H10-04s_Hardies | Paulin Creek at Hardies Ln - Shallow | 20.5 | 15-20 | 135.55 | 35 | S |

Notes:
ft BGS - Feet Below Ground Surface
ft MSL - Feet Above Mean Sea Level (North American Vertical Datum of 1988)
TOC - Top of Casing




## Shallow Aquifer System Groundwater-Level Monitoring Network and Existing Stream Gauges

**Data Sources:**

**Groundwater Basins** - California Department of Water Resources, Bulletin 118

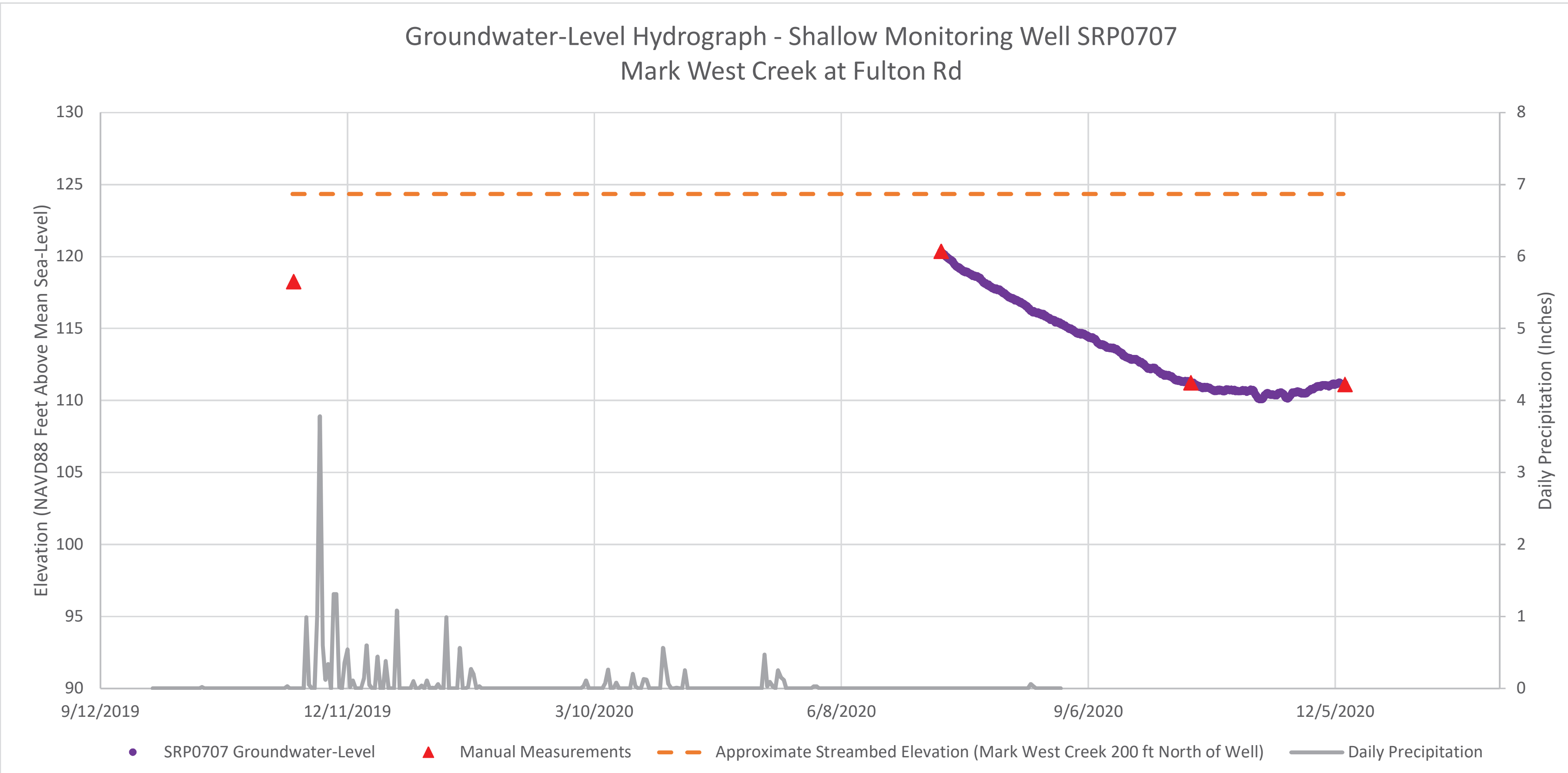
**Major Rivers and Creeks** - Department of Water Resources

**Streams** - Sonoma County Central GIS and Sonoma Water

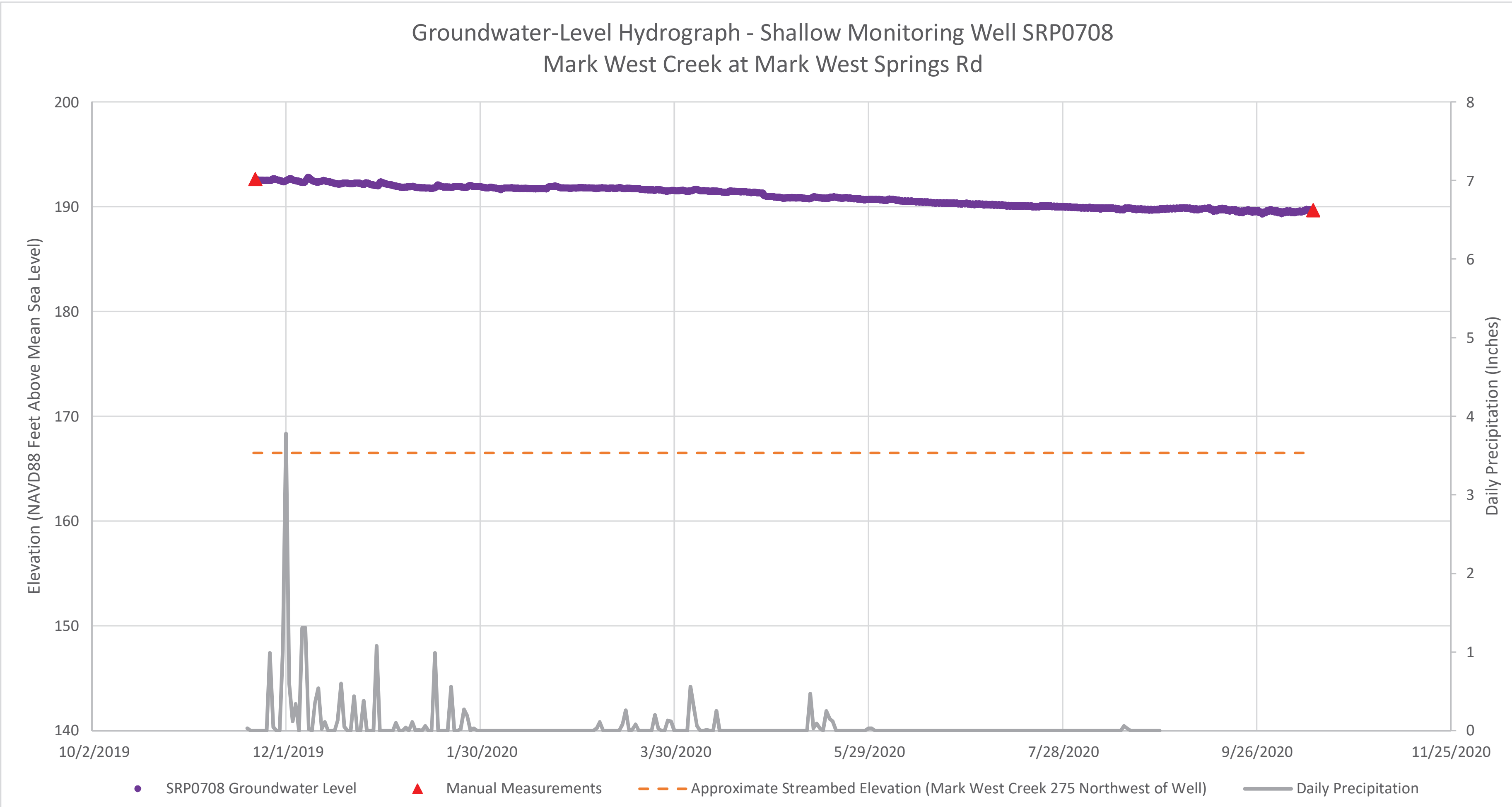
# DRAFT

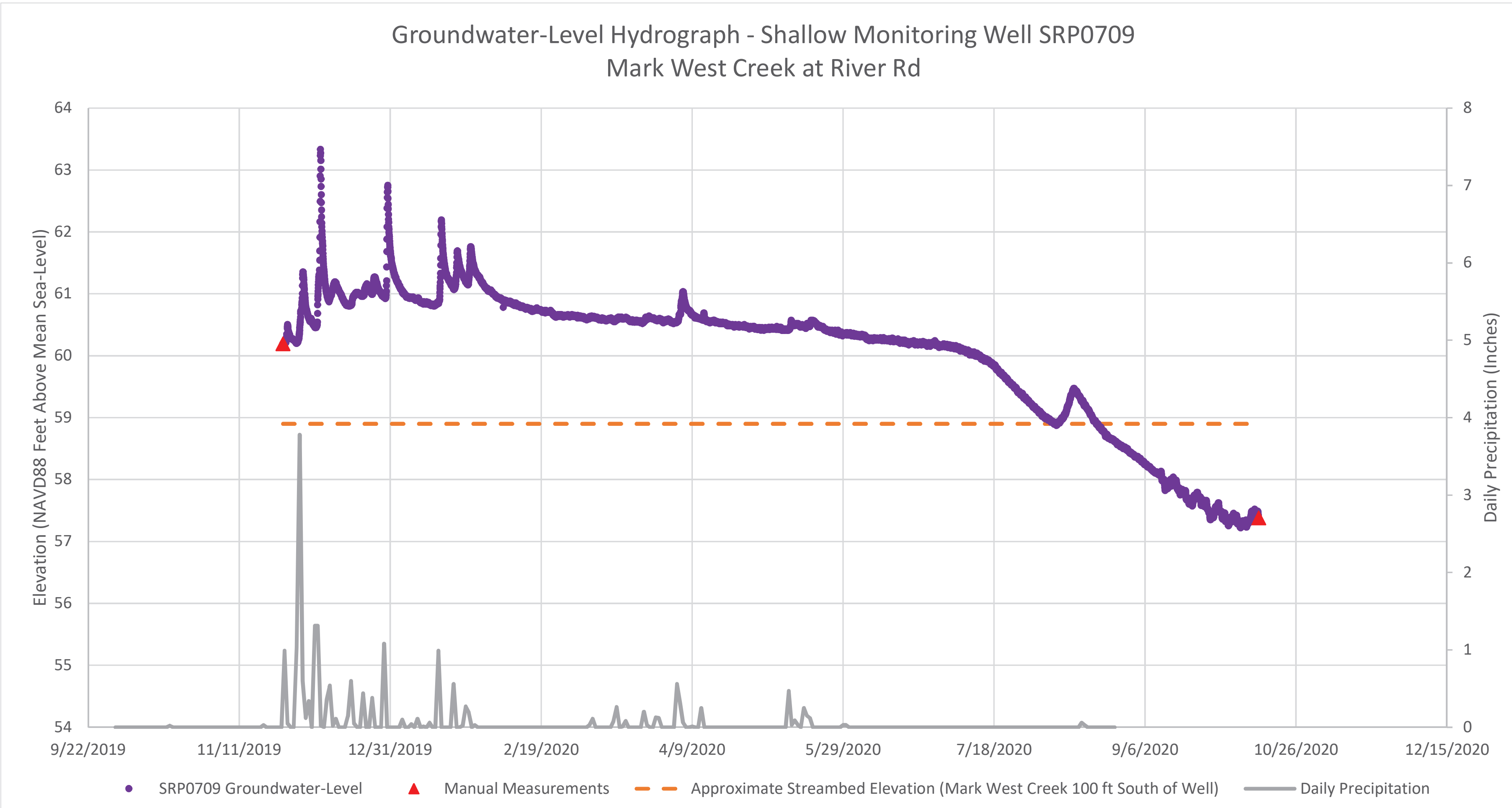
SANTA ROSA PLAIN GROUNDWATER SUSTAINABILITY AGENCY

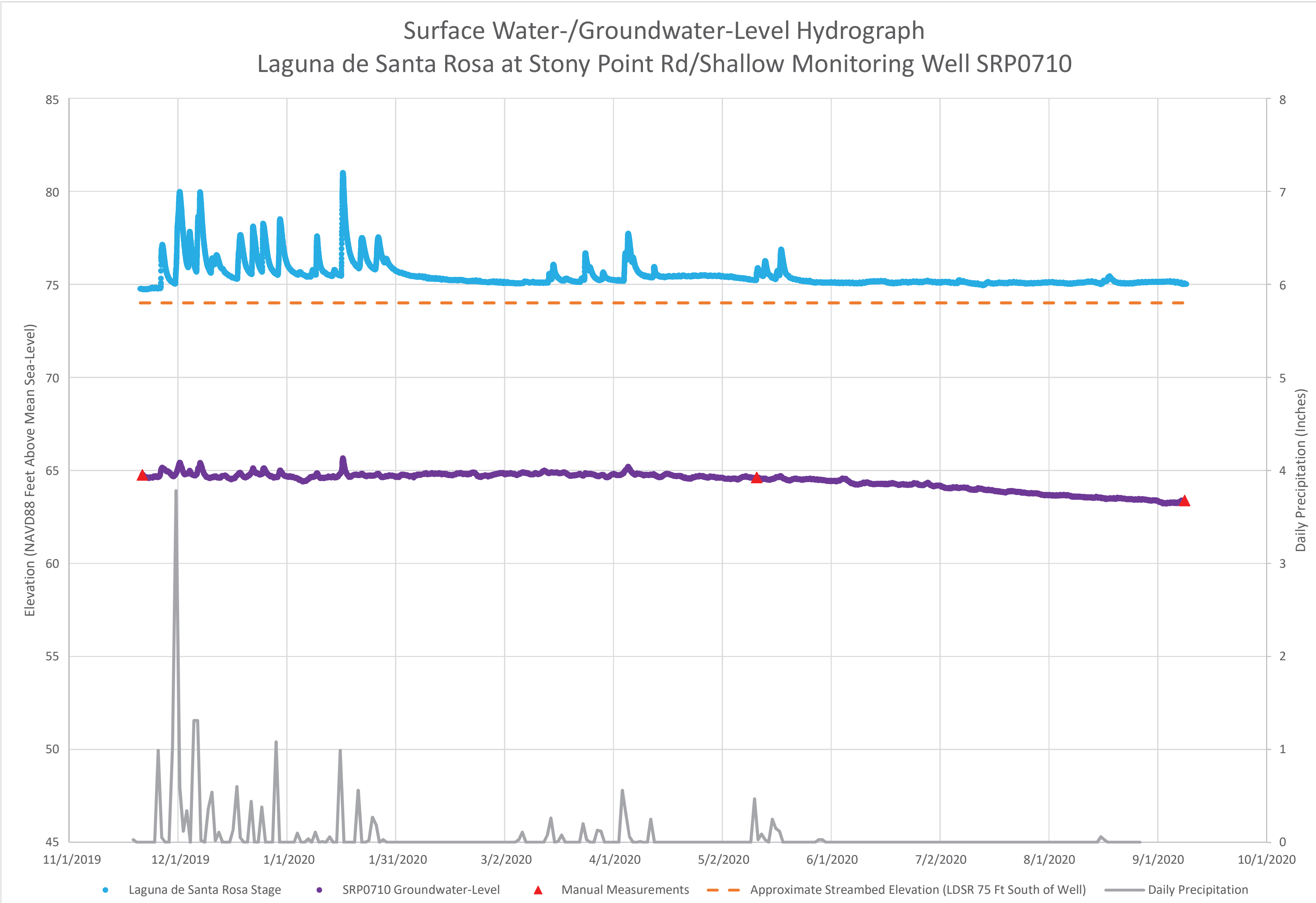
Filepath: T:\mbuttress\SGMA Monitoring Networks\Santa Rosa Plain\SRP_GW_Levl_FULLNet_S_SWGW.mxd Date prepared: 10/6/2020

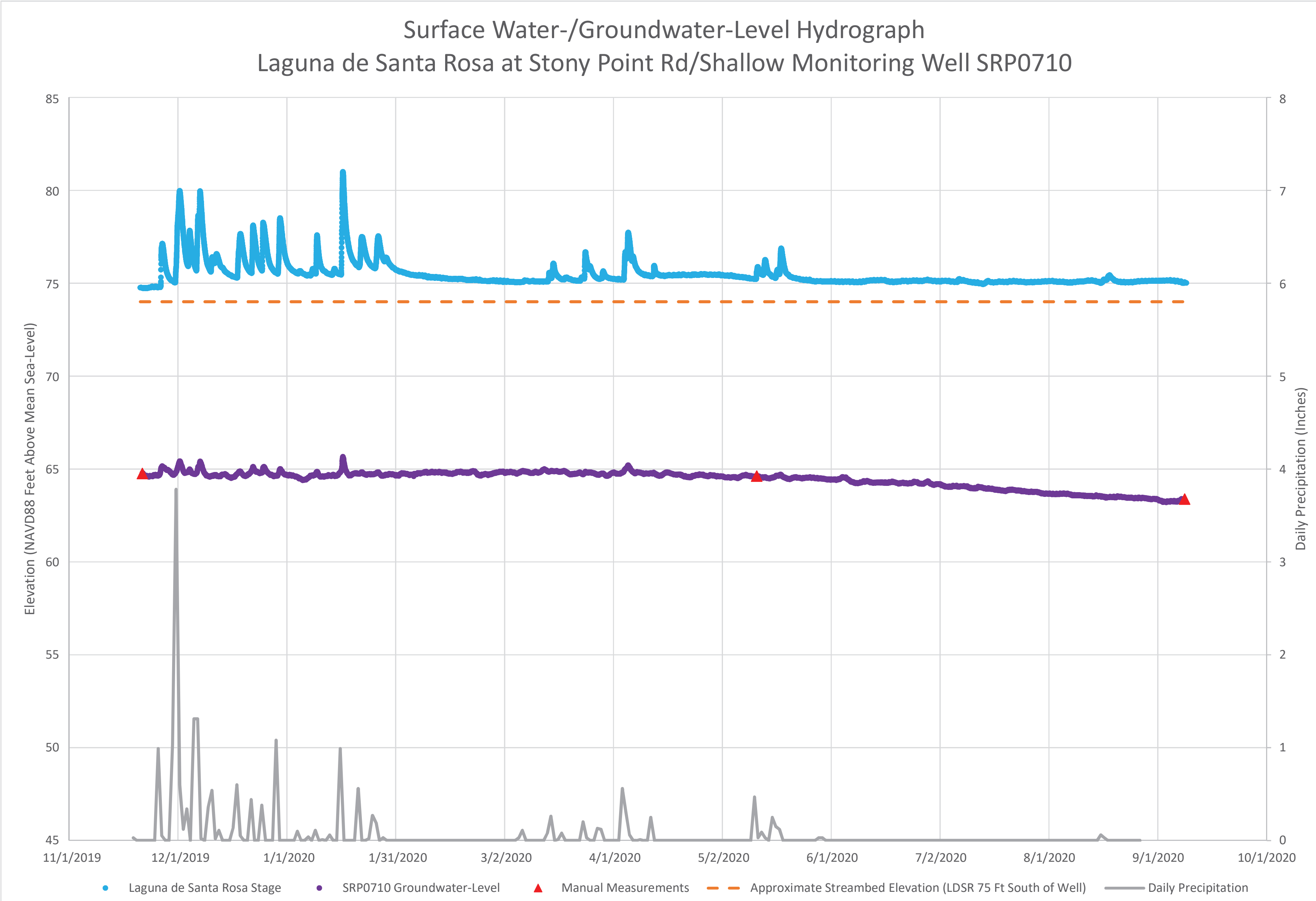


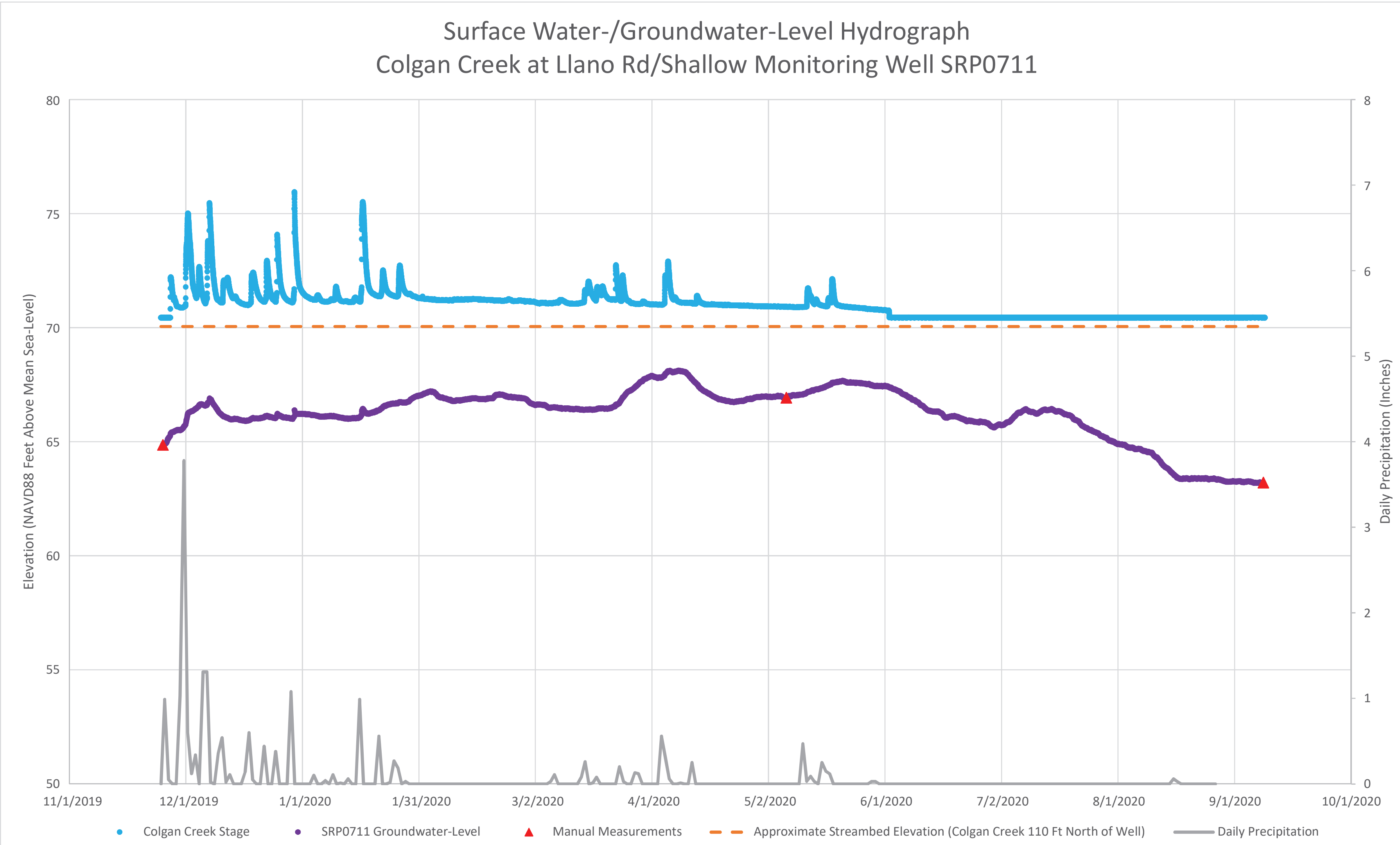
Groundwater-Level Hydrograph - Shallow Monitoring Well SRP0707
Mark West Creek at Fulton Rd
Elevation (NAVD88 Feet Above Mean Sea-Level)
Daily Precipitation (Inches)
130
125
120
115
110
105
100
95
90
8
7
6
5
4
3
2
1
0
9/12/2019
12/11/2019
3/10/2020
6/8/2020
9/6/2020
12/5/2020
SRP0707 Groundwater-Level
Manual Measurements
Approximate Streambed Elevation (Mark West Creek 200 ft North of Well)
Daily Precipitation

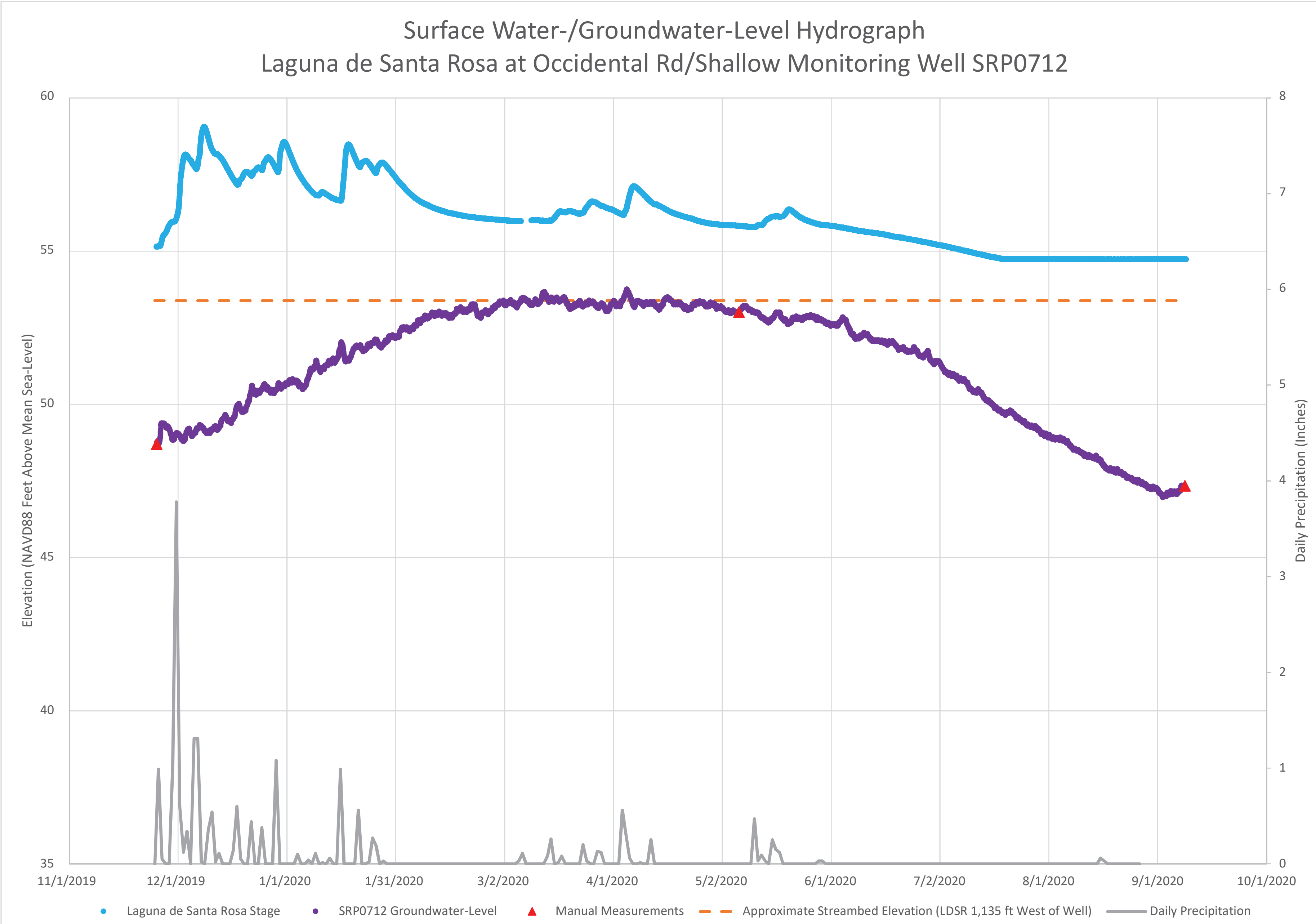

Groundwater-Level Hydrograph - Shallow Monitoring Well SRP0708
Mark West Creek at Mark West Springs Rd
Elevation (NAVD88 Feet Above Mean Sea Level)
Daily Precipitation (Inches)
200
190
180
170
160
150
140
8
7
6
5
4
3
2
1
0
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
7/28/2020
9/26/2020
11/25/2020
SRP0708 Groundwater Level
Manual Measurements
Approximate Streambed Elevation (Mark West Creek 275 Northwest of Well)
Daily Precipitation

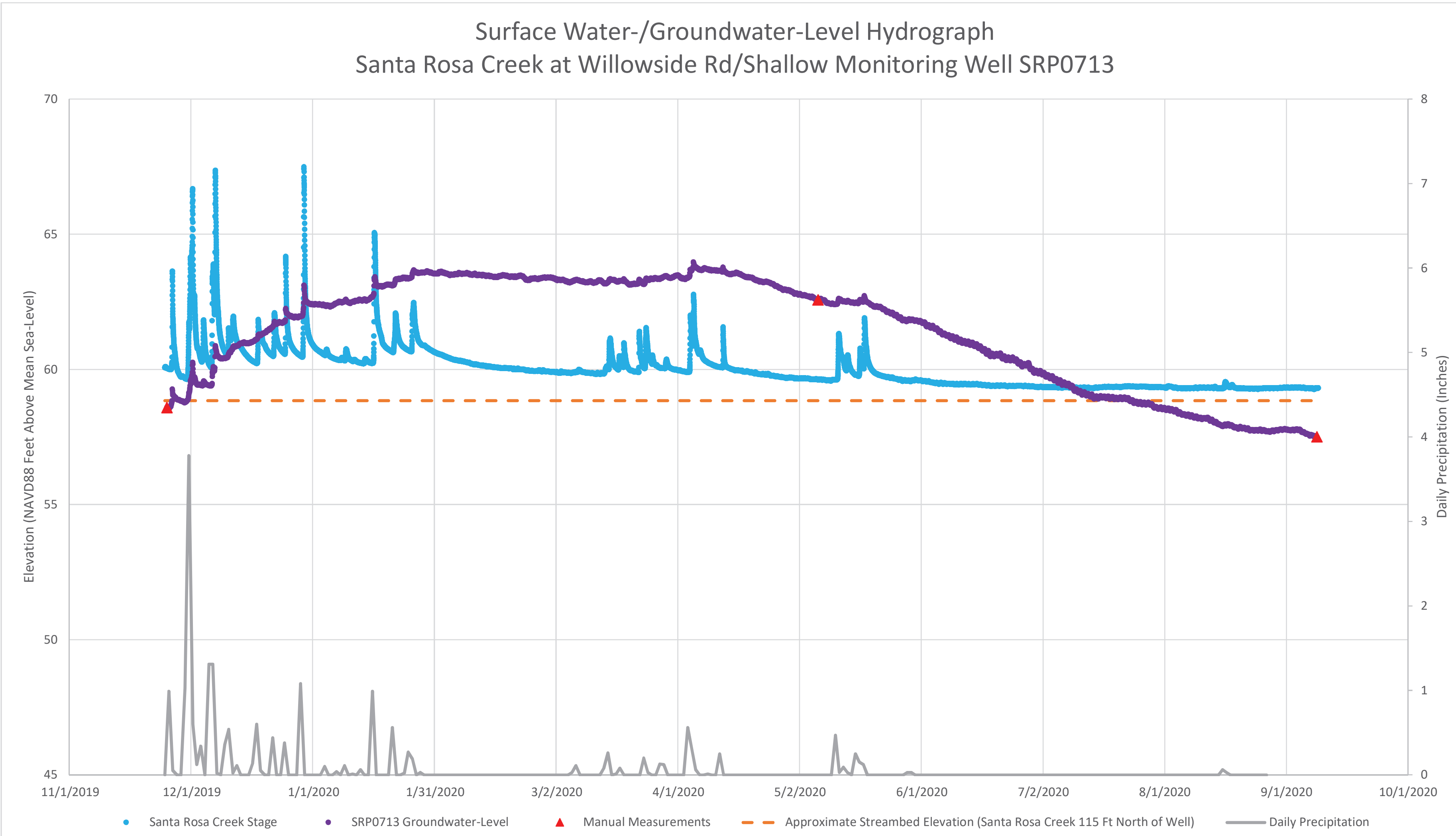

Groundwater-Level Hydrograph - Shallow Monitoring Well SRP0709
Mark West Creek at River Rd
Elevation (NAVD88 Feet Above Mean Sea-Level)
Daily Precipitation (Inches)
64
63
62
61
60
59
58
57
56
55
54
8
7
6
5
4
3
2
1
0
9/22/2019
11/11/2019
12/31/2019
2/19/2020
4/9/2020
5/29/2020
7/18/2020
9/6/2020
10/26/2020
12/15/2020
SRP0709 Groundwater-Level
Manual Measurements
Approximate Streambed Elevation (Mark West Creek 100 ft South of Well)
Daily Precipitation

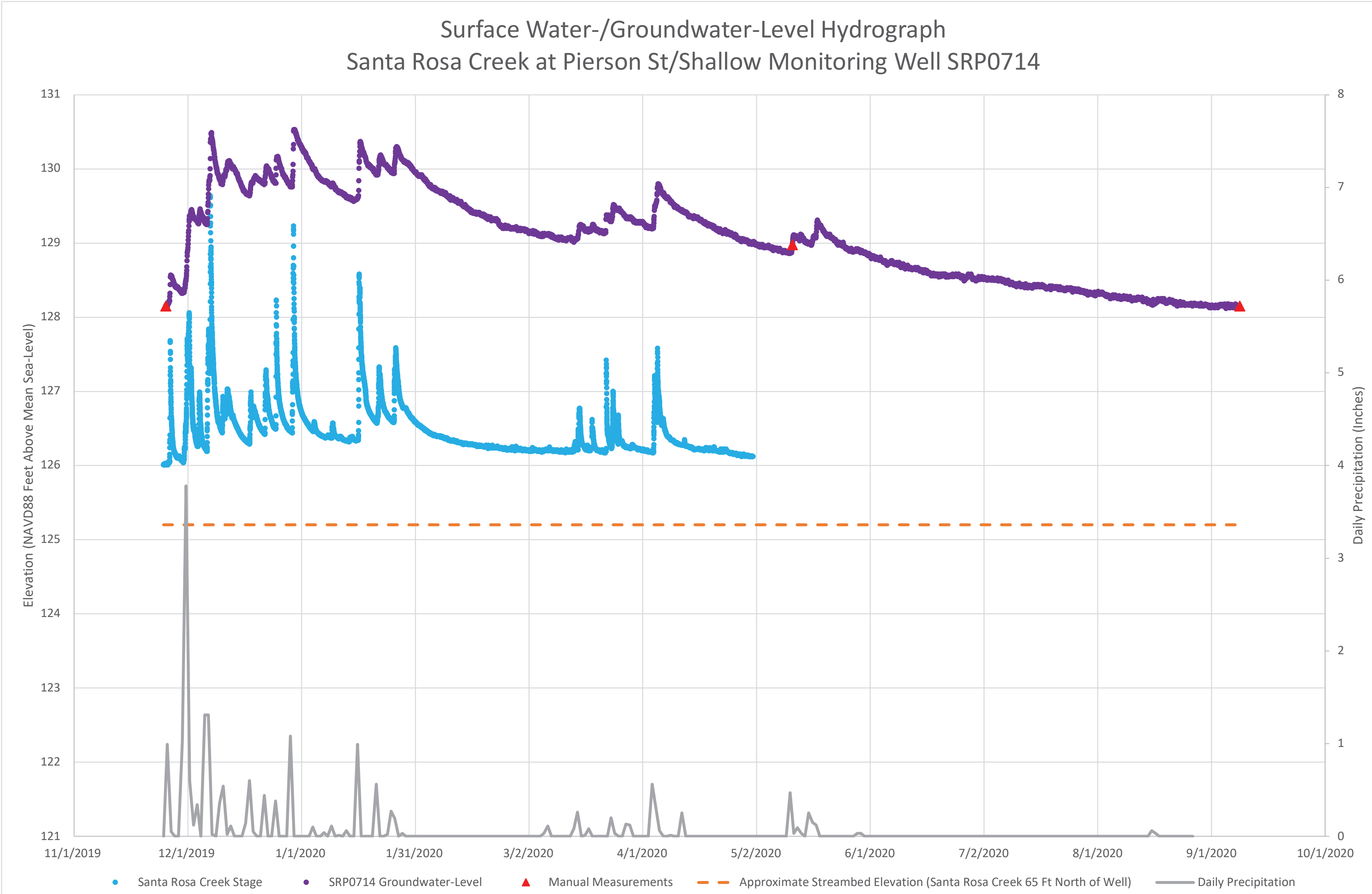

Surface Water-/Groundwater-Level Hydrograph
Laguna de Santa Rosa at Stony Point Rd/Shallow Monitoring Well SRP0710
Elevation (NAVD88 Feet Above Mean Sea-Level)
Daily Precipitation (Inches)
85
80
75
70
65
60
55
50
45
8
7
6
5
4
3
2
1
0
11/1/2019
12/1/2019
1/1/2020
1/31/2020
3/2/2020
4/1/2020
5/2/2020
6/1/2020
7/2/2020
8/1/2020
9/1/2020
10/1/2020
Laguna de Santa Rosa Stage
SRP0710 Groundwater-Level
Manual Measurements
Approximate Streambed Elevation (LDSR 75 Ft South of Well)
Daily Precipitation

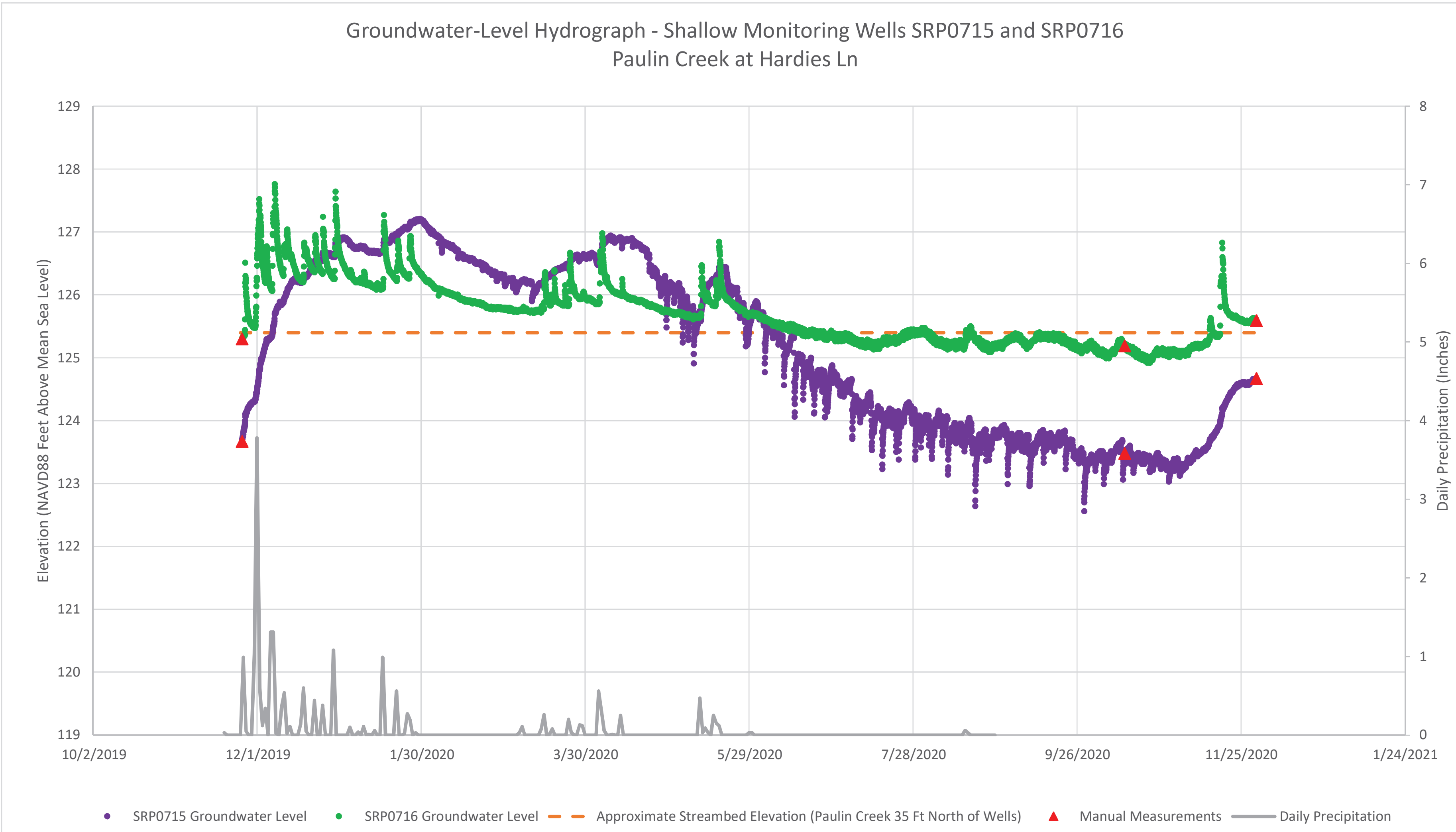

Surface Water-/Groundwater-Level Hydrograph
Laguna de Santa Rosa at Stony Point Rd/Shallow Monitoring Well SRP0710
Elevation (NAVD88 Feet Above Mean Sea-Level)
Daily Precipitation (Inches)
85
80
75
70
65
60
55
50
45
8
7
6
5
4
3
2
1
0
11/1/2019
12/1/2019
1/1/2020
1/31/2020
3/2/2020
4/1/2020
5/2/2020
6/1/2020
7/2/2020
8/1/2020
9/1/2020
10/1/2020
Laguna de Santa Rosa Stage
SRP0710 Groundwater-Level
Manual Measurements
Approximate Streambed Elevation (LDSR 75 Ft South of Well)
Daily Precipitation


Surface Water-/Groundwater-Level Hydrograph
Colgan Creek at Llano Rd/Shallow Monitoring Well SRP0711
Elevation (NAVD88 Feet Above Mean Sea-Level)
Daily Precipitation (Inches)
80
75
70
65
60
55
50
8
7
6
5
4
3
2
1
0
11/1/2019
12/1/2019
1/1/2020
1/31/2020
3/2/2020
4/1/2020
5/2/2020
6/1/2020
7/2/2020
8/1/2020
9/1/2020
10/1/2020
Colgan Creek Stage
SRP0711 Groundwater-Level
Manual Measurements
Approximate Streambed Elevation (Colgan Creek 110 Ft North of Well)
Daily Precipitation


Surface Water-/Groundwater-Level Hydrograph
Laguna de Santa Rosa at Occidental Rd/Shallow Monitoring Well SRP0712
Elevation (NAVD88 Feet Above Mean Sea-Level)
Daily Precipitation (Inches)
60
55
50
45
40
35
8
7
6
5
4
3
2
1
0
11/1/2019
12/1/2019
1/1/2020
1/31/2020
3/2/2020
4/1/2020
5/2/2020
6/1/2020
7/2/2020
8/1/2020
9/1/2020
10/1/2020
Laguna de Santa Rosa Stage
SRP0712 Groundwater-Level
Manual Measurements
Approximate Streambed Elevation (LDSR 1,135 ft West of Well)
Daily Precipitation


Surface Water-/Groundwater-Level Hydrograph
Santa Rosa Creek at Willowside Rd/Shallow Monitoring Well SRP0713
Elevation (NAVD88 Feet Above Mean Sea-Level)
Daily Precipitation (Inches)
70
65
60
55
50
45
8
7
6
5
4
3
2
1
0
11/1/2019
12/1/2019
1/1/2020
1/31/2020
3/2/2020
4/1/2020
5/2/2020
6/1/2020
7/2/2020
8/1/2020
9/1/2020
10/1/2020
Santa Rosa Creek Stage
SRP0713 Groundwater-Level
Manual Measurements
Approximate Streambed Elevation (Santa Rosa Creek 115 Ft North of Well)
Daily Precipitation


Surface Water-/Groundwater-Level Hydrograph
Santa Rosa Creek at Pierson St/Shallow Monitoring Well SRP0714
Elevation (NAVD88 Feet Above Mean Sea-Level)
Daily Precipitation (Inches)
131
130
129
128
127
126
125
124
123
122
121
8
7
6
5
4
3
2
1
0
11/1/2019
12/1/2019
1/1/2020
1/31/2020
3/2/2020
4/1/2020
5/2/2020
6/1/2020
7/2/2020
8/1/2020
9/1/2020
10/1/2020
Santa Rosa Creek Stage
SRP0714 Groundwater-Level
Manual Measurements
Approximate Streambed Elevation (Santa Rosa Creek 65 Ft North of Well)
Daily Precipitation


Groundwater-Level Hydrograph - Shallow Monitoring Wells SRP0715 and SRP0716
Paulin Creek at Hardies Ln
Elevation (NAVD88 Feet Above Mean Sea Level)
Daily Precipitation (Inches)
129
128
127
126
125
124
123
122
121
120
119
8
7
6
5
4
3
2
1
0
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
7/28/2020
9/26/2020
11/25/2020
1/24/2021
SRP0715 Groundwater Level
SRP0716 Groundwater Level
Approximate Streambed Elevation (Paulin Creek 35 Ft North of Wells)
Manual Measurements
Daily Precipitation

# Identification and Mapping
# Groundwater Dependent Ecosystems Workgroup
## Meeting Summary

Date/Time: Tuesday, July 7, 2020 | 1:00 p.m. - 3:00 p.m.
Location: https://csus.zoom.us/j/99011901938
Contact: Sam Magill, Practitioner Work Group Facilitator
Email: s.magill@csus.edu | Phone: (831) 251-4127

## MEETING SUMMARY

### Welcome and Introductions / Agenda and Meeting Schedule Review

Sam Magill, Work Group Facilitator walked through the agenda for the day and reminded the participants of the focus of the workgroup:

a. Description of existing datasets, model tools and preliminary mapping efforts
b. Discuss process for integration of datasets for developing Potential GDE Maps
c. Discussion of data gaps

Marcus Trotta, Hydrogeologist, welcomed the group and conveyed his appreciation for the attendees participating in the work group. He mentioned the input from this group will feed into the second Ecosystems work group.

Sam Magill then suggested a round of introductions.

### Sustainable Groundwater Management Act (SGMA) Update and Need for Identification of Groundwater Dependent Ecosystems

*Objective: Provide brief overview of SGMA requirements, update on GSP development, and need for GDE identification*

Marcus Trotta started with a high-level overview of SGMA and mentioned the three steps of compliance:

1. Form GSA by June 30, 2017
2. Develop GSP by January 31, 2022
3. Achieve sustainability 20 years after adoption of plan

Failure to meet any of the deadlines, triggers intervention by the State Water Resources Control Board.

There is one Groundwater Sustainability Plan in development for each of the three basins, Petaluma Valley, Santa Rosa Plain, and Sonoma Valley. The three agencies were formed in June 2017 and have been working on their GSP since then. Sonoma Water is leading the technical work on each of the plans with support from different consultants, the Advisory Committee, and the Board.

Trotta gave an overview of the main points for GDE Mapping:

- Focus on ecosystems that can be affected by groundwater conditions and management are within jurisdiction of the GSAs
- Utilize available statewide and local datasets to develop best available information
- Consider using "indicator" species and/or grouping of GDWs with similar characteristics/habitat needs
- Prioritize GDEs for consideration in developing SMCS for surface water depletion (separate workgroup)

*Questions/Discussion*

Dusterhoff – Is there a state defined definition for GDE that basins are following to determine what we consider GDEs or is it basin dependent and the scientists in the basin define what GDEs are?

> Trotta – The Definition under SGMA is that GDEs are ecological communities of species that depend on groundwater emerging from aquifers or groundwater occurring near the surface (i.e. areas of shallow groundwater, could be roots of vegetation are able to tap into groundwater to support their growth). The state through its partnership with the Nature Conservancy has developed initial indicators of groundwater dependent ecosystems. They encourage GSAs to use that information as well as local information. So, there are state guidance and suggestions, but how they are mapped out within each basin is up to the local GSA.
>
> Magill – That would include low lying wetlands not directly connected to existing surface water sources?
>
> Trotta – It could, provided there is a connection with groundwater for those wetlands.

Trowbridge – For this discussion, are we narrowing our focus to groundwater dependent ecosystems but can be impacted by the GSA? The SRP GSA only covers groundwater in the Santa Rosa Plain, but if the water is coming from the Mayacamas, no amount of management change in the Santa Rosa Plain is going to change that. Also, vernal pools, they fill through rainwater but could become groundwater. How does that fit in?

> Trotta – Vernal pools that are primarily perched features, rainwater that perches on low permeability layer, they do eventually contribute to groundwater. In terms of their dependency on groundwater, I wouldn't categorize them as being dependent on groundwater. We would want to focus on groundwater dependent ecosystems connected with aquifers that the GSA would have control over managing. For areas that are outside the basins, the GSA's jurisdiction is limited to those basin areas. They are required to demonstrate their Groundwater Sustainability Plan will not affect neighboring groundwater basins. In terms of upstream areas, we have been including information from those up lying adjoining areas in the contributing watershed in the basin. The GSA

could support projects that enhance conditions in those areas but that don't have direct control of groundwater use or anything that would affect groundwater conditions in those areas.

Marcus Trotta gave a high-level introduction overview of existing datasets for preliminary mapping of potential groundwater dependent ecosystems. Andy Rich talked about their work in identifying interconnected surface water in the basins. Definition in the GSP Regulations as 'surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted.' Our approach to identifying the interconnect surface water is dependent on the information we have for the basins Santa Rosa Plain and Sonoma Valley. For Sonoma Valley, we have a lot of observed data using seepage run monitoring results. For Santa Rosa Plain, we are much more dependent on model results from the USGS flow model developed for the SRP in 2014. We are currently updating the model, but the results presented here are from 2014.

*Questions*

Rogers – Just for clarification on interconnected definition: SGMA defines 'interconnected surface water' as 'surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted.'

Rogers – It seems like some of the graphs, figures and analyses in the presentation, focus on the percent of time when stream reach is gaining, but losing streams are interconnected surface water also, based on the definition.

Rich – Good point, we need to reconsider a little more.

Rohde – Are there shallow groundwater data prior to 2016? Using groundwater data from 2016 to characterize groundwater conditions in the basin is technically past the SGMA date. Also, it's important to understand inter-annual groundwater fluctuations across multiple water year types (i.e., dry, wet, average).

Trotta – Yes, we have initially contoured 2016, as it represented the largest dataset of observed groundwater levels at the time. We can evaluate earlier years as well. Additionally, each point (well) on those maps has a time series of groundwater levels that can be examined if certain areas are of interest.

Rohde - Fantastic! The depth-to-groundwater maps look very nice. The lidar ground elevation data makes a difference and is much better than interpolating depth to groundwater measurements between wells.

Dusterhoff – Would you see a different story in a dry period versus a wet period?

Rich – Certainly, as the groundwater system dries during a dry period. Based on observed data, you should see a decrease amount of interconnected surface water. The point raises the question of when is the best time to do the analysis?

Dusterhoff – You are doing the best you have with the funding you have to collect the data. Story can be skewed by the time data is retrieved. How do you plan on acknowledging drier periods versus wetter periods?

Rich – For the simulated data from Santa Rosa Plain, which is focused from 2000 to 2010, I don't think we are capturing too biased climate period. With the observed data, much of it is from the last five years which is a drier period. But, given the difficulty in replicating some of the observed data, it is hard to have data that reflects not so dry conditions.

Gaffney – Will the data be available once peer reviewed and completed? Will the recording of the meeting and presentation be available too?

Magill – Yes, we will make the presentations available. The meeting is also being recorded and there will be a meeting summary that can be shared.

Trotta – We can provide you all copies of the figures that we are presenting either as a packet or through a file share site, I know some of these can be hard to view on Zoom. We also have draft write-ups for how we developed the Interconnected Surface Water maps.

Gaffney - I am wondering about underlying "raw" data, specifically GIS data.

Rich – As there are a lot of GIS data, I think it would be better to have an offline discussion, we are happy to share the information.

Marcus Trotta then showed Santa Rosa Plain, Petaluma Valley and Sonoma Valley preliminary maps from the Nature Conservancy of groundwater dependent ecosystems, draft Steelhead streams maps and draft vegetation-related potential groundwater dependent ecosystem maps before handing over to Melissa Rohde, from the Nature Conservancy for comment, and to David Cook and Patrick Lei, both from Sonoma Water.

Melissa Rohde mentioned the map is basically a starting point and much of the map features are taken from aerial imagery, there been lots of expert review and ground truthing, maps of springs and other hydrologic features. In order to know the ecosystems are related to groundwater, it is important to look at the depth of groundwater. In most parts of the state there often isn't good data of shallow groundwater. Absence of evidence isn't evidence of absence! It is important to ensure that our groundwater data network is dense enough to pick up what the conditions are in the eco systems and to validate if they are groundwater dependent. These species are typically known to use groundwater, but the species are opportunistic and can use other sources of water, so it is important to make sure there is groundwater there.

David Cook said they wanted to find an indicator species that would represent groundwater dependent species throughout the three basins. Initially we focused on fish and amphibians and we were also looking for a solid data set. Through that process we found that steelhead are quite well distributed throughout the basins, and we had detailed data sets. Unfortunately, there wasn't one single dataset used for all three basins. For Petaluma and Sonoma Valley, we used a 2005 report from Leidy, this was supplemented with information from Sonoma Water. For Santa Rosa Plain, we had a good dataset from the Coastal Monitoring Program, along with in-house data from the Shawn Chase database. We put all the steelhead bearing streams on maps, excluded anything outside of the three basins and included any stream further downstream from a section that was identified as steelhead habitat. That is how we arrived at our process to get the steelhead layer.

Patrick Lei – We relied heavily on the Sonoma Veg Map and focused on communities with strong riparian composition such as willow and cottonwood, or species that may rely on groundwater in some parts of the year, such as oak. One limitation of maps is depth of groundwater. We probably will not include vernal pools in the final maps because we don't think there is much of a groundwater connection, but where there is, we would include it.

*Questions*

Trowbridge – How are the maps of groundwater dependent ecosystems going to inform SGMA? Are we expecting the maps to change over time as groundwater management changes or are we going to monitor attributes of these communities that we would expect to change with groundwater management? It seems like what is driving the maps is development.

> Trotta – The way that groundwater dependent ecosystems are written into SGMA and requirements related to them in the groundwater sustainable plan regulations that DWR has established, is related to identifying their occurrence and distribution and taking them into consideration during the development of GSP and SMC, establishing how much groundwater lowering can occur in the basin before there are impacts in the basin or how much surface depletion there is before there are impacts. I am envisioning the mapping based on our existing available data sets will be utilized by the second workgroup that would be focused on what are the minimum thresholds set for surface water depletion in the basin. Are there certain areas that should be prioritized more than others? Are there areas where there should be a focus on monitoring? Going forward, I would expect the maps to change over time as new information is developed. How does the distribution of these groundwater dependent ecosystems match up with where higher densities of groundwater pumping are occurring in the basins?
>
> Lee – Related to that concept of previous development and how it affects this. Things about the seepage and springs around, there are lots of places in the watershed where early in the history of the area, they were found and developed where there are stock ponds in the hills now, where the original seepage would have been. Now they are characterized by ponds more than whatever vegetation we are looking for otherwise.

Lee – Another question about the Veg map, there are lots of places on the developmental property, there is spring activity under forested cover, would that be one area of data gap? I guess you can't see through the upper canopy to see the lower plants.

> Lei – I agree with you, that would be one example of a data gap. We do have limitations, In the early discussion before putting the map together we talked about seepage and springs but decided to keep those out of this map.
>
> Lee – If we want to talk about those kinds of places that are not showing up in your analyses at this point, that is where local knowledge can come in.
>
> Trotta – Seepage and springs that may be missed by the veg mapping, could be picked up in the maps Andy Rich went through. It may not capture all of them but could give an insight. Also, maps that have been developed by USGS that include seepage and springs, that we could also incorporate.

Rohde – When you create the GDE map, it would be great to see how the Sonoma Veg data overlap with the NC dataset. It would be helpful to see which vegetation are added under the Sonoma veg database that weren't originally available in the NC dataset.

Trotta – What we see as some of the next steps is going to be integration of different data sets. We can produce various maps that highlight the differences between the maps or show where we are intersecting data. We will make sure the data is clearly shown on the next set of maps.

Sam Magill said staff would be very interested to hear if there are other existing data sources that should be included for the Groundwater Sustainability Plan, and what additional data collection is recommended for the implementation phase of the GSP.

Rogers – I have a question about the steelhead distribution maps – were those generated from records current steelhead distribution or were they taken from steelhead critical habitat maps? Some areas that probably don't have steelhead, might not have steelhead because of stream flow depletion impacts. How was that dynamic factored in the map making?

Cook – It is based on current information, doesn't account for any impact on groundwater. It was the most accurate data set we could find. Something up for discussion – how do you define what steelhead stream?

Rogers – What is the data here? What is the timeline? In more recent years, steelhead have been absent due to decrease in stream flow. Since the Leidy study was completed, Yulupa creek has dried considerably and has a significant passage barrier. I wouldn't consider it a steelhead stream currently, but it could become one again. Are we looking to restore past conditions through this or maintain existing GDEs as of a certain dateline?

Trotta – Ultimately it would be a GSA Board decision. No need to correct or address issues before GSA was enacted in 2017 – it is not a requirement of SGMA. Many GSPS have held it as a baseline in their criteria. We are aware of the baseline; it will depend on the costs and priorities of the GSA in complying with SGMA. At a minimum they would support to restore conditions to improve fisheries and other ecosystems in their plans. Whether it would be built into the criteria would be up for discussion.

Gaffney – Definitely, there is an opportunity for continued collaborative data collection and local refinement. When we developed the Sonoma Veg Map program, the intention was to create a fine scale veg map for the million-acre county that aligned with the CDFW MCV standards. There is a significant opportunity to continually refine with local data via this process, as well as through I-naturalist, stream maintenance program etc. Ag & Open Space has developed additional data sets related to future potential riparian habitat based on physical attributes and processes.

There are also relatively accurate maps for the main stem Russian (alluvial reaches) that document riparian and land use cover from 1940-1942, 1990. Combined with modeled outputs for where riparian "could" exist based on fluvial-geomorphic processes, this could contribute to this initiative one more potential gap (please forgive my ignorance of the constraints of this process): multi-benefit criteria such as agricultural use (such as rangelands) that are compatible with GW sustainability, biological diversity, etc. Since Ag & Open Space is a potential tool for protecting these areas (via conservation easements) it would be helpful to understand how you are looking at this (or if it is outside the realm of this effort).

Rich – Regarding the comment of the main stem of the Russian River, none of the three basins covers the main stem of the Russian River so, it won't be directly useful here, but it is interesting information

Trowbridge – To piggyback on Karen Gaffney's historic data, we have been working on a historical ecology map. We wouldn't want the GSA to be beholden to restoring it, we are working on a vision for restoration and it does seem like the historical ecology would be indicative of groundwater and how groundwater used to be in the basin, so it would provide valuable baseline information about groundwater even if some of the ecology has changed.

Trotta – What is the timeframe for that work?

Dusterhoff – It is a two-part project. Part 1 is developing restored landscape vision and Part is using the vision to identify several restoration concepts. The vision was completed in April; we are in the process of making some updates, but it is a public document now. Restoration plan will be done by February 2021. Here is the link for Laguna de Santa Rosa Restoration Vision: https://www.sfei.org/sites/default/files/biblio_files/Restoration%20Vision%20for%20the%20Laguna%20de%20Santa%20Rosa%20SFEI%20041520%20med%20res.pdf

Gaffney – Am I mistaken that the Ukiah reach of Russian River is not a high or medium priority basin? The middle Reach looks to be involved too.

Trotta – It is a medium priority basin and there is a GSA creating a plan for that basin in Mendocino county. We aren't directly involved in the development of that plan. The data sources you mention would most likely be of interest to that GSA, I can put you in contact with consultants working with GSA in that area.

Magill to Trotta – Should meeting participants send additional information to staff between meetings?

Trotta – Yes, that would be helpful; we will discuss offline, maybe a single point of contact or file share location would be best.

Lee – In terms of existing data sources to be included – there are local and anecdotal knowledge of data that exists out there. In terms of another data source, we at the Ecology Center, have installed 11 stream gauges in upper Sonoma creek in the last two years. Having the continuous data that can be used in an upstream and downstream fashion, is another potential data source that could be valuable and is available. Also, we recently installed a series of temperature loggers around the watershed for the dry season. In terms of additional data collection to be recommended, seeing more of the continuous stream flow data around the different watersheds beyond the USGS gauges is available, and could be valuable moving forward.

Pennington – Great work. I was thinking about other species of concern and endangered species. You chose steelhead but it does seem there are other species that are dependent on having water in the summer and into the fall, when the streams are most sensitive to groundwater depletion. I would recommend looking at species such as freshwater shrimp and where they existed historically. Think about steelhead passed through these streams but aren't necessarily there when the groundwater dependent ecosystems are sensitive to groundwater depletion.

David Cook – We can look at other species. The reason we selected steelhead is that it encompasses species that are most sensitive in the summertime. Steelhead streams, we are really talking about juvenile steelhead and they encapsulate all the amphibians such as CA giant salamander, etc. that need perennial water. Fresh water shrimp distribution is so patchy that there are no known occurrences within the three basins. It doesn't encapsulate enough to be of value for this kind of type of analysis.

Pennington – What about the possibility of using multiple species?

David Cook – We may add additional section in the streams. In general, when you look at the basins, lots of amphibians are outside the basin.

Rohde – We also need to consider how other state and federal listed species are impacted by groundwater. Here is a document that identifies what protected status species are likely reliant on groundwater in California:
https://groundwaterresourcehub.org/public/uploads/pdfs/Critical_Species_LookBook_web.pdf
This is an effort that Rick Rogers (NOAA), Briana Seepy (DFW), Xeronimo Castaneda (Audabon), and I have put together.

## Review Meeting Action Items

Sam Magill restated the action items from the meeting:

- Data sharing – staff to discuss offline how to share additional data, meeting summary, and other meeting materials
- Discussion for staff how to share raw data
- Marcus Trotta to connect Karen Gaffney to the GSA for the Ukiah reach of the Russian River

## Next Steps and Planning for Meeting #2

*Objective: Discuss next steps for planning workgroup meeting #2.*

Marcus Trotta said he will look at file share, take input received today and make any refinements and revisions to maps. He will develop a GIS process to integrate surface water maps to species and veg maps with the goal of having the information and those maps for a second meeting. Then we can determine if we need a third meeting or not. Would like a discussion of the importance of understanding their habitat needs including critical time periods. We are probably looking at the second or third week of August for the next meeting for this group. Sam Magill will reach out to you.

We proposed the other workgroup would meet on the tail end of this one. We will look at the overall schedule, it may make sense to have the two groups overlap a little to do some work in tandem with this workgroup.

Marcus Trotta and Andy Rich thanked the group for participating and said the comments were very helpful.

## Attendees:

Andres Ticlavilca, National Marine Fisheries Service
Karen Gaffney, Ag & Open Space Preservation District
Melissa Rohde, The Nature Conservancy
Rick Rogers, National Marine Fisheries Service
Robert Pennington, Permit Sonoma
Scott Dusterhoff, San Francisco Estuary Institute
Steve Lee, Sonoma Ecology Center
Wendy Trowbridge, Santa Rosa de Laguna Foundation

### Staff/Presenters

Marcus Trotta, Sonoma Water
Andy Rich, Sonoma Water
David Cook, Sonoma Water
Patrick Lei, Sonoma Water
David Manning, Sonoma Water
Ann DuBay, Sonoma Water
Simone Peters, Sonoma Water (recorder of meeting notes)

### Facilitator

Sam Magill, Sacramento State University – Consensus and Collaboration Program

SANTA ROSA PLAIN • PETALUMA VALLEY • SONOMA VALLEY
GROUNDWATER
SUSTAINABILITY AGENCIES

# IDENTIFICATION AND MAPPING OF GROUNDWATER DEPENDENT ECOSYSTEMS

Workgroup Meeting #1

July 7, 2020

# MEETING AGENDA

1. Welcome and Introductions
2. Agenda Review
3. Sustainable Groundwater Management Act (SGMA) Update and Need for Identification of GDEs
    - SGMA overview
    - Groundwater Sustainability Plan (GSP) status and schedule
    - How will identified GDEs be used in the GSPs
    - Proposed process for mapping GDEs
    - Questions/Discussion
4. Existing Datasets for Preliminary Mapping of Potential GDEs
    - Indicators of GDEs (iGDE) maps (The Nature Conservancy)
    - Draft Steelhead streams maps (Sonoma Water)
    - Draft Vegetation-related GDE maps (Sonoma Water)
    - Draft Interconnected Surface Water maps (Sonoma Water)
    - Draft Depth-to-Groundwater (DTW) maps for shallow unconfined aquifer system (Sonoma Water)
    - Discussion of Data Gaps
5. Next Steps and Planning for Meeting #2
6. Review Action Items
7. ADJOURN

# Required Steps to Groundwater Sustainability

**Step one**
Form Groundwater Sustainability Agency
June 30, 2017
**- Complete**

**Step two**
Develop Groundwater Sustainability Plan
January 31, 2022

**Step three**
Achieve Sustainability
20 years after adoption of plan*

* DWR may grant up to two, five-year extensions on implementation upon showing of good cause and progress

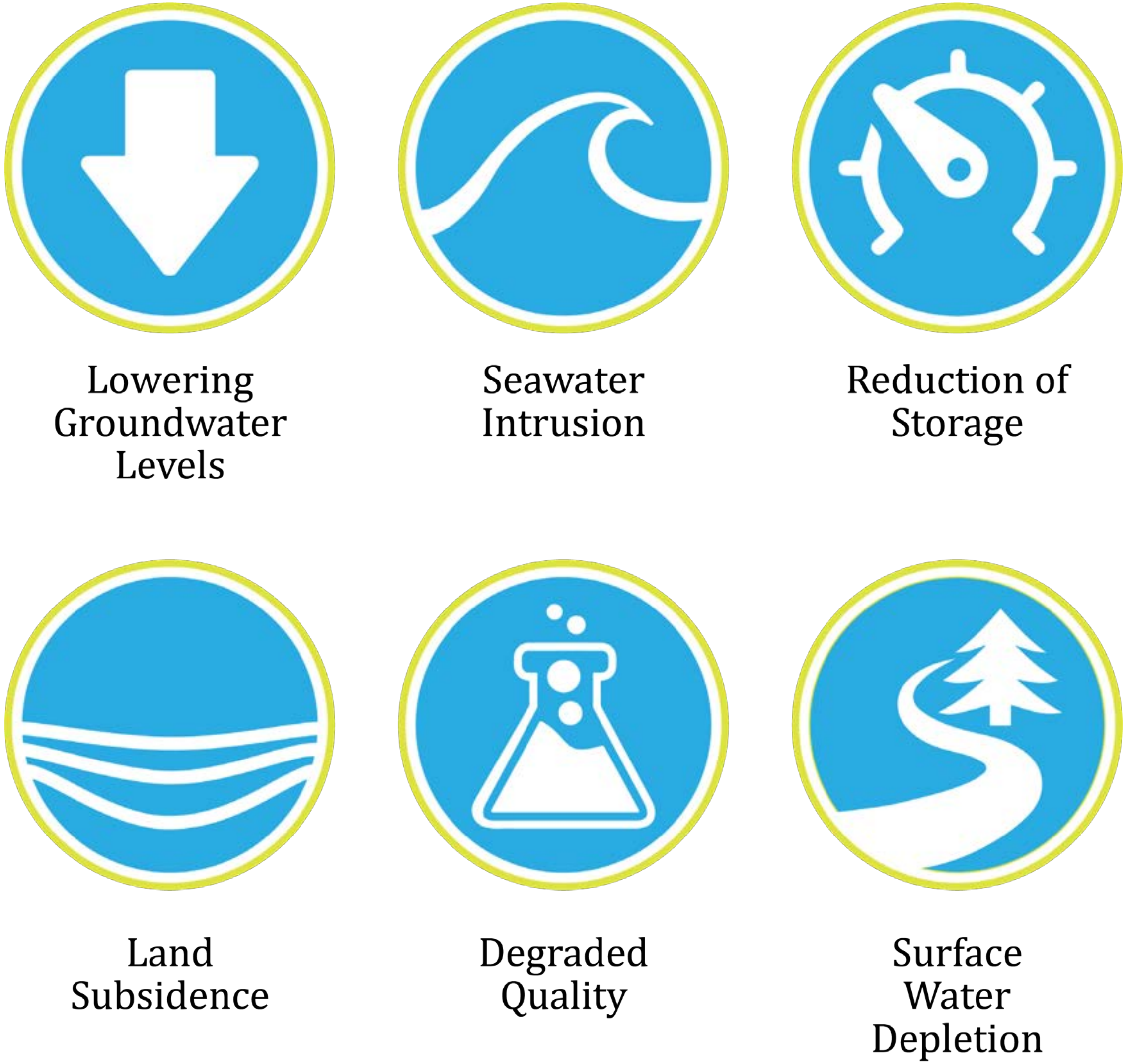
**Failure to meet any of these deadlines triggers intervention by the State Water Resources Control Board**

# Sustainable Management Criteria

Sustainable Management Criteria (SMCs) are defined locally based on ***basin conditions*** to avoid *significant and unreasonable* ***Undesirable Results*** for SGMA ***Sustainability Indicators***.

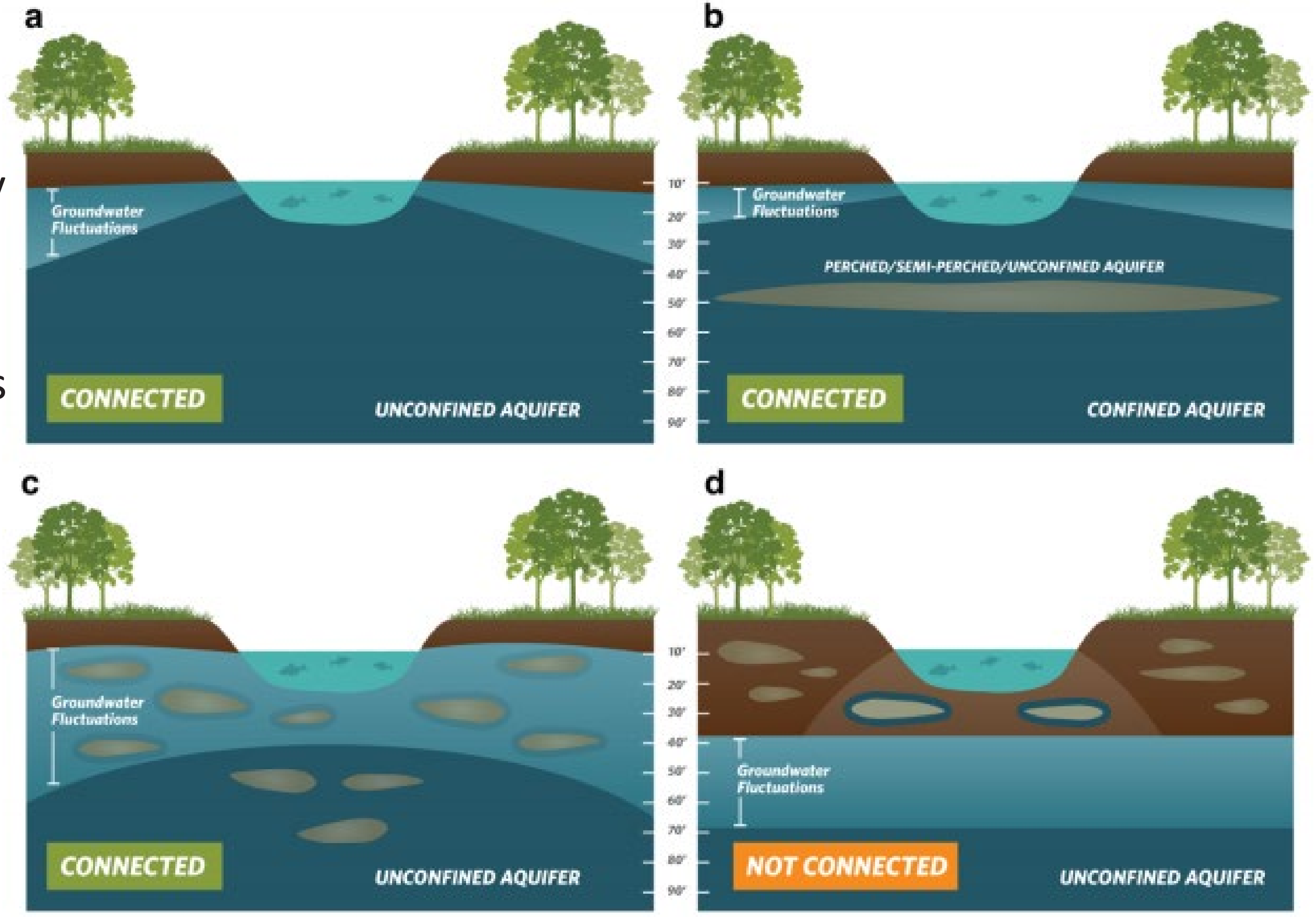
**Iterative Process** which will involve significant stakeholder engagement, modeling of future climate, growth, and projects and actions

## Sustainability Indicators



# Proposed Approach for GDE Mapping

- Focus on ecosystems that can be affected by groundwater conditions and management and are within jurisdiction of GSAs
- Utilize available statewide and local datasets to develop best available information
- Consider using "indicator" species and/or grouping of GDEs with similar characteristics/habitat needs
- Prioritize GDEs for consideration in developing SMCs for Surface Water Depletion (separate workgroup)




[https://groundwaterresourcehub.org/](https://groundwaterresourcehub.org/)

Source: The Nature Conservancy, Identifying GDEs Under SGMA Best Practices for using the NC Dataset, 2019

# Focus of Workgroup Meetings

**Meeting 1** - *July 7*

a. Background and Focus of Workgroup
b. Description of existing datasets, model tools and preliminary mapping efforts
c. Discuss process for integration of datasets for developing Potential GDE Maps
d. Discussion of data gaps

**Technical Work between Meetings 1 and 2**

a. Completion and refinement of maps based on Workgroup input
b. Develop initial information to support characterizing habitat needs and ecological value for potential grouping of GDEs

# Focus of Workgroup Meetings

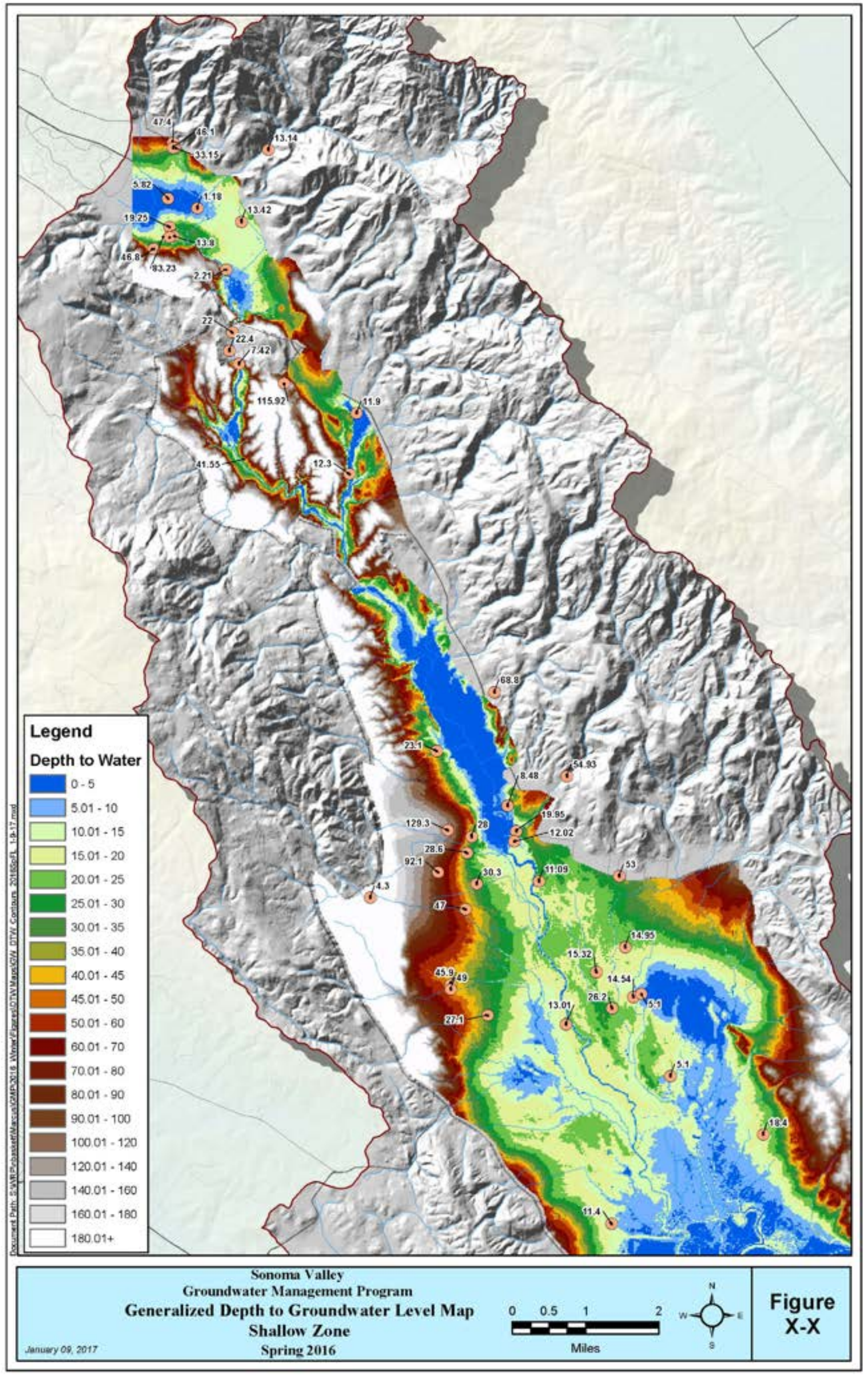
**Meeting 2 (and 3?)** - *August?*

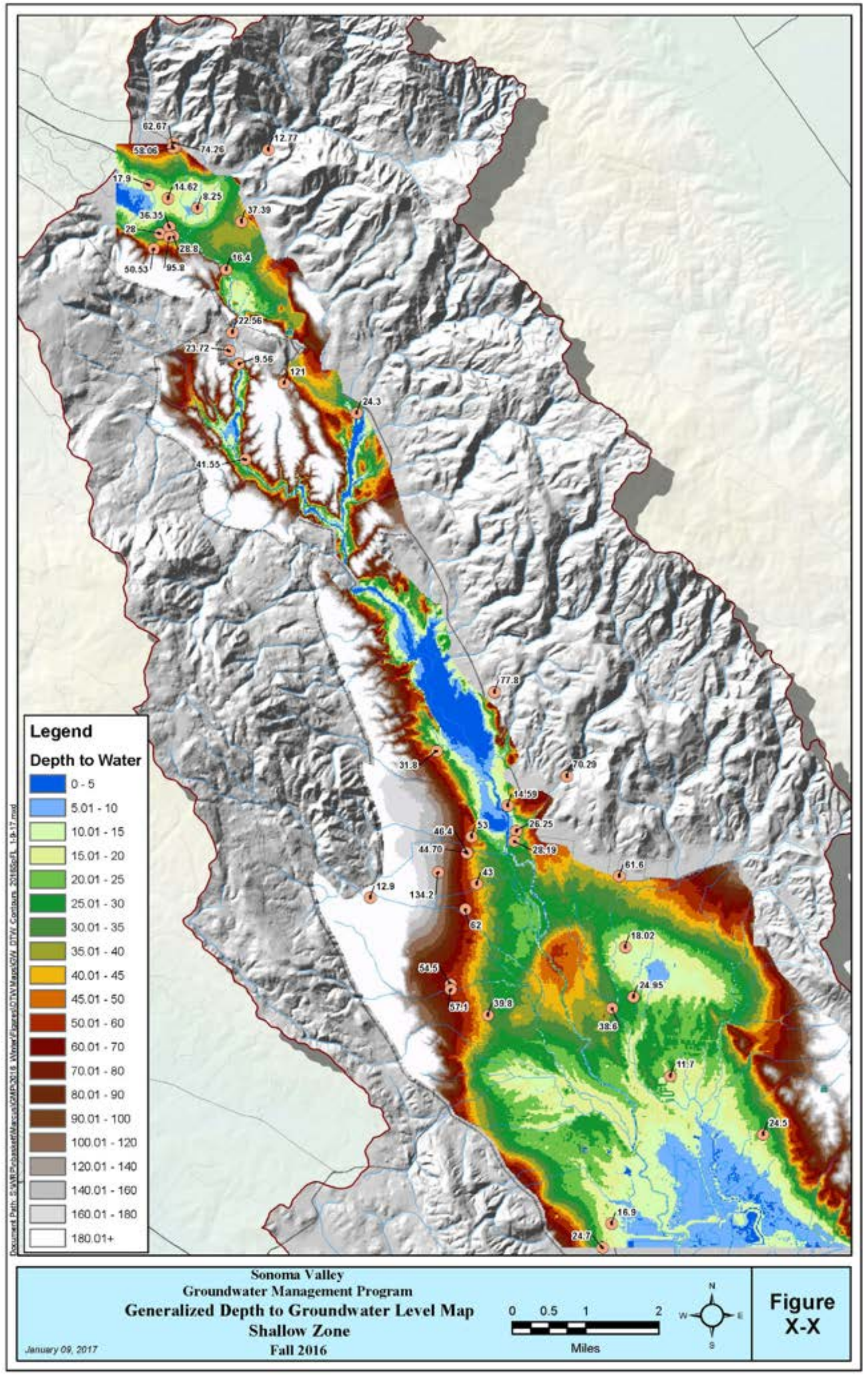
a. Review/discuss new maps and map revisions based on Meeting 1
b. Characterizing GDEs
    - General habitat needs (flow, temperature, critical time periods etc)
    - Group individual GDEs into GDE communities based on locations, habitat needs, connection to groundwater, density/amount of groundwater pumping etc. (as applicable)
    - Relative ecological value of each GDE community
    - Develop "priority" species/communities whose needs would cover others if they are met?

# Hydrologic Datasets and Tools

- Draft Depth-to-Groundwater (DTW) maps for shallow unconfined aquifer system
  - Initial maps for Santa Rosa Plain and Sonoma Valley
  - Under development for Petaluma Valley
- Draft Interconnected Surface Water (ISW) maps
  - Initial maps for Santa Rosa Plain and Sonoma Valley
  - Petaluma Valley to be developed following completion of USGS integrated hydrologic model

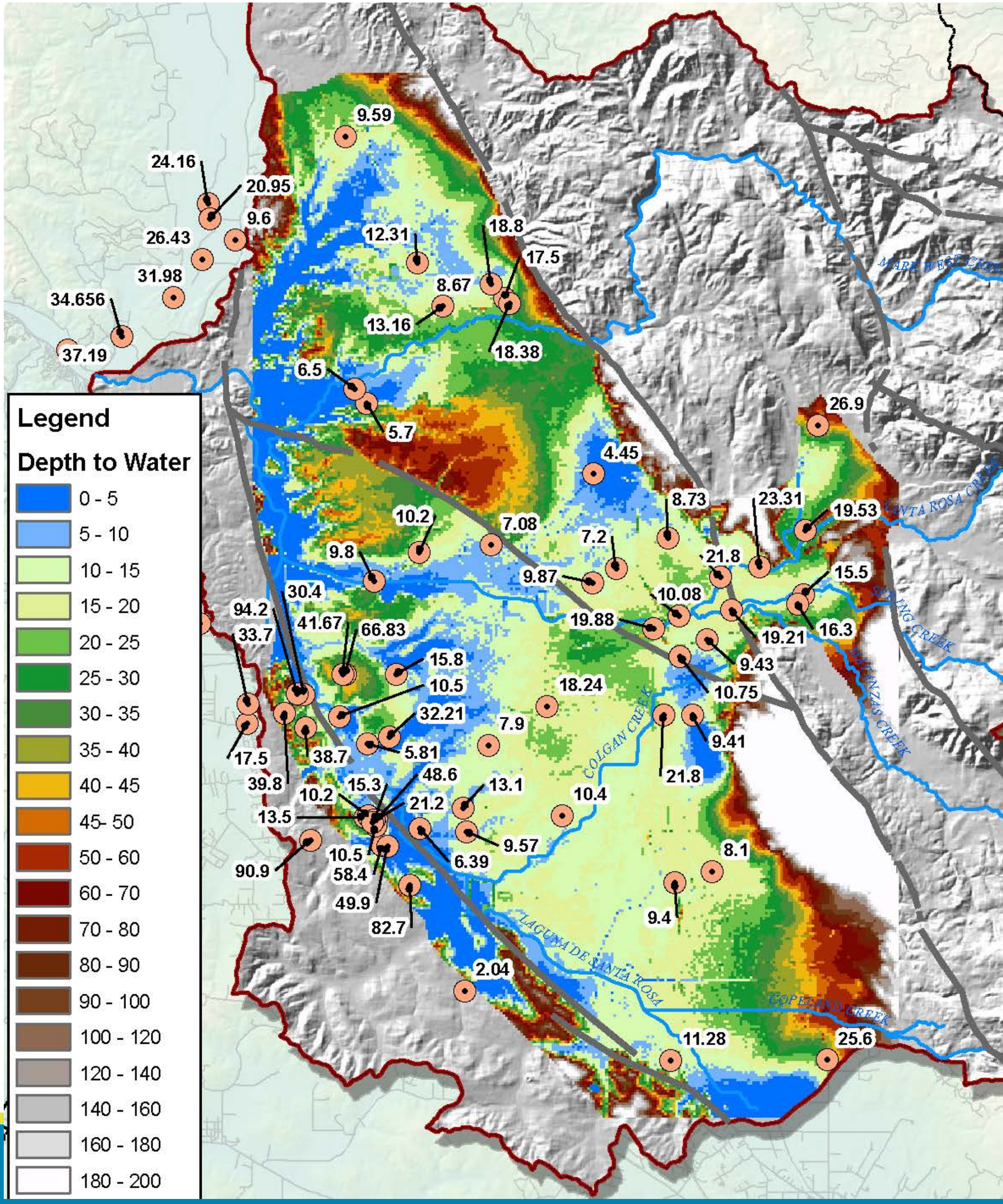
# Depth-to-Groundwater Maps for Shallow Unconfined Aquifer System: Sonoma Valley – Spring and Fall 2016



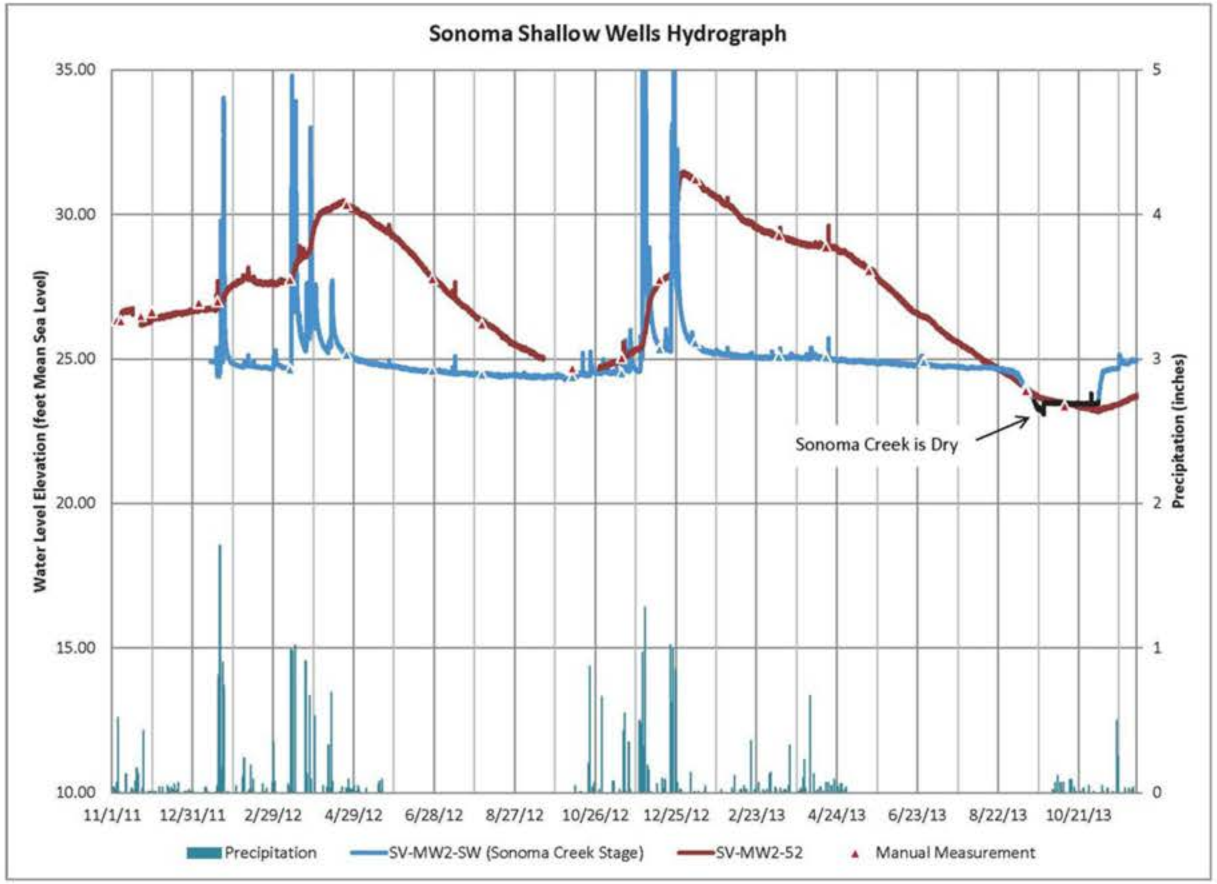



Depth-to-Groundwater Maps for Shallow Unconfined Aquifer System: Santa Rosa Plain – Spring 2015

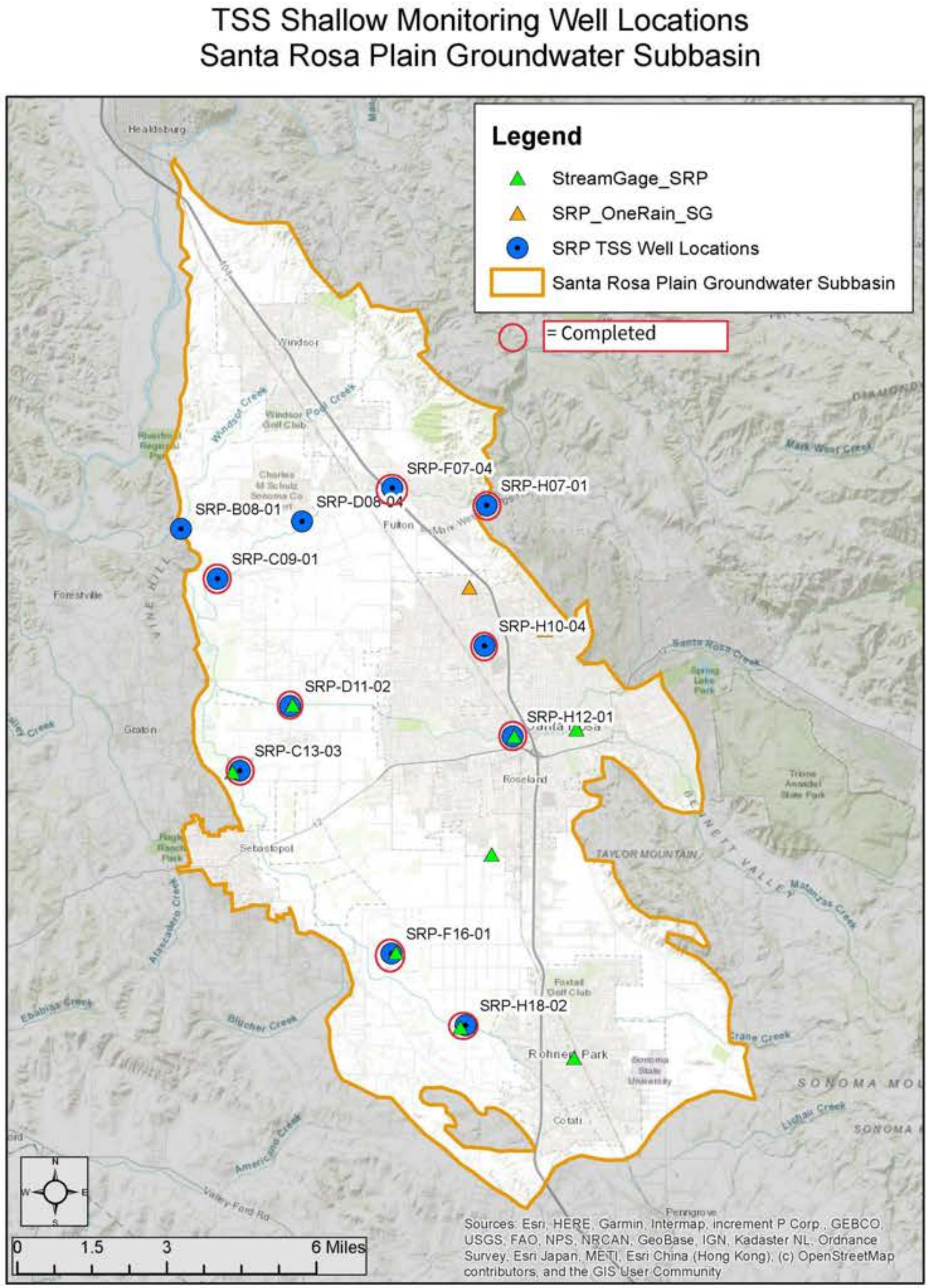
- Consider seasonal fluctuations and temporal trends



# Additional Data Sources: Paired Shallow Monitoring Wells with Stream Gauges




*Note: Gaps in data occur when pressure transducer is temporarily out of service or removed for sampling



# Interconnected Surface Water – Requirements and Approach

Defined in the GSP Regulations as ***surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted*** (DWR, 2016).

**Define with available data/existing tools using multiple lines of evidence (tools and datasets vary for each basin)**

**Sonoma Valley Approach**

(1) results of seepage run monitoring;

(2) frequency of observed or measured streamflow;

(3) comparison of interpolated groundwater levels within the shallow aquifer system and streambed elevations; and

(4) high frequency groundwater level observations from shallow monitoring wells located near streams.

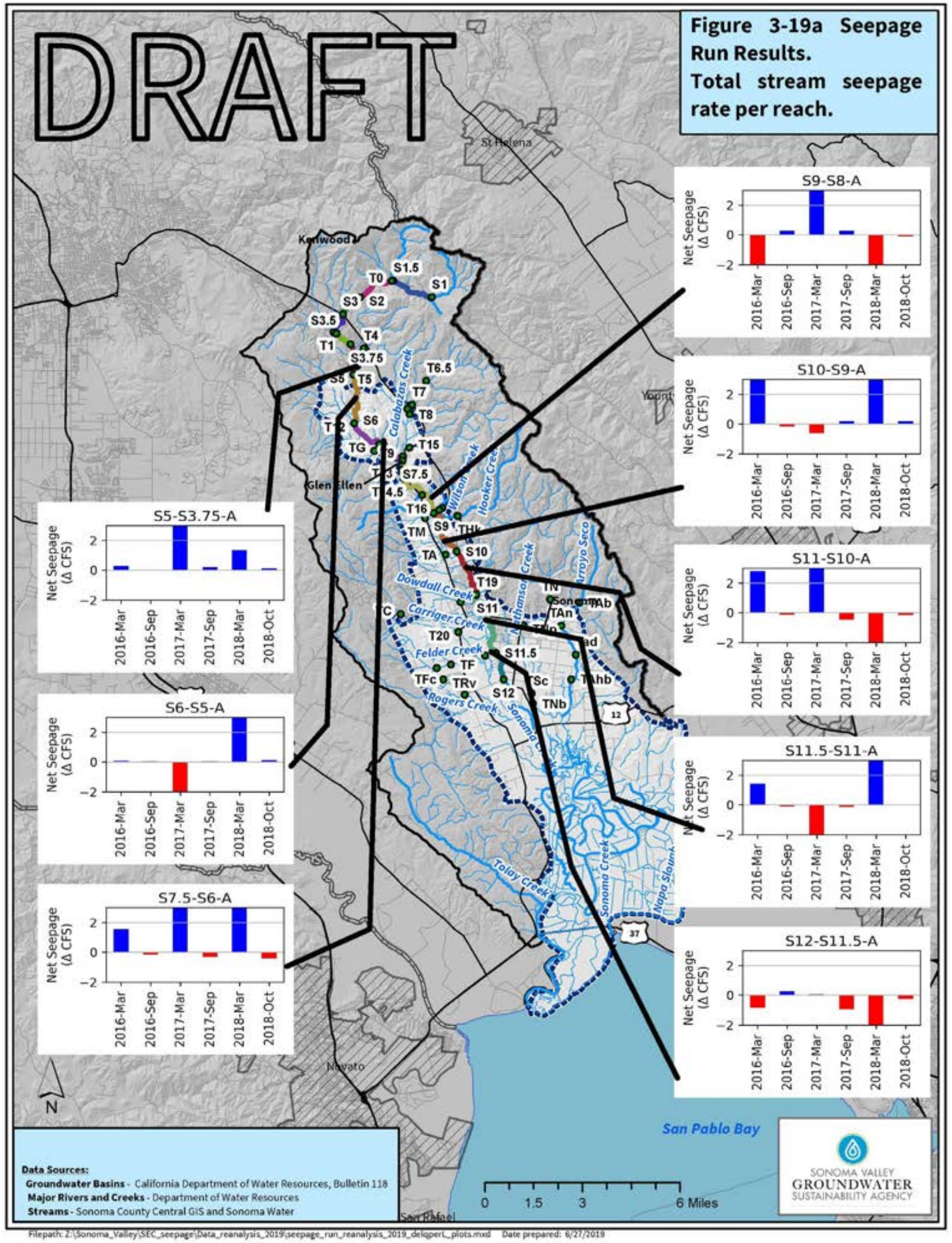
Did not use modeled interactions

**Santa Rosa Plain Approach**

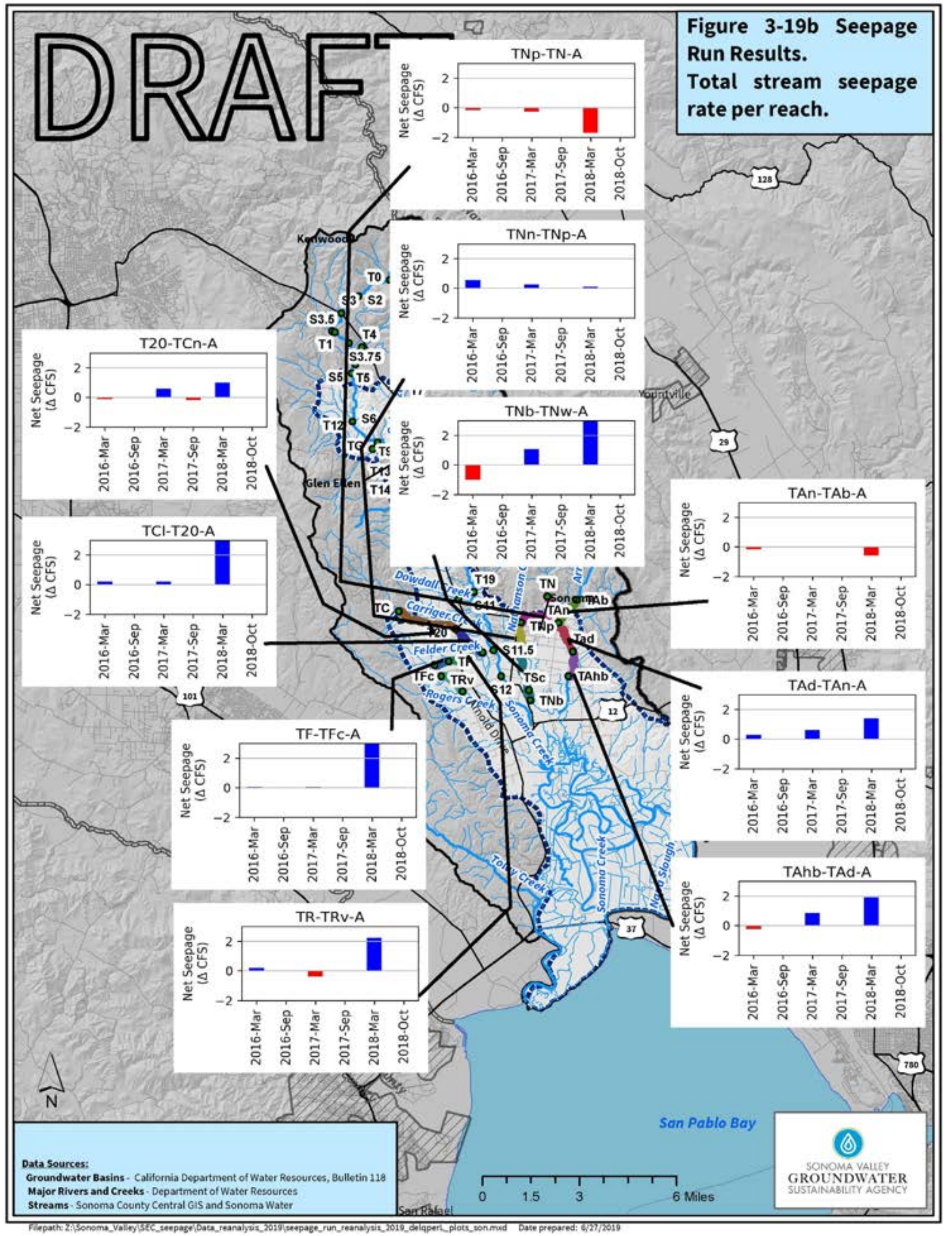
1) measured groundwater level and streambed elevation differences
2) modeled output derived from Wolfenden et al (2014)
   - Percent of time stream is gaining
   - Median streamflow
   - Surface leakage

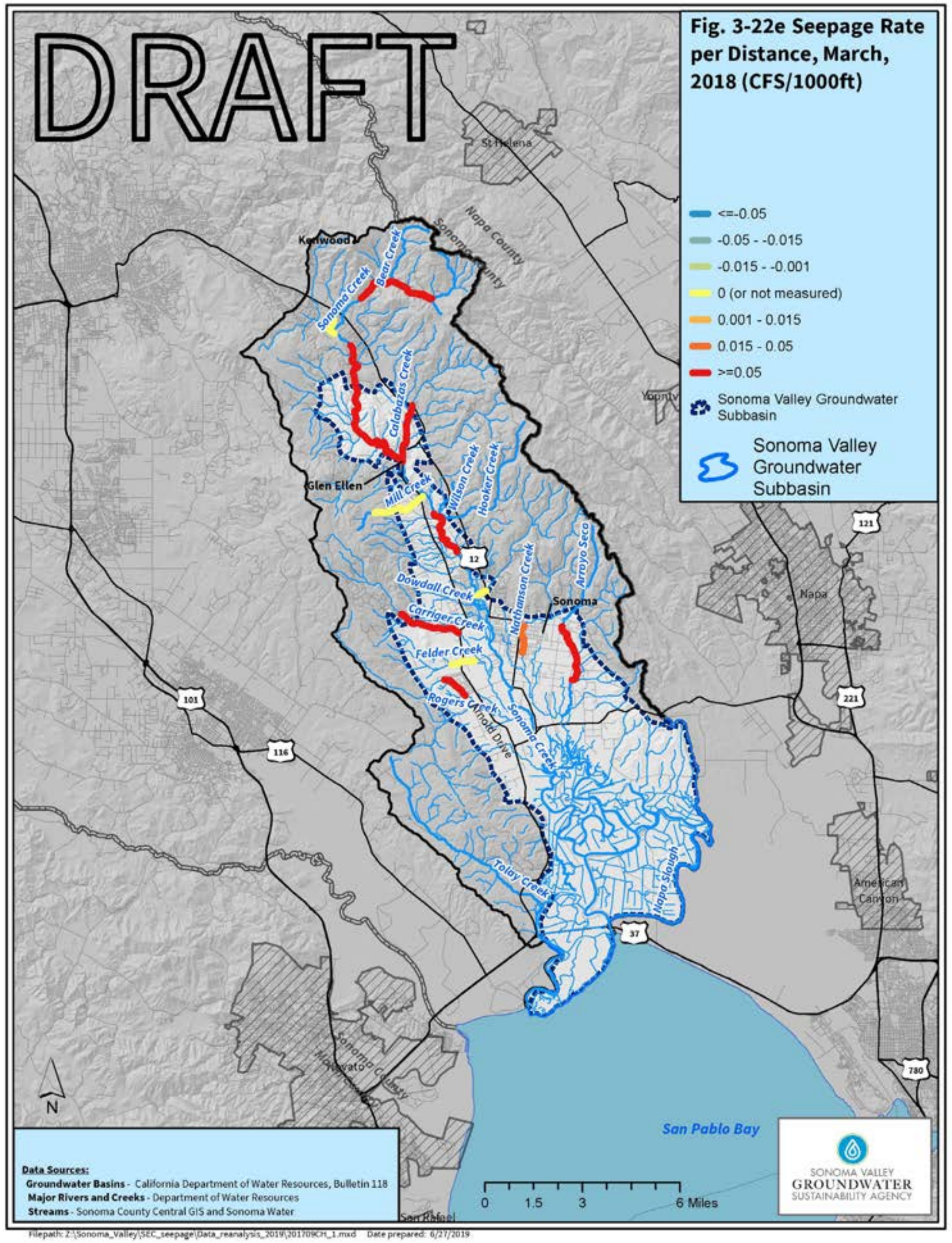
Additional information used in the assessment:

- streamflow seepage exchange through differential gaging
- baseflow separation of observed streamflow records

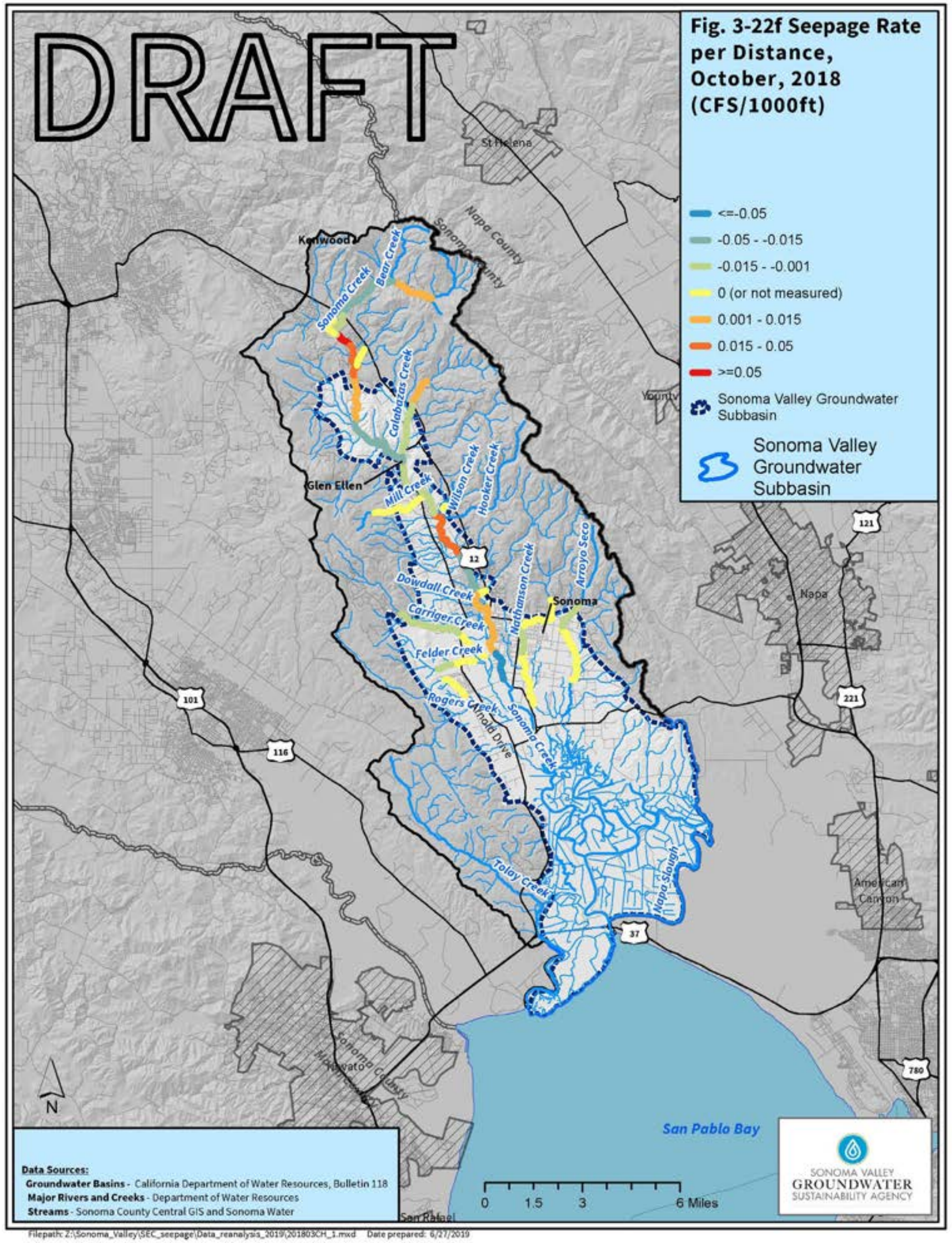


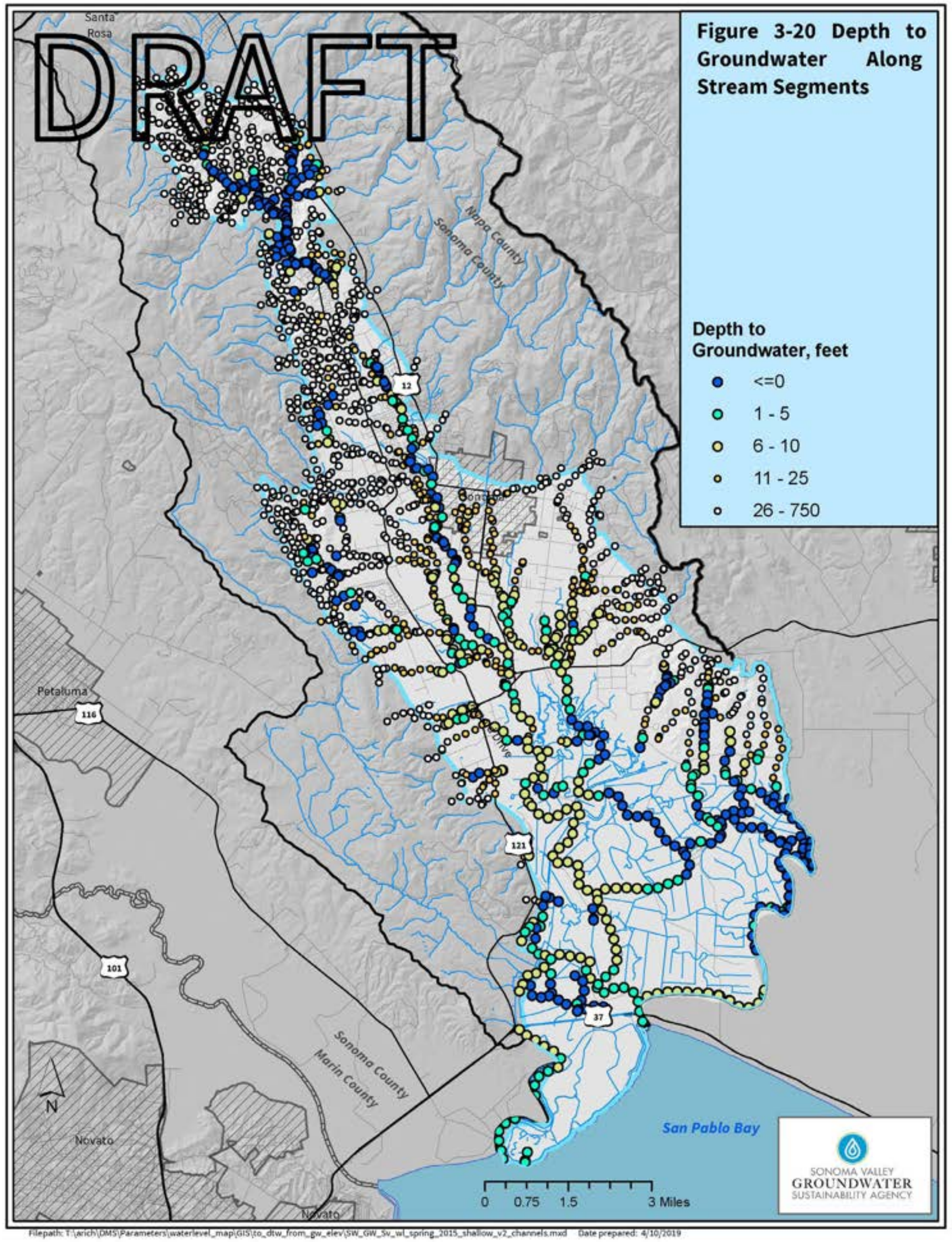

# Sonoma Valley Seepage Runs: Total Seepage Rate per Reach



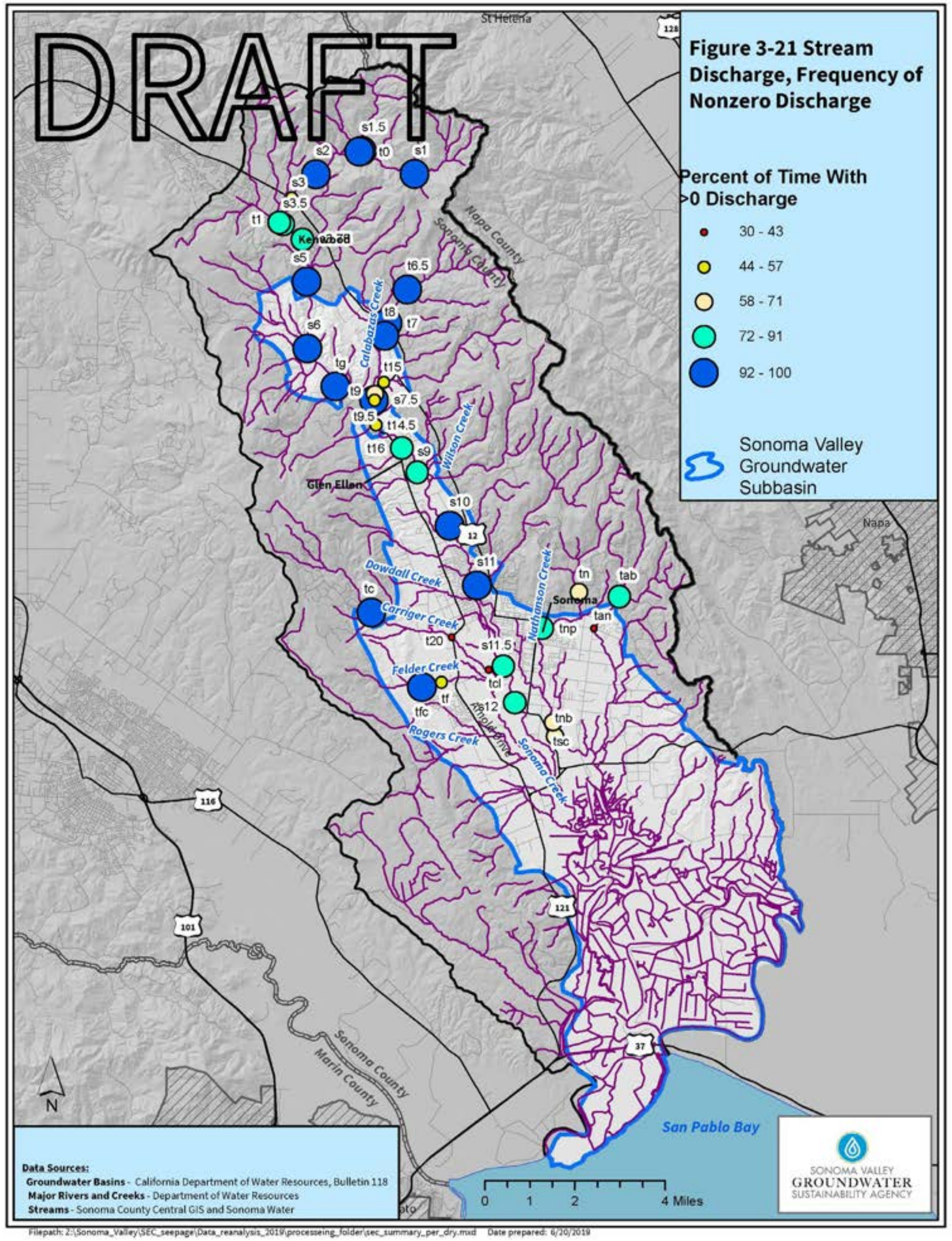



# Sonoma Valley Seepage Runs: Total Seepage Rate Distance

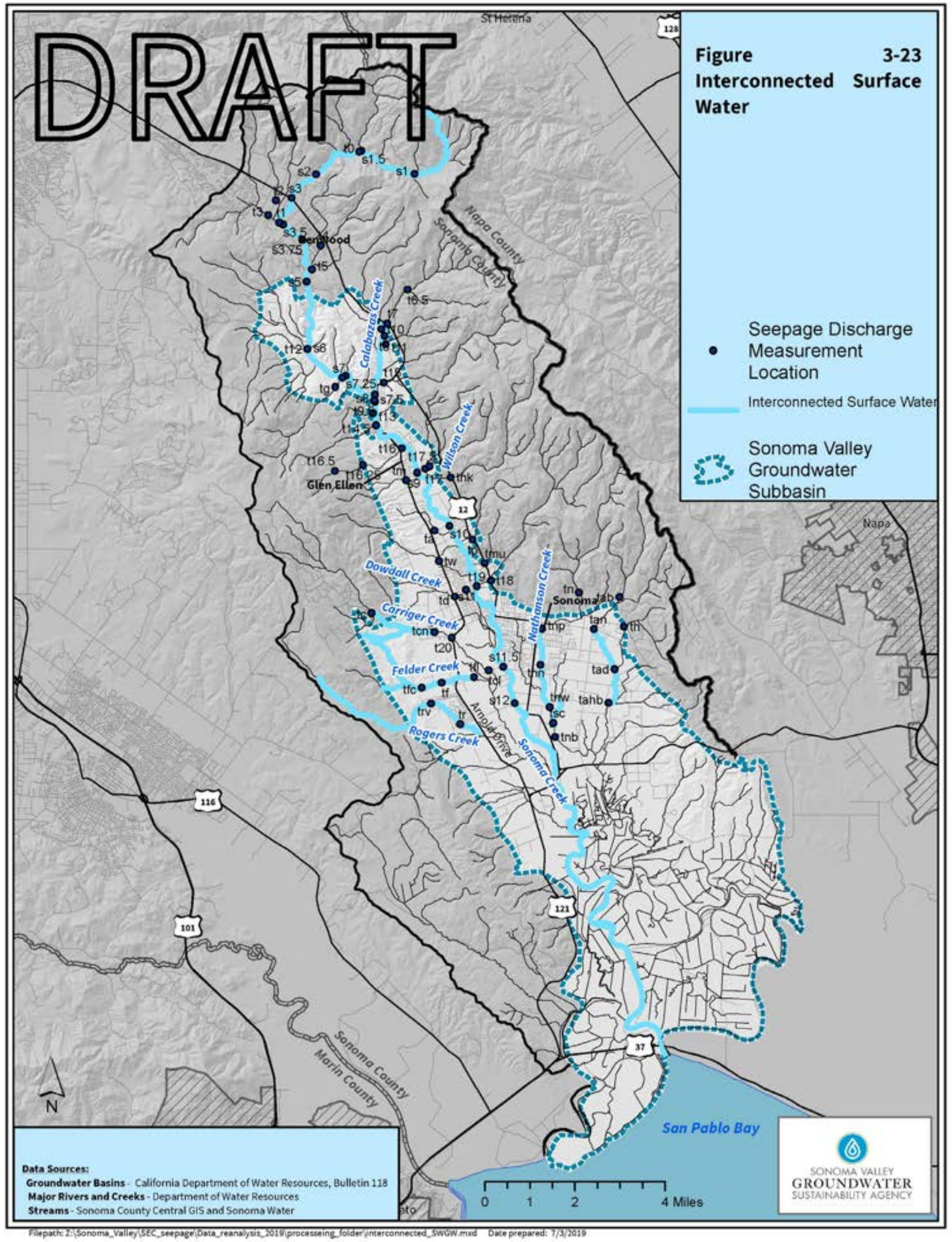




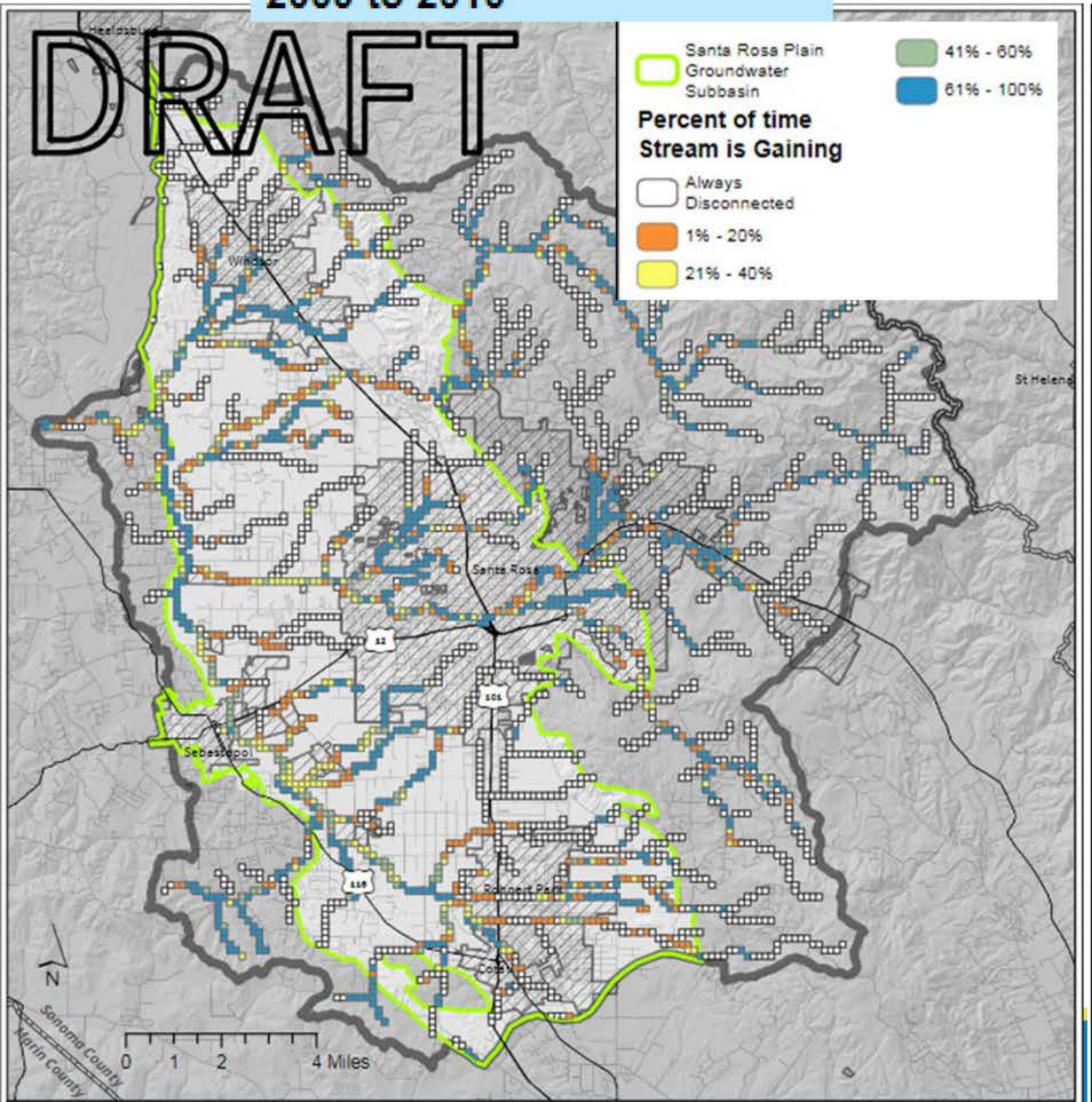

# Sonoma Valley Depth to Groundwater along Stream Segments & Frequency of Nonzero Discharge



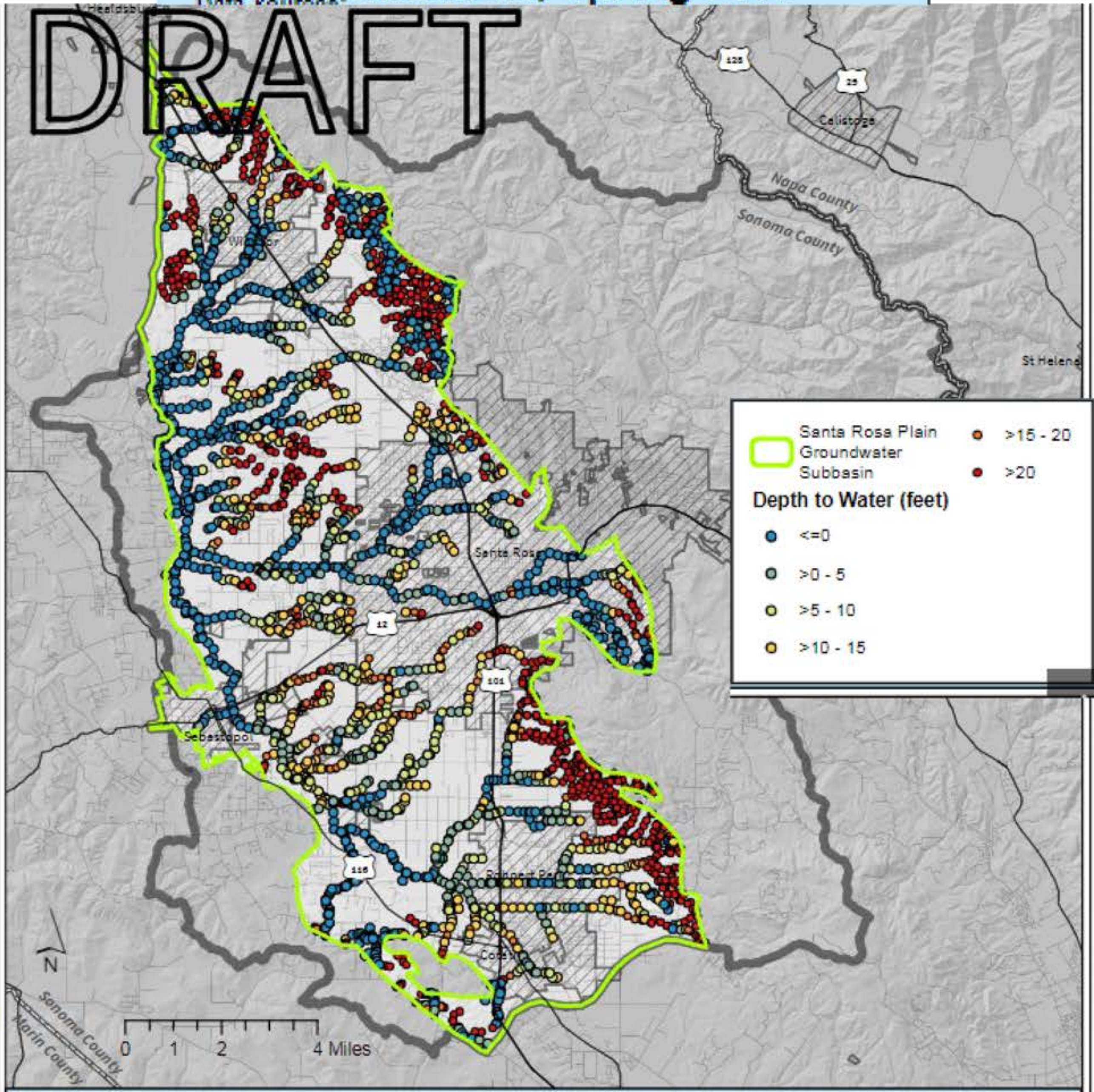
# Sonoma Valley Interconnected Surface Water Map



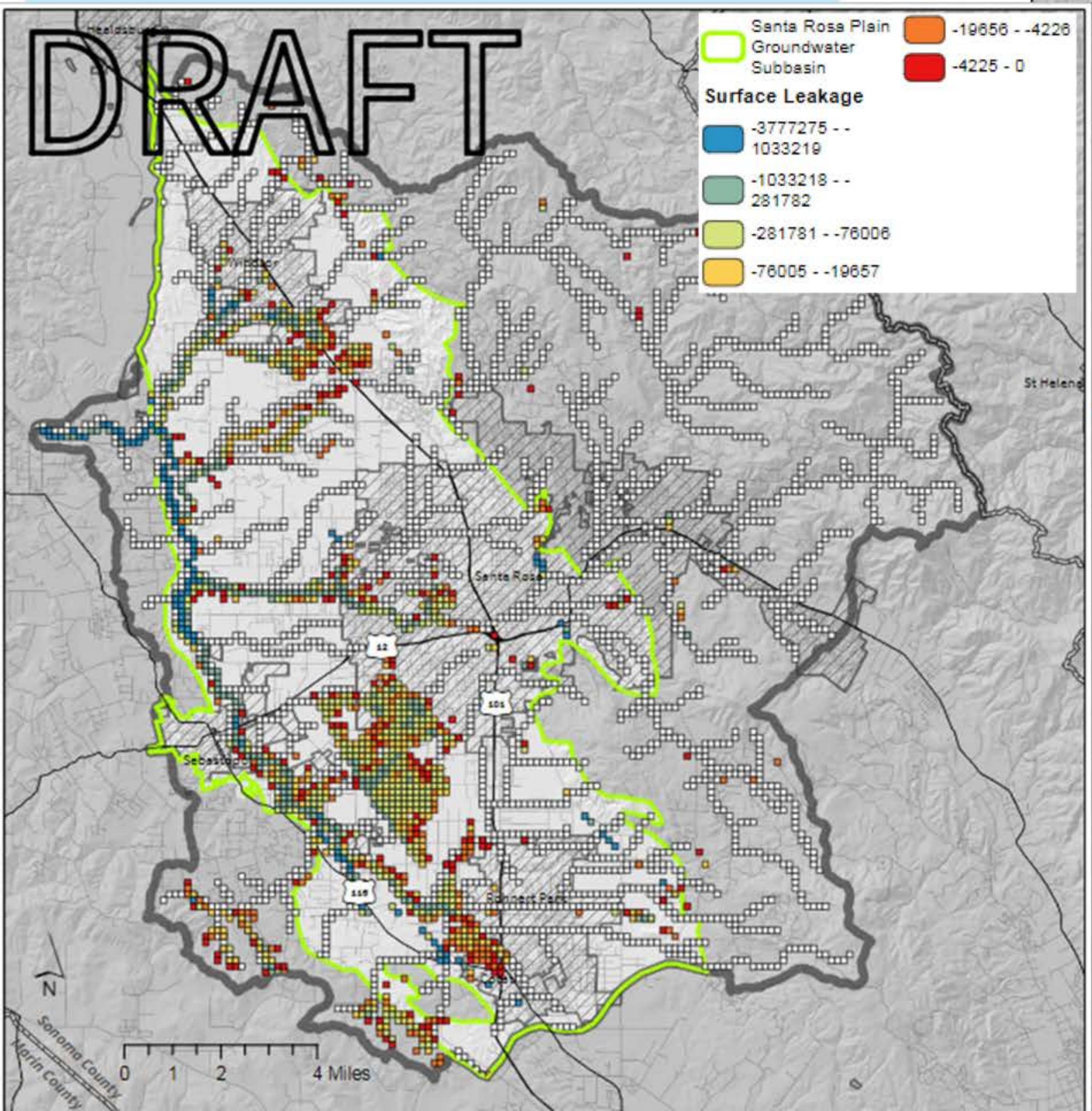
# Figure 3-18b Percent of time Stream is Gaining, from 2000 to 2010



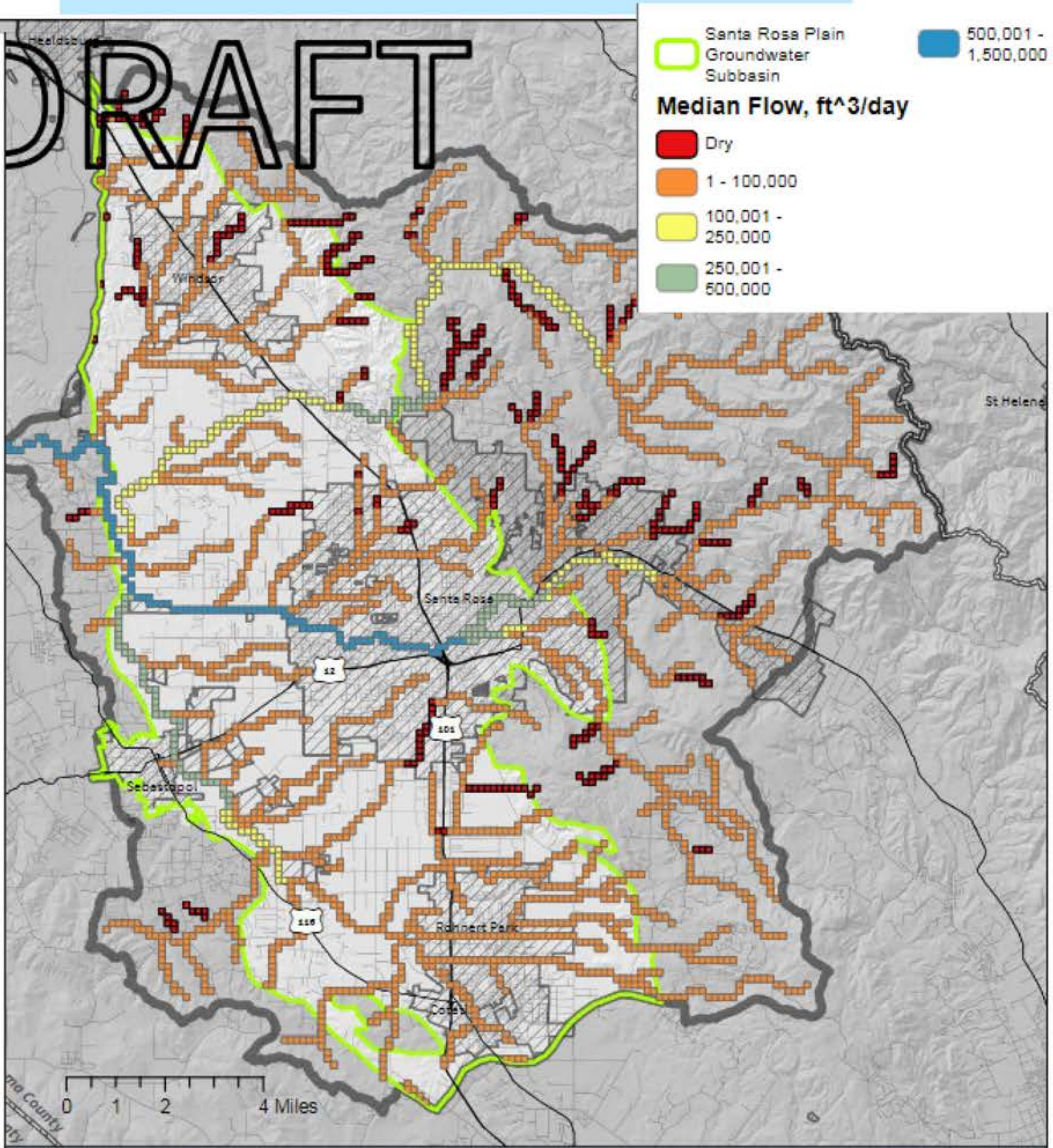

# Figure 3-18a Depth to Water Along Stream Channels, Spring 2015



## Figure 3-18d Surface Leakage, 2006

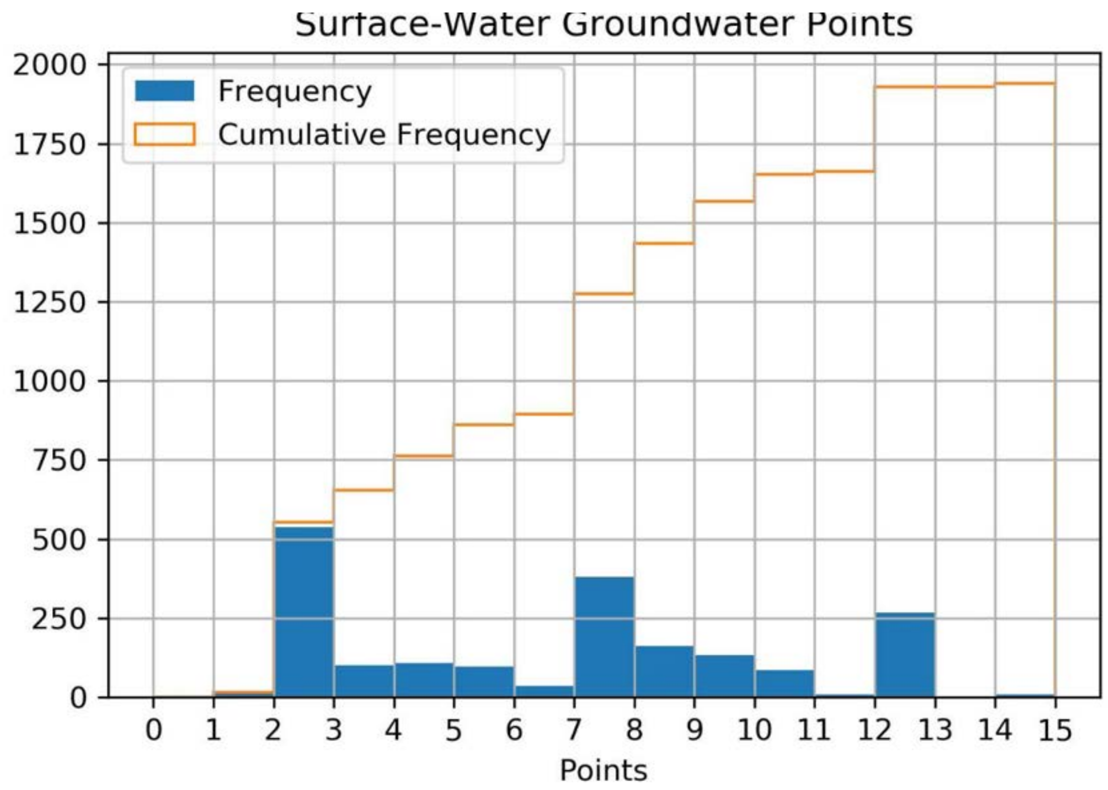


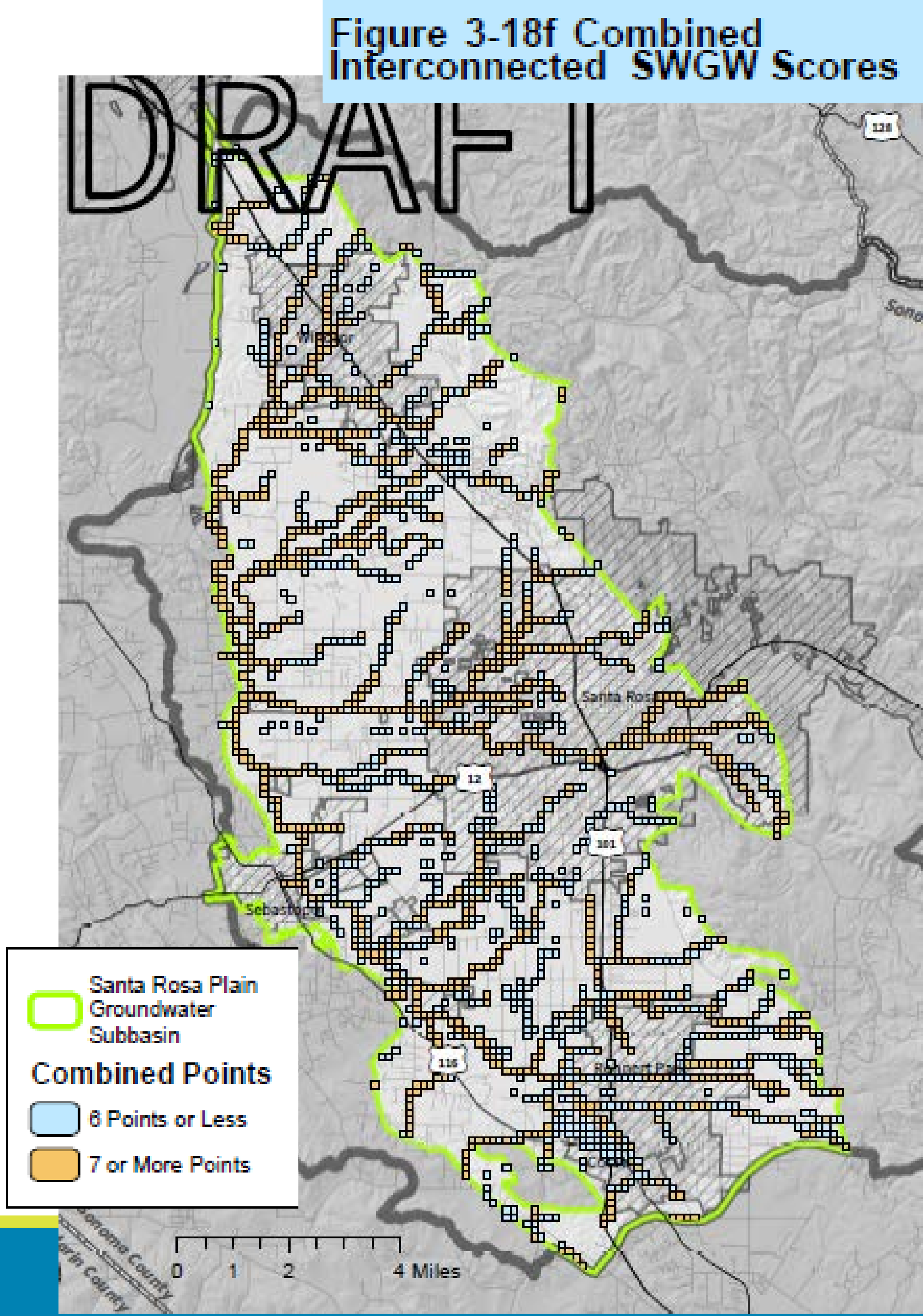

## Figure 3-18c Median Flow, from 2000 to 2010



# Santa Rosa Plain Interconnected Surface Water Mapping:

- Initial selection of Interconnected Surface Water based on Stream Reaches with 7 or more points (orange –colored cells



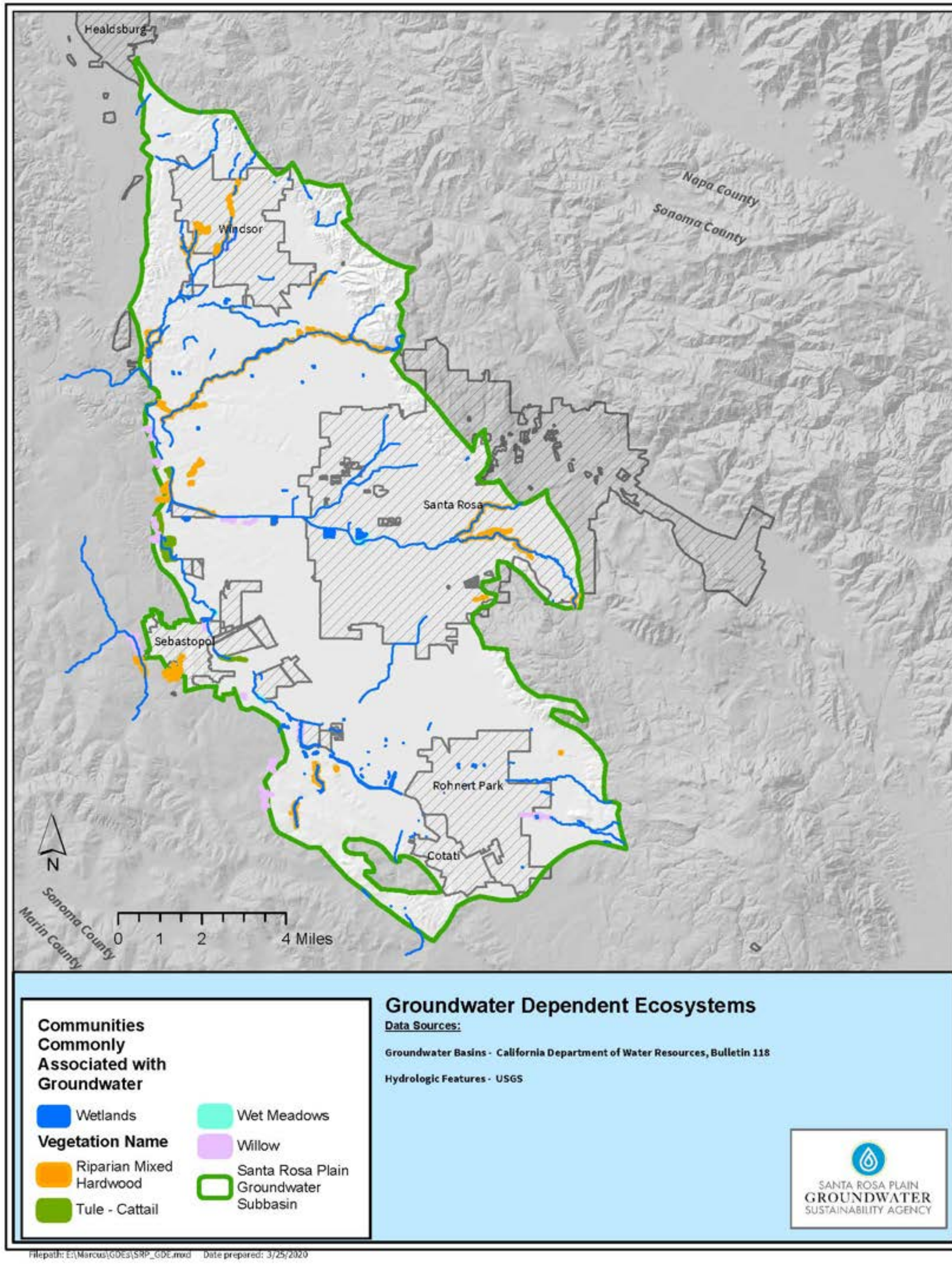



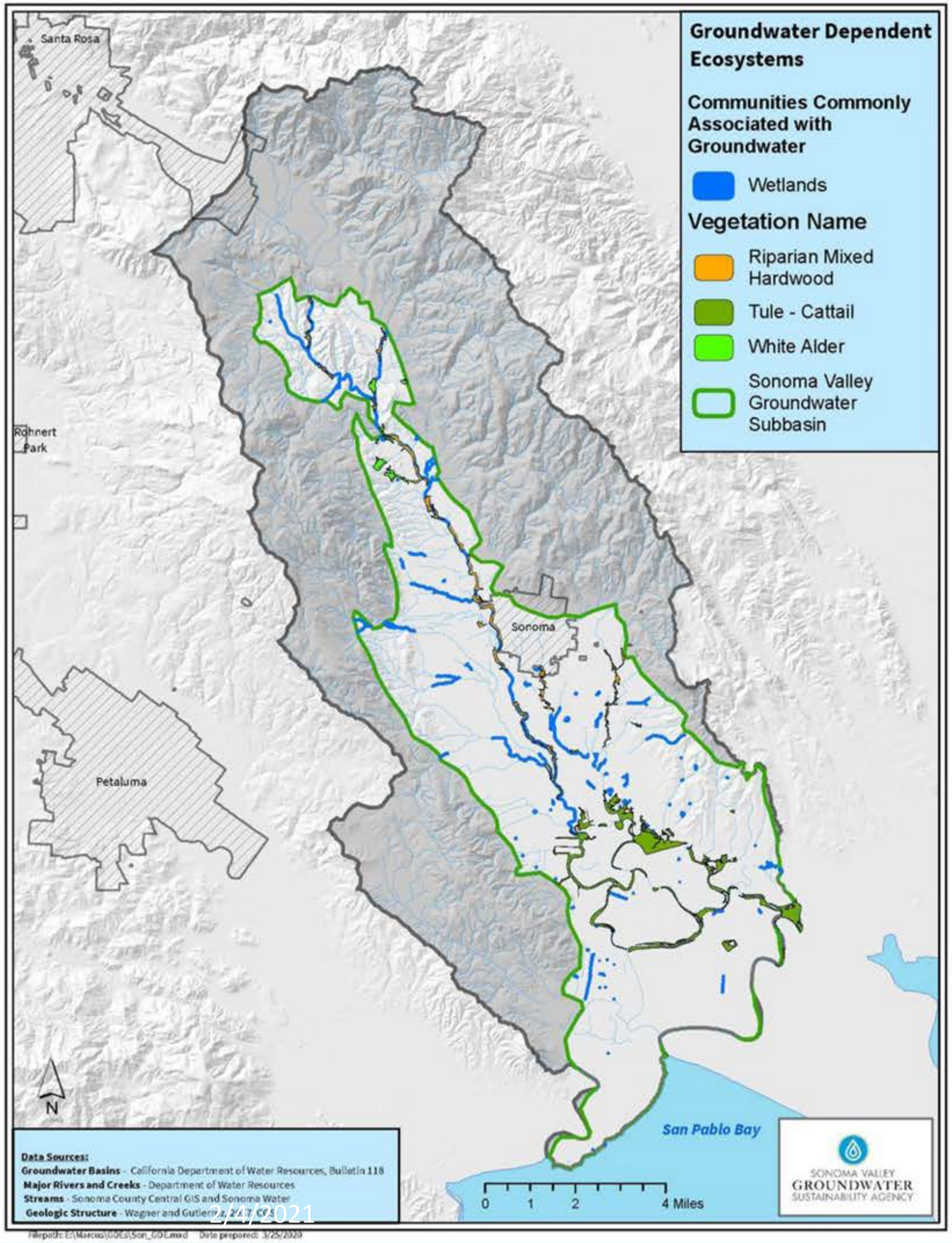
# Preliminary GDE Mapping

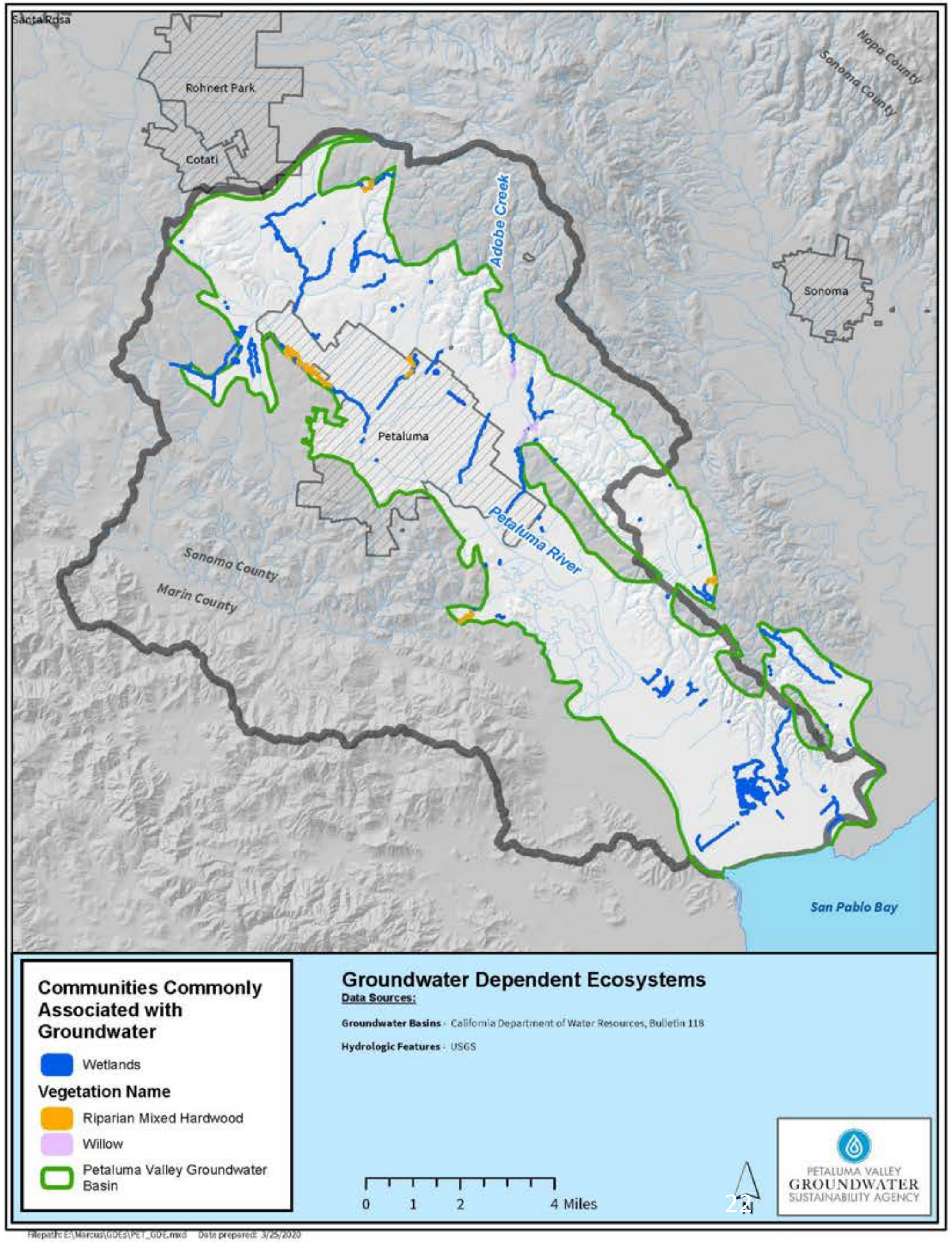
- Indicators of GDEs (iGDE) maps (The Nature Conservancy)
- Draft Steelhead streams maps (Sonoma Water)
- Draft Vegetation-related potential GDE maps (Sonoma Water)

# Indicators of GDEs (iGDEs) Mapping (TNC):

- Natural Communities Commonly Associated with Groundwater (NC Dataset).
- https://gis.water.ca.gov/app/NCDatasetViewer/




Groundwater Dependent Ecosystems
Communities Commonly Associated with Groundwater
Wetlands
Vegetation Name
Riparian Mixed Hardwood
Tule - Cattail
White Alder
Sonoma Valley Groundwater Subbasin
Santa Rosa
Rohnert Park
Petaluma
Sonoma
San Pablo Bay
N
0 1 2 4 Miles
Data Sources:
Groundwater Basins - California Department of Water Resources, Bulletin 118
Major Rivers and Creeks - Department of Water Resources
Streams - Sonoma County Central GIS and Sonoma Water
Geologic Structure - Wagner and Gutierrez
SONOMA VALLEY GROUNDWATER SUSTAINABILITY AGENCY
Filepath: E:\Marcus\GDEs\Son_GDE.mxd Date prepared: 3/25/2020


Santa Rosa
Rohnert Park
Cotati
Adobe Creek
Napa County
Sonoma County
Sonoma
Petaluma
Petaluma River
Sonoma County
Marin County
San Pablo Bay
Communities Commonly Associated with Groundwater
Wetlands
Vegetation Name
Riparian Mixed Hardwood
Willow
Petaluma Valley Groundwater Basin
Groundwater Dependent Ecosystems
Data Sources:
Groundwater Basins - California Department of Water Resources, Bulletin 118
Hydrologic Features - USGS
0 1 2 4 Miles
N
PETALUMA VALLEY GROUNDWATER SUSTAINABILITY AGENCY
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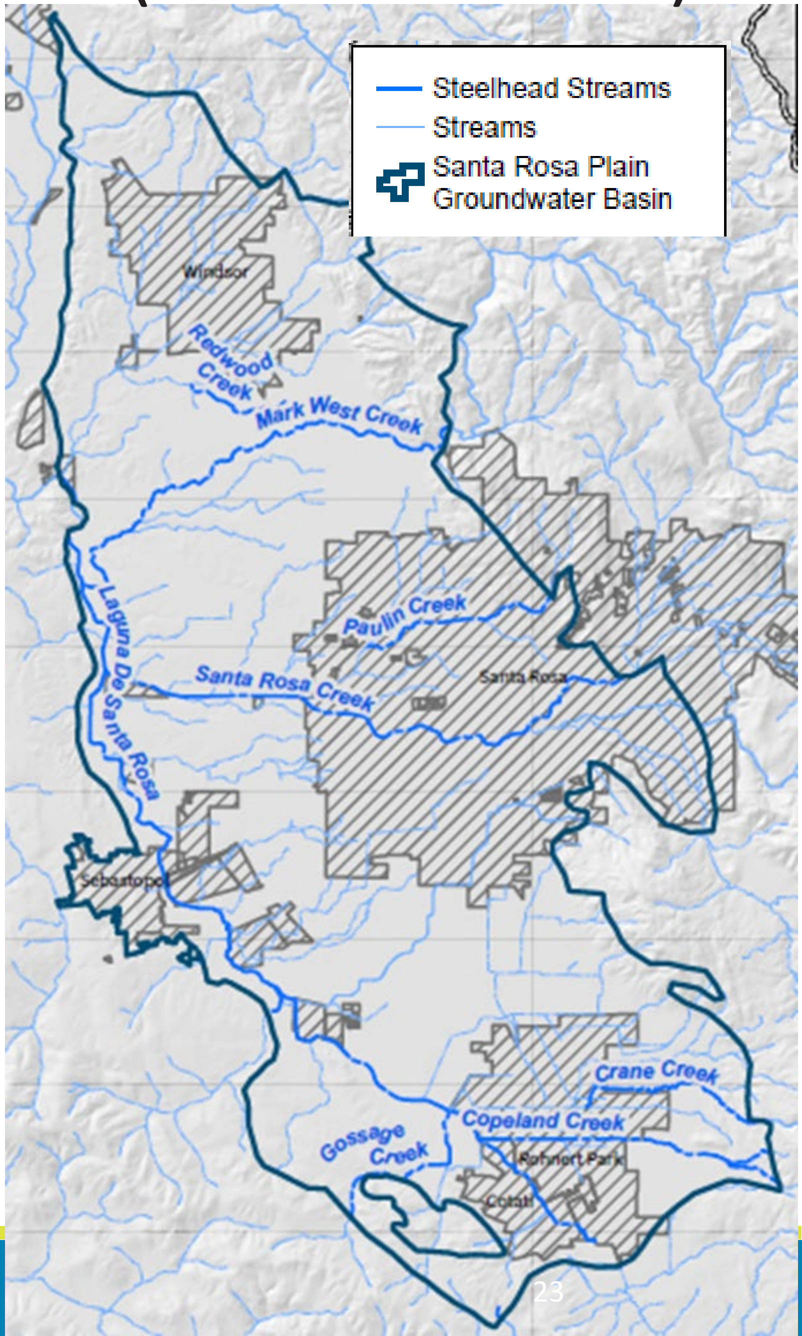
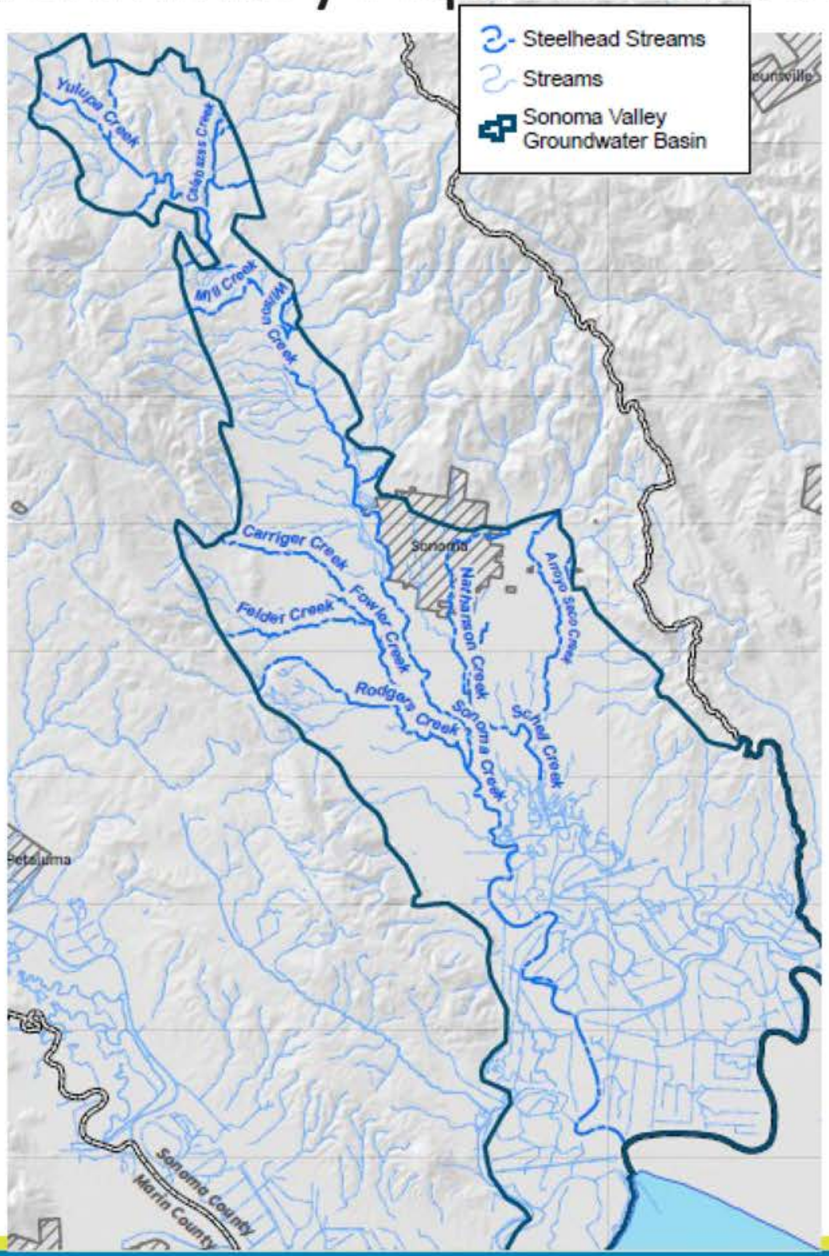
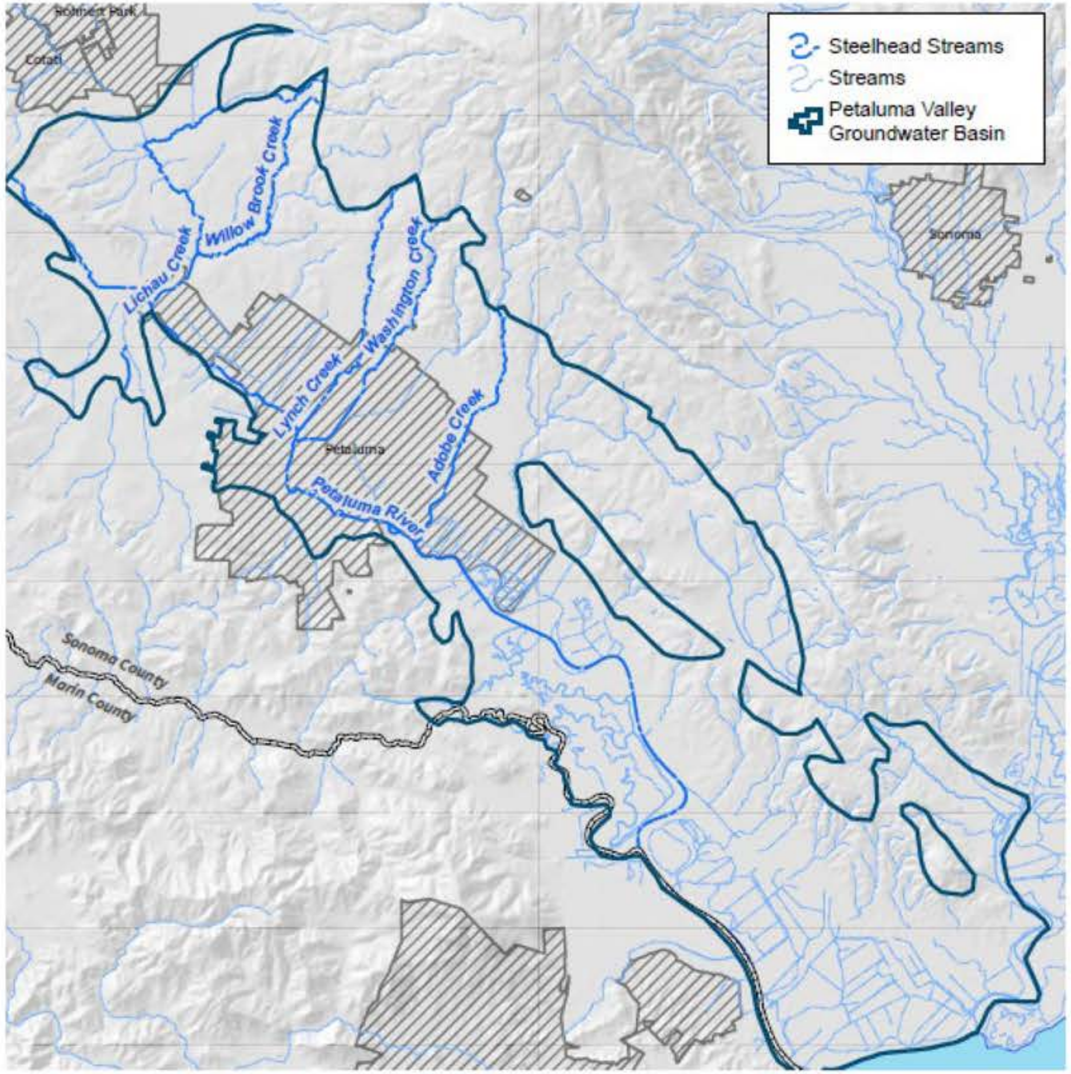
# Preliminary Aquatic Groundwater Dependent Species (Sonoma Water)

- Steelhead used as priority indicator species to cover all groundwater dependent species
- Source documents used to identify steelhead streams in three ground water basins
  - Petaluma and Sonoma Ground Water Basins
    - Leidy, R.A., G.S. Becker, B.N. Harvey. 2005. Historical distribution and current status of steelhead/rainbow trout (*Oncorhynchus mykiss*) in streams of the San Francisco Estuary, California. Center for Ecosystem Management and Restoration, Oakland, CA.
    - Stream Maintenance Program (SMP). Sonoma Water steelhead habitat evaluation database.
  - Santa Rosa Plain Ground Water Basin
    - Coastal Monitoring Program (CMP). Habitat evaluation for salmonids conducted by Sonoma Water and approved by NMFS and CDFW.
    - Shawn Chase database. Sonoma Water in-house database of known occurrences of steelhead in the Russian River watershed.
- Assumptions
  - Connecting stream reaches downstream of steelhead creeks included in steelhead GDE.



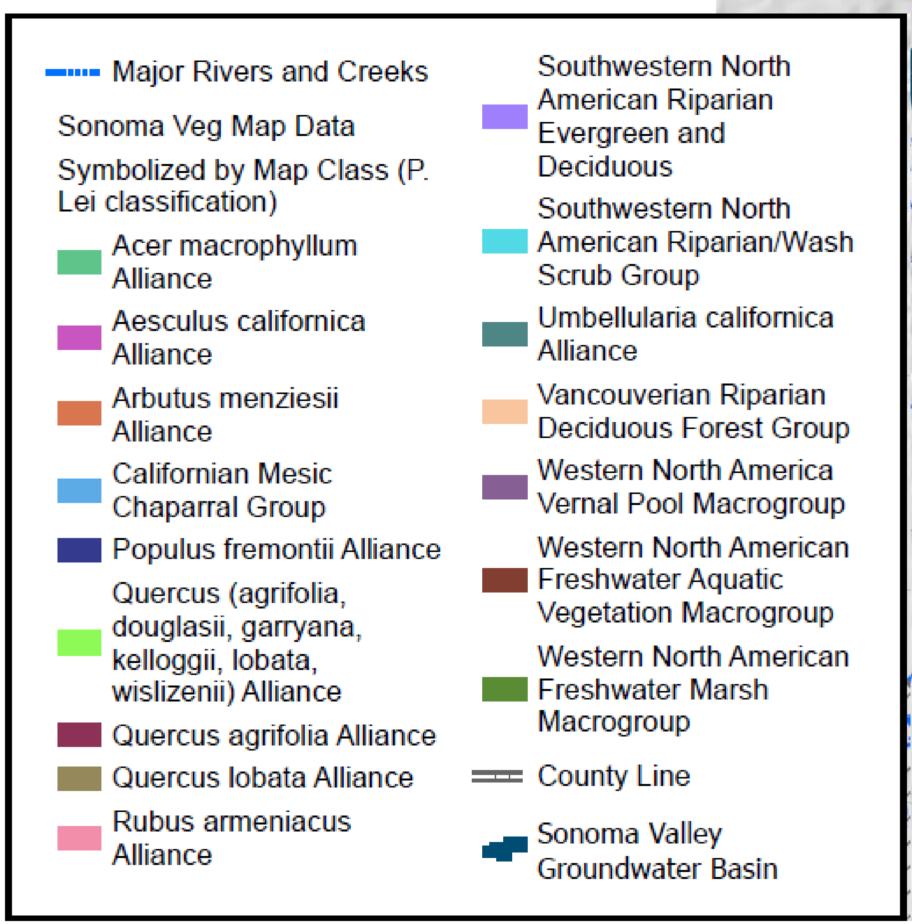
# Preliminary Aquatic Groundwater Dependent Species (Sonoma Water)

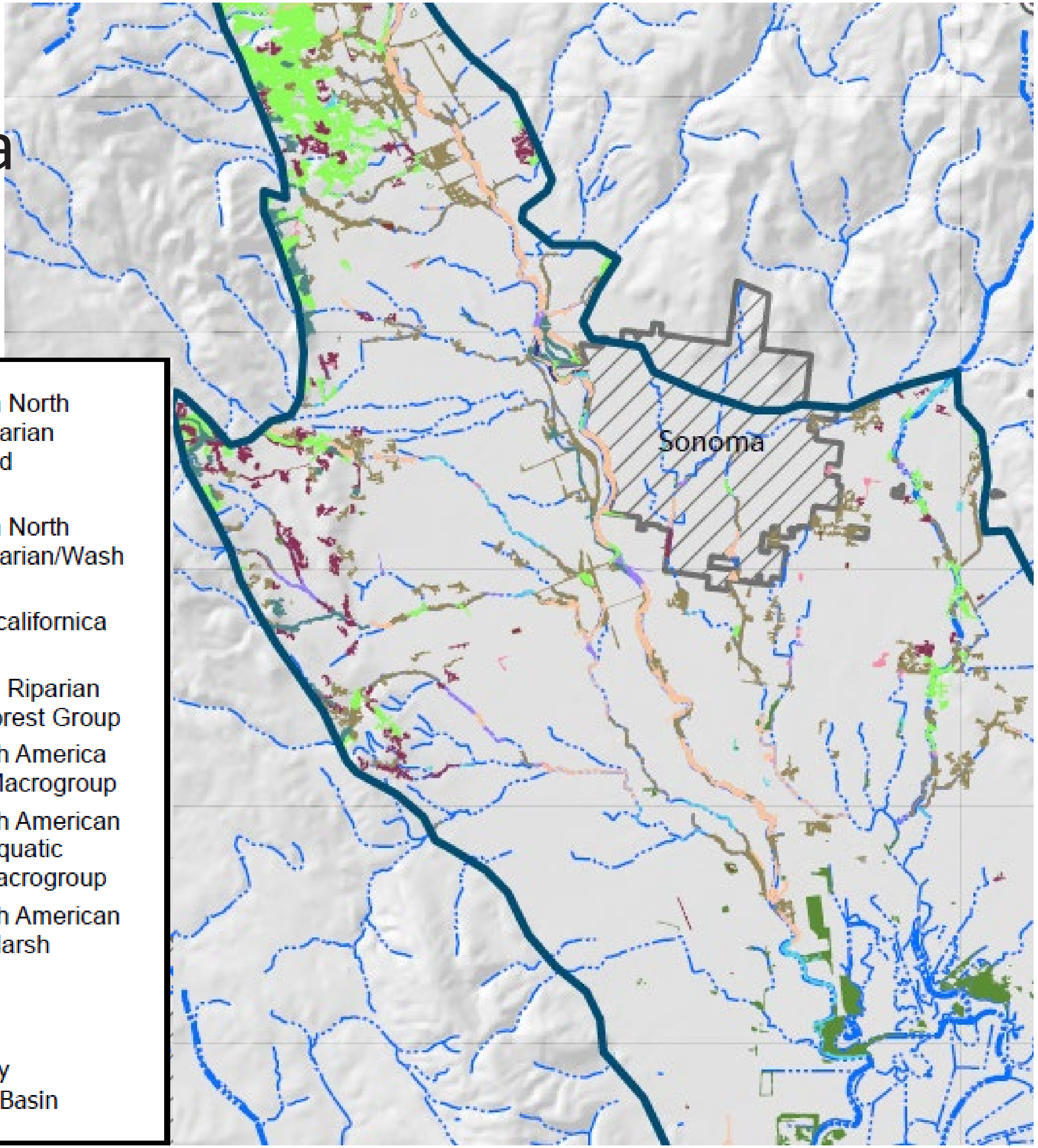


# Preliminary mapping of vegetation associated with groundwater (Sonoma Water): - Sonoma Valley Example

- Primary data source: Sonoma Veg Map
- Focus on communities with strong riparian composition (willows and cottonwoods) or species that may rely on groundwater some parts of year (oaks)



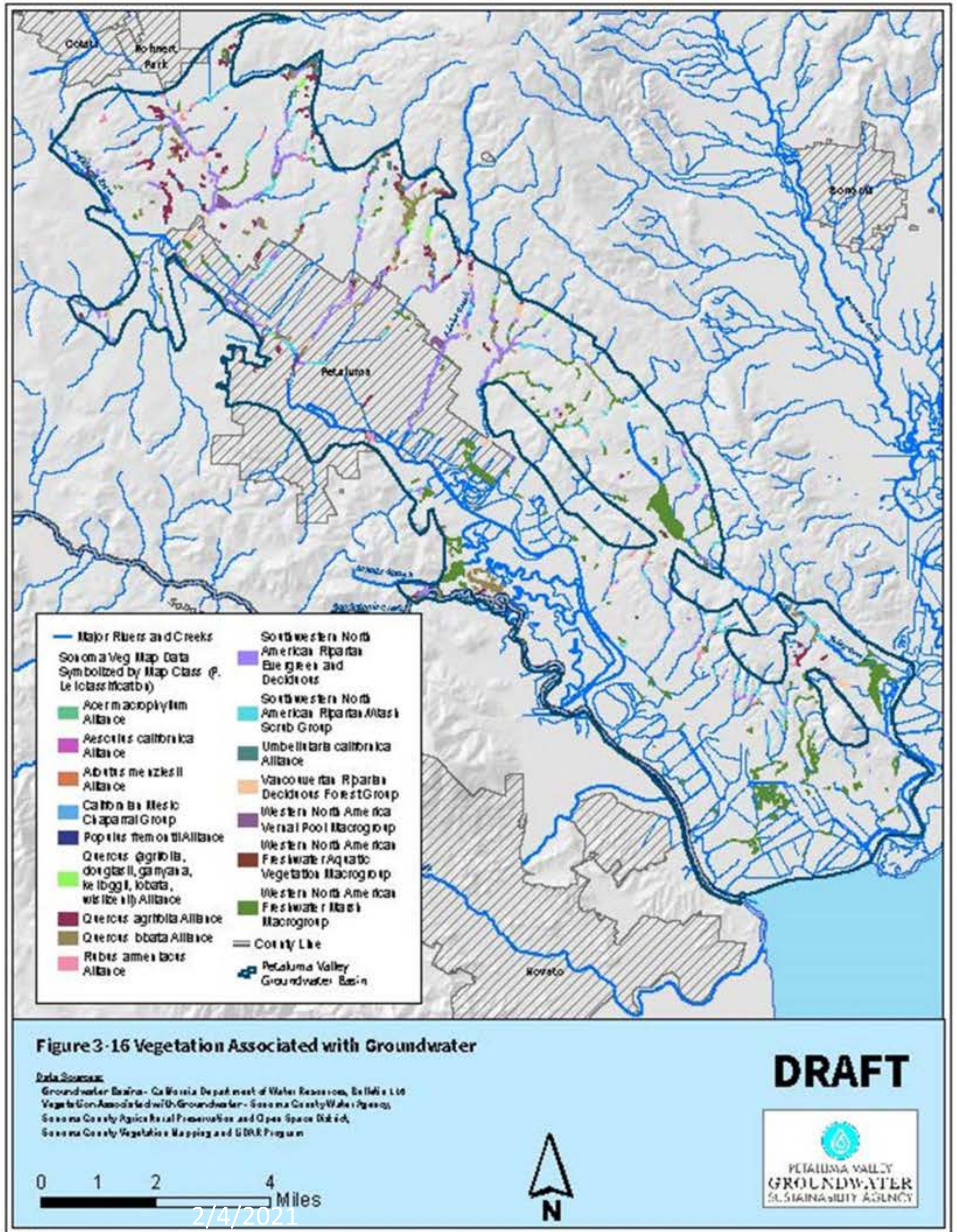
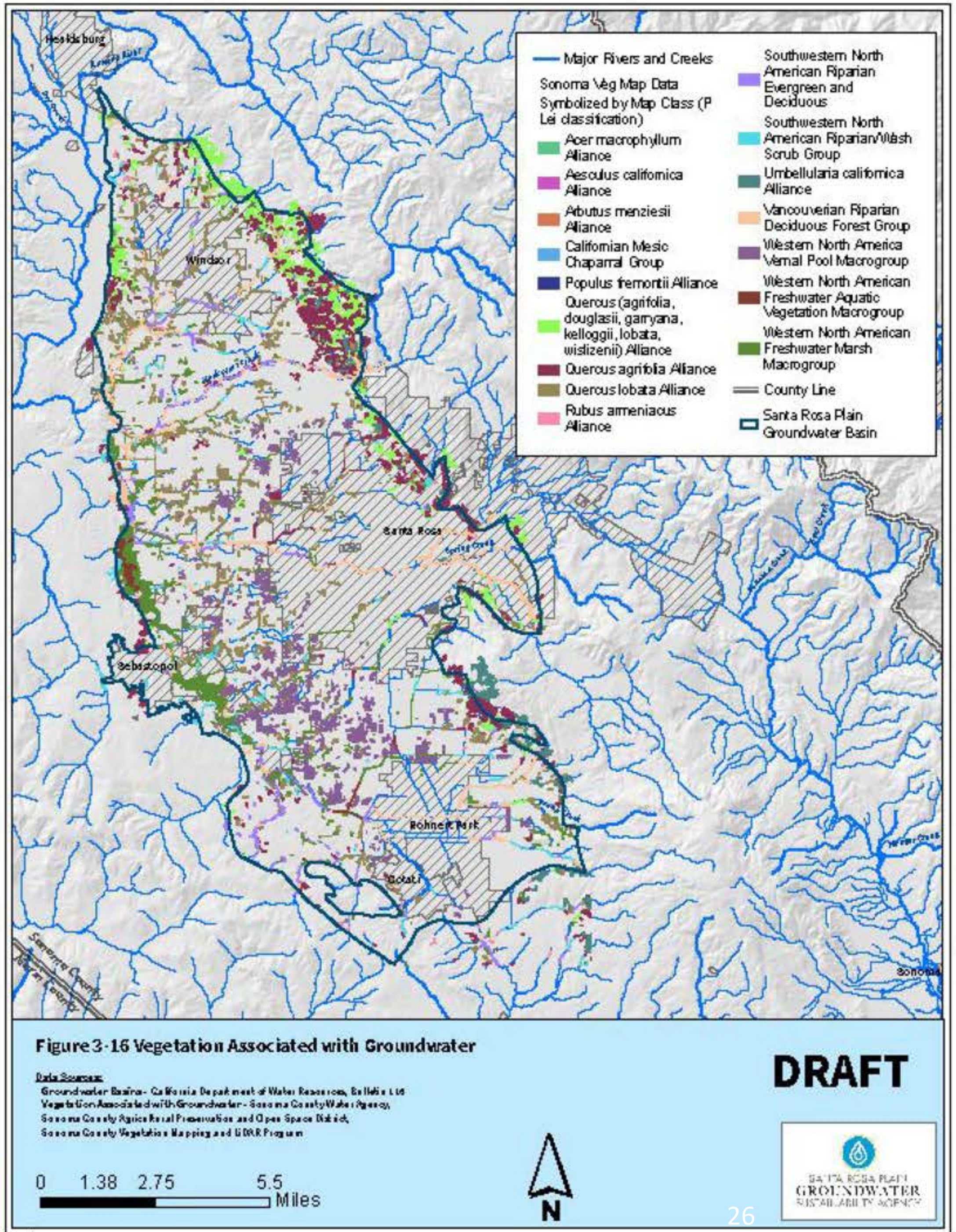



**Figure 3-16 Vegetation Associated with Groundwater**

Data Sources:
Groundwater Basins - California Department of Water Resources, Bulletin 118
Vegetation Associated with Groundwater - Sonoma County Water Agency,
Sonoma County Agricultural Preservation and Open Space District,
Sonoma County Vegetation Mapping and LiDAR Program

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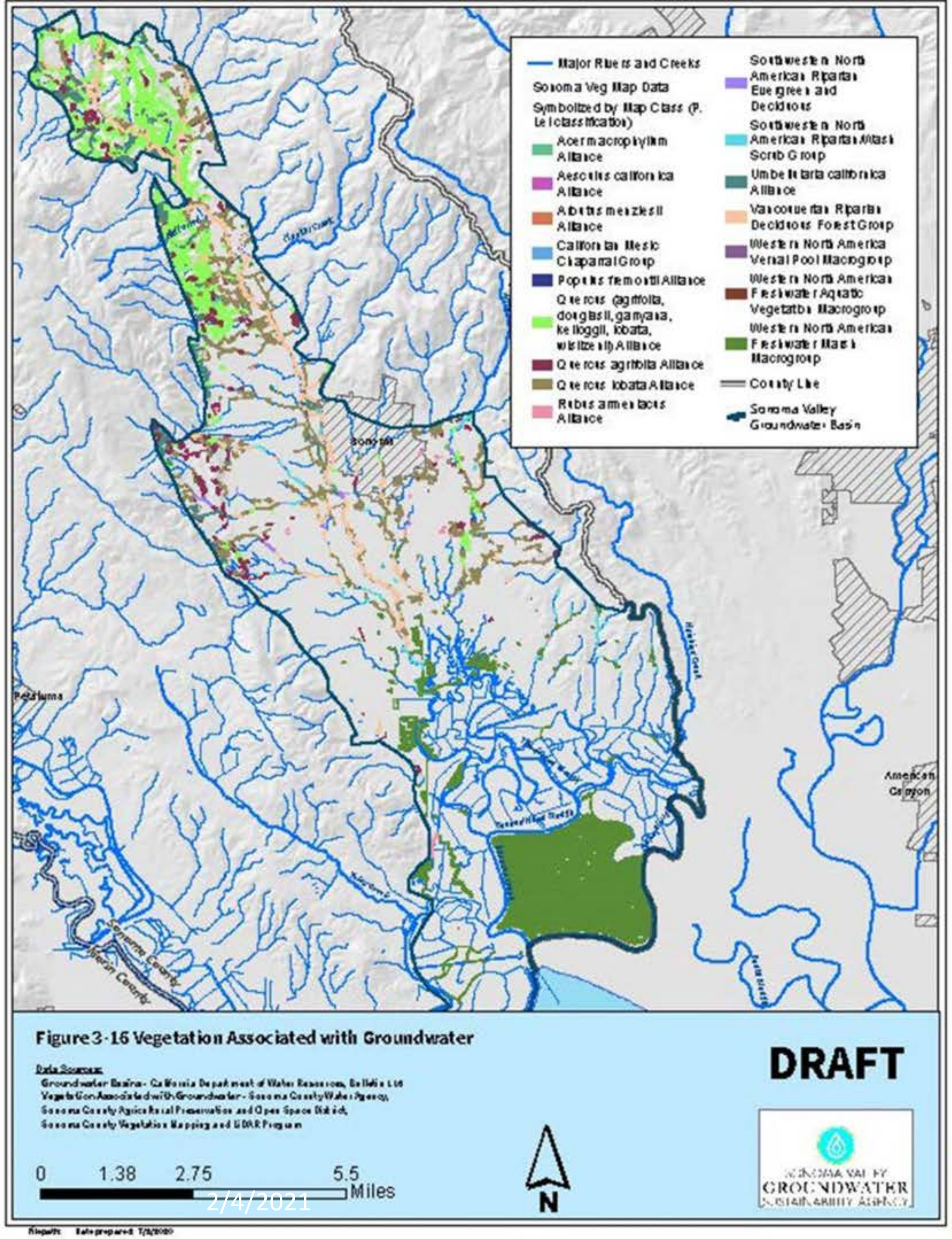



Figure 3-16 Vegetation Associated with Groundwater

Questions/Discussion

# Discussion of Data Gaps

1. Are there other existing data sources that should be included for GSP?
2. What additional data collection is recommended for implementation phase of GSP?

# Identification and Mapping
# Groundwater Dependent Ecosystems Workgroup
## Meeting Notes

Date/Time: Thursday, November 19, 2020 | 2:30 p.m.
Location: https://csus.zoom.us/j/87923439778
Contact: Sam Magill, Practitioner Work Group Facilitator
Email: s.magill@csus.edu | Phone: (831) 251-4127

## MEETING SUMMARY

### Welcome and Introductions / Agenda and Meeting Schedule Review

Sam Magill, Work Group Facilitator welcomed the group then ran through the day's agenda. He mentioned this meeting was the last one scheduled for the group, but staff would consider an additional meeting if needed.

Marcus Trotta welcomed the group and said there are some revisions and updates to the mapping that he wanted to share and receive input. He also was looking forward to hearing thoughts on prioritizing the GDEs' to help focus development of Sustainable Management Criteria and future monitoring of the GSA, future data collections, studies, and approaches of the implementation phase of the GDE.

### Update on Groundwater Dependent Ecosystem (GDE) Mapping Process

Marcus Trotta presented updated maps for sensitive aquatic species and vegetation and then presented draft integrated preliminary GDE maps. Patrick Lei, Sonoma Water, explained that three data sources are used to create the maps: 1) Sonoma Vegetation Map; interconnected surface water data; and depth to water threshold <30 feet. The analyses (presented by Marcus Trotta) help make sure we encompass areas that could potentially have groundwater within 30 feet. The maps have been shared with the Nature Conservancy and compared with their maps; there are some slight differences.

#### *Questions/Comments*

Rogers (chat) – What do the green stream channels signify in the Petaluma Valley map? Are those where riparian corridors exist but no sensitive aquatic species? I don't see the same on the other maps.

> Patrick Lei – I think we are seeing an artifact of the mapping; the orders and layers of the maps.

Wendy Trowbridge (chat) – The assumption here is that vegetation is an innocent victim of groundwater decline. How would the GSA deal with a situation where warmer summer conditions lead to an increase in evapotranspiration and the vegetation causes a decline in groundwater? It could create a difficult situation for the GSA.

> Trotta – Good question. That is something that will have to be considered and factored in. We will be developing 50-year projected model scenarios that will incorporate a climate future. It is something we could look at with the models and is factored into the SMC if it looks like a significant issue.

Magill – Maybe it is something we could flag for the Interconnect Surface Water work group.

Maxfield (chat) – How will diversions of surface water be factored in?

Trotta (chat) - Surface water diversions will need to be considered when developing the SMC for surface water depletion. I don't think they necessarily come in to play for GDE mapping.

Robert Pennington (chat) – Is this monitoring for GDE mapping or monitoring for SMC criteria?

Trotta (chat) – Monitoring for GDE mapping, although there could very well be overlap with SMC criteria.

Steve Rogers – For groundwater dependent vegetation, it seems the 30-foot threshold is specific to the rooting depth of oaks, but oaks have some of the deepest rooting systems of groundwater dependent vegetation species. Probably there are other shallower root species. Do they address other species besides oaks? It seems 30 feet wouldn't take into consideration other species.

Trotta – The 30 feet threshold is intended for consideration in mapping the potential presence of GDEs in the basin to be somewhat conservative.

Lei – We are trying to filter out eco systems that currently are not within 30 feet and probably not dependent on groundwater. It is a conservative model.

Rogers – I see now it is used for mapping vegetation and won't be used for management criteria for vegetation.

Lei – My understanding is that that is the next step.

Rogers – Makes sense.

Steven Lee – Looking at Sonoma Valley, there is one tributary, Stewart Creek off Calabasas, that might be underrepresented. It is a tributary that has Steelhead. It looks like Stewart Creek isn't listed on the map.

Trotta – Stewart Creek was included in the Steelhead mapping that David Cook did.

Lee – I don't think so.

Rob Pennington – Are there Steelhead present in the alluvial basin part of the groundwater basin or are they present in the upper watershed?

Lee – They have probably been cut off alluvially during the dry season months. I want to raise the issue, maybe it is intentionally left off the map.

Trotta – It looks like it is one of the streams filtered out through looking at the interconnected surface water. That stream isn't mapped as being interconnected surface water. We can follow up with David Cook.

Lee – What is the criteria for the delineation?

Trotta – If it isn't interconnected surface water, groundwater is below the streambed throughout the year and isn't contributing to the flow of water in that creek.

Lee – I recently did some temperature monitoring. Based on the way temperature data look, it seems there is a connection with groundwater feeding it.

Lee – In the areas identified less than 30 feet to the groundwater, it looks like the channels themselves, it doesn't seem to get wide beyond the channel area. Some monitoring I have done recently shows the groundwater is shallow southeast of Calabasas Creek, 500 yards or so off the creek.

Trotta – It would be great to see any additional data you have.

Melissa Rohde – Could you elaborate more why saltmarshes aren't included?

> Lei – We have been working under the assumption of tidally influenced rather than groundwater influenced. If we think it could be groundwater influenced, we should include saltwater marsh and aquatic. The map classes we have been working on from the beginning didn't include saltwater marsh.
>
> Rohde – It is worth considering, these ecosystems are defined as being dependent on groundwater near the earth's surface. If it is about using groundwater and is groundwater dependent, the species don't use multiple sources of water simultaneously at different times of the year. If the saltwater marsh areas were impacted by pumping there could be an inadvertent impact on the ecosystem if connected to groundwater.

Lei – If anyone has further questions about why some habitats were included or excluded from the maps, let me know, and I can get them added to the maps. I look forward to hearing your input.

## Preliminary Data Gaps/Recommendations on Future Data Collection

Marcus Trotta presented a slide with questions about recommendations for additional data collection and studies and asked the group for input.

1) *Are there additional monitoring needs for surface/groundwater interaction to better understand CDEs?*
2) *Are field verification surveys required to confirm maps?*
3) *Are there certain GDE parameters that should be considered?*
4) *How should any recommended studies/monitoring be prioritized for GSP implementation?*

Rogers – Are you planning on getting people together to discuss this?

> Trotta – It would be good to get initial ideas here on types of monitoring and prioritization of locations for monitoring, etc. The Surface Water Depletion workgroup will also have a discussion on monitoring related to surface water depletion.
>
> Rogers – My suggestion would be to put in monitoring that would best inform the modelling effort.
>
> Andy Rich – All the models that we are developing are data rich, there could be some improvement, such as the data collected by the Ecology Center of surface water - groundwater interactions.
>
> Lee – Basically we have most of the important creeks included in this. The question is what other areas aren't included? In terms of data gaps, when using vegetation mapping as a basis for the analysis, it seems underneath the canopy of other tree species that would indicate groundwater dependent eco-systems that wouldn't show up in those, I am thinking of seeps. Most areas I am thinking of are higher up in the watershed.

Trowbridge – I would be curious to hear how other GSAs have dealt with vernal pools. Clearly, there are perched aquifers, but water does flow out of vernal swells. And seepage runs. Also, another pitch for the importance of measuring evapotranspiration.

> Rohde – With regards to vernal pools, they are not generally included in the mapping. If the groundwater that the eco-systems are accessing and not connected to a principal aquifer it is not groundwater dependent in the context of SGMA. We have a GDE pulse we put together that includes satellite data from the last 35 years for mapped polygons, it doesn't include data from

your mapping. It would be good for us to talk about how you could do that. How to update the GDE pulse with recent data. Maybe we could give you the code.

Trowbridge – It seems like some of the differences between Sonoma Water's vegetation mapping and the TNC's vegetation maps in Santa Rosa Plain are related to perched aquifers associated with vernal pools.

Rohde – My understanding is the hydrogeology of the area is mostly unconfined aquifers. Can you explain the hydrogeology of the basin?

Trotta – The shallow groundwater conditions in the central portions of the plain, the shallow aquifer system is primarily unconfined. It is interesting the oaks are coinciding with areas of vernal pools.

Rohde – Is the groundwater essentially at the surface because of vernal pools or are the vernal pools there because the groundwater is at the surface?

Trotta – The vernal pools are superficial features that fill from precipitation in areas where the shallowest soils are sufficiently low permeability that allows for the formation of the vernal pools rather than filled by seasonal high groundwater fluctuations.

Rohde – When we are mapping the eco systems, one of the challenges is that we have a poor understanding of the shallow aquifer systems and the perched clay lands. SGMA is about adaptive management. If the vernal pools are driven by precipitation and surface run-off, under SGMA they wouldn't have to be categorized as groundwater dependent eco systems. We don't have data to prove that, so I think we should keep vernal pools in and address it as we move forward.

Pennington – Are there ideas for the SMC of the non-stream GDEs? What would the monitoring network look like? Will we have the monitoring such that it improves the mapping will make much difference in the end in terms of evaluating impacts of GDEs?

Trotta – I think it will for some of the next upcoming topics. If we had some areas that were higher priorities, maybe it would help identify monitoring needs.

Pennington – So you are thinking of using water levels for the GDE's sustainable management criteria.

Rich – It could be useful for identifying data gaps in the future.

Rohde – In general the non-riparian vegetation types should be considered when you are establishing SMC for chronic lowering of groundwater levels. You would have to define what an Undesirable Result looks like for that accounting for all the other beneficial users that rely on groundwater levels in the basin.

Trowbridge – I would encourage more monitoring. It seems like much of the Santa Rosa Plain where there are vernal pools are underlined by clay layers. I wonder if much of the riparian vegetation along the creeks isn't groundwater dependent on the deep groundwater so much as dependent on the shallow groundwater in the same way the vernal pools are. I don't think we have the information to say one way or another.

Trotta – When we look at the areas that have been mapped, we limited it to segments that have been mapped as interconnected surface water. Based on that data, those segments are connected to the shallow aquifer system. With all the clay in the Santa Rosa Plain, the continuity and degree of the connection is variable. We don't have a fine scale subsurface portion of the aquifer system to differentiate that. That is why the streams are made as interconnected.

Trowbridge – I think Santa Rosa Creek is interconnected. I wonder about some of the other smaller creeks that run by vernal pools, the lower parts of Copeland for example.

Trotta – Sounds like an area for future investigation and monitoring.

Pennington – In terms of what would be helpful, more shallow monitoring wells near streams would be useful for answering that question. I agree with the seepage runs, very useful. My knowledge of the stream gauging network is that it is quite good, I am not sure if there is a gauge is the upper end of Mark West Creek near Wikiup/Larkfield. Maybe one there would be useful. For Sonoma Creek, Sonoma Ecology Center would be able to advise.

Lee – We have three gauges in Sonoma Creek and a whole series of additional ones we have been trying to answer similar questions with other funding. Having more gauges and tracking more tributary flows would be an additional useful support. Steven Lee showed examples of stream temperature monitoring that he had done in the summer around the watershed. Temperature can be used as additional data to help inform this topic.

Rohde – I attended an fascinating session on groundwater dependent eco systems. There is interesting research being done using thermal imagery to map springs. There is some utility of using temperature to fill in data gaps.

Trotta – We have been using temperature as a tracer for groundwater-surface water interaction for years. It is a robust tool that can be used. In most applications it is usually more a focused study versus basin wide. New technology is coming out, it is worth considering.

## GDE Grouping and Prioritization

Marcus presented a slide with guiding questions for the group and asked for initial input on the topics.

1) *Do we need to prioritize different GDEs?*
2) *How do we assign value to different vegetation classes?*
3) *Are there certain streams or stream reaches that should be prioritized for focusing SMC development and monitoring?*
4) *How do we select areas for additional monitoring?*

### *Questions/Comments*

Rohde – Have you thought of grouping them into units first based on hydrogeologic setting? Associating polygons that are near each other and sharing same groundwater conditions – similar processes, easier to rank and monitor them?

Trotta – I have thought about it but not about how to implement it. It would be good to identify areas that have document groundwater level declines. Otherwise grouping based on hydrogeology could be a little challenging. The Bulletin 118 basins' mapping is similar hydrogeology in terms of superficial units, it may be difficult to parse them out that way.

Rohde – Well maybe not by hydrogeology but by location and habitat type? That would be my approach.

Rich – I think we could use some of the sub areas that were developed for the models. Some are based on hydrogeology and other groupings that might be helpful.

Trowbridge – One concern I have is that trees are a lagging indicator of groundwater depletion. What would be constrained are smaller trees and regeneration, and smaller vegetation. By using mature trees, you will miss the signal until it is too late.

Rohde – Yes, I echo Trowbridge's point. We need to maintain groundwater levels to ensure saplings survive. It is critical to ensuring the forests remain intact in the long term. It is key that groundwater needs to support spawning in future.

Lee – I appreciate the prioritization examples. Maybe there is a bit of a logic gap here. By choosing Steelhead streams we selected for high priority streams off the bat. But there are other streams that aren't Steelhead streams but that are fed by springs and have bugs and ecological value and are dependent on groundwater. Maybe they aren't the high value ones, but they are groundwater dependent eco systems that have been selected in the process.

Pennington – In terms of David Manning's assessment, the most sensitive GDE are the streams, riparian vegetation, and then the oak woodland. My feeling for the oak woodland is that their rooting depths can change significantly, probably a little more resilient and cover a large area. Also, in terms of Steelhead streams, once the streams have been mapped, it would probably be good to stop labeling them as Steelhead streams. There is a framework, CA Environmental Flows Framework that relates different flow criteria and beneficial uses and functions.

Rohde – My colleague, Julie Zimmerman is co-leading that effort, if you are interested, I can put you in touch with her. I second the eco-system approach.

Trotta – We have been moving away from calling them Steelhead streams or Steelhead maps and changing it to Aquatic streams and maps. It is a change you will see going forward.

Pennington – In terms of grouping by stream, it would be useful to group them by what periods/seasons the different species exist in the streams.

Marcus Trotta said staff would send out the questions and PDFs of the maps for the group to review and consider and provide input, especially on prioritization of grouping. When staff receives your input, we will make additional adjustments and develop a draft narrative for the Advisory Committee and Surface Water Depletion workgroup. If needed, we can schedule another meeting to discuss remaining issues.

Marcus Trotta closed with a slide indicating next steps including: initial draft narrative describing process and how mapping will be used in GSP; develop draft assignment of ecological value; share maps and approach with Surface Water Depletion SMC workgroup; and compile list of prioritized recommended data collection activities.

## Review Meeting Action Items

Marcus Trotta, Andy Rich and Rob Pennington thanked the attendees for their time, thoughts and interest.

Melissa Rohde asked if there would be a meeting on SMC for groundwater levels regarding groundwater dependent eco systems. Marcus Trotta said there is a separate workgroup meeting to discuss Interconnected Surface Water SMC. He said it would be great to get any thoughts from this group for developing the SMC for lowering groundwater levels and added that maybe we can loop this group into the discussions with the Advisory Committee.

Rob Pennington asked if draft SMC on chronic lowering of groundwater levels already been developed in all the basins.

Trotta – There have been some initial drafts of our proposed methodology, we are currently working on it and plan to bring it to the Advisory Committee in January.

Pennington – In discussions so far, have there been any conversations about the ecosystem?

Trotta – Most of the discussions have been about maintaining groundwater levels within or above historical ranges and making sure they stay above nearby wells. We did say we would revisit the SMC with information from groundwater eco system mapping but there hasn't been discussion yet on how it would be incorporated.

## Attendees:

Jessie Maxfield, CA Department of Fish & Wildlife
Melissa Rohde, The Nature Conservancy (joined 3:10)
Rick Rogers, National Marine Fisheries Service
Robert Pennington, Permit Sonoma
Steve Lee, Sonoma Ecology Center
Wendy Trowbridge, Santa Rosa de Laguna Foundation

### Staff/Presenters

Marcus Trotta, Sonoma Water
Andy Rich, Sonoma Water
Patrick Lei, Sonoma Water
Simone Peters, Sonoma Water (recording meeting notes)

### Facilitator

Sam Magill, Sacramento State University – Consensus and Collaboration Program

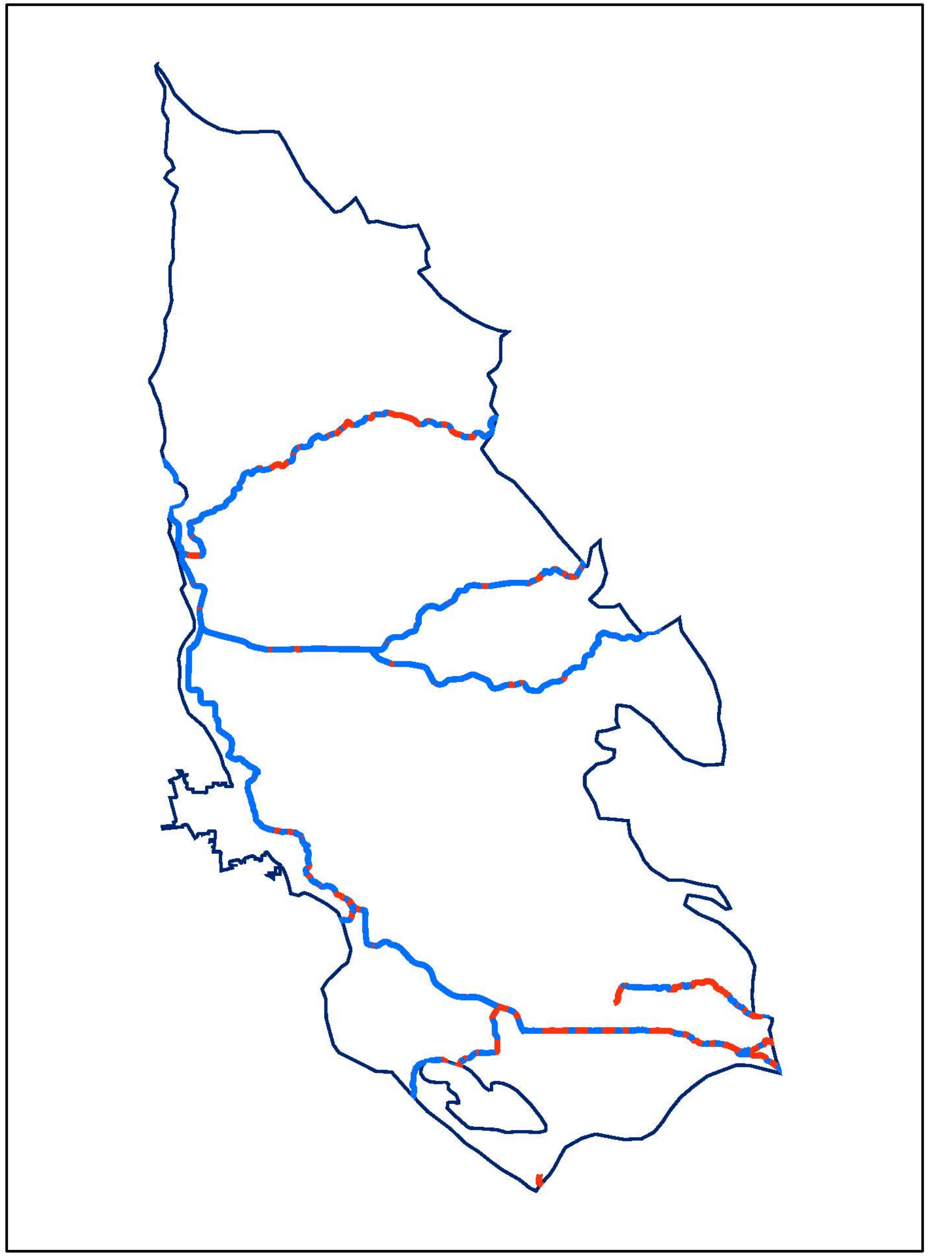
SANTA ROSA PLAIN • PETALUMA VALLEY • SONOMA VALLEY

GROUNDWATER SUSTAINABILITY AGENCIES

# IDENTIFICATION AND MAPPING OF GROUNDWATER DEPENDENT ECOSYSTEMS

Workgroup Meeting #3

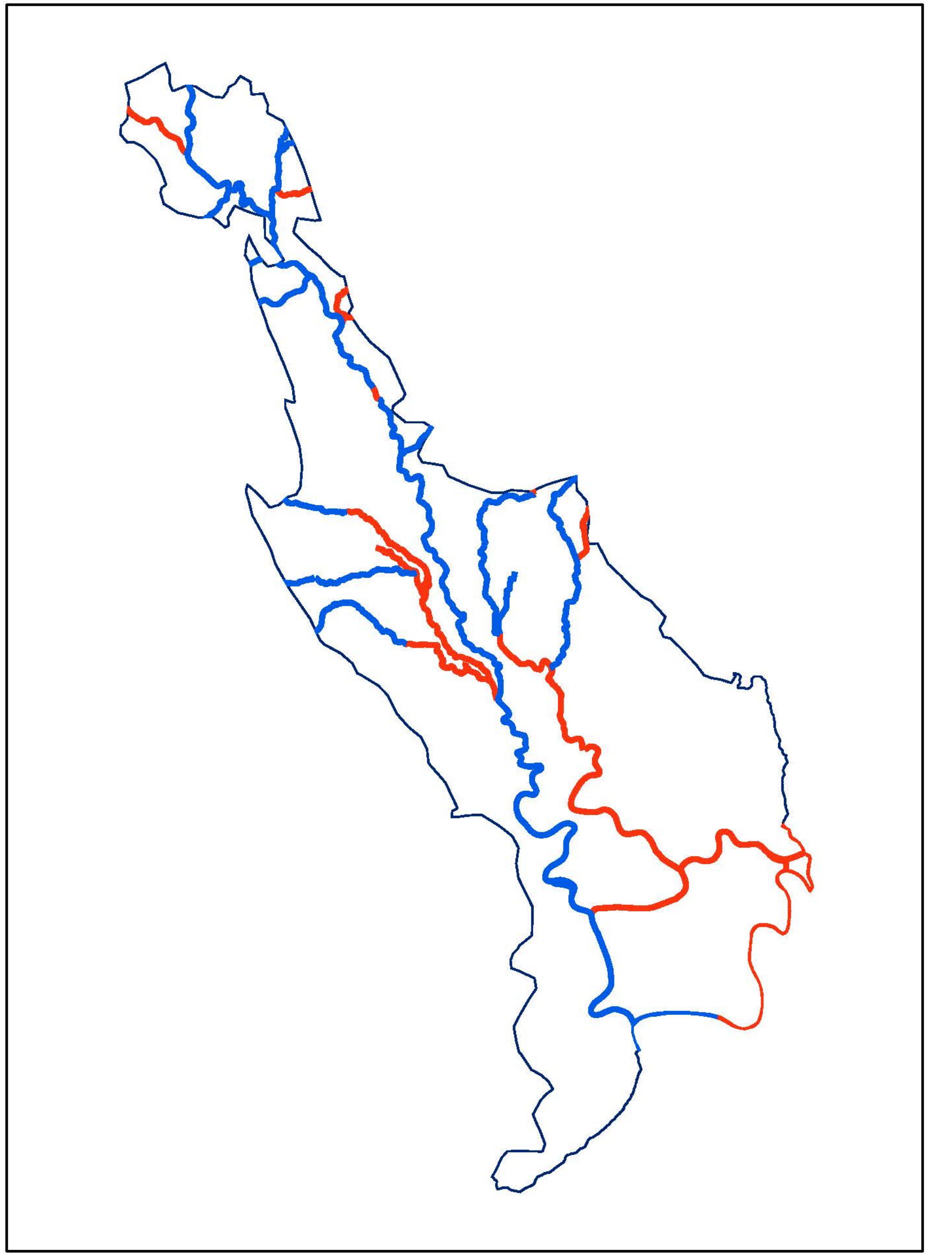
November 19, 2020



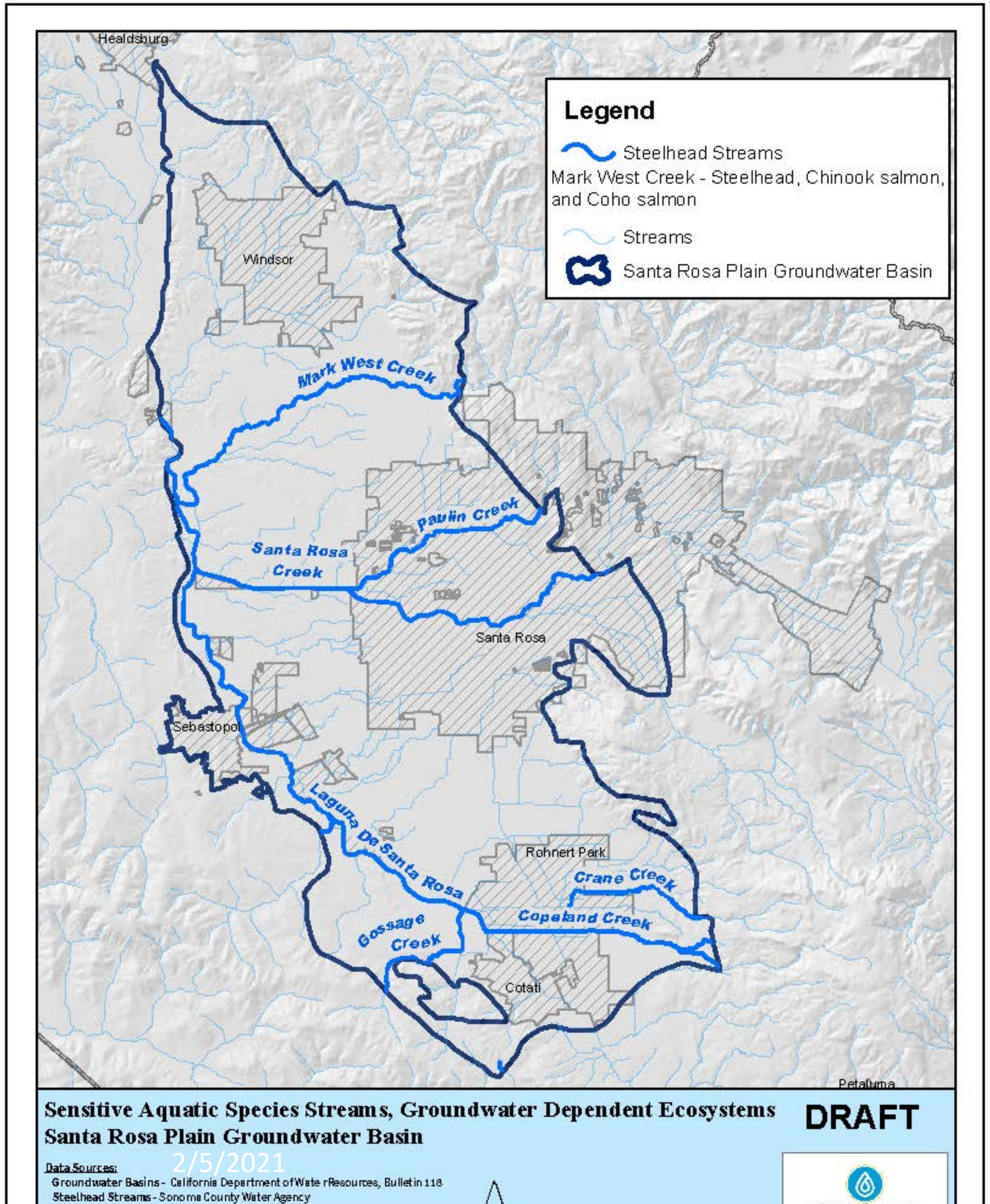
## Sensitive Aquatic Species GDE Mapping Process (SRP and SV*)

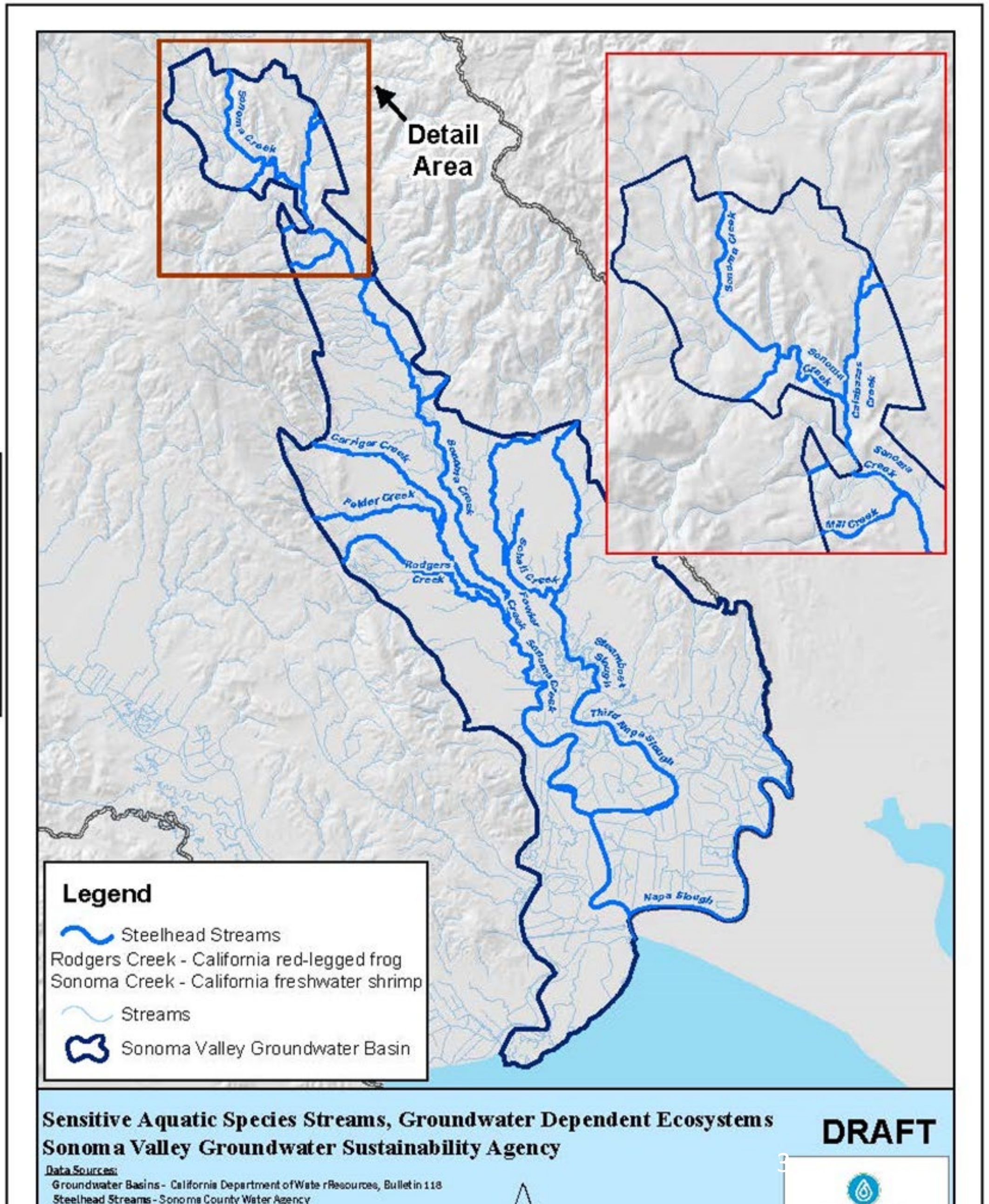
If any segment of a Sensitive Aquatic Species stream (**red**) intersects with mapped interconnected surface water (**blue**), entire reach of stream downstream of interconnected portion included as Sensitive Aquatic Species GDE.

*Petaluma Valley Interconnected Surface Water Mapping is pending completion

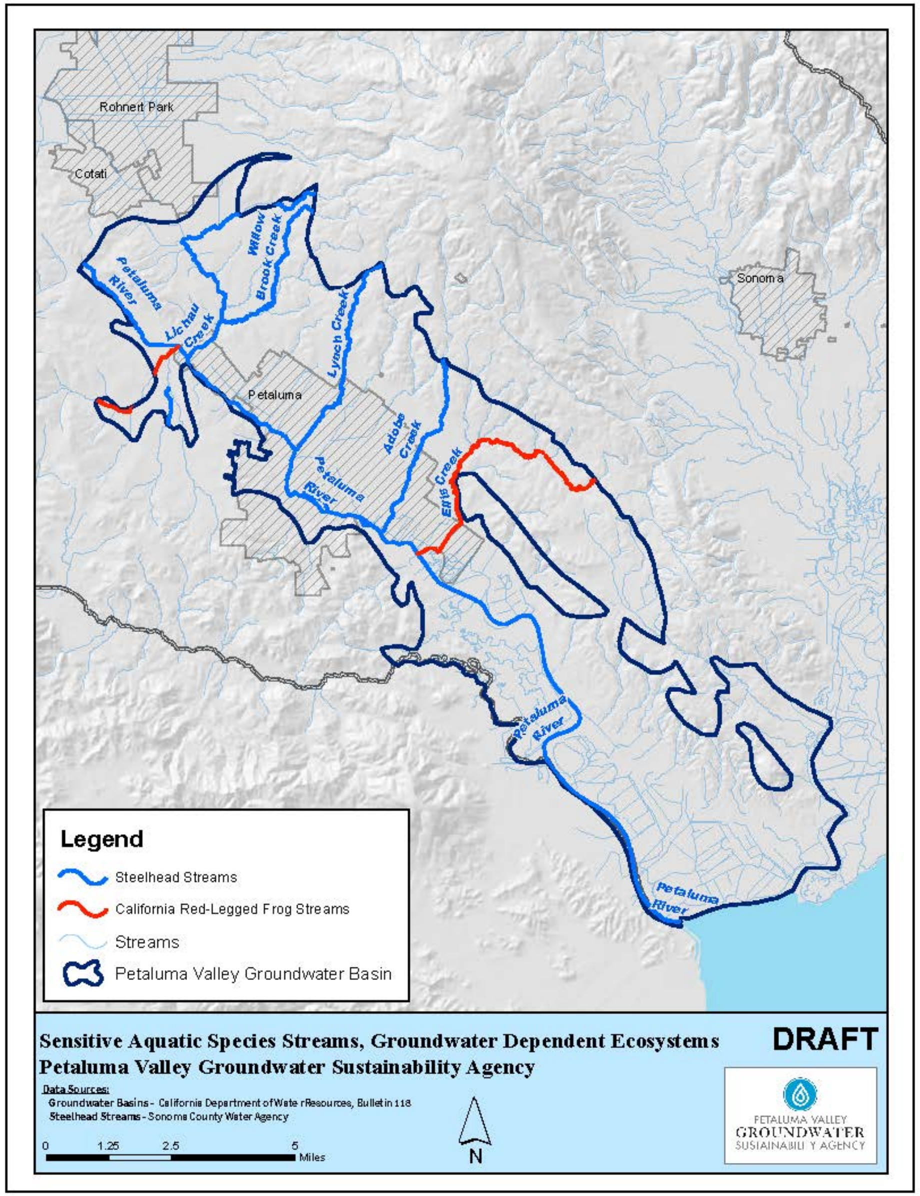


# Updated Preliminary Aquatic Groundwater Dependent Species

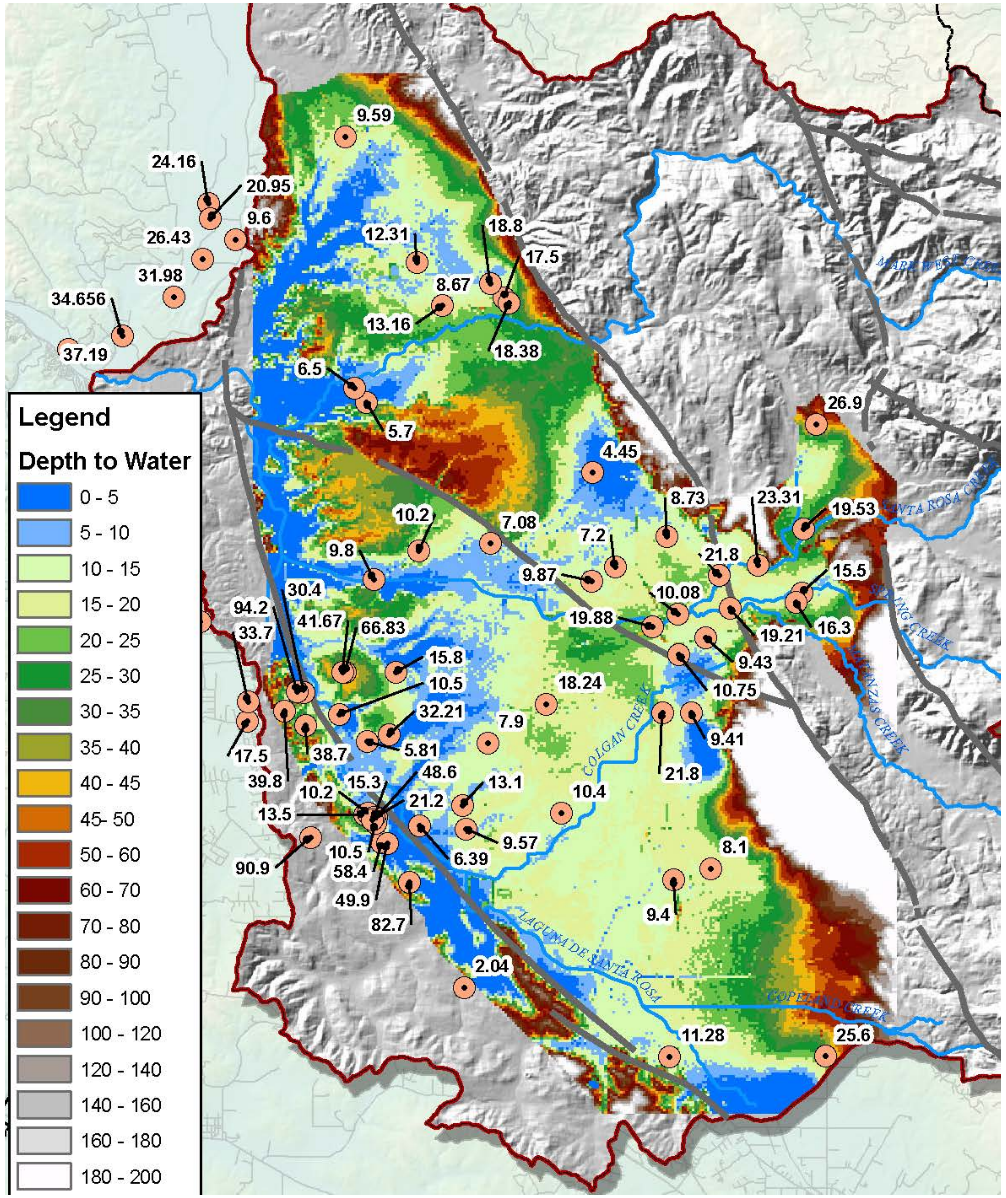


# Updated Preliminary Aquatic Groundwater Dependent Species

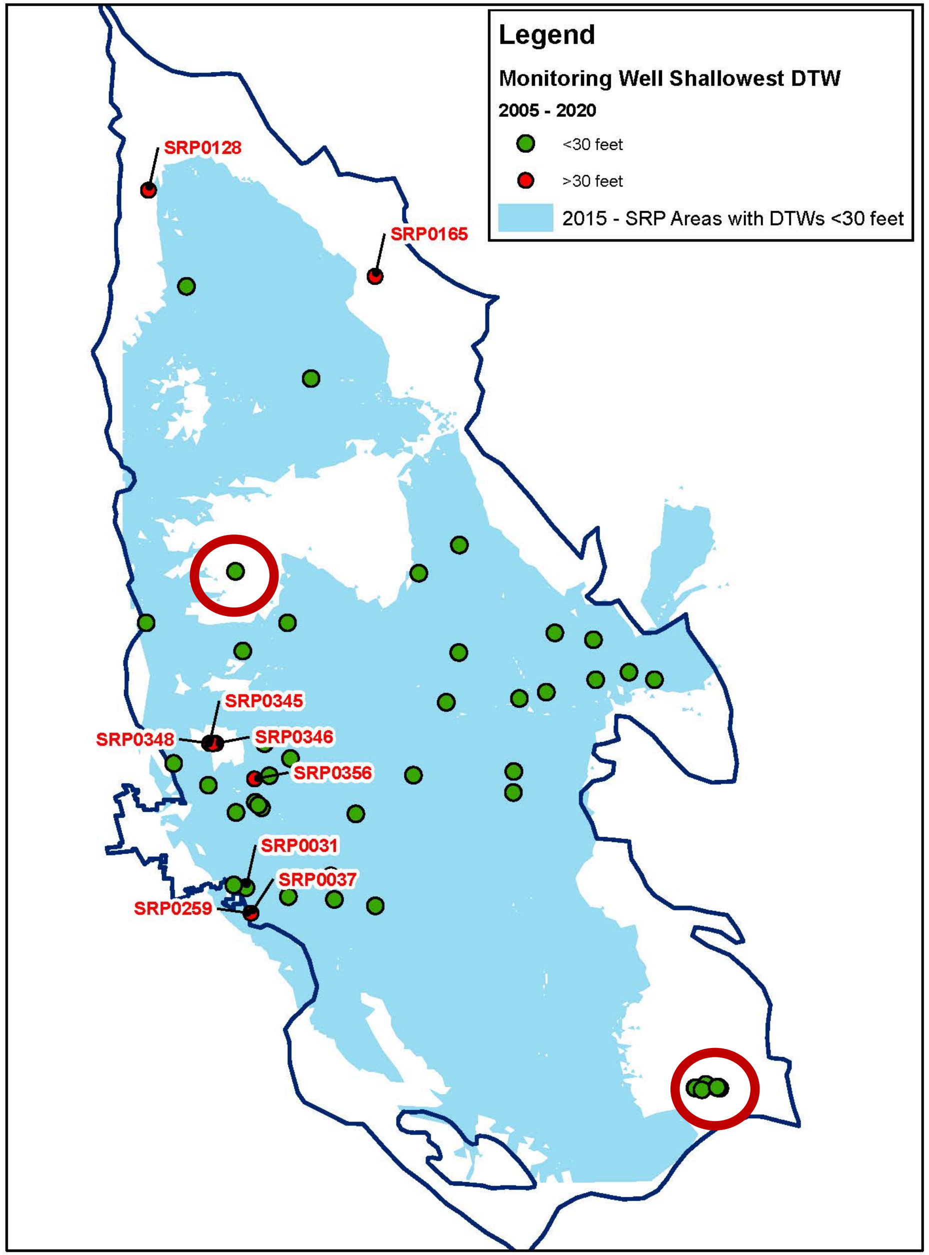



**Petaluma Valley (draft pending mapping of ISW)**

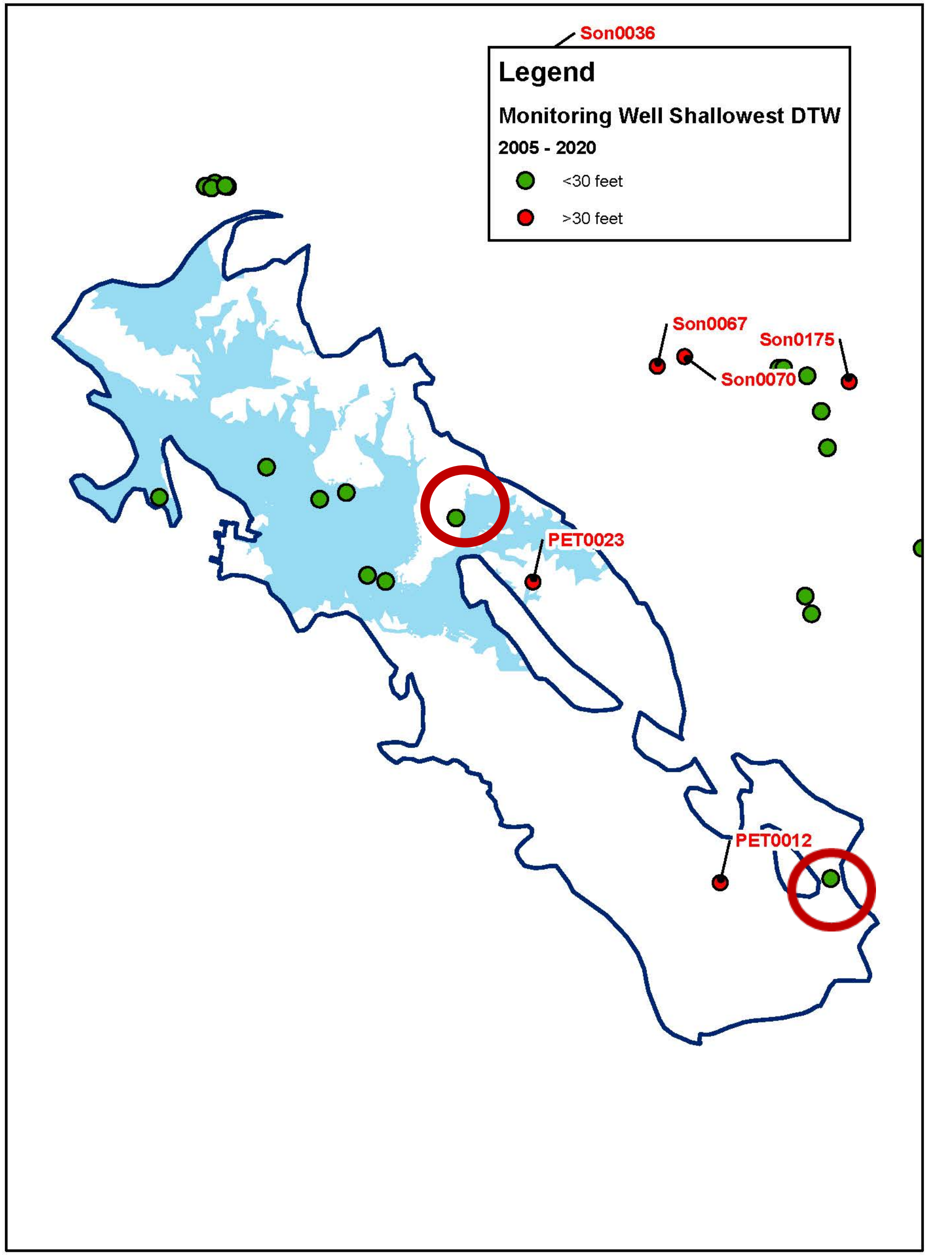


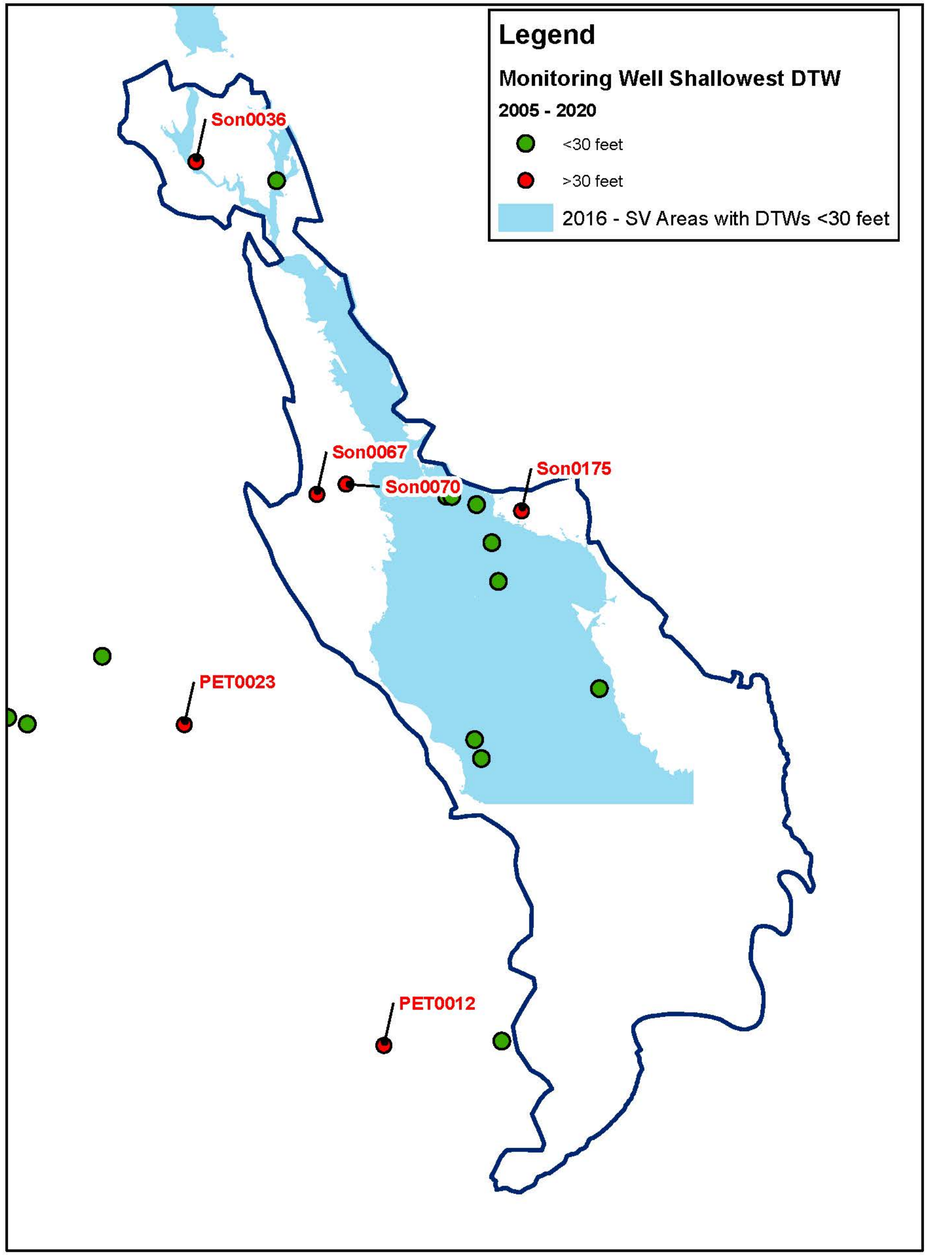

# Vegetation Mapping Update (DTW maps)

- Analyzed all availab groundwater-level data from 2005-202 for shallowest deptl to water on record for each well
- Identified a few are for further investigation and modification

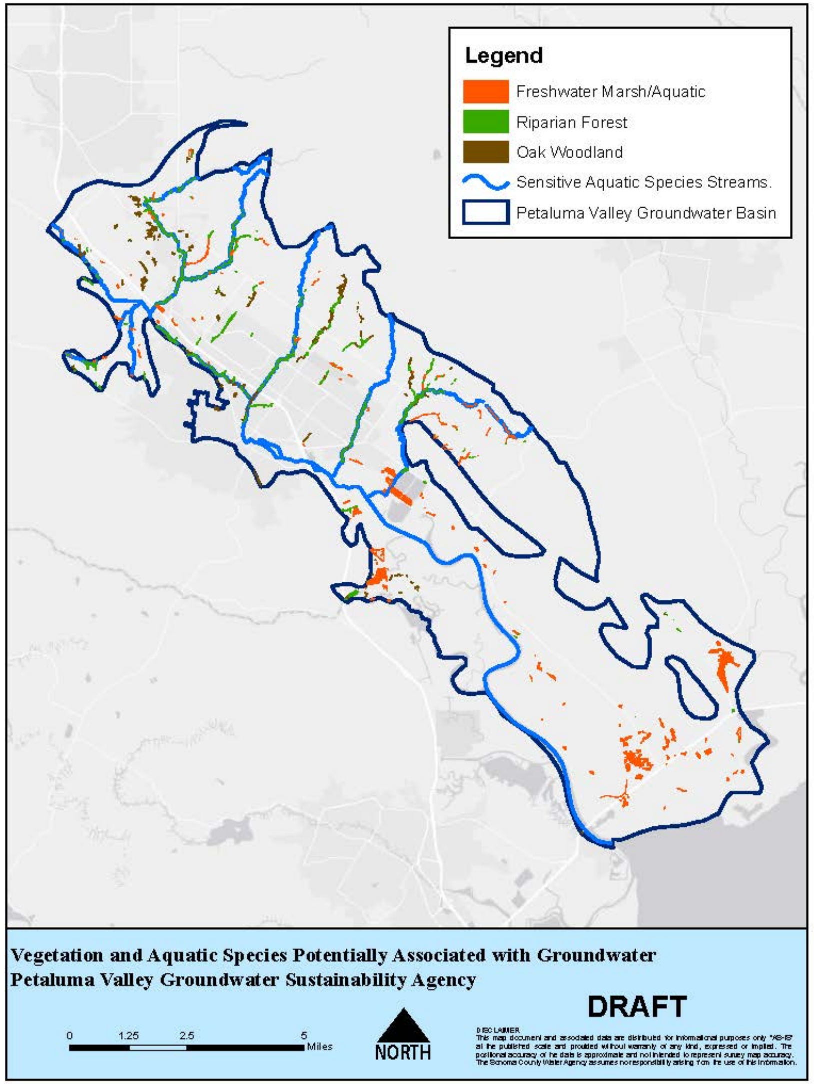


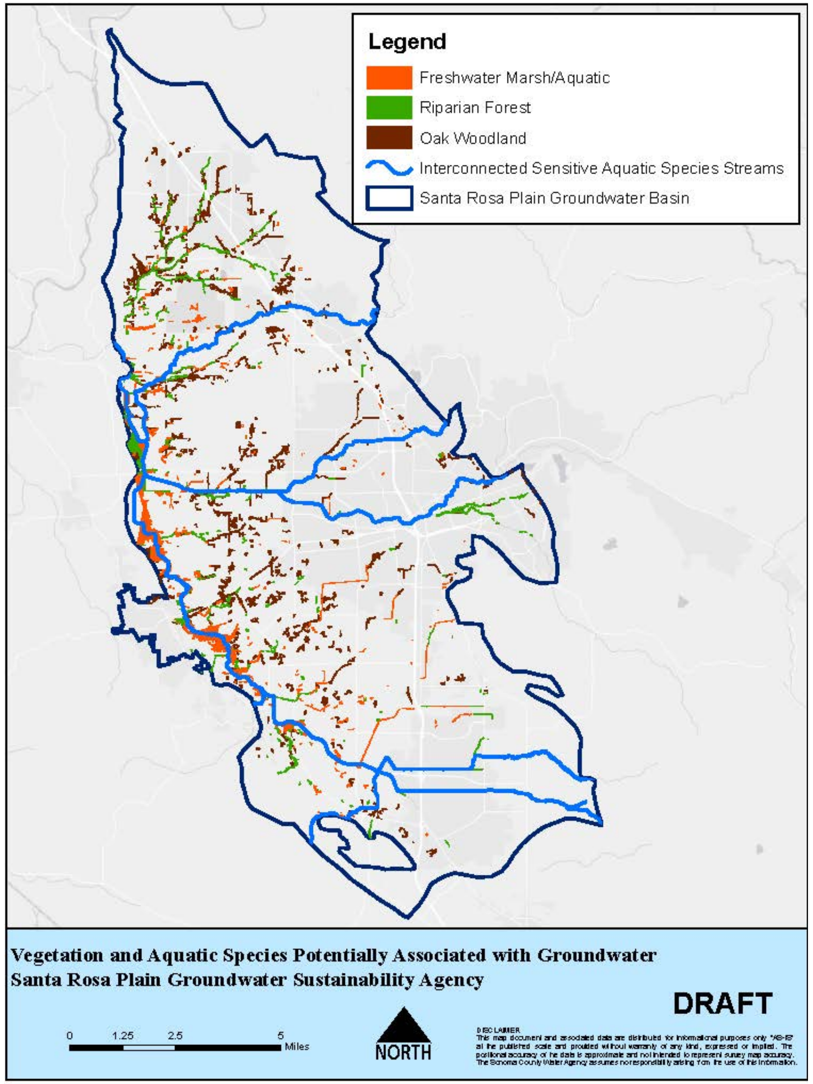
# Vegetation Mapping Update (DTW maps)

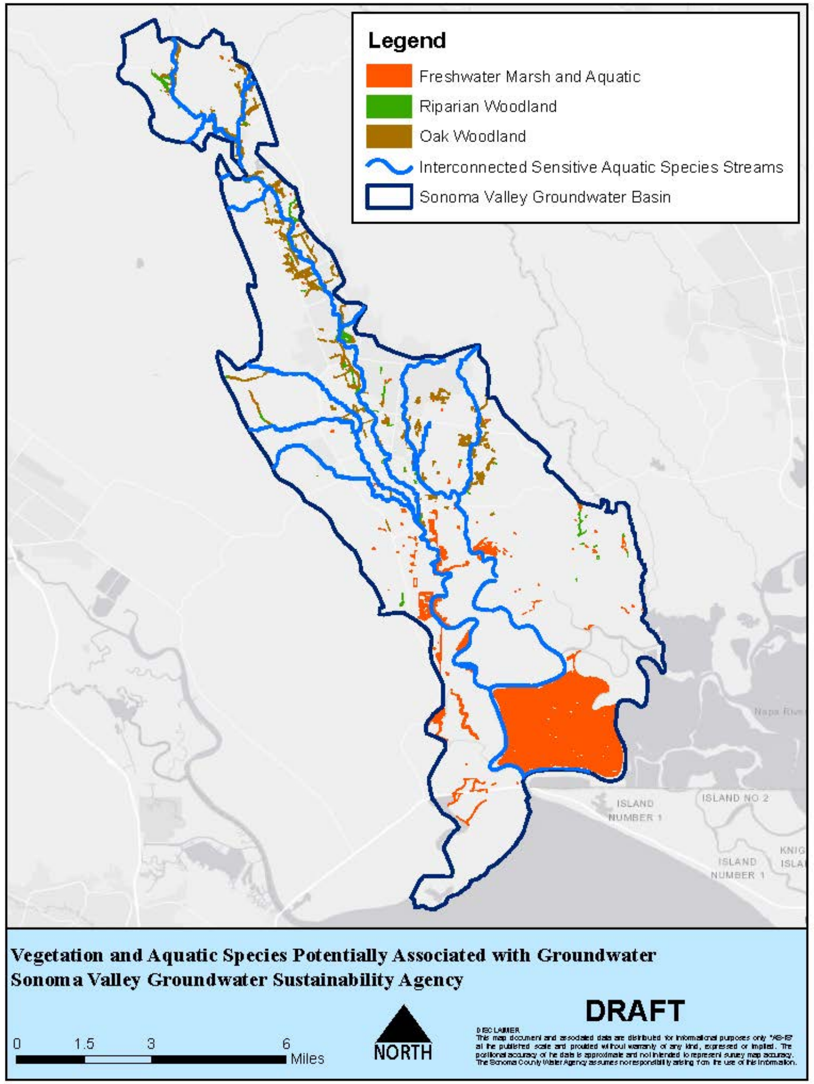


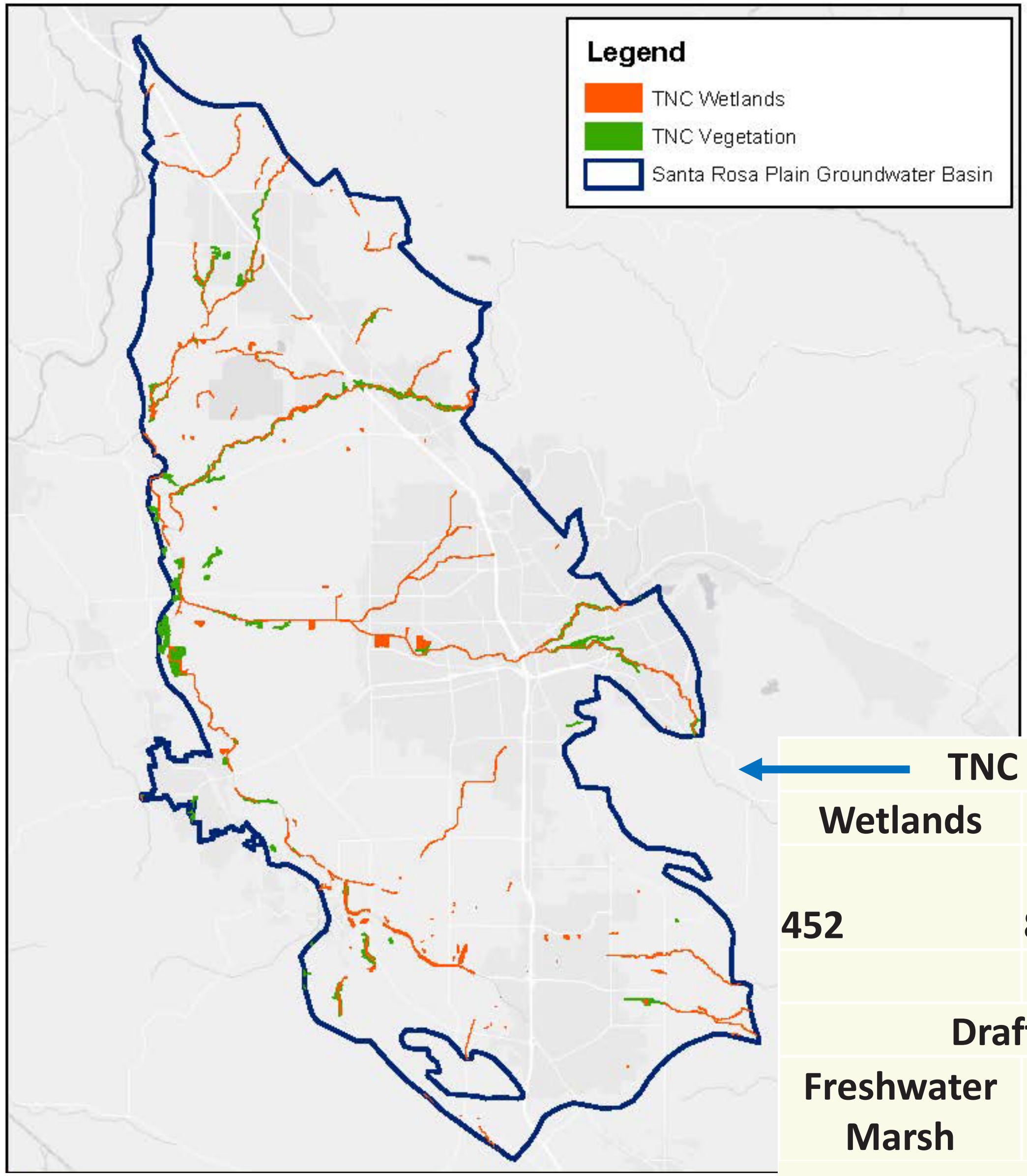



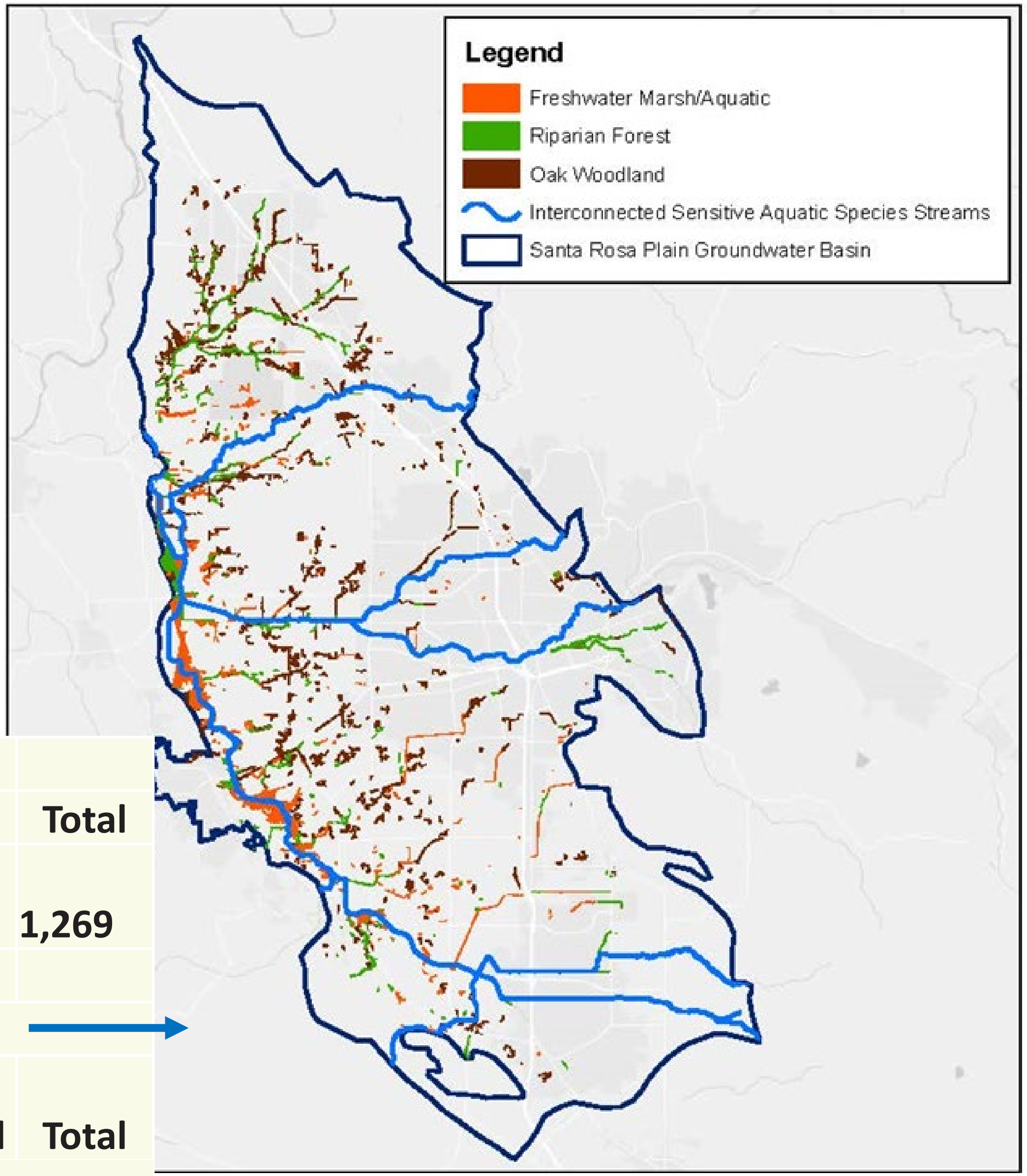
# Draft Integrated Preliminary GDE Maps



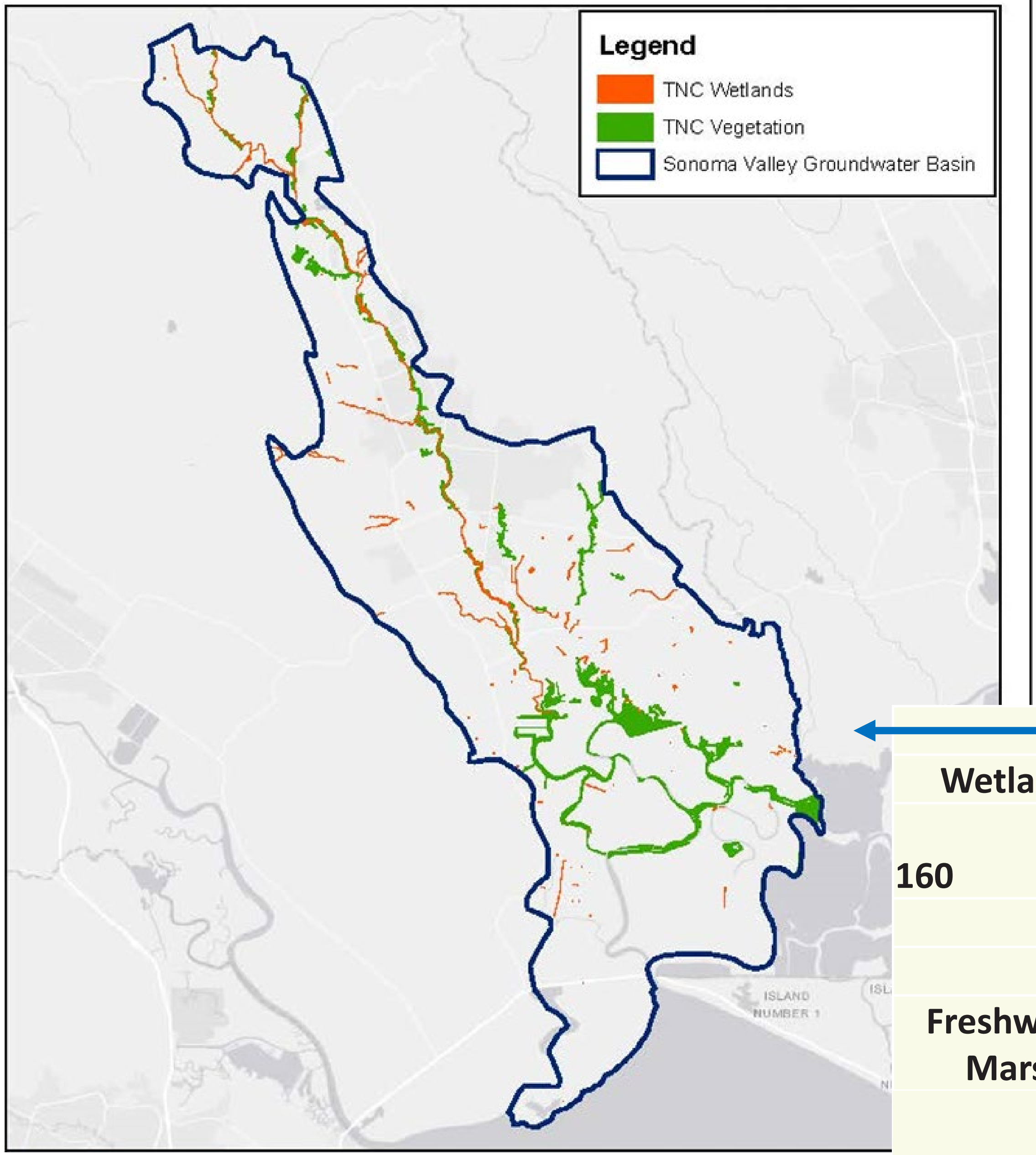





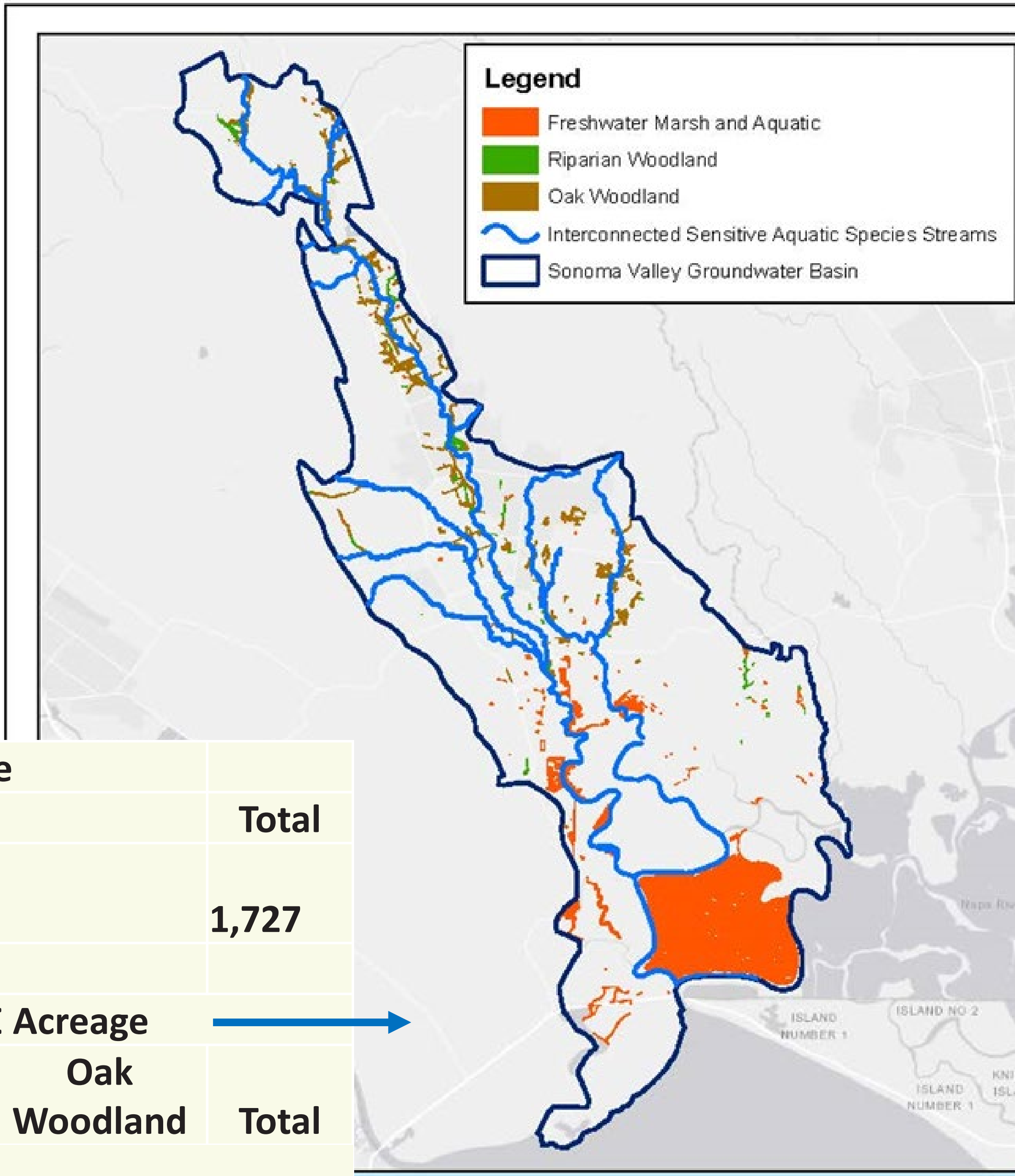



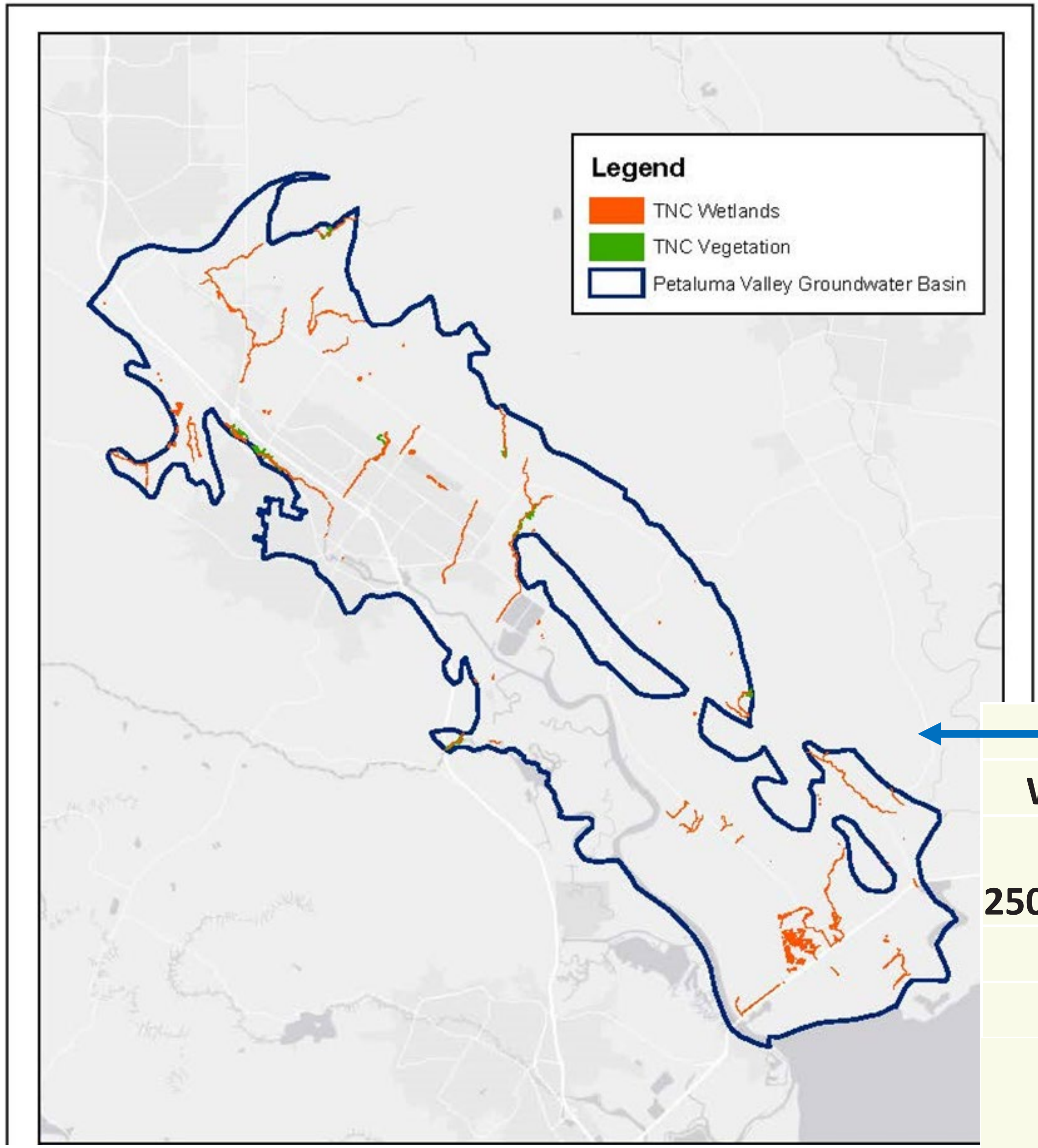

| TNC iGDE Acreage | | | |
|---|---|---|---|
| Wetlands | Vegetation | | Total |
| 452 | 817 | | 1,269 |

| Draft Prelim GDE Acreage | | | |
|---|---|---|---|
| Freshwater Marsh | Riparian Forest | Oak Woodland | Total |
| 952 | 1,152 | 1,710 | 3,813 |

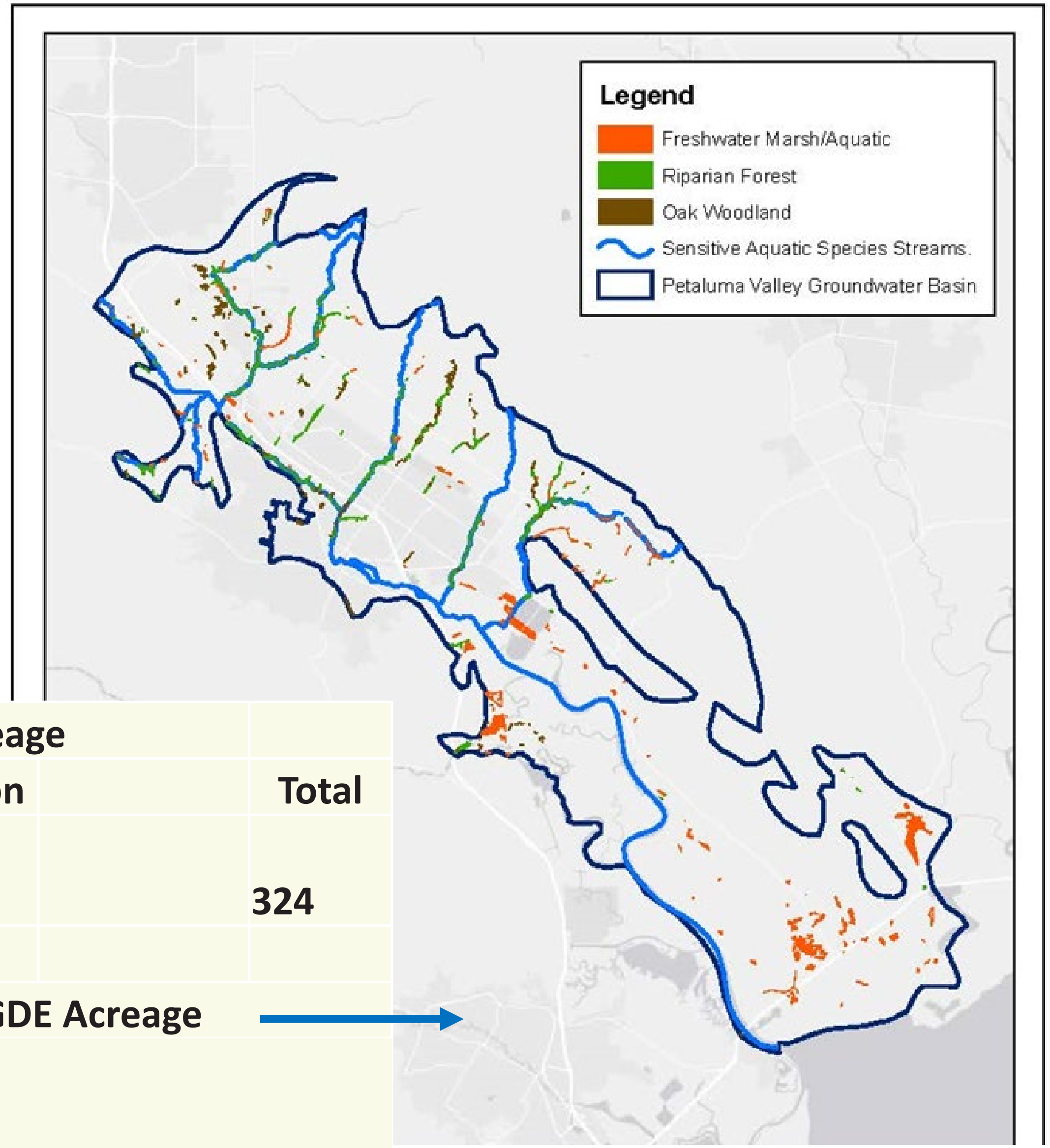



| TNC iGDE Acreage | | | |
|---|---|---|---|
| Wetlands | Vegetation | | Total |
| 160 | 1,567 | | 1,727 |
| **Draft Prelim GDE Acreage** | | | |
| Freshwater Marsh | Riparian Forest | Oak Woodland | Total |
| | 556 | 880 | 1,644 |






| TNC iGDE Acreage | | | |
|---|---|---|---|
| Wetlands | Vegetation | | Total |
| 250 | 74 | | 324 |
| Draft Prelim GDE Acreage | | | |
| 431 | 299 | 172 | 903 |



# Recommendations for Additional Data Collection/Studies for GSP Implementation

- Are there additional monitoring needs for surface/groundwater interaction to better understand GDEs?
  - Shallow monitoring wells, stream gauges, seepage runs, etc.
- Are field verification surveys required to confirm maps?
- Are there certain GDE parameters that should be considered?
  - Rooting depths, Normalized Difference Vegetation Index (NDVI), etc.
- How should any recommended studies/monitoring be prioritized for GSP implementation?

# Grouping/Prioritization of GDEs

- Do we need to prioritize different GDEs?
  - Steelhead/special status species?
  - Oak woodland vs. riparian?
- How do we assign value to different vegetation classes?
- Are there certain streams or stream reaches that should be prioritized for focusing SMC development and monitoring?
- How do we select areas for additional monitoring?

# TNC Guidance for Assigning Ecological Value

***High Ecological Value***

- All or part of the GDE unit has been designated as having important significance by environmental agencies, by other laws, in international agreements, or by local GSA stakeholders
- Contains species that are entirely dependent on groundwater (obligate) for their survival, are extremely sensitive to environmental characteristics provided by groundwater, or are rare or unique.
- Contains species or ecological communities that are vulnerable to slight to moderate changes in groundwater discharge or groundwater levels that would result in a substantial change in their distribution, species composition, and/or health.

# TNC Guidance for Assigning Ecological Value

***Moderate Ecological Value***

- The species or ecological communities within the GDE are not legally protected but may have been designated as a beneficial use and/or as having important significance by environmental agencies, local conservation plans, or local stakeholders.
- Contains mostly species that are partially dependent on groundwater (facultative).
- Contains species or ecological communities that are somewhat vulnerable to slight to moderate changes in groundwater discharge or groundwater levels that would result in some change(s) in their distribution, species composition, and/or health.

# TNC Guidance for Assigning Ecological Value

***Low Ecological Value***

- The species or ecological communities within the GDE are not legally protected and have not been designated as having important significance by other environmental agencies, local conservation plans, or local stakeholders.
- Contains only species that are partially dependent on groundwater (facultative).
- Contains species or ecological communities that are not vulnerable to slight to moderate changes in groundwater discharge or water tables, resulting in minimal change(s) in their distribution, species composition, and/or health.

# Next Steps

- Initial draft narrative describing process and how mapping will be used in GSP
- Develop draft assignment of ecological value
- Share maps and approach with Surface Water Depletion SMC Workgroup
- Compile list of prioritized recommended data collection activities

.

# Appendix 4-D
# Development of Sustainable Management Criteria of Interconnected Surface Water – Petaluma Valley

# Development of Sustainable Management Criteria for Depletion of Interconnected Surface Water by Groundwater Pumping—Petaluma Valley GSP

Determination of Sustainable Management Criteria (SMCs) for depletion of interconnected surface water (ISW) by groundwater pumping is based on a methodology that uses shallow groundwater level (GWL) measurements as a pro y for surface water depletion by pumping at dedicated shallow monitoring wells installed at representative monitoring point (RMP) locations adjacent to ISW. The use of GWLs as a pro y for a rate or volume of surface water depletion relies on correlation between surface water depletion by pumping and shallow GWLs adjacent to streams. uantifying surface water depletion due to pumping is a challenge because (1) it cannot be measured directly and (2) the influence of surface water depletion by pumping is often obscured other factors, such as precipitation and runoff, diversions, evapotranspiration, and natural groundwater/surface-water interactions. The general approach outlined here sets initial SMCs at RMP locations (Fig. 1) to maintain the observed gaining/losing conditions during the 2019 2020 period that data have been collected. Gaining/losing conditions are appro imated by evaluating the position of shallow groundwater levels at RMP locations relative to the streambed and stream stage elevations. The approach will be modified to incorporate (1) modeling results to demonstrate the correlation between shallow GWLs and depletion of ISW using future model results at RMP locations, and (2) and additional shallow groundwater level monitoring data collected at each RMP.

## 1 Selection of Depletion of Interconnected Surface Water RMPs

Groundwater elevations from 3 shallow monitoring wells located near streams in the Petaluma Valley are equipped with high frequency monitoring provided by dedicated pressure transducers. These monitoring wells provide location-specific groundwater level data on the distribution and timing of surface water-groundwater interconnectivity in the Subbasin (Figs. 1). Streambed elevations obtained from LiDAR datasets and stream-surface water measurements near each monitoring well compared with groundwater elevations to assess interconnectedness and to assess the presence of gaining or losing conditions. All 3 shallow monitoring wells were included as RMPs based on observed interconnection and pro imity to GDEs at these locations (Figs. 2 3). Additional details of shallow monitoring wells near streams are included in Section 4 of the GSP.

## 2 Current Methodology

SGMA regulations define the metric for depletion of ISW as a volume or rate of surface water depletion by groundwater pumping. Since direct measurement of depletion of ISW by groundwater pumping is not possible, SGMA allows groundwater elevations to be used as a pro y for the volume or rate of depletion of ISW, provided significant correlation between groundwater elevations and depletion of ISW can be demonstrated. In the absence of modeling results to evaluate the correlation between surface water depletion and groundwater levels, the current methodology sets SMC values using groundwater level pro ies by evaluating the groundwater level position relative to observed streambed and stream stage elevations at RMP locations (Figs. 4  6). As outlined in Section 3, the approach will be modified to incorporate future modeling results and groundwater level data.

## 2.1 Minimum Thresholds

For RMP PET0172 (Fig 3), the minimum threshold (MT) groundwater level pro  y value was set as the appro  imate streambed elevation. For RMPs PET0173 and PET0174 (Figs. 5  6), the MT value was set as 1ft below the appro  imate streambed elevation. These MT values were chosen to be slightly below 2019 and 2020 groundwater levels. Lacking additional historical measurements at these RMPs, these MT choices were informed by observations from adjacent basins (Santa Rosa Plain and Sonoma Valley), which show that the years in the recent historical period with the greatest depletion (2014  2016) had shallow dry-season low groundwater levels typically slightly lower than 2019 and 2020 values. MT values for each RMP are summarized in Table 1.

## 2.2 Measurable Objectives

For all three RMPs, the measurable objective (MO) groundwater level pro  y value was set as    of the distance between the MT value and the average observed dry-season surface water stage during the period of record (Nov. 2019  Dec. 2020  Figs. 5  6). MO values for each RMP are summarized in Table 1.

# 3 Future Methodology

Given the limited period of record of data collection at RMP locations, an adaptive approach is outlined below in which future modifications to SMCs for this sustainability indicator will be incorporated as more data become available and as model simulations of surface water depletion are improved. While the Petaluma Valley Hydrologic Model (PVHM) offers a robust platform to accurately simulate most hydrologic processes in the basin, at present, it is not sufficiently calibrated to simulate surface water depletion from pumping with the degree of accuracy required to use the results here. It is anticipated that future updates to the model and additional data collection at each RMP will make these analyses possible at or before the 5-year update. The following sections outline the adaptive approach for incorporating future model results and additional groundwater level observations to determine SMCs for depletion of ISW.

## 3.1 Methodology for Determining Correlation between Simulated SWD and GWLs

### 3.1.1 Modeling Framework for Isolating Impacts of Groundwater Pumping on Streamflow

To isolate the impact of depletion of ISW by groundwater pumping, a sensitivity approach is proposed to subtract simulated streamflow outputs from two model scenarios simulated with the Petaluma Valley integrated hydrologic model. The general procedure is derived from Barlow and Leake (2012)[1] and is illustrated in Steps 1  2 in Fig. 7:

1. Simulate (a) a historical baseline scenario, which includes historical groundwater pumping, and (b) an identical historical baseline scenario, but remove historical groundwater pumping, i.e., a no-pumping scenario.
2. At each time step, subtract the simulated streamflow outputs from the historical baseline scenario from the no-pumping scenario at each RMP location.

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[1] Barlow, Paul M., and Stanley A. Leake. *Streamflow depletion by wells: understanding and managing the effects of groundwater pumping on streamflow*. Reston, VA: US Geological Survey, 2012.

The resulting streamflow volume is an estimate of ISW depletion from groundwater pumping that occurred at all ISW locations upstream of each RMP location at each time step (e.g., as illustrated in Step 2 in Fig. 7). In effect, the volume of ISW depletion is the amount of additional streamflow volume at each RMP location if historical groundwater pumping had not occurred. Of course, the no-pumping scenario is outside the bounds of real-world conditions and is not presented as an aspirational goal for the basin, but instead provides a means to estimate the relative magnitude of ISW depletion over time and across locations.

### 3.1.2 Demonstrating Correlation between Groundwater Levels and Surface Water Depletion at RMP Locations

To evaluate the correlation between surface water depletion from groundwater pumping and shallow groundwater levels at RMP locations, this methodology will focus on a 15-year simulation period from 2004  2018 representing recent historical groundwater pumping conditions in the basin. The evaluation period may be e  tended if the model is updated to include simulations past 2018. Surface water depletion will be estimated at each RMP location as the percent decrease in minimum monthly simulated streamflow during the July-September period at the corresponding SFR cell for each year during 2004  2018. The corresponding shallow groundwater level will be estimated as the minimum monthly simulated groundwater level in model layer 1 at each RMP location during the July  September period for each year. Correlation will be determined with linear regression and evaluated using the coefficient of determination (R-squared). R-squared values greater than 0.60 will be determined to be sufficiently correlated. Correlation between surface water depletion from groundwater pumping and shallow groundwater levels is illustrated in Step 3 in Fig. 7.

## 3.2 Methodology for Determining Minimum Thresholds and Measurable Objectives for Depletion of Interconnected Surface Water at RMPs

Based on input from the Depletion of Interconnected Surface Water Work Group, it was suggested that future MT values at RMP locations should be sufficiently protective so as to not e  ceed the average, basin-wide, dry-season (July  September) surface water depletion from pumping that occur during the years with the greatest depletion during the evaluation period. Additionally, it was suggested that MO values at RMP locations should maintain the observed average dry-season surface water depletion from pumping that occur during the years with available observations during the evaluation period. This approach is consistent with the methodology used for the adjacent Santa Rosa Plain and Sonoma Valley GSAs

### 3.2.1 Methodology for Determining Groundwater Level Minimum Thresholds using Percentile Ranking at RMP Locations

The methodology for setting the groundwater level pro  y MT value relies on evaluating the model-derived percentile ranking of observed dry-season low groundwater levels at each RMP location. This approach is conceptualized in Steps 3 and 4 in Fig. 7. As an e  ample, the adjacent Santa Rosa Plain and Sonoma Valley GSAs determined that MT values at RMP locations should be sufficiently protective so as to not e  ceed the average, basin-wide, dry-season (July  September) surface water depletion from pumping that occurred for the three years with the greatest depletion during the 2004  2018 evaluation period. In both basins, the three years with the greatest simulated depletion were 2014, 2015, and 2016. Accordingly, the average percentile ranking of simulated dry-season low GWLs for 2014, 2015, and 2016 was evaluated at each RMP location. This percentile ranking was then used to set the MT for observed dry-season low GWLs at each RMP location. Because the observation period at RMP wells in the Petaluma Valley is relatively short (2019  Present), there currently is insufficient dry-season low groundwater level measurements to determine a percentile ranking. However, in several years the observation period will be sufficient to determine a percentile ranking (   5 years of observations).

### 3.2.2 Methodology for Determining Groundwater Level Measurable Objectives at RMP Locations

MO values at each RMP will likely be set to reflect average observed dry-season low groundwater levels during years with available observations. This is consistent with the present methodology, but will include additional dry-season low groundwater level observations from future years as they become available.

# 4 Figures

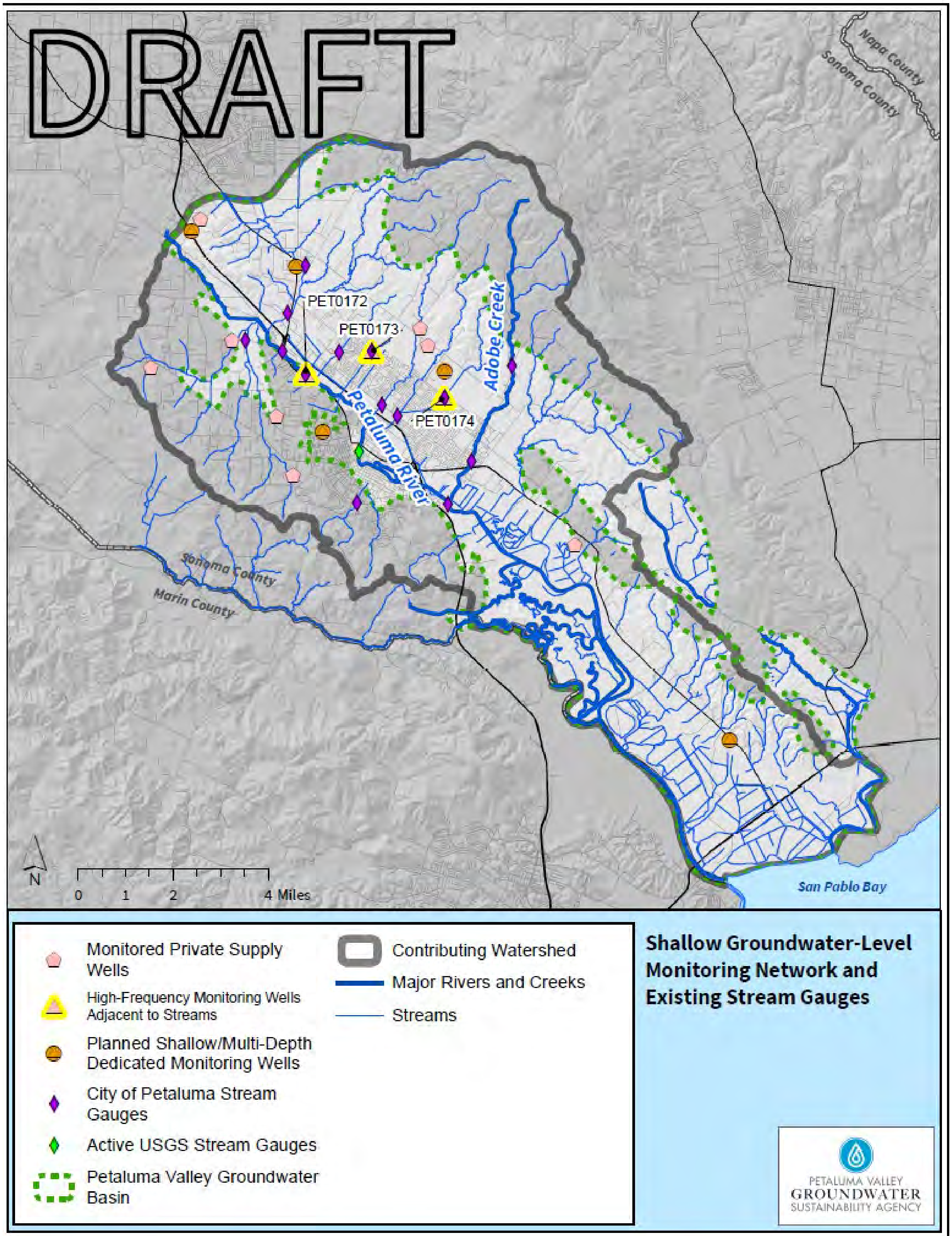


Figure 1: Petaluma Valley depletion of interconnected surface water RMP locations.

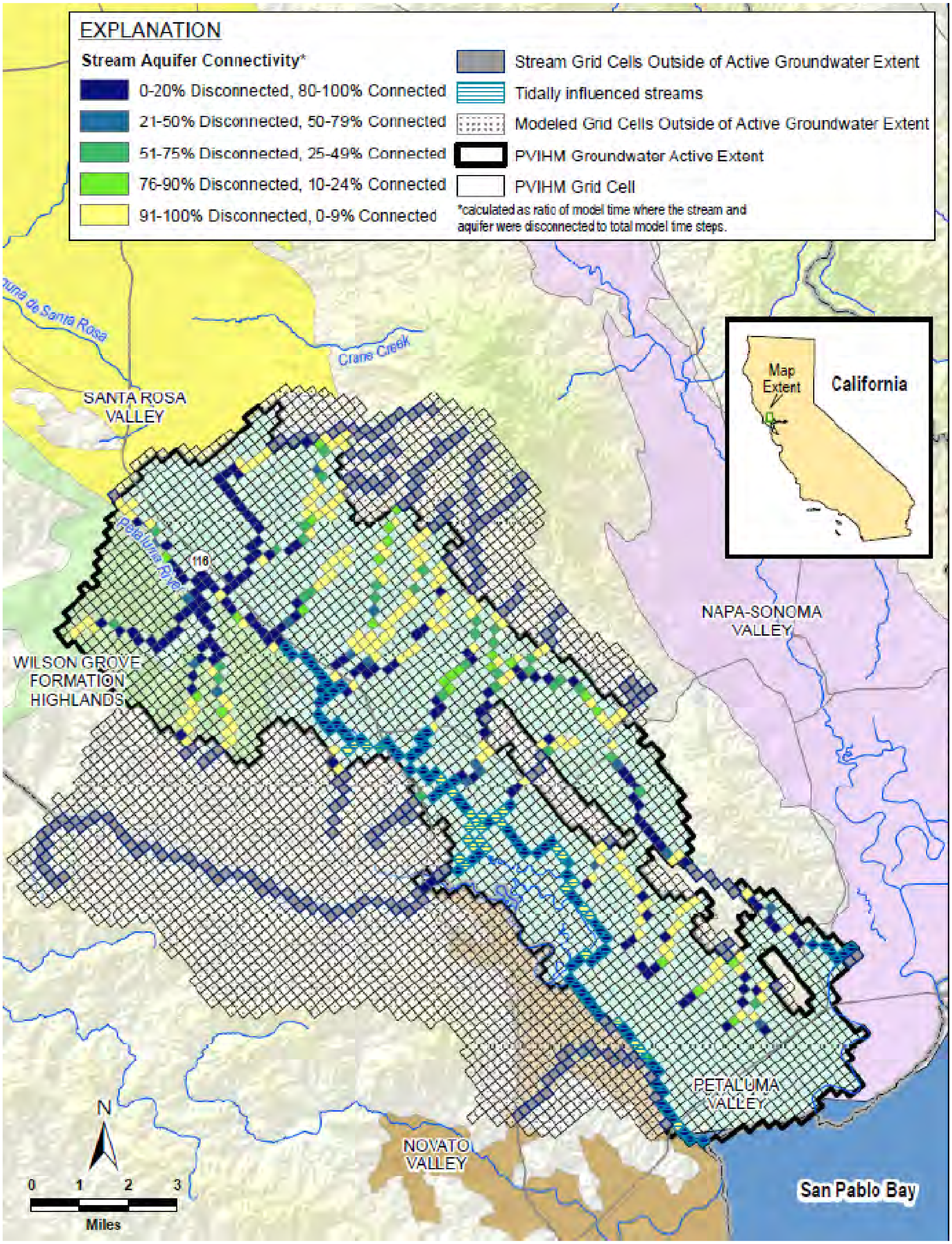


Figure 2: Petaluma Valley depletion of interconnected surface water locations identified from modeling analyses.

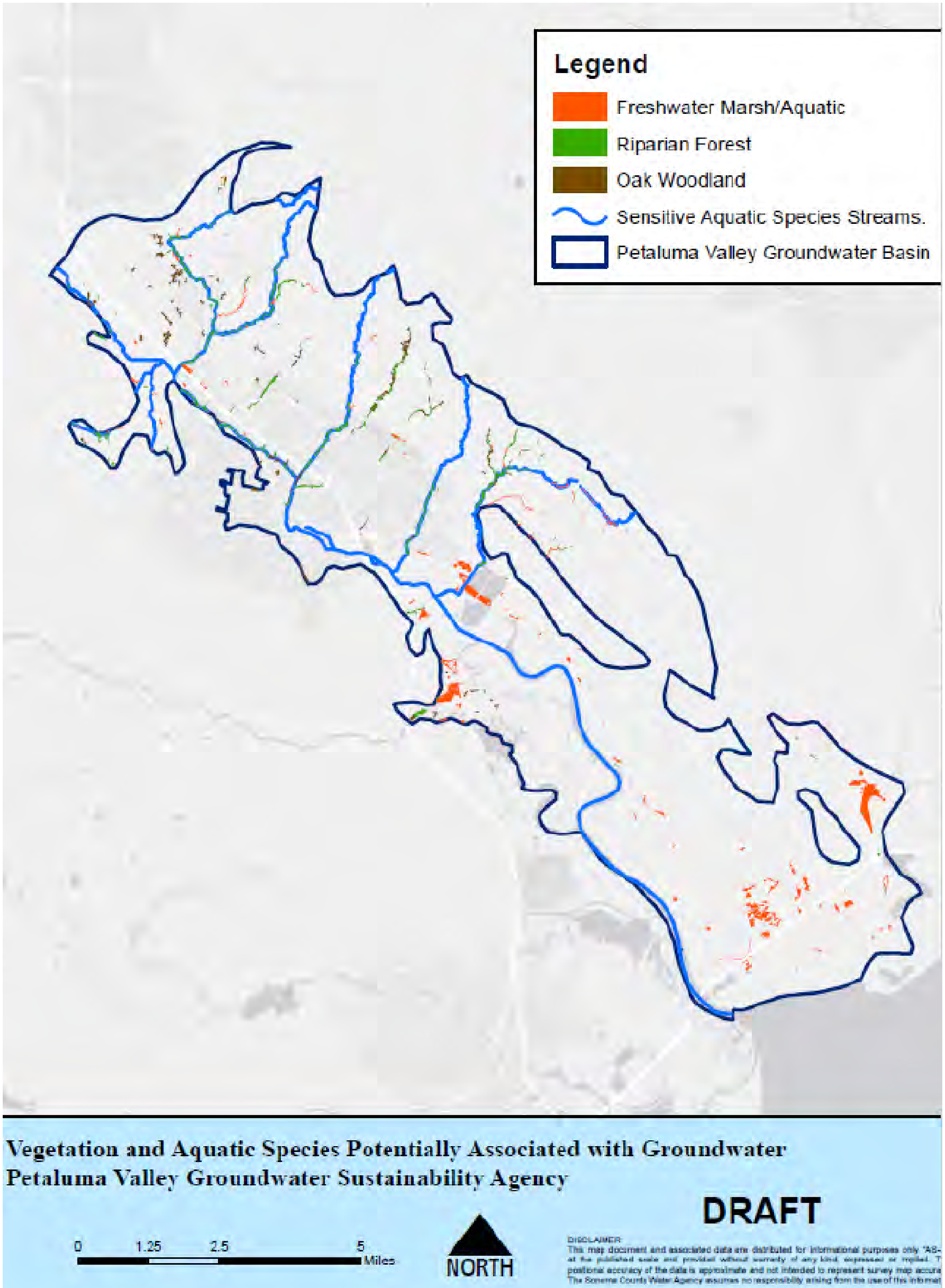


Figure 3: Locations with GDEs and Sensitive Aquatic Species Streams in the Petaluma Valley GSA area.

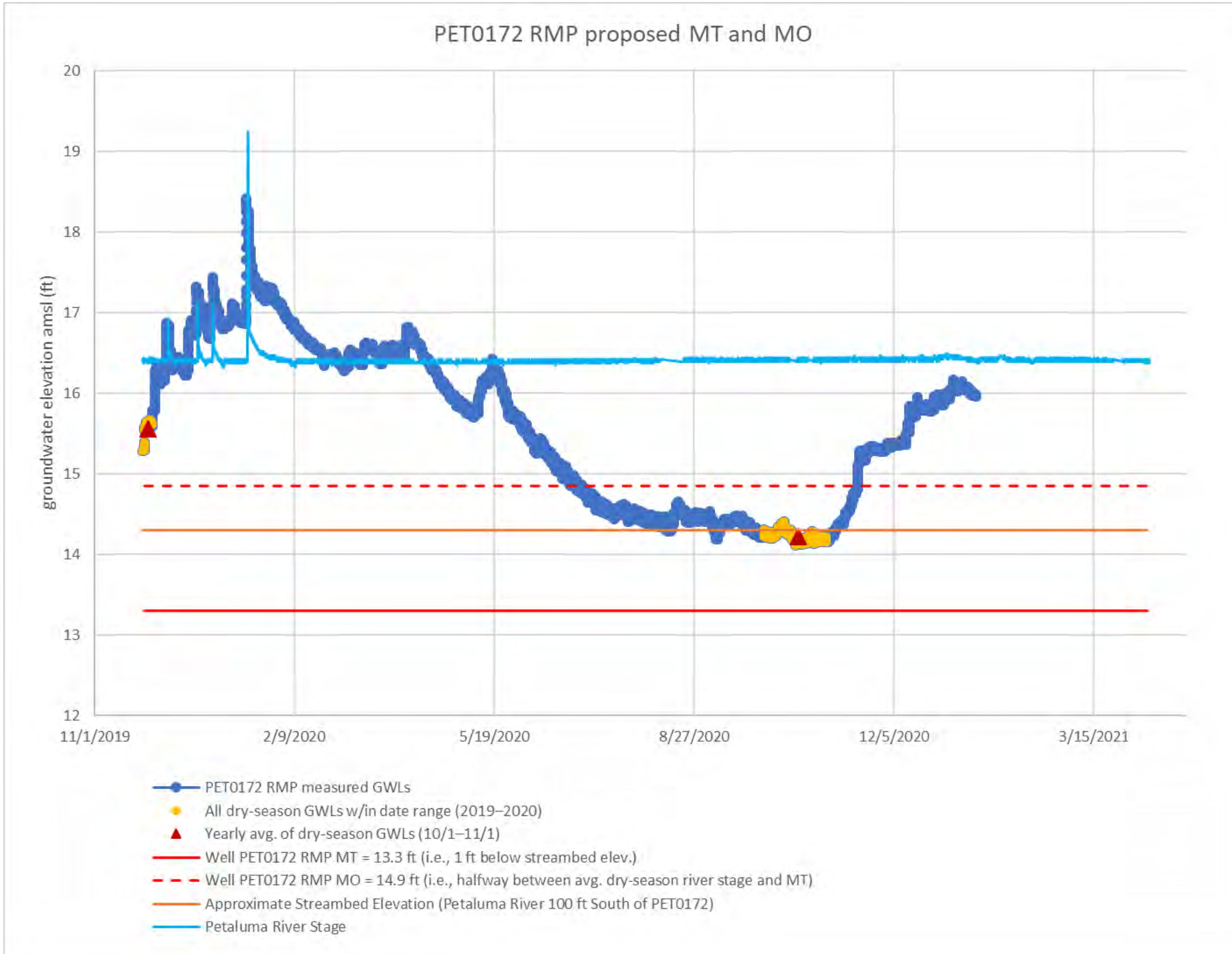


Figure 4: Measured groundwater levels at RMP PET0172, along with Minimum Threshold and Measureable Objective groundwater level pro ies for depletion of interconnected surface water by groundwater pumping.

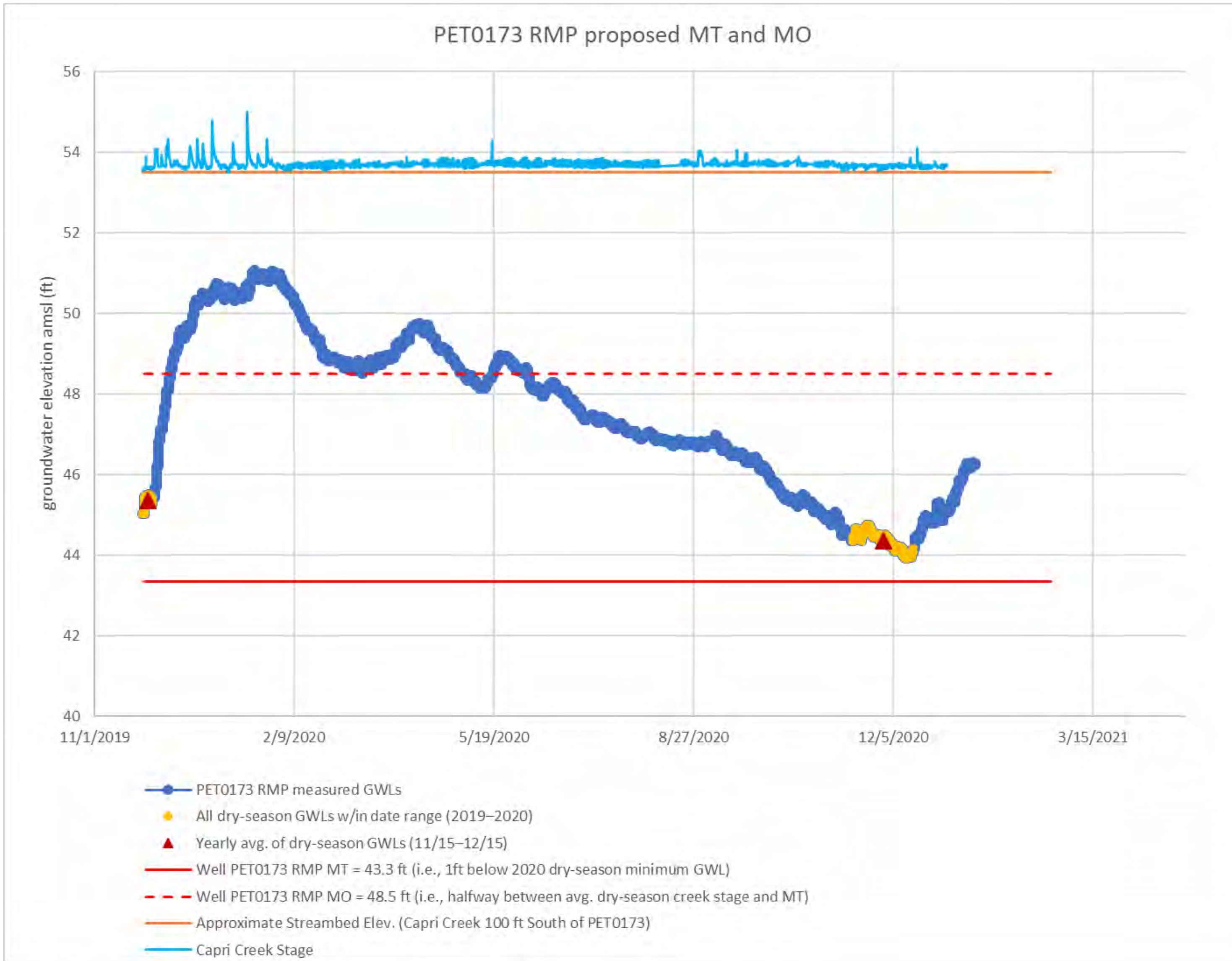


Figure 5: Measured groundwater levels at RMP PET0173, along with Minimum Threshold and Measureable Objective groundwater level pro ies for depletion of interconnected surface water by groundwater pumping.

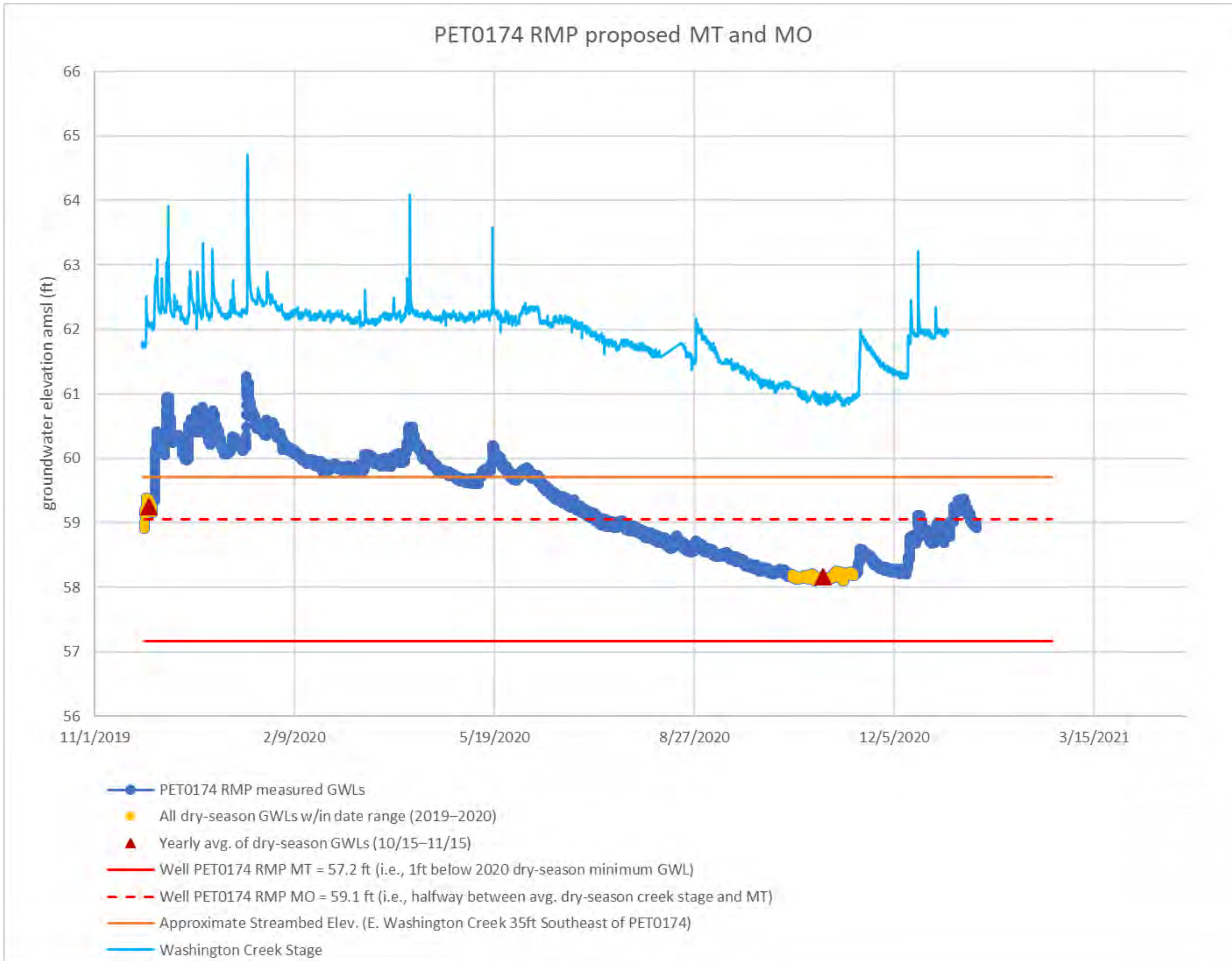


Figure 6: Measured groundwater levels at RMP PET0174, along with Minimum Threshold and Measureable Objective groundwater level pro ies for depletion of interconnected surface water by groundwater pumping.

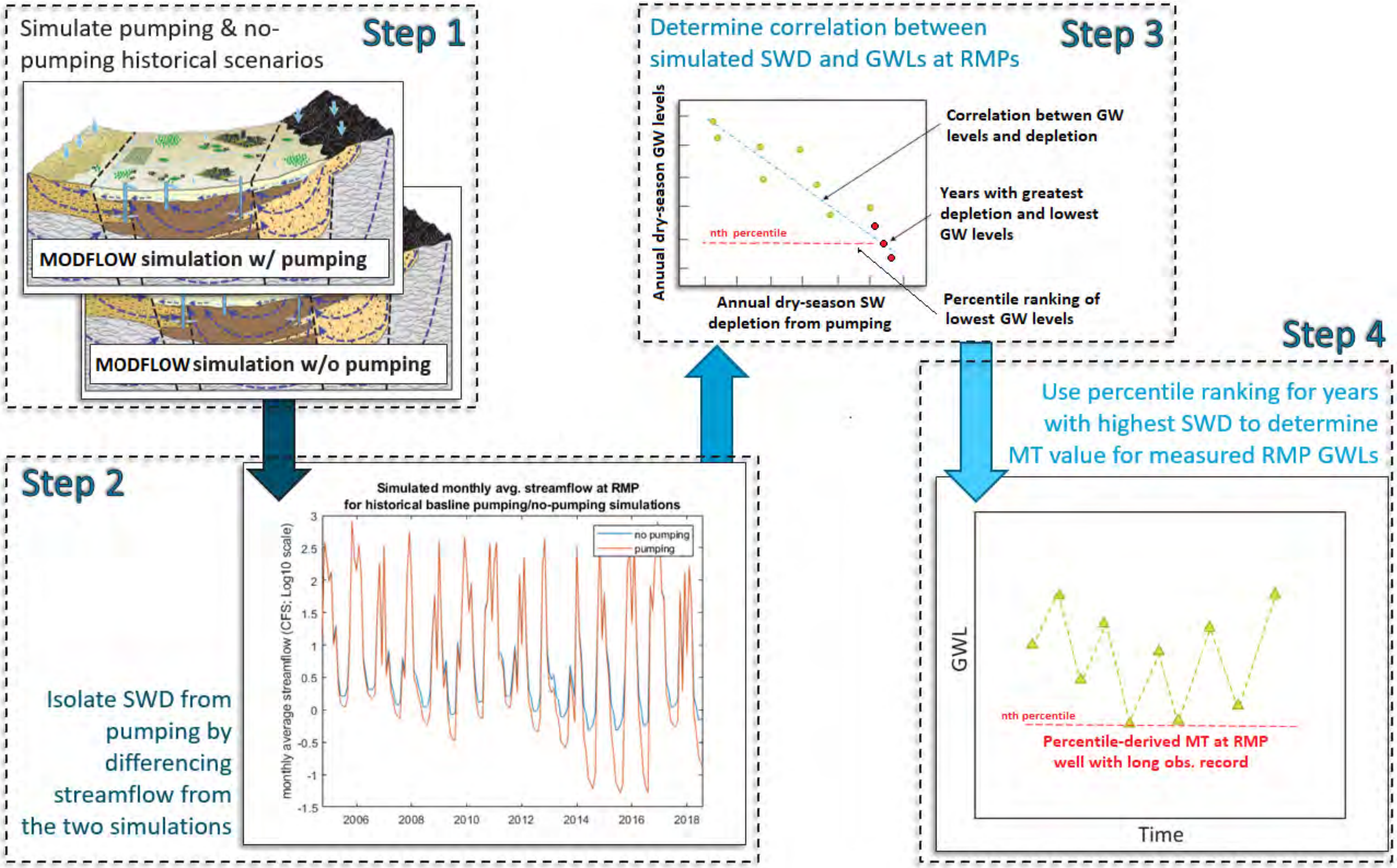


Figure 5: Future methodology conceptualization for establishing depletion of interconnected surface water SMCs.

Table 1: Summary table depletion of interconnected surface water SMCs at RMP locations.

| RMP Well | Proposed MT (ft amsl) | Proposed MT Method | Proposed MO (ft amsl) | Proposed MO Method |
|---|---|---|---|---|
| PET0172 | 14.3 | Streambed elevation | 15.4 | distance between MT and 2019  20 dry season stream stage |
| PET0173 | 43.3 | 1ft below 2020 dry-season low GWL | 48.5 | distance between MT and 2019  20 dry season stream stage |
| PET0174 | 57.2 | 1ft below 2020 dry-season low GWL | 59.1 | distance between MT and 2019  20 dry season stream stage |

notes:

RMP: Representative Monitoring Point
MT: Minimum Threshold
MO: Measurable Objective
GWL: Groundwater Level

# Appendix 5-A
# Monitoring Protocols

# Appendix 5-A

# Monitoring Protocols
# Petaluma Valley Groundwater Basin

In accordance with the GSP Regulations, monitoring protocols have been established for the Petaluma Valley Groundwater Basin monitoring networks. The following monitoring protocols, intended to ensure the quality and consistency of data, are adapted from DWR's BMPs for Monitoring Protocols, Standards and Sites (DWR 2016).

**General Well Monitoring Information**

- Long-term access agreements should be maintained for each monitoring site. Access agreements should include year-round site access to allow for increased monitoring frequency. At the time of GSP submittal, some sites included in the monitoring networks for GSP implementation may lack or have outdated access agreements. A basin-wide inventory of access agreement status and efforts to standardize access agreements will be conducted in the early phases of GSP implementation.

- Each monitoring site shall have unique identifier and documentation should include a general written description of the site location, date established, access instructions and point of contact (if necessary), type of information to be collected, latitude, longitude, and elevation. Each monitoring location should also track all modifications to the site in a modification log. This information is stored in the Data Management System (DMS).

- Groundwater elevation data from Spring and Fall semi-annual measurement events will form the basis of Basin-wide potentiometric surface maps and should approximate conditions at a discrete period in time. Therefore, all groundwater-level measurements for the semi-annual events should be collected within as short a time as possible, preferably within a 1-to-2-week period.

- Depth to groundwater must be measured relative to an established Reference Point (RP) on the well casing. The RP is usually identified with a permanent marker, paint spot, or a notch in the lip of the well casing. By convention in open casing monitoring wells, the RP reference point is located on the north side of the well casing. If no mark is apparent, the person performing the measurement should measure the depth to groundwater from the north side of the top of the well casing.

- The elevation of the RP of each well must be surveyed to the North American Vertical Datum of 1988 (NAVD88), or a local datum that can be converted to NAVD88. The elevation of the RP must be accurate to within 0.5 foot. It is preferable for the RP elevation to be accurate to 0.1 foot or less. At the time of GSP submittal, some sites included in the monitoring networks for

GSP implementation lack sufficient RP survey data. Information related to this data gap, including plans to address it, is included in Section 5 of this GSP.

- Depth to groundwater must be measured to an accuracy of 0.1 foot below the RP. It is preferable to measure depth to groundwater to an accuracy of 0.01 foot. Air lines and acoustic sounders may not provide the required accuracy of 0.1 foot. While the GSA recognizes that acoustic sounders may not produce data as accurate as that produced by electronic sounding tape or steel tape, for certain privately owned wells in voluntary monitoring programs, an acoustic sounder may be used if requested by the well owner or deemed the only feasible measurement device. For all groundwater-level measurements, the measurement device type shall be noted.

**Groundwater-Level Measurement and Field Data Recording Protocols**

- The sampler should remove the appropriate cap, lid, or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement should follow a period of time to allow the water level to equilibrate. For measuring wells that are under pressure, multiple measurements should be collected to ensure the well has reached equilibrium such that no significant changes in water level are observed. Every effort should be made to ensure that a representative stable depth to groundwater is recorded. If a well does not stabilize, the quality of the value should be appropriately qualified as a questionable measurement. In the event that a well is artesian, site-specific procedures should be developed to collect accurate information and be protective of safety conditions associated with a pressurized well.

- Measure depth to water in the well using procedures appropriate for the measuring device. A typical measuring device should be an electronic sounding tape (electronic water-level meter) capable of 0.01-foot accuracy unless conditions at a particular well require an alternate type of measuring device. Equipment must be operated and maintained in accordance with manufacturer's instructions. Groundwater levels should be measured to the nearest 0.01 foot relative to the RP.

- The sampler should calculate the groundwater elevation as:

  $GWE = RPE - DTW$

  Where:
  GWE = Groundwater Elevation
  RPE = Reference Point Elevation
  DTW = Depth to Water

  The sampler must ensure that all measurements are in consistent units of feet, tenths of feet, and hundredths of feet. Measurements and RPEs should not be recorded in feet and inches.

- The sampler should record the well identifier, date, time (24-hour format), RPE, height of RP above or below ground surface, DTW, GWE, and comments regarding any factors that may influence the depth to water readings such as weather, nearby irrigation, flooding, potential for tidal influence, or well condition. If there is a questionable measurement or the measurement cannot be obtained, it should be noted. Standardized field forms should be used for all data collection.

- The sampler should replace any well caps or plugs and lock any well buildings or covers.

- The water-level meter and/or any other downhole equipment should be decontaminated after measuring each well.

- All data should be entered into the DMS as soon as possible. Care should be taken to avoid data entry mistakes and the entries should be checked by a second person for quality assurance.

**Pressure Transducer Protocols**

Pressure transducers with dataloggers are used in many dedicated monitoring wells and inactive supply wells in the Petaluma Valley Groundwater Basin monitoring networks to record groundwater-level, temperature, and conductivity data. The following monitoring protocols apply to the use of pressure transducers:

- When installing pressure transducers, care must be exercised to ensure that the data recorded by the transducers is confirmed with hand measurements.

- The sampler must use an electronic water-level meter and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the pressure transducer installation. It is recommended that transducers record pressure or measured groundwater level to conserve data capacity; groundwater elevations can be calculated at a later time after downloading.

- The sampler must note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.

- Transducers must be able to record groundwater levels with an accuracy of at least 0.1 foot. Professional judgment should be exercised to ensure that the data being collected is meeting the monitoring objectives and that the instrument is capable. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers should be included in the evaluation.

- The sampler must note whether each pressure transducer uses a vented or non-vented cable for barometric compensation. If non-vented units are utilized, they must be properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressure to coincide with measurement intervals.

- Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that monitoring objectives are being met for the GSP.

- Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or a permanent marker to allow for estimates of future cable slippage.

- Manual groundwater-level measurements should be collected in accordance with the procedures outlined above at least semi-annually to confirm the accuracy of transducer data and monitor for electronic drift or cable movement.

- The data should be downloaded as necessary (at least semi-annually) to ensure no data is lost and entered into the Data Management System following established protocols as soon as possible. Data collected with non-vented data logger cables should be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been safely downloaded and stored, the data should be deleted from the data logger to ensure that adequate data logger memory remains.

**Protocols for Installation of New Monitoring Wells**

It is anticipated that several new dedicated monitoring wells will be installed to fill data gaps during GSP implementation. The design, installation, and documentation of new monitoring wells must consider the following:

- Construction consistent with California Well Standards as described in Bulletins 74-81 and 74-90, and local permitting agency standards of practice.

- Logging of borehole cuttings under the supervision of a California Professional Geologist and described consistent with the Unified Soil Classification System methods according to ASTM standard D2487-11.

- Written criteria for logging of borehole cuttings for comparison to known geologic formations, principal aquifers and aquitards/aquicludes, or specific marker beds to aid in consistent stratigraphic correlation within and across basins, to the extent feasible.

- Geophysical surveys of boreholes to aid in consistency of logging practices, when funding allows. Methodologies should include resistivity, spontaneous potential, spectral gamma, or other methods as appropriate for the conditions. Selection of geophysical methods should be based upon the opinion of a professional geologist or professional engineer and address the objectives for the specific borehole and characterization needs.

- Ensure that the drilling contractor submits State well completion reports according to the requirements of §13752. Well completion report documentation should include geophysical logs, detailed geologic log, and formation identification as attachments, if available.

**Groundwater Quality Monitoring Protocols**

In general, the GSP relies on water quality data generated through existing programs. In some cases, it may be necessary to collect additional water quality data to support monitoring programs or evaluate specific projects. The USGS National Field Manual for the Collection of Water Quality Data (USGS, 2018) should be used to guide the collection of reliable data.

While specific groundwater sampling protocols vary depending on the constituent being sampled for, the protocols listed below provide guidance which is applied to all groundwater quality sampling.

- Prior to sampling, the sampler must contact the laboratory to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements.

- Each well used for groundwater quality monitoring must have a unique identifier. This identifier should appear on the well housing or the well casing to avoid confusion.

- In the case of wells with dedicated pumps, samples should be collected at or near the wellhead. Samples should not be collected from storage tanks, at the end of long pipe runs, or after any water treatment.

- The sampler should clean the sampling port and/or sampling equipment and the sampling port and/or sampling equipment must be free of any contaminants. The sampler must decontaminate sampling equipment between sampling locations or wells to avoid cross-contamination between samples.

- The groundwater elevation in the well should be measured following the protocols described above.

- For any well not equipped with low-flow or passive sampling equipment, an adequate volume of water should be purged from the well to ensure that the groundwater sample is representative of ambient groundwater and not stagnant water in the well casing. Purging three well casing volumes is generally considered adequate. Professional judgment should be used to determine the proper configuration of the sampling equipment with respect to well construction such that a representative ambient groundwater sample is collected. If pumping causes a well to be evacuated (go dry), document the condition and allow well to recover to within 90% of original level prior to sampling.

- Field parameters of pH, electrical conductivity, and temperature should be collected for each sample. Field parameters should be evaluated during the purging of the well and should stabilize prior to sampling. Other parameters, such as oxidation-reduction potential (ORP), dissolved oxygen (DO - in situ measurements preferable), or turbidity, may also be useful for meeting monitoring objectives and assessing purge conditions. All field instruments should be calibrated daily and evaluated for drift throughout the day.

- Sample containers should be labeled prior to sample collection. The sample label must include: sample ID (often well ID), sample date and time, sample personnel, sample location, preservative used, and analytes and analytical method.

- Samples should be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection.

- All samples requiring preservation must be preserved as soon as practically possible, ideally at the time of sample collection. Ensure that samples are appropriately filtered as recommended for the specific analyte. Entrained solids can be dissolved by preservative leading to inconsistent results of dissolve analytes. Specifically, samples to be analyzed for metals should be field-filtered prior to preservation; do not collect an unfiltered sample in a preserved container.

- Samples should be chilled and maintained at 4 °C to prevent degradation of the sample. The laboratory's Quality Assurance Management Plan should detail appropriate chilling and shipping requirements.

- Samples must be transported under chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.

- Instruct the laboratory to use reporting limits that are equal to or less than applicable Sustainable Management Criteria values or regional water quality objectives/screening levels.

**Seawater Intrusion Monitoring Protocols**

Monitoring seawater intrusion requires analysis of chloride concentrations within groundwater of each principal aquifer subject to seawater intrusion. While no significant standardized approach exists, the methodologies described above for groundwater quality monitoring also apply to seawater intrusion monitoring. In addition to the protocols described above, the following protocols should be followed for seawater intrusion monitoring:

- Water quality samples should be collected and analyzed at least semi-annually. Samples will be analyzed for dissolved chloride at a minimum. It may be beneficial to include analyses of iodide and bromide to aid in determination of salinity source. The development of surrogate measures of chloride concentration may facilitate cost-effective means to monitor more frequently to observe the range of conditions and variability of the flow dynamics controlling seawater intrusion.

- Groundwater levels will be collected at a frequency adequate to characterize changes in head in the vicinity of the leading edge of degraded water quality in each principal aquifer. Frequency may need to be increased in areas of known preferential pathways, groundwater pumping, or efficacy evaluation of mitigation projects.

- The use of geophysical surveys, electrical resistivity, or other methods may provide for identification of preferential pathways and optimize monitoring well placement and evaluation of the seawater intrusion front. Professional judgment should be exercised to determine the appropriate methodology and whether monitoring objectives would be met.

**Protocols for Measuring Streamflow**

Monitoring of streamflow is necessary for incorporation into water budget analysis and for use in evaluation of stream depletions associated with groundwater extractions. The use of existing streamflow monitoring locations is incorporated into the Basin's monitoring networks to the greatest extent possible.

Establishment of new streamflow discharge sites should consider the existing network and the objectives of the new location. Professional judgment should be used to determine the appropriate permitting that may be necessary for the installation of any monitoring locations along surface water bodies. Regular frequent access will be necessary to these sites for the development of ratings curves and maintenance of equipment.

To establish a new streamflow monitoring station special consideration must be made in the field to select an appropriate location for measuring discharge. Once a site is selected, development of a relationship of stream stage to discharge will be necessary to provide continuous estimates of streamflow. Several measurements of discharge at a variety of stream stages will be necessary to develop the ratings curve correlating stage to discharge. The use of Acoustic Doppler Current Profilers (ADCPs) can provide accurate estimates of discharge in the correct settings. Professional judgment must be exercised to determine the appropriate methodology. Following development of the ratings curve a simple stilling well and pressure transducer with data logger can be used to evaluate stage on a frequent basis.

Streamflow measurements should be collected, analyzed, and reported in accordance with the procedures outlined in USGS Water Supply Paper 2175, Volume 1. – Measurement of Stage Discharge and Volume 2. – Computation of Discharge (Rantz and others, 1982). This methodology is currently used by both the USGS and DWR for existing streamflow monitoring throughout the State.

**Protocols for Monitoring Land Subsidence**

Evaluating and monitoring inelastic land subsidence can utilize multiple data sources to evaluate the specific conditions and associated causes. At the time of GSP submittal, the GSA generally relies on existing Interferometric Synthetic Aperture Radar (InSAR) data and data from continuous GPS (CGPS) stations. Subsidence can also be estimated from numerous other techniques including: level surveying tied to known stable benchmarks or benchmarks located outside the area being studied for possible subsidence; installing and tracking changes in borehole extensometers; or obtaining data from static GPS surveys or Real-Time-Kinematic (RTK) surveys. No standard procedures exist for collecting data from the potential subsidence monitoring approaches. However, an approach may include:

*Identification of Land Subsidence Conditions*

- Evaluation of existing regional long-term leveling surveys of regional infrastructure, i.e., roadways, railroads, canals, and levees.

- Inspection of existing County and State well records where collapse has been noted for well repairs or replacement.
- Determining if significant fine-grained layers are present such that the potential for collapse of the units could occur should there be significant depressurization of the aquifer system.
- Inspection of geologic logs and the hydrogeologic conceptual model to aid in identification of specific units of concern.
- Analysis of regional remote-sensing information such as InSAR.
- Review of seismic related data and records that might explain land subsidence observations.
- Review of groundwater elevation measurements and trends in Representative Monitoring Points (established as part of groundwater-level Sustainable Management Criteria) and other nearby wells being monitored, including an assessment as to whether groundwater levels are below historical lows or exceeding Minimum Thresholds.
- Evaluation of known or estimated groundwater pumping patterns within the vicinity of any observed potential land subsidence.

*Monitor regions of suspected subsidence where potential exists*

- Establish CGPS network to evaluate changes in land surface elevation.
- Establish leveling surveys transects to observe changes in land surface elevation.
- Establish extensometer network to observe land subsidence. Extensometer design should be based on local conditions, professional judgement, and monitoring objectives.

Standards and guidance documents for collecting data for land subsidence monitoring include:

- GPS and Leveling surveys must follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual (California Department of Transportation, various dates).
- Instruments installed in borehole extensometers must follow the manufacturer's instructions for installation, care, and calibration.

**References**

California Department of Transportation, various dates. *Caltrans Surveys Manual*.

California Department of Water Resources (DWR). 2016. *Best Management Practices for the Sustainable Management of Groundwater, Monitoring Protocols, Standards, and Sites*. December

Rantz, S.E., and others, 1982. *Measurement and computation of streamflow*; U.S. Geological Survey, Water Supply Paper 2175.

U.S. Geological Survey, 2018, *Preparations for water sampling*: U.S. Geological Survey Techniques and Methods, book 9, chap. A1.

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# Appendix 5-B
# Comparative Hydrographs – Chronic Lowering of Groundwater Levels Representative Monitoring Points

# Appendix 5-B

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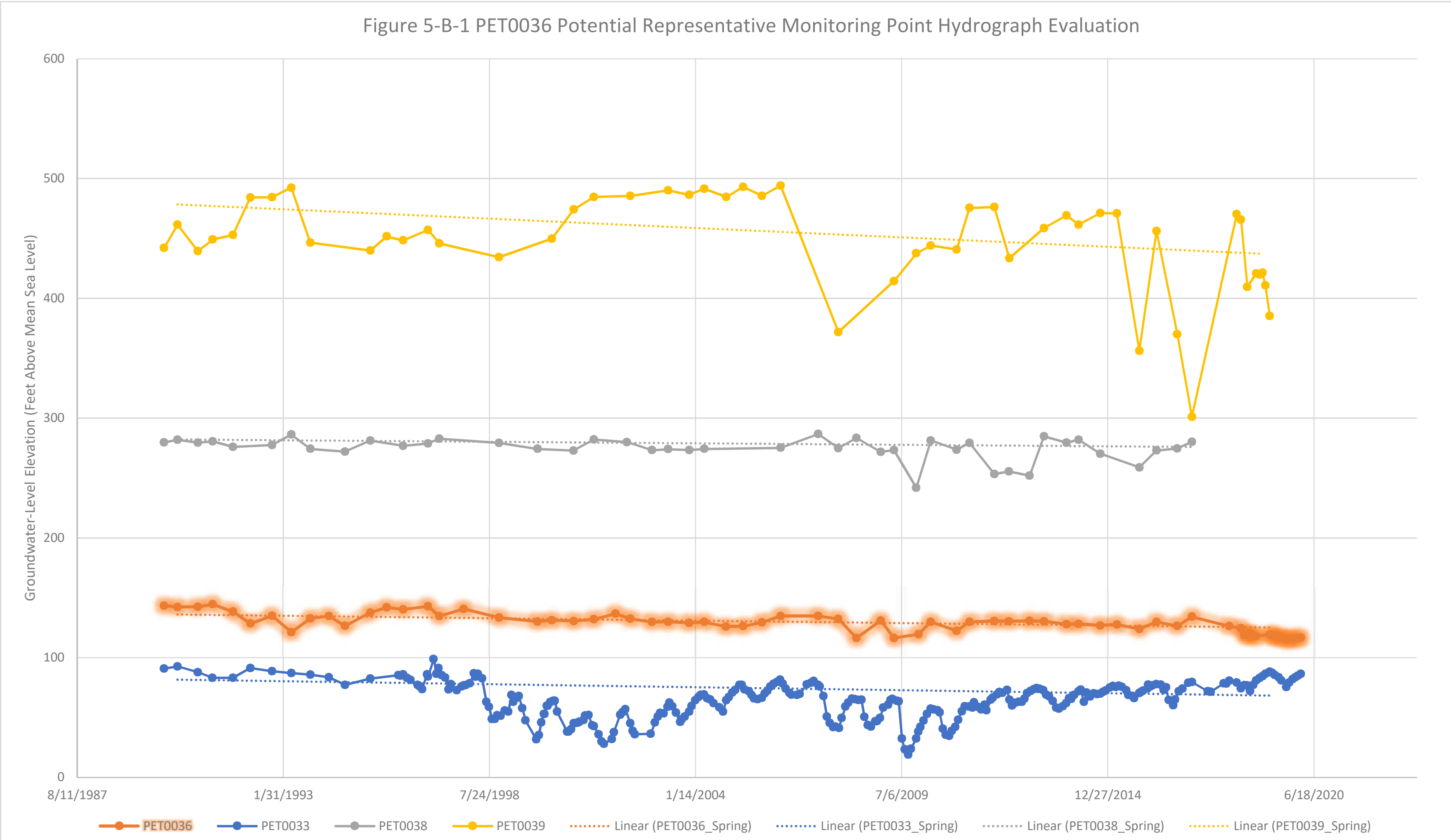


Figure 5-B-1 PET0036 Potential Representative Monitoring Point Hydrograph Evaluation
Groundwater-Level Elevation (Feet Above Mean Sea Level)
600
500
400
300
200
100
0
8/11/1987
1/31/1993
7/24/1998
1/14/2004
7/6/2009
12/27/2014
6/18/2020
PET0036
PET0033
PET0038
PET0039
Linear (PET0036_Spring)
Linear (PET0033_Spring)
Linear (PET0038_Spring)
Linear (PET0039_Spring)

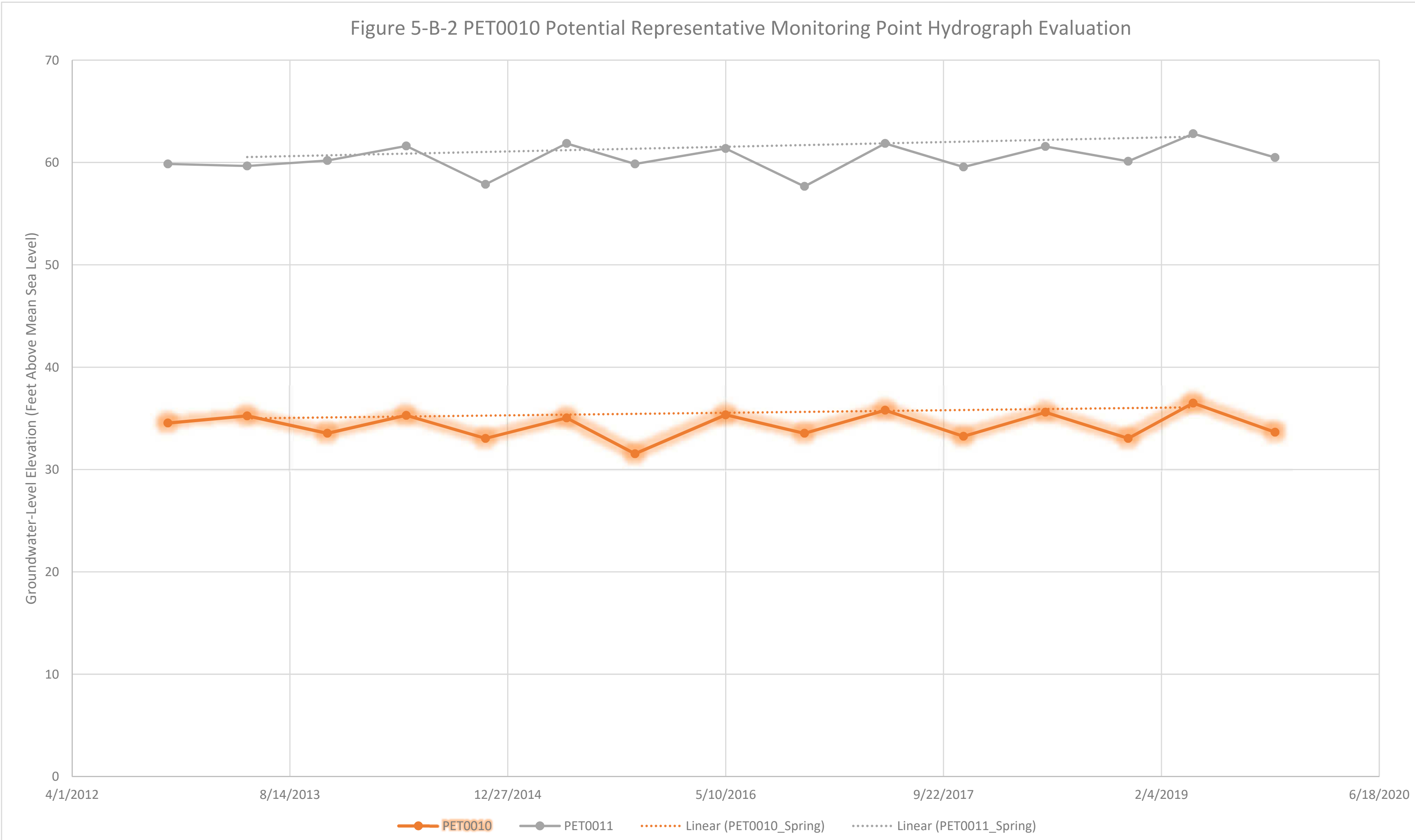


Figure 5-B-2 PET0010 Potential Representative Monitoring Point Hydrograph Evaluation
Groundwater-Level Elevation (Feet Above Mean Sea Level)
70
60
50
40
30
20
10
0
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019
6/18/2020
PET0010
PET0011
Linear (PET0010_Spring)
Linear (PET0011_Spring)

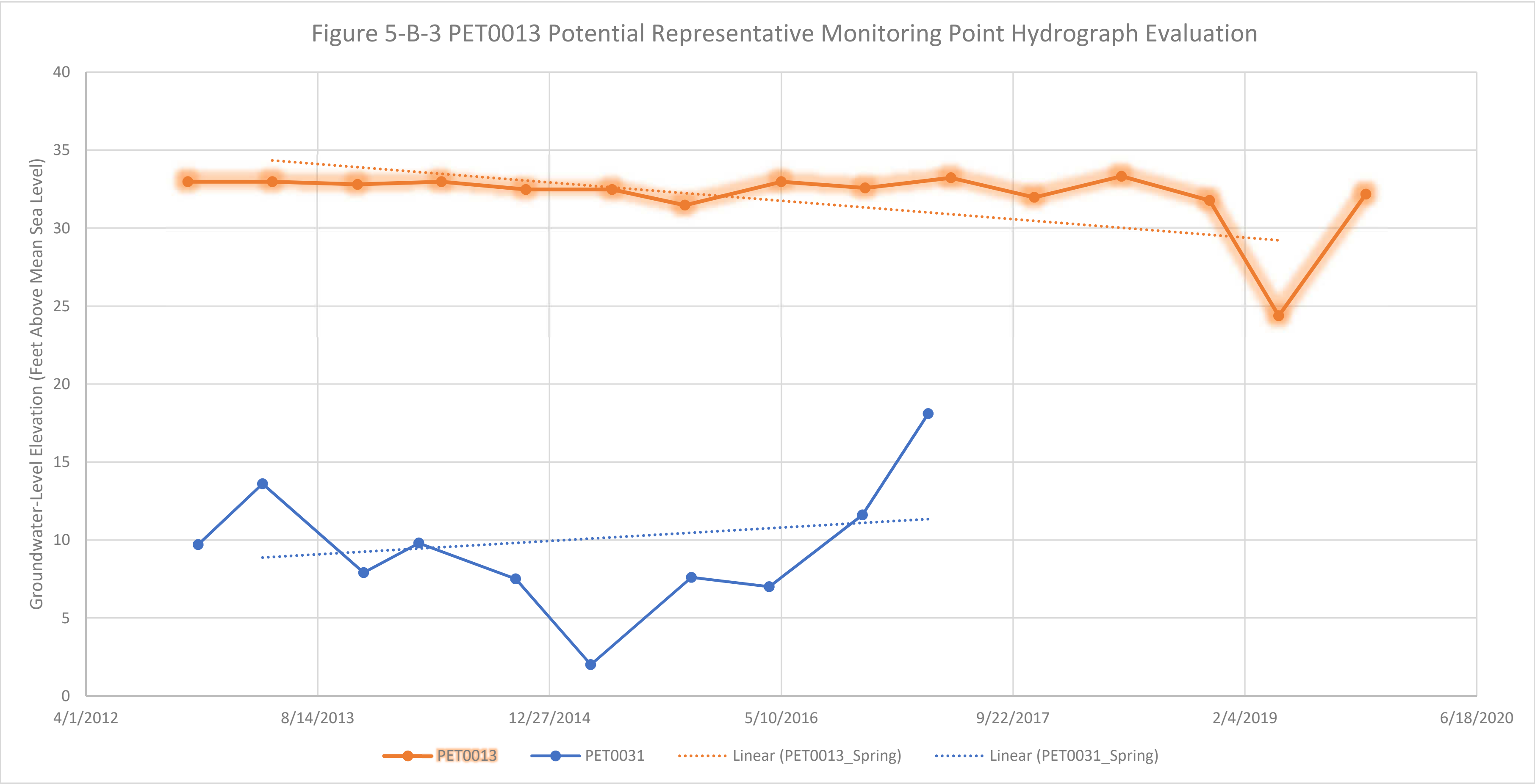


Figure 5-B-3 PET0013 Potential Representative Monitoring Point Hydrograph Evaluation
Groundwater-Level Elevation (Feet Above Mean Sea Level)
40
35
30
25
20
15
10
5
0
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019
6/18/2020
PET0013
PET0031
Linear (PET0013_Spring)
Linear (PET0031_Spring)

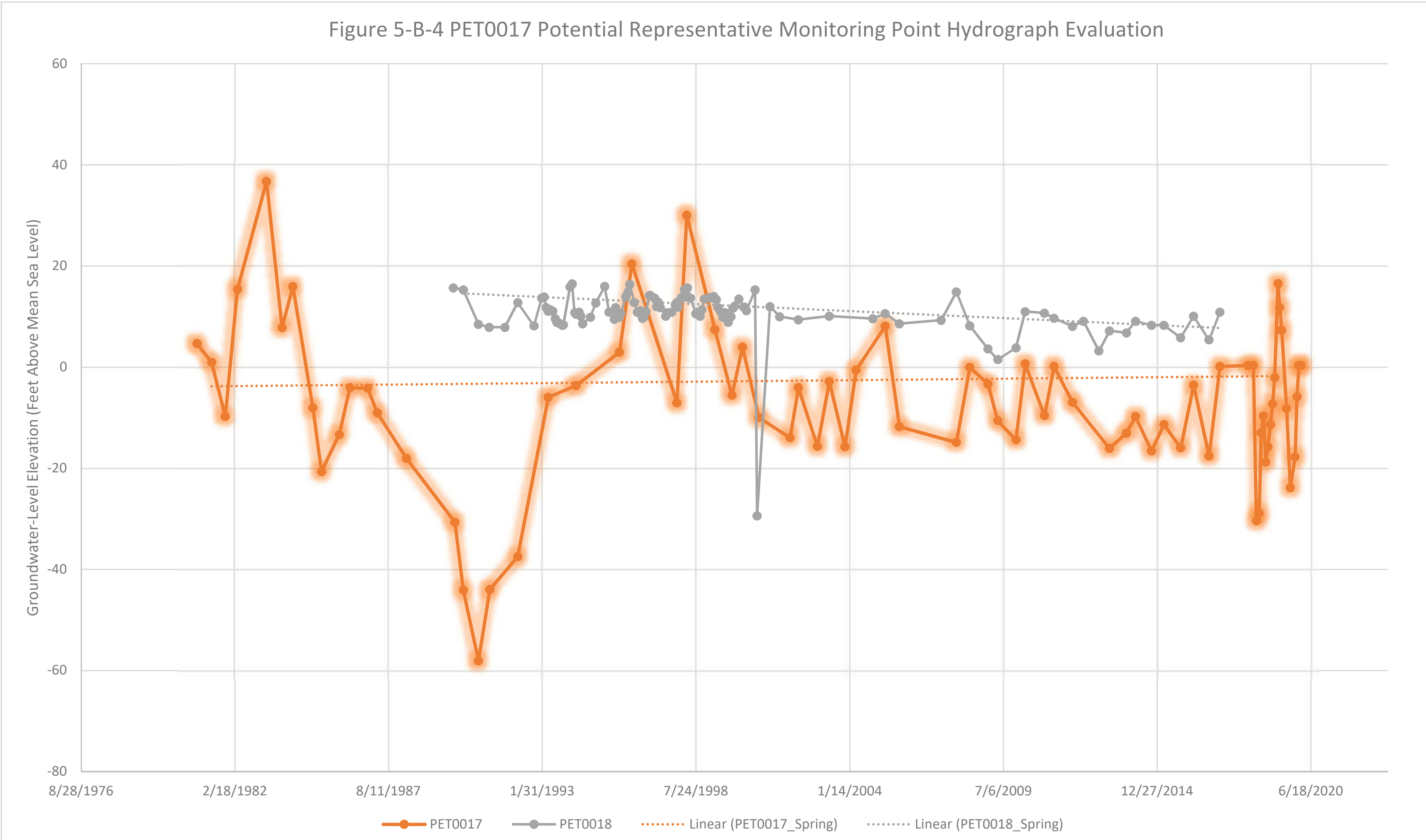


Figure 5-B-4 PET0017 Potential Representative Monitoring Point Hydrograph Evaluation
Groundwater-Level Elevation (Feet Above Mean Sea Level)
60
40
20
0
-20
-40
-60
-80
8/28/1976
2/18/1982
8/11/1987
1/31/1993
7/24/1998
1/14/2004
7/6/2009
12/27/2014
6/18/2020
PET0017
PET0018
Linear (PET0017_Spring)
Linear (PET0018_Spring)

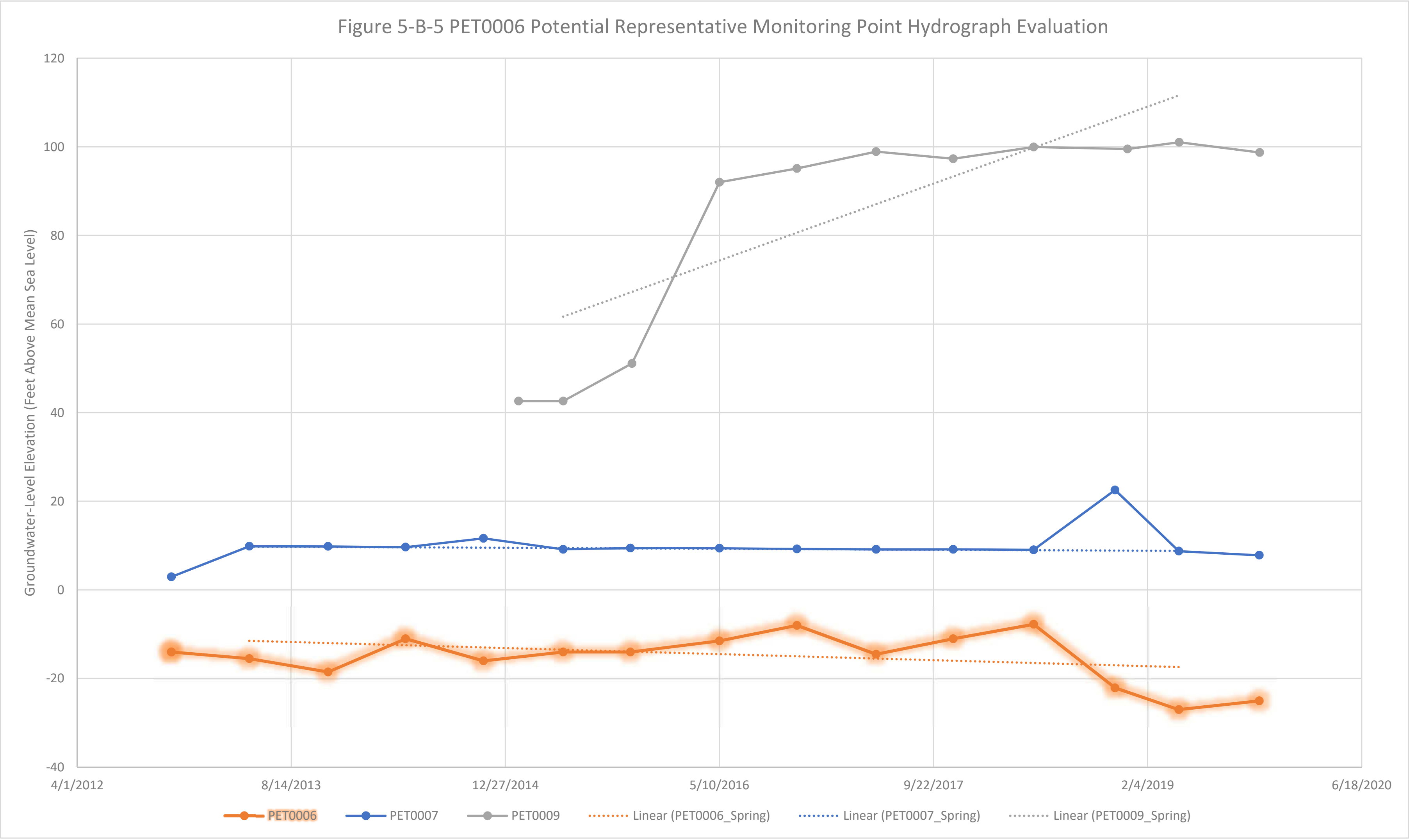
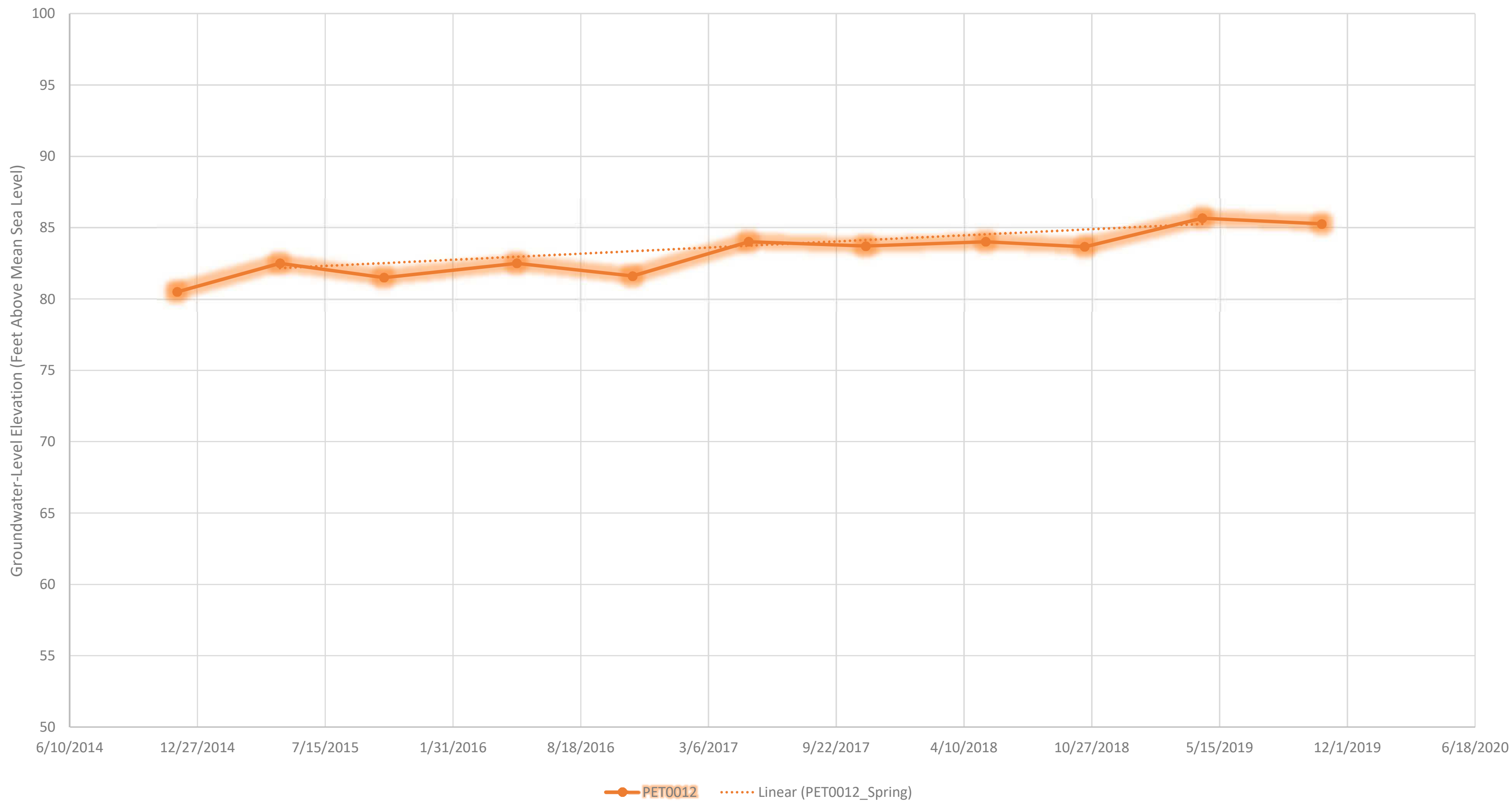


Figure 5-B-5 PET0006 Potential Representative Monitoring Point Hydrograph Evaluation
Groundwater-Level Elevation (Feet Above Mean Sea Level)
120
100
80
60
40
20
0
-20
-40
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019
6/18/2020
PET0006
PET0007
PET0009
Linear (PET0006_Spring)
Linear (PET0007_Spring)
Linear (PET0009_Spring)

Figure 5-B-6 PET0012 Potential Representative Monitoring Point Hydrograph Evaluation



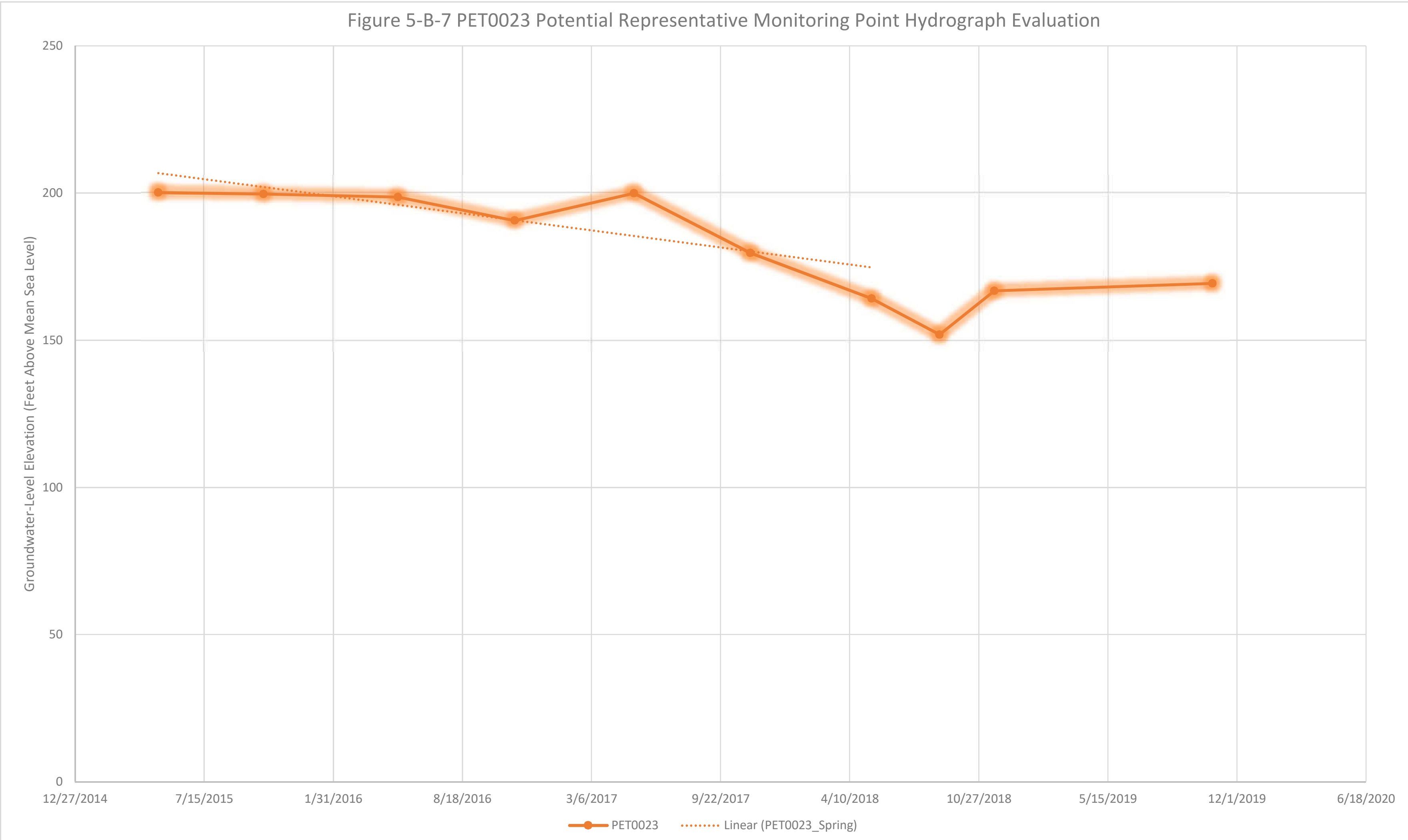


Figure 5-B-7 PET0023 Potential Representative Monitoring Point Hydrograph Evaluation
Groundwater-Level Elevation (Feet Above Mean Sea Level)
250
200
150
100
50
0
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
9/22/2017
4/10/2018
10/27/2018
5/15/2019
12/1/2019
6/18/2020
PET0023
Linear (PET0023_Spring)

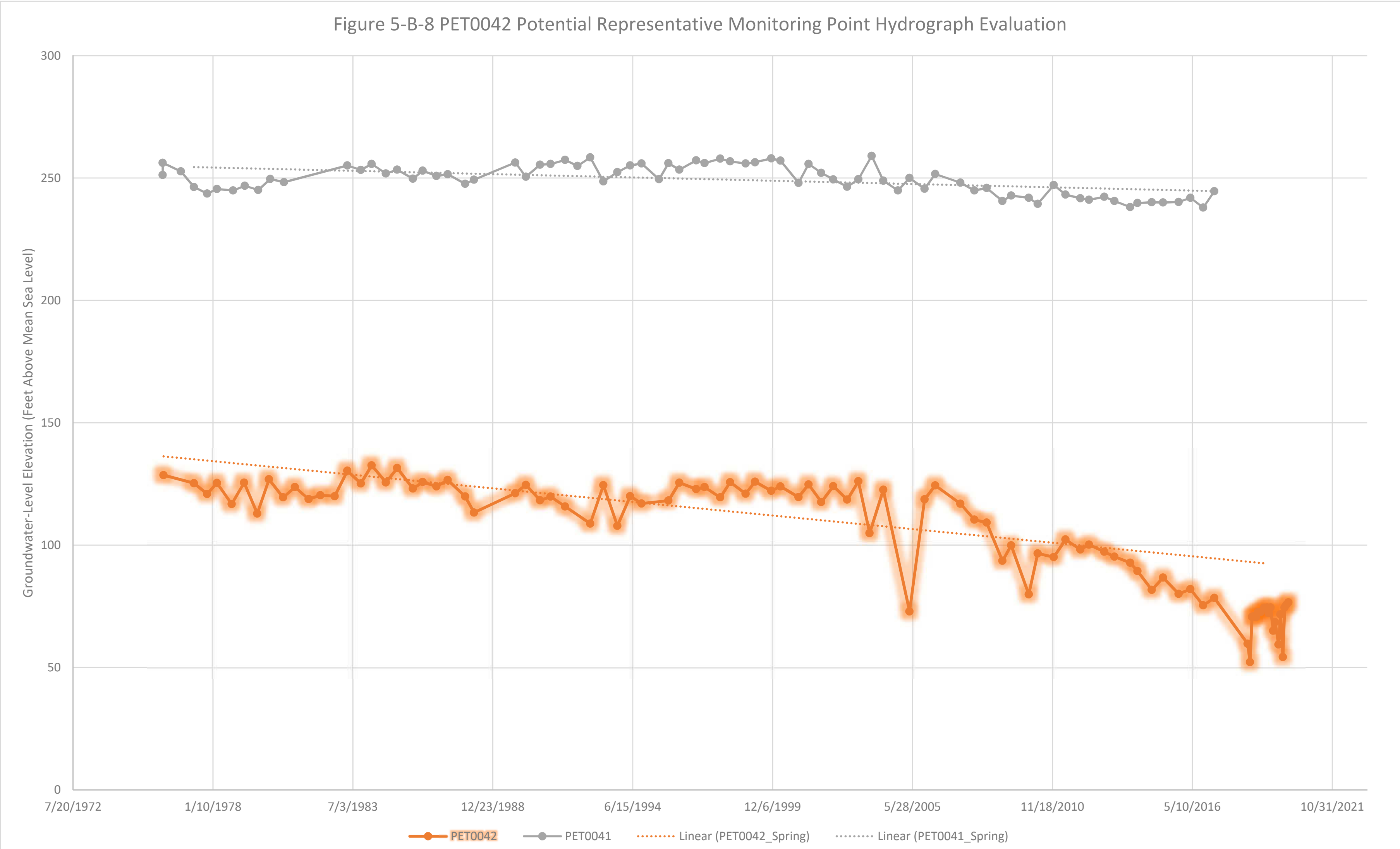
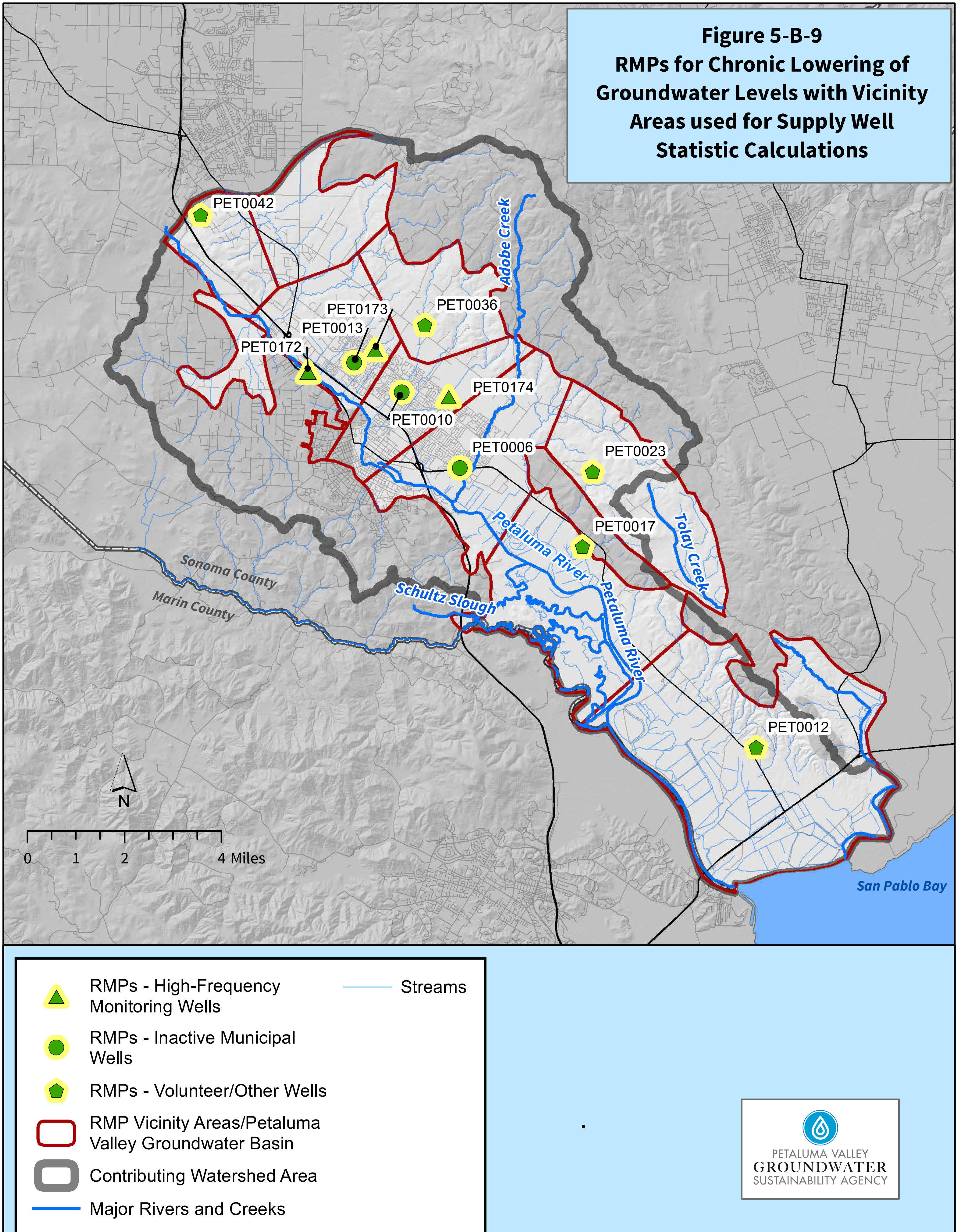


Figure 5-B-8 PET0042 Potential Representative Monitoring Point Hydrograph Evaluation
Groundwater-Level Elevation (Feet Above Mean Sea Level)
300
250
200
150
100
50
0
7/20/1972
1/10/1978
7/3/1983
12/23/1988
6/15/1994
12/6/1999
5/28/2005
11/18/2010
5/10/2016
10/31/2021
PET0042
PET0041
Linear (PET0042_Spring)
Linear (PET0041_Spring)

## Figure 5-B-9
## RMPs for Chronic Lowering of Groundwater Levels with Vicinity Areas used for Supply Well Statistic Calculations




Filepath: T:\mbuttress\SGMA Monitoring Networks\Petaluma Valley\PET_GWL_RMPs.mxd Date prepared: 11/5/2021

**Table 5-B-1**

**Representative Monitoring Points for Chronic Lowering of Groundwater Levels with Supply Well Statistics**

**Petaluma Valley Groundwater Basin**

| Data Management System ID | | | | | | Data Record | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station Name | Station Number | Type of Well | Well Depth (ft BTOC) | Screened Interval(s) (ft BTOC) | Current Monitoring Frequency | From | Until | Addditional Information | TOC Elevation* (ft MSL) | BOC Elevation* (ft MSL) | Well Owner | Well Screened in Single Aquifer? | Total Supply Wells in Vicinity Area[1] | Shallowest Supply Well in Vicinity Area (ft BGS) | 98th Percentile Shallowest Supply Well in Vicinity Area (ft BGS)[2] | 98th Percentile Shallowest Well Elev. at RMP (ft MSL) | 95th Percentile Shallowest Supply Well in Vicinity Area (ft BGS)[2] | 95th Percentile Shallowest Well Elev. at RMP (ft MSL) | 90th Percentile Shallowest Supply Well in Vicinity Area (ft BGS)[2] | 90th Percentile Shallowest Well at RMP (ft MSL) | Average Depth of Supply Wells in Vicinity Area (ft BGS)[2] |
| PET0012 | 381531N1224876W001 | Observation | 276 | 75-275 | Semi-Annually | 11/25/2014 | 10/15/2020 | Sears Point | 132.5 | -143.5 | Private | Yes | 85 | 27 | 120 | 12.50 | 130 | 2.50 | 157 | -24.50 | 369 |
| PET0017 | 382117N1225556W001 | Supply | 180 | 140-180 | Monthly | 10/13/1980 | 12/9/2020 | | 51.93 | -128.1 | Private | Yes | 43 | 39 | 60 | -8.07 | 93 | -41.07 | 130 | -78.07 | 267 |
| PET0023 | 382342N1225525W001 | Supply | 370 | 30-370 | Semi-Annually | 5/5/2015 | 10/15/2020 | Cardinaux | 237.17 | -132.8 | Private | Yes | 25 | 155 | 200 | 37.17 | 230 | 7.17 | 248 | -10.83 | 483 |
| PET0006 | 381402N1223610W001 | Municipal | 229 | 89-229 | Semi-Annually | 11/7/2012 | 10/15/2020 | Casa de Arroyo | 19.97 | -209.0 | City of Petaluma | Yes | 67 | 34 | 53 | -33.03 | 59 | -39.03 | 80 | -60.03 | 309 |
| PET0174 | PET-F06-01_Garfield | Observation | 35.5 | 15-35 | Hourly | 11/26/2019 | Present | East Washington Creek at Garfield Dr. | 65.95 | 30.45 | PVGSA | Yes | 91 | 34 | 58 | 7.95 | 60 | 5.95 | 75 | -9.05 | 228 |
| PET0010 | 381522N1223733W001 | Municipal | 425 | 305-382 | Semi-Annually | 11/7/2012 | 10/15/2020 | Tahola | 49.04 | -376.0 | City of Petaluma | Yes | | | | -8.96 | | -10.96 | | -25.96 | |
| PET0036 | 382766N1226179W001 | Supply | 177 | 158-177 | Monthly | 12/1/1989 | 12/9/2020 | 05N07W15K002M | 158.24 | -18.8 | Private | Yes | 64 | 30 | 100 | 58.24 | 106 | 52.24 | 158 | 0.24 | 350 |
| PET0172 | PET-D06-01_Corona | Observation | 40.5 | 20-40 | Hourly | 11/25/2019 | Present | Petaluma River at Old Cornona Rd | 27.99 | -12.51 | PVGSA | Yes | 227 | 35 | 54 | -26.01 | 80 | -52.01 | 100 | -72.01 | 235 |
| PET0173 | PET-E05-01_Casella | Observation | 45.5 | 35-45 | Hourly | 11/25/2019 | Present | Capri Creek at Casella Way | 60.97 | 15.47 | PVGSA | Yes | | | | 6.97 | | -19.03 | | -39.03 | |
| PET0013 | 381553N1223839W001 | Municipal | 562 | 52-538 | Semi-Annually | 11/7/2012 | 10/15/2020 | Station 1401 | 42.47 | -519.5 | City of Petaluma | Yes | | | | -11.53 | | -37.53 | | -57.53 | |
| PET0042 | 383076N1227041W001 | Supply | 155 | 30-150 | Monthly | 2/3/1976 | 12/9/2020 | 05N08W02H001M | 160 | 5.0 | Private | Yes | 237 | 65 | 92 | 68.00 | 108 | 52.00 | 155 | 5.00 | 257 |

**Notes**

ft BTOC - Feet Below Top of Casing
TOC Elevation - Top-of-Casing Elevation
BOC Elevation - Bottom-of-Casing Elevation
* - Accuracy of Well Casing Elevation Data Varies. Top-of-Casing Elevations to be Surveyed in Accordance with SGMA Requirements
ft MSL - Feet Above Mean Sea Level
ft BGS - Feet Below Ground Surface
1: Only Wells with Known Total Depth Used in Calculations. This Represents Only a Subset of All Supply Wells in the Subbasin
2: Statistics Calculated Using Only Supply Wells With Total Depths of 40 Feet or Greater
SCWA - Sonoma County Water Agency
PVGSA - Petaluma Valley Groundwater Sustainability Agency

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# Appendix 6-A
# Simulation of Projects and Management Actions for the Petaluma Valley Groundwater Sustainability Plan

## Introduction and Scenario Development

To inform groundwater sustainability planning in the Petaluma Valley Basin (Basin), projects and management actions (PMA) were simulated using the Petaluma Valley Integrated Hydrologic Model (PVIHM) and compared with future baseline scenario results (Petaluma Valley GSP Section 3.7) to identify potential changes to the Basin aquifer. Project benefits were evaluated by comparing projected groundwater elevations and water budget components with and without PMA.

A single PMA scenario was evaluated for the Basin. This scenario is referred to as the Group 1 Scenario, in case additional scenarios need to be evaluated in future planning. The Group 1 Scenario also parallels Group 1 Scenarios evaluated for the Sonoma Valley and Santa Rosa Plain basins in Sonoma County. The Group 1 Scenario for the Basin consists of two feasible water conservation efforts:

1. A 20% reduction in rural domestic pumping starting in water year (WY) 2025, and
2. A 10% reduction in vineyard irrigation starting in WY 2025.

The 20% reduction in rural domestic pumping is intended to reflect increasing outdoor water use efficiency by rural residences resulting from turf removal, rainwater harvesting, stormwater capture and reuse. This project does not include any potential future drought-related conservation requirements. The exact types of these projects and management actions are not specified for the purposes of evaluating potential project benefits.

The 10% reduction in vineyard irrigation is intended to reflect potential future changes such as delaying the start to the irrigation season, irrigation efficiency improvements, deficit irrigation, and grape varietals that require less water. The exact types of these changes are not specified for the purposes of evaluating potential project benefit.

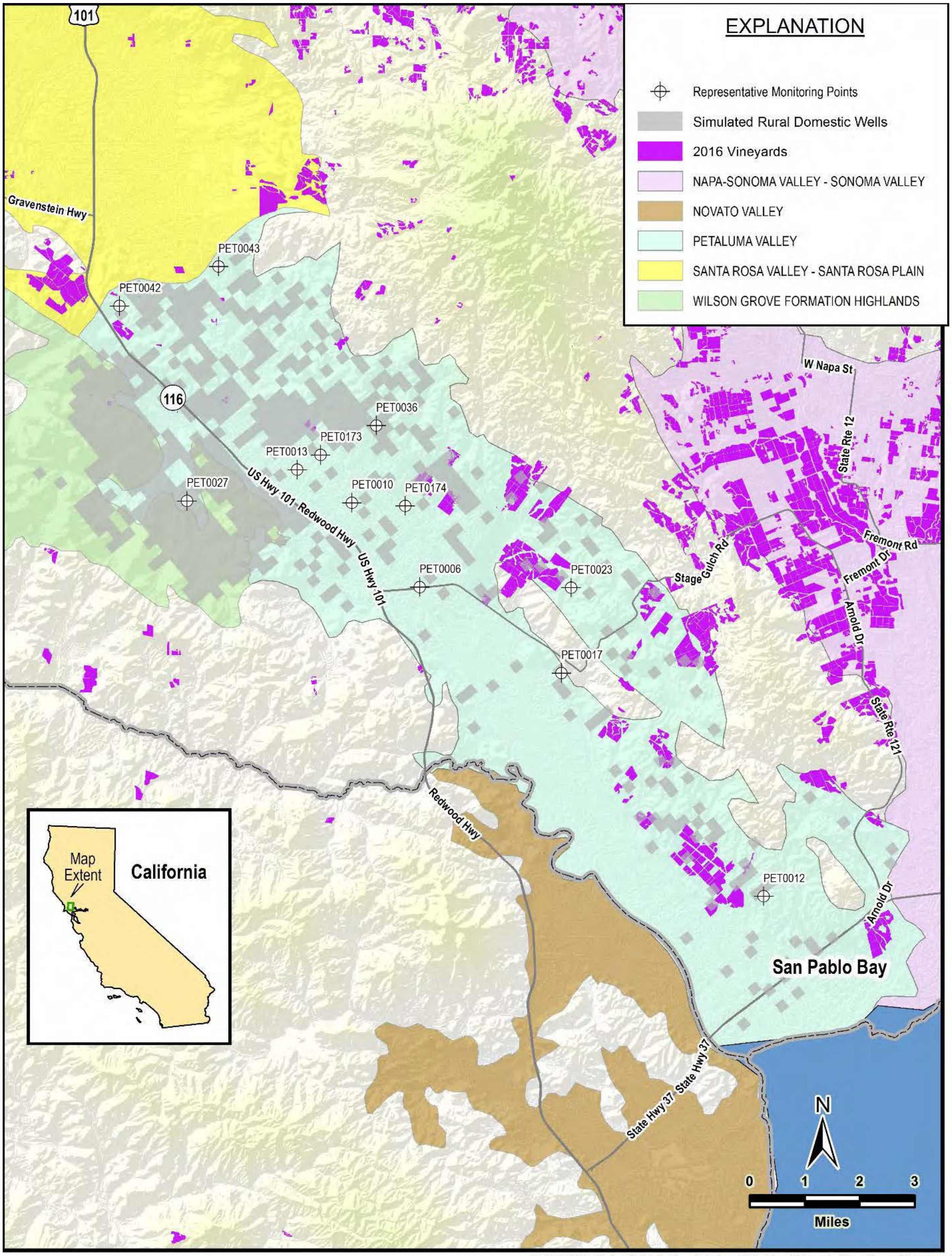


Figure 1: Modeled Urban and Vineyard Land use in the Petaluma Valley Basin

## Implementation of Group 1 Projects in PVIHM

The Group 1 scenario was implemented by changing the following model inputs:

**Rural Domestic Pumping**: For Group 1, rural domestic pumping reductions were simulated by rescaling specified pumping rates for rural domestic wells in the MODFLOW WEL file. From WY 2025 until the end of the simulation, the rural domestic pumping rates were reduced by 20% from the baseline scenario.

**Vineyard Consumptive Use**: For Group 1, vineyard consumptive use reductions were simulated by reducing crop coefficients ($K_c$) by 10% during the growing season from what was used for the baseline scenario, beginning in water year 2025. Crop coefficients in the PVIHM were specified as part of the inputs to the MODFLOW-OWHM Farm Process (FMP).

Figure 2 below shows changes in projected agricultural and rural domestic pumping as part of the Group 1 scenario compared to the baseline scenario.

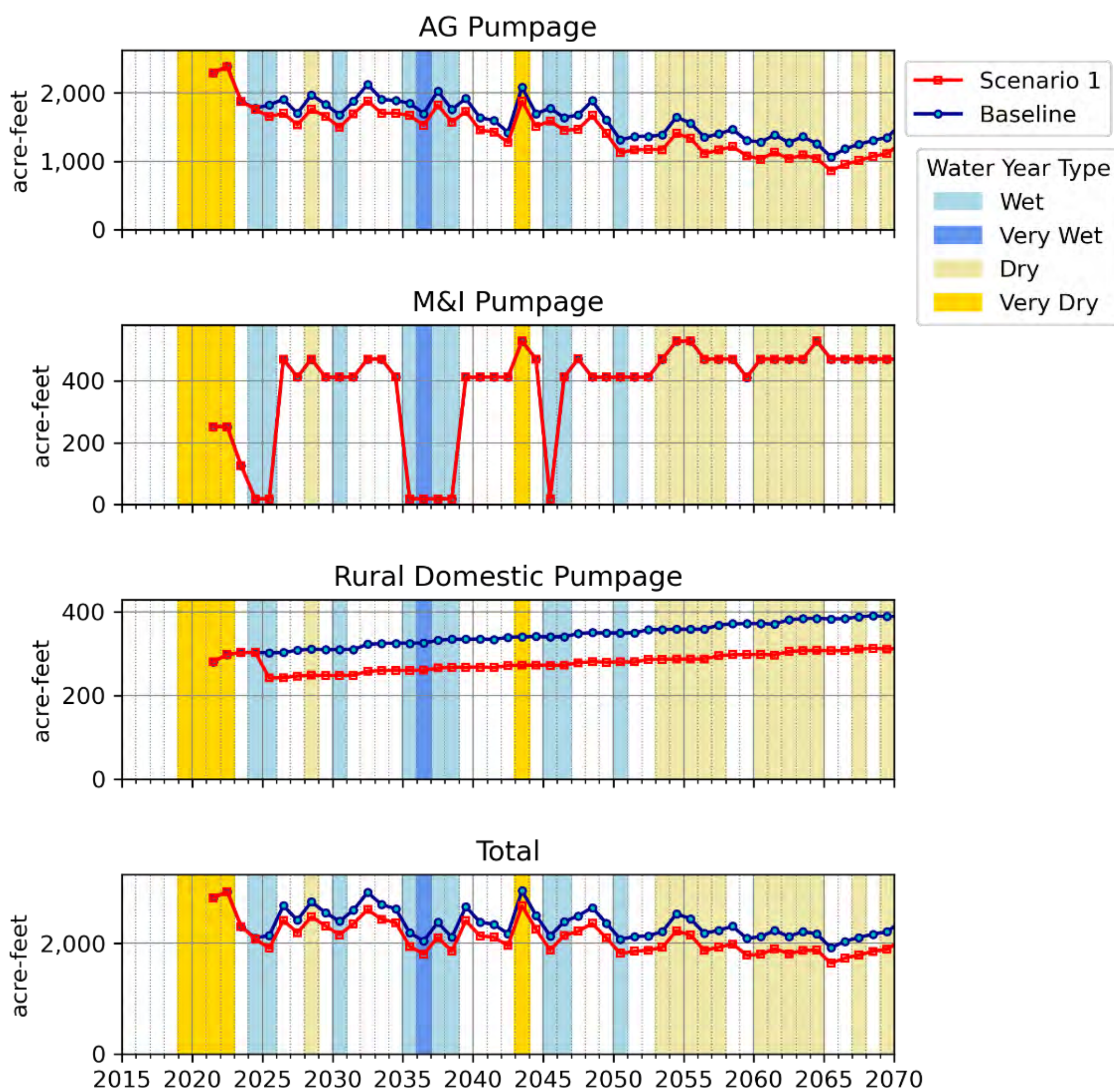

Figure 2: Baseline and Group 1 Scenario Projected Agricultural and Rural Domestic Groundwater Pumping

Table 1 compares average annual agricultural and rural domestic pumping between the baseline and Group 1 scenario. WY 2021 through WY 2070 projected pumping under the Group 1 scenario is approximately 250 AFY less than baseline projected pumping.

Table 1. Average Agricultural and Rural Domestic Pumping Rates

| Mean Pumping (AFY) | Agricultural Baseline | Agricultural Group 1 | Rural Domestic Baseline | Rural Domestic Group 1 |
|---|---|---|---|---|
| WY 2021 – 2070 | 1,600 | 1,400 | 300 | 300 |
| WY 2021 – 2040 | 1,900 | 1,700 | 300 | 300 |
| WY 2041 – 2070 | 1,500 | 1,200 | 400 | 300 |

## SCENARIO RESULTS

# Project Benefits to Groundwater Levels

Figure 3 shows the difference in September 2070 projected groundwater levels between the Group 1 and baseline scenarios for PVIHM model layer 2, which represents the depth in the Petaluma Valley Basin Aquifer where most agricultural and domestic wells are screened (USGS, unpublished). Changes in groundwater elevation with Group 1 implementation are slight and impact small areas of the Basin, with less than 5 feet of increase from baseline expected by 2040, and less than 10 feet expected by 2070. As evidenced by the minimal amount of groundwater elevation change, the reduced pumping associated with Group 1 is not projected to significantly increase groundwater elevations. Instead, the primary projected benefit from Group 1 projects is to increase groundwater discharge to streams, as will be described in the Groundwater Budget section of this appendix.

The differences in projected groundwater elevation between the Group 1 and baseline scenarios for September 2040 were also reviewed, but found to be relatively minor. Differences between the two scenarios are more pronounced at the end of September 2070 due to the characteristics of the future climate scenario selected for the GSP, which consists of average to wet conditions through 2040, and then an extended drought from 2055 through 2070.

These simulation results indicate that the benefit from Group 1 projects in terms of increasing groundwater levels will be most significant during drought conditions, and least significant during wet periods when the water table is relatively shallow and there is minimal (unsaturated) storage capacity.

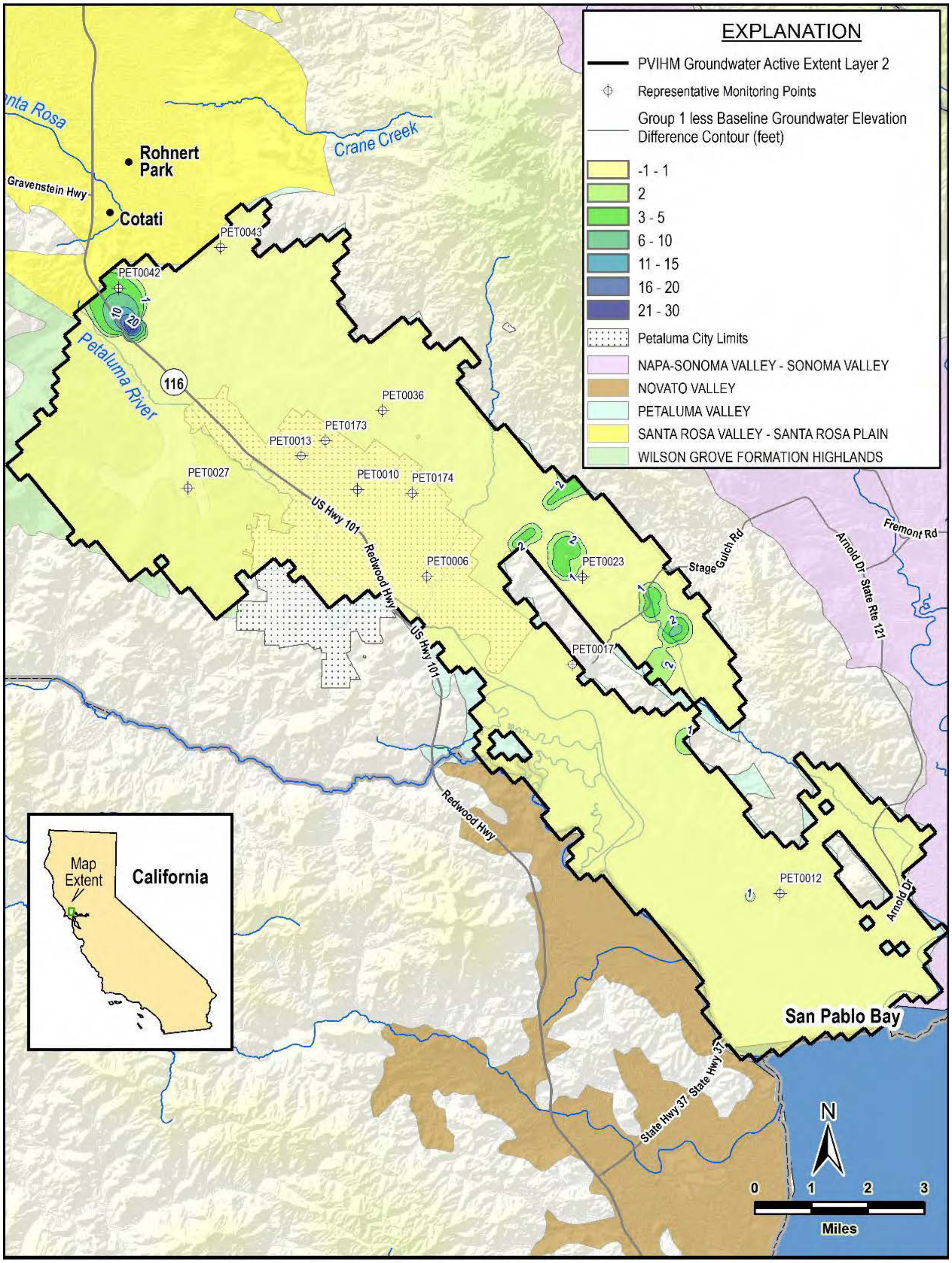


Figure 3: Group 1 Scenario Groundwater Elevation Changes from Baseline, September 2070, Model Layer 2

Appendix 6B compares projected groundwater level hydrographs between the baseline and Group 1 scenarios. As discussed above, projected groundwater level changes due to Group 1 are small. Table 2 shows the number of years for which projected groundwater levels are below the minimum thresholds (MT) set for representative monitoring point (RMP) wells in the Petaluma Valley Basin Aquifer. For all but one RMP well (PET0174), projected groundwater levels at each RMP well are above the corresponding MT. The MT exceedances at PET 0174 only are projected to occur after WY 2040 and the Group 1 scenario shows a reduction of MT exceedances.

Table 2. Number of Years with Water Levels Below Minmum Threshold for RMP Wells

| RMP Well Name | Baseline | | Group 1 | |
|---|---|---|---|---|
| | WY 2021-2040 | WY 2041-2070 | WY 2021-2040 | WY 2041-2070 |
| PET0006 | 0 | 0 | 0 | 0 |
| PET0010 | 0 | 0 | 0 | 0 |
| PET0012 | 0 | 0 | 0 | 0 |
| PET0013 | 0 | 0 | 0 | 0 |
| PET0017 | 0 | 0 | 0 | 0 |
| PET0023 | 0 | 0 | 0 | 0 |
| PET0027 | - | - | - | - |
| PET0036 | 0 | 0 | 0 | 0 |
| PET0042 | 0 | 0 | 0 | 0 |
| PET0043 | 0 | 0 | 0 | 0 |
| PET0172 | - | - | - | - |
| PET0173 | 0 | 0 | 0 | 0 |
| PET0174 | 0 | 2 | 0 | 1 |

# Groundwater Budget

Figure 4 shows cumulative change in storage for the future baseline and Group 1 scenarios. Table 3 shows the average annual change in storage for the Baseline and Group 1 scenarios. Both the Baseline and Group 1 scenarios project net depletion of groundwater storage over 2021-2070. On average, the Group 1 scenario projected groundwater storage depletion over WY 2021-2070 is about 20 AFY less than the Baseline groundwater storage depletion, when rounded to the nearest 10 AFY.

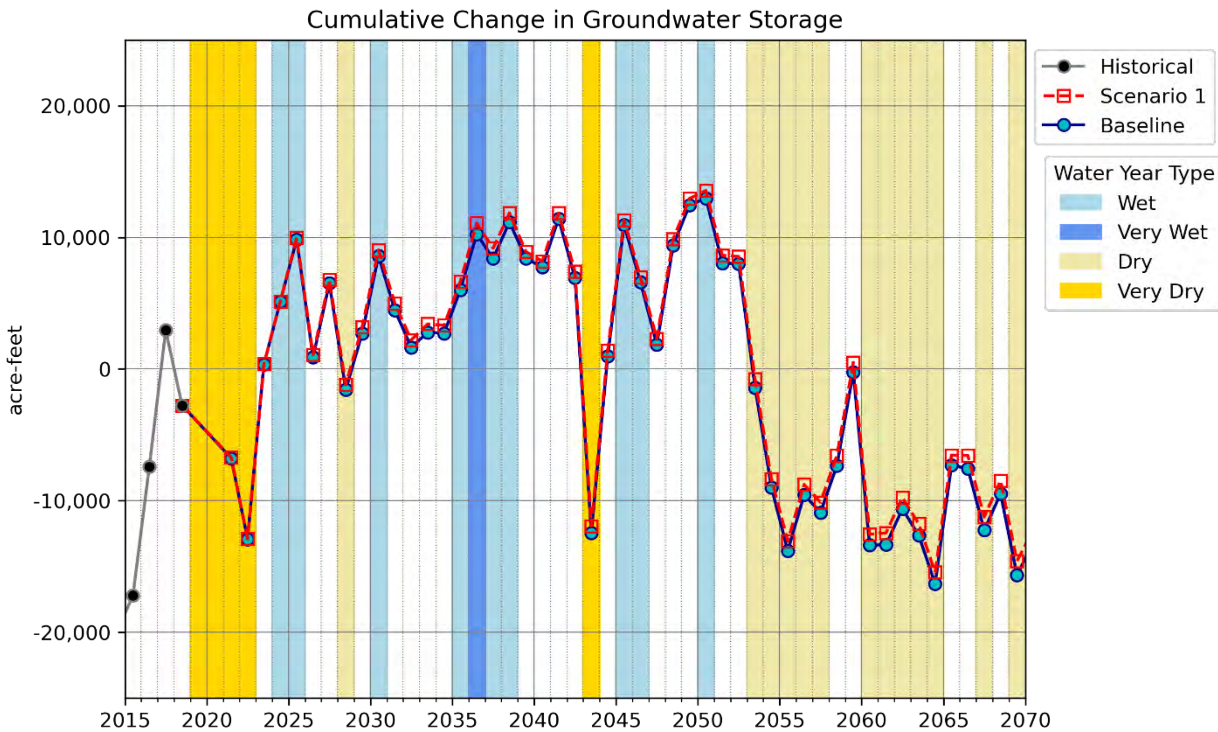


Figure 4 Projected Cumulative Change in Storage for Baseline and Group 1 Scenarios.

Table 3. Mean Annual Change in Storage (values in parentheses are unrounded values)

| Average annual change in groundwater storage (AFY) | Baseline | Group 1 |
|---|---|---|
| WY 2021 – 2040 | 500 (530) | 600 (550) |
| WY 2041 – 2070 | -700 (-700) | -700 (-680) |
| WY 2021 – 2070 | -200 (-210) | -200 (-190) |

Figure 5 shows the impact of the Group 1 scenario on net stream leakage, compared to the baseline. Table 4 shows the average annual mean net stream leakage for the Baseline and Group 1 scenario. Positive values indicate net leakage from surface water to groundwater, negative values indicate net discharge from groundwater to surface water. Results show that with Group 1, there is a projected increase in the magnitude of net groundwater discharge to surface water. This is due to diminished rates of stream leakage into the groundwater system rather than increased groundwater discharge to streams.

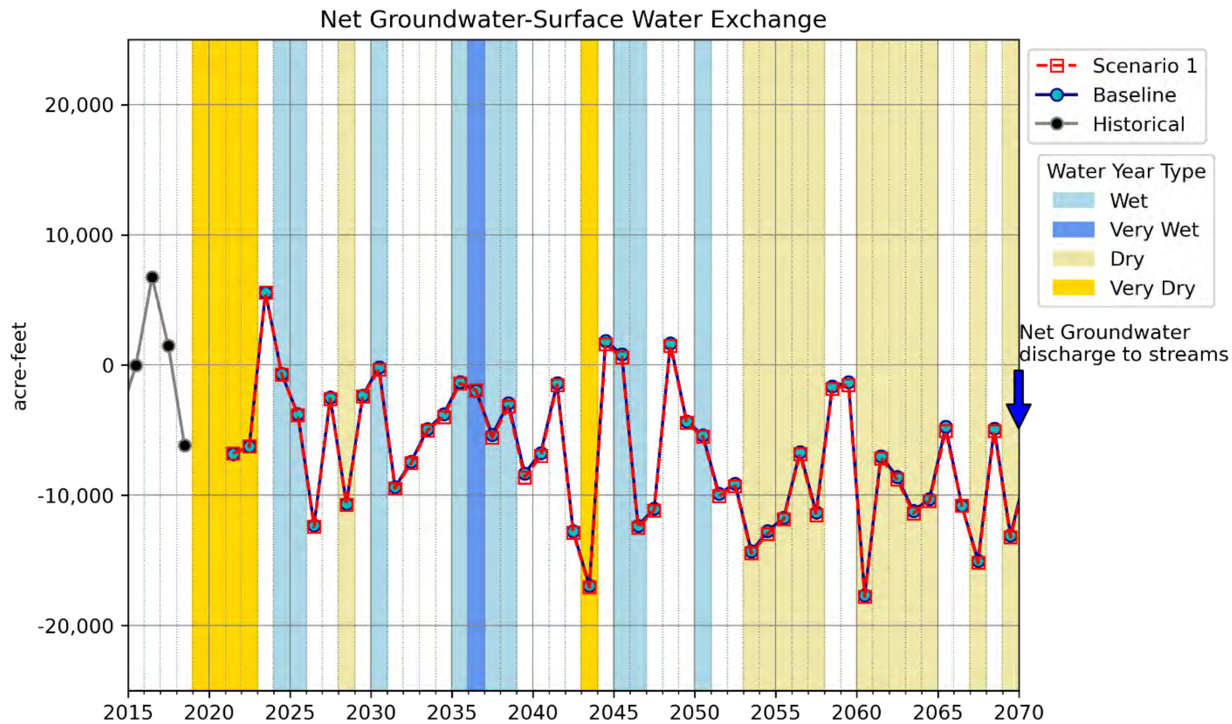


Figure 5. Projected Net Stream Leakage for Baseline and Group 1 Scenarios.

Table 4. Mean Net Stream Leakage.

| Mean Net Stream Leakage (AFY) | Baseline | Group 1 |
|---|---|---|
| WY 2021 – 2040 | -4,600 | -4,700 |
| WY 2041 – 2070 | -8,300 | -8,500 |
| WY 2021 – 2070 | -6,800 | -7,000 |

Figure 6 shows the impacts of the Group 1 scenario on net flow to the Baylands area and total inflow from the Petaluma River. Together, these inflows represent the potential inflow of brackish groundwater to the Basin. The trend of these inflows is notably upward throughout the 50-year simulation period as sealevels continue to rise. The response of surface leakage is also shown in Figure 6. This groundwater outflow continues to increase throughout the simulation period mirroring inflow from the Baylands, thus muting the effect of the sealevel rise on groundwater levels. Table 5 shows average annual net inflows from the Baylands. Table 6 shows average annual net inflow from the tidally-influenced Petaluma River. The Group 1 scenario has a negligible impact on flow from the Baylands. Projected inflow from the Petaluma River is about 30 AFY less in the Group 1 scenario, compared to the Baseline scenario (not shown in Table due to rounding).

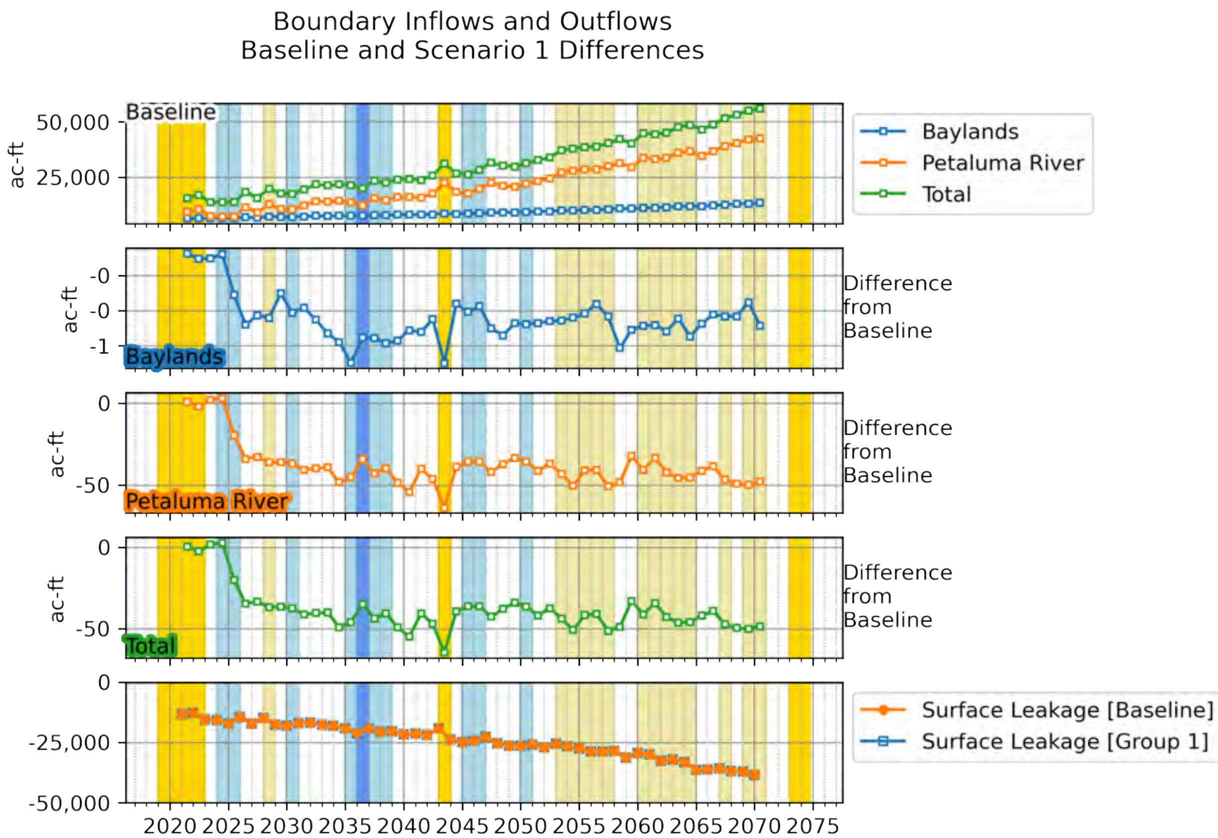


Figure 6. Projected Net Inflows from the Baylands and Tidally-Influenced Petaluma River for Baseline and Group 1 Scenarios.

Table 5. Mean Net Inflow From Baylands.

| **Mean Net Flow To/From Baylands (AFY)** | **Baseline** | **Group 1** |
|---|---|---|
| WY 2021 – 2040 | 7,200 | 7,200 |
| WY 2041 – 2070 | 10,400 | 10,400 |
| WY2021 – 2070 | 9,100 | 9,100 |

Table 6. Mean Net Inflow in from Tidally-Influenced Petaluma River

| Mean Inflow from Petaluma River (AFY) | Baseline | Group 1 |
|---|---|---|
| WY 2021 – 2040 | 11,900 | 11,900 |
| WY 2041 – 2070 | 28,700 | 28,600 |
| WY2021 – 2070 | 22,000 | 21,900 |

## REFERENCES CITED

USGS, unpublished, "Petaluma Valley Groundwater Resources and Model Development" [currently unpublished, will update when published]

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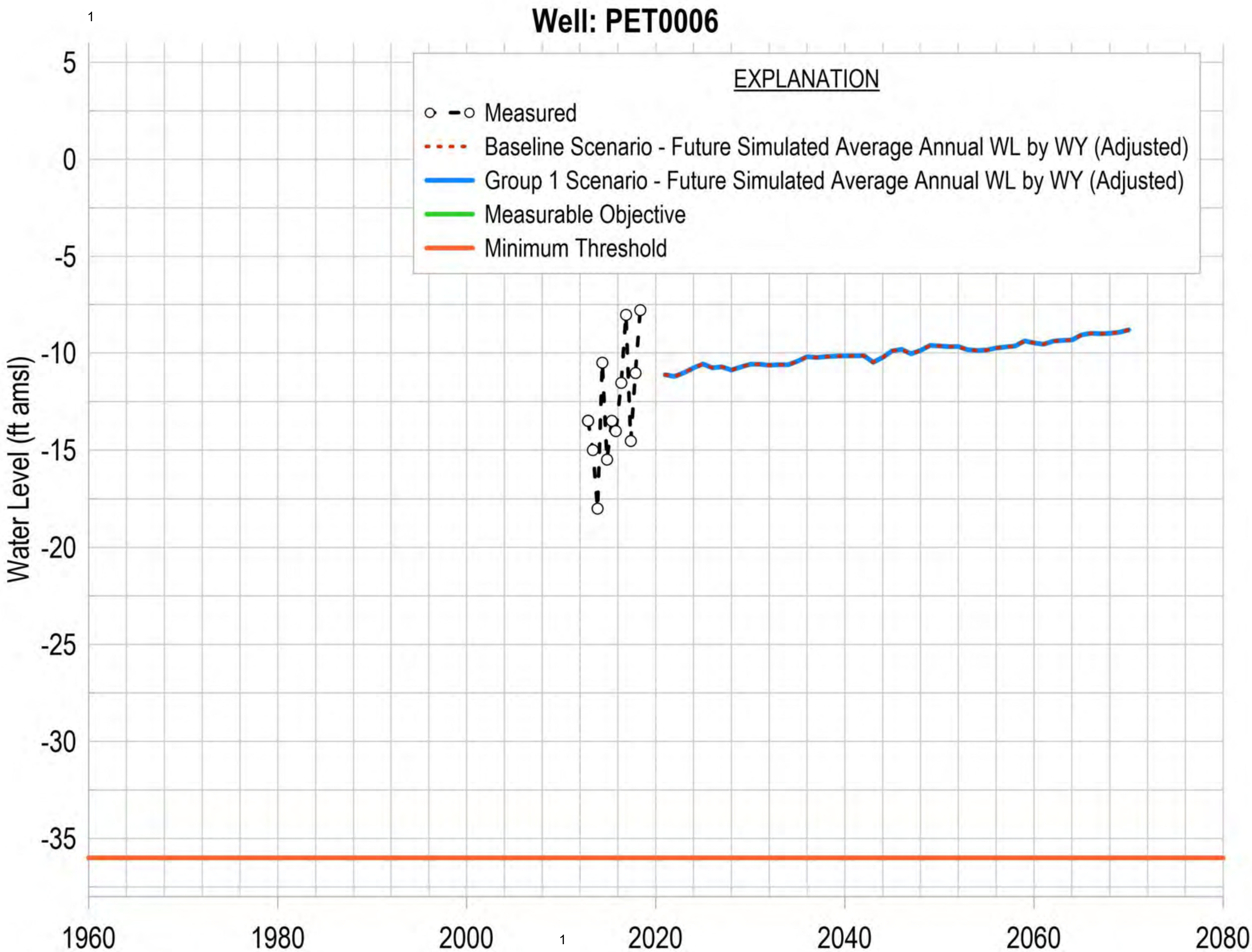
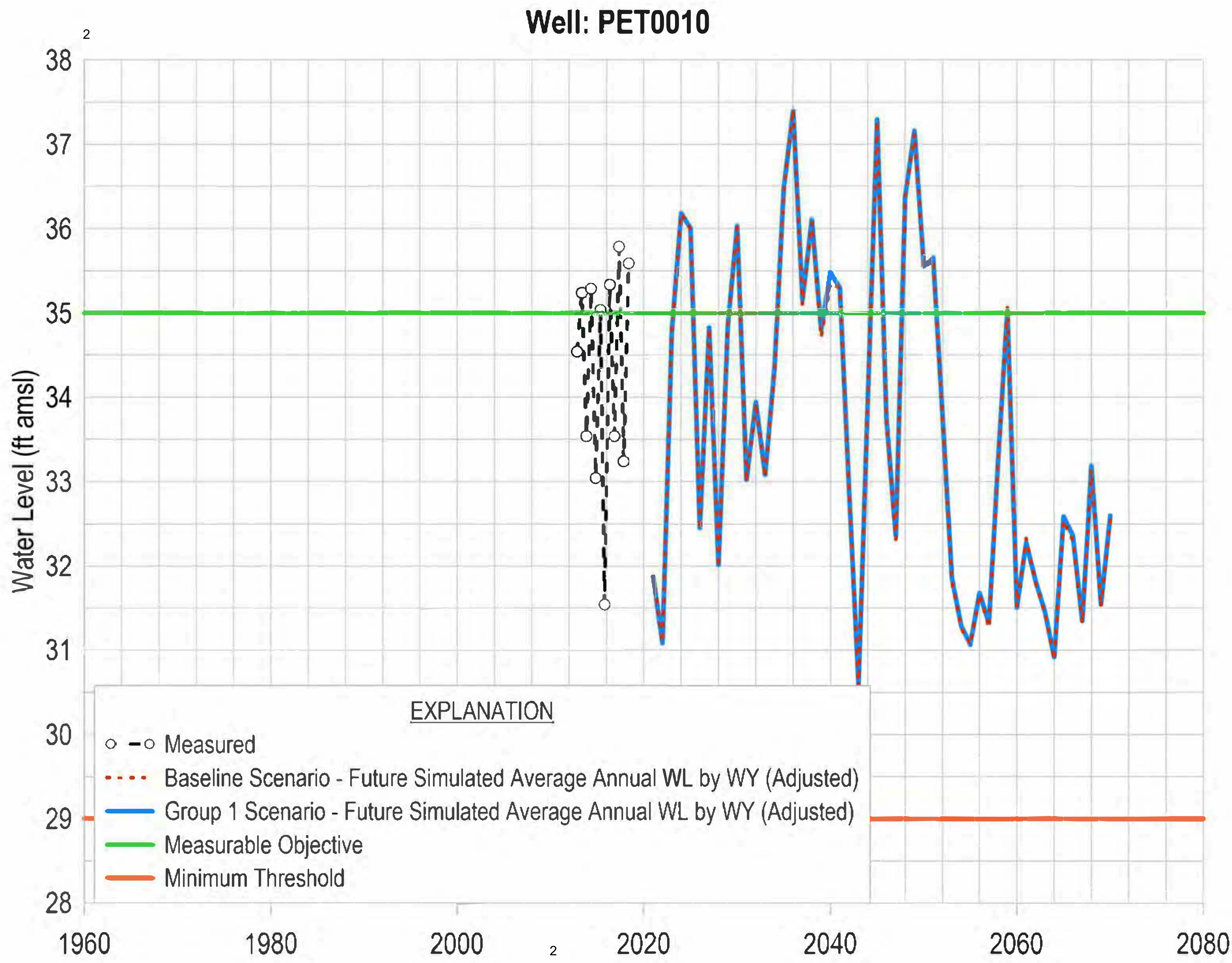
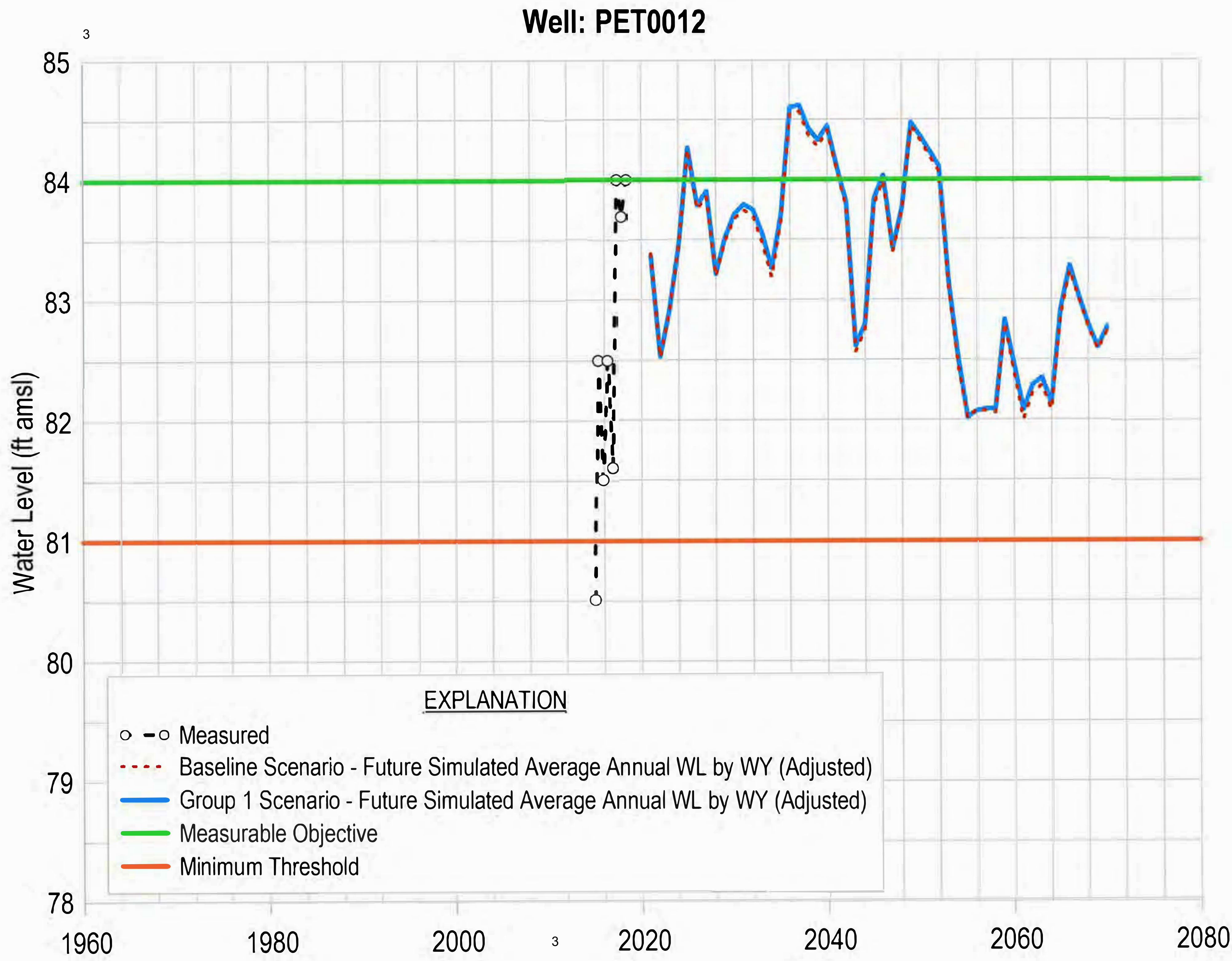
# Appendix 6-B
# Simulated Waterlevel Hydrographs from the Simulation of Projects and Management Actions



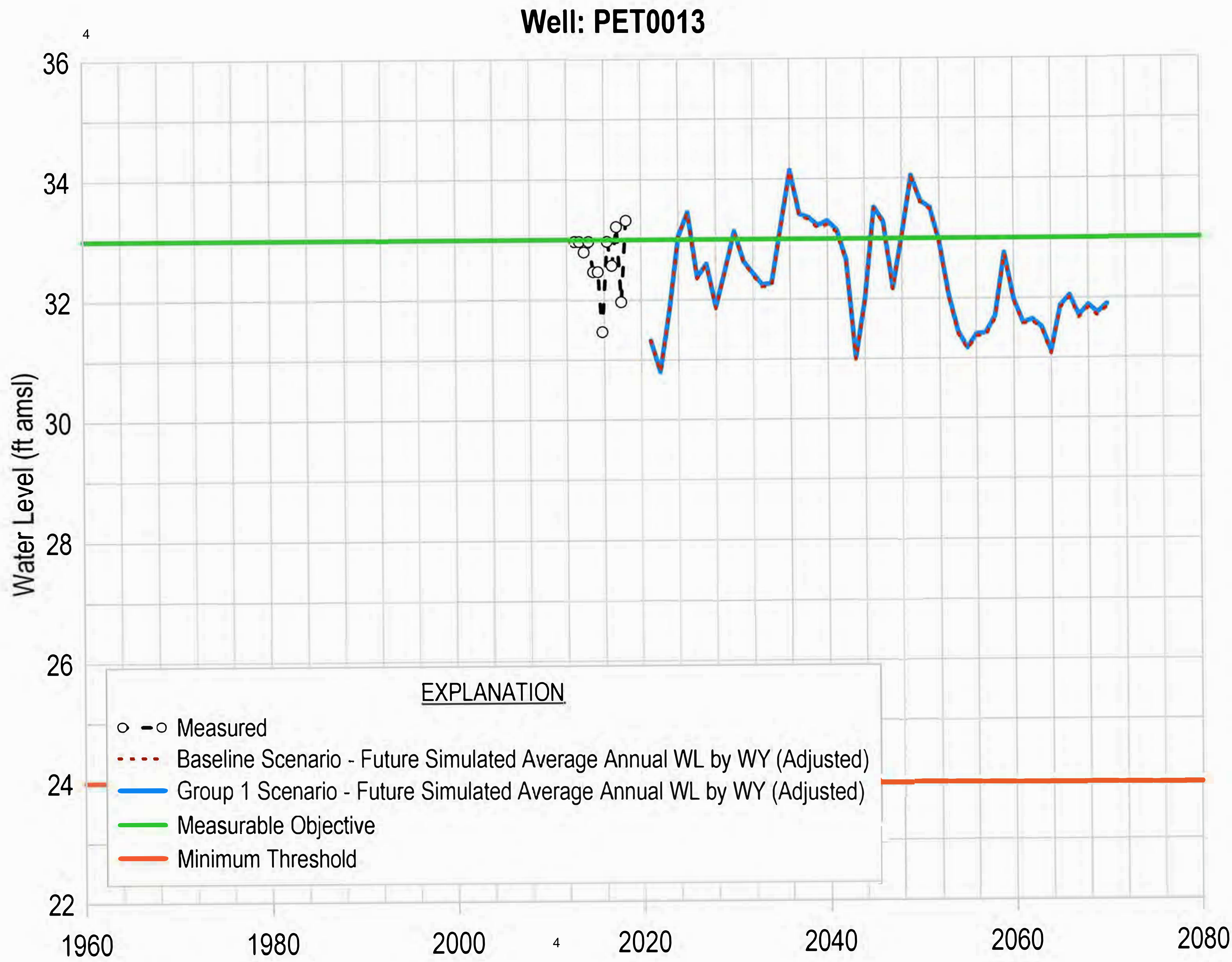
Well: PET0006
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold
Water Level (ft amsl)
5
0
-5
-10
-15
-20
-25
-30
-35
1960
1980
2000
2020
2040
2060
2080



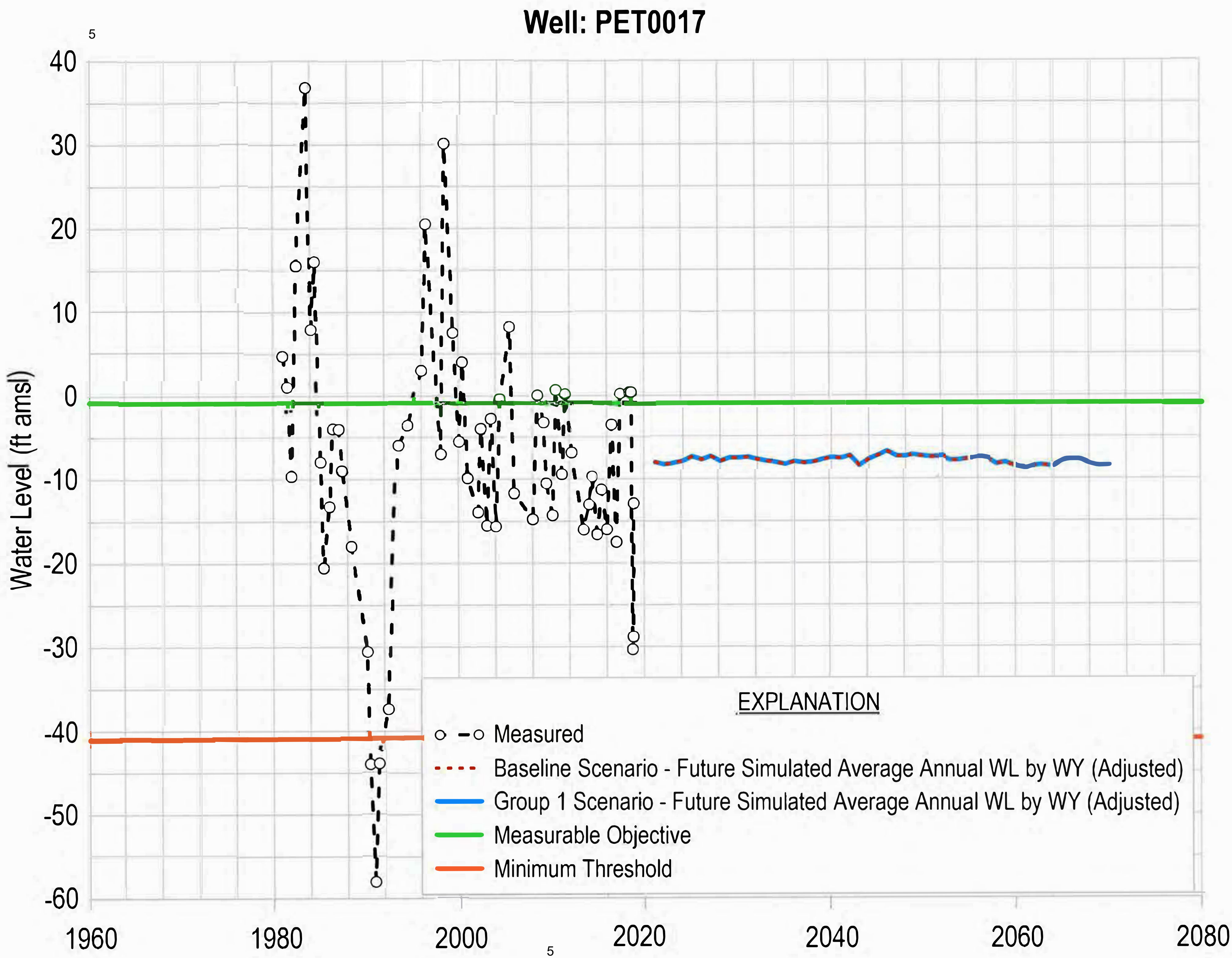
Well: PET0010
Water Level (ft amsl)
38
37
36
35
34
33
32
31
30
29
28
1960
1980
2000
2020
2040
2060
2080
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold



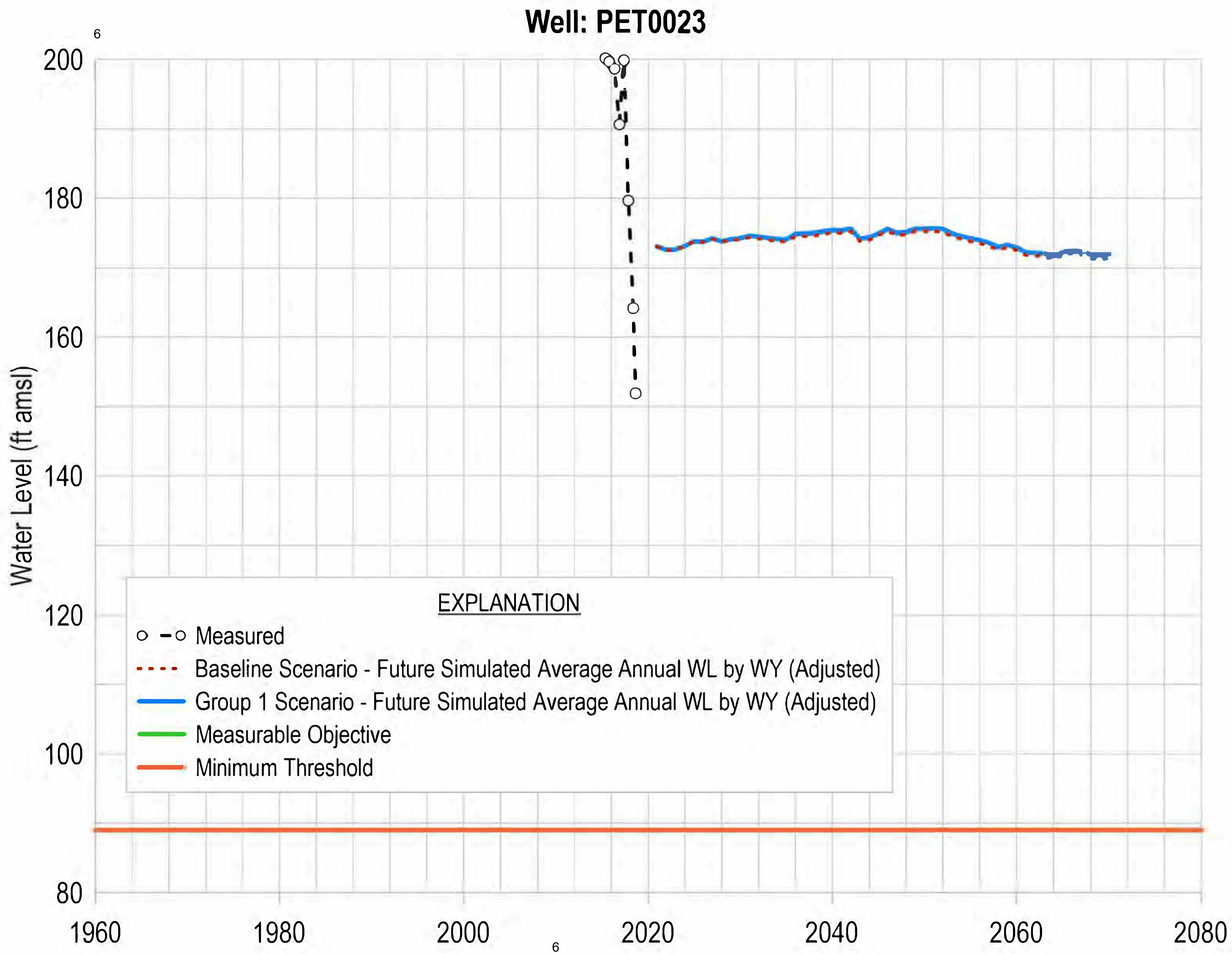
Well: PET0012
Water Level (ft amsl)
85
84
83
82
81
80
79
78
1960
1980
2000
2020
2040
2060
2080
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold



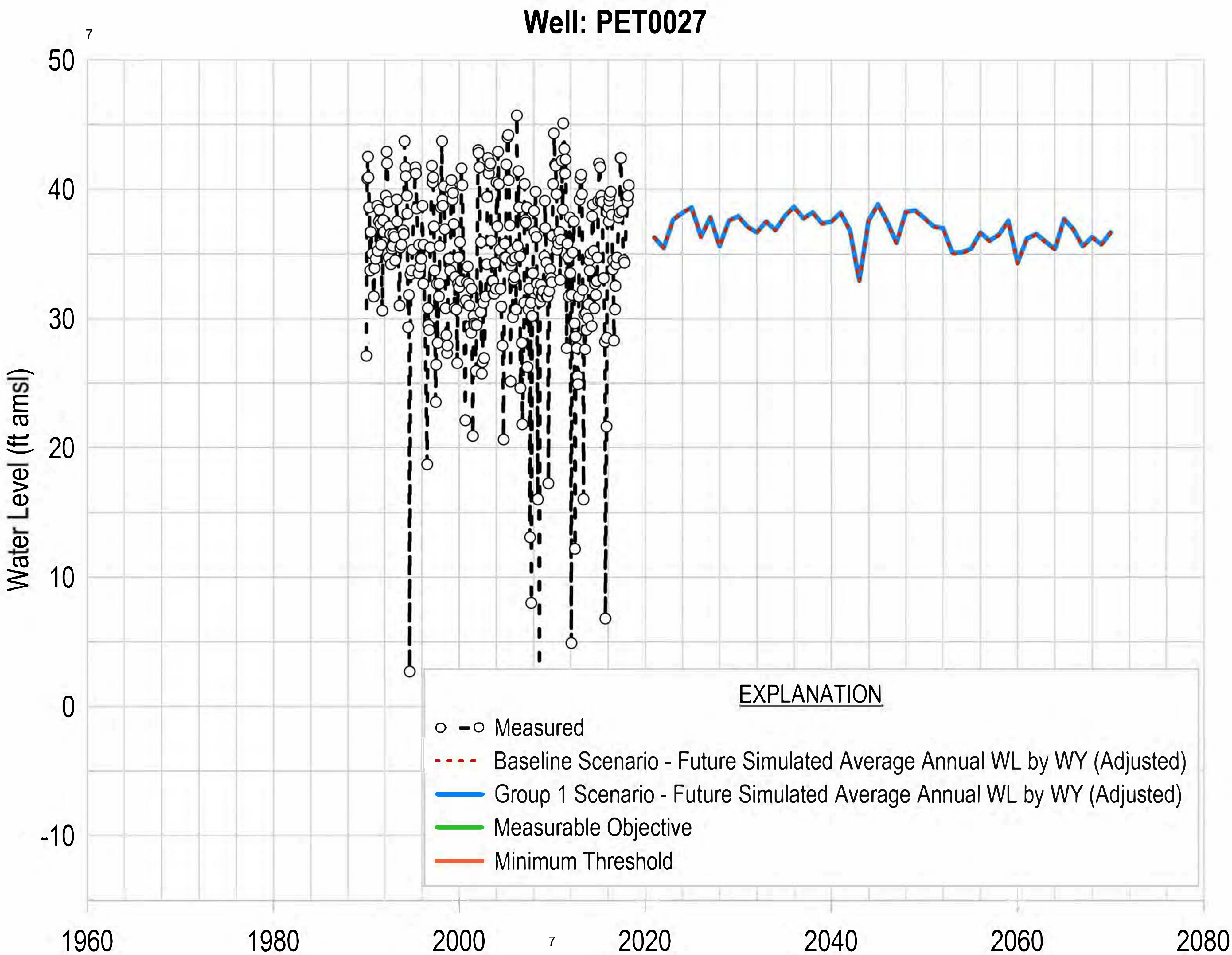
Well: PET0013
Water Level (ft amsl)
36
34
32
30
28
26
24
22
1960
1980
2000
2020
2040
2060
2080
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold

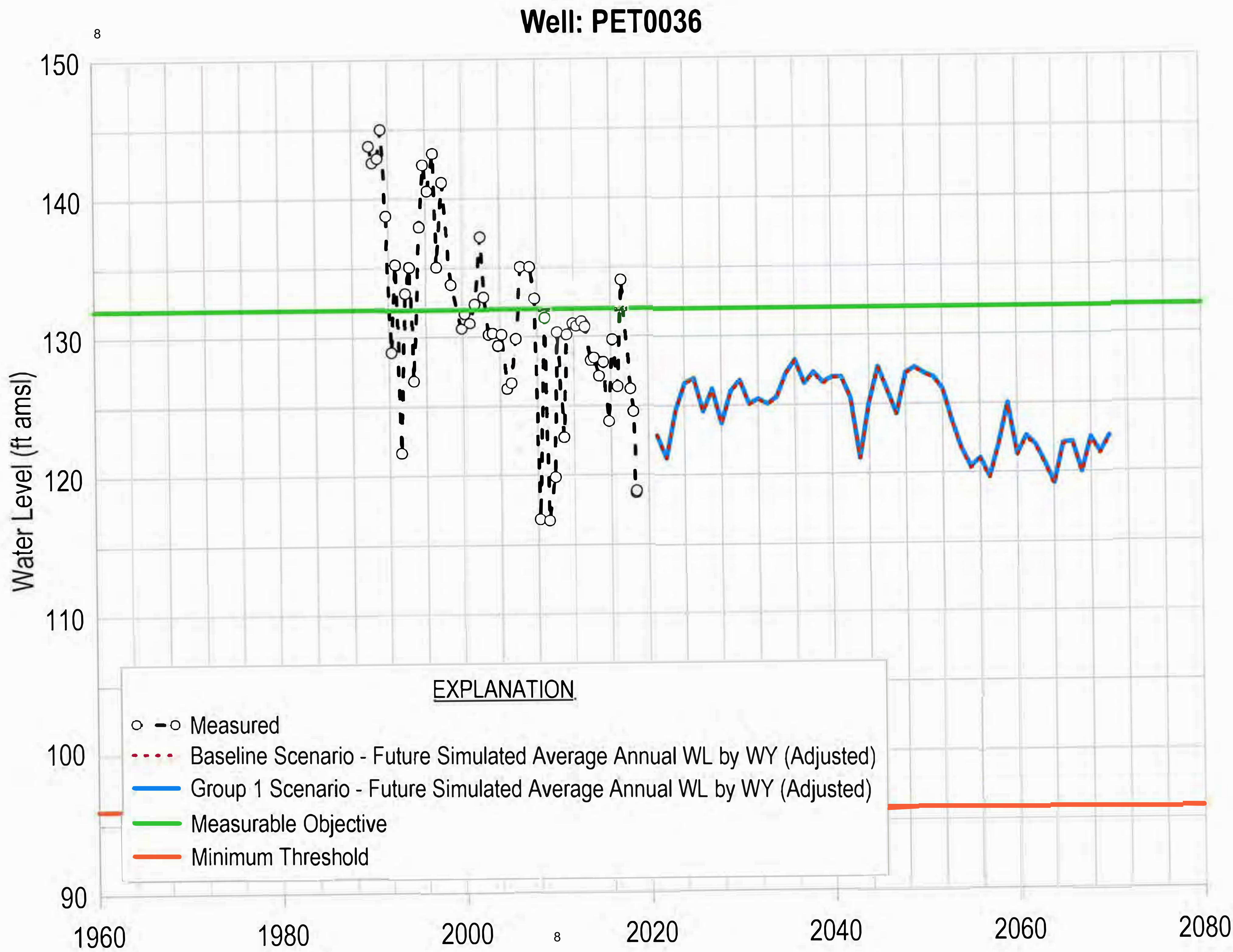


Well: PET0017
Water Level (ft amsl)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
1960
1980
2000
2020
2040
2060
2080
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold

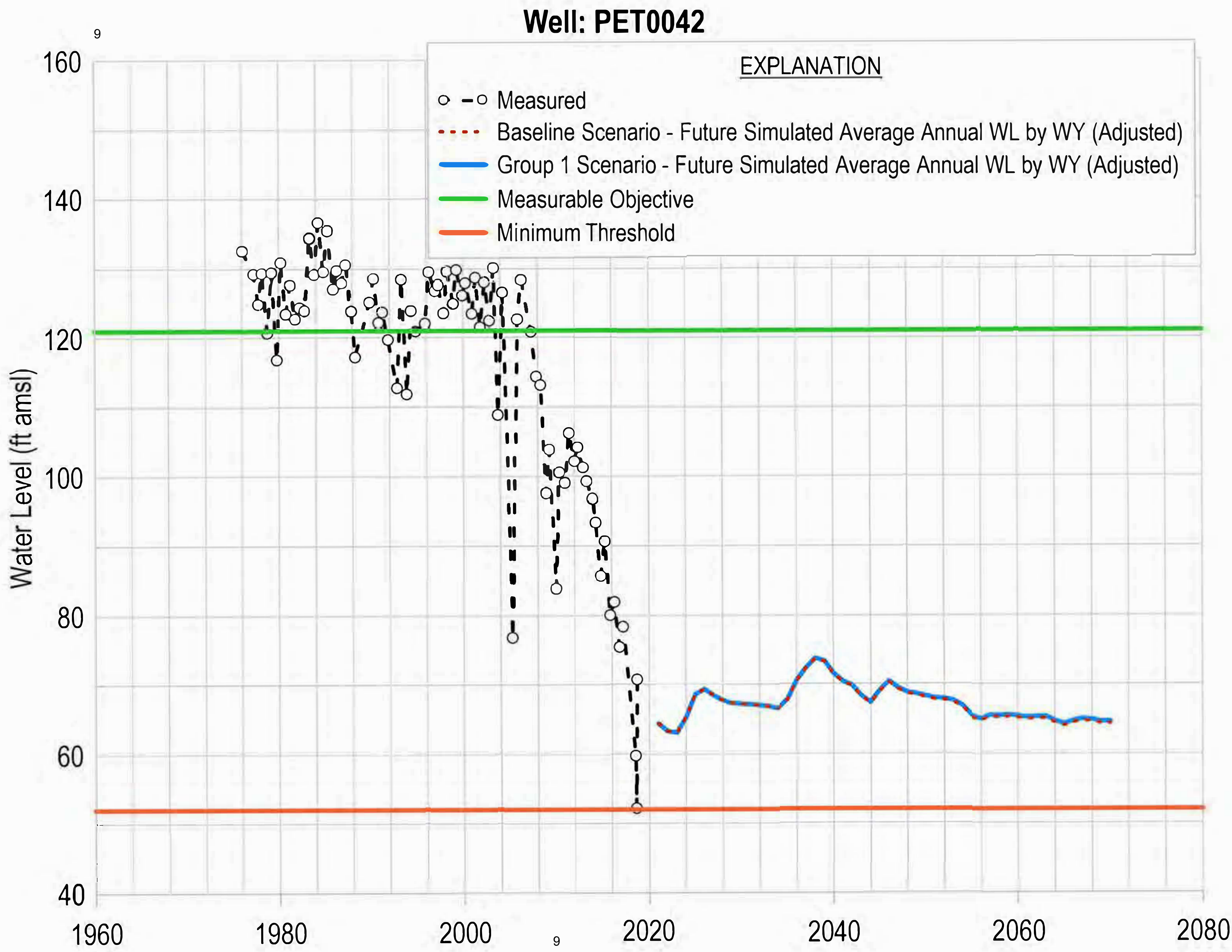


Well: PET0023
6
Water Level (ft amsl)
200
180
160
140
120
100
80
1960
1980
2000
2020
2040
2060
2080
6
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold


Well: PET0027
Water Level (ft amsl)
50
40
30
20
10
0
-10
1960
1980
2000
2020
2040
2060
2080
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold

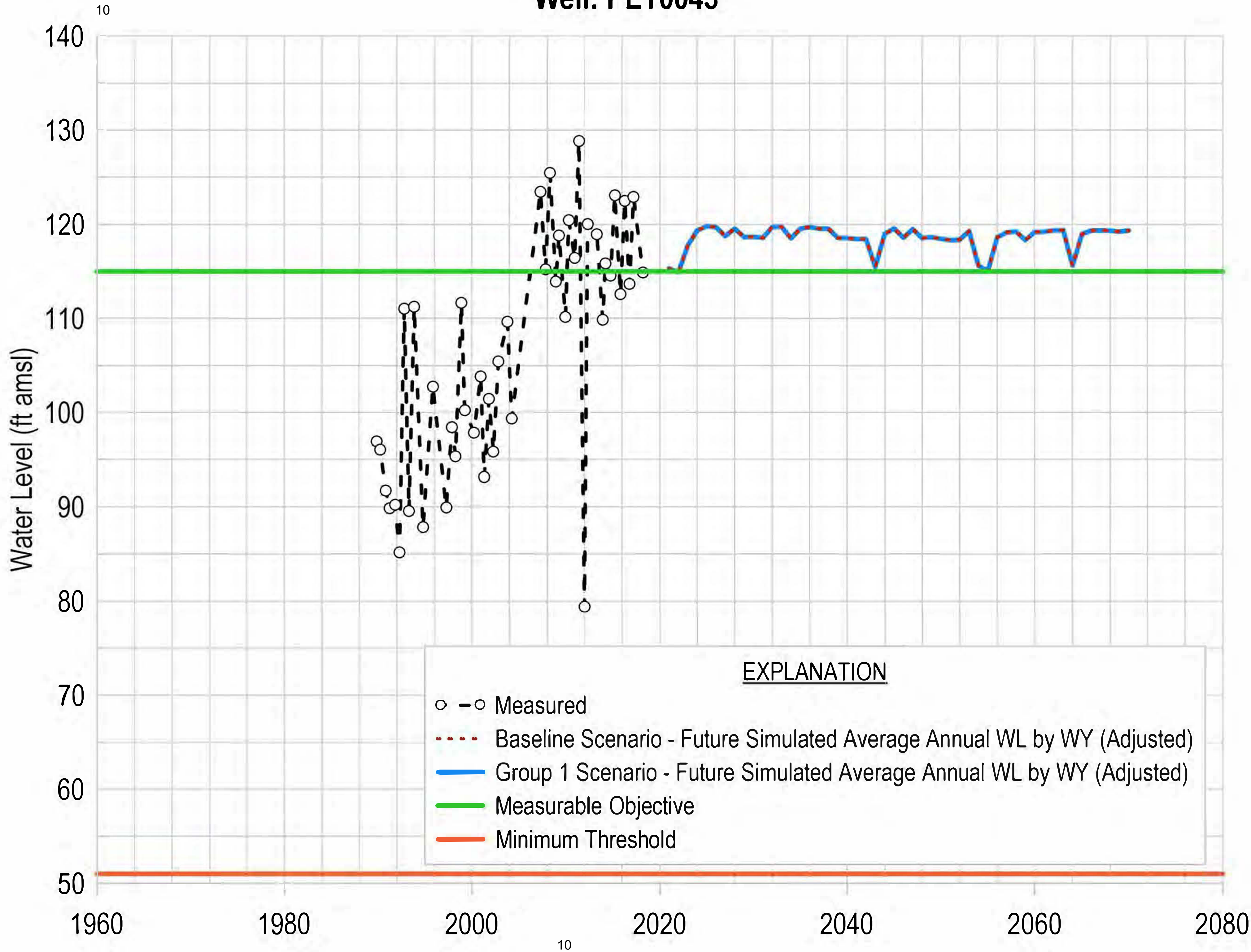


Well: PET0036
Water Level (ft amsl)
150
140
130
120
110
100
90
1960
1980
2000
2020
2040
2060
2080
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold



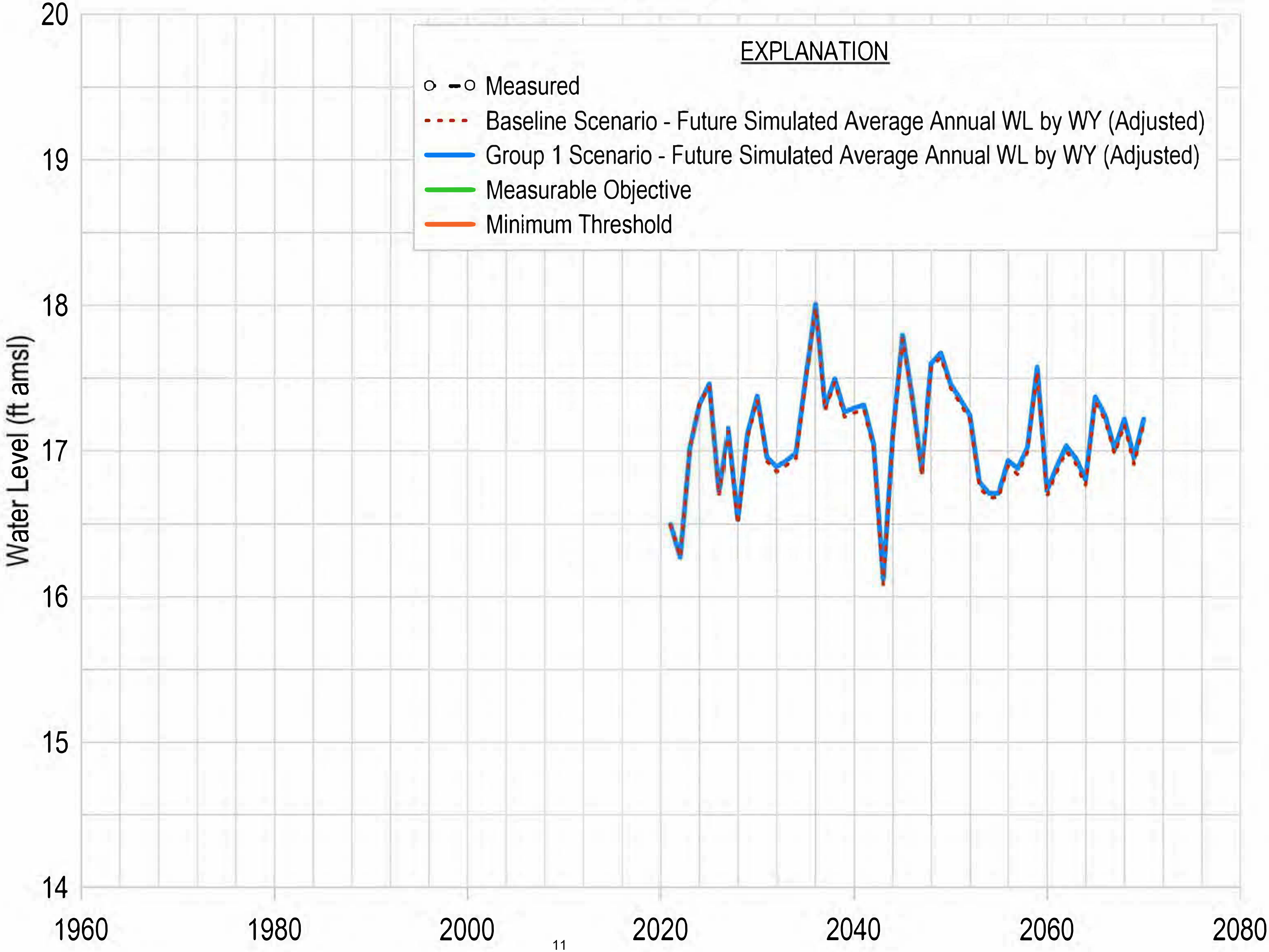
Well: PET0042
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold
Water Level (ft amsl)
160
140
120
100
80
60
40
1960
1980
2000
2020
2040
2060
2080

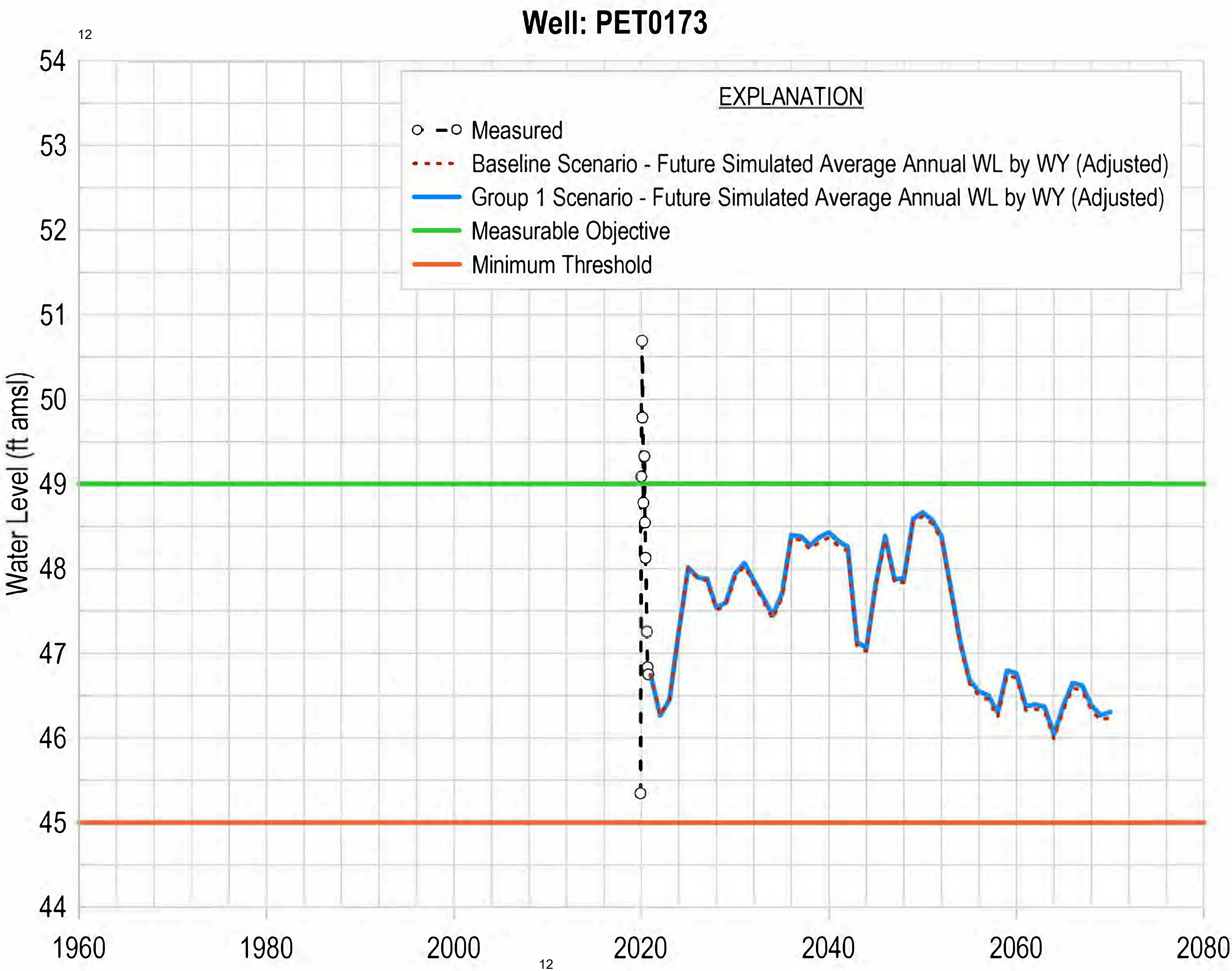
# Well: PET0043



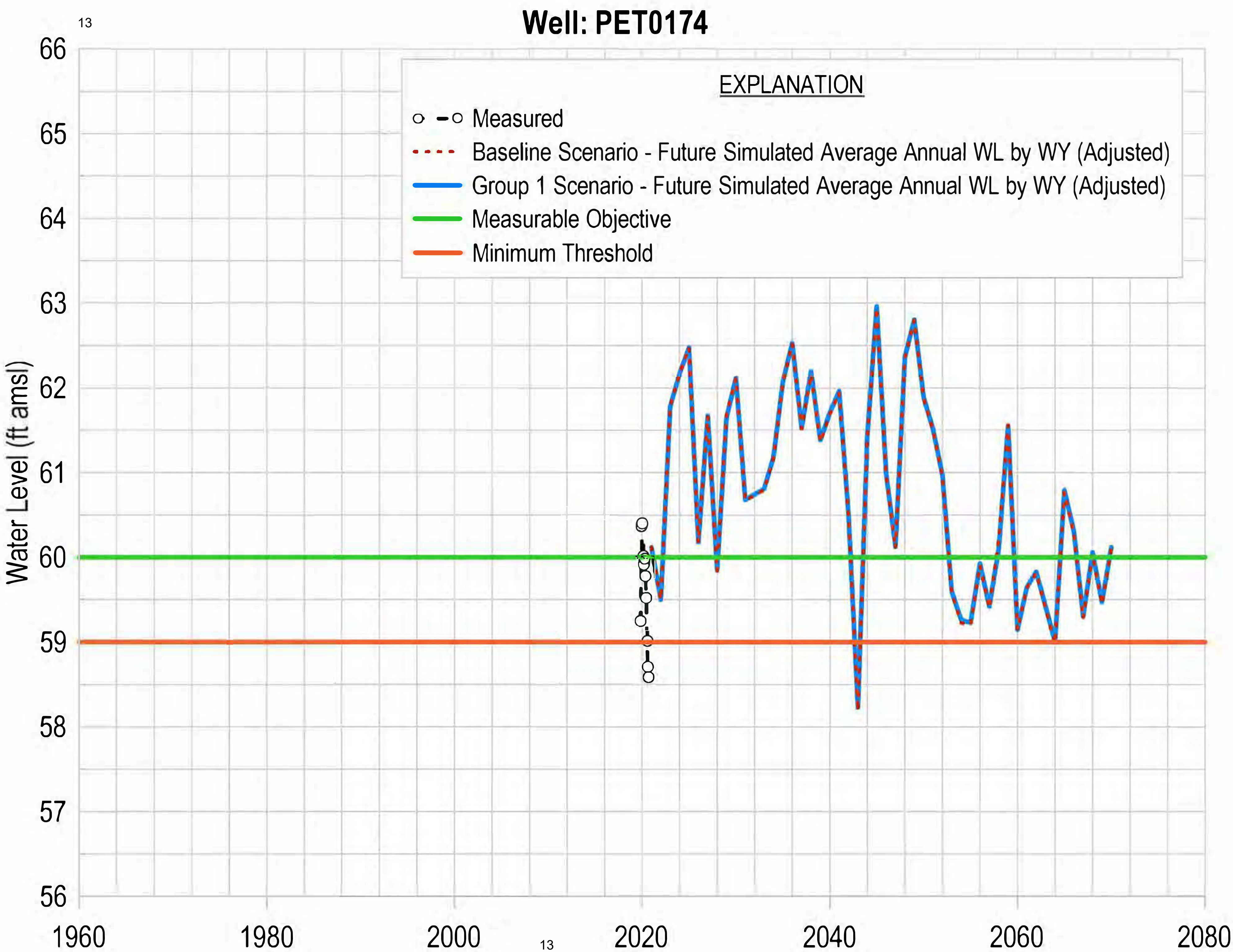
# Well: PET0172







Well: PET0173
12
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold
Water Level (ft amsl)
54
53
52
51
50
49
48
47
46
45
44
1960
1980
2000
2020
2040
2060
2080
12



13
Well: PET0174
EXPLANATION
Measured
Baseline Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Group 1 Scenario - Future Simulated Average Annual WL by WY (Adjusted)
Measurable Objective
Minimum Threshold
Water Level (ft amsl)
66
65
64
63
62
61
60
59
58
57
56
1960
1980
2000
2020
2040
2060
2080
13