APPENDIX 4-B

DEVELOPMENT OF SUSTAINABLE MANAGEMENT CRITERIA FOR DEPLETION OF INTERCONNECTED SURFACE WATER BY GROUNDWATER PUMPING
PETALUMA VALLEY GSP

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 proxy 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 proxy for a rate or volume of surface water depletion relies on correlation between surface water depletion by pumping and shallow GWLs adjacent to streams. Quantifying 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 approximated 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 proximity 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 proxy 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 proxies 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 proxy value was set as the approximate streambed elevation. For RMPs PET0173 and PET0174 (Figs. 5–6), the MT value was set as 1ft below the approximate 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 proxy value was set as ½ 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 extended 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 exceed 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 proxy 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 example, the adjacent Santa Rosa Plain and Sonoma Valley GSAs determined that MT values at RMP locations should be sufficiently protective so as to not exceed 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

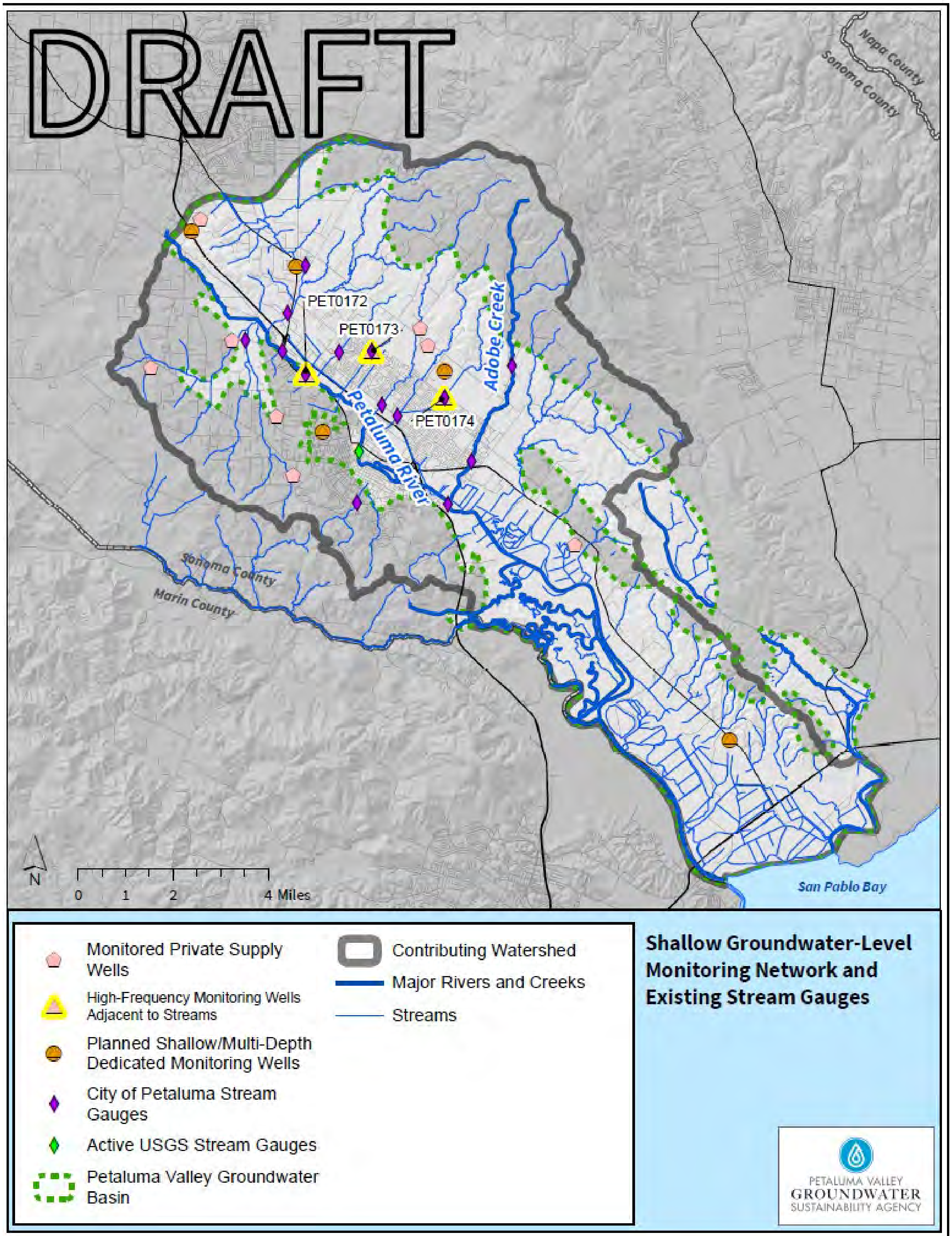

Figure 1: Petaluma Valley depletion of interconnected surface water RMP locations.

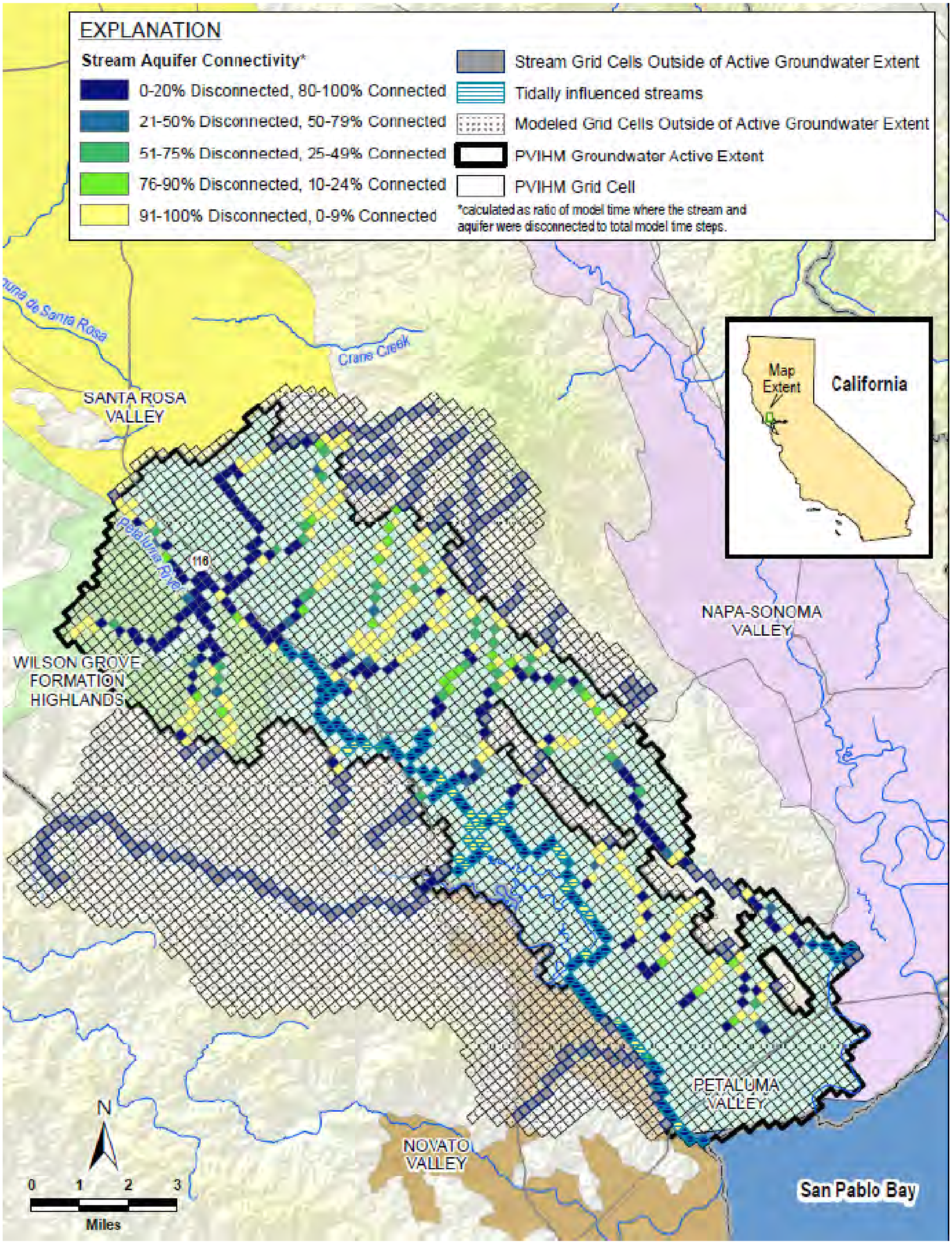

Figure 2: Petaluma Valley depletion of interconnected surface water locations identified from modeling analyses.

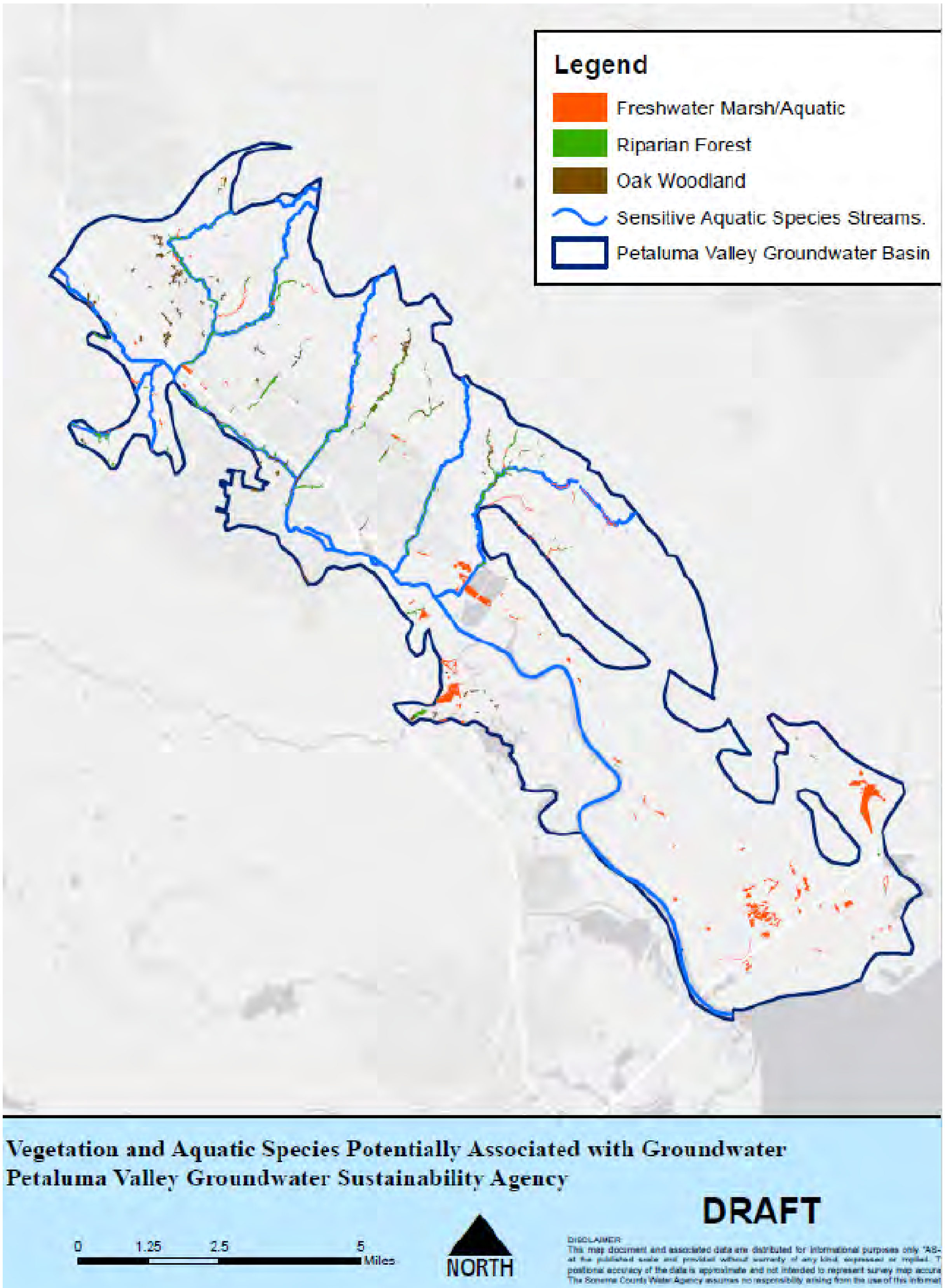

Figure 3: Locations with GDEs and Sensitive Aquatic Species Streams in the Petaluma Valley GSA area.

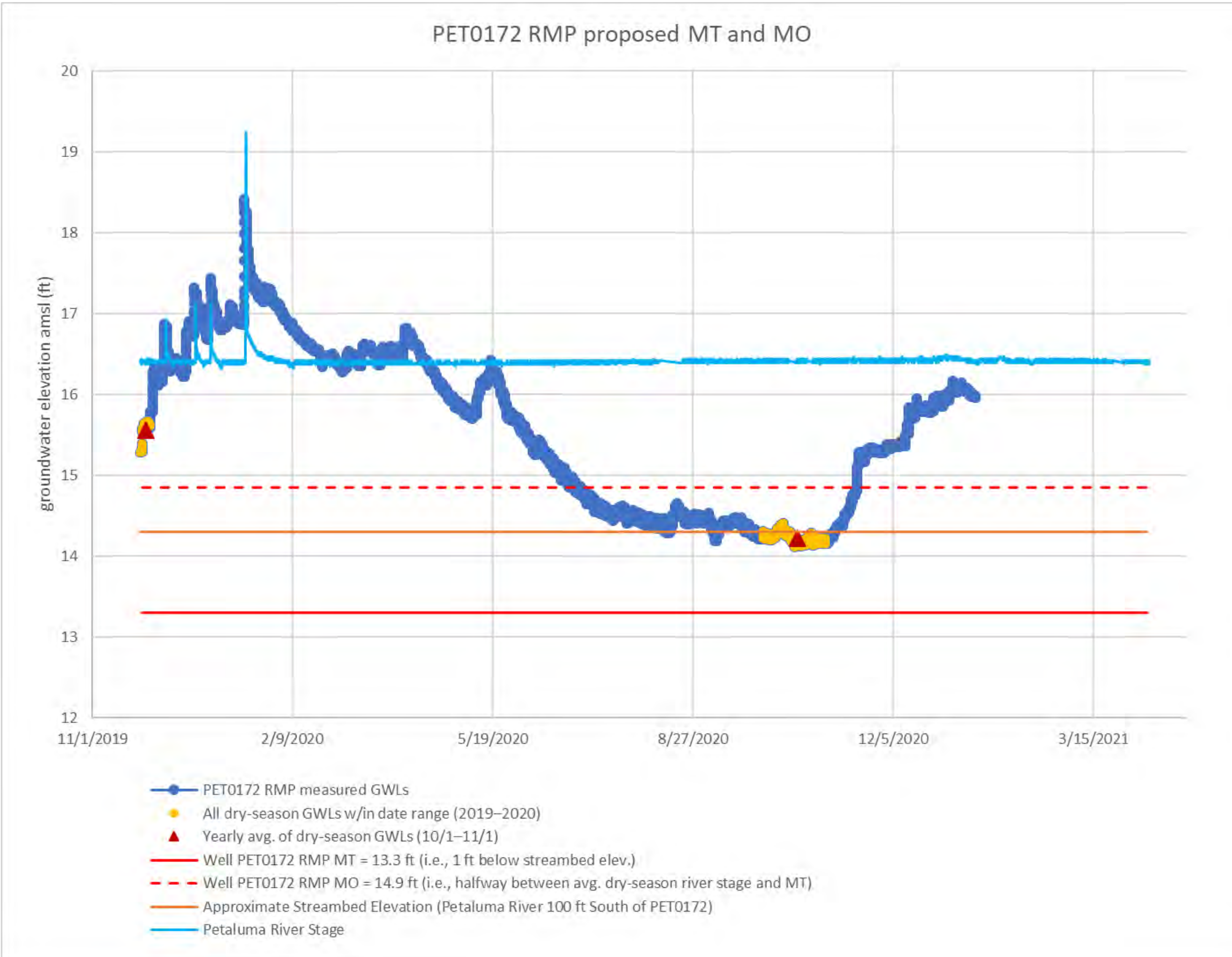

Figure 4: Measured groundwater levels at RMP PET0172, along with Minimum Threshold and Measureable Objective groundwater level proxies for depletion of interconnected surface water by groundwater pumping.

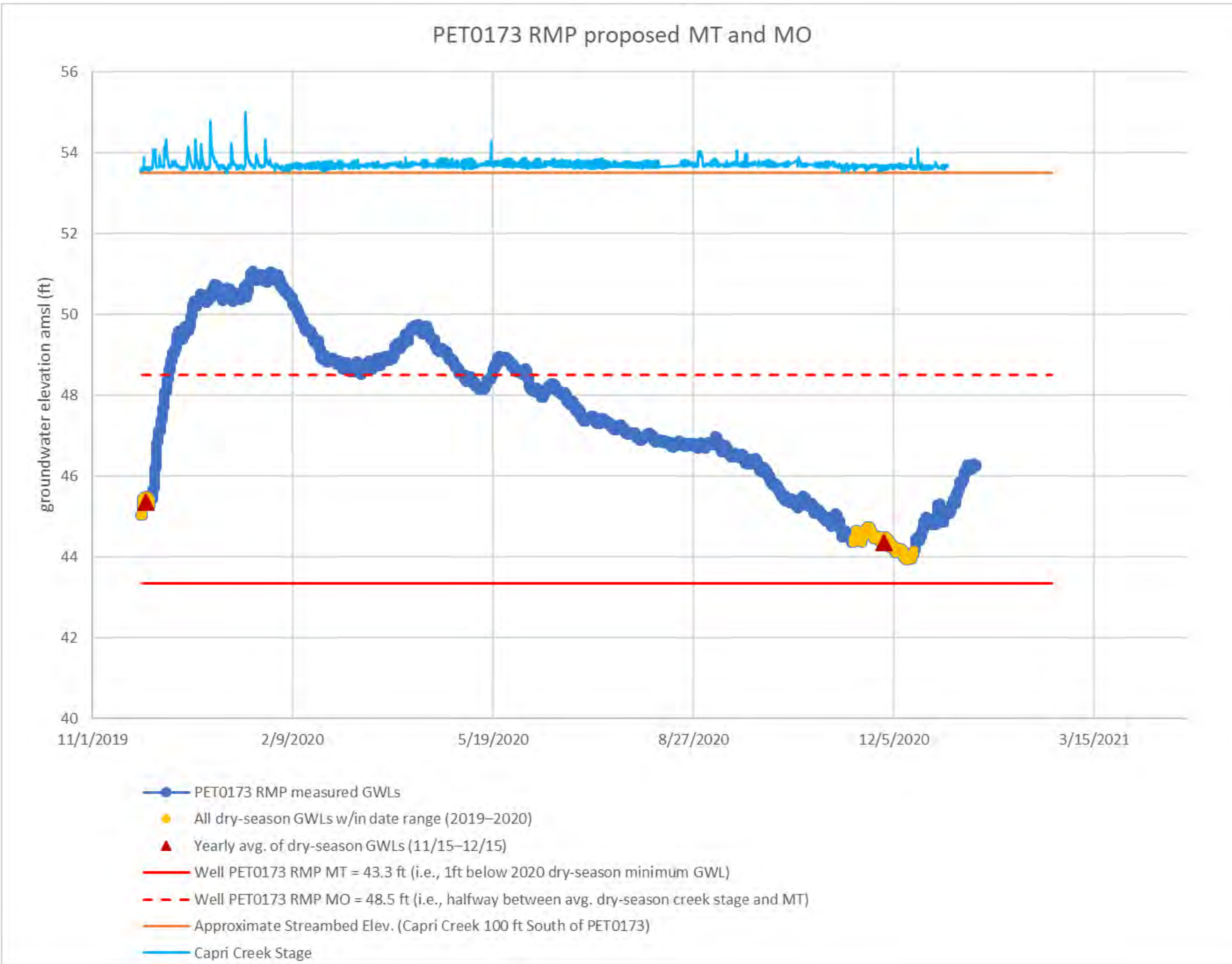

Figure 5: Measured groundwater levels at RMP PET0173, along with Minimum Threshold and Measureable Objective groundwater level proxies for depletion of interconnected surface water by groundwater pumping.

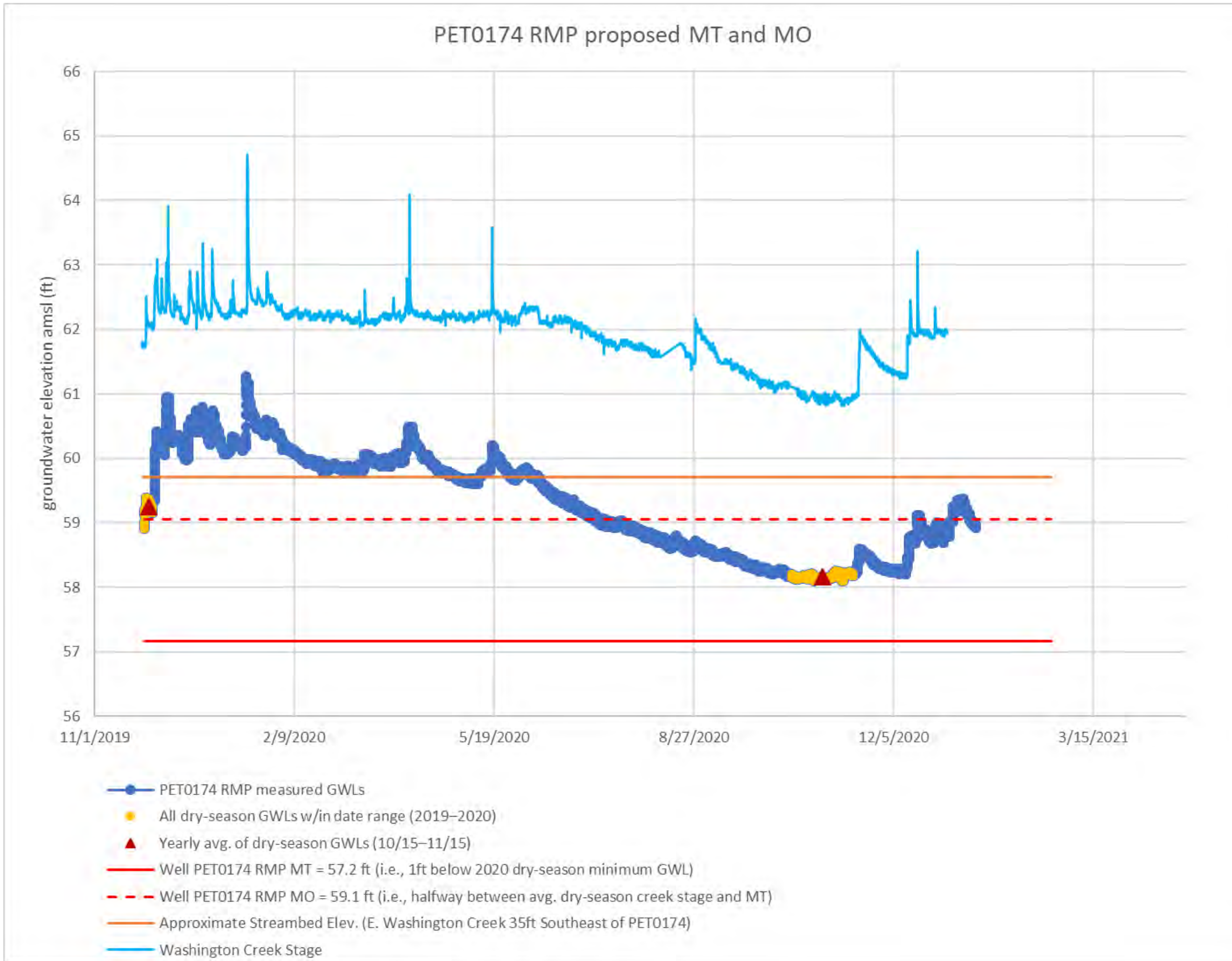

Figure 6: Measured groundwater levels at RMP PET0174, along with Minimum Threshold and Measureable Objective groundwater level proxies for depletion of interconnected surface water by groundwater pumping.

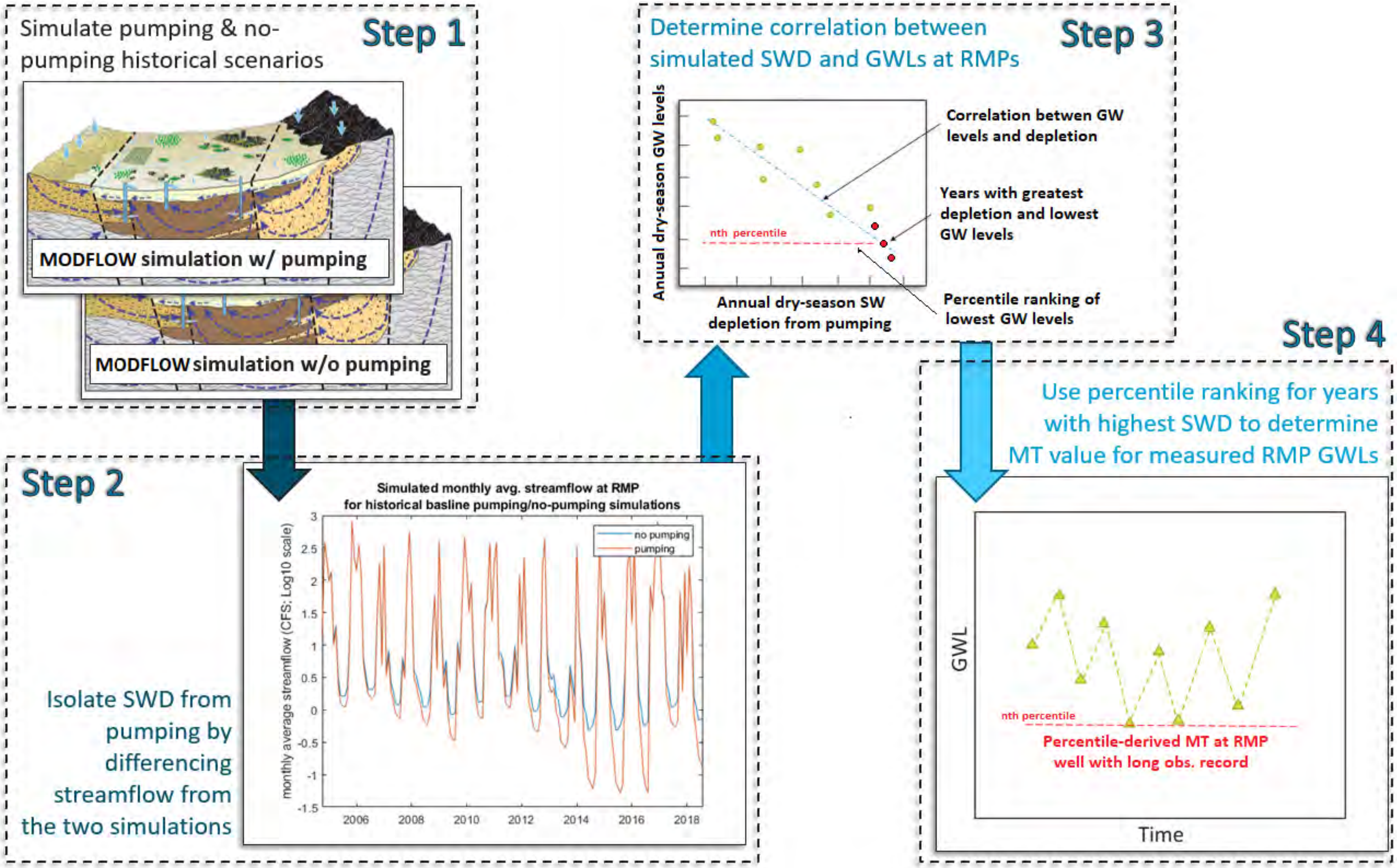

Figure 5: Future methodology conceptualization for establishing depletion of interconnected surface water SMCs.

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	½ distance between MT and 2019–20 dry season stream stage
PET0173	43.3	1ft below 2020 dry-season low GWL	48.5	½ distance between MT and 2019–20 dry season stream stage
PET0174	57.2	1ft below 2020 dry-season low GWL	59.1	½ distance between MT and 2019–20 dry season stream stage

notes:

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