Table 3-2. Summary of Historical and Current Water Budget Time Periods

Time Period	Proposed Date Range	WY Types Represented in Time Period	Rationale
Historical	WYs 1976 to 2018	Very dry: 1 Dry: 7 Normal: 20 Wet: 13 Very wet: 2	Based on entire model timeframe (after a 1-year model spin-up period). Provides insights on water budget response to a wide range of variations in climate and groundwater use over an extensive period of record.
Current	WYs 2012 to 2018	Very dry: 0 Dry: 2 Normal: 4 Wet: 1 Very wet: 0	Best reflection of current land use and water-use conditions with a range of recent climate variability.

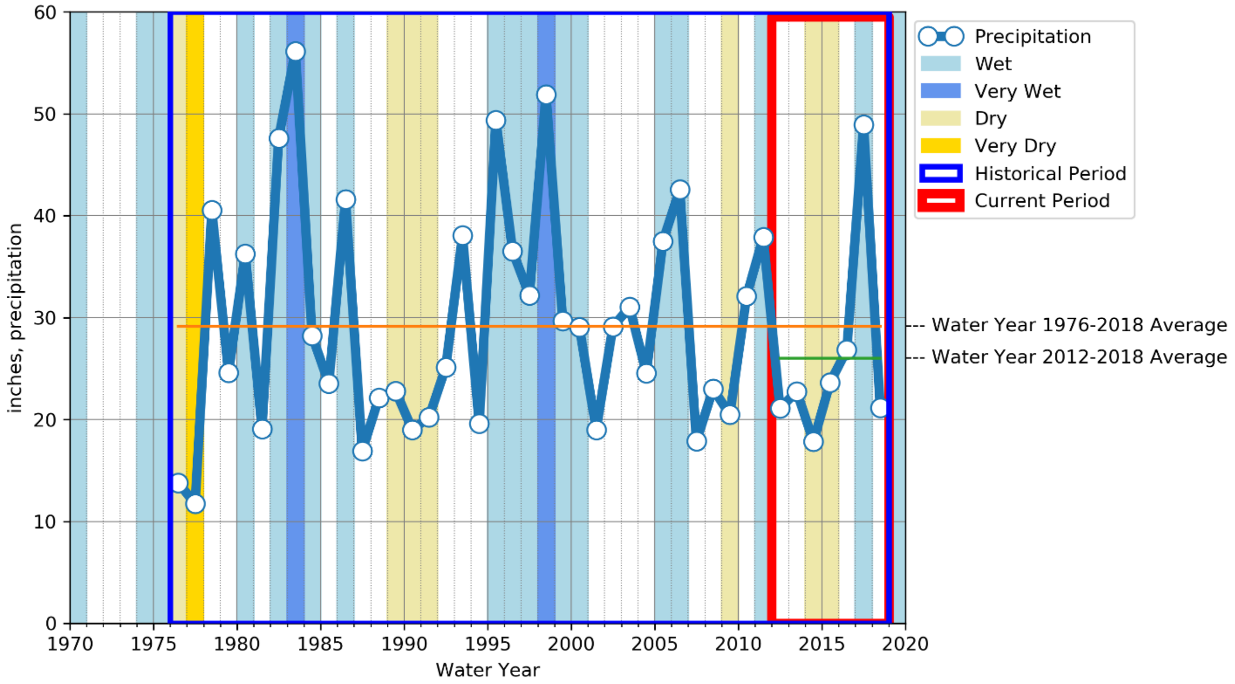

Figure 3-23. Climate and Precipitation for Historical and Current Water Budget Time Periods
Years with no color are "normal" water year type.

Historical Water Budgets Time Period

The only specific GSP guideline requirement is that the historical water budget be at least 10 years.

From Section 354.18. Water Budget: A quantitative assessment of the historical water budget, starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the tools and methods used to estimate and project future water budget information and future aquifer response to proposed sustainable groundwater management practices over the planning and implementation horizon.

The water budget is computed using the revised SRPHM, which simulates the time period from October 1974 to December 2018 encompassing the period of best available science and information for the Subbasin. It is recommended that the first year of the model simulation is used as a “spin-up” period to account for possible boundary effects influences of initial conditions; in other words, so that the model equilibrates with the initial conditions. The SRPHM fully covers WYs 1975 to 2018, and therefore, the historical period is selected to encompass WYs 1976 to 2018 (a 43-year period).

Current Water Budgets Time Period

The current water budget time period is also computed using the revised SRPHM and is based on the average of conditions between WYs 2012 through 2018 (a 7-year period). This time period includes 2 years classified as dry, 1 year classified as wet, and 4 years classified as normal, providing both pre-and post-drought WYs so that a variety of WY types are covered in the current average. This time period is also most reflective of current and recent patterns of groundwater use and imported surface water deliveries.

Future Projected Water Budgets Time Period

Future projected conditions are based on model simulations using the revised SRPHM numerical flow model and using projected land use changes, population growth estimates, and a projected climate change scenario. Projected climate based on the selected general circulation model (GCM) will represent WY 2020 through 2071.

3.3.2 Overview of Model Assumptions for Water Budget Development

All groundwater models contain assumptions and some level of uncertainty, particularly when predicting future conditions. Model uncertainty stems from heterogeneity in Subbasin and the surrounding watershed geology, hydrology, and climate, in addition to assumptions regarding unmetered groundwater pumping. However, inputs to the SRPHM are carefully selected using best available data, resulting in a model well suited to simulate Subbasin hydrogeologic conditions. As GSP implementation proceeds, the SRPHM will be updated and recalibrated with new data to better inform model simulations of current and projected water budgets.

The USGS report discusses model assumptions and uncertainty. Some of the more significant model limitations identified by the USGS include uncertainties in the following:

- Estimates and spatial distribution of agricultural and rural domestic pumpage
- Amount and spatial distribution of precipitation
- Long-term streamflow discharge
- Vertical distribution of hydraulic head in deeper aquifer zones

Figure 3-24 depicts the SRPHM modules that contribute to the various water budget components. **Table 3-3** provides the detailed water budget components and model assumptions and limitations for each.

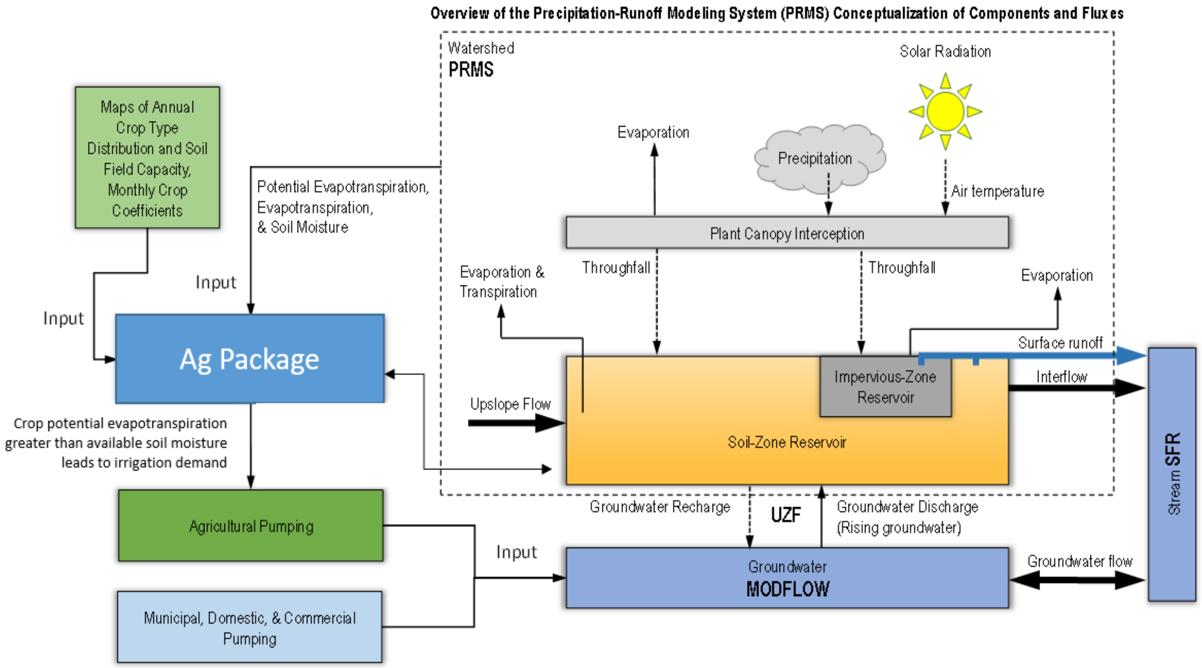

Figure 3-24. Overview of the SRPHM Modules

Table 3-3. Santa Rosa Plain Hydrologic Model - Summary of Water Budget Component Data Sources

Water Budget Component	Source of Model Input Data	Limitations
Precipitation	Measured precipitation at two stations within the Subbasin; spatially distributed for historical simulations.	Spatial distribution of precipitation may change with changing climate.
ET from Soil Zone	Measured and estimated temperature spatially distributed for historical simulations from two climate stations; future climate temperature uses same spatial distribution as historical simulations. Simulated from calibration to potential ET.	Not simulated from surface water bodies or riparian vegetation.
Soil Moisture	Simulated from calibrated model.	Not measured but based on calibration of streamflow to available data from gaged creeks.
Surface Water Inflows		
Inflow from Streams Entering Basin	Simulated from calibrated model for all creeks.	Not all creeks are gaged.
Groundwater Discharge to Streams	Simulated from calibrated model.	Based on calibration of streamflow to available data from gaged creeks.

Water Budget Component	Source of Model Input Data	Limitations
Overland Runoff	Simulated from calibrated model.	Based on calibration of streamflow to available data from gaged creeks.
Surface Water Outflows		
Streambed Recharge to Groundwater	Simulated from calibrated model.	Based on calibration of streamflow to available data from gaged creeks.
Diversions	Not modeled.	Diversions known to exist, but are currently limited in number and small in magnitude.
Streambed Recharge to Groundwater	Simulated from calibrated model.	Based on calibration of streamflow to available data from gaged creeks.
Groundwater Inflows		
Deep Percolation of Precipitation	Measured precipitation spatially distributed for historical simulations and percolation simulated by watershed component of calibrated model.	Based on calibration of streamflow to available data from gaged creeks. Simulated model output combined with irrigation return flows.
Streambed Recharge to Groundwater	Simulated from calibrated model.	Based on calibration of streamflow to available data from gaged creeks.
Irrigation Return Flows	Simulated from demands based on crop, acreage, temperature, and soil-zone processes.	Based on land use datasets of 8 years to represent historical period and regional crop coefficient values. Simulated model output combined with deep percolation of precipitation. These years are 1976, 1979, 1986, 1999, 2008, 2012, 2014, and 2016.
Septic System Return Flows	Estimated based on percentage of indoor water use for non-sewered parcels.	Based on uniform estimates indoor use and estimate of return flow from indoor use.
Subsurface Inflow from Neighboring Basins	Simulated from calibrated model.	Limited groundwater calibration data in adjacent basins.
Subsurface Inflow from Surrounding Watershed Other than Neighboring Basins	Simulated from calibrated model.	Limited data for calibration.
Groundwater Outflows		
Groundwater Pumping	Metered for historical municipal pumping and some small water systems.	Nonmunicipal domestic pumping based on uniform estimate of indoor use per parcel and uniform irrigation depth. Simulated agricultural irrigation based on land use datasets of 8 years to represent historical period and regional crop coefficient values.
	Estimated for nonmunicipal domestic pumping.	
	Simulated from model for agricultural and large-scale turf irrigation.	
Groundwater Discharge to Streams	Simulated from calibrated model.	Based on calibration of streamflow to available data from gaged creeks.

Water Budget Component	Source of Model Input Data	Limitations
Subsurface Outflow to Adjacent Basins	Simulated from calibrated model.	Limited calibration data in adjacent boundaries.
Riparian ET	Simulated from calibrated model.	Based on uniform extinction depth.
Surface Leakage (Flow to Soil Zone)	Simulated from calibrated model.	Based on calibration of streamflow to available data from gaged creeks.

3.3.3 Historical and Current Water Budgets

Water budgets for the historical (WYs 1976–2018) and current (WYs 2012–2018) are presented in 3.3.3.1 and 3.3.3.2. The surface water budgets are presented first, then the groundwater budgets are presented. Watershed budgets are also presented to show how precipitation provides water supply to the surface water and groundwater budgets, as well as a soil-zone budget of the Subbasin. The detailed surface water, watershed, and soil-zone water budgets are not required components of the GSP but are presented to provide insight into the hydrologic cycle in the Subbasin.

3.3.3.1 Surface Water Budget

The surface water budget shows the inflows and outflows for the streams within the Santa Rosa Plain Subbasin. This includes streamflows of tributaries that enter and exit the Subbasin as well as flows into and out of streams within the Subbasin. The number of stream inflow and outflows locations for each HUC 12 and stream are presented in **Table 3-4**. Flows within the Subbasin include overland runoff to streams and stream-aquifer interactions (net streambed exchange). The model does not simulate diversions from the streams. Stream-aquifer interactions within the Subbasin, including recharge to groundwater and discharge from groundwater, are also part of the groundwater budget. The net streambed exchange is not equal to the net stream leakage in the groundwater budget because there may be flow out of streams to the unsaturated zone.

Figure 3-25 shows the surface water budget for the historical period, which also includes the current period. **Table 3-5** and **Table 3-6** show summary statistics of surface water budget for the historical and current periods, respectively. Positive values are inflows into the stream system, and negative values are outflows from the stream system. A positive net streambed exchange indicates more groundwater discharge to streams than stream seepage to groundwater. Boundary inflows and outflows dominate the surface water budget. **Figure 3-26** indicates that streamflows exiting the Subbasin are generally double the streamflows entering the Subbasin, which is primarily due to overland runoff that occurs within the Subbasin. On average, groundwater discharge to streams exceeds streambed losses, resulting in a net streambed exchange into streams of approximately 300 AFY. The value of the net streambed exchange depends less on year-to-year variability in precipitation, and more on 5- to 10-year (climatic) variability in precipitation. WY 2017 is one of the top 3 wettest years in the historical period but still experiences a negative streambed exchange. This is because WYs 2012 to 2016 were all dry or normal precipitation years. Consequently, in the current period there is a negative net streambed exchange of -1,300 AFY. **Figure 3-26** shows net stream inflows and outflows at the Subbasin boundaries by HUC 12 subregion. Subregions with negative flows are those where the streamflow is greater at its outflow than at its inflows at Subbasin boundaries, and those with positive values have greater inflows than outflows (**Figure 3-26**). Not all subregions have both inflows and outflows that cross the Subbasin boundary. **Table 3-4** lists the number of inflow and outflow locations by HUC region and stream name. Mark West Creek, for example, crosses the Subbasin boundary at the eastern and the western boundary before finally discharging from the basin near Trenton. The largest net streamflows entering the Subbasin are from Upper Santa Rosa Creek and Upper Laguna de Santa Rosa. The largest net streamflows exiting the Subbasin are from Porter Creek-Mark West Creek and Windsor Creek (**Figure 3-26**). The net combined surface water outflow from the Subbasin ranges from 47,000 to 1,165,000 AFY. **Figure 3-27** displays only stream inflows entering the Subbasin, as well as removing intermediate inflows and outflows. Intermediate flows are inflows and outflows where stream segments leave and re-enter the basin. The largest inflows into the Subbasin are from Porter Creek-Mark West Creek and Upper Santa Rosa Creek.

Figure 3-28 shows the surface water budget components as hydrographs for a wet WY and a normal WY. WY 1999 is the fifth of 5 consecutive wet WYs, whereas WY 2016 is a normal WY that follows 2 previous dry WYs in 2014 and 2015. In WY 1999 stream inflows at the Subbasin boundary and overland runoff are the main contributors to flows from December to May. From December to March net streambed recharge averages roughly zero, then becomes consistently positive from April until the end of the WY. The stream budget is distinctly different in the normal WY of 2016. Early in the WY of 2016, from October to February, net streambed exchange is entirely into the groundwater system from the streambed, generating about 2,000 acre-feet of recharge in both January and February. In the summer, the groundwater system provides baseflow in May and June, but this tapers off by July when the surface water system returns to losing water to the groundwater system.

Average monthly budget components for the surface water system are shown on **Figure 3-29** for the historical and current budget periods. The historical period receives greater surface water inflows at the boundaries than does the current period for the first half of the calendar year. For the second half of the calendar year the current period has greater stream inflows and outflows at the Subbasin boundary. The historic period net stream recharge is either more positive than, or less negative than, the current period net stream recharge from March through December. This likely reflects the impacts of a drier current period than the historical period and the cumulative impacts of groundwater pumpage.

Table 3-4. Number of Stream Inflow and Outflow Locations for Each HUC 12 Area and Major Stream[a]

HUC 12 Region Name	Stream Name	Number of Stream Inflow Segments	Number of Stream Outflow Segments
Lower Laguna De Santa Rosa	Small Stream	2	0
Lower Santa Rosa Creek	Small Stream	2	0
Petaluma River-Estero de San Antonio	Small Stream	0	2
Porter Creek-Mark West Creek	Mark West Creek	2	2
Porter Creek-Mark West Creek	Small Stream	3	2

HUC 12 Region Name	Stream Name	Number of Stream Inflow Segments	Number of Stream Outflow Segments
Porter Creek-Russian River	Small Stream	4	7
Upper Laguna de Santa Rosa	Blucher Creek	1	0
Upper Laguna de Santa Rosa	Colgan Creek	1	0
Upper Laguna de Santa Rosa	Copeland Creek	1	0
Upper Laguna de Santa Rosa	Crane Creek	1	0
Upper Laguna de Santa Rosa	Gossage Creek	1	0
Upper Laguna de Santa Rosa	Small Stream	12	4
Upper Santa Rosa Creek	Matanzas Creek	1	0
Upper Santa Rosa Creek	Santa Rosa Creek	1	0
Upper Santa Rosa Creek	Small Stream	2	1
Windsor Creek	Pool Creek	1	0
Windsor Creek	Small Stream	3	1
Windsor Creek	Windsor Creek	1	1
Windsor Creek	Wright Creek	1	0

[a] Refer to **Figure 3-22** for HUC 12 Regions and Streams.

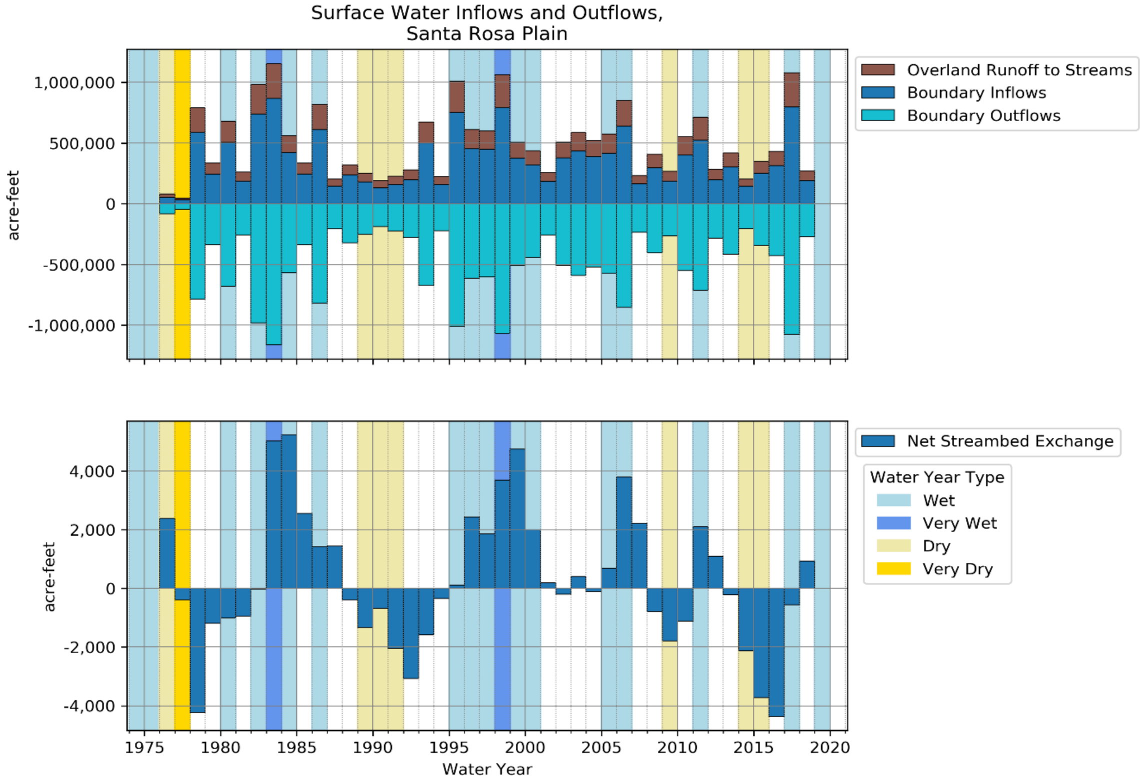

Figure 3-25. Historical and Current Surface Water Budget

Table 3-5. Historical (WY 1976 to WY 2018) Surface Water Budget Summary (AFY)[a]

	Net Streambed Exchange	Overland Runoff to Streams	Boundary Outflows	Boundary Inflows
Mean	300	130,200	-492,200	362,000
Minimum	-4,400	15,700	-1,161,600	31,200
Maximum	5,200	288,900	-46,600	868,500
Median	-100	118,600	-427,600	312,300

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-6. Current (WY 2012 to WY 2018) Surface Water Budget Summary (AFY)[a]

	Net Streambed Exchange	Overland Runoff to Streams	Boundary Outflows	Boundary Inflows
Mean	-1,300	119,900	-432,200	313,700
Minimum	-4,400	64,000	-1,077,900	142,600
Maximum	1,100	282,100	-204,500	797,000
Median	-600	95,300	-342,900	251,300

[a] Values are rounded to the nearest 100 acre-feet.

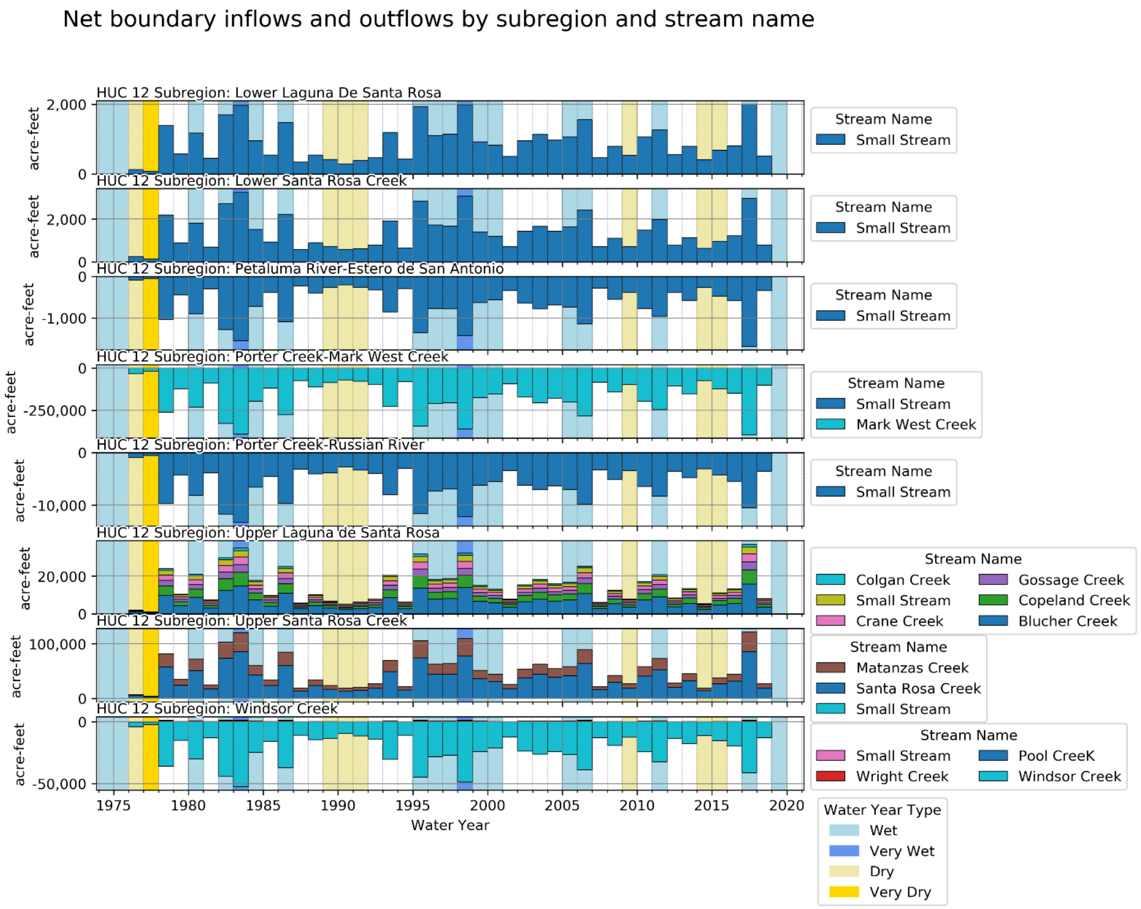

Figure 3-26. Net Boundary Inflows and Outflows by HUC 12 Subregion and Stream Name

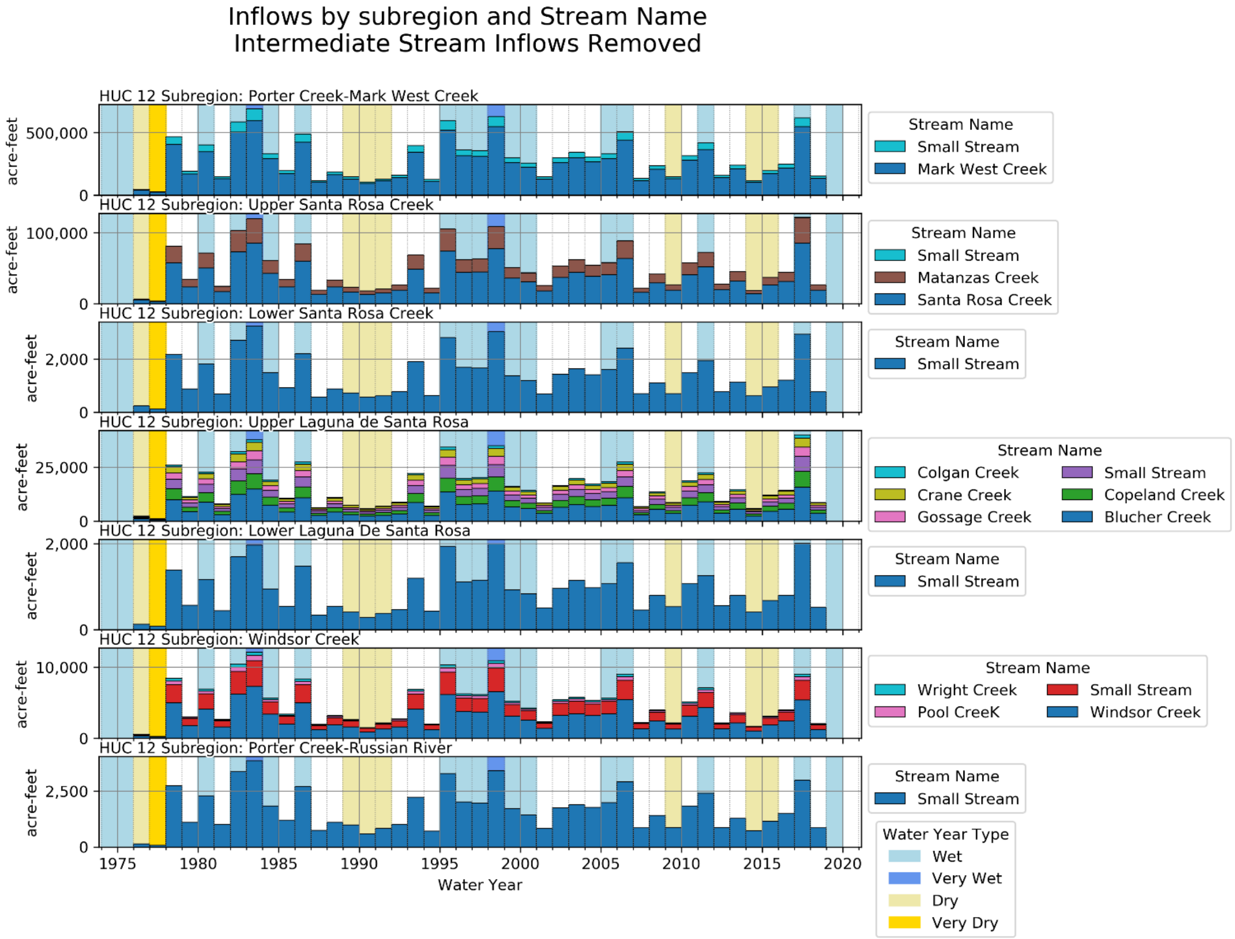

Figure 3-27. Inflows by HUC 12 Subregion and Stream Name[1]

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[1] Intermediate inflows removed; values intended to represent surface inflows at headwaters where streams cross the boundary the first time. Some streams cross the Subbasin boundary multiple times, but only the inflows from the initial inflow location are shown here.

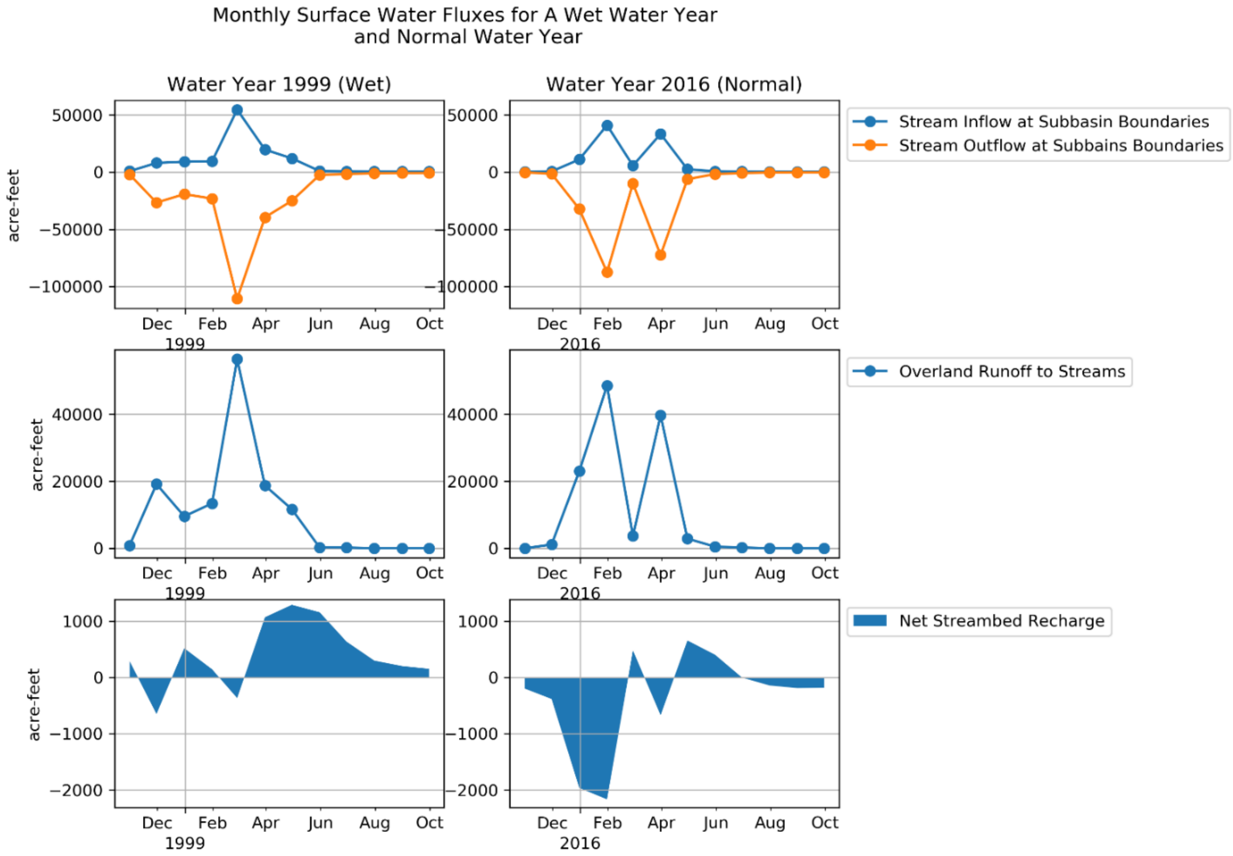

Figure 3-28. Monthly Surface Water Fluxes for a Wet Water Year and Normal Water Year

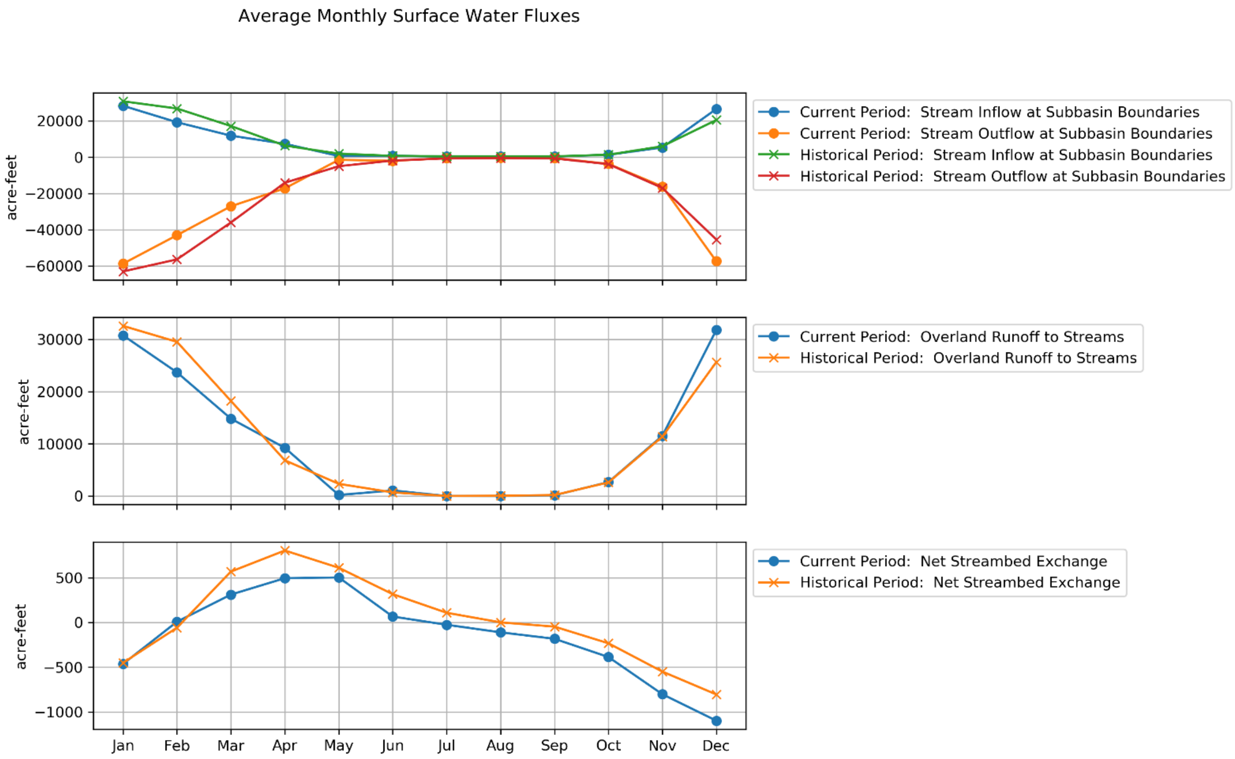

Figure 3-29. Average Monthly Surface Water Fluxes the Historical and Current Periods

3.3.3.2 Groundwater Budget

The groundwater budget shows the inflows and outflows for the saturated aquifer system of the Santa Rosa Plain Subbasin. This includes inflows and outflows of groundwater at the Subbasin boundaries, recharge, pumping, and flows of groundwater to and from streams, the surface, and the ET.

Figure 3-30 shows inflows to the groundwater system for the historical and current time periods. The majority of groundwater inflow into the Subbasin are: (1) the percolation of precipitation and applied agricultural irrigation water (53 percent of total), (2) streambed recharge (28 percent of total), and (3) subsurface inflow from neighboring DWR groundwater basins and subbasins (14 percent of total).

Table 3-7 and **Table 3-8** provide summary statistics for groundwater inflows for the historical and current period, respectively. The largest inflow is deep percolation of precipitation and applied irrigation water and the next largest inflow is inflows stream recharge for the historical and current time periods. In general, the historical and current inflows are similar; however, the current deep percolation is about 88 percent of the historical average value, reflecting the lower average precipitation in the current period.

Figure 3-31 shows outflows from the groundwater system for the historical and current time periods. **Table 3-9** and **Table 3-10** provide summary statistics for groundwater outflows of the historical and current period, respectively. Groundwater pumping is the biggest stress (municipal and industrial [M&I] and rural domestic users and agricultural) followed by discharge to streams for the historical and current time periods. ET from groundwater and groundwater leakage to the surface soil zone are also substantial outflows. Total groundwater pumpage during the historical and current time periods was fairly constant.

Figure 3-32 shows the entire groundwater water budget and includes the annual change in groundwater storage. Change in groundwater storage is equal to total inflow minus total outflow in the groundwater budget. A negative change in groundwater storage indicates groundwater-storage depletion while a positive value indicates groundwater-storage accretion. Cumulative groundwater storage represents the total change in storage over a given period. The maximum (positive) cumulative storage change occurred in the wet period in WY 1983 and the lowest cumulative storage change occurred in WY 1992 following a period of dry and normal years, and concurrent municipal groundwater pumping.

Table 3-11 shows the annual change in groundwater storage for the historical and current budget periods. On average, the historical period shows a negative change in groundwater storage with a larger magnitude negative change in groundwater storage during the current period, which includes the recent drought. The increased rate of groundwater-storage depletion during the recent period appears to be more a result of a drier climate than increased groundwater pumping during that period. This is supported by **Figure 3-33**, showing groundwater pumpage by water-use sector, along with the 5-year moving average for the historical period. The peak of the 5-year moving average of the current period (21,000 AFY) is exceeded 5 years of the 2000 to 2011 period, indicating that total groundwater pumpage for the current period is not greater than the previous 12-year period. (**Table 3-12** and **Table 3-13** shows the historical and current groundwater pumpage by sector.) The continued decline in groundwater storage reflects a Subbasin that has not yet reached a dynamic equilibrium between the inflows and outflows. If the Subbasin is to reach dynamic equilibrium (that is, zero groundwater storage decline over a multiyear period) with the same average groundwater pumpage and a climate that is comparable to the current period, rates of depletion of surface water depletion will continue to increase (Barlow and Leake 2012). In this case, surface water depletion refers to the pumping-induced decline in surface water flows caused by decreased aquifer discharge to streams or groundwater ET, or by increased discharge to groundwater from streams. If surface water depletion does not increase, pumpage remains the same, and a similar climate persists, the Subbasin will experience continued declines in groundwater storage. The average annual results indicate that about 3 percent of pumpage was supplied by groundwater-storage depletion.

Figure 3-34 and **Table 3-14** and **Table 3-15** show net subsurface flows entering and exiting the Subbasin by watershed and neighboring subbasin. The Subbasin is a net recipient of inflows from surrounding groundwater basins and watershed areas. Subsurface inflows from adjacent basins exceed subsurface outflows by approximately a factor of 5. The largest subsurface inflows are from the Rincon-Kenwood and Wilson Grove Subbasins. The largest subsurface outflows are to the Healdsburg Area Subbasin.

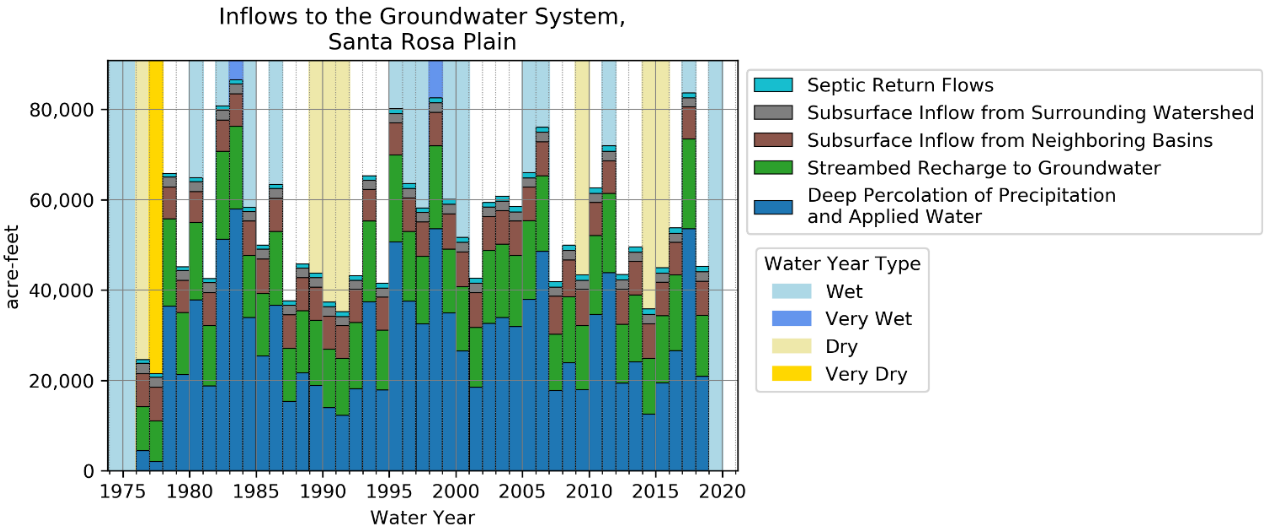

Figure 3-30. Inflows to the Groundwater System

Table 3-7. Historical (WY 1976 to WY 2018) Groundwater Inflows Budget Summary (AFY)[a]

	Deep Percolation of Precipitation and Applied Water	Streambed Recharge to Groundwater	Septic Return Flows	Subsurface Inflow from Surrounding Watershed	Subsurface Inflow from Neighboring Basins
Mean	28,700	15,100	1,000	2,100	7,400
Minimum	2,000	9,100	800	2,000	6,900
Maximum	58,100	19,700	1,200	2,300	8,400
Median	26,500	14,700	1,100	2,100	7,400

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-8. Current (WY 2012 to WY 2018) Groundwater Inflows Budget Summary (AFY)[a]

	Deep Percolation of Precipitation and Applied Water	Streambed Recharge to Groundwater	Septic Return Flows	Subsurface Inflow from Surrounding Watershed	Subsurface Inflow from Neighboring Basins
Mean	25,200	14,900	1,200	2,000	7,400
Minimum	12,600	12,300	1,200	2,000	7,100
Maximum	53,400	19,700	1,200	2,100	7,700
Median	20,800	14,700	1,200	2,000	7,400

[a] Values are rounded to the nearest 100 acre-feet.

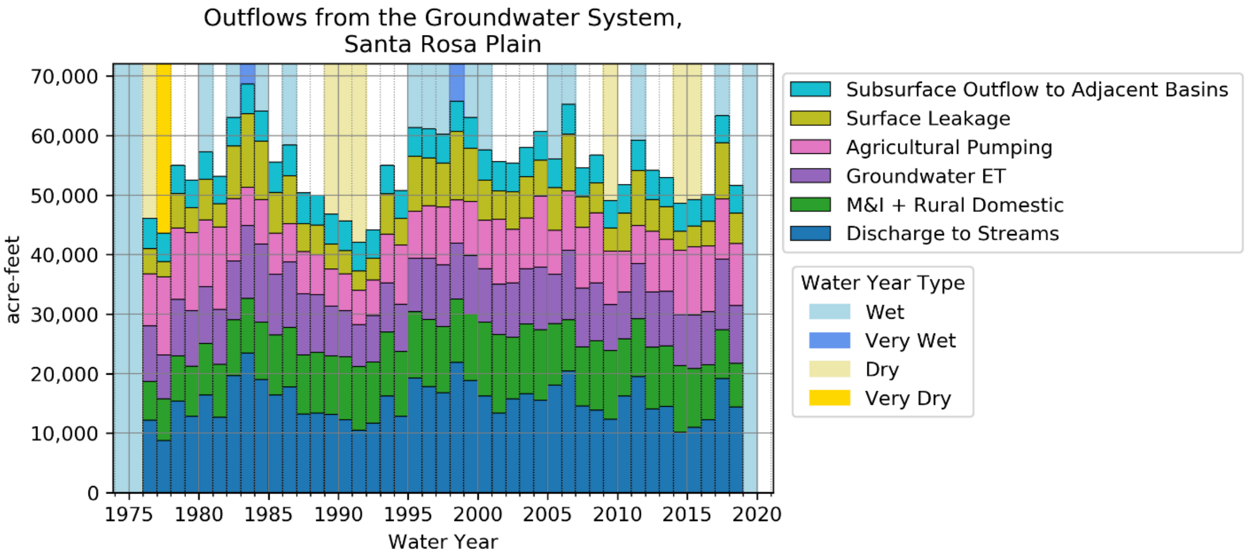

Figure 3-31. Outflows from the Groundwater System

Table 3-9. Historical (WY 1976 to WY 2018) Groundwater Outflows Budget Summary (AFY)[a]

	Agricultural Pumping	Groundwater ET	Subsurface Outflow to Adjacent Basins	Discharge to Streams	Surface Leakage	M&I + Rural Domestic
Mean	9,100	9,400	4,900	15,400	6,200	10,000
Minimum	5,700	7,100	4,500	8,700	2,500	6,500
Maximum	13,900	13,100	5,200	23,400	12,300	13,200
Median	9,000	9,300	4,900	15,400	5,800	10,100

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-10. Current (WY 2012 to WY 2018) Groundwater Outflows Budget Summary (AFY)[a]

	Agricultural Pumping	Groundwater ET	Subsurface Outflow to Adjacent Basins	Discharge to Streams	Surface Leakage	M&I + Rural Domestic
Mean	10,400	9,500	4,700	13,700	5,200	9,500
Minimum	8,700	8,600	4,500	10,200	3,200	7,300
Maximum	11,400	11,800	5,000	19,200	9,500	11,200
Median	10,400	9,200	4,700	14,100	5,100	9,900

[a] Values are rounded to the nearest 100 acre-feet.

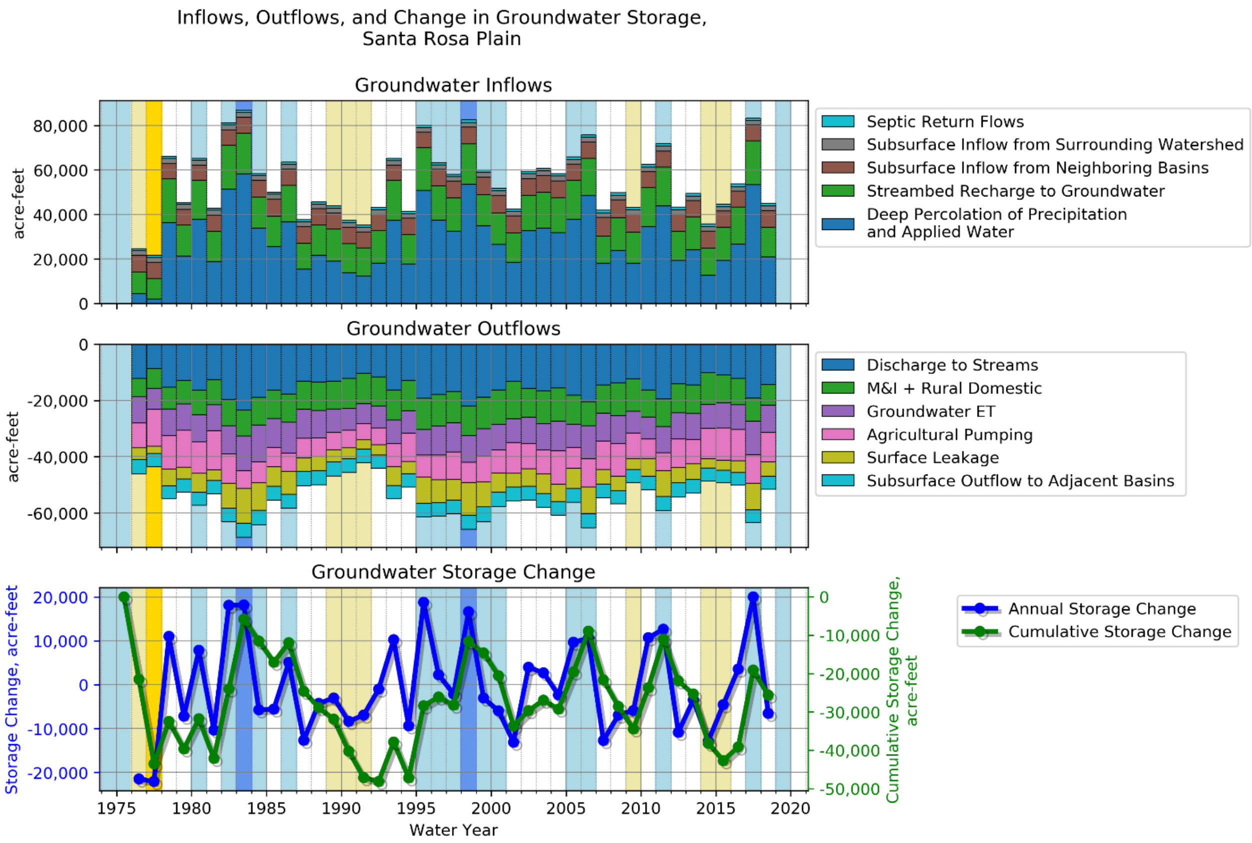

Figure 3-32. Historical and Current Groundwater Budget

Table 3-11. Average Annual Change of Groundwater in Storage (AFY)[a]

	Historical[a] (WY 1976 to WY 2018)	**Current (WY 2012 to WY 2018)**
Mean	-600	-2,100
Minimum	-22,000	-12,900
Maximum	20,000	20,000
Median	-3,000	-4,500

[a] Values may not equal inflows minus outflows due to rounding.

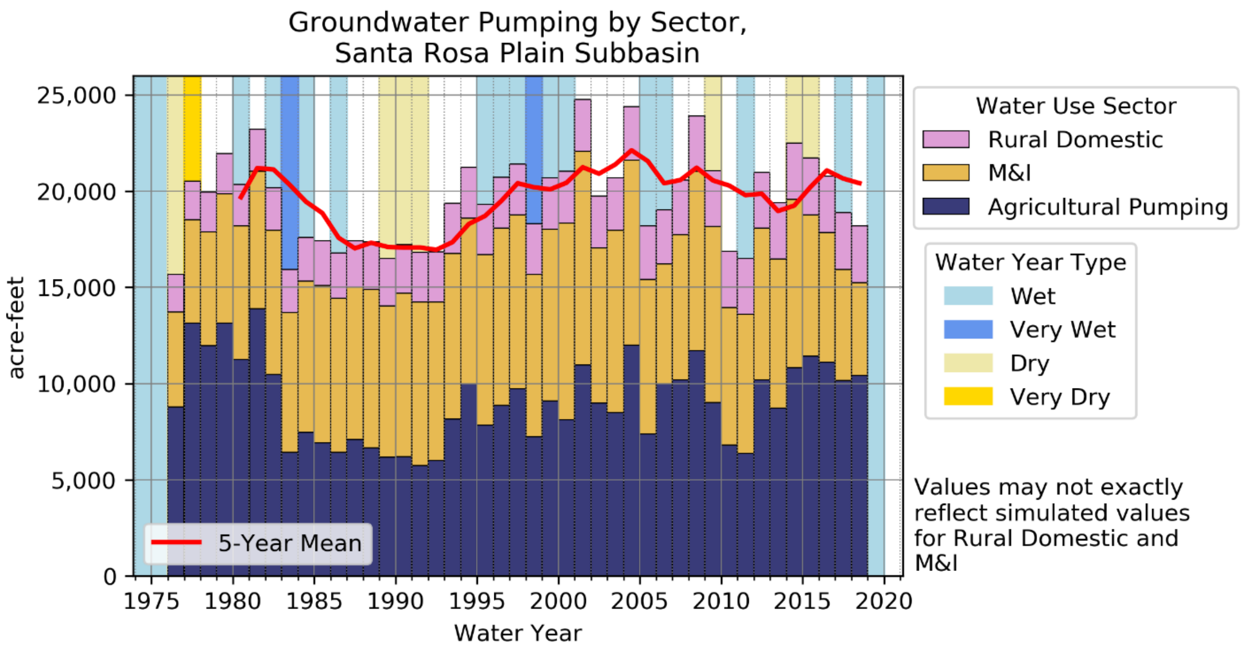

Figure 3-33. Groundwater Pumpage by Water-use Sector[2]

Table 3-12. Historical (WY 1976 to WY 2018) Groundwater Pumpage by Water-use Sector (AFY)[a]

	M&I	Rural Domestic	Agricultural Pumping
Mean	7,900	2,600	9,100
Minimum	4,800	2,000	5,700
Maximum	11,100	2,900	13,900
Median	8,000	2,600	9,000

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-13. Current (WY 2012 to WY 2018) Groundwater Pumpage by Water-use Sector (AFY)[a]

	M&I	Rural Domestic	Agricultural Pumping
Mean	7,000	2,900	10,400
Minimum	4,800	2,900	8,700
Maximum	8,800	2,900	11,400
Median	7,300	2,900	10,400

[a] Values are rounded to the nearest 100 acre-feet.

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[2] The values shown for M&I and rural-domestic are not equal to the combined outflows on **Figure 3-31** because of the manner in which boundary conditions (pumping) are treated by the model.

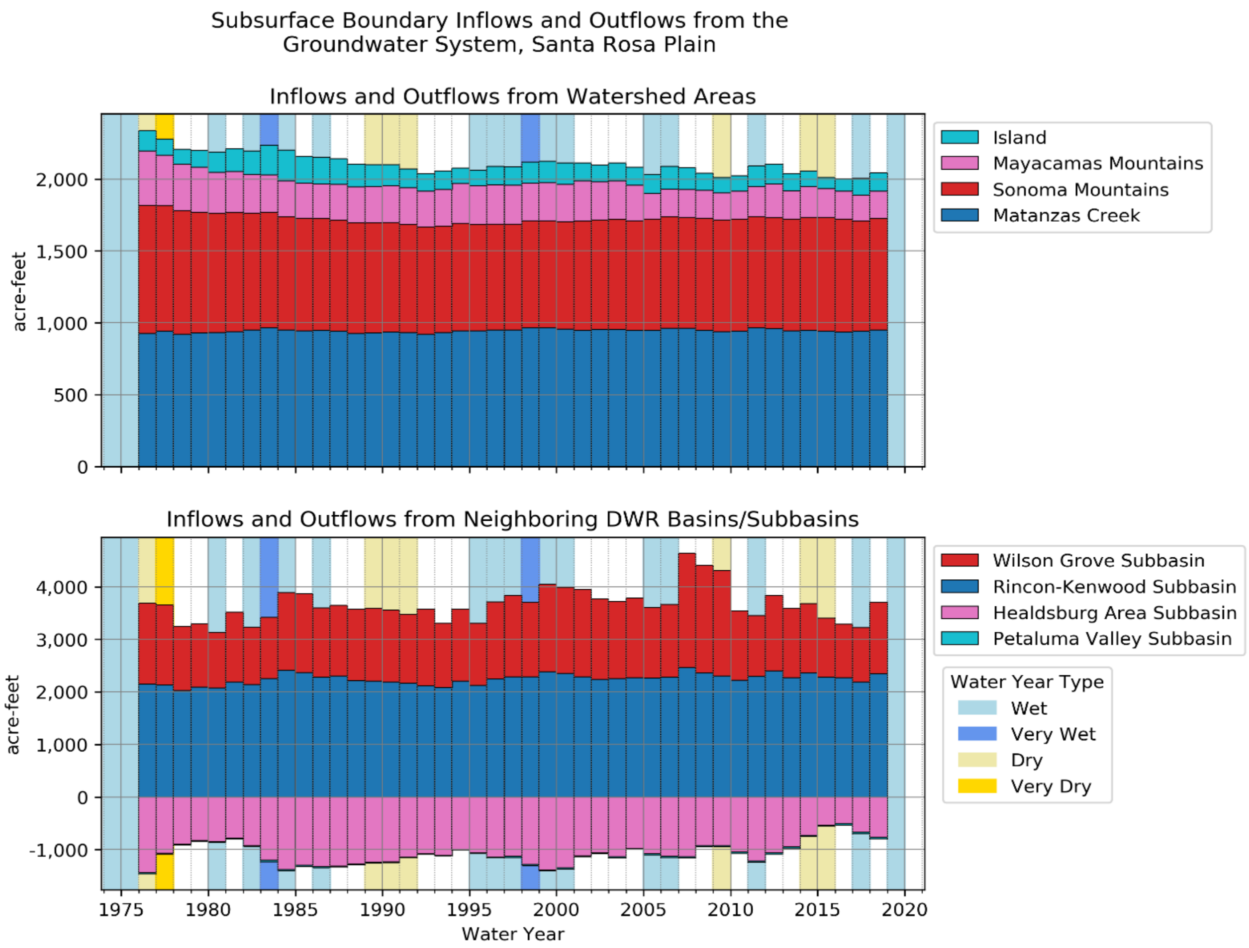

Figure 3-34. Inflows and Outflows from Watershed Areas and Neighboring Basins/Subbasins

Table 3-14. Historical (WY 1976 to WY 2018) Subbasin Boundary Flows (AFY)[a]

	Petaluma Valley Basin	Rincon-Kenwood Subbasin	Healdsburg Area Subbasin	Wilson Grove Subbasin
Mean	-20	2,200	-1,100	1,400
Minimum	-30	2,000	-1,400	1,000
Maximum	-10	2,500	-500	2,200
Median	-20	2,300	-1,100	1,400

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-15. Current (WY 2012 to WY 2018) Subbasin Boundary Flows (AFY)[a]

	Petaluma Valley Basin	Rincon-Kenwood Subbasin	Healdsburg Area Subbasin	Wilson Grove Subbasin
Mean	-20	2,300	-700	1,200
Minimum	-30	2,200	-1,100	1,000
Maximum	-20	2,400	-500	1,400
Median	-20	2,300	-700	1,300

[a] Values are rounded to the nearest 100 acre-feet.

3.3.3.3 Watershed and Soil-zone Budget

Watershed budgets show how precipitation and applied water are apportioned to surface water and the soil zone. In this case, “watershed” includes the watershed areas (Mayacamas Mountains, Sonoma Mountains, and Matanzas Creek) and portions of neighboring basins (Petaluma Valley) and subbasins (Healdsburg Area, Rincon-Kenwood, and Wilson Grove). **Figure 3-35** shows the watershed water budget for watershed areas outside the Subbasin for the historical and current period. **Table 3-16** and **Table 3-17** show the historical soil-zone fluxes and subsurface inflows, respectively, and **Table 3-18** and **Table 3-19** show current summary statistics for the soil-zone fluxes and subsurface inflows, respectively. In Precipitation Runoff Modeling System (PRMS), precipitation is first routed through vegetation, where it may be intercepted and transpired, then onto the surface where it may cause runoff depending on imperviousness, soil hydraulic conductivity, and surface storage. After these and other processes it will enter the soil zone as infiltration where it will get partitioned into the capillary and gravity reservoir. ET of soil moisture is the largest outflow of water within the soil zone. In drier years ET is significantly greater than the combined outflows of recharge and runoff from Dunnian runoff and interflow. Dunnian flow is surface flow that results from saturation excess in the soil zone, and interflow is water that infiltrates the soil zone and then flows laterally within that zone to a stream (Nishikawa et al. 2013a). In wetter periods recharge and runoff exceed total soil ET. This is because ET is limited by total soil moisture storage and potential ET. The soil-water storage responds to interannual variation in precipitation, whereas the boundary inflows into the Subbasin from the watershed areas do not fluctuate as readily. Surface flows into the Subbasin are orders of magnitude greater than subsurface inflows, though the fate of the surface water inflows depends on groundwater levels within the basin.

Figure 3-36 shows the soil-zone water budget for watershed areas within the Subbasin for the historical period. Compared to the watershed soil-zone fluxes, Dunnian flow is a significantly greater contributor to runoff than is interflow, indicating that soils are typically saturated during wet months when precipitation is rejected by the soil zone. Agricultural irrigation is relatively small compared to precipitation totals, at about 1/100th of average precipitation. Soil moisture storage responds quickly to interannual variability in precipitation; after the very dry WY of 1977, when the total soil moisture storage reached its minimum for the historical period, it recovered after 1 year of above average precipitation. **Tables 3-20** and **3-21** show summary statistics for the Subbasin soil-zone budget for the historical period and current period, respectively.

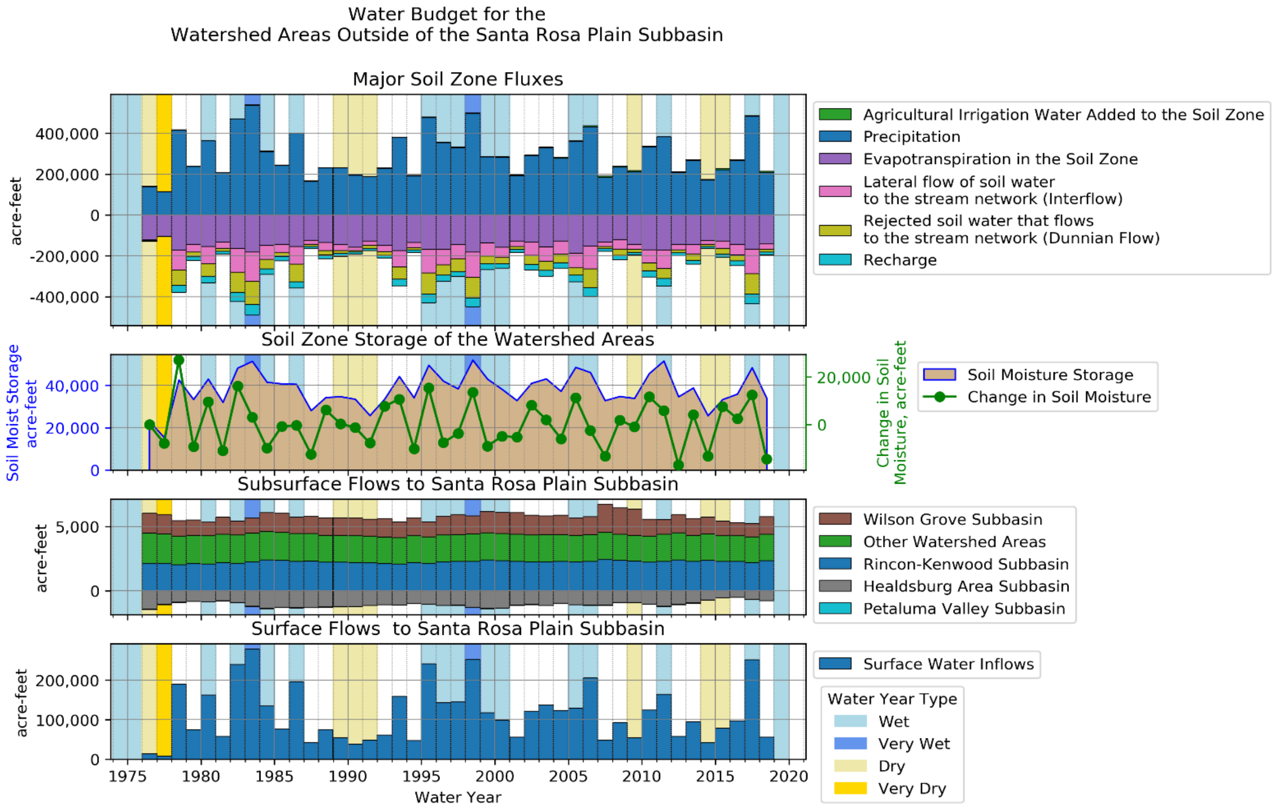

Figure 3-35. Historical and Current Budget for Watershed Areas Outside Subbasin

Table 3-16. Historical (WY 1976 to WY 2018) Budget for Watershed Areas Outside Subbasin and Major Soil-zone Fluxes[a]

	Precipitation (AFY)	Agricultural Irrigation Water Added to the Soil Zone (AFY)	ET in the Soil Zone (AFY)	Soil-zone Recharge (AFY)	Rejected soil water that flows to the stream network (Dunnian Flow; AFY)	Lateral flow of soil water to the stream network (Interflow; AFY)	Soil Moisture (acre-feet)	Change in Soil Moisture (AFY)
Mean	290,400	3,100	-147,600	-23,700	-40,100	-57,100	38,200	200
Minimum	112,500	1,000	-186,500	-51,600	-112,900	-143,100	15,400	-16,900
Maximum	536,800	6,100	-103,500	-900	-900	-900	52,000	27,200
Median	266,100	3,000	-144,800	-21,000	-31,600	-50,400	38,200	-200

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-17. Historical (WY 1976 to WY 2018) Budget for Watershed Areas Outside Subbasin, and Subsurface and Surface Inflows (AFY)[a]

	Other Watershed Areas	Surface Water Inflows
Mean	2,100	114,200
Minimum	2,000	8,400
Maximum	2,300	278,900
Median	2,100	98,000

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-18. Current (WY 2012 to WY 2018) Watershed Budget for Watershed Areas Outside Subbasin and Major Soil-zone Fluxes[a]

	Precipitation (AFY)	Agricultural Irrigation Water Added to the Soil Zone (AFY)	ET in the Soil Zone (AFY)	Soil-zone Recharge (AFY)	Rejected soil water that flows to the stream network (Dunnian Flow; AFY)	Lateral flow of soil water to the stream network (Interflow; AFY)	Soil Moisture (acre-feet)	Change in Soil Moisture (AFY)
Mean	260,300	4,300	-142,700	-20,200	-32,700	-45,900	35,900	-2,500
Minimum	169,700	3,300	-166,300	-47,100	-101,100	-120,800	25,700	-16,900
Maximum	482,800	4,700	-126,400	-8,700	-10,500	-17,600	48,400	12,500
Median	221,000	4,500	-144,400	-15,600	-27,900	-35,800	34,700	2,600

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-19. Current (WY 2012 to WY 2018) Watershed Budget for Watershed Areas Outside Subbasin, Subsurface Flows to Santa Rosa Plain Subbasin, and Surface Flows to the Subbasin[a]

	Other Watershed Areas	Surface Water Inflows
Mean	2,000	97,300
Minimum	2,000	41,900
Maximum	2,100	252,400
Median	2,000	79,600

[a] Values are rounded to the nearest 100 acre-feet.

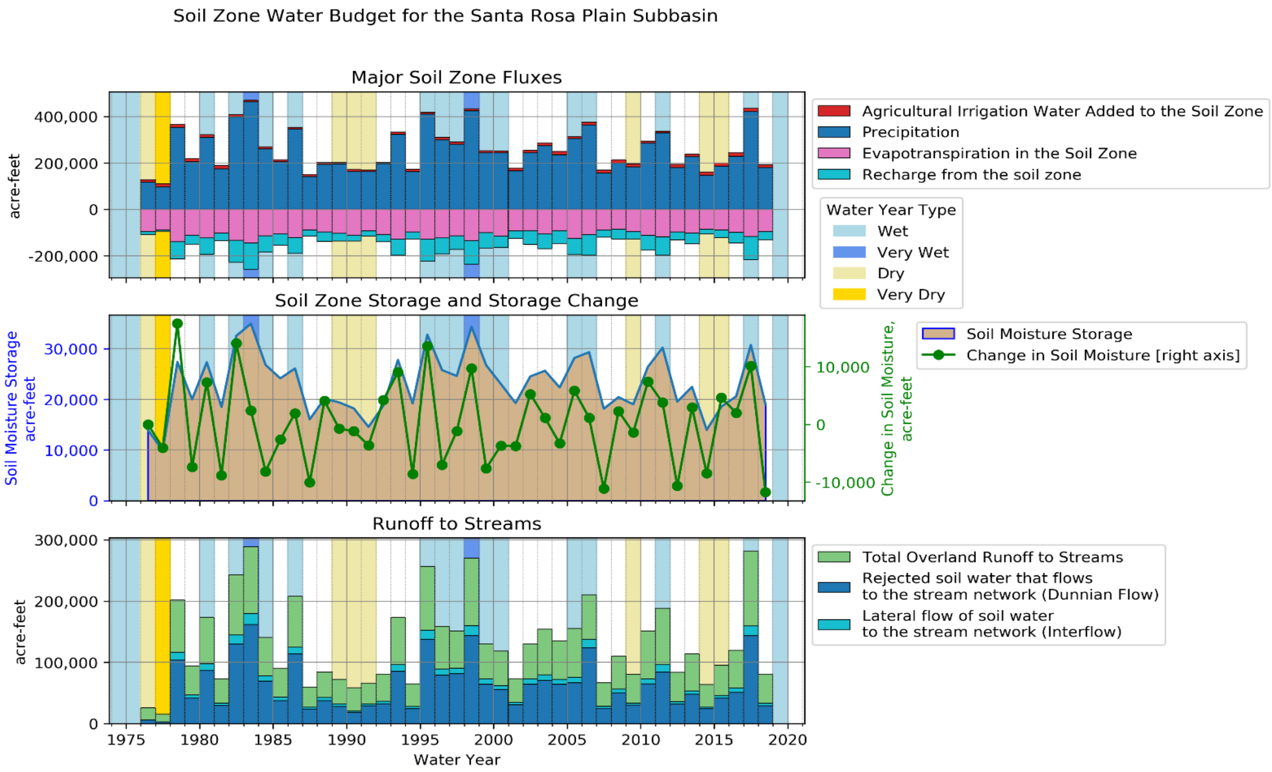

Figure 3-36. Historical and Current Soil-zone Budget for the Subbasin

Table 3-20. Historical (WY 1976 to WY 2018) Budget for the Subbasin Soil Zone[a]

	Precipitation (AFY)	Agricultural Irrigation Water Added to the Soil Zone (AFY)	ET in the Soil Zone (AFY)	Soil-zone Recharge (AFY)	Rejected soil water that flows to the stream network (Dunnian Flow; AFY)	Lateral flow of soil water to the stream network (Interflow; AFY)	Soil Moisture (acre-feet)
Mean	248,800	10,600	-107,300	-53,000	62,200	7,400	23,100
Minimum	96,200	6,700	-145,800	-111,900	2,800	300	9,900
Maximum	463,000	15,100	-84,900	-5,400	161,900	18,000	35,000
Median	229,500	10,800	-105,400	-48,900	51,500	6,500	22,500

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-21. Current (WY 2012 to WY 2018) Budget for the Subbasin Soil Zone[a]

	Precipitation (AFY)	Agricultural Irrigation Water Added to the Soil Zone (AFY)	ET in the Soil Zone (AFY)	Soil-zone Recharge (AFY)	Rejected soil water that flows to the stream network (Dunnian Flow; AFY)	Lateral flow of soil water to the stream network (Interflow; AFY)	Soil Moisture (acre-feet)
Mean	224,800	13,200	-97,600	-45,100	53,000	6,000	20,700
Minimum	147,500	10,800	-116,900	-98,500	24,500	2,500	14,000
Maximum	422,900	14,400	-85,100	-21,600	144,200	15,000	30,800
Median	186,100	13,400	-97,000	-35,200	41,500	4,600	19,600

[a] Values are rounded to the nearest 100 acre-feet.

3.3.3.4 Water Budget Summary

The main groundwater inflows into the Subbasin are: (1) the percolation of precipitation and applied agricultural irrigation water (53 percent of total), (2) streambed recharge (28 percent of total), and (3) subsurface inflow from neighboring DWR groundwater basins and subbasins (14 percent of total). Together these inflows contribute 95 percent of total groundwater inflows. Subsurface inflows from surrounding watershed areas and septic return flows are smaller inflows compared to the others. Discharge to streams, total pumpage, and groundwater ET comprise about 80 percent of groundwater outflows. The smaller outflow terms are surface leakage and subsurface outflow to adjacent basins.

Overall groundwater outflows are greater than inflows into the groundwater system, resulting in an estimated decline in groundwater storage in both the historical and current water budget periods. The historical (WYs 1976-2018) annual change in storage is -600 AFY, whereas the current (WYs 2012-2018) annual change in groundwater storage is -2,100 AFY. Historically, storage depletion comprised about 3 percent of the average groundwater pumpage. If groundwater pumping, climate, and net streambed recharge and groundwater ET remain similar as that of the current period, the Subbasin will continue to experience declines in groundwater storage. If groundwater pumping and climate remain similar to the current period, and if groundwater storage declines were to stabilize, losses from the streambed will become greater and groundwater ET will decrease until inflows equal outflows from the groundwater system.

The Healdsburg subarea (containing the middle reach of the Russian River) receives the greatest boundary outflow from the Subbasin, whereas the Rincon-Kenwood and Wilson Grove Formation Highlands subbasins are greatest contributors of boundary inflow to the Subbasin. Interflow and Dunnian flow are important soil-zone processes that generate runoff into streams. Hortonian overland flow, which occurs when precipitation rates exceed soil hydraulic conductivity, is another important source of runoff. Stream discharge into the basin is much greater than subsurface boundary inflows into the Subbasin.

A comparison of the historical water budget and current water budget shows greater stress on the Subbasin in the current period than historically on average. Conditions are drier in the current periods with approximately 10 percent less precipitation. This results in approximately 12 percent less deep percolation to groundwater in the Subbasin. Meanwhile, pumping increased 5 percent in the current period compared to the historical period, mostly due to a greater than 14 percent increase in agricultural pumping.

Subbasin boundary inflows and outflows dominate the surface water budget by total volume. Overland flows to streams are the greatest contributor to discharge within the basin, compared to the net groundwater discharge to streams. Mark West Creek is the main drainage within the Subbasin by volume discharged. Surface water-groundwater interactions (net streambed exchange) is controlled more by 5- to 10-year variations in precipitation than by interannual variability in precipitation. During wet years there is a net groundwater discharge to streams whereas normal precipitation years may experience net seepage to groundwater, especially when following a dry period. One result of the increased stress in the current water budget is that net streambed exchange changes from net discharge of groundwater to streams to net recharge to groundwater from streams. Net streambed exchange was 300 AFY during the historical period and the rate for the current period was -1,300 AFY. This reflects a wetter climate during the historical period, and the cumulative impacts of groundwater pumping on streamflows during the current period. Groundwater discharge to streams in the historical period is nearly equal to or greater for all months than the current period.

3.3.4 Subbasin Water Supply Reliability

Based on analysis conducted for Sonoma Water's 2020 UWMP (Sonoma Water 2021), Sonoma Water has adequate water supply to deliver imported surface water through the 2045 planning horizon analyzed in the 2020 UWMP. The exception are single-dry years, starting after 2025. For single-dry years, model simulations predict that storage levels in Lake Sonoma will drop below 100,000 AF prior to July 15th, thus requiring demand curtailments by Sonoma Water customers per SWRCB Decision 1610 (SWRCB 1986) for some portion of the year. In these circumstances, Sonoma Water will work with its customers to reduce demands on the imported surface water. Based on efforts over the last 5 years during dry conditions, Sonoma Water does not anticipate any difficulty in maintaining an adequate supply of imported surface water during the single-dry year. The magnitude of these single-dry year potential shortfalls is estimated to be about 19 percent of average annual demand by 2045. This condition is accounted for in the baseline projected water budget developed for this GSP by assuming higher levels of groundwater demands from Sonoma Water contractors during dry conditions.

3.3.5 Uncertainties in Water Budget Calculations

The level of accuracy and certainty is highly variable between water budget components. A few water budget components are directly measured, but most water budget components are estimated as input to the model or simulated by the model. Both estimated and simulated values are based on assumptions and there is additional model uncertainty for simulated results. Model uncertainty stems from an imperfect representation of natural condition and is reflected in model calibration error. However, inputs to the model are carefully selected using best available data, the model's calculations represent established science for groundwater flow, and the model calibration error is within acceptable bounds. Therefore, the model is the best available tool for estimating water budgets.

Simulated components based on calibrated model have the most uncertainty because those simulated results encompass uncertainty of other water budget components used in the model in addition to model calibration error. The following lists groups of water budget components in descending order of uncertainty:

- Measured: metered municipal and some small water system pumping
- Estimated: nonmunicipal domestic pumpage and septic system return flow, including depth and location
- Simulated primarily based on climate data: precipitation, ET, irrigation pumpage, including depth and location
- Simulated based on calibrated model: all other water budget components

3.3.6 Projected Water Budgets

SGMA Legislation and GSP Regulation requirements for projected water budgets are as follows:

- Simulate projected groundwater conditions 50 years into the future
- Incorporate projections of land use change, climate change, and other changes in groundwater demands (such as population increase)

The results of the projected conditions simulation will be used to assess how the sustainability indicators respond to the changing climate and groundwater demands in the future. If undesirable results are simulated to occur, the GSP will need to plan for projects and management actions that respond to the undesirable results.

Projected water budgets will be useful for showing that sustainability will be achieved in the 20-year implementation period and maintained over the 50-year planning and implementation horizon.

The projected water budget is developed using a predictive simulation from the SRPHM that incorporates a climate change scenario.

3.3.6.1 Method and Assumptions Used to Develop Projected Water Budgets

Future projected conditions are based on model simulations using the updated SRPHM numerical flow model and using estimates of the following:

- Projected land use changes
- Projected population growth
- Projected climate change

Future Projected Land Use Change and Water Demand Assumptions

Assumptions for future projected land use changes and water demands were estimated for rural-residential groundwater pumping, agricultural land use footprint, and municipal demands. Several workgroups and surveys helped develop the data used in the projected model. Assumptions for each set of data are described and projections are provided in **Appendix 3-D**.

Municipal purveyors provided ranges of projected demands based on combination of historical and potential future use. The projections included higher-end ranges for GSP planning that are generally higher in comparison with planning projections for UWMPs. Nonpotable groundwater demands were included where applicable for GSP modeling (City of Santa Rosa).

To capture these ranges and incorporate potential climate variability in the model, the following steps were taken:

- For purveyors with both surface water and groundwater sources, varied annual future pumping based on projected future climate year classifications (very dry, dry, normal, wet, very wet) using calculated standard deviation from historical pumping records
- Applied patterns of seasonality of groundwater production based on historical wellfield operations

Projected Climate Change Simulation Approach

SGMA requires the incorporation of climate change into projected future simulation scenarios for purposes of assessing impact of climate change on groundwater conditions, demands, and availability, and identifying uncertainties in future conditions when including projects and management actions and identifying SMC. For the GSP, after review of DWR Climate Change Guidance and recommendations, the GSA decided to choose one potential climate change scenario representative of regional conditions to limit the number of simulations and provide better comparability between various potential projects and actions. During the 5-year GSP update, the status of climate change science will be assessed and the use of different climate futures will be considered, as appropriate.

Projections of future climate conditions are generally performed through GCMs forced with specific global greenhouse gas (GHG) emissions scenarios (IPCC 2013). **Appendix 3-E** provides a description of GCM selection.

The overall approach for selecting and simulating projected climate change can be summarized as follows:

1. Choose projected climate future by selecting regionally representative GCM and then selecting a specific GHG emissions scenario.
    a. Review DWR-recommended GCMs and choose one GCM and emissions scenario that best represents projected median conditions in Russian River Watershed area (including groundwater basins)

2. Update model inputs for the following:
   a. Precipitation
   b. Temperature/ET
3. Use climate data as follows:
   a. Define precipitation and calculate potential ET and actual evaporation and transpiration
   b. Calculate projected irrigation water demands and groundwater pumping

Selection of Regional Representative General Circulation Model

The projections reviewed for purposes of developing this GSP relied upon available climate projections using the models and emissions scenarios included in the Coupled Model Intercomparison Project 5 (CMIP5). Twenty individual downscaled GCM projections were reviewed using 10 different GCMs and 2 different Representative Concentration Pathways (RCPs), RCP4.5 and RCP8.5 for each model (**Appendix 3-E**). The 10 GCMs were chosen by the DWR Climate Change Technical Advisory Group (CCTAG) based on a regional evaluation of climate model ability to reproduce a range of historical climate conditions (CCTAG 2015) and are contained in the California Fourth Climate Change Assessment (He et al. 2018).

For GSP planning purposes, it is desirable to identify projected climate scenarios that more specifically represent the climate and hydrologic conditions within the Russian River watershed and Sonoma County. To identify the model that was most representative of the Russian River watershed, a technical analysis was conducted to compare how well each model performed relative to historical data for objective metrics (for example, river flow and reservoir storage). The evaluation identified the HadGEM2-ES GCM as best representing the middle of the ensemble for mean climate and hydrologic metrics for the Russian River watershed and did not stray to any of the extremes for other metric rankings.

Greenhouse Gas Emissions Scenario

Upon selection of the HadGEM2-ES model, the next step focused on selection of an emissions scenario. Emissions scenarios are possible pathways that society might take in the emission of GHGs in the future. Each are categorized as a RCP. DWR has recommended the use of two potential RCPs: RCP 4.5 and RCP 8.5.[3] RCP 4.5 is sometimes considered "most likely" based on current projections of GHG emissions, and RCP 8.5 is often known as "worst-case scenario." Experts and scientists contacted by GSA staff have differing views on which emissions scenario is more likely, although many acknowledge that selection of an emissions scenario is not a technical or scientific issue but rather a societal issue. Accordingly, the process to select which emissions scenario to use was based on several Advisory Committee and GSA Board meetings in addition to a focused workshop for the three Sonoma County SGMA basins and subbasins. As part of this effort, the model results for both RCP 4.5 and RCP 8.5 for the Santa Rosa Plain Subbasin were presented and discussed. In general, the model results indicated that RCP 8.5 was the worst-case scenario (relative to RCP 4.5) in terms of groundwater storage, groundwater recharge, groundwater discharge to streams, and pumping. RCP 8.5 provided a stiffer stress test

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[3] RCP 4.5 refers to the additional 4.5 watts per meter squared energy above a baseline that will enter into the atmosphere, and the amount of GHGs necessary to accomplish such an increase.

for groundwater resources due to a forecasted sustained period of several dry years after the mid-21st century and the increased temperature associated with this higher emissions scenario (increased pumping and ET). Based on this review of groundwater model results from simulating the combination of each RCP with the chosen HadGEM2-ES GCM (**Appendix 3-E**), the majority of Advisory Committee members supported RCP 8.5 and the GSA Board affirmed that recommendation.

Projected climate based on the selected GCM and emissions scenario represent WY 2021 through 2070.

3.3.6.2 Modifications to Modeling Platform to Simulate Future Projected Conditions

Where possible, all model inputs used the same assumptions that were made in the historic water budget simulation.

Projected climate input assumptions and modifications

The climate portion of the inputs was incorporated into the model via the PRMS component of GSFLOW. The projected values are defined as daily precipitation, and minimum and maximum temperatures over the projected simulation period. The changing land use patterns and associated water uses were simulated in two distinct manners. The agricultural (AG) package was used to simulate the projected growth and contraction of agriculture, and the associated groundwater demand. As with the historical model, the AG package uses the locations of crops to determine the potential ET not met by soil moisture. The AG package applies water pumped from an associated well to satisfy this demand. These simulations account for changing climate patterns, including potential ET and precipitation, soil moisture, and other factors. The AG package input was modified with the changing land use patterns described in **Appendix 3-D**.

Projected groundwater pumping assumptions and modifications

Municipal, rural domestic, and industrial projected water uses are simulated using the USGS Well Package. These uses are defined on a monthly basis and incorporate the projected population growth and associated groundwater demands. As with the historical model, the groundwater use of the rural domestic parcels was estimated based on parcel size. Parcel groundwater use is aggregated by groundwater model cell for each stress period.

Other projected boundary conditions assumptions and modifications

The projected model starts in October 2020 (beginning of WY 2021). The initial groundwater heads for each layer were extracted from the ending conditions of the historical model. The intervening period from October 2018 to October 2020 was not simulated, nor does the model reflect any changes between those two periods.

The general head boundary conditions that represent the model interface with the Petaluma Valley Basin, Wilson Grove, and the Healdsburg Area Subbasins require values of boundary head for the simulation period. The values used in the historic model were carried forward into the projected simulation. Therefore, the model does not account for changing hydrologic conditions at those boundaries and assumes they remain constant into the future. Additionally, the model does not account for changes in impervious surface area as this is not readily available for use in the model. The projected impervious values incorporated in the model reflect values as of 2016.

3.3.6.3 Climate of the Projected Water Budget Simulation Period

The first 20 years of the projected simulation period are relatively wet compared to the historical precipitation. The first 2 years of the projection are very dry, but are then followed by a total of 6 wet, 1 very wet, 1 dry, and 10 normal years. In this period, the average precipitation is 35.6 inches per year, which is 20 percent greater than the historical average. After WY 2041 there is an 11-year period with 3 wet years, 1 dry year, and the rest normal. In the final 20 years, the conditions become drier when compared to the prior simulation period; there are no wet WY types, and 13 dry WYs (**Figure 3-37**). Both minimum and maximum daily temperatures increase in the projected simulations as calculated by the HadGEM2-ES RCP 8.5 scenario (**Figure 3-38**).

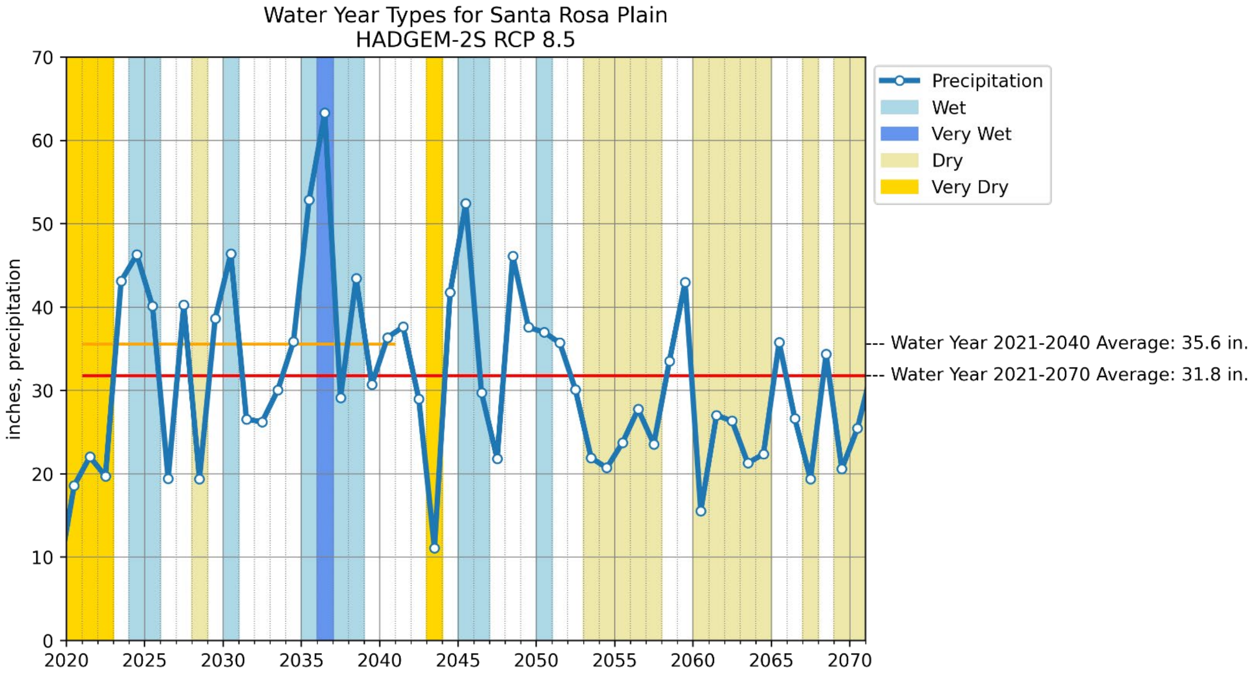

Figure 3-37. Water Year Types for Santa Rosa Plain Future Projected Water Budget

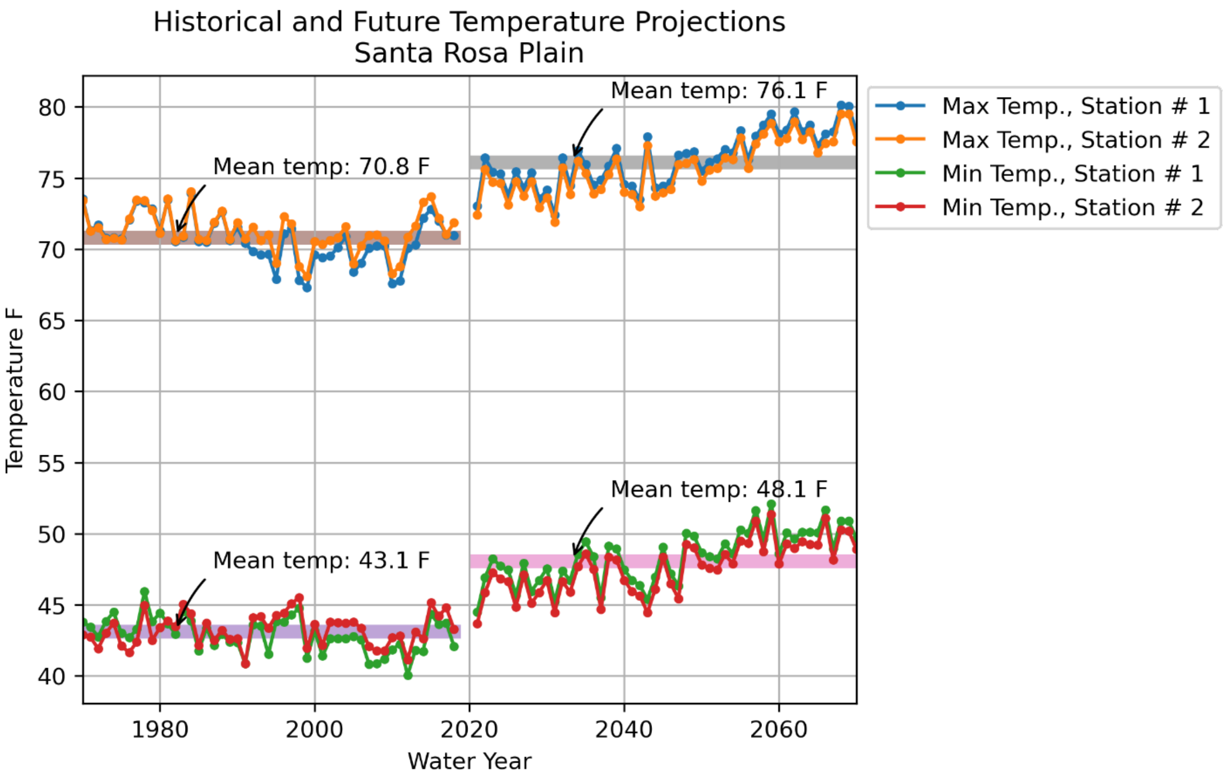

Figure 3-38. Historical, Current, and Future Temperature Projections for Windsor (Station No. 1) and Santa Rosa (Station No. 2) Weather Stations

3.3.6.4 Projected Surface Water Budget

Surface water inflows and outflows at the Subbasin margins increase in the WY 2021-2040 period (**Figure 3-39**). In the historical period the average inflow was 362,000 AFY, and in the WY 2021-2040 period it is 468,500 AFY (**Table 3-22**), representing a 29 percent increase. Streamflow generated by overland runoff increases similarly in the projected period, with a 33 percent increase from 130,200 AFY to 172,700 AFY. The WY 2021 to 2040 period exhibits higher minimum flows than the historical minimum, and also greater maximum inflows. The trend in net streambed exchange contrasts that of the surface water inflows. Despite the wetter conditions in the WY 2021 to 2040 period, the net streambed exchange transitions from an average gaining conditions of the historical period to a relatively consistently losing stream system (**Table 3-22**). A gaining system discharges more groundwater to the streams than stream seepage to the groundwater system. The rates of net streambed exchange are +500, -1,300, and -2,200 for the historical, current and WY 2021 to 2040 periods, respectively. Only 3 years of the first 20 years exhibit positive net streambed exchange, whereas 20 years of the historical record are positive (**Figure 3-39**).

Following the trend of Subbasin precipitation, surface water inflows are lower in the latter 30 years of the projected period, especially after WY 2050 (**Figure 3-39**). During the entire WY 2021 to 2070 period the mean boundary inflows, outflows, and overland runoff to streams is 376,000, 514,900, and 143,200 AFY, respectively (**Table 3-23**). A summary of the average fluxes for the historical, current, and projected water budget periods is shown on **Figure 3-40**. The magnitude of these values is greater than the corresponding values for the historical period. On the other hand, net streambed exchange shows nearly monotonic declines after WY 2050 (**Figure 3-39**). The net groundwater exchange averages -4,100 AFY for the entire future projected period. The decline in net groundwater exchange rates is driven by a decline in groundwater discharge (baseflows) to streams, rather than an increase in stream seepage to groundwater. In contrast to groundwater discharge to streams, stream discharge to groundwater remains nearly unchanged in the projected simulation.

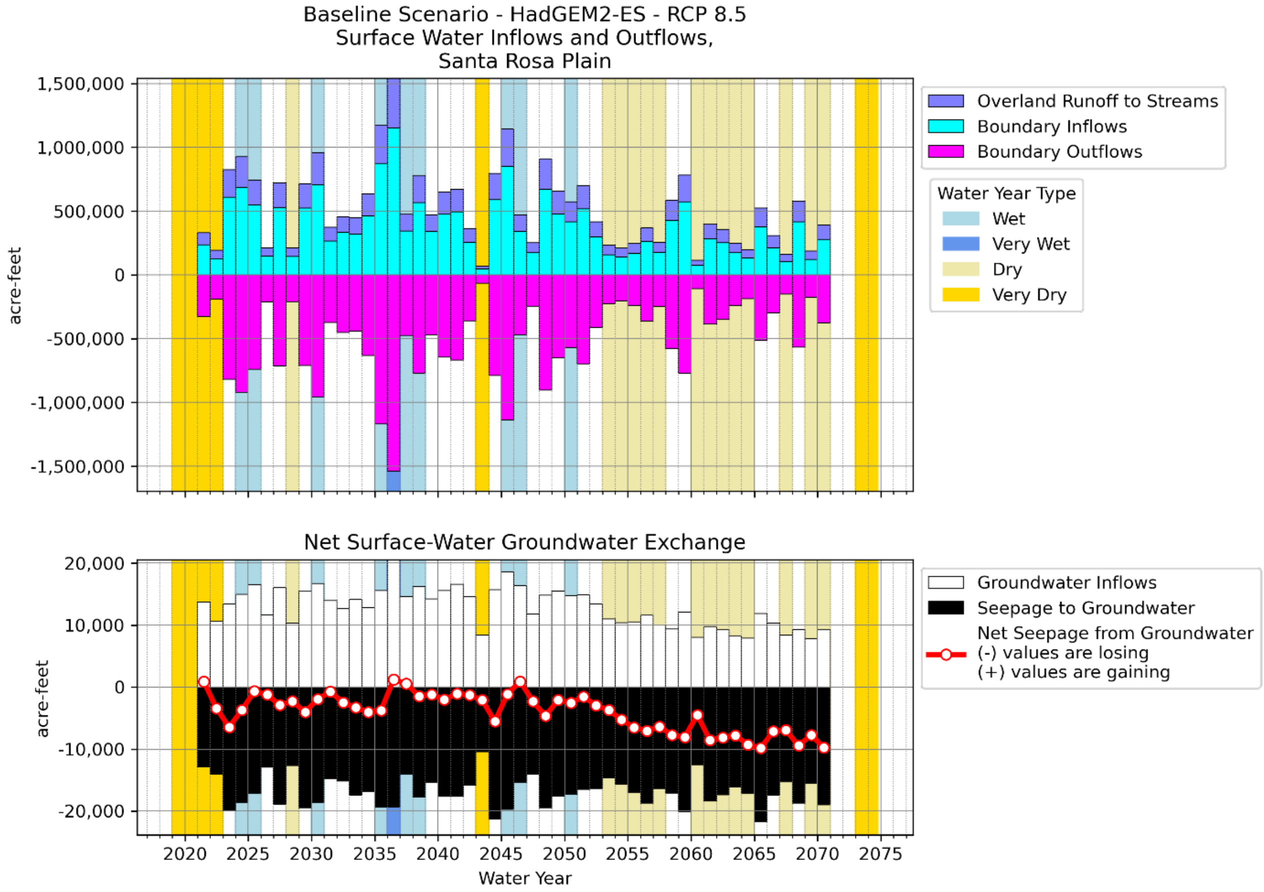

Figure 3-39. Projected Surface Water Budget

Table 3-22. Projected (WY 2021 to WY 2040) Surface Water Budget Summary (AFY)[a]

	Net Streambed Exchange	Overland Runoff to Streams	Boundary Outflows	Boundary Inflows
Mean	-2,200	172,700	-638,800	468,500
Minimum	-6,500	65,500	-1,540,900	128,400
Maximum	1,300	389,100	-190,500	1,151,600
Median	-2,100	174,300	-637,800	466,800

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-23. Projected (WY 2021 to WY 2070) Surface Water Budget Summary (AFY)[a]

	Net Streambed Exchange	Overland Runoff to Streams	Boundary Outflows	Boundary Inflows
Mean	-4,100	143,200	-514,900	376,000
Minimum	-9,800	23,800	-1,540,900	44,500
Maximum	1,300	389,100	-66,300	1,151,600
Median	-3,600	127,600	-460,000	335,200

[a] Values are rounded to the nearest 100 acre-feet.

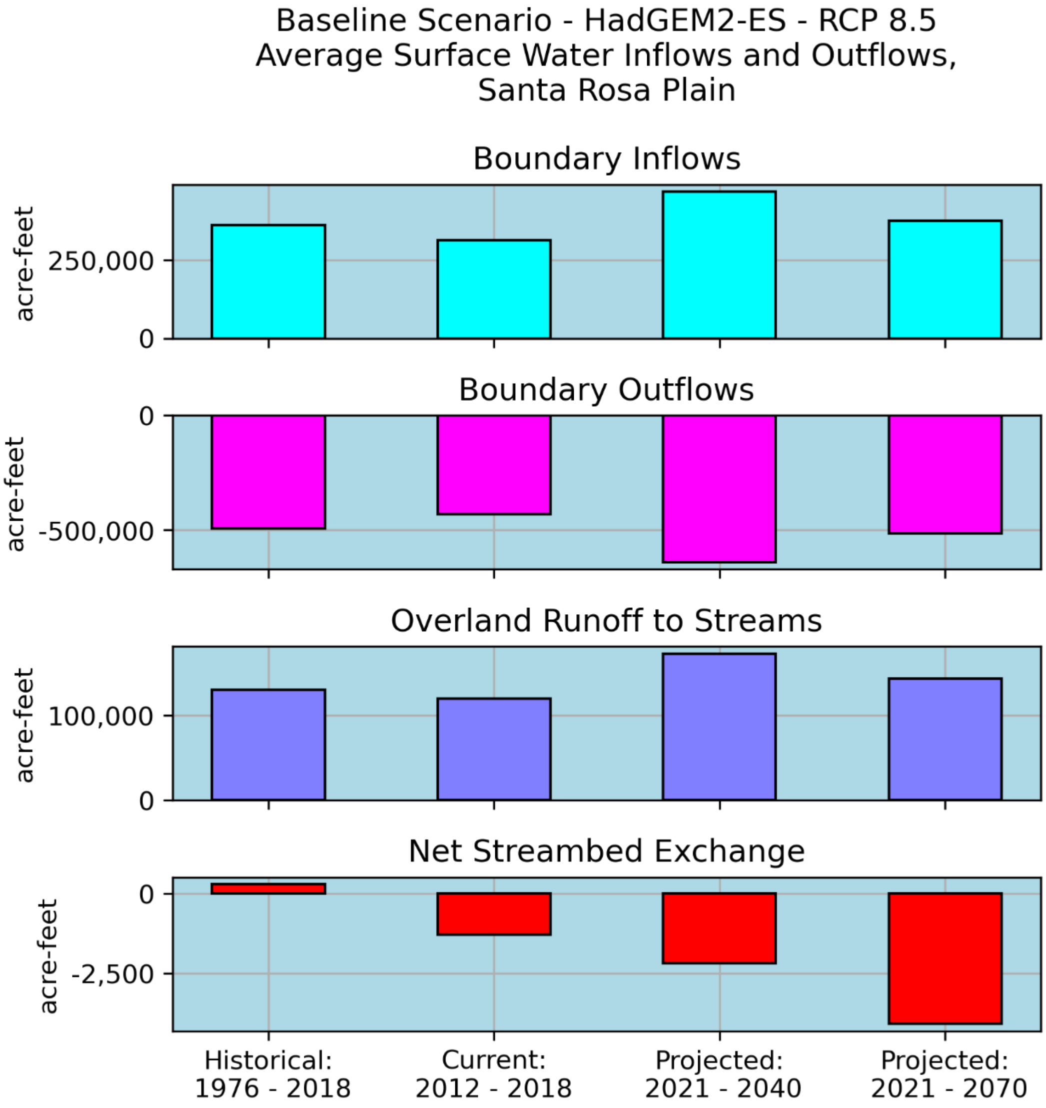

Figure 3-40. Average Surface Water Inflows and Outflows

Figure 3-41 and **Figure 3-42** illustrate the net boundary inflows and outflows for each of the HUC 12 watershed subregions, and the streams that drain them. The locations and extents of the watersheds is shown on **Figure 3-22**. The relative discharges in the projected conditions from each watershed are similar to those of the historical values (**Figure 3-25**). For example, in both the projected and historical conditions, the discharge from Windsor Creek is equal to about 50 percent of the inflows from Upper Santa Rosa Creek. However, as previously discussed, yearly discharge values for the projected conditions are greater principally as a result of the projected increase in precipitation in the WY 2021 – 2050 period.

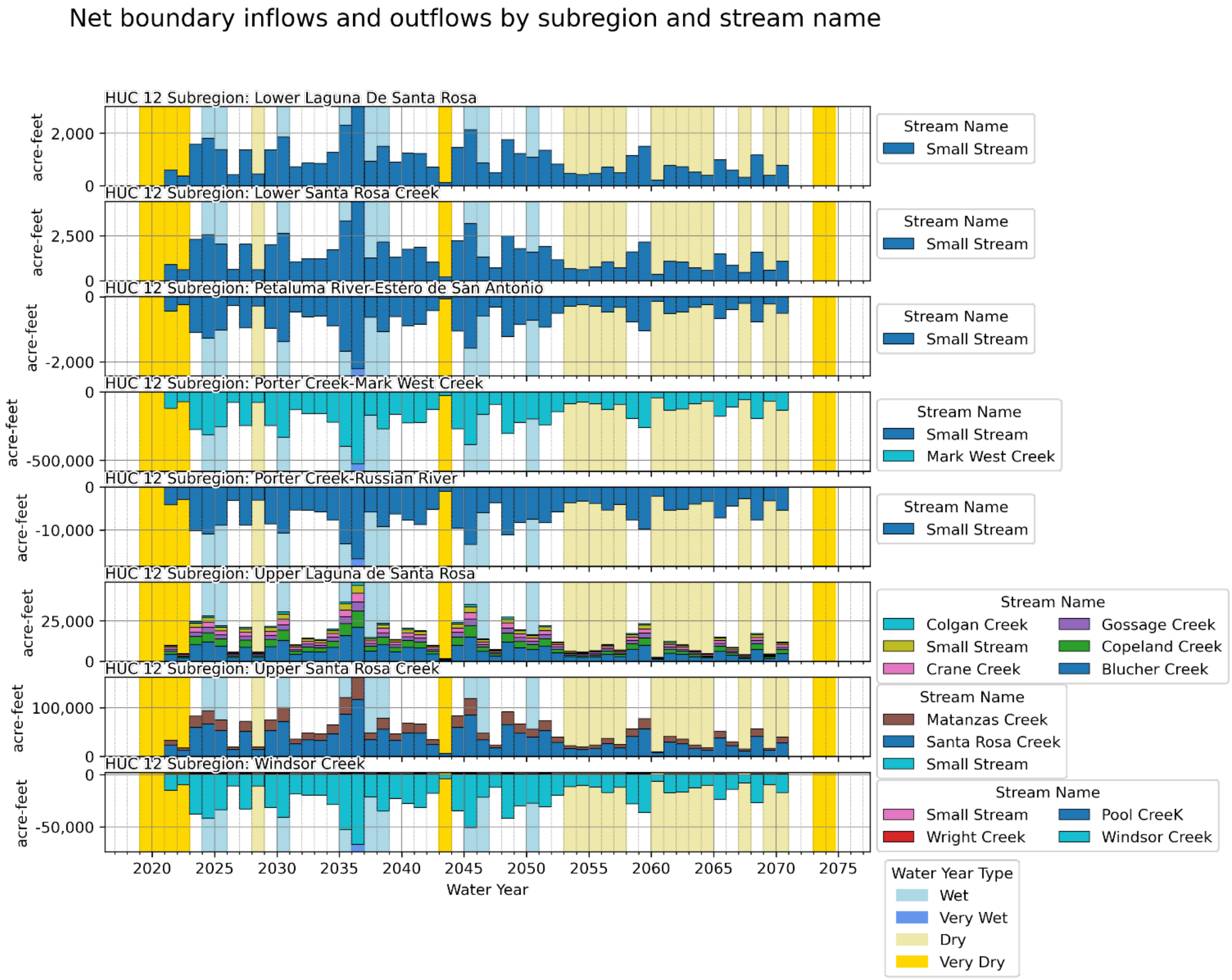

Figure 3-41. Net Boundary Inflows and Outflows by HUC 12 Subregion and Stream Name

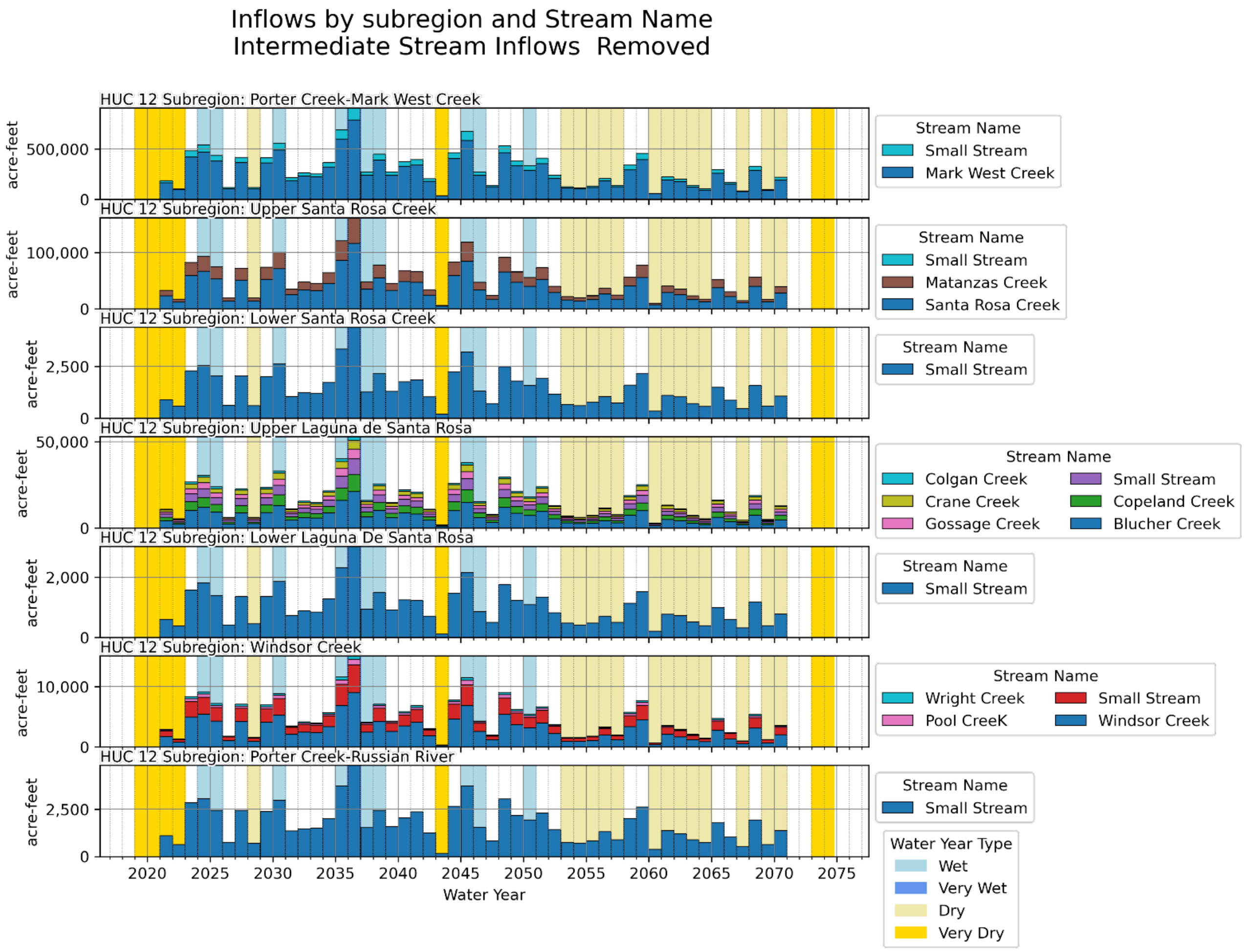

Figure 3-42. Inflows by HUC 12 Subregion and Stream Name[4]

On **Figure 3-43** fluxes for the surface water system are displayed for a wet (WY 2026) and normal (WY 2057) WY. WY 2026 occurs after 3 consecutive years of wet or normal conditions whereas WY 2057 is preceded by 4 dry WYs. Likely because of these precedent conditions, the net groundwater exchange dynamics are markedly different. During the WY 2026, the net groundwater exchange ranges from -1,000 acre-feet to +500 acre-feet. In this WY, there is a significant portion of the year in which baseflows are sustaining streamflows. The WY 2057 has negative values (losing conditions) for all but 1 month, and generally ranges from -1,500 AFY to -250 AFY. In this year there is little to no net baseflow discharge to streams in the Subbasin. Overland runoff to streams generates similar total volumes in these 2 years.

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[4] Intermediate inflows removed; values intended to represent surface inflows at headwaters where streams cross the boundary the first time. Some streams cross the Subbasin boundary multiple times, but only the inflows from the initial inflow location are shown here.

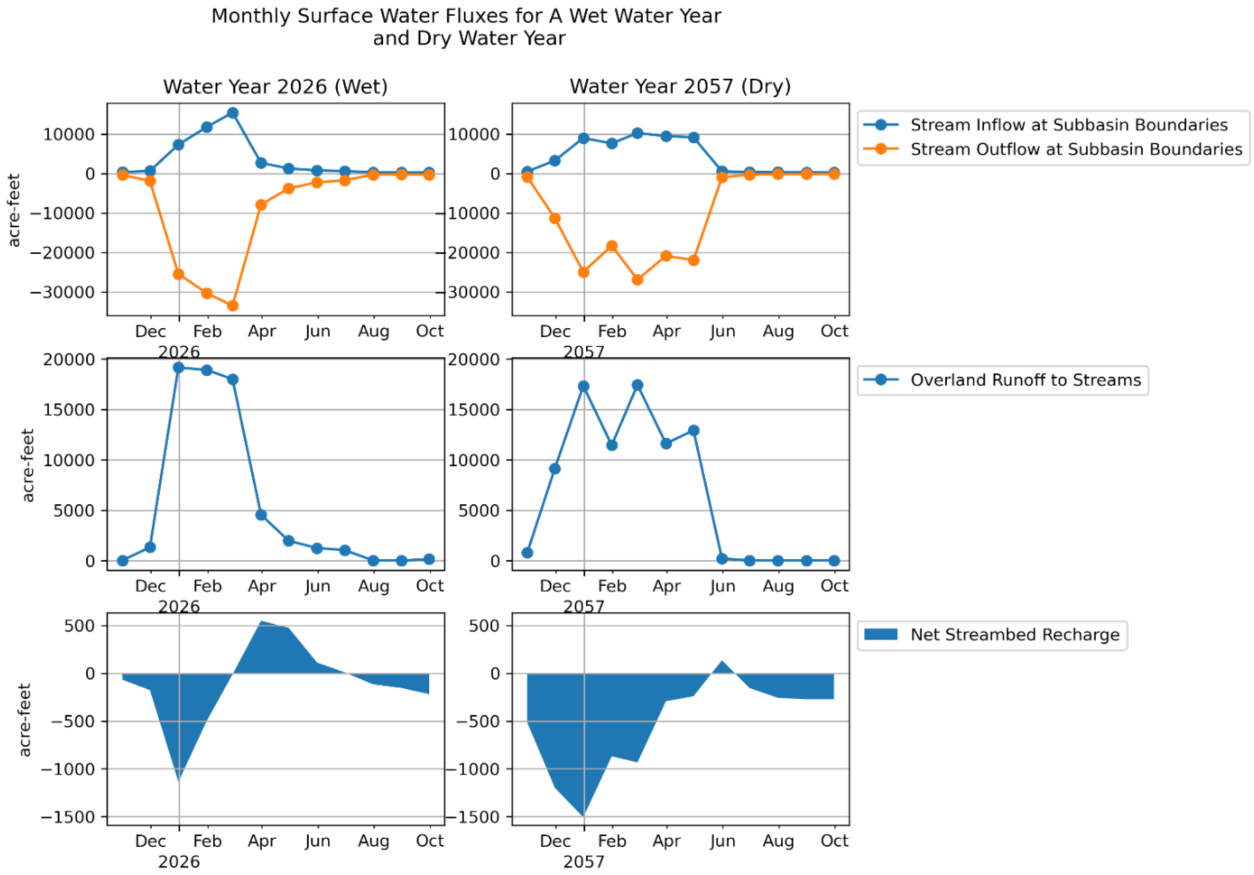

Figure 3-43. Monthly Surface Water Fluxes for a Wet Water Year and Normal Water Year

On **Figure 3-44** the average monthly surface water fluxes are shown for the WY 2021 to 2040 and the WY 2021 to 2070 periods. In the projected conditions the net streambed exchange is less than zero from July to January. The historical period, by comparison, is below zero for October through January. The net streambed exchange is -500 acre-feet for October in the projected conditions, but is half that value in the historical conditions.

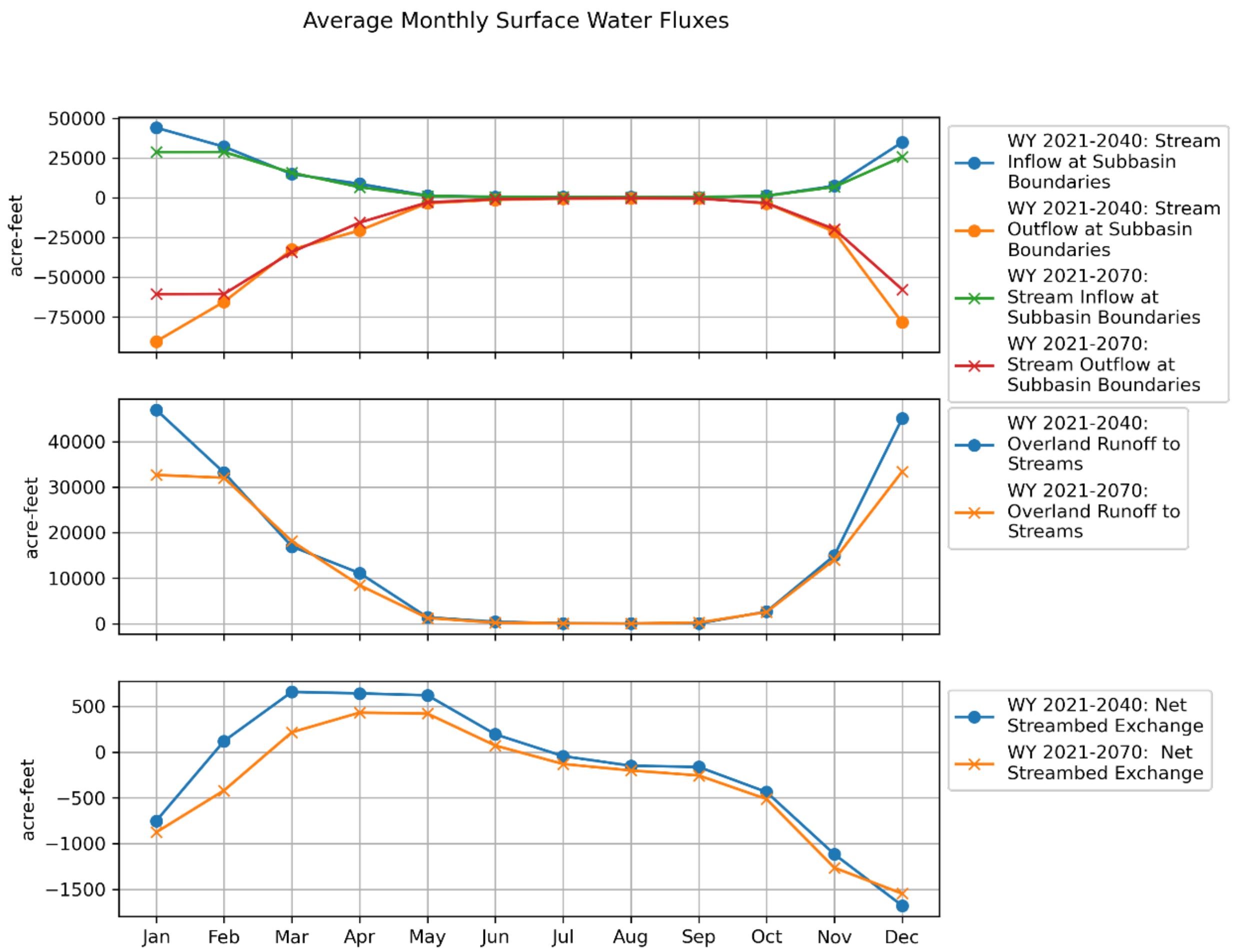

Figure 3-44. Average Monthly Surface Water Fluxes in the Projected Period

3.3.6.5 Projected Groundwater Budget

During the projected WY 2021 to 2040 period the increased precipitation impacts groundwater inflows in different ways (**Figure 3-45** and **Table 3-24**). Compared to the historical water budget, the deep percolation of precipitation and streambed recharge increase the most with increases of 4,100 AFY and 1,600 AFY of the mean values, respectively, whereas subsurface inflow from neighboring watersheds and basins changes -100 AFY and 300 AFY, respectively. For the entire projection from WY 2021 to 2070 (**Table 3-25**), deep percolation of precipitation and applied water values are nearly equal to the historical values (**Figure 3-46** and **Figure 3-47**). Streambed recharge increased from an average of 15,100 AFY in the historical period to a mean of 16,900 AFY in the WY 2021 to 2070 period, representing an increase of 12 percent. Septic return flows increased by 50 percent between the two periods, resulting in a mean of 1,500 AFY in the WY 2021 to 2070 period. The average combined total inflows for the entire projection period is 57,200 AFY, representing a 5 percent increase from the historical value of 54,300 AFY. This increase is predominantly caused by the greater deep percolation of precipitation and applied water that occur in the WY 2021 to 2040 period rather than the following 30 years.

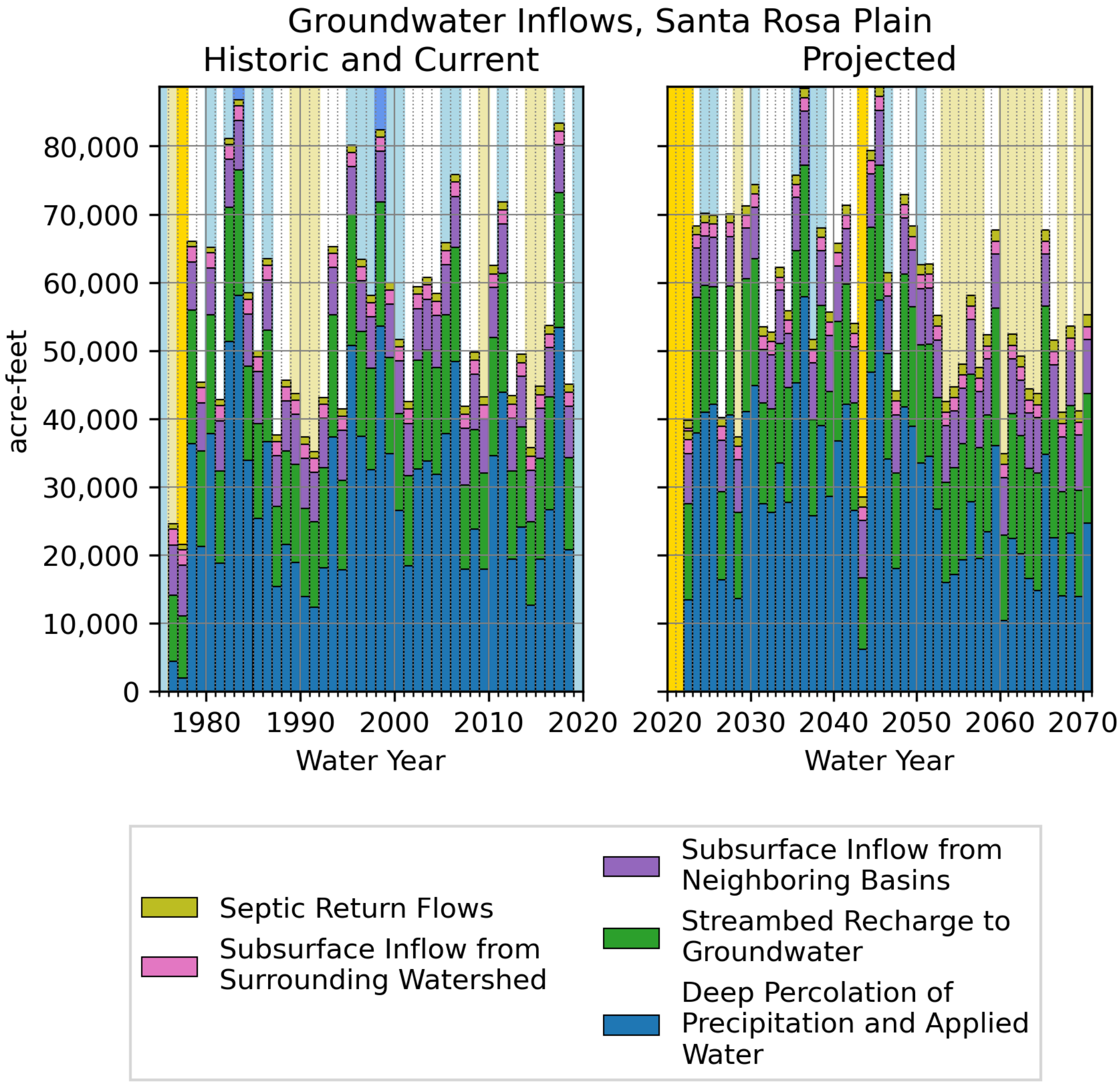

Figure 3-45. Groundwater Inflows to the Groundwater System: Historic, Current, and Projected Periods

Table 3-24. Projected (WY 2021 to WY 2040) Groundwater Inflows Budget Summary (AFY)[a]

	Deep Percolation of Precipitation and Applied Water	Streambed Recharge to Groundwater	Septic Return Flows	Subsurface Inflow from Surrounding Watershed	Subsurface Inflow from Neighboring Basins
Mean	32,800	16,700	1,400	2,000	7,700
Minimum	13,400	12,600	1,200	1,900	7,200
Maximum	57,900	19,900	1,400	2,200	8,400
Median	35,100	17,300	1,300	2,000	7,700

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-25. Projected (WY 2021 to WY 2070) Groundwater Inflows Budget Summary (AFY)[a]

	Deep Percolation of Precipitation and Applied Water	Streambed Recharge to Groundwater	Septic Return Flows	Subsurface Inflow from Surrounding Watershed	Subsurface Inflow from Neighboring Basins
Mean	28,800	16,900	1,500	2,000	8,000
Minimum	6,200	10,500	1,200	1,900	7,200
Maximum	57,900	21,700	1,700	2,200	8,500
Median	27,200	17,200	1,500	2,000	8,100

[a] Values are rounded to the nearest 100 acre-feet.

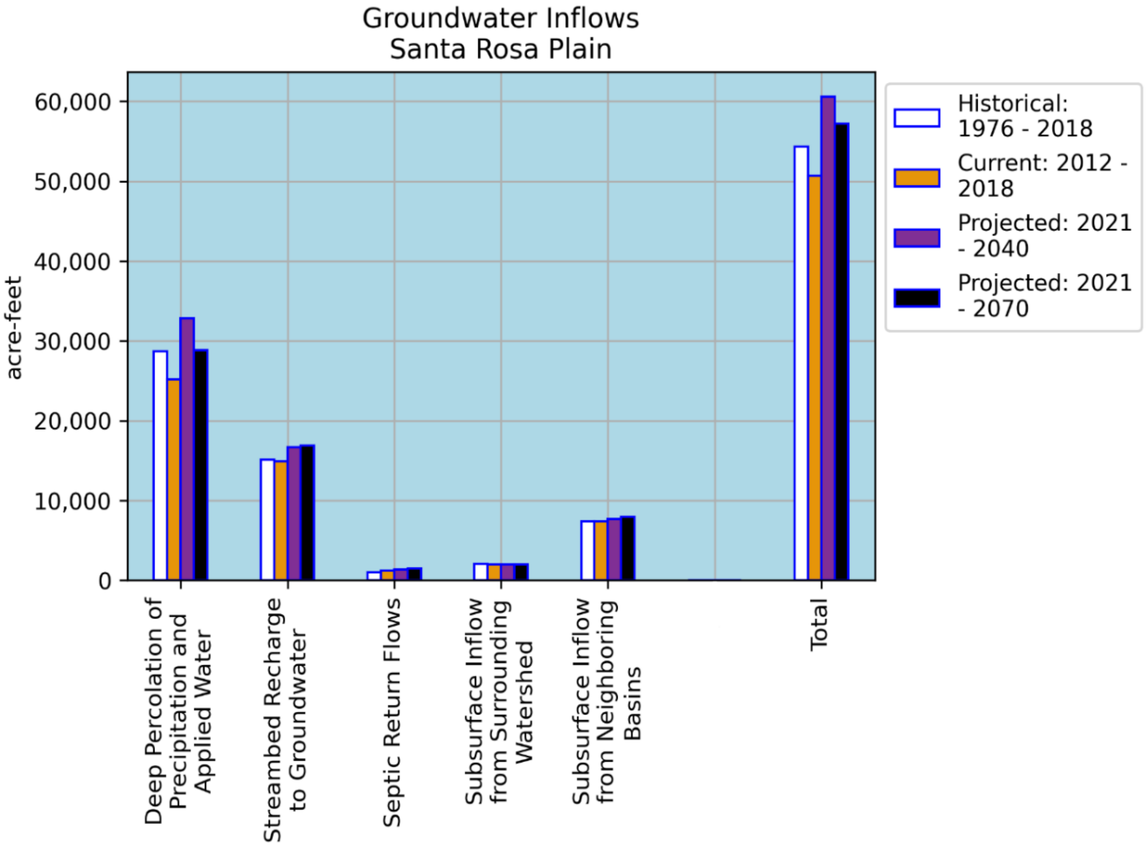

Figure 3-46. Groundwater Inflows by Water Budget Period

Figure 3-47, **Table 3-26**, and **Table 3-27** show groundwater outflows for the projected period. Groundwater outflows generally mirror groundwater inflows, with greater total outflows in the first 30 years during the wetter period, followed by declining total outflows for the last 20 years. This overall pattern is reflected in some of the fluxes, but is absent in others. Surface leakage, groundwater discharge to streams, and groundwater ET reach their peaks between WY 2035 and WY 2045 and decline steadily in the final 30 years of the simulation such that they average 79 percent, 88 percent, and 90 percent, respectively, of their WY 2021 to 2040 averages. The average surface leakage, groundwater discharge to streams, and groundwater ET for the WY 2021 to 2040 period are 6,200 AFY, 14,500 AFY, and 11,700 AFY. In contrast to leakage, ET, and discharge to streams, two of the outflow terms–groundwater pumpage by municipal, and the combined rural domestic and agriculture users–actually increase from their WY 2021 to 2040 means. Agricultural pumpage increases by 10 percent, and the combined municipal and rural domestic pumpage increases by 9 percent, compared to the WY 2021 to 2040 period. Compared to the historical period, agricultural pumpage experienced the largest increase in the groundwater outflows, followed by groundwater ET (**Figure 3-48**). Subsurface outflows to adjacent basins, discharge to streams, and surface leakage decreased over the same two periods.

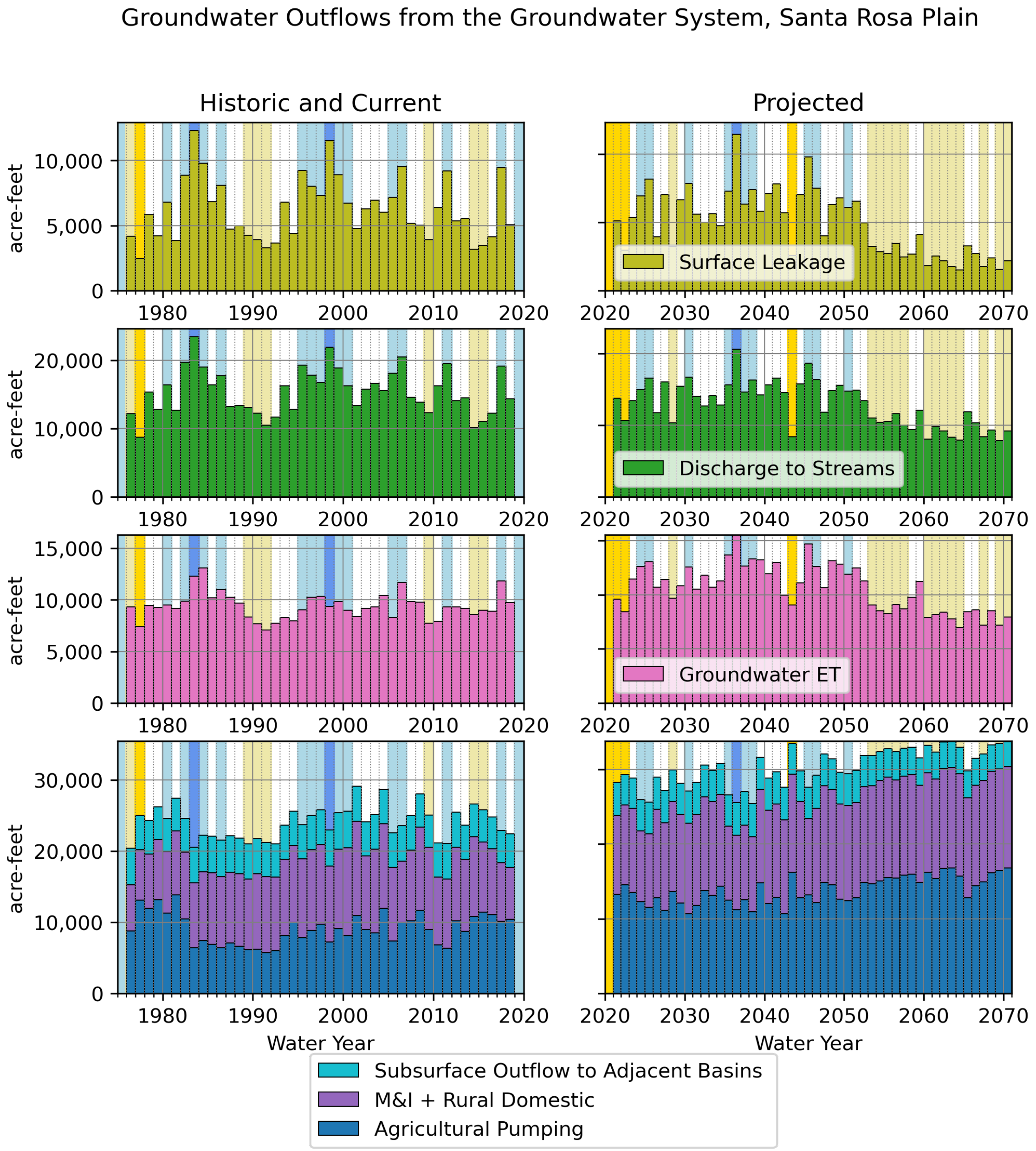

Figure 3-47. Groundwater Outflows from the Groundwater System: Historic, Current, and Projected Periods

Table 3-26. Projected (WY 2021 to WY 2040) Groundwater Outflows Budget Summary (AFY)[a]

	Agricultural Pumping	Groundwater ET	Subsurface Outflow to Adjacent Basins	Discharge to Streams	Surface Leakage	M&I + Rural Domestic
Mean	12,600	11,700	4,300	14,500	6,200	11,300
Minimum	10,700	8,400	4,000	10,400	3,000	9,500
Maximum	14,800	15,500	4,500	20,600	11,400	12,500
Median	12,500	11,600	4,300	14,400	6,100	11,800

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-27. Projected (WY 2021 to WY 2070) Groundwater Outflows Budget Summary (AFY)[a]

	Agricultural Pumping	Groundwater ET	Subsurface Outflow to Adjacent Basins	Discharge to Streams	Surface Leakage	M&I + Rural Domestic
Mean	13,800	10,600	4,000	12,800	4,900	12,300
Minimum	10,700	6,900	3,400	7,800	1,500	9,500
Maximum	16,800	15,500	4,500	20,600	11,400	13,700
Median	13,700	10,700	4,100	13,100	5,000	12,700

[a] Values are rounded to the nearest 100 acre-feet.

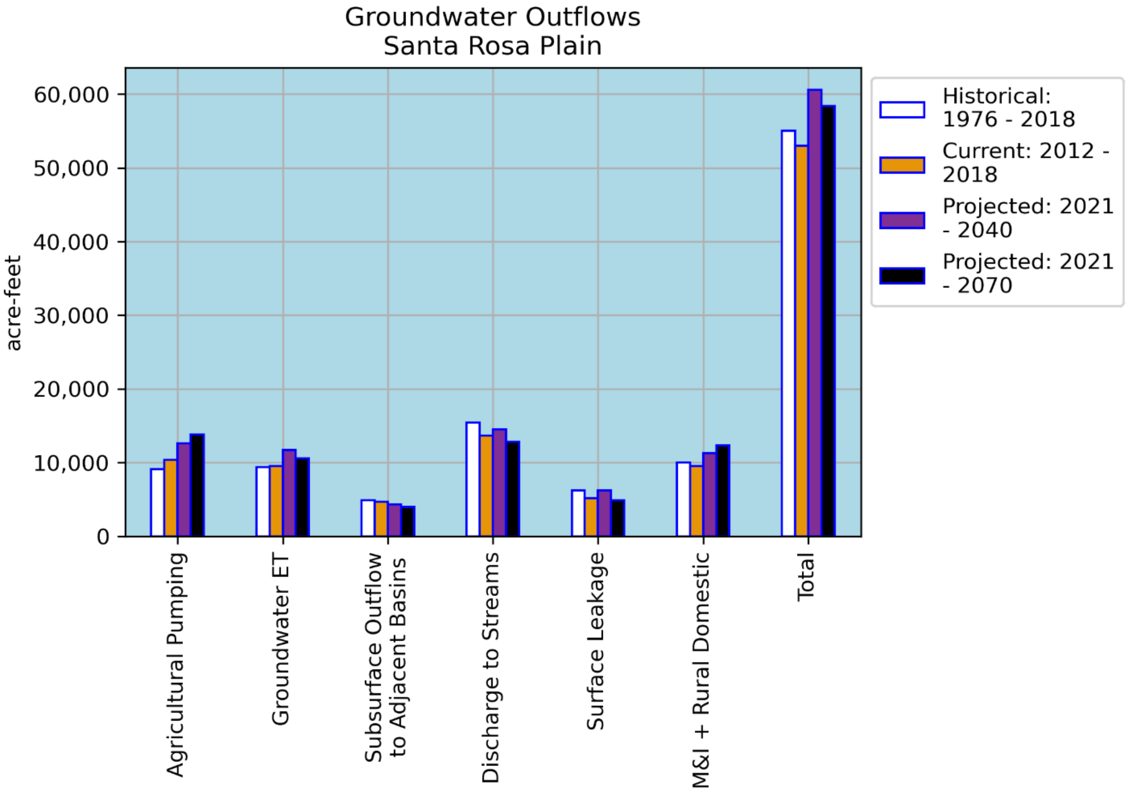

Figure 3-48. Groundwater Outflows by Water Budget Period

The change in groundwater storage is equal to the sum of groundwater inflows and the sum of groundwater outflows. Groundwater inflows and outflows are depicted on **Figure 3-49** in the first two rows of plots, and the change in groundwater storage is shown in the third row. The cumulative storage change from the initiation of the historic model in WY 1976 to the conclusion of the projected conditions in WY 2070 is a total decline of -97,200 acre-feet. By the end of WY 2040, the cumulative storage change from the initiation of the historic model is -28,900 acre-feet. For the 20-year period, from WY 2021 to 2040, the average change in groundwater storage is -200 AFY (-3,300 acre-feet total), whereas for the WY 2021 to 2070, the average change in groundwater storage is -1,400 AFY (-71,500 acre-feet total; **Table 3-28**). Groundwater storage in the Subbasin experiences a moderate increase in the first 25 years of the projected period, followed by a more rapid decline from WY 2046 to 2070 at a rate of -3,100 AFY.

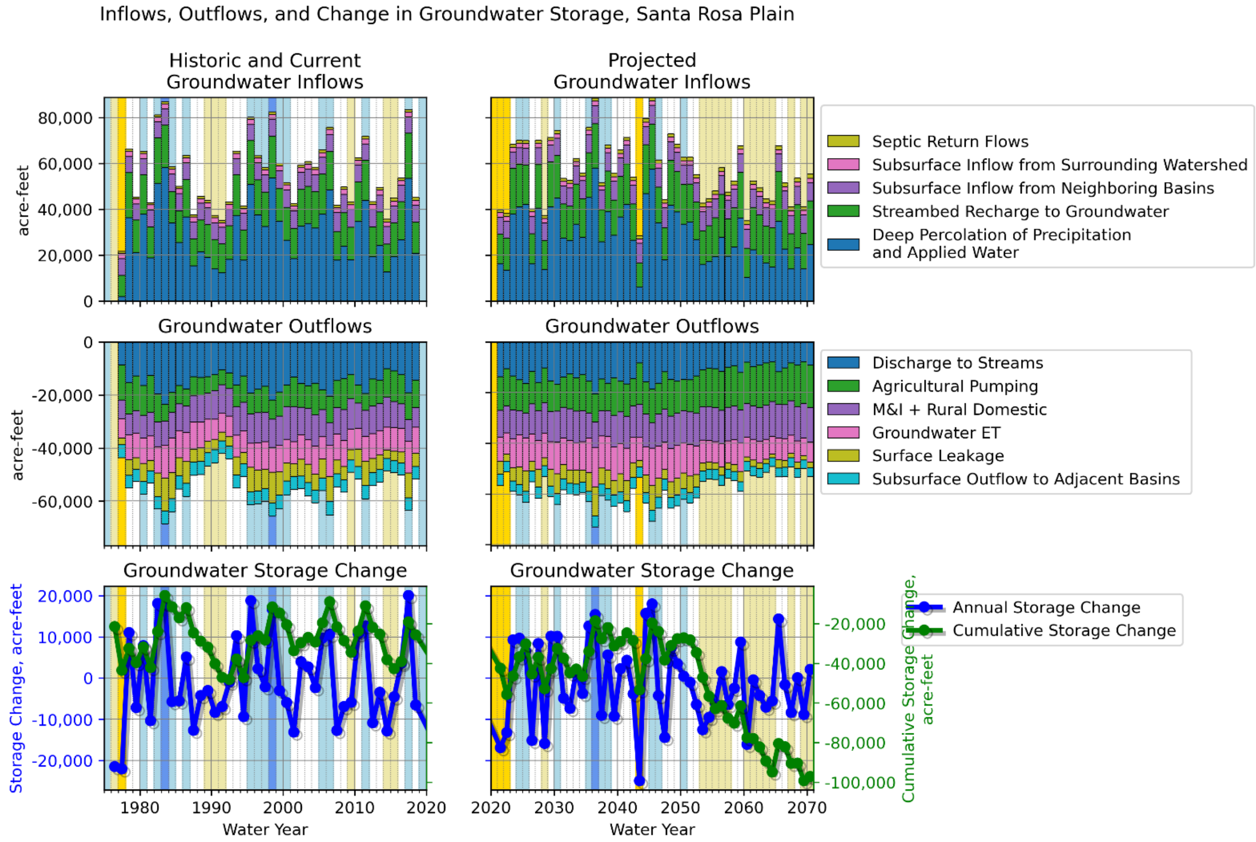

Figure 3-49. Inflows, Outflows, and Change in Groundwater Storage

Table 3-28. Average Annual Change of Groundwater in Storage (AFY)[a]

	Projected (WY 2021 to WY 2070)	Projected (WY 2021 to WY 2040)
Mean	-1,400	-200
Minimum	-24,900	-16,900
Maximum	18,000	15,400
Median	-2,000	2,100

[a] Values are rounded to the nearest 100 acre-feet.

Figure 3-50 shows the groundwater pumpage by water-use sector. For the WY 2021 to 2040 period, rural domestic pumpage is similar to the current period. Rural domestic pumpage is projected to increase over the 50-year simulation period, however. Municipal pumpage increases by 1,400 AFY for WY 2021 to 2040 period, and agriculture pumpage increases by 2,200 AFY, compared to the current period. Together these changes combine to increase the total groundwater pumpage by 3,600 AFY, which represents an 18 percent increase in pumpage for the WY 2021 to 2040 period, compared to the current period (**Table 3-29**). The increase in agricultural pumpage is caused by crop expansion in the Subbasin and by the projected warming climate. Increases in both minimum and maximum temperatures cause an increase in potential ET, which thus increases agricultural irrigation demands. These effects become more important by the end of the simulation. Near WY 2070 agricultural pumpage reaches its peak. The total increase in groundwater pumpage for agriculture is 33 percent for the WY 2021 to 2070 period, compared to the current water budget period. Municipal water uses increase 31 percent (2,200 AFY) for the same periods, and rural domestic uses increase by 10 percent (300 AFY). Overall total groundwater pumpage increases by 29 percent or 5,900 AFY for the WY 2021 to 2070 simulation (**Table 3-30**).

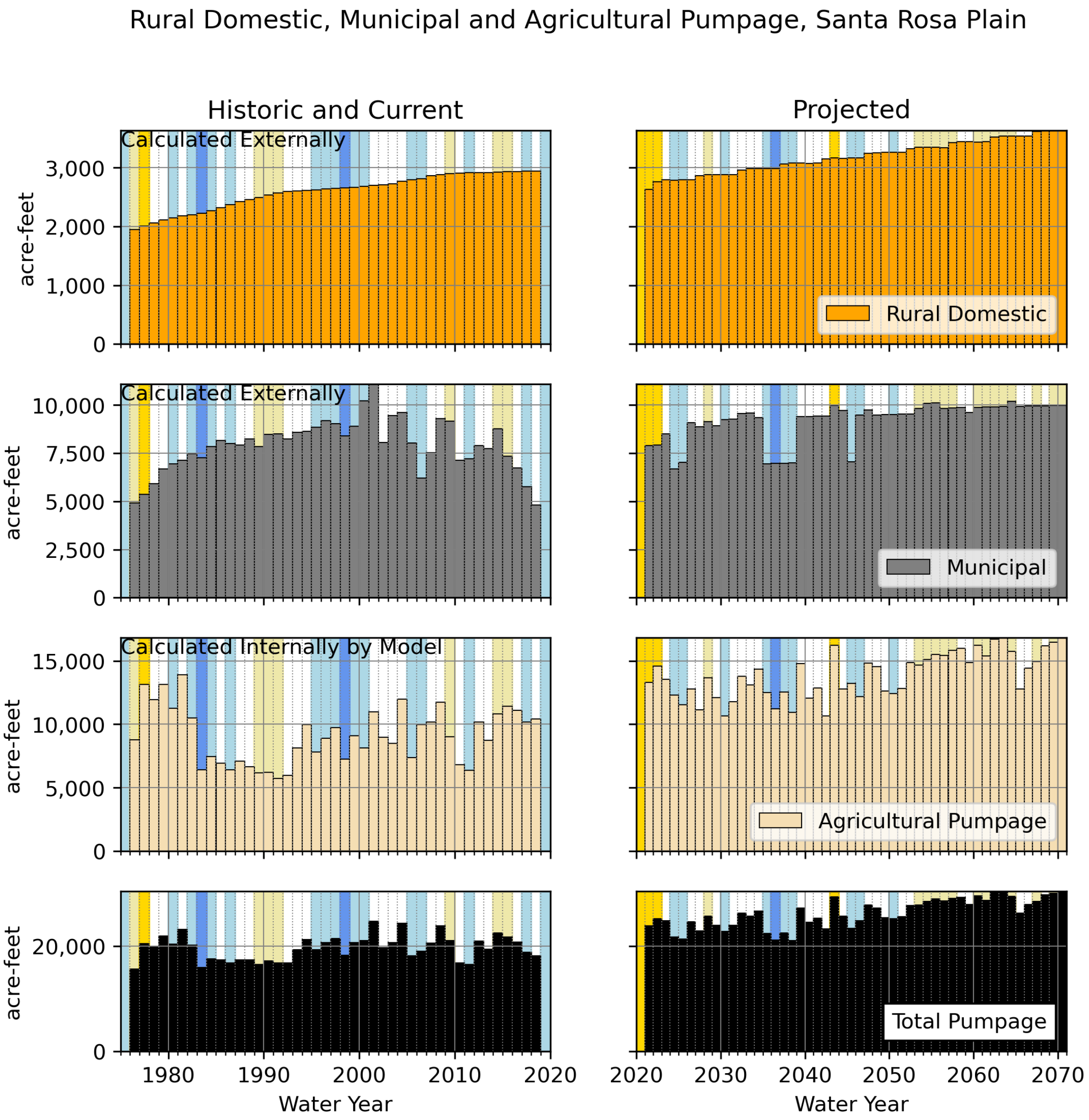

Figure 3-50. Groundwater Pumpage by Water-use Sector

Table 3-29. Projected (WY 2021 to WY 2040) Groundwater Pumpage by Water-use Sector (AFY)[a]

	M&I	Rural Domestic	Agricultural Pumping
Mean	8,400	2,900	12,600
Minimum	6,700	2,600	10,700
Maximum	9,600	3,100	14,800
Median	8,900	2,900	12,500

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-30. Projected (WY 2021 to WY 2070) Groundwater Pumpage by Water-use Sector (AFY)[a]

	M&I	Rural Domestic	Agricultural Pumping
Mean	9,200	3,200	13,800
Minimum	6,700	2,600	10,700
Maximum	10,200	3,600	16,800
Median	9,500	3,200	13,700

[a] Values are rounded to the nearest 100 acre-feet.

Figure 3-51 shows the historical, current, and projected groundwater inflows from neighboring watershed areas and neighboring groundwater subbasins. Groundwater inflows from neighboring watershed areas are projected to continue to decline to the end of the simulation period at WY 2070. Groundwater inflows from Rincon-Kenwood Subbasin inflows increase by 200 AFY for both the WY 2021 to 2040 (**Table 3-31**) and WY 2021 to 2070 periods (**Table 3-32**) compared to the historic budget, which is a 9 percent change. The Wilson Grove inflows decrease by 300 AFY for both projected simulation budget periods, which is a -21 percent change compared to historic values. Finally, the groundwater inflows from the Healdsburg Area Subbasin change the most significantly compared to the other inflows. Because of lowered groundwater levels in the Subbasin after WY 2050, the Healdsburg Area switches from its previous outflow conditions to one in which groundwater flow is predominantly moving into the Subbasin from the Healdsburg Area Subbasin. In the historic period this boundary received 1,100 AFY from the Subbasin, but during the entire future budget period the flow into the basin is +400 AFY.

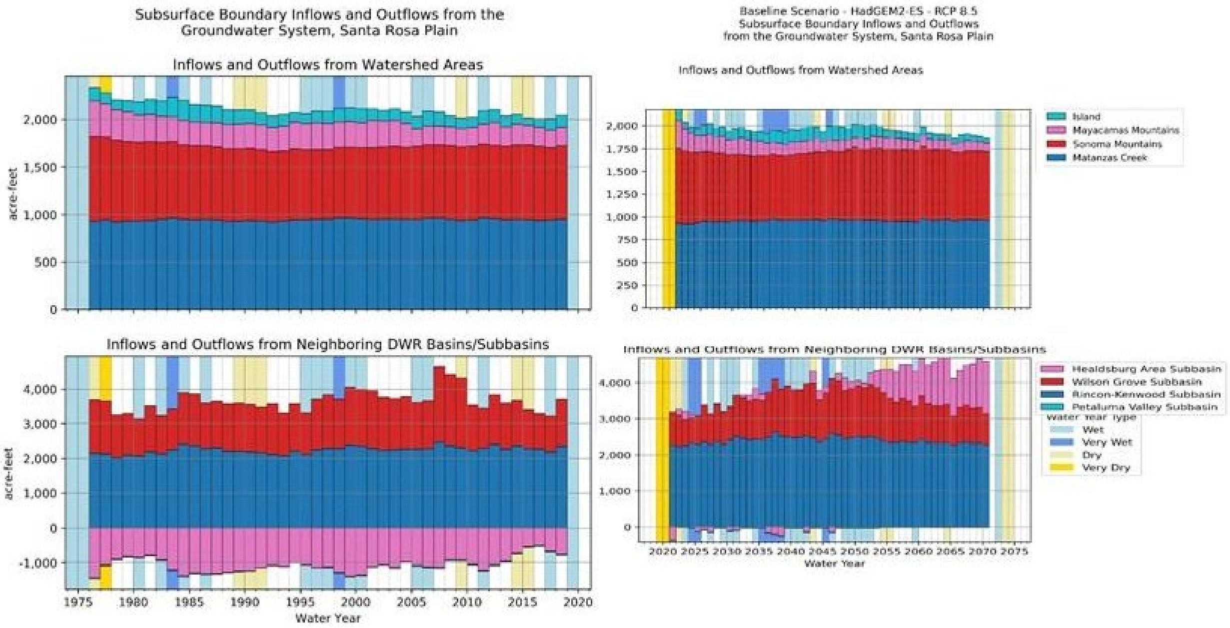

Figure 3-51. Historical, Current, and Projected Inflows and Outflows from Watershed Areas and Neighboring Basins/Subbasins

Table 3-31. Projected (WY 2021 to WY 2040) Subbasin Boundary Flows (AFY)[a]

	Petaluma Valley Basin	Rincon-Kenwood Subbasin	Healdsburg Area Subbasin	Wilson Grove Subbasin
Mean	-0	2,400	-0	1,100
Minimum	-0	2,200	-400	700
Maximum	-0	2,600	300	1,500
Median	-0	2,400	0	1,100

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-32. Projected (WY 2021 to WY 2070) Subbasin Boundary Flows (AFY)[a]

	Petaluma Valley Basin	Rincon-Kenwood Subbasin	Healdsburg Area Subbasin	Wilson Grove Subbasin
Mean	-0	2,400	400	1,100
Minimum	-0	2,200	-400	700
Maximum	-0	2,600	1,400	1,600
Median	-0	2,400	200	1,100

[a] Values are rounded to the nearest 100 acre-feet.

3.3.6.6 Projected Watershed and Soil-zone Budgets

The projected watershed and soil-zone budgets are shown on **Figure 3-52**, and are summarized in **Table 3-33**, **Table 3-34**, **Table 3-35**, and **Table 3-36**. In the WY 2021 to 2040 period, soil-zone recharge increases 15 percent, similar to the change in precipitation, compared to the historical period. Precipitation increases 19 percent for the same period. The historical mean precipitation is 290,400 AFY and the WY2021-2040 mean precipitation is 346,100 AFY. Likely as a result of the increased precipitation and some very wet years in that period, the mean Dunnian flow and interflow increase 38 percent and 22 percent, respectively, compared to their historic values, changing from -40,100 AFY to -55,500 AFY, and -57,100 AFY to -69,800 AFY, respectively. Soil moisture remains similar to the historic period, while total soil ET increased by 13 percent.

For the projected period from WY 2021 to 2070, overall soil moisture decreases by 6 percent, from an average of 38,200 AF in the historic to 36,000 AF in the WY 2021 to 2070 period (**Table 3-35**, and **Table 3-36**). Dunnian flow and interflow showed deviations of 3 percent and -1 percent, respectively, from their historic averages. Aside from agricultural water applied to the soil zone, which experienced a 2,900 AFY increase in the projected period, ET in the soil zone showed the biggest change. It increased by 12 percent from its historical value of -147,600 AFY to 165,700 AFY in the WY 2021-2070 period likely due to the increased potential ET in the warmer projected climate.

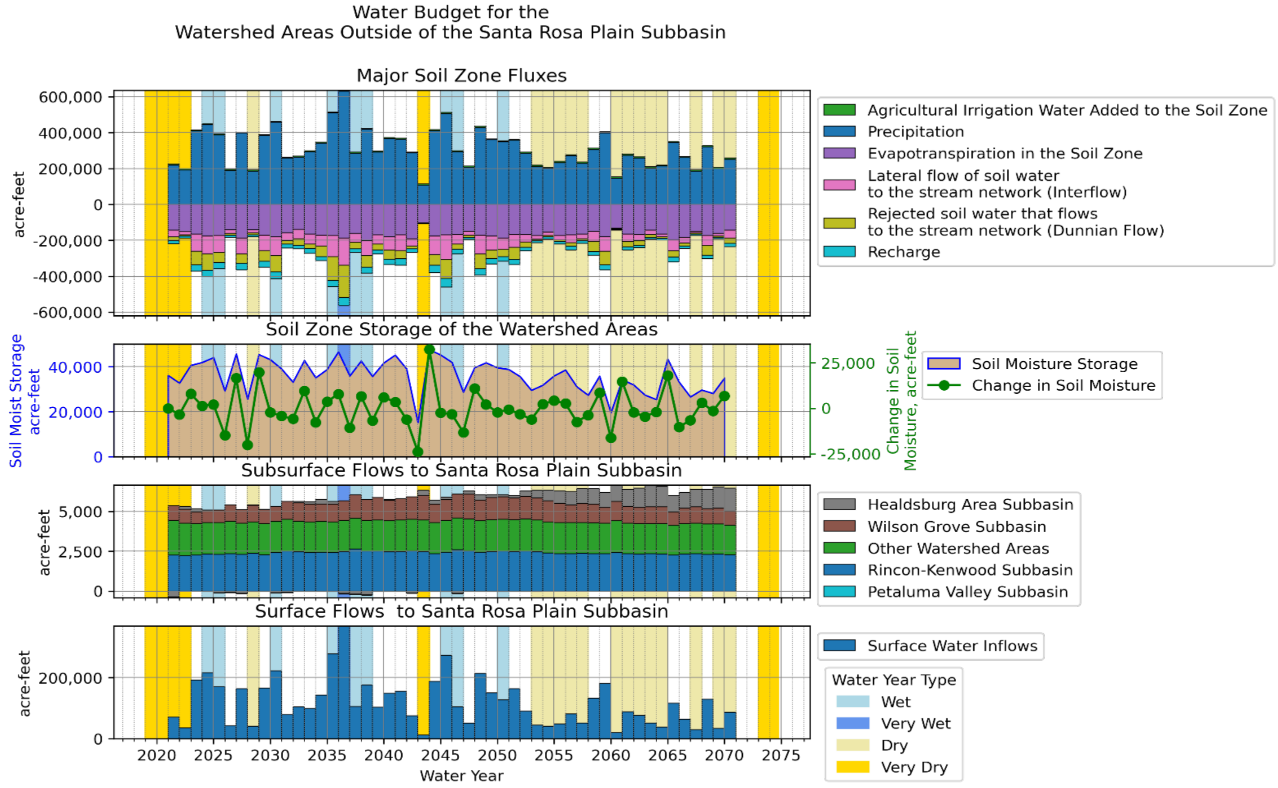

Figure 3-52. Projected Budget for Watershed Areas Outside Subbasin

Table 3-33. Projected (WY 2021 to WY 2040) Budget for Watershed Areas Outside Subbasin and Major Soil-zone Fluxes[a]

	Precipitation (AFY)	Agricultural Irrigation Water Added to the Soil Zone (AFY)	ET in the Soil Zone (AFY)	Soil-zone Recharge (AFY)	Rejected Soil Water that Flows to the Stream Network (Dunnian Flow; AFY)	Lateral flow of Soil Water to the Stream Network (Interflow; AFY)	Soil Moisture (acre-feet)	Change in Soil Moisture (AFY)
Mean	346,100	5,400	-167,200	-27,100	-55,500	-69,800	38,800	300
Minimum	185,100	4,400	-201,400	-46,600	-179,200	-151,100	25,700	-20,100
Maximum	630,600	6,800	-139,600	-8,600	-7,100	-16,500	46,600	19,800
Median	353,600	5,300	-170,500	-28,400	-52,200	-67,400	39,800	600

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-34. Projected (WY 2021 to WY 2040) Budget for Watershed Areas Outside Subbasin, Subsurface, and Surface Flows into Subbasin (AFY)[a]

	Other Watershed Areas	Surface Water Inflows
Mean	2,000	146,300
Minimum	1,900	35,300
Maximum	2,200	369,000
Median	2,000	145,500

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-35. Projected (WY 2021 to WY 2070) Watershed Budget for Watershed Areas Outside Subbasin and Major Soil-zone Fluxes[a]

	Precipitation (AFY)	Agricultural Irrigation Water Added to the Soil Zone (AFY)	ET in the Soil Zone (AFY)	Soil-zone Recharge (AFY)	Rejected Soil Water that Flows to the Stream Network (Dunnian Flow; AFY)	Lateral Flow of Soil Water to the Stream Network (Interflow; AFY)	Soil Moisture (acre-feet)	Change in Soil Moisture (AFY)
Mean	307,600	6,000	-165,700	-22,900	-41,300	-56,300	36,000	-0
Minimum	107,200	4,400	-201,400	-49,800	-179,200	-151,100	15,200	-23,800
Maximum	630,600	7,800	-104,300	-1,300	-1,400	-1,300	47,700	32,400
Median	289,000	6,000	-168,600	-20,900	-31,200	-51,100	36,000	-1,800

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-36. Projected (WY 2021 to WY 2070) Watershed Budget for Watershed Areas Outside Subbasin, Subsurface Flows to Subbasin, and Surface Flows to the Subbasin[a]

	Other Watershed Areas	Surface Water Inflows
Mean	2,000	116,800
Minimum	1,900	12,300
Maximum	2,200	369,000
Median	2,000	103,600

[a] Values are rounded to the nearest 100 acre-feet.

The soil-zone water budget for the Subbasin is shown on **Figure 3-53** and is summarized in **Table 3-37** and **Table 3-38**. The biggest change in soil-zone fluxes is ET with a change of -48,400 AFY in the WY 2021 to 2040, and -51,100 AFY in the WY 2021 to 2070 period, compared to the historic period. The historical value is -107,300 AFY and the values are -155,700 AFY and -158,400 AFY for the WY 2021-2040 and WY 2021-2070 periods, respectively (**Table 3-37** and **Table 3-38)**. Given that the longer period has a greater magnitude of ET than the WY 2021 to 2040 period, the increased rate of ET is more likely due to an increase in temperatures than an increased availability of water. The future maximum temperatures are 5.3 F greater than the historical period, and the minimum temperatures are 5.0 F greater (**Figure 3-38**). In addition, the soil moisture storage of the entire projection period is 8 percent lower than the historic period despite the prolonged period of increased precipitation. Again, given the relative similarity of average precipitation in the projected period compared to the historic, this decrease in soil moisture storage is likely due to the increased soil ET.

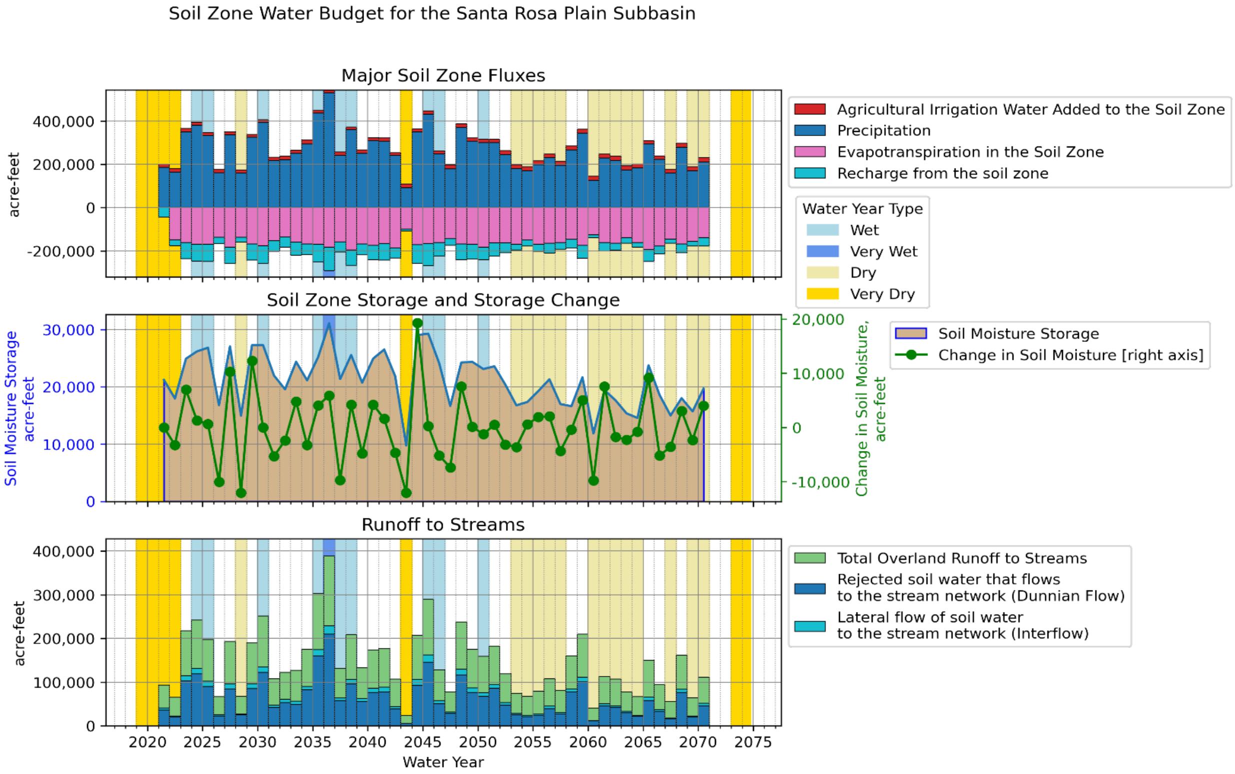

Figure 3-53. Projected Soil-zone Budget for the Subbasin

Table 3-37. Projected (WY 2021 to WY 2040) Budget for the Subbasin Soil Zone[a]

	Precipitation (AFY)	Agricultural Irrigation Water Added to the Soil Zone (AFY)	ET in the Soil Zone (AFY)	Soil-zone Recharge (AFY)	Rejected Soil Water that Flows to the Stream Network (Dunnian Flow; AFY)	Lateral Flow of Soil Water to the Stream Network (Interflow; AFY)	Soil Moisture (acre-feet)
Mean	294,900	14,500	-155,700	-60,700	79,500	8,900	23,300
Minimum	159,200	12,200	-196,100	-109,300	20,000	2,500	15,000
Maximum	530,500	17,000	-0	-23,400	210,000	18,800	31,100
Median	302,200	14,400	-167,200	-63,200	79,500	8,500	24,600

[a] Values are rounded to the nearest 100 acre-feet.

Table 3-38. Projected (WY 2021 to WY 2070) Budget for Subbasin Soil Zone[a]

	Precipitation (AFY)	Agricultural Irrigation Water Added to the Soil Zone (AFY)	ET in the Soil Zone (AFY)	Soil-zone Recharge (AFY)	Rejected Soil Water that Flows to the Stream Network (Dunnian Flow; AFY)	Lateral Flow of Soil Water to the Stream Network (Interflow; AFY)	Soil Moisture (acre-feet)
Mean	262,600	15,900	-158,400	-50,800	62,800	7,200	21,200
Minimum	91,300	12,200	-196,100	-109,300	5,400	500	9,800
Maximum	530,500	19,200	-0	-8,100	210,000	18,800	31,100
Median	246,900	15,700	-164,200	-46,900	52,100	6,600	21,300

[a] Values are rounded to the nearest 100 acre-feet.

3.3.6.7 Projected Water Budget Summary

The projected water budget is characterized by an elevated average precipitation in the first 30 years of the 50-year simulation. This period is followed by an increasingly warm and dry climate for the last 20 years of the simulation period. Mean annual minimum and maximum temperatures are greater for the future simulation period, averaging 5.0°F and 5.3°F greater, respectively, than the historical period.

In the initial wetter 30-year period, the groundwater storage experiences a net positive increase as groundwater inflows respond via increased recharge from precipitation and streamflow recharge. Starting around WY 2050, surface leakage, groundwater discharge to streams, and groundwater ET begin to decline steadily, while groundwater storage begins a notable decline. From WY 2046 to 2070 the average rate of groundwater storage change is -3,100 AFY. The average rate of groundwater storage change is -200 AFY for the WY 2021 to 2040 period. Though most of storage loss occurred in the last 20 years, the WY 2021 to 2070 change in groundwater storage is -1,400 AFY.

During the implementation period from WY 2021 to 2040, total inflows increase by 11 percent whereas outflows increase by 10 percent, compared to the historical mean values. The largest absolute gains to inflows is observed in deep percolation of precipitation and applied waters (4,100 AFY increase or 14 percent), and streambed recharge to groundwater (1,600 AFY increase or 11 percent increase). The increases in groundwater outflows result from a 25 percent increase in groundwater pumpage (4,800 AFY) and a 25 percent increase in groundwater ET (2,300 AFY). Similar to the increases in groundwater ET, the increased temperatures also cause greater soil-zone ET to occur in both the watershed and Subbasin areas. The total soil-zone ET increases 48 percent from the historic period to the WY 2021- 2040 period, for areas within the Subbasin. Despite the large increases in soil ET, mean values of soil moisture decrease by only -8 percent in the Subbasin from the historic to the WY 2021-2070 period.

Total groundwater pumpage for the entire WY 2021-2070 simulation period increases from its current period mean annual value by 5,900 AFY (from 20,300 AFY). Agricultural pumpage experiences the largest growth of the water-use sectors. For the WY 2021-2070 period, agricultural pumpage increase 3,400 AFY from the current period mean value of 10,400 AFY. Along with the increased temperatures and a drying climate, the projected growth in agricultural crop acreage is a driver of the increased agricultural groundwater pumpage demands.

During the historic period groundwater typically flowed from the Subbasin into the Healdsburg Area Subbasin. But due to lowered groundwater levels, the groundwater flow direction reverses direction, changing the Healdsburg Area into a continuous net contributor of groundwater into the Subbasin by the end of the simulation period.

3.3.6.8 Uncertainties in Projected Water Budget Simulations

The uncertainty of the projected water budget components is similar to those of the historical budget, but there are additional uncertainties due to the incorporation of long-term projections. The projected budget incorporates uncertain projections of land use changes for agriculture, changes in groundwater demands for municipal users, and modeled estimates of rural domestic groundwater demands. These projections are based on the simplification of complex socioeconomic, cultural and political forces, amongst many other drivers of change that will impact how groundwater usage changes in the future. The incorporation of a climate change scenario creates additional uncertainty. Like the projections of groundwater demand and land use changes, there are numerous factors that prohibit accurate and reliable climate change conditions. Despite these challenges, it should be emphasized that the projections of climate change and groundwater demands are within the bounds of reasonableness for such projections, and do provide a useful tool for understanding future groundwater conditions. Other model boundary conditions are also characterized by increased uncertainty in the projected simulation. General head boundaries (GHBs) simulate subsurface groundwater inflow and outflow from neighboring areas, such as the Wilson Grove, Petaluma Valley Basin, and the Healdsburg Area Subbasin. For the historical simulation, the boundary head defined for these interfaces was derived from observed data nearby the boundaries. For the projected simulation there exist no observed data that can be used to establish the boundary heads. Because of this, the historical boundary heads were used for the projected boundary heads. The overall impact of this approach should be limited given the relative magnitude of the net subsurface inflow from neighboring basins compared to the other sources of inflow. The net groundwater inflow simulated by the GHBs is 1/20th the magnitude of the remaining groundwater inflow components.

There does exist inescapable uncertainty in the projected simulation water budget. Despite these limitations, the model and its conclusions should be regarded as a useful tool and source of information for the planning and implementation of the GSP.

3.3.7 Sustainable Yield

The sustainable yield of the Subbasin is an estimate of the quantity of groundwater that can be pumped on a long-term average annual basis without causing undesirable results. Basinwide pumping within the sustainable yield estimate is neither a measure of, nor proof of, sustainability. Sustainability under SGMA is only demonstrated by avoiding undesirable results for the five applicable sustainability indicators. However, estimates of sustainable yield using the current and projected simulations may prove useful in estimating the need for projects and management actions to help achieve sustainability.

The role of sustainable yield estimates in SGMA, as described in the SMC BMP (DWR 2017), are as follows:

> "In general, the sustainable yield of a basin is the amount of groundwater that can be withdrawn annually without causing undesirable results. Sustainable yield is referenced in SGMA as part of the estimated basinwide water budget and as the outcome of avoiding undesirable results.
>
> Sustainable yield estimates are part of SGMA's required basinwide water budget. Section 354.18(b)(7) of the GSP Regulations requires that an estimate of the basin's sustainable yield be provided in the GSP (or in the coordination agreement for basins with multiple GSPs). A single value of sustainable yield must be calculated basinwide. This sustainable yield estimate can be helpful for estimating the projects and programs needed to achieve sustainability."

The 20-year period from WY 2021 to 2040 is used to determine the sustainable yield of the Subbasin. This period is selected based on the following factors:

- Representative of long-term conditions: Mix of 6 wet years, 1 very wet year, 1 dry year, 2 very dry years and 10 normal years.
- The simulated net groundwater storage change during this period is near zero (**Figure 3-54**).
- There are no simulated undesirable results related to chronic lowering of groundwater during this period.
- The sustainable yield is derived from Projected Baseline conditions that include climate change.

The average total groundwater pumpage for this period is 23,900 AFY, which is defined here as the sustainable yield (**Figure 3-54**). This value is 39 percent of the total groundwater inflows into the Subbasin, and is greater than the average total groundwater pumpage experienced during the current water budget period.

The sustainable yield is dependent on the anticipated reasonable climate conditions (Loaiciga 2016) and is not predicated on implementation of projects and actions. If future climate conditions are better represented by the hotter and drier conditions observed in the WY 2050-2070 period of the projected scenario rather than the wetter WY 2021-2040 period, then the sustainable yield will need to be reduced, or projects and management actions will need to occur to allow for the Subbasin to avoid undesirable results.

Minimum thresholds for depletion of interconnected surface water will be further refined during the five-year GSP update. As such the sustainable yield does not fully account for the impact of basinwide pumpage on surface water depletion.

The sustainable yield pertains to a basinwide pumping value. Changes in the location of pumping may induce greater depletion of surface waters or movement of waters of poor water quality, for example, which may lead to undesirable results. As described in **Section 7**, the water budget and estimated sustainable yield will continue to be evaluated with new information and alternative climate scenarios during the five-year GSP updates.

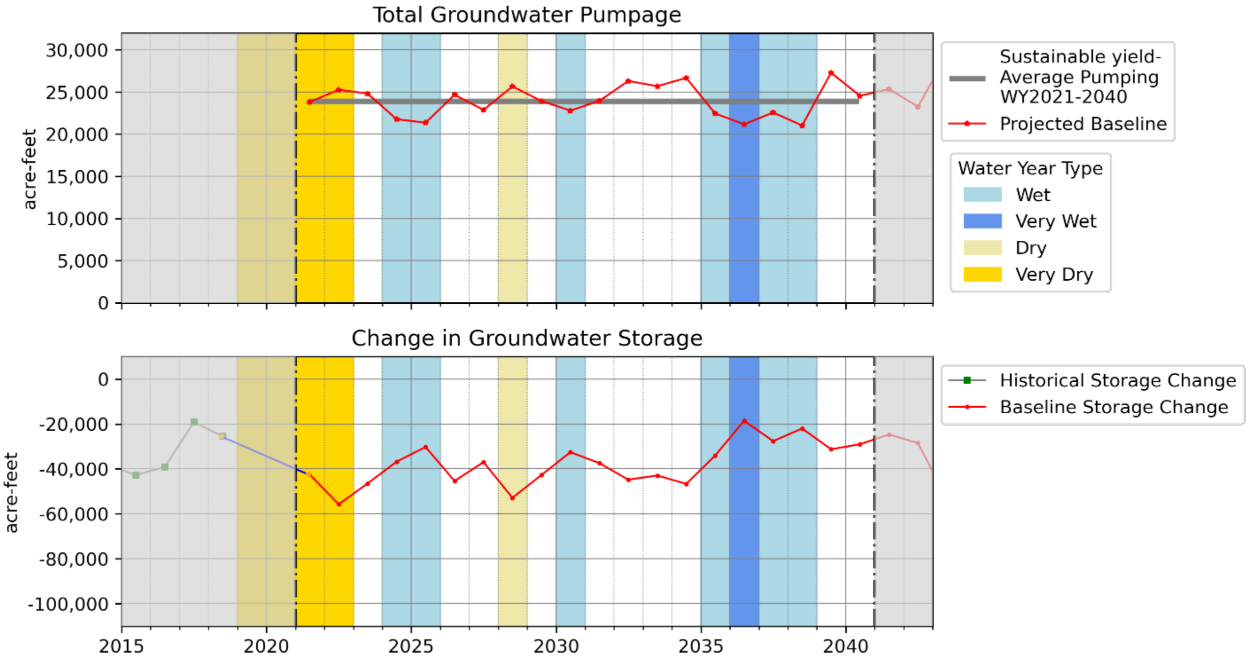

Figure 3-54. Sustainable Yield: Total Groundwater Pumpage and Change in Groundwater Storage

3.4 Management Areas

SGMA provides GSAs with the ability to define one or more management areas within a basin if the GSA determines that the creation of management areas will facilitate implementation of the GSP. Management areas can be used to define different minimum thresholds and be operated to different measurable objectives than the basin at large, provided that undesirable results are defined consistently throughout the basin (23 CCR 354.20).

Management areas were not defined for the Subbasin. Management areas may be considered in the future if the GSA finds that doing so will facilitate implementation of the GSP.

Section 4: Sustainable Management Criteria

Groundwater Sustainability Plan

Santa Rosa Plain Groundwater Subbasin

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4 SUSTAINABLE MANAGEMENT CRITERIA

This section identifies the sustainability goal, defines the conditions that constitute sustainable groundwater management, discusses the process by which the GSA will characterize undesirable results, and establishes minimum thresholds (MTs) and measurable objectives (MOs) for each applicable sustainability indicator.

The MOs, MTs, and undesirable results detailed in this section define the Subbasin's future desired conditions and inform the selection, prioritization, and planning for projects and management actions to achieve these conditions. Defining these sustainable management criteria (SMC) included both a significant level of technical analysis utilizing currently available data and information and best available science and substantial input from stakeholders. This section includes a description of how SMC were developed and how they influence all beneficial uses and users. Uncertainty caused by data gaps in the hydrogeologic conceptual model and existing monitoring networks was considered when developing the SMC. Due to this uncertainty, these SMC are considered initial criteria and will be re-evaluated and potentially modified in the future as new data become available.

SMC are provided for each of the following sustainability indicators:

- Chronic lowering of groundwater levels
- Reduction in groundwater storage
- Degraded water quality
- Land subsidence
- Depletion of interconnected surface water

Seawater intrusion is not applicable to the Subbasin and therefore no SMC are defined for this sustainability indicator.

Each sustainability indicator subsection follows a consistent format that contains the information required by Section 354.22 et. seq of the GSP Regulations and outlined in the SMC BMP (DWR 2017). The subsection for each sustainability indicator includes a description of:

- How locally defined significant and unreasonable conditions were developed
- How MTs were developed, including:
    - The information and methodology used to develop MTs, Section 354.28 (b)(1)
    - The relationship between MTs for other sustainability indicators, Section 354.28 (b)(2)
    - Potential effects of MTs on neighboring basins, Section 354.28 (b)(3)
    - Potential effects of MTs on beneficial uses and users, Section 354.28 (b)(4)
    - Relationship of MTs to relevant federal, state, or local standards, Section 354.28 (b)(5)
    - The method for quantitatively measuring MTs, Section 354.28 (b)(6)

- How MOs were developed, including:
    - The methodology for setting MOs, Section 354.30
    - Interim milestones, where applicable, Sections 354.30 (a), 354.30 (e), 354.34 (g)(3)

- How undesirable results were developed, including:
    - The criteria for defining undesirable results, Section 354.26 (b)(2)
    - Potential causes of undesirable results, Section 354.26 (b)(1)
    - Potential effects of these undesirable results on the beneficial users and uses, Section 354.26 (b)(3)

4.1 Definitions

The SGMA legislation and GSP Regulations contain terms relevant to the SMC. These terms are defined as follows using the definitions included in the GSP Regulations, and explanatory text is provided where appropriate. This explanatory text is not part of the official definitions of these terms but provides useful clarifications.

Interconnected surface water refers to 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. Interconnected surface waters are sections of streams, lakes, or wetlands where the groundwater table is at or near the ground surface or surface water body/stream channel bottom. Interconnection between surface water and groundwater may be seasonal.

Interim milestone refers to a target value representing measurable groundwater conditions, in increments of 5 years. Interim milestones are targets such as groundwater elevations that should be achieved every 5 years to demonstrate progress towards sustainability.

Measurable objectives refer to specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted plan to achieve the sustainability goal for the basin. MOs are goals that the GSP is designed to achieve, but failure to achieve those objectives shall not be grounds for a finding of inadequacy of the Plan.

Minimum threshold refers to a numeric value for each sustainability indicator used to define undesirable results. MTs are indicators of an unreasonable condition. For example, groundwater levels that maintain operational capacity for water wells may be a MT because groundwater levels dropping below levels that significantly impact well production capacities or dewater wells would be an unreasonable condition.

Representative monitoring sites refers to a monitoring site within a broader network of sites that typifies one or more conditions within the basin or an area of the basin.

Significant and unreasonable conditions

> "Significant and unreasonable conditions" is a phrase used to identify conditions that lead to undesirable results but is not specifically defined in the definitions section of the GSP Regulations (Section 351). This expression is often confused with, or used interchangeably with, undesirable results. This GSP defines significant and unreasonable conditions as a narrative description of physical conditions to be avoided; an undesirable result is a

quantitative assessment based on MTs. Defining significant and unreasonable conditions early in the process of developing SMC for each sustainability indicator helps set the framework by which the quantitative SMC metrics are determined.

Sustainability indicator refers to any of the effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, cause undesirable results, as described in Water Code Section 10721(x). The five sustainability indicators relevant to this Subbasin include chronic lowering of groundwater levels; reduction of groundwater storage; degraded water quality; land subsidence; and depletion of interconnected surface waters. Seawater intrusion is not applicable to the Subbasin.

Uncertainty refers to a lack of understanding of the basin setting that significantly affects an Agency's ability to develop SMC and appropriate projects and management actions in a plan, or to evaluate the efficacy of plan implementation, and therefore may limit the ability to assess whether a basin is being sustainably managed.

Undesirable Result means one or more of the following effects caused by groundwater conditions occurring throughout the basin, as described in Water Code Section 10721(x):

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.
- Significant and unreasonable reduction of groundwater storage.
- Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
- Significant and unreasonable land subsidence that substantially interferes with surface land uses.
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

Undesirable Result is not defined in the definitions section of the GSP Regulations (Section 351). However, the Regulations' description of undesirable result states that it should be a quantitative description of the combination of MT exceedances that cause significant and unreasonable effects in the Subbasin. Undesirable results should not be confused with significant and unreasonable conditions.

4.2 Sustainability Goal

Per Section 354.24 of the GSP Regulations, the sustainability goal for the Subbasin has three parts:

- A description of the sustainability goal
- A discussion of the measures that will be implemented to ensure the Subbasin will be operated within sustainable yield
- An explanation of how the sustainability goal is likely to be achieved

Description of Sustainability Goal:

The goal of this GSP is to adaptively and sustainably manage, protect, and enhance groundwater resources while allowing for reasonable and managed growth through:

- Careful monitoring of groundwater conditions
- Close coordination and collaboration with other entities and regulatory agencies that have a stake or role in groundwater management in the Subbasin
- A diverse portfolio of projects and management actions that ensure clean and plentiful groundwater for future uses and users in an environmentally sound and equitable manner

Measures to Achieve Sustainability Goal:

Projects and actions that the GSA has identified as potential measures to be implemented to ensure sustainability are included in **Sections 6** and **7** of this GSP. These measures include actions proposed to fill data gaps and reduce uncertainty to inform future refinement and possible modification of the initial SMC described herein. While all of the identified measures may not be implemented, some combination of these measures will be implemented to ensure the Subbasin is operated within its sustainable yield and achieves sustainability. The measures to achieve sustainability are centered on advancing the following four projects within the Subbasin while also developing and prioritizing demand management policy options for the GSA Board to consider in the early stages of GSP implementation:

- Implementation and assessment of voluntary conservation and groundwater-use efficiency projects
- Planning and implementation of ASR projects
- Planning and implementation of stormwater capture and recharge projects

Section 6 also describes the following management actions to supplement the previously described projects:

- Assessment and prioritization of potential policy options, including demand management measures, for future GSA consideration
- Coordination with agricultural groundwater users within the Subbasin to integrate measures that support sustainable groundwater management with farm plans that are developed at individual farm sites
- Assessment of additional opportunities to expand and/or maximize efficiencies of recycled water supplies

The projects and management actions will be implemented using an adaptive management strategy, which will allow the GSA to react to the progress and outcomes of projects and management actions implemented in the Subbasin and to make management decisions to redirect efforts in the Subbasin as necessary to effectively achieve the sustainability goal. **Section 7** of this GSP describes the initial prioritization and sequencing of measures that are considered likely to be implemented in the early stages of GSP implementation.

4.3 General Process for Establishing Sustainable Management Criteria

The SMC presented in this section were developed using technical analysis of publicly available information, meetings with GSA and member agency staff, Advisory Committee members, GSA Board, practitioner work groups, discussions with regulatory agencies, and feedback gathered during public meetings. The general process included:

- Identification of technical data sources in the Subbasin and review of information developed for the Santa Rosa Plain GMP.
- Discussions with GSA technical staff to develop initial overarching methodologies to developing SMC, and specific approaches for each sustainability indicator.
- Public meeting presentations to the Advisory Committee outlining the approach to developing SMC and discussing initial SMC ideas. The public was provided opportunity to comment during these presentations. The Advisory Committee provided feedback and suggestions for the development of initial SMC.
- Discussions and meetings with staff from other regulatory agencies and local organizations that have shared interests or responsibilities for components of some sustainability indicators, including practitioner work groups convened to inform and support development of SMC for depletion of interconnected surface water.
- Public meeting presentations to the GSA Board on the SMC requirements, proposed methodology for establishing MTs and MOs, options for establishing undesirable results and SMC implications.

- Modifying MTs, MOs, and undesirable results, where appropriate, based on technical analyses, input from GSA and member agency staff, Advisory Committee members, GSA Board members, and the public.

This general process resulted in the SMC presented in this section.

4.4 Sustainable Management Criteria Summary

Table 4-1 provides a succinct summary of the SMC for each of the five applicable sustainability indicators. Further discussion of the SMC, including the rationale and background for developing these criteria are described in detail in the following subsections.

Table 4-1. Sustainable Management Criteria Summary

Sustainability Indicator	Significant and Unreasonable Statement	Minimum Threshold	Measurement	Measurable Objective	Undesirable Result	Interim Milestones
Chronic lowering of groundwater levels	Chronic lowering of groundwater levels that significantly exceed historical levels or cause significant and unreasonable impacts on beneficial users.	**Stable Wells:** Maintain near historical observed ranges while accounting for future droughts and climate variability and protect at least 98 percent of nearby water supply wells. Metric: Shallower (more protective) of historical low elevations minus 4-year drought assumption or above the 98th percentile of nearby water supply well depths.	Monthly or monthly-averaged groundwater levels measured at RMP wells.	**Stable Wells:** Maintain within historical observed ranges. Metric*:* Historical median spring groundwater elevation	10 percent of RMPs (2 RMPs within the shallow or deep aquifer) exceed MT for 3 consecutive years	The MO is based on recent conditions therefore interim milestones are identical to the MO.
		Wells with Historical Declines and then recovery: Maintain above historical low elevations and protect at least 98 percent of nearby water supply wells. Metric: Shallower (more protective) of historical low elevations OR above the 98th percentile of nearby water supply well depths.		**Wells with Historical Declines and then recovery:** Maintain within recent (recovered or recovering) historical observed ranges. Metric: Recent (2010-2019 for recovered wells and 2015-2019 for recovering wells) median spring groundwater elevation		

Sustainability Indicator	Significant and Unreasonable Statement	Minimum Threshold	Measurement	Measurable Objective	Undesirable Result	Interim Milestones
Reduction in groundwater storage	Reduction of groundwater storage that causes significant and unreasonable impacts on the long-term sustainable beneficial use of groundwater in the Subbasin, as caused by either: • Long-term reductions in groundwater storage • Pumping exceeding the sustainable yield	Measured using groundwater elevations as a proxy. MT for groundwater storage is identical to the MT for chronic lowering of groundwater levels.	Annual groundwater storage will be calculated and reported by comparing changes in contoured groundwater elevations. However, monitoring for the chronic lowering of groundwater levels will be used to compare with MTs and MOs.	MO for groundwater storage is identical to the MO for chronic lowering of groundwater levels.	Undesirable result for groundwater storage is identical to the undesirable result for chronic lowering of groundwater levels.	Interim milestones for groundwater storage are identical to the interim milestones for chronic lowering of groundwater levels.
Degraded water quality	Significant and unreasonable water quality conditions occur if an increase in the concentration of COCs in groundwater leads to adverse impacts on beneficial users or uses of groundwater, due to either: • Direct actions by Santa Rosa Plain GSP projects or management activities • Undesirable results occurring for other sustainability indicators	The MT is based on two additional supply wells exceeding MCLs for (1) arsenic, (2) nitrate, or (3) salts (measured as TDS).	The number of public supply wells with annual average concentrations of arsenic, nitrate, or TDS that exceed MCLs in groundwater quality data available through state data sources.	The MO is based on zero additional supply wells exceeding the applicable maximum contaminant level for (1) arsenic, (2) nitrate, or (3) salts (measured as TDS).	An undesirable result occurs if, during 2 consecutive years, a single groundwater quality MT is exceeded when computing annual averages at the same well, as a direct result of projects or management actions taken as part of GSP implementation.	The MO is based on current conditions; therefore, interim milestones are identical to the MO.

Sustainability Indicator	Significant and Unreasonable Statement	Minimum Threshold	Measurement	Measurable Objective	Undesirable Result	Interim Milestones
Subsidence	Any rate of inelastic subsidence caused by groundwater pumping is a significant and unreasonable condition, everywhere in the Subbasin and regardless of the beneficial uses and users.	0.1 ft/yr of inelastic subsidence (elastic and inelastic).	DWR-provided InSAR dataset average annual subsidence for each 100-meter-by-100-meter grid cell.	The MO is identical to the MT (0.1 ft/yr of subsidence)	Annual MT of 0.1 foot total subsidence is exceeded over a minimum 25-acre area or cumulative total subsidence of 0.2 foot is exceeded over a geographic area of 35 acres within 5-year period and MT exceedance is determined to be correlated with: (1) groundwater pumping, (2) a MT exceedance of the chronic lowering of GWLs SMC (that is, groundwater levels have fallen below historical lows)	The MO is set at current conditions; therefore, interim milestones are also identical to current conditions.

Sustainability Indicator	Significant and Unreasonable Statement	Minimum Threshold	Measurement	Measurable Objective	Undesirable Result	Interim Milestones
Depletion of interconnected surface water	Significant and unreasonable depletion of surface water from interconnected streams occurs when surface water depletion, caused by groundwater pumping within the Subbasin, exceeds historical depletion or adversely impacts the viability of GDEs or other beneficial users of surface water.	Maintain estimated streamflow depletions below historical maximum amounts. Metric: Shallow groundwater elevations are used as a proxy for stream depletion. The MT is the equivalent groundwater level, representing the 3 years (2014-2016) during which the most surface water depletion due to groundwater pumping was estimated between 2004-2018.	Monthly-averaged groundwater levels measured in RMPs (shallow monitoring wells near interconnected surface water).	The MO is to maintain groundwater levels within historical observed ranges. Metric: Mean groundwater level for available dry-season observations between 2004 and 2020.	When MTs are exceeded at 40 percent of RMP wells during drought years and 10 percent of RMP wells during non-drought years and are entirely or partially attributable to groundwater pumping under the jurisdiction of the GSA.	The MO is based on current conditions; therefore, interim milestones are identical to current conditions.

Notes:

COC = constituent of concern

GWL = groundwater levels

RMP = representative monitoring point

4.5 Chronic Lowering of Groundwater Levels Sustainable Management Criteria

Chronic lowering of groundwater levels was the first sustainability indicator addressed in the SMC process described in **Section 4.3**, as it contains the most readily available and robust datasets and is directly related to most of the other indicators. Additionally, SGMA allows for use of groundwater levels as proxy for other sustainability indicators if a significant correlation is established between groundwater levels and the other metrics. In this GSP, groundwater levels are used as a proxy for two other sustainability indicators (reduction of groundwater storage and depletion of interconnected surface water). This is further described in **Sections 4.6** and **4.10**, respectively.

For the chronic lowering of groundwater-level SMC, the following SGMA definition of an undesirable result assisted in characterizing significant and unreasonable conditions for the Subbasin and establishing the SMC described as follows:

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon.
- Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.

As described in **Section 3.2.2**, recent groundwater-level trends exhibit relatively stable groundwater-level conditions or recovering trends. The recovering trends generally occur within the southern and western portions of the Subbasin and are associated with higher levels of municipal pumping that historically occurred through the late 1970s and early 2000s that has since been reduced.

Taking these conditions and stakeholder input into account, the following overall approach guided development of the SMC for chronic lowering of groundwater levels:

1. For areas with stable groundwater-level trends, maintain groundwater levels within or near historical conditions while accounting for future droughts and climate variability.
2. For areas with historical declining trends and subsequent recovery and wells with increasing trends, maintain groundwater levels near current elevations and above the historical lows.

4.5.1 Locally Defined Significant and Unreasonable Conditions

Locally defined significant and unreasonable conditions were determined based on public meetings, and discussions with GSA staff, Advisory Committee members, and GSA Board.

Significant and unreasonable chronic lowering of groundwater levels in the Subbasin was defined as follows:

Chronic lowering of groundwater levels that significantly exceed historical levels or cause significant and unreasonable impacts on beneficial users, such as the following.

- Declining groundwater levels that limit the ability of domestic, agricultural, and municipal well owners to access groundwater for beneficial uses (for example, falling groundwater levels below pumping depths of water supply wells), causing significant and unreasonable economic burden on those who rely on basin groundwater
- Groundwater levels falling near basin boundaries that indicate impacts on or from neighboring basins
- Falling groundwater levels that cause impacts on groundwater-dependent vegetation (shallow aquifer only)

4.5.2 Minimum Thresholds

Section 354.28 (c)(1) of the GSP Regulations states that "The minimum threshold for chronic lowering of groundwater levels shall be the groundwater elevation indicating a depletion of supply at a given location that may lead to undesirable results." The GSP Regulations further specify that MTs for chronic lowering of groundwater levels are to be supported by information on the rate of groundwater elevation decline based on historical trends, WY type, projected water use in the basin, and potential effects on other sustainability indicators.

The process for developing the MTs for the chronic lowering of groundwater levels involved development of numerous alternatives for stakeholder consideration, which include (1) the above GSP Regulations, (2) the approach for considering differing patterns of historical groundwater-level trends, and (3) the significant and unreasonable statement. The alternatives were developed on behalf of the GSA by technical staff and subconsultants based on the evaluation of historical groundwater elevations over the available period of record (including consideration of average water levels over various time periods, long-term trends, and response to the recent drought), well construction data, and input from stakeholders. The following sections provide details on the development of MTs.

4.5.2.1 Information and Methodology Used to Establish Chronic Lowering of Groundwater Levels Minimum Thresholds

The information used for establishing the MTs for the chronic lowering of groundwater levels sustainability indicator included:

- Historical groundwater elevation data
- Depths and locations of existing wells

- Maps of current and historical groundwater elevation data
- Input from member agency staff, Advisory Committee members, GSA Board members, and the public regarding significant and unreasonable conditions and desired current and future groundwater elevations communicated during public meetings
- Results of modeling of future groundwater-level conditions

As described in this section and in **Section 3.2.2**, different patterns of historical groundwater-level trends are observed within the Subbasin, with areas exhibiting long-term stable groundwater-level trends and areas with historical declining trends that have exhibit recovered or recovering groundwater levels. To account for the distinct patterns of historical groundwater-level trends observed within the Subbasin, different methodologies were applied to the following two categories of RMPs based on observed patterns in historical and recent groundwater-level trends:

- RMPs with relatively stable long-term groundwater levels, defined as less than 0.5 ft/yr of decline during dry years and measurable recovery following wet years
- RMPs that have exhibited recovering, or recovered, trends following historical declines in groundwater levels (includes RMPs with historical recovery and less than 0.5 ft/yr decline within the last 10 years and RMPs with ongoing or recent recovery trends within the last 10 years)

These two different patterns were distinguished based on visual inspection and evaluation of trend lines calculated by linear regression of observed groundwater levels at each RMP (or from a similarly constructed nearby monitoring well where historical records are limited). **Figures 4-1** and **4-2** present which RMPs are associated with each pattern and hydrographs for each RMP with historical groundwater-level data are included in **Appendix 4-A**. Some RMPs on **Figures 4-1** and **4-2** have no trend, and SMC are set for these wells following the same methodology that was used for RMPs with stable trends.

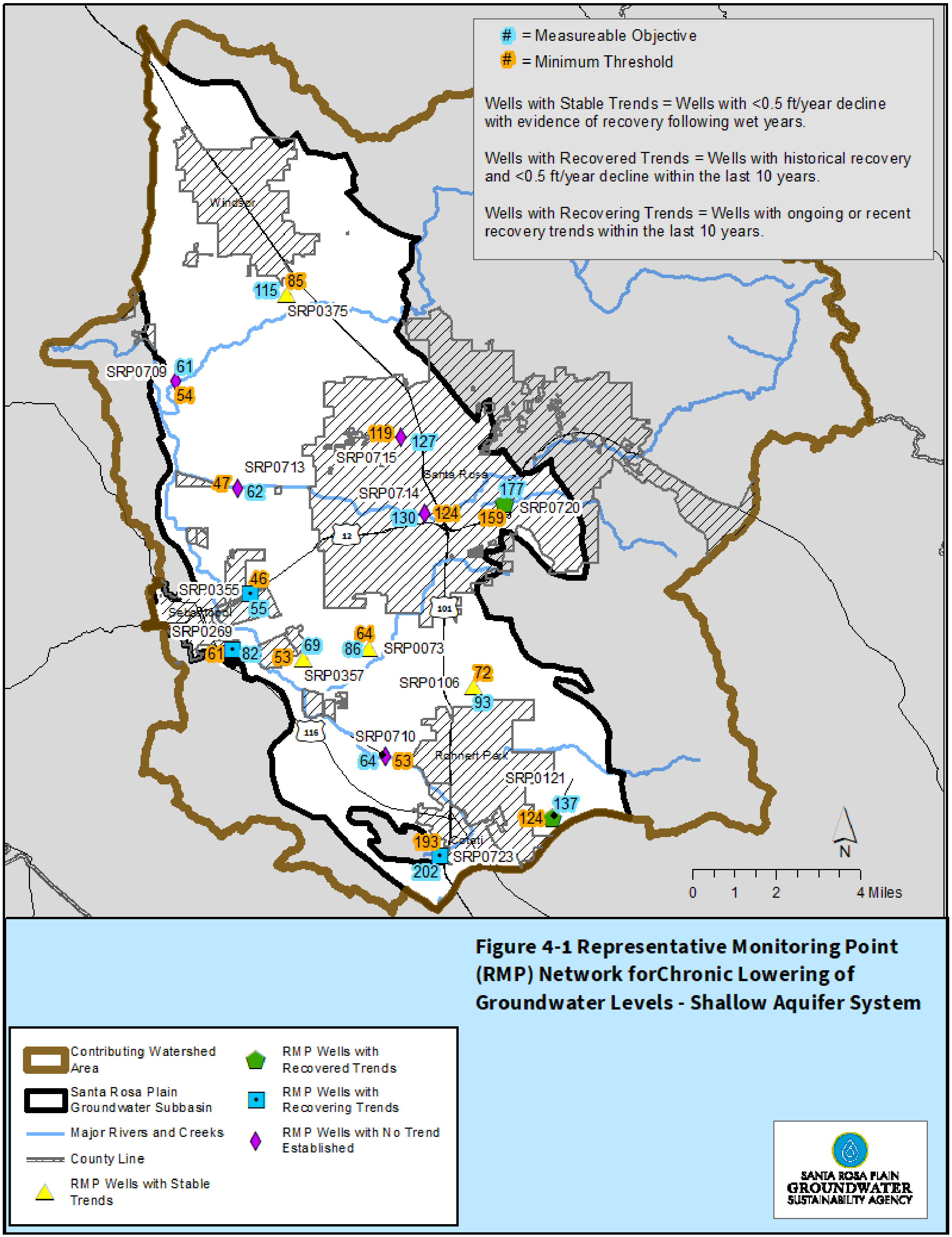

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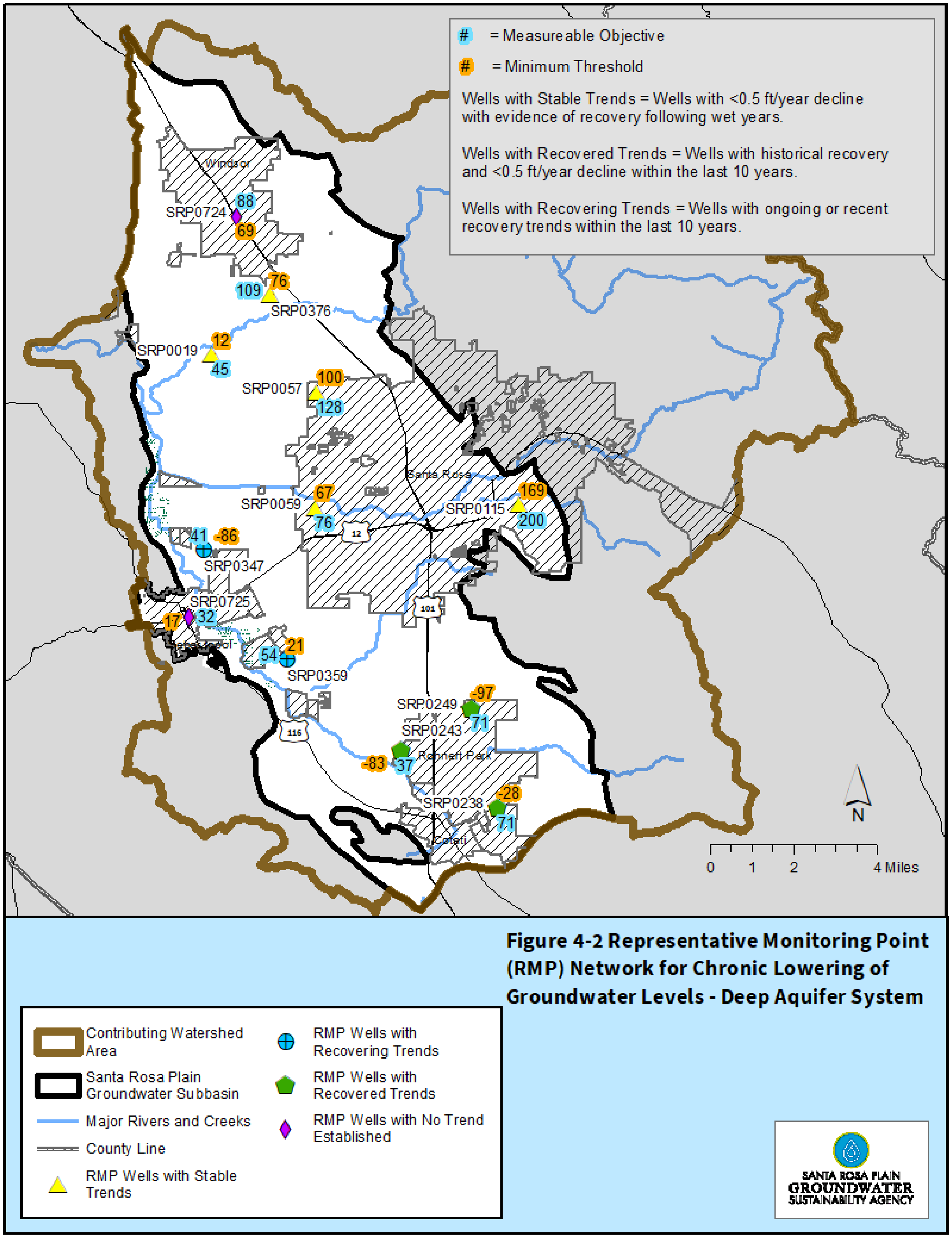
Figure 4-1. Proposed Representative Monitoring Point Network for Chronic Lowering of Groundwater Levels – Shallow Aquifer System



\# = Measureable Objective

\# = Minimum Threshold

Wells with Stable Trends = Wells with <0.5 ft/year decline with evidence of recovery following wet years.

Wells with Recovered Trends = Wells with historical recovery and <0.5 ft/year decline within the last 10 years.

Wells with Recovering Trends = Wells with ongoing or recent recovery trends within the last 10 years.

Figure 4-2 Representative Monitoring Point (RMP) Network for Chronic Lowering of Groundwater Levels - Deep Aquifer System

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Figure 4-2. Proposed Representative Monitoring Point Network for Chronic Lowering of Groundwater Levels – Deep Aquifer System

The MTs were set at each RMP based on the three following primary factors:

1. Review of groundwater-level data and hydrographs to identify the lowest historical groundwater elevation at each RMP after removing any measurements flagged as "questionable measurements" or otherwise anomalous measurements from the datasets.

2. Calculation of "well impact depths" in the vicinity of each RMP to identify depths at which lowering of groundwater levels may impact well users, including domestic, agricultural, public supply, and industrial wells.

3. Calculation of a "drought factor" at each RMP exhibiting relatively stable historical groundwater levels and each RMP with sufficient historical data to determine trends to account for reasonably foreseeable future droughts.

Calculation of Well Impact Depths

The methodology for incorporating the potential impact on existing well users involved the statistical evaluation of known completion information for water supply wells located within the vicinity of each potential RMP. These statistics were calculated by drawing polygons for each potential RMP area and querying Sonoma Water's Water Well Database (sourced from DWR's Online System for Well Completion Reports, Permit Sonoma, and the USGS). Generally, the Subbasin boundary and midpoints between potential RMPs were used to draw the vicinity areas. In some cases, physical features that appear to have a direct influence on groundwater movement were used as boundaries to the vicinity areas. For each vicinity area polygon, the total number of supply wells, shallowest supply well total depth, 98th percentile shallowest supply well total depth, and the average supply well depth were calculated (these statistics, along with maps showing the vicinity area polygons, are provided in **Appendix 5-B**). For each RMP, the analysis included all types of supply wells contained within the datasets (domestic wells, irrigation wells, public supply wells, and industrial wells) with the listed total depth occurring in the same aquifer system as the RMP.

To ensure that the analysis accounts for a reasonable level of drawdown due to production from existing wells, the calculated well impact depths incorporate "saturated thickness factors," which are added to the 98th percentile shallowest supply well depths. The saturated thickness factors for each principal aquifer system are described as follows:

- Shallow aquifer system wells (wells with total depth greater than 40 feet and less than 200 feet):

- Wells shallower than 40 feet were filtered out from database to remove records for non-supply wells for example, monitoring wells) and some older (greater than 50-year-old wells) that have likely been replaced.

- A saturated thickness factor of 10 feet was added to the 98th percentile shallowest supply well total depths.

- Deep aquifer system wells (wells with total depth greater than 200 feet and more than half of screened interval below 200 feet below ground surface):
- A saturated thickness factor of 50 feet was added to the total depth to compensate for increased drawdown responses within confined aquifer systems (Alley et al. 1999) and the typical higher production rates of deeper wells.

Figure 4-3 provides a conceptual illustration of this methodology. The figure presents a series of wells, with the well on the farthest right representing the 98th percentile shallowest well depth and showing how the saturated thickness factor would be applied.

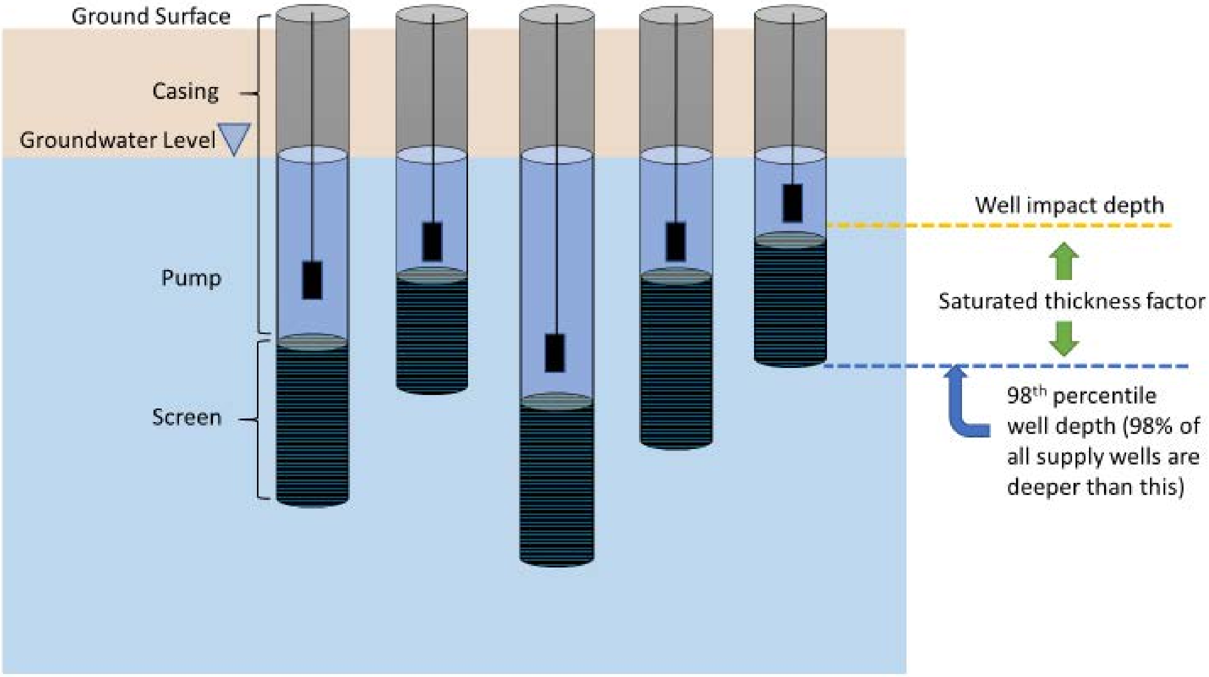

Figure 4-3. Calculated 98th Percentile Well Depths and Saturated Thickness Factor

Factoring for Future Drought Conditions

A factor to account for reasonably foreseeable future droughts was calculated at each RMP that exhibits stable trends or has insufficient historical data available to establish a trend. The calculations were made using the following methodology:

- For wells with 10 or more years of historical data, the largest consecutive 4-year decline during historical dry periods was used
- For wells with less than 10 years of historical data, the drought factor is based on either the future simulated largest consecutive 4-year decline or extrapolation of observed declines during the 2020/2021 drought

As the degree of groundwater-level responses to yearly climate conditions varies based on localized hydrogeologic condition, calculating a factor specific to each RMP incorporates observed groundwater-level responses specific to each RMP vicinity area into the MTs. The declines associated with these drought factors are consistent with levels of observed declines within the Subbasin during historical droughts, which then recovered during subsequent normal and/or wet WYs. For wells with 10 or more years of historical data, the calculated drought factors range from 5 to 14 feet within the shallow aquifer system RMPs and 2 to 17 feet within the deep aquifer system RMPs, which are generally representative of confined conditions. The range of projected drought factors for five shallow RMPs and three deep RMPs with insufficient historical data is 3 to 12 feet.

As presented on **Figure 4-4** (Case 1), the historical lows or historical lows minus the drought factor (for wells exhibiting stable historical conditions) were applied as the MT to RMPs where these levels are above the well impact depth. For RMPs where the well impact depth is shallower than the historical lows or historical lows minus the drought buffer, the well impact depth was applied as the MT, as presented on **Figure 4-4** (Case 2). **Table 4-2** provides a summary of these metrics and presents the final criteria used for calculating the MT at each of the 26 existing RMPs. As indicated in **Table 4-2**, MTs for 5 (Son0073, Son0355, Son0347, Son0243, and Son0249) of the 26 existing RMPs represent the calculated well impact depths (that is, at these locations the well impact depth is shallower than the historical low with the drought factor and is considered more protective of beneficial users (including domestic well users) (**Figure 4-4**). At the remaining 21 RMPs with the MTs calculated using the historical low elevations, the drought factors were determined to be above (protective of) the calculated well impact depths (Case 1 [**Figure 4-4**]).

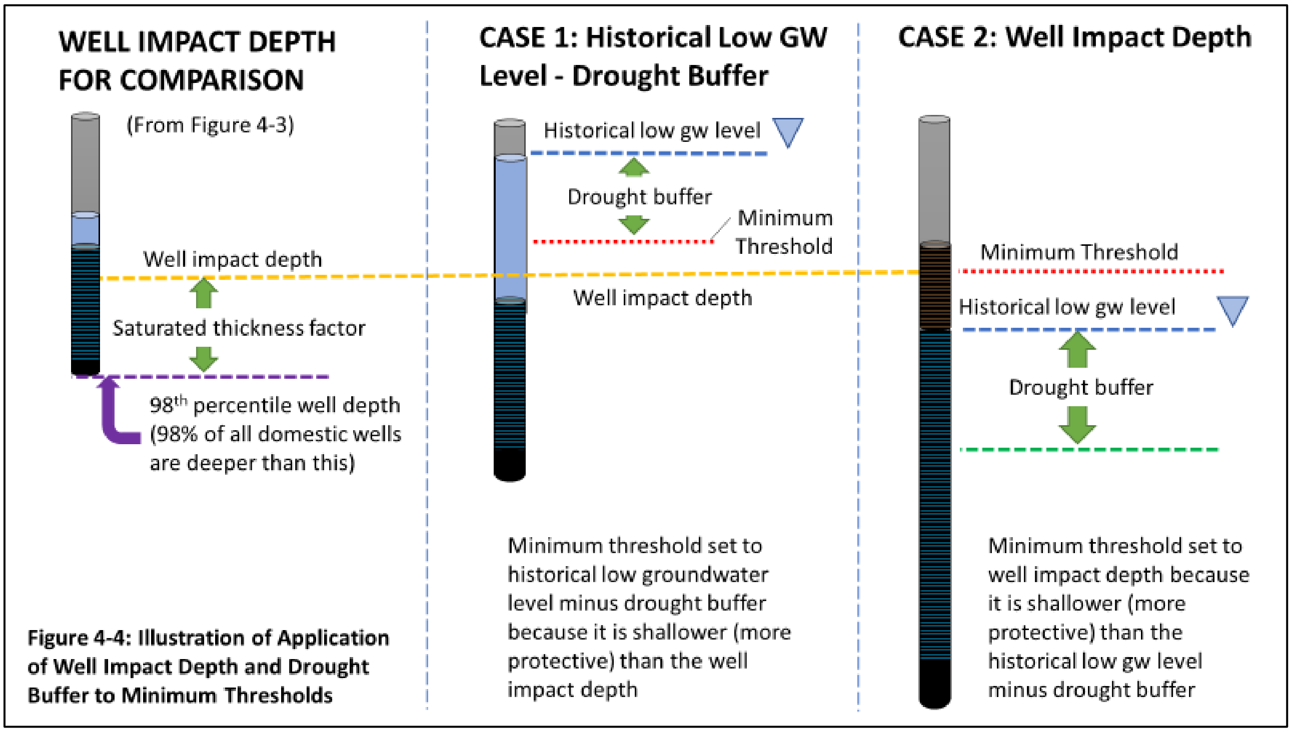

Figure 4-4. Application of Well Impact Depth and Drought Buffer to Minimum Thresholds

Table 4-2. Summary of Calculations for Minimum Thresholds and Measurable Objectives

Shallow Aquifer System (stable or no trend)							**MT**	**MO**
Well ID	**Observed Historical Low (feet msl)**	**Year of Observed Historical Low**	**Calculated Drought Factor (feet)**	**Drought Factor Years**	**Historic Low minus Drought Factor (feet msl)[a]**	**Well Impact Depths (feet msl)[a] 98th percentile plus 10 feet**	**Shallower of Historical Low minus 4-year Drought or Well Impact Depth**	**Historical Spring Median (entire)**
SRP0073	64.8	1992	-13.6	2011-2015	51	**64**	64	86
SRP0106	77.4	1992	-5.3	1998-2002	**72**	64	72	93
SRP0357	59.1	1977	-5.6	1986-1990	**53**	49	53	69
SRP0375	98.2	2020	-13.2	2016-2020	**85**	82	85	115
SRP0709	57.2	2020	-3.0	Projected	**54**	28	54	61
SRP0710	61.2	2020	-8.0	Projected	**53**	43	53	64
SRP0713	56.7	2020	-10.0	Projected	**47**	33	47	62
SRP0714	127.9	2020	-4.0	Projected	**124**	118	124	130
SRP0715	123.2	2020	-4.0	Projected	**119**	106	119	127
Shallow Aquifer System (recovered)							**MT**	**MO**
Well ID	**Observed Historical Low (feet msl)**	**Year of Observed Historical Low**	**Calculated Drought Factor (feet)**	**Drought Factor Years**	**Historic Low minus Drought Factor (feet msl)[a]**	**Well Impact Depths (feet msl)[a] 98th percentile plus 10 feet**	**Shallower of Historical Low or Well Impact Depth**	**Historical Spring Median (2010-current)**
SRP0121	**75.1**	1994	NA	NA	NA	23	75	137
SRP0720	**159.1**	2008	NA	NA	NA	157	159	177
Shallow Aquifer System (recovering)							**MT**	**MO**

Well ID	Observed Historical Low (feet msl)	Year of Observed Historical Low	Calculated Drought Factor (feet)	Drought Factor Years	Historic Low minus Drought Factor (feet msl)[a]	Well Impact Depths (feet msl)[a] 98th percentile plus 10 feet	Shallower of Historical Low or Well Impact Depth	Historical Spring Median (2015-current)
SRP0269	**60.6**	2009	NA	NA	NA	49	61	82
SRP0355	34.9	2009	NA	NA	35	**46**	46	55
SRP0723	**193.4**	2015	NA	NA	NA	189	193	202
Deep Aquifer System (stable or no trend)							**MT**	**MO**
Well ID	**Observed Historical Low (feet msl)**	**Year of Observed Historical Low**	**Calculated Drought Factor (feet)**	**Drought Factor Years**	**Historic Low minus Drought Factor (feet msl)**	**Well Impact Depths (feet msl)[a] 98th percentile plus 50 feet**	**Shallower of Historical Low minus 4-year Drought or Well Impact Depth**	**Historical Spring Median (entire)**
SRP0019	29.4	2002	-17.3	1998-2002	**12**	-91	12	45
SRP0059	68.9	2012	-1.9	2016-2020	**67**	-62	67	76
SRP0057	110.0	2016	10.0	Projected	**100**	-58	100	128
SRP0115	177.4	2011	-9.2	2012-2016	**169**	26	169	200
SRP0376	89.1	2020	-13	2011-2015	**76**	-37	76	109
SRP0724	81.0	2020	-12.0	Projected	**69**	-47	69	88
SRP0725	25.0	2020	-8.0	Projected	**17**	-85	17	32
Deep Aquifer System (recovering)							**MT**	**MO**
Well ID	**Observed Historical Low (feet msl)**	**Year of Observed Historical Low**	**Calculated Drought Factor (feet)**	**Drought Factor Years**	**Historic Low minus Drought Factor (feet msl)**	**Well Impact Depths (feet msl)[a] 98th percentile plus 50 feet**	**Shallower of Historical Low or Well Impact Depth**	**Historical Spring Median (2015-current)**
SRP0347	-95.5	2009	NA	NA	NA	**-86**	-86 (-54[b])	41
SRP0359	**20.9**	2004	NA	NA	NA	-123	21	54

Deep Aquifer System (recovered)							**MT**	**MO**
Well ID	**Observed Historical Low**	**Year of Observed Historical Low**	**Calculated Drought Factor**	**Drought Factor Years**	**Historic Low minus Drought Factor**	**Well Impact Depths (feet msl)[a] 98th percentile plus 50 feet**	**Historical Low or 98th Percentile Well Depth plus 50 Feet**	**Historical Spring Median (2010-current)**
SRP0238	**-28.0**	1992	NA	NA	NA	-52	-28(25[b])	71
SRP0243	-153.0	1987	NA	NA	NA	**-83**	-83(-24[b])	37
SRP0249	-128.0	1988	NA	NA	NA	**-97**	-97(-30[b])	71

[a] Bold values indicate criteria used for final MT value.

[b] At these RMPs a “warning-level” threshold has also been developed to address uncertainties associated with potential impacts on beneficial users of groundwater.

Note: There are NA entries because drought factors are not applied to RMPs with recovered or recovering historical trends.

NA = not applicable

Warning-level Thresholds for Representative Monitoring Points with Significant Historical Declines

Based on concerns raised by Advisory Committee members during development of the SMC, for wells with historical declines exceeding 100 feet, a shallower "warning-level" threshold has been developed and included in the hydrographs in **Table 4-2** and **Appendix 4-A**, which would initiate an investigation into potential causes of any future declines. The RMPs that have a "warning-level" threshold include three wells around the City of Rohnert Park (SRP0238, SRP0243, and SRP0249), where higher amounts of municipal pumping occurred between the 1980s and early 2000s, and one RMP (SRP0347) located in the vicinity of Sonoma Water's production wells, where higher amounts of municipal pumping occurred between approximately 1998 and 2009. The "warning-level" thresholds were developed due to (1) uncertainties associated with well depth datasets, (2) uncertainties as to whether historical lows could cause undesirable results, and (3) in the case of the RMPs near the City of Rohnert Park, the presence of other pumpers that do not have existing policy limitations on groundwater production in the area. For the RMPs near the City of Rohnert Park, the "warning-level" thresholds were calculated using the mean historical seasonal lows for 1998 to 2004, which represents a time period after significant late 1980s/early 1990s drought years and prior to full recovery when groundwater levels were relatively stable. For the RMP in the vicinity of Sonoma Water's production wells, the "warning-level" thresholds were calculated using the mean historical seasonal lows for 2014 and 2015, which represents a time period when Sonoma Water's wells were activated to address drought conditions but were pumped at lower volumes and for much shorter continuous durations than during the 1998 to 2009 time period.

Adaptive Management to Address Data Gaps and Improve/Refine Sustainable Management Criteria

There is appreciable uncertainty regarding the SMC developed for the chronic lowering of groundwater levels sustainability indicator. In addition to developing the previously described warning-level thresholds to account for this uncertainty, specific planned data collection activities that will reduce uncertainty and inform future adjustments or refinements to the chronic lowering of groundwater-level SMC are described in **Section 5** and include:

- Refine information on depths of nearby water wells from well log databases and information obtained through future GUIDE program implementation
- Improve mapping and correlation of well depth data with stratigraphic data
- Assess and develop plans to fill data gaps in monitoring networks through targeted additional dedicated monitoring wells and suitable volunteered private wells based on:
  - Hydrogeologic properties and geologic features
  - Areas of boundary inflows and outflows
  - Distribution of pumping
  - Location of sensitive beneficial users, such as shallow domestic well users or GDEs

4.5.2.2 Relationship between Individual Minimum Thresholds and Relationship to Other Sustainability Indicators

Section 354.28 of the GSP Regulations requires that the description of all MTs include a discussion of the relationship between the MTs for each sustainability indicator. In the SMC BMPs (DWR 2017), DWR clarified that the GSP must describe the relationship between each sustainability indicator’s MT by describing why or how a water level MT set at a particular RMP is similar to or different to water level thresholds in a nearby RMP. Additionally, the GSP must describe the relationship between the selected MTs and MTs for other sustainability indicators.

Groundwater elevation MTs are derived from examination of the historical record reflected in hydrographs at each individual RMP and depths of nearby water wells, including domestic well users. Therefore, the MTs are unique at every well, but when combined represent reasonable and achievable groundwater conditions and flow paths.

Assessment of how other sustainability indicators could be influenced by the chronic lowering of groundwater levels MT indicates the following:

- **Reduction in groundwater storage**. Changes in groundwater elevations are directly correlated to changes in the amount of groundwater in storage and groundwater levels are used as a proxy for the reduction in groundwater storage sustainability indicator. The groundwater elevation MTs are set to establish a minimum elevation that will not lead to undesirable conditions, and that is acceptable to the stakeholders in the area. Therefore, if the groundwater elevation MTs are met (that is, groundwater levels remain stable and above historical lows), they will not result in long-term significant or unreasonable changes in groundwater storage.

- **Degraded water quality**. A significant and unreasonable condition for degraded water quality would occur if an increase in the concentration of COCs in groundwater leads to adverse impacts on beneficial users or uses of groundwater, due to direct actions by Santa Rosa Plain GSP projects or management activities or undesirable results occurring for other sustainability indicators. If future declines in groundwater levels occur, that could potentially impact water quality by inducing poor-quality water into areas not previously impacted by water quality degradation. However, since MTs are set to avoid significant declines of groundwater levels below historically observed levels, this is not expected to occur.

- **Subsidence**. A significant and unreasonable condition for subsidence is the occurrence of inelastic subsidence caused by groundwater pumping. Since MTs are set to avoid significant declines of groundwater levels below historically observed levels, inelastic land subsidence is not expected to occur.

- **Depletion of interconnected surface water**. MTs for chronic lowering of groundwater levels do not promote additional pumping or lower groundwater elevations adjacent to interconnected surface water than has historically occurred. Therefore, the chronic lowering of groundwater elevations MTs will not result in a significant or unreasonable depletion of interconnected surface water.

4.5.2.3 Effect of Minimum Thresholds on Neighboring Basins and Subbasins

The Santa Rosa Plain Subbasin has one neighboring subbasin that is categorized as medium-priority and is also subject to SGMA: the Petaluma Valley Basin, to the south.

The Santa Rosa Plain Subbasin is also adjacent to the very low-priority Healdsburg Area Subbasin to the northwest, and the Wilson Grove Formation Highlands Basin to the west, both of which are not required to develop GSPs under SGMA.

The boundary between the Santa Rosa Plain Subbasin and the Petaluma Valley Basin coincides with a surface watershed divide between the Laguna de Santa Rosa drainage subbasin and the Petaluma River Watershed. The boundary is also the approximate location of a groundwater flow divide; however, no known structural or geologic features restrict flow between the two areas and groundwater-level changes on one side of the boundary have the potential to influence groundwater levels on the other side. During the historical groundwater-level declines that occurred in the southern portions of the Santa Rosa Plain Subbasin through the early 2000s, no impacts on wells located within the adjacent areas of the Petaluma Valley Basin are known to have occurred. Since the MTs for chronic lowering of groundwater aim to maintain groundwater levels above historical lows within the Santa Rosa Plain Subbasin, the potential for any negative effects to occur within the Petaluma Valley Basin related to the MTs for chronic lowering of groundwater levels is limited.

The boundary between the Santa Rosa Plain Subbasin and the Wilson Grove Formation Highlands Basin generally follows the contact between the Quaternary alluvial deposits and the Wilson Grove Formation, with the exception of the City of Sebastopol, where the boundary follows the jurisdictional boundary of the city and three neighboring mutual water system service areas and extends into a portion of the Wilson Grove Formation. The boundary also roughly coincides with the mapped trace of the Sebastopol Fault and uncertainty regarding the hydrogeologic connection between the two areas, including any potential boundary effects of the Sebastopol Fault, has been identified as an important data gap to be addressed during GSP implementation, as described in **Section 7**. Available groundwater-level data along the boundary and information from the simulated water budget do indicate that the basins are connected with groundwater from the Wilson Grove Formation Highlands Basin representing an important source of inflow to the Santa Rosa Plain Subbasin. Therefore, groundwater-level changes on one side of the boundary have the potential to influence groundwater levels on the other side. Since the MTs for chronic lowering of groundwater aim to maintain groundwater levels above historical lows within the Santa Rosa Plain Subbasin, the potential for any negative effects to occur within the Wilson Grove Formation Highlands Basin related to the MTs for chronic lowering of groundwater levels is limited.

The northwestern boundary of the Subbasin generally follows the contact between the Glen Ellen Formation and Quaternary alluvial deposits of the Russian River Valley within the

Healdsburg Area Subbasin. Available groundwater-level data along the boundary and information from the simulated water budget do indicate that the basins are connected with groundwater from the Santa Rosa Plain Subbasin flowing into the Healdsburg Area Subbasin. Therefore, groundwater-level changes on one side of the boundary have the potential to influence groundwater levels on the other side. Since the MTs for chronic lowering of groundwater aim to maintain groundwater levels above historical lows within the Santa Rosa Plain Subbasin, the potential for any negative effects to occur within the Healdsburg Area Subbasin related to the MTs for chronic lowering of groundwater levels is limited.

While not required to be evaluated by SGMA, the potential effect of the chronic lowering of groundwater levels MTs are also very unlikely to influence groundwater levels in other adjoining areas that are not classified as groundwater basins or subbasins by DWR. Groundwater use in these upland areas that flank the eastern and western boundaries of the Subbasin primarily occurs within the Sonoma Volcanics upgradient of the Subbasin.

The potential for impacts to occur along all of the above-described boundaries will be evaluated as part of the GSA's routine MRP, which includes both RMP wells and other wells monitored for groundwater levels in the Santa Rosa Plain Subbasin and within the neighboring areas near these boundaries (including the Petaluma Valley Basin, Wilson Grove Formation Highlands Basin, and contributing watershed areas). **Section 5.3** describes (1) the specific wells currently incorporated into this boundary monitoring program; (2) identified data gaps in these areas; and (3) plans to address the data gaps.

Additionally, the Santa Rosa Plain GSA will continue to closely coordinate with the Petaluma Valley GSA and the County (for areas that are not under a GSA's jurisdiction) should any future issues arise.

4.5.2.4 Effect on Beneficial Uses and Users

MTs for chronic lowering of groundwater levels are set at the more protective of historical low conditions with allowances for future droughts and the depths at which existing water supply wells could be impacted by lowering of groundwater levels. The MTs are generally advantageous to beneficial users and land uses in the Subbasin:

- **Agricultural land uses and users**. The chronic lowering of groundwater-level MTs protects existing agricultural users' ability to meet typical demands by maintaining groundwater levels near current conditions. However, the chronic lowering of groundwater-level MTs places a practical limit on the acceptable lowering of groundwater levels in the Subbasin, thus conceptually restricting future levels of agriculture in the Subbasin beyond what is projected in the 50-year baseline scenario without projects to supplement water supplies, or management actions to limit future pumping increases. The potential for this to occur will be addressed through considering the implementation of the projects and management actions discussed in **Section 6**.

- **Urban land uses and users.** The chronic lowering of groundwater-level MTs protects existing municipal and industrial groundwater users' ability to meet typical demands by maintaining groundwater levels near current conditions. However, the chronic lowering of groundwater-level MTs places a practical limit on the acceptable lowering of groundwater levels in the Subbasin, thus conceptually restricting future levels of municipal and industrial groundwater pumping in the Subbasin beyond what is projected in the 50-year baseline scenario without projects to supplement water supplies, or management actions to limit future pumping increases. The potential for this to occur will be addressed through considering the implementation of the projects and management actions discussed in **Section 6**.

- **Domestic land uses and users**. The chronic lowering of groundwater levels MTs are established to protect as many rural residential domestic wells as possible. Therefore, the MTs will likely have an overall beneficial effect on existing domestic land uses by protecting the ability to pump from domestic wells within the Subbasin.

- **Ecological land uses and users**. Maintaining groundwater near or above historical levels will help maintain the interconnected nature of groundwater and surface water in the Subbasin. This will protect GDE habitat and generally benefit environmental land uses and users.

4.5.2.5 Relation to State, Federal, or Local Standards

No federal, state, or local standards exist that are specific to chronic lowering of groundwater levels.

4.5.2.6 Method for Quantitative Measurement of Minimum Thresholds

Depth to groundwater will be directly measured at the RMPs identified in **Section 5.3.1** for comparison to MTs. The RMP network includes 14 existing shallow aquifer wells and 12 existing deep aquifer wells, resulting in a total of 26 wells. Additionally, between two and four new multi-level monitoring wells, which will monitor both the shallow and deep aquifer system at each location, are planned for construction by the GSA in 2022. It is anticipated that these wells will be incorporated into the RMP network following their construction and development of SMC for each. The groundwater-level data will be collected in accordance with the monitoring protocols outlined in **Section 5.3.1** and converted to groundwater elevation by subtracting the measured depth to water from the reference point elevation used to take the depth to water measurement.

Available groundwater-level data, including historical data used for calculation of the MTs and MOs, contains a variety of measurement frequencies ranging from hourly to semiannually. Groundwater-level measurement frequency for the 26 existing wells in the RMP monitoring networks include the following:

- 18 measured more than once per day
- 4 measured monthly
- 4 measured semiannually

As indicated in **Section 5.3.1**, the goals for groundwater-level measurement frequency will be to: (1) measure groundwater levels at least monthly for all RMPs during GSP implementation; and (2) use pressure transducers where feasible to provide a higher level of quality control, as potential short-term or residual pumping influences can be identified and flagged. Consistent with the monitoring protocols, only static groundwater levels will be compared to MTs.

For reporting seasonal highs and lows for future comparison with MTs, all measurements collected at a higher frequency than monthly will be reported as monthly averages to better align with the measurement frequency within historical datasets used to calculate the MTs. During GSP implementation, individual groundwater-level measurements collected manually and by data loggers will be reviewed for quality control and analyzed for MT exceedances during compilation of GSP annual and 5-year update reports.

Staff has identified data gaps in some areas of the Subbasin in the monitoring networks discussion (**Section 5**). The GSP includes a plan to expand the monitoring network as described in the implementation discussion (**Section 7**).

4.5.3 Measurable Objectives

MOs for chronic lowering of groundwater levels represent target groundwater elevations for 2042, considering realistic project implementation and allowing for operational flexibility over a range of climate and hydrologic variability.

4.5.3.1 Method for Setting Measurable Objectives

Similar to the approach and methodology used for setting MTs, MOs are reflective of the distinct patterns of historical groundwater-level trends observed within the Subbasin.

For RMPs exhibiting relatively stable long-term groundwater-level trends, the MO is calculated as the historical median spring groundwater elevation, given that the aim of the MO is to maintain groundwater levels within historical ranges for these areas.

For RMPs that have exhibited recovering trends following historical declines, the MO is calculated as the median spring groundwater elevation of the most recent 5 or 10 years (for wells with increasing trends and wells with historical declines and subsequent recovery, respectively), because the aim of the MO is to maintain groundwater levels within recent (recovered or recovering) historical observed ranges.

MOs for each RMP are listed in **Table 4-2**.

4.5.3.2 Interim Milestones

For all RMPs, the MO is essentially set at recent conditions (that is, the aim of the MO is to maintain groundwater levels within historical and recent ranges), therefore interim milestones are essentially equivalent to the MO throughout the GSP implementation period.

4.5.4 Undesirable Results

4.5.4.1 Criteria for Defining Undesirable Results

The chronic lowering of groundwater levels undesirable result is a quantitative combination of groundwater elevation MT exceedances. For the Subbasin the specific groundwater conditions that constitute an undesirable result is: Groundwater levels in 10 percent of the RMPs in either the shallow or deep aquifer systems exceed their MTs for three consecutive fall measurements.

Consistent with DWR guidance, if MT exceedances are caused by emergency operational issues or droughts that extend for longer than the 4-year drought factor incorporated into the MTs (as described in **Section 4.6.2.1**), it is not considered an undesirable result unless the groundwater levels do not rebound to above the thresholds during future normal and wet years following long-term droughts.[1]

Exceedances of MTs at a single well will require investigation to determine if any actions should be considered to avoid potential future onset of undesirable results, as described in **Section 4.6.4.2**.

The 3 consecutive years of MT exceedances was selected by the GSA Board to: (1) balance protection of beneficial users with costs related to response actions and (2) limit the potential for shorter-duration MT exceedances that may not be chronic in nature to trigger undesirable results.

4.5.4.2 Potential Causes of Undesirable Results

The potential causes of undesirable results for chronic lowering of groundwater levels include:

- Increased groundwater pumping in the Subbasin leading to chronic groundwater-level declines
- A significant reduction in natural recharge as a result of climate change, reduced groundwater and surface water interaction, or other land surface processes

If the location and volumes of groundwater pumping change as a result of unforeseen rural residential, agricultural, and urban growth that depend on groundwater as a water supply without supplemental supplies, these increased demands might lower groundwater to undesirable levels. Reduction in recharge or changes in rainfall patterns could also lead to more prolonged periods of lowered groundwater levels than have occurred historically.

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[1] The draft SMC BMP (DWR 2017) provides information on how droughts may affect the groundwater-level SMC: “Undesirable results are one or more of the following effects: Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.”

As described in **Section 6**, projects and actions are being considered for implementation to augment recharge and reduce groundwater pumping to mitigate the potential for these conditions to occur.

Additionally, to respond to these potential conditions prior to the onset of an undesirable result, the following actions would be implemented if an MT is exceeded at a single RMP that does not trigger an undesirable result:

- Review available data from full monitoring network (that is, non-RMP monitoring wells) to assess the potential scale of areas exhibiting declines.
- Assess whether exceedance is climate-related.
- Review any known or potential changes in groundwater pumping patterns, as needed (for example, new wells brought online, changes in land/water use).
- Consider whether additional RMPs are needed.
- Share information with nearby well owners, as appropriate.
- Consider planning or implementing projects/actions, as appropriate (for example, begin with lower cost and/or voluntary projects/actions).

The approach is a proactive means for avoiding exceedance of undesirable results when warning signs are available. Not all actions would be implemented for each individual exceedance of a MT. These tasks would generally be performed sequentially based on potential severity of the occurrence.

4.5.4.3 Effects on Beneficial Users and Land Use

The potential effects of undesirable results for chronic lowering of groundwater levels on beneficial users and land use could be the inability of a significant number of private, agricultural, and municipal and industrial production wells from supplying groundwater to meet their water demands. The beneficial users that could be impacted by undesirable results from chronic lowering of groundwater levels include domestic well users, irrigation well users, and public water supply well users (inclusive of DACs that obtain water from these user categories). Lowered groundwater levels reduce the saturated thickness of aquifers from which wells can pump, which could lead to increased pumping costs, reduced pumping capacity, or the need to drill new deeper wells. This would effectively increase the cost of using groundwater as a water source for all users. Avoiding undesirable results for the chronic lowering of groundwater levels will limit the potential for these conditions to occur in the future.

4.6 Reduction in Groundwater Storage Sustainable Management Criteria

The reduction in groundwater storage SMC will be evaluated using groundwater levels as a proxy based on well-established hydrogeologic principles that the volume of groundwater in storage is directly proportional to groundwater elevations (Alley et al. 1999). The groundwater elevations MTs and MOs are established to maintain adequate groundwater supplies for all beneficial uses and users. Therefore, preventing groundwater elevations from dropping below MTs, by definition, maintains adequate amount of water in storage. Maintaining groundwater elevations within the operational range between MTs and MOs is equivalent to no long-term change in storage.

4.6.1 Locally Defined Significant and Unreasonable Conditions

Locally defined significant and unreasonable conditions were determined based on public meetings, and discussions with GSA staff, Advisory Committee members, and the GSA Board. Significant and unreasonable reduction in groundwater storage in the Subbasin is defined as: Reduction of groundwater storage that causes significant and unreasonable impacts on the long-term sustainable beneficial use of groundwater in the basin, as caused by long-term reductions in groundwater storage; or pumping exceeding the sustainable yield.

4.6.2 Minimum Thresholds

Section 354.28(c)(2) of the GSP Regulations states that “The minimum threshold for reduction of groundwater storage shall be a total volume of groundwater that can be withdrawn from the basin without causing conditions that may lead to undesirable results. Minimum thresholds for reduction of groundwater storage shall be supported by the sustainable yield of the basin, calculated based on historical trends, WY type, and projected water use in the basin.”

This GSP will monitor changes in groundwater levels at the RMPs as a proxy for the change in groundwater storage metric. As allowed in Section 354.36(b)(1) of the GSP Regulations, groundwater elevation data at the RMPs will be reported annually as a proxy to track changes in the amount of groundwater in storage.

Based on well-established hydrogeologic principles, stable groundwater elevations maintained above the MTs will indicate that groundwater storage is not being depleted (Alley, et al. 1999). Therefore, using groundwater elevations as a proxy, the MT for groundwater storage will be met if MTs for the chronic lowering of groundwater levels are not exceeded.

4.6.2.1 Information and Methodology Used to Establish Groundwater Storage Minimum Thresholds

Similar to the chronic lowering of groundwater-levels SMC, the information used for establishing the MTs for the groundwater storage sustainability indicator included:

- Historical groundwater elevation data
- Depths and locations of existing wells
- Maps of current and historical groundwater elevation data

- Input from stakeholders regarding significant and unreasonable conditions and desired current and future groundwater elevations communicated during public meetings
- Results of modeling of future groundwater-level conditions

4.6.2.2 Relationship between Individual Minimum Thresholds and Relationship to Other Sustainability Indicators

The MTs for reduction in groundwater storage are the same as those used for the chronic lowering of groundwater levels. Because groundwater elevations will be used as a proxy for estimating changes in groundwater storage, the reduction in groundwater storage sustainability indicator cannot cause undesirable results for the chronic lowering of groundwater levels sustainability indicator.

The relationship between the groundwater storage sustainability indicator and other sustainability indicators is the same as the relationship between chronic lowering of groundwater levels and other sustainability indicators, as described in **Section 4.5.2.2**.

4.6.2.3 Effect of Minimum Thresholds on Neighboring Basins and Subbasins

The potential effect of the groundwater storage MT on neighboring basins, subbasins and other adjoining areas is the same as the relationship described for chronic lowering of groundwater levels in **Section 4.5.2.3**.

4.6.2.4 Effect on Beneficial Uses and Users

The MT for reduction in groundwater storage will maintain stable average groundwater elevations and encourages minimal long-term net change in groundwater elevations and storage.

The potential effects of the groundwater storage MT on beneficial uses and users are the same as the potential effects described for chronic lowering of groundwater levels in **Section 4.5.2.4**.

4.6.2.5 Relation to State, Federal, or Local Standards

No federal, state, or local standards exist that are specific to groundwater storage.

4.6.2.6 Method for Quantitative Measurement of Minimum Thresholds

Storage MTs will be measured by collecting groundwater-level measurements at the RMP sites in the monitoring network, as described in **Sections 4.5.2.6** and **5.3.1**. This data will be used to monitor groundwater elevations and compare with MTs.

Annual groundwater storage will also be calculated and reported by comparing changes in contoured groundwater elevations to assess changes in groundwater storage.

4.6.3 Measurable Objectives

The change in storage sustainability indicator was defined using groundwater levels as a proxy for the change in storage MO. The same MTs and MOs are used as are defined in the chronic lowering of groundwater-level indicator to protect against significant and unreasonable reduction in groundwater storage.

Additionally, even though groundwater levels are being used as a proxy in lieu of using the total volume of groundwater pumped, the achievement of MOs for chronic lowering of groundwater levels will require that groundwater levels either increase or are maintained at their current levels. Therefore, the MOs will necessitate pumping within the sustainable yield calculated for the Subbasin in order to have no long-term change in storage once sustainability is reached.

4.6.3.1 Method for Setting Measurable Objectives

The methods for setting the MO for groundwater storage incorporates the same methods for setting the MO for chronic lowering of groundwater levels described in **Section 4.5.3.1**.

4.6.3.2 Interim Milestones

Interim milestones for groundwater storage are the same as those established for chronic lowering of groundwater levels. Achieving the chronic lowering of groundwater levels interim milestones will prevent long-term reductions in groundwater in storage.

4.6.4 Undesirable Results

4.6.4.1 Criteria for Defining Undesirable Results

Assessment of groundwater in storage will be evaluated with the same MTs and MOs as the chronic lowering of groundwater levels sustainability criteria.

Therefore, for the purposes of this GSP, the definition of undesirable conditions for the reduction of groundwater storage is the same as following definition for the chronic lowering of groundwater levels: Groundwater levels in 10 percent of the RMPs in either principal aquifer system exceed their MTs for three consecutive fall measurements.

4.6.4.2 Potential Causes of Undesirable Results

The potential causes of undesirable results for reduction of groundwater storage are the same as those identified for chronic lowering of groundwater levels in **Section 4.5.4.2**:

- Increased groundwater pumping in the Subbasin leading to chronic groundwater-level declines
- A significant reduction in natural recharge as a result of climate change or other processes

4.6.4.3 Effects on Beneficial Users and Land Use

The potential effects of undesirable results for groundwater storage on beneficial users and land use are the same as those identified for the chronic lowering of groundwater levels, as described in **Section 4.5.4.3**, which could include the inability of a significant number of private, agricultural, and municipal and industrial production wells from supplying groundwater to meet their water demands. Lowered groundwater levels reduce the thickness of saturated aquifer from which wells can pump, which could lead to increased pumping costs or the need to drill new deeper wells. This would effectively increase the cost of using groundwater as a water source for all users. Avoiding undesirable results for the reduction in groundwater storage will limit the potential for these conditions to occur in the future.

4.7 Seawater Intrusion Sustainable Management Criteria

The Subbasin does not border the Pacific Ocean, bays, deltas, or inlets and therefore seawater intrusion is not an applicable sustainability indicator and is not further discussed in this GSP.

4.8 Degraded Water Quality Sustainable Management Criteria

Unlike most other sustainability indicators, degraded water quality is the subject of robust federal, state, and local regulatory regimes carried out by a number of different entities and is not regulated by SGMA. The GSA is not responsible for enforcing existing water quality standards or collecting data to support existing water quality programs, nor is the GSA responsible for natural changes in groundwater quality or groundwater degradation caused by others. However, potential groundwater quality degradation needs to be considered during GSP development to ensure that activities associated with implementing the GSP, such as GSP projects and actions, do not degrade current water quality conditions.

One of the primary challenges in implementing the degraded water quality SMC will be to assess in the future if any degradation to groundwater quality is due to GSA actions.

4.8.1 Locally Defined Significant and Unreasonable Conditions

Locally defined significant and unreasonable conditions were determined based on public meetings, and discussions with GSA staff, Advisory Committee members, and GSA Board.

Significant and unreasonable water quality conditions occur if an increase in the concentration of COCs in groundwater leads to adverse impacts on beneficial users or uses of groundwater due to either:

1. Direct actions by Santa Rosa Plain GSP projects or management activities
2. Undesirable results occurring for other sustainability indicators

Examples of potential adverse impact are in **Sections 4.8.2.7** and **4.8.4.3**.

As noted in the GSP Regulations, MTs are based on a degradation of water quality, not an improvement of water quality (CCR Title 23. Section 354.28). Therefore, this GSP is designed to avoid taking any action that may inadvertently move groundwater constituents that have already been identified in the Subbasin in such a way that the constituents have a significant and unreasonable impact that would not otherwise occur. COCs were identified based on three criteria:

1. They have an established level of concern such as an MCL or secondary maximum contaminant level (SMCL), or a level that reduces crop production

2. They have been found in the Subbasin at levels above the level of concern and are routinely analyzed and reported through existing regulatory monitoring programs

3. The occurrence of the COC is extensive throughout the Subbasin

Based on the review of groundwater quality in **Section 3.2.5**, three COCs were identified that may affect groundwater supply in the Subbasin. The COCs include:

- Arsenic
- Nitrate
- Salinity (measured as TDS)

There are other point source contaminants found sporadically in the Subbasin, but these are not regional in extent, are monitored through various other regulatory programs, and consequently SMC are not established in the GSP. New or additional water quality constituents may be identified as potential COCs applicable to the GSP implementation activities through routine consultation and information sharing with other regulatory agencies. The GSA would then consider adding potential COCs and assigning SMC during the 5-year GSP updates.

Future GSP implementation projects or actions that require their own site-specific monitoring network would take into consideration any localized COCs and regulatory requirements.

4.8.2 Minimum Thresholds

The GSP Regulations allow three options for setting degraded water quality MTs: “The minimum threshold shall be based on the number of supply wells, a volume of water, or a location of an isocontour that exceeds concentrations of constituents determined by the Agency to be of concern for the basin” (CCR Title 23. Section 354.28). In this Subbasin, MTs are based on a number of supply wells that exceed concentrations of constituents determined to be of concern for the Subbasin.

The currently available supply wells for monitoring COCs that have an MCL or SMCL are public supply wells. Should domestic wells or agricultural irrigation wells be incorporated into future monitoring programs established by the GSA or other entities, they could also be included in monitoring COCs during future GSP updates.

4.8.2.1 Existing Water Quality Monitoring Programs and Networks

The SMC are based on a number of supply wells, and the GSA identified sets of supply wells that are currently monitored (or are proposed to be monitored in the future) for various groundwater constituents and supply uses such as drinking water and irrigation water. Because these supply wells are monitored under different programs and may have different required sampling schedules (even under the same program), no one set of constituents will be sampled in all wells.

The goal is to use existing monitoring programs for supply well water quality assessment and not create new water quality monitoring networks that the GSA would be responsible for sampling. Initially, it is anticipated that RMPs will come from public supply wells that are already monitored. The only additional sampling the GSA would perform is on a project as-needed basis to specifically identify potential impacts on supply wells due to the development of a project related to GSP implementation.

Existing monitoring programs identified in this Subbasin include:

- Public supply wells, regulated by the SWRCB DDW. Public drinking water supply wells are included in the water quality monitoring network because they are routinely sampled to meet CCR Title 22 water quality reporting requirements as regulated by the SWRCB DDW. Title 22 analyses include arsenic, nitrate, and TDS, which are the Subbasin COCs. This dataset can be obtained from the SWRCB through the GAMA online portal.

- Monitoring wells, agricultural irrigation supply, and public drinking water supply wells are included in the water quality network in the Santa Rosa Plain SNMP (City of Santa Rosa 2013a). The Revised SNMP MRP was submitted to the NCRWQCB in August 2021 and is currently being reviewed by the NCRWQCB, regulated by the NCRWQCB, requires annual sampling and analysis of water quality constituents in a network of wells (City of Santa Rosa 2021). The monitoring network is initially proposed to include six monitoring wells in the central portions of the Subbasin. Per the MRP, each of the wells is required to be sampled annually and analyzed for nitrate and TDS. The analytical datasets from the MRP wells will be available from the SWRCB through the GAMA online portal.

Existing and future water quality monitoring programs may be used to help collect data during GSP implementation and establish consistency with other programs. This includes the North Coast Water Board’s dairy program that started in 2020 but has yet to upload groundwater quality data to publicly available databases. Additional information on each of the existing monitoring programs is provided in **Table 4-3**. **Table 4-4** provides information on future monitoring networks to be used specifically for monitoring projects and management actions for GSP implementation.

Table 4-3. Santa Rosa Plain Subbasin Monitoring Networks

Monitoring Network	Responsible Party	Type of Wells	Constituents Sampled	Sampling Frequency	Purpose of Network
Salt and Nutrient Management Plan	City of Santa Rosa	Public Supply; Irrigation; Monitoring	EC, TDS, Nitrate, pH, temperature	Varies	Abide by SNMP requirements
DDW Public Supply Wells	Cities and small water systems	Public Supply	Subset of Title 22 constituents	Varies	Protect drinking water beneficials users
North Coast Water Board's Dairy Program	Dairies under DWR	Irrigation and domestic wells	Nitrate, TDS	This monitoring program started in 2020 and data will be made available on the GeoTracker site	Includes monitoring of wells in the vicinity of dairy operations

Table 4-4. Future Monitoring Networks for Project-Specific Monitoring

Future As-needed Monitoring Network	Responsible Party	Type of Wells	Constituents Sampled	Sampling Frequency	Purpose of Network
Future Project Implementation Monitoring Network	GSA	To be determined (public and private wells)	COCs identified as part of the GSP – and to the constituents as required by the project permitting	To be determined	Identify water quality impacts related to site-specific project and action implementation

Each of these well networks are monitored for different purposes and overseen by different entities; therefore, sampling frequency and analytical suites vary. Water quality MTs for each well are selected based on which constituents are analyzed in water samples per existing programs, summarized in **Table 4-5**.

Table 4-5. Summary of Constituents Monitored at Each Well Network

Constituent	Public Supply	SNMP
Arsenic	✓	
Nitrate	✓	✓
TDS	✓	✓

4.8.2.2 Level of Concern for each Constituent of Concern

Each COC has an associated level of concern for each category of beneficial user. For the drinking water supply well category, the level of concern is represented by the MCL, or SMCL, as applicable.

The NCRWQCB Basin Plan (Basin Plan) designates a municipal water quality management objective for the Subbasin (that is the Russian River watershed). The municipal designation aims to maintain water quality for public supplies below the California MCL and SMCL drinking water standards (NCRWQCB 2017). There are no specific numeric thresholds for agricultural water quality for groundwater in the Subbasin.

The basis for establishing MTs for each COC in the Subbasin are summarized in **Table 4-6**. This table does not identify the total number of supply wells that may exceed the level of concern, but rather identifies how many additional wells will be allowed to exceed the level of concern. Wells that already exceed this level are not counted against the MTs.

Table 4-6. Groundwater Quality Minimum Thresholds Basis

Constituent of Concern	Minimum Threshold Based on Number of Wells
Arsenic	Two additional supply wells exceed the arsenic MCL of 0.010 mg/L.
Nitrate	Two additional supply wells exceed the nitrate measured as nitrogen MCL of 10 mg/L.
TDS	Two additional supply wells exceed the TDS recommended SMCL of 500 mg/L.

4.8.2.3 Development of Minimum Thresholds at Supply Wells

The MTs for degraded water quality for the supply wells are based on the number of additional exceedances of any MCL or SMCL in existing supply wells presented in **Table 4-6**. Establishing the MT as the number of additional exceedances accounts for supply wells with previous exceedances, assuming these exceedances will likely continue into the future. The GSA Board selected two as the number of additional supply wells with exceedances to represent the MT. The MT for the number of allowed exceedances is therefore equal to the baseline number of exceedances (calculated as the number of supply wells with any MCL or SMCL exceedance between 2015 and 2019) plus two additional supply wells with an exceedance. Based on the number of supply wells in the existing water quality monitoring network, the number of existing exceedances since 2015 for each constituent is tabulated in **Table 4-7** and the distribution of exceedances are on **Figures 4-5** through **4-7**, along with all of the other supply wells included in the initial RMP network.

Table 4-7. Minimum Thresholds for Degradation of Groundwater Quality for the Public Supply Wells Under the Current Monitoring Network

Constituent of Concern	Regulatory Exceedance Standard	Standard Units	Number of Sampled Wells in Monitoring Network (2015-2019)	Total Number of Exceedances (2015-2019)	Number of Wells Exceeding Regulatory Standard (2015-2019)	Minimum Threshold
Arsenic	10	µg/L	104	778	21	23
Nitrate	10	mg/L	122	12	2	4
TDS	500	mg/L	94	2	2	4

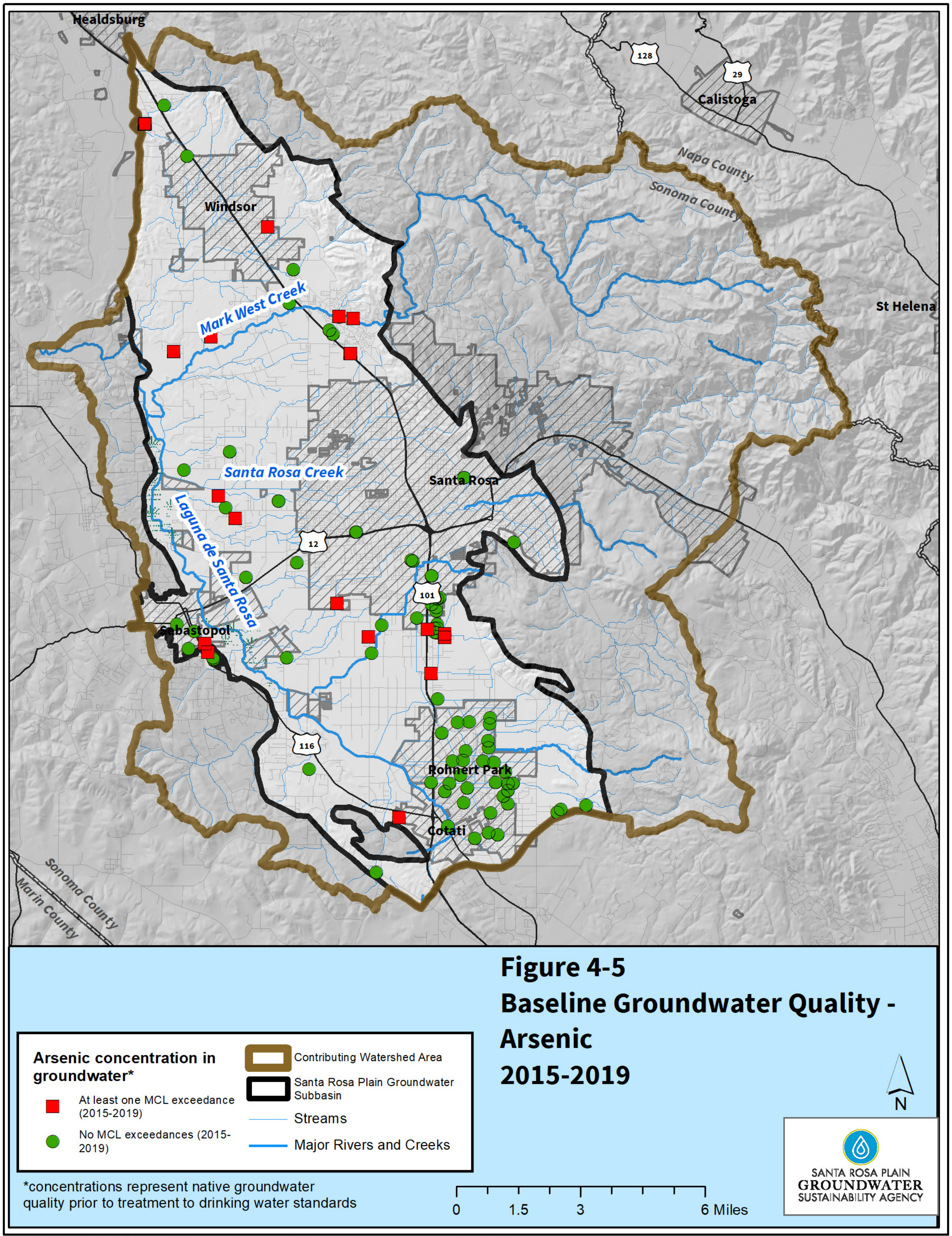
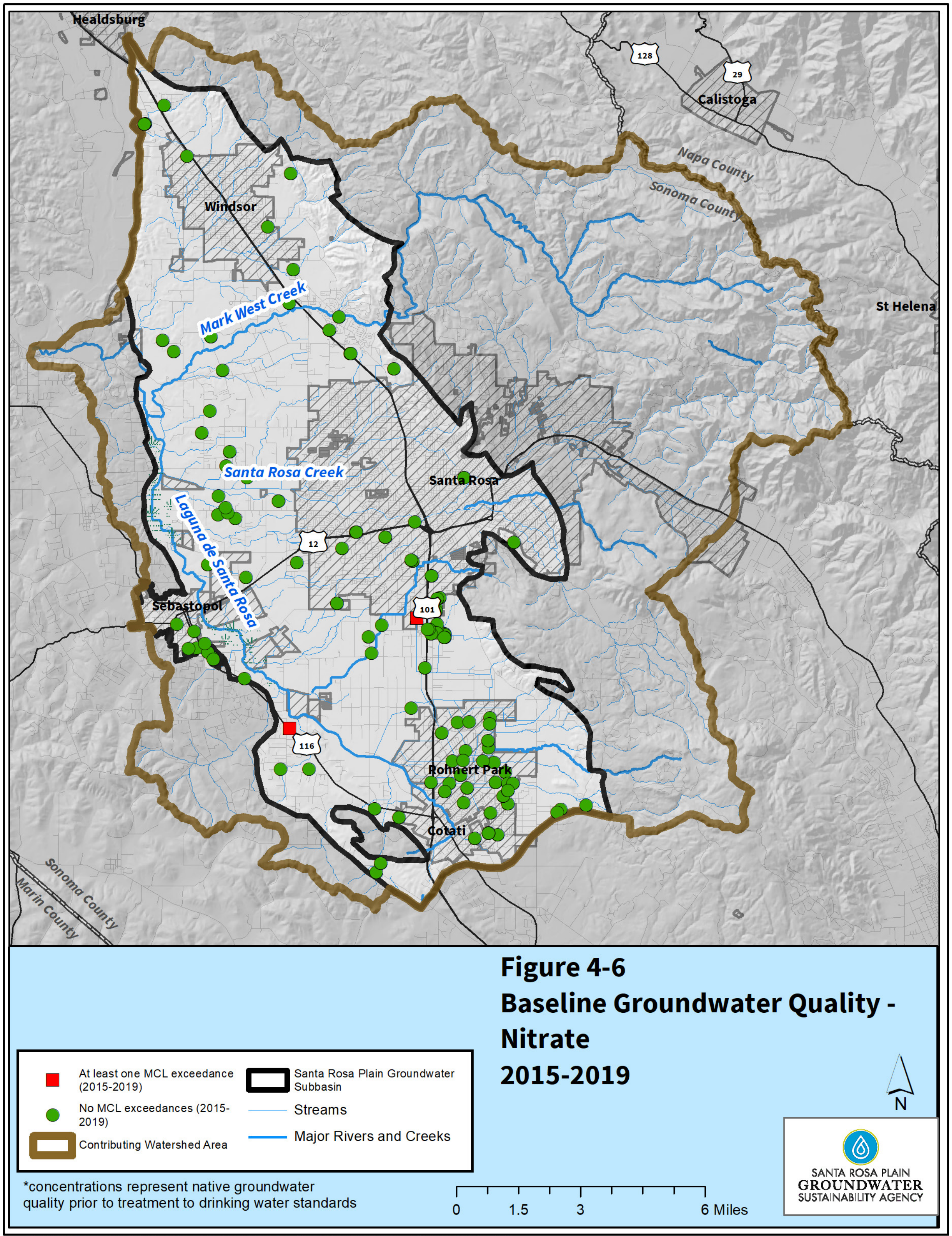


Figure 4-5 Baseline Groundwater Quality Arsenic 2015-2019



Filepath: T:\SGMA\GSAs\SRP\MXD\Fig4-1_4-3_SantaRosaPlain_GSA_GroundwaterQuality.mxd Date prepared: 11/8/2021

Figure 4-6. Baseline Groundwater Quality Nitrate 2015-2019

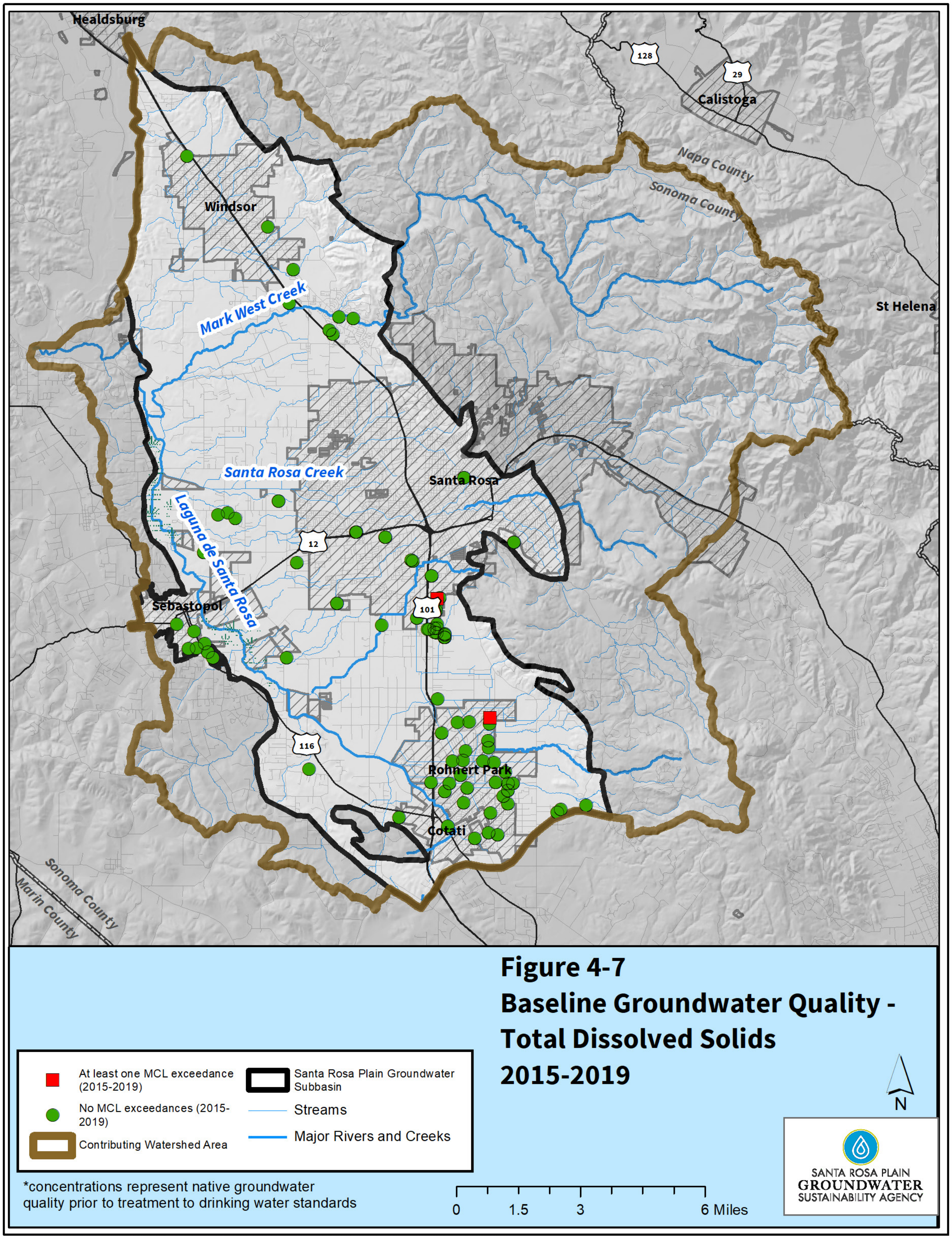


Figure 4-7. Baseline Groundwater Quality TDS 2015-2019

MT exceedances are based on existing supply wells only. According to the GSP Regulations, the MTs are based on the same number of supply wells to have exceedances, not necessarily the same wells. The well networks will be re-assessed every 5 years to identify any new supply wells that could be added to the monitoring networks. The MT will be increased by one for each new supply well added to the monitoring network with an initial measured concentration exceeding the MCL or SMCL. Additionally, if the MCL or SMCL changes for a GSP-identified COC, the specific MT should be examined and updated as appropriate.

If new exceedances of MTs are observed that are not due to GSP implementation, those new levels may be used to modify the MT accordingly to better reflect Subbasin conditions regardless of the GSP implementation actions.

4.8.2.4 Information and Methodology Used to Establish Water Quality Minimum Thresholds and Measurable Objectives

The exceedances in **Table 4-7** were based on a review of recent datasets. The information used for establishing the degradation of groundwater quality MTs includes:

- Historical groundwater quality data from public supply in the Subbasin
- Federal and state drinking water quality standards
- Feedback from GSA staff members and Advisory Committee members

The historical groundwater quality data used to establish groundwater quality MTs are presented in **Section 3.2.5**. Based on the reviews of historical and current groundwater quality data, federal and state drinking water standards, these standards are appropriate to define groundwater quality MTs.

4.8.2.5 Relationship between Individual Minimum Thresholds and Relationship to Other Sustainability Indicators

Because SGMA does not require projects or actions to improve groundwater quality, there will be no direct actions under the GSP associated with the groundwater quality MTs. Therefore, there are no actions that directly influence other sustainability indicators. However, preventing migration of poor groundwater quality may limit activities needed to achieve MTs for other sustainability indicators.

- **Chronic lowering of groundwater levels**. Groundwater quality MTs could influence groundwater elevation MTs by limiting the types of water that can be used for recharge to raise groundwater elevations. Water used for recharge cannot result in exceedances of any of the groundwater quality MTs. In addition, a change in groundwater elevations may cause a change in groundwater flow direction which in turn could cause poor water quality to migrate into areas of good water quality.

- **Change in groundwater storage**. Nothing in the groundwater quality MTs promotes pumping in excess of the sustainable yield. Therefore, the groundwater quality MTs will not result in an exceedance of the groundwater storage MT.

- **Subsidence**. Nothing in the groundwater quality MTs promotes additional pumping that could cause subsidence. Therefore, the groundwater quality MTs will not result in an exceedance of the subsidence MT.

- **Depletion of interconnected surface waters**. Nothing in the groundwater quality MTs promotes additional pumping or lower groundwater elevations adjacent to interconnected surface waters. Therefore, the groundwater quality MTs will not result in a significant or unreasonable depletion of interconnected surface waters.

4.8.2.6 Effect of Minimum Thresholds on Neighboring Basins and Subbasins

The anticipated effect of the degraded water quality MTs on each of the neighboring subbasins is addressed in this section.

The Santa Rosa Plain Subbasin has one neighboring subbasin that is categorized as medium-priority and is also subject to SGMA: the Petaluma Valley Basin, to the south.

The Santa Rosa Plain Subbasin is also adjacent to the very low-priority Healdsburg Area Subbasin to the North, and the Wilson Grove Formation Highlands Basin to the west, both of which are not subject to SGMA.

Because the MTs in the Santa Rosa Plain Subbasin are to prevent migration of poor-quality water, it is likely that the MTs will not prevent the Petaluma Valley Basinfrom achieving and maintaining sustainability. The MTs are also not likely to negatively impact the Healdsburg Area Subbasin or the Wilson Grove Formation Highlands Basin. The Santa Rosa Plain GSA will coordinate closely with the Petaluma Valley GSA as they both set MTs to ensure that the subbasins do not prevent each other from achieving sustainability.

4.8.2.7 Effect on Beneficial Uses and Users

Agricultural land uses and users. The degradation of groundwater quality MTs is designed to avoid negative effects to groundwater quality associated with implementation of the GSP. Avoiding degradation of groundwater quality for the identified COCs, including salts which can impact agricultural irrigation, helps maintain groundwater quality providing positive benefits to the Subbasin’s agricultural water users.

Urban land uses and users. The degradation of groundwater quality MTs is designed to avoid negative effects to groundwater quality associated with implementation of the GSP. Avoiding degradation of groundwater quality from the identified COCs helps maintain municipal drinking water quality providing positive benefits to the Subbasin’s urban water users.

Domestic land uses and users. The degradation of groundwater quality MTs is designed to avoid negative effects to groundwater quality associated with implementation of the GSP. Avoiding degradation of groundwater quality from the identified COCs helps maintain drinking water quality providing benefits for domestic well users.

Ecological land uses and users. Although the groundwater quality MTs are not designed to directly benefit ecological uses, it can be inferred that the degradation of groundwater quality MTs provide generally positive benefits to the Subbasin's ecological water uses by helping maintain groundwater quality.

4.8.2.8 Relation to State, Federal, or Local Standards

The degradation of groundwater quality MTs specifically incorporate state and federal standards for drinking water.

4.8.2.9 Method for Quantitative Measurement of Minimum Thresholds

Degradation of groundwater quality MTs will be measured directly using analysis of samples collected from public drinking water supply wells reported through SWRCB DDW. An average concentration of water quality samples will be used for wells that are sampled more than once a year. If any other routine monitoring of supply wells is initiated in the Subbasin at a later date, these wells, will also be considered for inclusion in the water quality monitoring network. The data review will focus on exceedances of MTs, or MCLs and SMCLs for the COCs identified for this GSP. However, if during review of the water quality data, additional constituents appear to frequently exceed MCLs and SMCLs, MTs and MOs will be considered for these additional constituents during GSP 5-year updates.

4.8.3 Measurable Objectives

The MOs for degradation of groundwater quality represent target groundwater quality distributions in the Subbasin. SGMA does not mandate the improvement of groundwater quality. Therefore, the GSA has set the MO for each COC to the number of existing supply wells that exceeded the MCL or SMCL from 2015 to 2019 (**Table 4-7**). In other words, the MO is to have zero additional supply wells exceeding the applicable MCL or SMCL for any of the COCs.

4.8.3.1 Method for Setting Measurable Objectives

MOs are established using a similar method to the MTs detailed in **Section 4.8.2**, except the target number of additional MCL or SMCL exceedances will be zero.

4.8.3.2 Interim Milestones

The MOs for degradation of groundwater quality are set at current conditions; there is no anticipated degradation of groundwater quality during GSP implementation that results from the implementation of projects and actions as described in **Section 6**. Therefore, the expected interim milestones are identical to current conditions.

4.8.4 Undesirable Results

4.8.4.1 Criteria for Defining Undesirable Results

By regulation, the degradation of groundwater quality undesirable result is a quantitative combination of groundwater quality MT exceedances. Some groundwater quality changes are expected to occur independent of SGMA activities; because these changes are not related to SGMA activities they do not constitute an undesirable result. The degradation of groundwater quality undesirable result occurs if, during 2 consecutive years, a single groundwater quality MT is exceeded when computing annual averages at the same well, as a direct result of projects or management actions taken as part of GSP implementation.

4.8.4.2 Potential Causes of Undesirable Results

Conditions that may lead to an undesirable result include the following:

- If the location and rates of groundwater pumping change as a result of projects implemented under the GSP, these changes could alter hydraulic gradients and associated flow directions, and cause movement of one of the COCs towards a supply well at concentrations that exceed relevant standards.

- Active recharge of imported water or captured runoff could modify groundwater gradients or alter local geochemical conditions and move one of the COCs towards a supply well in concentrations that exceed relevant limits.

- Recharging the Subbasin with water that exceeds an MCL, SMCL, or level that reduces crop production may lead to an undesirable result.

- The exceedance of an undesirable results for another sustainability indicator may lead to an undesirable result for degraded water quality.

Prior to determining whether an undesirable result has occurred based on MT exceedances, an investigation of the cause for the exceedance(s) will be conducted by the GSA. Such investigation would likely include the following steps, as needed:

1. Is a project or action by the GSA located in the vicinity and can be reasonably linked to the exceedance?

2. Are undesirable results occurring for any other sustainability indicators that could impact water quality?

If the answer to either question above is yes, then the following additional steps would be taken:

- Evaluate monitoring data from any projects and actions in the vicinity of the exceedance and correlate to the data from the well that had an exceedance

- Review of any other available groundwater quality data in the vicinity of the exceedance
- A detailed review of available laboratory analytical data and laboratory quality assurance/quality control measures
- Resampling of wells with the exceedances if it is established that the GSA projects or actions may be the cause of the exceedance

For any projects and actions implemented under the GSP, additional groundwater quality monitoring in the vicinity of the project or actions sites may be implemented to determine the possibility of causing undesirable results. Any needed mitigation measures to avoid the negative conditions will be included.

4.8.4.3 Effects on Beneficial Users and Land Use

The undesirable result for degradation of groundwater quality is adverse impacts on beneficial uses and users in the Subbasin from groundwater degradation due to actions directly resulting from GSP implementation. Adverse impacts include diminished supply due to water quality impacts that cause non-compliance with drinking water standards or undue costs for mitigating impacts through wellhead treatment or well replacement. Beneficial users that could be impacted by undesirable results from groundwater quality degradation include domestic well users, irrigation well users, and public water supply well users (inclusive of DACs that obtain water from these user categories). If water quality degradation due to GSP implementation activities is avoided, there will be no impact on the use of groundwater and there will be no negative effect on the beneficial users and uses of groundwater. If projects and actions are shown to cause the degradation of localized groundwater quality, however, the GSA will develop mitigation actions.

This undesirable result only applies to groundwater quality changes directly caused by projects or management actions implemented as part of this GSP. This undesirable result does not apply to groundwater quality changes that occur due to other causes.

4.9 Subsidence Sustainable Management Criteria

Land surface subsidence is the change in land surface elevation caused by an increase in effective stress due to groundwater overdraft, tectonics, or other natural processes such as hydrologic isostatic loading. Land surface subsidence may be elastic or inelastic. Elastic subsidence is recoverable as groundwater conditions change. Inelastic subsidence is unrecoverable and is primarily due to irreversible compaction of clay-rich sediments. Per the GSP Regulations, the GSAs are only responsible for managing inelastic land subsidence caused by lowered groundwater elevations. They are not responsible for managing elastic subsidence or subsidence conditions caused by something other than groundwater pumping, such as tectonic activity.

Available land surface subsidence datasets for the Subbasin do not indicate the occurrence of inelastic subsidence due to groundwater pumping. Subsidence measurements have been collected in the Subbasin at one discrete GPS location since 2005 and by InSAR satellite in most of the Subbasin since 2015. Two detailed studies were also performed to map and assess the Rodgers Creek Fault for evidence of creep from 1992 to 2001 and from 2003 to 2010. The available datasets and studies were summarized in the Basin Setting section of this GSP (**Section 3.2.4**).

Recent land surface elevation measured by GPS and InSAR indicate that land surface elevation is relatively stable in the Subbasin with some areas demonstrating slight increasing land surface elevation and others demonstrating slight land surface elevation decrease. Land surface elevation measured by GPS surveys at one discrete location between Santa Rosa and Sebastopol slightly increased by about 0.1 inch (or 0.008 foot) since 2005. Similarly, land surface elevation measured throughout the Subbasin by InSAR satellite since 2015 was less than 0.25-inch (or 0.021 foot) with some areas of land surface elevation increase up to 0.25 inch.

The Rodgers Creek Fault studies between 1992 and 2010 identified slight land surface elevation increase to the east of the fault and slight subsidence west of the fault, which follows a north-northwest trending plane through the City of Santa Rosa. While not specifically designed to investigate potential land surface subsidence due to groundwater pumping, the fault studies identified an area in the southern portions of the Subbasin near Rohnert Park and Cotati where the ground surface subsided between 1992 and 2001 at a rate of about 0.2 inch (0.017 foot) per year and subsequently rebounded between 2003 and 2010 at the same rate. This location generally coincided with an area of groundwater-level declines and subsequent recovery over similar timeframes as discussed in **Section 3.2.2**. The subsequent rebound of the land surface following the reduction in groundwater pumping and recovery of groundwater levels provides evidence that the relatively minor historical land surface subsidence in this area likely represents elastic land surface subsidence, which has not caused permanent (or inelastic) collapse of fine-grained units within the aquifer system.

Together, the subsidence datasets indicated that the land surface elevation is relatively stable throughout the Subbasin and where land surface movement is occurring, it appears to be related to fault movement rather than groundwater pumping. Areas to the east of the Rodgers Creek Fault appear to have slight upward movement and areas to the west of the fault appear to have slight downward movement. The overall land displacement trends in other portions of the Subbasin beyond the fault zone are generally stable with similar land surface elevation fluctuations in areas both with and without groundwater pumping. It is not known if the historical subsidence was elastic or inelastic; however, since the subsidence was found to be regionally consistent with the active fault location, it is not likely attributed to groundwater pumping and more likely due to natural causes such as tectonics or hydrostatic loading. Consequently, it appears that no significant inelastic subsidence has occurred within the Subbasin due to groundwater pumping.

4.9.1 Locally Defined Significant and Unreasonable Conditions

As described above and in **Section 3.2.3**, available Subbasin-wide datasets (while limited to recent time periods) do not indicate the occurrence of inelastic land surface subsidence due to groundwater pumping within the Subbasin. There have been no problems reported by Subbasin stakeholders related to historical inelastic subsidence (for example, damage to infrastructure or modified drainage patterns). However, the risk of future inelastic land surface subsidence and consolidation of the clay-rich portions of the Subbasin's aquifer system exists if there are chronic declines of groundwater levels.

Locally defined significant and unreasonable conditions were determined based on public meetings, and discussions with GSA staff, Advisory Committee members, and GSA Board. Significant and unreasonable land subsidence in the Subbasin was defined as any rate of future inelastic subsidence caused by groundwater pumping everywhere in the Subbasin regardless of the beneficial uses and users.

4.9.2 Minimum Thresholds

Section 354.28(c)(5) of the GSP Regulations states that "The minimum threshold for land subsidence shall be the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results" CCR Title 23. Section 354.28. As such, the defined metric from the GSP Regulations for measuring total subsidence includes the rate of change in land surface elevation. This can be measured with extensometers, continuous GPS stations, levelling surveys, or by satellite with InSAR. It is difficult to assess a-priori whether subsidence interferes with surface land uses to address the second portion of the GSP regulation; therefore, the GSA has selected a single protective MT for subsidence for the entire Subbasin. While zero inelastic subsidence due to pumping is the desire to avoid significant and unreasonable conditions, there is an inherent 0.1-foot potential error in the InSAR technology. The following MT was developed for the Subbasin to account for this potential measurement error of the data collection method:

The MT for subsidence in the Subbasin is 0.1 feet per year of inelastic subsidence measured by InSAR for each of the 100 square meter, or approximately 2.5 acre, grids or pixels in the Subbasin.

4.9.2.1 Information and Methodology Used to Establish Subsidence Minimum Thresholds and Measurable Objectives

The subsidence MT and MO allow for no measurable additional inelastic subsidence in the Subbasin due to groundwater pumping. The MT allowance of 0.1 ft/yr of subsidence was developed based on the inherent measurement error of InSAR technology described above.

The InSAR pixels serve as the RMPs. The reported total subsidence value is an average of many individual measurements within each InSAR pixel. InSAR is the method used for establishing MTs and MOs given the spatial coverage, accuracy, and availability at no cost to the GSA (state funded program for SGMA). Disadvantages of InSAR are that it measures total subsidence rather than inelastic subsidence and the available data record only extends to 2015.

4.9.2.2 Relationship between Individual Minimum Thresholds and Relationship to Other Sustainability Indicators

Subsidence MTs have little or no impact on other MTs, detailed as follows:

- Chronic lowering of groundwater levels. Nothing in the subsidence MT promotes additional pumping that could cause chronic lowering of groundwater levels. Therefore, the subsidence MT will not result in an exceedance of the groundwater storage MT.

- Change in groundwater storage. Nothing in the subsidence MT promotes pumping in excess of the sustainable yield. Therefore, the subsidence MT will not result in an exceedance of the groundwater storage MT.

- Degraded water quality. Nothing in the subsidence MT promotes additional pumping that could cause degradation of groundwater quality. Therefore, the subsidence MT will not result in an exceedance of the groundwater quality MT.

- Depletion of interconnected surface waters. Nothing in the subsidence MT promotes additional pumping or lower groundwater elevations adjacent to interconnected surface waters. Therefore, the subsidence MT will not result in a significant or unreasonable depletion of interconnected surface waters.

4.9.2.3 Effect of Minimum Thresholds on Neighboring Basins and Subbasins

The anticipated effect of the subsidence MT on each of the neighboring subbasins is addressed in this section.

The Santa Rosa Plain Subbasin has one neighboring subbasin that is categorized as medium-priority and is also subject to SGMA: the Petaluma Valley Basin, to the south. The Santa Rosa Plain Subbasin is also adjacent to the very low-priority Healdsburg Area Subbasin to the North, and the Wilson Grove Formation Highlands Basin to the west, both of which are not subject to SGMA.

Because the MTs in the Santa Rosa Plain Subbasin is intended to prevent any measurable inelastic subsidence due to groundwater pumping, it is likely that the MTs will not prevent the Petaluma Valley GSA from achieving and maintaining sustainability. The Santa Rosa Plain GSA will coordinate closely with the Petaluma Valley GSA as they both set MTs to ensure that the subbasins do not prevent each other from achieving sustainability.

4.9.2.4 Effect on Beneficial Uses and Users

Agricultural land uses and users. The subsidence MT is designed to avoid negative effects to infrastructure associated with implementation of the GSP. Avoiding land subsidence helps protect wells and water conveyance infrastructure that are critical to the Subbasin’s agricultural water users.

Urban land uses and users. The subsidence MT is designed to avoid negative effects to infrastructure associated with implementation of the GSP. Avoiding land subsidence helps protect buildings, roads, utilities, wells, and other infrastructure. This provides positive benefits to the Subbasin’s urban water users.

Domestic land uses and users. The subsidence MT is designed to avoid negative effects to infrastructure associated with implementation of the GSP. Avoiding land subsidence helps protect buildings, roads, utilities, wells and other infrastructure. This provides positive benefits to the Subbasin’s domestic water users.

Ecological land uses and users. The subsidence MT is not designed to directly benefit ecological uses. Preventing future subsidence in the Subbasin will not harm or benefit ecological water users.

4.9.2.5 Relation to State, Federal, or Local Standards

There are no federal, state, or local regulations related to land subsidence.

4.9.2.6 Method for Quantitative Measurement of Minimum Thresholds

There are two existing subsidence monitoring networks in the Subbasin, InSAR and one continuous GPS monitoring location. The continuous GPS data are temporally extensive, but spatially limited. Therefore, the GSA intends to use the InSAR method for assessment of subsidence SMC. Statewide subsidence data is currently estimated every month by satellite using InSAR methodology. DWR maintains a database of InSAR data and makes it publicly available for use in GSPs.

Quantitative measurements for InSAR data are provided on a monthly timestep by DWR. The DWR database and webmap reports an average total subsidence value of many individual measurements within a single 100 square meter, or approximately 2.5 acres pixel. The average for each pixel will be used for the subsidence MT. DWR has stated that, on a statewide level, for the total vertical displacement measurements between June 2015 and June 2019, the errors are as follows:

1. The error between InSAR data and continuous GPS data is 16 mm (0.052 foot) with a 95 percent confidence level (DWR 2021b).
2. The measurement accuracy when converting from the raw InSAR data to the maps provided by DWR is 0.048 foot with 95 percent confidence level.

For the purposes of this GSP, the cumulative errors for InSAR data are considered the sum of errors 1 and 2, for a combined total error of 0.1 foot.

The InSAR data provided by DWR reflects both elastic and inelastic subsidence. While it is difficult to compensate for elastic subsidence, visual inspection of monthly changes in ground elevations suggest that elastic subsidence is largely seasonal. Due to the seasonal elastic fluctuations, annual subsidence will be calculated by comparing InSAR datasets at the same time each year to reduce the effect of any seasonal elastic fluctuations of elevation on observed data.

4.9.3 Measurable Objectives

The MO is the aspirational goal to achieve optimal protection of groundwater conditions. The recommended MO is the same as the MT given that zero subsidence related to groundwater pumping is the significant and unreasonable condition. In other words, there is not a more stringent condition for land subsidence than the MT. Similar to the MT, the subsidence MO allows for 0.1 foot of measurement error per year.

4.9.3.1 Method for Setting Measurable Objectives

MOs are set to be identical to the MTs and therefore follow the same method as detailed in **Section 4.9.2**.

4.9.3.2 Interim Milestones

The MOs for subsidence are set at current conditions and there is no anticipated additional subsidence during GSP implementation that results from groundwater pumping; therefore, the expected interim milestones are identical to current conditions, MTs, and MOs.

4.9.4 Undesirable Results

By regulation, the subsidence undesirable result is a quantitative combination of subsidence MT exceedances. For the Subbasin, any inelastic subsidence as a direct result of groundwater pumping is considered unacceptable. Since the GSP Regulations allow for elastic and inelastic subsidence due to natural conditions such as plate tectonics and hydrostatic loading, any subsidence resulting from these phenomena are not included in the definition of undesirable results.

A land subsidence undesirable result will occur in the Subbasin if:

1. The land subsidence MT of 0.1 feet of total subsidence is exceeded over a geographic area of 25 acres in a single year.

2. Cumulative total subsidence of 0.2 feet is exceeded over a geographic area of 25 acres within a 5-year period.

3. The MT exceedance is determined to be correlated with (1) groundwater pumping, and (2) a MT exceedance of the chronic lowering of groundwater-levels SMC.

The geographic area of 25 acres was selected to reduce the likelihood that a very small area or a single data point anomaly within a single 2.5-acre grid could result in Subbasin-wide undesirable results. The cumulative cap of 0.2 foot within a 5-year period was selected to account for the risk of cumulative small amounts of annual total subsidence less than 0.1 foot adding up to a more significant level of subsidence. The 0.2-foot cumulative total represents an estimated minimum limit for elastic subsidence during groundwater-level decline and subsequent recover related to changes in groundwater pumping near Rohnert Park and Cotati discussed in **Section 4.9**. Maintaining 0.2 foot or less of cumulative subsidence allows for elastic land surface deformation from groundwater-level decline and subsequent recovery, while maintaining protections to avoid the potential for future inelastic subsidence. The undesirable result is tied to groundwater pumping and an exceedance of the chronic lowering of groundwater-levels SMC to isolate subsidence caused by groundwater pumping from other causes such as plate tectonics and hydrostatic loading.

4.9.4.1 Criteria for Defining Undesirable Results

An important aspect of the recommended SMC is the determination of whether total subsidence measured by InSAR is correlated to groundwater-level declines caused by pumping.

Activities that the GSAs will conduct if future MT exceedances occur to evaluate if inelastic land subsidence occurred due to groundwater pumping include the following:

- Review of land surface elevation data from InSAR, continuous GPS stations, or other measurement devices in the Subbasin
- Review of groundwater elevation measurements and trends in RMPs (established as part of the declining groundwater-level SMC) and other nearby wells being monitored, including an assessment as to whether groundwater levels are below historical lows or exceeding MTs
- Evaluation of time series plots of groundwater levels from nearby monitoring wells
- Review of seismic related data and records that might explain land subsidence observations
- Evaluation of known or estimated groundwater pumping patterns within the vicinity of any observed potential land subsidence
- Assessment of whether data gaps hamper the ability to determine the cause of MT exceedances

The number of the actions implemented for each individual exceedance of an MT would depend upon the severity and extent of the MT exceedances.

4.9.4.2 Causes of Undesirable Results

Conditions that may lead to an undesirable result for land subsidence include the following:

- Continued decline of groundwater levels due to groundwater pumping within the Subbasin could trigger inelastic subsidence in areas with clay-rich sediments.
- If the location and rates of groundwater pumping change as a result of projects implemented under the GSP, subsidence may occur.

- Shifting a significant amount of pumping to an area that is susceptible to subsidence could trigger subsidence that has not been observed before.
- The exceedance of an undesirable result for another sustainability indicator may lead to an undesirable result for subsidence.

4.9.4.3 Effects on Beneficial Users and Land Use

The undesirable result for subsidence does not allow any inelastic subsidence to occur in the Subbasin. Therefore, there is no negative effect on any beneficial uses and users.

4.10 Depletion of Interconnected Surface Water Sustainable Management Criteria

The SMC for depletion of interconnected surface water are more technically complex to develop and requires robust modeling tools, historical records of streamflow and groundwater levels near streams, and identification of potential impacts from streamflow depletion. To develop these SMC, staff convened two practitioner work groups to provide expert input on: (1) mapping of groundwater- dependent ecosystems; and (2) development of the SMC for depletion of interconnected surface water. Collectively, these work groups met seven times between July 2020 and March 2021. The work group focused on the development of the SMC for depletion of interconnected surface water included the following participants:

- Rick Rogers, National Marine Fisheries Service
- Jessie Maxfield, California Department of Fish and Wildlife
- Natalie Stork, State Water Resources Control Board
- Val Zimmer, State Water Resources Control Board
- Sam Boland-Brien, State Water Resources Control Board
- Maurice Hall, Environmental Defense Fund
- Melissa Rohde, The Nature Conservancy
- Andrew Renshaw, California Department of Water Resources

Key themes and outcomes from work group members that assisted in developing the SMC for interconnected surface water are documented in **Appendix 4-C**. As described in **Appendix 4-**C the SMC for depletion of interconnected surface water are unique in that information in the historical record linking surface water depletion directly to groundwater usage under the jurisdiction of the GSAs is very limited. Variable levels of correlation between simulated streamflow depletion and groundwater levels, a lack of existing instream flow targets, and limited data for assessing the presence of any historically significant and unreasonable conditions complicate the development of this SMC.[2] An additional complication is that depletions of surface water can be caused by diversions under surface water rights (for

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

example, direct surface water diversions or wells pumping under appropriative or riparian rights) that are outside the jurisdiction of SGMA and the GSAs. Therefore, the cause of the depletion must be evaluated to assess if such depletions are caused by pumping under the jurisdiction of the GSA.

Empirical data are not currently available within the Subbasin on potential causes and effects of surface water depletion due to groundwater pumping to adequately determine when it "adversely impacts the viability of GDEs or other beneficial users of surface water." For this reason, this GSP includes:

- A detailed adaptive management plan for developing new information and data to refine the SMC during initial years of GSP implementation
- Initial SMC focused on not exceeding historical levels of depletion based on available data and modeling tools

4.10.1 Locally Defined Significant and Unreasonable Conditions

Locally defined significant and unreasonable conditions were determined based on public meetings, and discussions with GSA staff, Work Group members, Advisory Committee members, and GSA Board. Significant and unreasonable depletion of interconnected surface water in the Subbasin was defined as:

> Significant and unreasonable depletion of surface water from interconnected streams occurs when surface water depletion, caused by groundwater pumping within the Subbasin, exceeds historical depletion or adversely impacts the viability of groundwater dependent ecosystems (GDEs) or other beneficial users of surface water.[3]

4.10.2 Minimum Thresholds

Section 354.28(c)(6) of the GSP Regulations states that "The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results."

Available data are currently insufficient to directly calculate the rate or volume of surface water depletions from streamflow measurements or reliably estimate depletions from a surface water budget. Quantifying surface water depletion due to pumping is a challenge because: (1) it

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[3] Important definitions related to the significant and unreasonable statement include:

- "Groundwater pumping" excludes any diversions by surface water rights holders
- "Historical depletion" estimated as simulated surface water depletion caused by groundwater pumping as informed by available historical measured data (2004-2018)
- "Groundwater dependent ecosystems" includes aquatic species and vegetation, as defined in **Section 3**
- "Other beneficial users of surface water" include surface water rights holders and recreational uses (where applicable)

cannot be measured directly; and (2) the influence of surface water depletion by pumping is often obscured by other factors, such as precipitation and runoff, surface water diversions, ET, and natural groundwater/surface water interactions. Therefore, groundwater levels are used as a proxy for the rate or volume of surface water depletion for these initial SMC. The use of groundwater levels as a proxy metric for the depletion of interconnected surface water sustainability indicator is considered the best available criteria because:

- The depletion of interconnected surface water is driven by the gradient between water surface elevation in the surface water body and groundwater elevations in the connected, shallow aquifer system.
- Groundwater levels are also one of the controlling factors in supporting rooting depths for vegetation-based GDEs.
- Groundwater levels represent criterion that the GSA has direct authority to manage within the Subbasin (for example, compared with streamflows that can be strongly influenced by the factors described above, as well as inflows from upland areas outside of the Subbasin).

4.10.2.1 Information and Methodology Used to Establish Depletion of Interconnected Surface Water Minimum Thresholds

The information used for establishing the MTs and MOs for the depletion of interconnected surface water sustainability indicator included:

Frequency of observed or measured streamflow:

- Comparison of interpolated groundwater levels within the shallow aquifer system and streambed elevations
- High frequency groundwater-level observations from shallow monitoring wells located near streams
- Map of interconnected surface water reaches within the Subbasin
- Map of the distribution of GDEs within the Subbasin
- Input from the practitioner work group for interconnected surface water

Appendix 4-D provides a description of the specific methodology used for developing the SMC for the depletion of interconnected surface water sustainability indicator, including: (1) the selection of appropriate RMPs for depletion of interconnected surface water, (2) methodology for demonstrating correlation between groundwater levels and interconnected surface water depletion, and (3) methodology for determining MTs and MOs for depletion of interconnected surface water at the RMPs.

As detailed in **Appendix 4-D** the initial SMC for depletion of interconnected surface water were developed based on simulated data and the best available historical information. The SMC will be refined, as needed, with observed data during the implementation phase. The general procedure for developing the initial SMC involves:

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

The MTs developed using this methodology are provided in **Table 4-8** and represent: The equivalent groundwater level, representing the 3 years (2014–2016) during which the most surface water depletion due to groundwater pumping was estimated between 2004 and 2018.

The goal of the MTs is to maintain estimated rates and volume of streamflow depletion below historical levels, using groundwater-level measurements as a proxy.

Table 4-8. Minimum Thresholds and Measurable Objectives for Depletion of Interconnected Surface Water

RMP Well	Proposed MT (feet above msl)	Proposed MO (feet above msl)
SRP0707	111.4	118.1
SRP0709	56.0	58.2
SRP0711	63.3	63.7
SRP0712	45.2	46.3
SRP0713	57.9	58.4
SRP0714	126.2	128.2
SRP0716	124.4	125.2

msl = mean sea level

Adaptive Management to Address Data Gaps and Improve/Refine Sustainable Management Criteria

In recognition of the significant information and data limitations and the importance of interconnected surface water to beneficial users within the Subbasin, potential future studies and activities have been identified and prioritized in coordination with the work group according to relative importance and potential costs. These studies and activities listed in two groups are described more thoroughly in **Section 7** of this GSP for implementation in the early implementation phase of the GSP. Initial identification of monitoring network data gaps, which consider the distribution of currently mapped GDEs within the Subbasin, is also provided in **Section 5**. Additionally, at this time, none of the streams in the Subbasin have instream flow criteria established by the state. If and when the state agencies conduct habitat and other studies to establish instream flow criteria, the GSA will use this information to evaluate surface water depletions to ensure compliance with SGMA.

Group 1

This group will focus on improved characterization of causes and effects of depletion, lower cost studies, and outside funding or leveraged funding opportunities with partners:

- Improve data/information on existing water wells and stream diversions
- Model improvements – focused calibration of surface water and groundwater interaction
- Improve GDE mapping/remote sensing for vegetation health (for example, use of Normalized Difference Vegetation Index, GDE pulse)
- Compile and evaluate existing and relevant habitat field surveys
- Evaluate future airborne geophysical data

Group 2

This group will focus on monitoring network improvements, higher cost studies, and related tasks:

- Additional shallow monitoring wells and stream gages
- Focused geophysical studies
- Geomorphic and streambed conductivity assessments
- Additional focused habitat field mapping in partnership with other agencies, as needed

4.10.2.2 Relationship between Individual Minimum Thresholds and Relationship to Other Sustainability Indicators

Assessment of how other sustainability indicators could be influenced by the depletion of interconnected surface water MT indicates the following:

- **Chronic lowering of groundwater levels**. Groundwater levels are used as a proxy for monitoring the depletion of interconnected surface water MTs. Because the MTs for the depletion of interconnected surface water are generally set within close proximity to streambed elevations within the Subbasin, they are shallower (more protective) than MTs set for nearby RMPs for the chronic lowering of groundwater levels. Therefore, an exceedance of the depletion of interconnected surface water MTs will not result in exceedances for chronic lowering of groundwater-level MTs.

- **Reduction in groundwater storage**. Because the chronic lowering of groundwater levels MTs will be used as a proxy for estimating groundwater pumping and changes in groundwater storage, an exceedance of the depletion of interconnected surface water MTs will not result in an exceedance of the groundwater storage MTs, for the same reasons described for the chronic lowering of groundwater levels sustainability indicator.

- **Degraded water quality**. MTs for depletion of interconnected surface water are intended to maintain groundwater levels near streams above historical levels, which is not anticipated to lead to degradation of water quality.

- **Subsidence**. MTs for depletion of interconnected surface water are intended to maintain groundwater levels near streams above historical levels, which is not anticipated to lead to subsidence.

4.10.2.3 Effect of Minimum Thresholds on Neighboring Basins and Subbasins

The Santa Rosa Plain Subbasin has one neighboring subbasin that is categorized as medium-priority and is also subject to SGMA: the Petaluma Valley Basin, to the south.

The Santa Rosa Plain Subbasin is also adjacent to the very low-priority Healdsburg Area Subbasin to the northwest, and the Wilson Grove Formation Highlands Basin to the west, both of which are not required to develop GSPs under SGMA.

The reaches of interconnected streams within the Subbasin that are subject to the MTs for depletion of interconnected surface water are separated by surface water divides from the Petaluma Valley Basin, and do not flow into the Healdsburg Area Subbasin or the Wilson Grove Formation Highlands Basin. Therefore, the MTs for depletion of interconnected surface water depletion will not have an effect on these neighboring basins and subbasins.

Additionally, the Santa Rosa Plain GSA will continue to closely coordinate with the Petaluma Valley GSA and the County (for areas that are not under a GSA’s jurisdiction) should any future issues arise.

4.10.2.4 Effect on Beneficial Uses and Users

The MTs for depletion of interconnected surface water measured using groundwater levels as a proxy assumes that maintaining groundwater levels at or above historical low levels in the Subbasin will avoid surface water depletion that exceeds historical levels. Avoiding surface water depletion at levels greater than historical conditions will provide a benefit to beneficial users and land uses that rely on interconnected surface water. The following specifically describes how MTs will benefit land and beneficial water use in the Subbasin:

- **Agricultural land uses and users**. Maintaining the historical levels of surface water depletion should not impact agricultural land uses or irrigation water supplies.

- **Urban land uses and users.** Municipal groundwater pumpers are not anticipated to be affected if surface water depletion from groundwater pumping remains similar to historical levels.

- **Domestic land uses and users**. Maintaining rates of surface waters depletion from groundwater pumping at or above historical levels will protect residential beneficial users of groundwater by keeping groundwater levels at or above historical low levels.

- **Ecological land uses and users**. The main benefit of the surface water depletion MTs is to GDEs (primarily aquatic species and riparian vegetation). Maintaining shallow groundwater levels near streams at or above historical low levels helps maintain interconnected conditions and historical levels of baseflow. Better understanding the causal effects of interconnected surface water depletion due to groundwater pumping on GDEs and habitat is a primary focus of the early stages of GSP implementation and will be used to further evaluate potential effects on GDEs and refine the MTs in future GSP updates, as appropriate.

4.10.2.5 Relation to State, Federal, or Local Standards

No federal, state, or local standards exist that are specifically address depletion of interconnected surface water, however state and federal endangered species provisions call for the protection and restoration of conditions necessary for steelhead and coho salmon. These provisions were considered in development of the surface water depletion MTs.

If and when new standards, such as instream flow targets, are developed by other agencies they will be evaluated and incorporated into any potential future refinements to the MTs for depletion of interconnected surface water.

4.10.2.6 Method for Quantitative Measurement of Minimum Thresholds

Groundwater elevations will be measured in seven RMPs used to monitor surface water depletion as a proxy. Groundwater-level monitoring will be conducted in accordance with the monitoring protocol outlined in **Section 5.3.3**. For reporting seasonal highs and lows for future comparison with MTs, all measurements collected more frequently than monthly will be reported as monthly averages in order to better align with the measurement frequency within historical datasets used to calculate the MTs. During GSP implementation, individual groundwater-level measurements collected manually and by data loggers will be reviewed for quality control and analyzed for MT exceedances during compilation of GSP annual and 5-year update reports. As described in **Section 4.10.2.1** and in **Sections 5** and **7**, additional work to fill data gaps and implement monitoring network improvements are identified as high-priority actions during GSP implementation.

4.10.3 Measurable Objectives

MOs for depletion of interconnected surface water represent achievable target groundwater elevations near streams that allow for operational flexibility over a range of climate and hydrologic variability. Based on input from the work group, the Advisory Committee, and GSA Board, it was decided that MO values at RMP locations should maintain the observed average dry-season surface water depletion from pumping that occurred during the years with available observations during 2004-2020. This time period is considered representative of average conditions, because it contains 8 normal years, 5 wet years, and 1 dry year. **Table 4-8** lists the MOs for each RMP.

4.10.3.1 Method for Setting Measurable Objectives

A description of the specific methodology used for developing the MOs for the depletion of interconnected surface water sustainability indicator is provided in **Appendix 4-D**.

4.10.3.2 Interim Milestones

Interim milestones are intended to show how MOs will be achieved during the initial 20-year implementation period of the GSP. As the MOs are set at the average groundwater elevations during recent years (average of 2004–2020), interim milestones are identical to the groundwater levels associated with the MOs.

4.10.4 Undesirable Results

4.10.4.1 Criteria for Defining Undesirable Results

The depletion of interconnected surface water undesirable result is defined using groundwater levels as a proxy. Per the GSP Regulations, the description of undesirable results is based on a quantitative description of the combination of MT exceedances that cause significant and unreasonable effects in the Subbasin. For the Subbasin the specific groundwater conditions that constitute an undesirable result is:

Undesirable result occurs if MTs are exceeded at 40 percent of RMP wells during drought years and 10 percent of RMP wells during non-drought years and are entirely or partially attributable to groundwater pumping under the jurisdiction of the GSA.

The different percentages associated with drought years versus non-drought years were selected to help address the concerns expressed by some work group and Advisory Committee members that setting MTs at levels experienced during significant droughts could be detrimental to aquatic species and associated habitat if allowed during future normal and wet years. Placing the different weights on drought and non-drought years helps address the expressed concern by ensuring that during normal/wet years the higher levels of estimated streamflow depletion from 2014-2016 are avoided.

Exceedances of MTs at a single RMP will require investigation to determine if any actions should be considered to avoid potential future onset of undesirable results, as in **Section 4.10.4.2**.

4.10.4.2 Potential Causes of Undesirable Results

Many factors influence surface water flows and interconnected surface water depletion which are outside the control of the GSA. For undesirable results to occur, the cause of surface water depletion must be related to the extraction of groundwater or other project and management actions implemented for groundwater sustainability, and not due to lack of precipitation during periods of prolonged drought or surface water diversions under the jurisdiction of the SWRCB.

Undesirable results may occur in the future to GDEs if groundwater-level declines near creeks are caused by groundwater pumping or if there is reduced recharge in the shallow aquifer system.

Prior to determining if undesirable results are occurring based on MT exceedances, the GSA would need to assess whether potential causes of exceedances are related to depletions associated with groundwater pumping or other activities not under the jurisdiction of the GSA. Staff is currently working with staff of the SWRCB to develop a description of a coordination process with SWRCB to address this. The goal of the coordination process is to assess whether potential causes of exceedances are related to depletions (entirely or in part) associated with groundwater conditions under the jurisdiction of the GSA or other activities not under the jurisdiction of the GSA and will include (1) information and data sharing; (2) conferring on potential causes of exceedances; and (3) improving the SMC as needed based on outcomes and new information.

Additionally, in order to respond prior to the onset of undesirable results the following actions would be implemented if a MT is exceeded at a single RMP that does not trigger an undesirable result:

- Review available data from full monitoring network (that is, non-RMP monitoring wells) to assess potential scale of areas exhibiting declines
- Assess whether exceedance is climate-related
- Review of any known or potential changes in groundwater pumping patterns for example, new wells brought online, changes in land/water use)
- Consider whether additional RMPs are needed
- Information sharing with other stakeholder, as appropriate

4.10.4.3 Effects on Beneficial Users and Land Use

If depletions of interconnected surface water were to reach undesirable results, adverse effects could include the reduced ability of the streamflows to meet instream flow requirements for local fisheries and critical habitat, including GDEs, in the Subbasin. Reduction of streamflow directly reduces the amount of suitable rearing habitat for fisheries by reducing the amount of wetted area, stream depth, flow velocity, cover, and dissolved oxygen. Reduced flow can also result in increased water temperature. In extreme conditions, dewatering of stream reaches eliminates the ability of fish to move to more suitable areas and can cause mortality. Reduced surface flows can also negatively affect permitted surface water diversions. Riparian vegetation GDEs can also be impacted by lowered groundwater levels in the vicinity of interconnected surface water within the Subbasin. Consideration of these effects was included as part of SMC development.

4.10.5 Consideration of Public Trust Resources

While SGMA does not require the plan to address California's public trust doctrine, a 2018 California Court of Appeal ruling found that groundwater pumping that directly reduces the flow or volume of water in a navigable waterway (and tributaries that are known to supply those navigable waters) may violate the public trust doctrine under certain fact-specific circumstances where public trust resources are adversely affected. The public trust doctrine does not apply to groundwater itself. Rather, the public trust doctrine may apply if extraction of groundwater adversely impacts a navigable waterway or tributary to a navigable waterway to which the public trust doctrine does apply (Environmental Law Foundation et al. v. State Water Resources Control Board [2018], 26 Cal.App.5th 844). As described elsewhere in this plan, to the extent that tributaries in the Subbasin flow into the Russian River, the plan analyzes potential impacts on interconnected surface water (ISW), GDEs, and public trust resources.

The public trust doctrine is the principle that the government holds in trust designated resources for the benefit of the people. Public trust uses can include commerce, recreation, and fishing in navigable waters, as well as wildlife habitat and recreation. It is a balancing doctrine that protects these resources to the extent feasible and includes a reasonable consideration of public trust resources in specific governmental decision-making processes. Here, the plan reasonably considers and incorporates public trust resources protection to the extent feasible; the plan accomplishes this by using an inclusive public process and using the best data and best available science.

The various beneficial uses and users of surface waters (including known water rights holders, ecological surface water users and uses, and recreational surface water users) were addressed when setting the ISW depletion SMC. This is a reasonable review of all uses and users in an attempt to balance all interests that must be considered. GSAs under SGMA are "charged with procedural and substantive obligations designed to balance the needs of the various stakeholders in groundwater in an effort to preserve [groundwater], and replenish [it] to the extent possible" (Environmental Law Foundation et al. v. State Water Resources Control Board, citing CWC Sections 10721[u], [v, [x][6]; 10723.2; 10725.2; 10725.4; 10726.2; 10726.4;

10726.5). This is not an assessment about what constitutes a reasonable and beneficial use under Article X, Section 2 of the California Constitution. The SMC for depletion of ISW are developed as described in **Section 4.10** and in **Appendix 4-D**, including public information about critical habitat, locations of ISW derived from best available data, and available information about known water rights holders.

This plan specifically recognizes the importance of protecting environmental public trust resources. As described in the introduction of **Section 4.10**, the GSA sought expert advice regarding the best available science and applied for and received grant funding through Proposition 68 to convene and facilitate a Practitioners Working Group. The purpose of this working group, as described in **Section 4.10**, was to help develop the SMC for the consideration of ISW to avoid or reduce potential depletion. This process involved the reasonable analysis and consideration of public trust resources.

Another example of the GSA's efforts to consider public trust resources is a second Practitioners Working Group that was convened to assist in identifying the GDEs, including fish and wildlife that use streamflows that could be affected by the potential depletion of ISW as applicable in some parts of the Subbasin. This working group included representatives from National Marine Fisheries Service, California Department of Fish and Wildlife, TNC, San Francisco Estuary Institute, Permit Sonoma, Sonoma County Agricultural Preservation and Open Space District, Sonoma Ecology Center, and The Laguna de Santa Rosa Foundation.

As described in **Section 3.2.6**, available information to map ISW is limited in the Subbasin, and is further complicated by challenges in quantifying surface water depletion due to pumping (described in **Section 4.10**). The current monitoring network for ISW does include some data gaps, which are described in **Section 5.4.2**. The plan proposes an aggressive adaptive management plan and methodology, described in **Appendix 4-D**, which uses existing information to avoid adverse effects on public trust resources and makes adjustments as new information and data become available. The implementation plan (**Sections 7.2.4.1** and **7.2.4.2**) describes how these data gaps will be filled and how the monitoring network and mapping will be improved within the first 5 years of implementation. This shows that the GSA has a proactive approach to fully understanding and taking steps to identify and avoid adverse effects on public trust resources. The GSA has taken steps to make use of the best available science, and additionally taken steps to make additional information and data available to update the best available science as soon as is feasible. Specifically, as it has in the past, the GSA will apply to DWR for the next round of available funding to support GSP implementation, including funding to further analyze and address data gaps, ISW, and public trust resources.

Section 5: Monitoring Networks

Groundwater Sustainability Plan for Santa Rosa Plain Groundwater Subbasin

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5 MONITORING NETWORKS

This section describes the monitoring networks that are planned in the Subbasin and contributing watershed areas for implementation of the GSP and how the existing monitoring networks described in **Section 2.5** were evaluated and refined. RMPs, for which SMC are set, are identified in this section and the processes used to select suitable RMPs, along with monitoring objectives, are described. This section also presents an assessment of the monitoring networks identified for GSP implementation, including identification of data gaps and improvements to the monitoring networks.

5.1 Monitoring Network Objectives

SGMA regulations require monitoring networks be developed to promote the collection of data of sufficient quality, frequency, and spatial distribution to characterize groundwater and related surface water conditions in the Subbasin, and to evaluate changing conditions that occur during implementation of the GSP. Monitoring networks should accomplish the following:

- Demonstrate progress toward achieving MOs described in the GSP.
- Monitor impacts on the beneficial uses and users of groundwater.
- Monitor changes in groundwater conditions relative to MOs and MTs.
- Quantify annual changes in water-budget components.

Specific objectives for each monitoring network in the Subbasin are described in **Sections 5.2 through 5.4**. To ensure the quality and consistency of the data collected, monitoring protocols have been established and are presented in **Appendix 5-A**.

5.2 Description of Monitoring Networks for Groundwater Sustainability Plan Implementation

The monitoring networks included in this section are based on existing monitoring networks described generally in **Section 2.5** (Existing Monitoring Programs and Networks). To relate monitoring stations to sustainability indicators, monitoring networks are described in **Sections 5.2.1** through **5.2.4** for each of the information types that are needed to evaluate the sustainability indicators described in **Section 4**.

5.2.1 Groundwater-level Monitoring Network

The existing groundwater-level monitoring network described in **Section 2.5** was evaluated in accordance with SGMA regulations and guidelines, with the monitoring network objectives in mind, and refined into the Groundwater-level Monitoring Network for GSP Implementation (GSP Implementation Network).

SGMA requirements and guidance for monitoring are described in the GSP Regulations and DWR's BMPs for Monitoring Protocols, Standards, and Sites (DWR 2016b) and Monitoring

Networks and Identification of Data Gaps (DWR 2016c). These include the following data and reporting standards and guidance related to groundwater levels:

- Well location, accurate to within 30 feet
- Elevation of the ground surface and reference point, accurate to within 0.5 foot
- Field measurements measured and reported to accuracy of 0.1 foot
- Description of the well type (for example, public supply, irrigation, domestic, monitoring, or other type of well) and whether the well is active or inactive
- Construction information (casing perforations, borehole depth, and total well depth)
- Well completion reports, if available, from which the names of private owners have been redacted
- Identification of principal aquifers monitored
- Selection of aquifer-specific wells and avoidance of wells that are screened across more than one aquifer
- Active water supply wells (for example, agricultural or municipal wells) that can be used temporarily until either dedicated monitoring wells can be installed or an existing well can be identified that meets the required criteria
- Any active water supply wells used for monitoring, screened across a single water-bearing unit, and care must be taken to ensure that pumping drawdown has sufficiently recovered before collecting data from a well

Specific objectives for the Groundwater-level Monitoring Network are to provide a sufficient number of monitoring sites with adequate spatial distribution, monitoring frequency, and data quality to achieve the following:

- Produce seasonal maps of potentiometric surfaces for the shallow and deep aquifer systems throughout the Subbasin that clearly identify changes in groundwater-flow direction and gradient.
- Demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features.
- Demonstrate groundwater occurrence, flow directions, and hydraulic gradients across basin boundaries, when combined with data from adjacent basins.
- Identify short-term and long-term trends and seasonal fluctuations when combined with historical data.

- Track water levels relative to MTs and MOs.
- Support water-budget calculations and calibration of the groundwater model for the Subbasin.

5.2.1.1 Rationale for Selection of Groundwater Sustainability Plan Implementation Groundwater-level Monitoring Network Sites

The following criteria were used for assessment and initial screening of the entire existing Groundwater-level Monitoring Network to identify which wells are suitable for inclusion into the GSP Implementation Network:

- Well Construction: Wells with known complete construction information (that is, total depth, casing diameter, depth of screened interval[s]) are preferred and wells to be included in the GSP Implementation Network should be screened within a single aquifer system. For wells selected for inclusion into the GSP Implementation Network that have incomplete construction information, attempts will be made to ascertain the information through records searches of applicable databases or records requests directly to the well owner, or applying for video-logging services through the DWR’s Technical Support Services (TSS) program.
- Historical Data Record: Wells with complete data records of 10 years or longer that are part of a current monitoring program are preferred. In some cases, for wells where monitoring has been discontinued in the past few years (2017 or later), efforts are being made to reinstate monitoring as a part of GSP implementation.
- Well Type: Dedicated monitoring wells are preferred. Secondary preference is given to inactive supply wells and the lowest preference is given to active supply wells (that is, domestic, irrigation, or municipal). For active supply wells included in the GSP Implementation Network, special precautions will be taken to ensure representative measurements are collected as described in **Appendix 5-A**, **Monitoring Protocols**. Environmental monitoring wells were not considered for the GSP Implementation Network because they are typically privately owned and somewhat temporary in nature.
- Spatial Coverage: Monitoring sites were selected to maximize horizontal and vertical coverage of the entire Subbasin. Special considerations were given to areas near streams and areas of uncertainty such as near faults or basin boundaries. Where available, wells outside of the Subbasin, but within the contributing watershed areas, are included in the GSP Implementation Network.
- Well Ownership: Wells owned by a GSA member agency are preferred. Privately owned wells are also included in the GSP Implementation Network to maximize spatial coverage of the Subbasin.