Atascadero Basin Groundwater Sustainability Plan

Draft Chapter for Public Comment

Section 6

Water Budgets

Thank you for your interest in sustainable groundwater management.

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Draft Atascadero Groundwater Sustainability Plan

Atascadero Groundwater Subbasin Section 6

Prepared for: Atascadero Subbasin Groundwater Sustainability Agency

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6. Water Budgets

This chapter summarizes the estimated water budgets for the Atascadero Area Groundwater Sub-basin of the Salinas Valley Basin (Basin), including information required by the Sustainable Groundwater Management Act (SGMA) Regulations and information that is important for developing an effective Groundwater Sustainability Plan (GSP) to achieve sustainability. In accordance with the SGMA Regulations §354.18, the GSP should include a water budget for the basin that provides an accounting and assessment of the total annual volume of surface water and groundwater entering and leaving the basin, including historical, current, and projected water budget conditions, and the change in the volume of water stored. The regulations require that the water budgets be reported in graphical and tabular formats, where applicable.

6.1 Overview of Water Budget Development

This section is subdivided into three sections: (1) historical water budgets, (2) current water budgets, and (3) future water budgets. Within each section, a surface water budget and groundwater budget are presented. Water budgets were developed using computer models of the Basin hydrogeologic conditions. Before presenting the water budgets, a brief overview of the models is presented. Appendix 6A provides additional information about the models and compares previously reported water budgets to the water budgets developed for this GSP.

The water budgets reported herein are for the Basin defined in Section 1.2 and depicted on Figure 1-1.

The safe yield of a groundwater basin is the volume of pumping that can be extracted from the basin on a long-term basis without creating a chronic and continued lowering of groundwater levels and groundwater in storage volumes. The safe yield is not a fixed constant value, but is a dynamic value that fluctuates over time as the balance of the groundwater inputs and outputs change; thus, the calculated safe yield of the Basin will be estimated and likely modified with each future update of the GSP.

Safe yield is not the same as sustainable yield. Sustainable yield is defined in SGMA as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus that can be withdrawn annually from a groundwater supply without causing an undesirable result." An undesirable result is one or more of the following effects on the six sustainability indicators:

- Chronic lowering of groundwater levels in the aquifer(s)
- Significant and unreasonable reduction of groundwater in storage
- Significant and unreasonable degradation of water quality

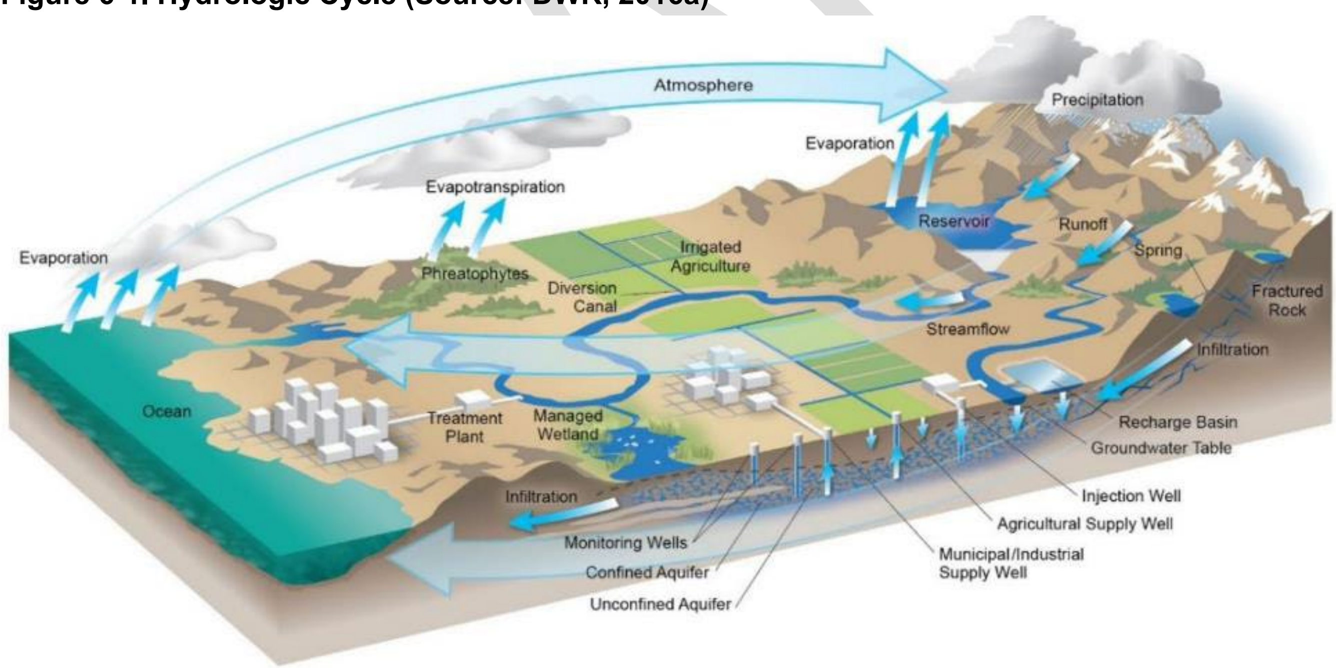
- Sea water intrusion
- Significant and unreasonable land subsidence that interferes with surface land uses
- Depletion of interconnected surface water that has significant and unreasonable adverse impacts on beneficial uses of surface water

Defining the safe yield of a groundwater basin provides a starting point for later establishing sustainable yield by considering each of the six sustainability indicators listed above.

Section 354.18 of the SGMA Regulations requires development of water budgets for both groundwater and surface water that provide an accounting of the total volume of water entering and leaving the basin. To satisfy the requirements of the regulations, a surface water budget was prepared for the Atascadero Basin and an integrated groundwater budget was developed for each water budget period for the combined inflows and outflows for the two principal aquifers – Alluvial Aquifer (including the Salinas River alluvial aquifer and associated tributaries; see Section 4) and Paso Robles Formation Aquifer. Groundwater is pumped from both aquifers for beneficial use.

Figure 6-1 presents a general schematic diagram of the hydrologic cycle. The water budgets include the components of the hydrologic cycle.

Figure 6-1. Hydrologic Cycle (Source: DWR, 2016a)



A few components of the water budget can be measured, like streamflow at a gaging station or groundwater pumping from a metered well. Other components of the water budget are estimated, like recharge from precipitation or unmetered groundwater pumping. The water budget is an inventory and accounting of total surface water and groundwater inflows (recharge) and outflows (discharge) from the Basin, including:

Surface Water Inflows:

- Runoff of precipitation and reservoir releases into streams and rivers that enter the Basin from the surrounding watershed
- Imported surface water (e.g. Nacimiento Water Project)

Surface Water Outflows:

- Streamflow exiting the Basin
- Percolation of streamflow to the groundwater system
- Evaporation

Groundwater Inflows:

- Recharge from precipitation
- Subsurface groundwater inflow
- Irrigation return flow (water not consumed by crops/landscaping)
- Percolation of surface water from streams
- Percolation of treated wastewater from disposal ponds
- Percolation of imported surface water (e.g. Nacimiento Water Project)

Groundwater Outflows:

- Evapotranspiration
- Groundwater pumping
- Subsurface outflows to the adjoining, downgradient groundwater basins
- Groundwater discharge to surface water

The difference between inflows and outflows is equal to the change in storage.

6.2 Water Budget Data Sources and Basin Model

Water budgets for the Basin were estimated using an integrated system of three hydrologic models (collectively designated herein as the “basin model”), including:

1. A watershed model
2. A soil water balance model
3. A groundwater flow model

The groundwater model was originally developed by Fugro (2005). The watershed and soil water balance models were developed and integrated with an updated version of the groundwater model by Geoscience Support Services, Inc. (GSSI) (GSSI, 2014 and 2016). These models were developed for San Luis Obispo County Flood Control and Water Conservation District (SLOFCWCD). The domain of these models encompasses an area that includes both the Paso Robles Subbasin and the Basin as well as a portion of the Salinas Valley – Upper Valley Aquifer

Subbasin north of the Monterey County line[1]. The original models are documented in the following reports:

- Final Report, Paso Robles Groundwater Basin Study Phase II, Numerical Model Development, Calibration, and Application: Fugro, February 2005
- Paso Robles Groundwater Basin Model Update: Geoscience Support Services, Inc., December 2014
- Refinement of the Paso Robles Groundwater Basin Model and Results of Supplemental Water Supply Options Predictive Analysis: Geoscience Support Services, Inc., December 2016.

The GSSI 2016 version of the basin model was updated by Montgomery & Associates (M&A; 2020) for the Paso Robles Subbasin GSP. Because the model domain of the basin model encompasses the entirety of the original Fugro 2002 basin, the basin model simulates groundwater flow conditions and water budgets for both the Paso Robles Subbasin and the Atascadero Subbasin.

The M&A (2020) basin model update included updating the GSSI 2016 basin model by incorporating hydrologic data for the period 2012 through 2016 into the models. Appendix 6A includes a brief summary of the model update process, including:

- A summary of data sources used for the update (Table 6A-1)
- A summary of modifications made to the basin model to address computational refinements, data processing issues, and conceptual application of the model codes

The updated versions of the basin models are referred to herein collectively as the "GSP model". The GSP model has been utilized for both the Atascadero Basin GSP and the Paso Robles Subbasin GSP as the model domain covers large portions of both subbasins.

Numerous sources of raw data were used to update the basin models for the GSP. Examples of raw data include metered pumping and deliveries from the Atascadero Mutual Water Company (AMWC), Templeton Community Services District (TCSD), and the city of Paso Robles, precipitation data obtained from weather stations in the Basin, and crop acreage from the office of the San Luis Obispo County Agricultural Commissioner, among many others. Data sources are listed in Table 6A-1. Raw data were compiled, processed, and used to develop model input files. Model results were used to develop estimates of the individual inflow and outflow

[1] The domain of the Fugro 2005 model and subsequent model updates completed by GSSI (2014 and 2016) were designed to encompass the area defined as the Paso Robles Groundwater Basin by Fugro in 2002. The 2002 Fugro study defined the lateral and vertical extent of the Paso Robles Groundwater Basin, which included a portion north of the Monterey County line and identification of the Atascadero Subbasin (Basin) as a hydrogeologically distinct portion of the basin. The basin extents defined by Fugro (2002) varies slightly from the basin extents defined in the current DWR Bulletin 118 (DWR 2016b).

components of the surface water and groundwater budgets. Thus, all the estimated flow components herein were extracted from the GSP model.

6.2.1 *Model Assumptions and Uncertainty*

The GSP model is based on available hydrogeologic and land use data from the past several decades, previous studies of Basin hydrogeologic conditions, and earlier versions of the basin models. The GSP model gives insight into how the complex hydrologic processes are operating in the Basin. During previous studies, available data and a peer-review process were used to calibrate the basin model to Basin hydrogeologic conditions. Results of the previous calibration process demonstrated that the model-simulated groundwater and surface water flow conditions were similar to observed conditions. The GSP model was not recalibrated. However, after updating it for this GSP, calibration of the model was reviewed and found to be similar to the previous model. The groundwater flow model module of the GSP model does not cover the northwestern upland portion of the Atascadero Basin (as defined by DWR Bulletin 118) so groundwater processes have not been modeled in this area, yet, the watershed model does include this area so contributing surface and subsurface flows from this upland area have been incorporated into the GSP model; therefore, use of the GSP model was considered appropriate for development of the Atascadero Basin GSP.

Projections made with the GSP model have uncertainty due to limitations in available data and assumptions made to develop the models. Model uncertainty has been considered when developing and using the reported GSP water budgets for developing sustainability management actions and projects (Section 9).

New data will be collected and/or refined throughout the early implementation of this GSP (after adoption by the GSA). The information will be used to recalibrate and potentially expand the domain of the GSP model, and perhaps develop a stand-alone, Atascadero Basin-specific groundwater flow model rather than continued utilization of the coupled Paso Robles Subbasin/Atascadero Basin model. New hydrologic data and a calibrated model will be used to simulate impacts from proposed sustainability management actions, and possible water resource improvement projects, to monitor that progress toward the sustainability goal is being achieved.

6.3 Historical Water Budget

The SGMA Regulations require that the historical surface water and groundwater budget be based on at least the most recent 10 years of data. The period 1981 to 2011 was selected as the time period for the historical water budget (referred to as the historical base period) because it is long enough to capture typical climate variations, it corresponds to the period simulated in the basin model, and it ends at about the time the latest drought period began. Estimates and assumptions of the surface water and groundwater inflows and outflows, and changes in storage for the historical base period are provided below.

6.3.1 *Historical Surface Water Budget*

The SGMA Regulations (§354.18) require development of a surface water budget for the GSP. The surface water budget quantifies important sources of surface water and evaluates their historical and future reliability. The water budget Best Management Practice (BMP) document states that surface water sources should be identified as one of the following (DWR, 2016a):

- Central Valley Project
- State Water Project
- Colorado River Project
- Local imported supplies
- Local supplies

The Basin relies on two of these surface water source types: local imported supplies and local supplies.

6.3.1.1 **Historical Local Imported Supplies**

As described in Section 4.7.1, the Nacimiento Water Project (NWP) regional raw water transmission facility delivers water from Lake Nacimiento to communities in San Luis Obispo County, including AMWC, TCSD, and the city of Paso Robles. TCSD has an allocation of 406 acre-feet per year (AFY) of NWP water and began taking deliveries in 2011. A total of 74 acre-feet (AF) was taken by TCSD in 2011, and constitutes the only NWP deliveries in the historical period. AMWC and the city of Paso Robles began taking deliveries in 2012 and 2013, respectively (these deliveries will be discussed further in Section 6.4 - Current Water Budget). Within the Basin, all three municipal purveyors utilize their imported NWP water to recharge the Basin via percolation ponds or direct discharge located in the Alluvium adjacent to the Salinas River[2]. Table 6-1 summarizes the annual average, minimum, and maximum values for the imported NWP water during the historical base period.

6.3.1.2 **Historical Local Supplies**

Local surface water supplies include surface water flows that enter the Basin from precipitation runoff within the watershed and Salinas River inflow to the Basin (including releases from the Salinas Reservoir). Table 6-1 summarizes the annual average, minimum, and maximum values for these inflows.

2 The city of Paso Robles utilizes their NWP allocation in two ways: treatment in a package water treatment plant, and applying directly to the ground surface on the alluvial gravels of the Salinas River floodplain in the north end of the Basin. The treated portion of NWP water is used outside of the Basin and is therefore not considered.

Table 6-1. Estimated Historical (1981-2011) Annual Surface Water Inflows to Basin

Surface Water Inflow Component	Average	Minimum[2]	Maximum[2]
Inflow to Basin including the Salinas River and Tributaries[1]	90,600	1,400	407,800
Imported (Nacimiento Water Project)	2	0	74
Total	90,600		

notes:

All values in acre-feet

[1] - Tributaries include Santa Margarita Creek, Paloma Creek, Atascadero Creek, Graves Creek, and Paso Robles Creek

[2] – Minimum and maximum values are not totaled because the values for each component may have occurred in different years.

The estimated average annual total inflow from these sources over the historical base period is about 90,600 AF. The largest component of this average inflow is releases and flow in the Salinas River. The large difference between the minimum and maximum inflows reflects the difference between dry and wet years in the Basin.

6.3.1.3 Historical Surface Water Outflows

The estimated annual average total surface water outflow leaving the Basin as flow in the Salinas River, and percolation into the groundwater system over the historical base period is summarized in Table 6-2.

Table 6-2. Estimated Historical (1981-2011) Annual Surface Water Outflows from Basin

Surface Water Outflow Component	Average	Minimum[1]	Maximum[1]
Salinas River Outflow from Basin	83,500	300	380,600
Streamflow Percolation	7,100	1,100	27,200
Nacimiento Water Project Percolation	2	0	74
Total	90,600		

notes:

All values in acre-feet

[1] – Minimum and maximum values are not totaled because the values for each component may have occurred in different years.

The estimated average annual total outflow from these sources over the historical base period is about 90,600 AF. The largest component of this average outflow is the Salinas River. The large difference between the minimum and maximum outflows reflects the difference between dry and wet years in the Basin.

6.3.1.4 Historical Surface Water Budget

Figure 6-2 summarizes the historical surface water budget for the Basin.

Figure 6-2. Historical (1981-2011) Surface Water Inflows and Outflows

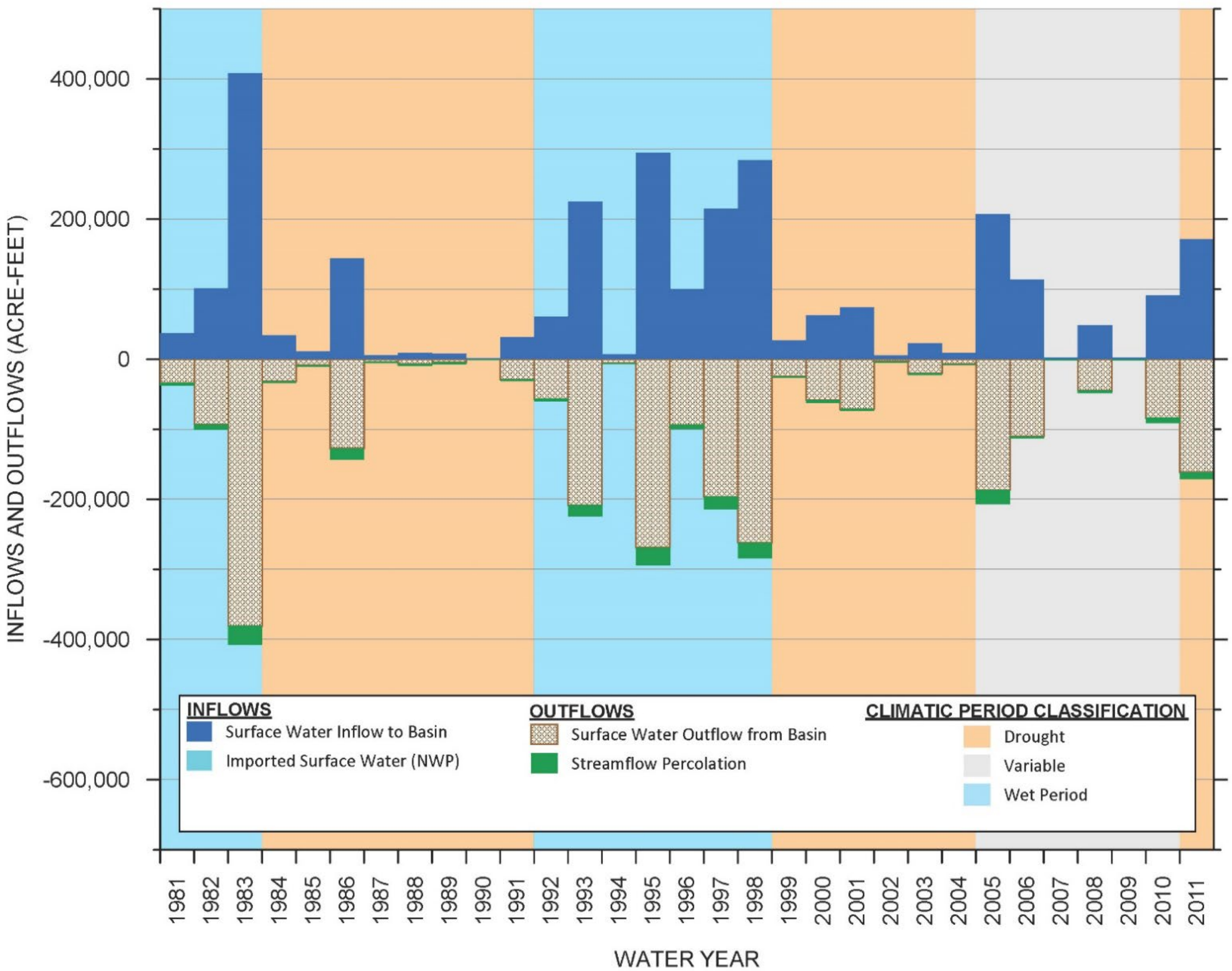


Figure 6-2 shows the strong correlation between precipitation and streamflow in the Basin. In wet periods, shown with a blue background, surface water inflows and outflows are large. In contrast, in dry periods, shown with an orange background, surface water inflows and outflows are small.

6.3.2 *Historical Groundwater Budget*

Groundwater, including production from both the Alluvial Aquifer (Salinas River underflow) and the Paso Robles Formation Aquifer, supplied virtually all of the water used in the Basin over the historical base period. The historical groundwater budget includes a summary of the estimated groundwater inflows, groundwater outflows, and change in groundwater in storage.

6.3.2.1 Historical Groundwater Inflows

Groundwater inflow components include streamflow percolation, agricultural irrigation return flow, deep percolation of direct precipitation, subsurface inflow into the Basin, imported surface water percolation, wastewater treatment plant pond percolation, and urban irrigation return flow. Estimated annual groundwater inflows for the historical base period are summarized in Table 6-3. Values reported in the table were estimated or derived from the GSP model using data sources reported in Table 6A-1 in Appendix 6A.

Table 6-3. Estimated Historical (1981-2011) Annual Groundwater Inflows to Basin

Groundwater Inflow Component[1]	Average	Minimum[2]	Maximum[2]
Streamflow Percolation	7,100	1,100	27,200
Agricultural Irrigation Return Flow	1,200	500	2,700
Deep Percolation of Direct Precipitation	3,700	100	13,000
Subsurface Inflow into Basin	2,300	0	5,400
Wastewater Pond Percolation	2,000	1,570	2,540
Nacimiento Water Project Percolation	2	0	74
Urban Irrigation Return Flow	1,200	100	2,800
Total	17,500		

notes:

All values in acre-feet

[1] - Percolation from septic systems is not directly accounted for because it is subtracted from the total estimated rural-domestic pumping to simulate a net rural-domestic pumping amount

[2] – Minimum and maximum values are not totaled because the values for each component may have occurred in different years.

For the historical base period, estimated total average groundwater inflow ranged from 5,700 AFY to 49,800 AFY, with an average annual inflow of 17,500 AF. The largest groundwater inflow component is streamflow percolation, which accounts for approximately 41 percent of the total annual average inflow. The large difference between the minimum and maximum inflows from streamflow percolation and direct precipitation reflect the variations in precipitation over the historical base period.

6.3.2.2 Historical Groundwater Outflows

Groundwater outflow components include total groundwater pumping from all water use sectors, subsurface flow out of the Basin, and riparian evapotranspiration. On occasion, the minimum subsurface outflows were negative during the historical base period. Estimated annual groundwater outflows for the historical base period are summarized in Table 6-4.

Table 6-4 Estimated Historical (1981-2011) Annual Groundwater Outflow from Basin

Groundwater Outflow Component	Average	Minimum[1]	Maximum[1]
Total Groundwater Pumping	15,300	11,900	20,400
Subsurface Flow Out of Basin	300	-500	1,400
Riparian Evapotranspiration	500	500	500
Total	16,100		

notes:
All values in acre-feet
[1] – Minimum and maximum values are not totaled because the values for each component may have occurred in different years.

The largest groundwater outflow component from the Basin is groundwater pumping. Estimated annual groundwater pumping by water use sector for the historical base period is summarized in Table 6-5.

Table 6-5 Estimated Historical (1981-2011) Annual Groundwater Pumping by Water Use Sector from Basin

Water Use Sector	Average	Minimum[1]	Maximum[1]
Agricultural	5,500	2,100	12,900
Municipal	8,900	4,900	12,000
Rural Domestic	300	200	500
Small Public Water Systems	600	600	700
Total	15,300		

notes:
All values in acre-feet
[1] – Minimum and maximum values are not totaled because the values for each component may have occurred in different years.

Municipal and agricultural pumping were the largest components of total groundwater pumping, accounting for about 58 percent and 36 percent of total pumping over the historical base period, respectively. In general, agricultural pumping decreased and municipal pumping increased over the historical base period. Rural-domestic, and small commercial pumping account for 2 percent and 4 percent, respectively, of total average annual pumping over the historical base period.

6.3.2.3 **Historical Groundwater Budget and Changes in Groundwater Storage**

Groundwater inflows and outflows for the historical base period are summarized on Figure 6-3 and tabulated in Appendix 6B. Figure 6-3 shows groundwater inflow and outflow components for every year of the historical period. Inflow components are graphed above the zero line and outflow components are graphed below the zero line. Groundwater outflow by pumping (green bars) includes pumping from all water use sectors (Table 6-5).

Figure 6-4 shows annual and cumulative change in groundwater storage during the historical base period. Annual increases in groundwater storage are graphed above the zero line and annual decreases in groundwater storage are graphed below the zero line. The red line shows the cumulative change in groundwater storage over the historical base period.

Figure 6-3. Historical (1981-2011) Groundwater Inflows and Outflows

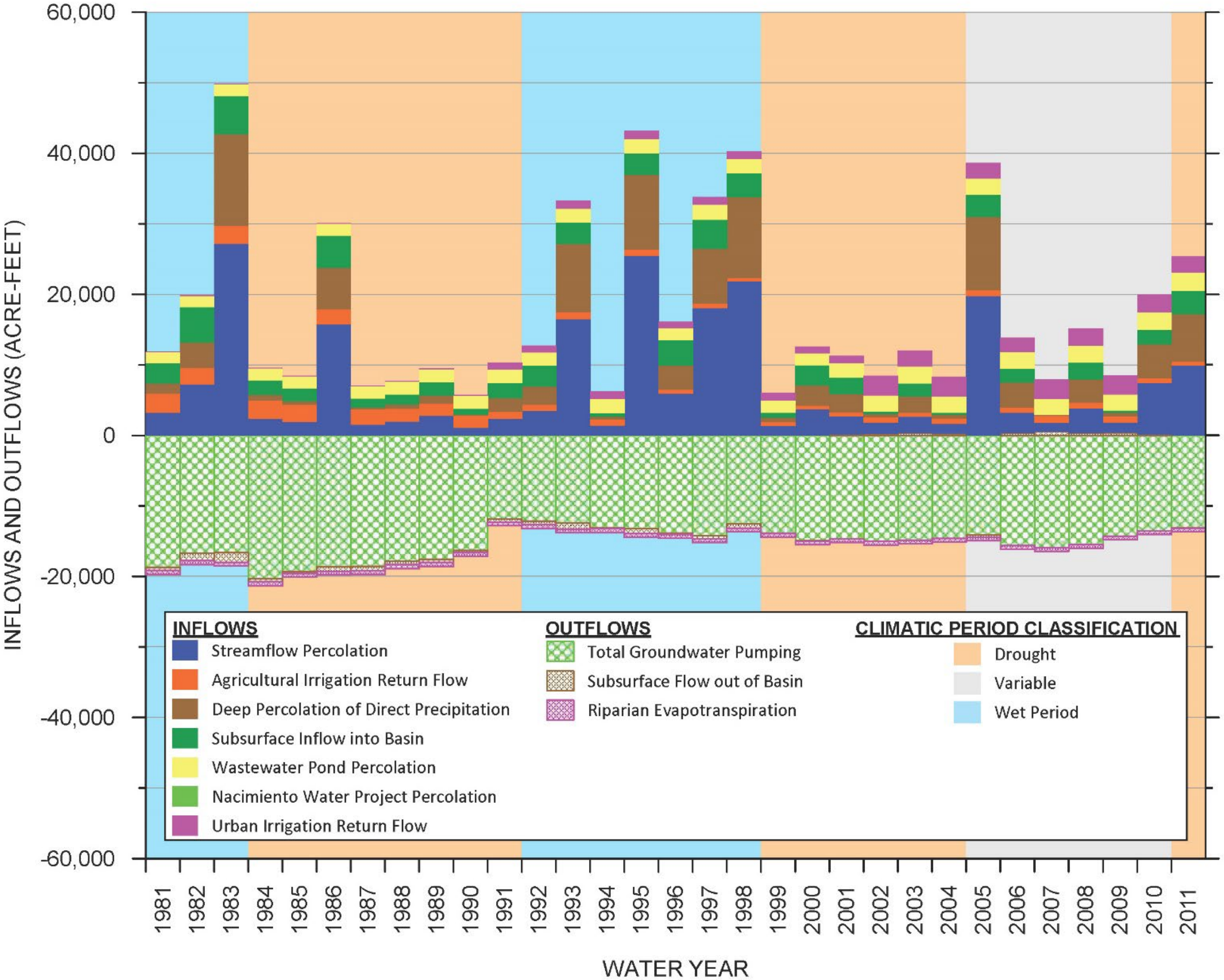
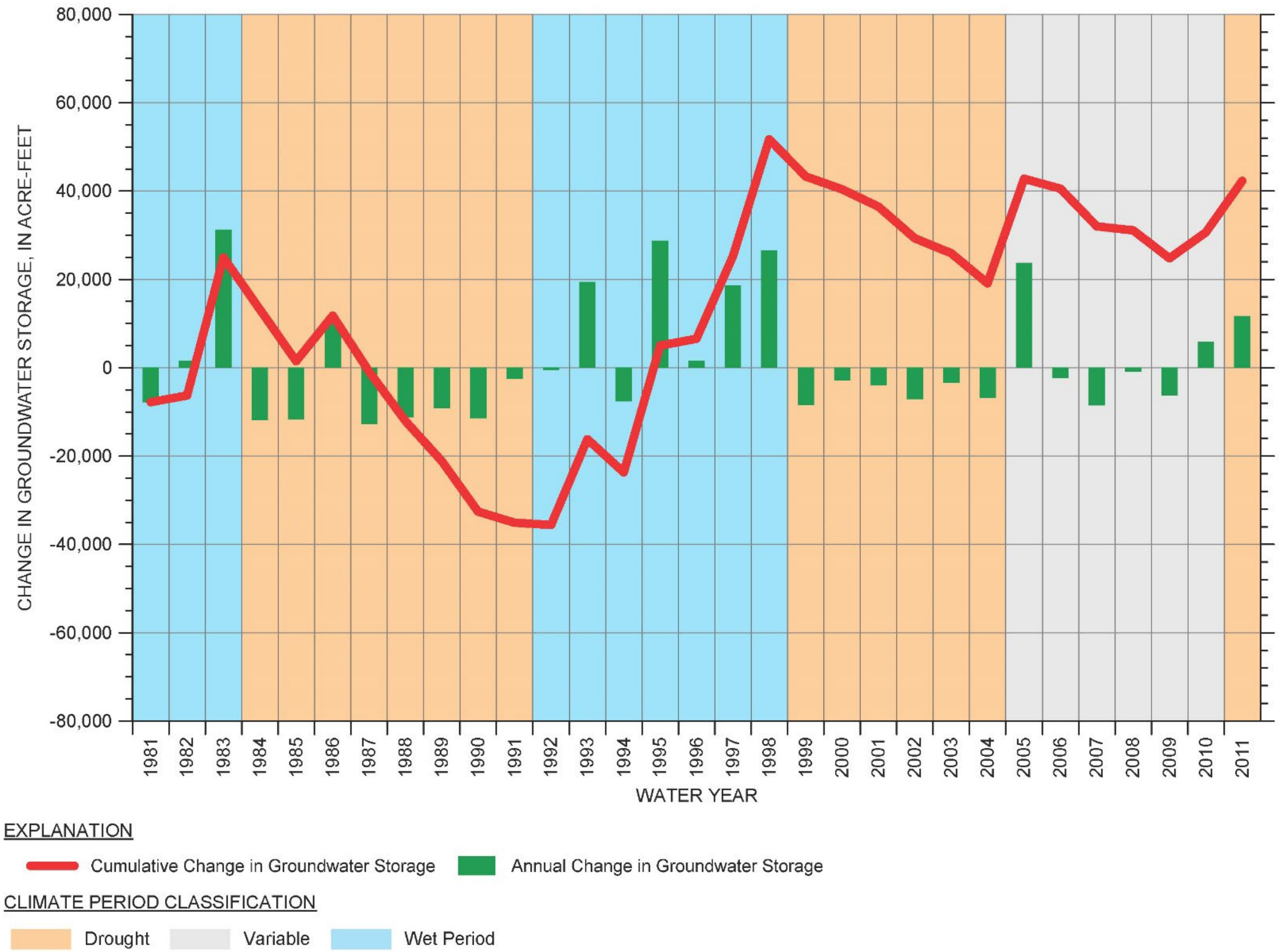


Figure 6-4. Historical (1981-2011) Annual and Cumulative Change in Groundwater Storage



The historical groundwater budget is strongly influenced by the amount of precipitation. During the historical base period, dry conditions prevailed from 1984 through 1991 and 1999 through 2004, as depicted by the orange areas on Figure 6-3 and Figure 6-4. During these dry periods, the amount of recharge and streamflow percolation was relatively low. The net result was a loss of groundwater from storage. In contrast, wet conditions prevailed in the early 1980s and 1992 through 1998, as shown by blue areas on Figure 6-3 and Figure 6-4, and one wet year in 2005. During these wet periods, the amount of recharge and streamflow percolation was relatively high. The net result was a gain of groundwater in storage. The period from 2006 through 2010 had generally alternating years of average precipitation. During this period, the amount of recharge and streamflow percolation was average and the amount of groundwater pumping was relatively high, compared to the prior 15 years. The net result was a loss of groundwater from storage.

The historical groundwater budget is also influenced by the amount of groundwater pumping. Over the historical base period, the total amount of groundwater pumping decreased in the early 1990s, corresponding with a period when irrigation of alfalfa and pasture acreage declined and irrigated vineyard acreage increased (Fugro, 2002). The transition from alfalfa and pasture to vineyard resulted in a net decrease in groundwater pumping because the irrigation demand per acre of vineyards is significantly less than the per-acre demand for alfalfa and pasture. This decrease in pumping contributed to the increase in groundwater in storage during the 1990s.

Over the 31-year historical base period, a net gain of groundwater storage of about 42,300 AF occurred. The average annual groundwater storage gain was approximately 1,400 AFY.

6.3.2.4 **Historical Water Balance of the Basin**

The computed long-term increase of groundwater in storage indicates that total groundwater inflow exceeded the total outflow in the Basin from 1981 through 2011. As summarized in Table 6-5, total groundwater pumping averaged approximately 15,300 AFY during the historical base period.

Section 354.18(b)(7) of the SGMA Regulations requires a quantification of sustainable yield for the Basin for the historical base period. Sustainable yield is the maximum quantity of groundwater, calculated over a base period representative of long-term conditions in the Basin and including any temporary surplus that can be withdrawn annually from a groundwater supply without causing an undesirable result. The historical safe yield was estimated by summing the estimated average groundwater storage increase of 1,400 AFY with the estimated total average amount of groundwater pumping of 15,300 AFY for the historical base period. This results in a historical safe yield of about 16,700 AFY. This estimated value reflects historical climate, hydrologic and water resource conditions and provides insight into the amount of groundwater pumping that could be sustained in the Basin to maintain a balance between groundwater inflows and outflows.

6.4 **Current Water Budget**

The SGMA Regulations require that the current surface water and groundwater budget be based on the most recent hydrology, water supply, water demand, and land use information. For the GSP, the period 2012 to 2016 was selected as the time period for the current water budget. In part, the 2012 to 2016 time period was selected because it corresponds with the current water budget period utilized in the Paso Robles Subbasin GSP and it is believed that not only is this time period representative of basin conditions, but the use of the Paso Robles Subbasin GSP model is the best available information and tool for groundwater sustainability planning purposes in the Atascadero Basin.

The current water budget period corresponds to a drought period when annual precipitation averaged about 60 percent of the historical average and streamflow percolation averaged about 19 percent of the historical average. As a result, the current water budget period represents an extreme drought condition in the Basin and is not representative of long-term Basin conditions needed for sustainability planning purposes. Estimates of the surface water and groundwater inflow and outflow, and changes in storage for the current water budget period are provided below.

6.4.1 *Current Surface Water Budget*

The current surface water budget quantifies important sources of surface water. Similar to the historical surface water budget, the current surface water budget includes two surface water source types: local imported supplies and local supplies.

6.4.1.1 Current Local Imported Supplies

Imported surface water from the NWP was utilized by AMWC, TCSD, and the city of Paso Robles to recharge the Basin via percolation in the Alluvium adjacent to the Salinas River during the current water budget period. In addition to TCSD, which began taking NWP water during the historical based period (see Section 6.3.1.1), AMWC and the city of Paso Robles began taking deliveries of NWP water in 2012 and 2013, respectively. Utilization of NWP water peaked in 2015 at 4,792 AF during the height of the latest drought, providing recharge to the Basin. Table 6-6 summarizes the annual average, minimum, and maximum values for the imported NWP water during the current water budget period.

6.4.1.2 Current Local Supplies

Local surface water supplies include surface water flows that enter the Basin from precipitation runoff within the watershed and Salinas River inflow to the Basin (including releases from the Salinas Reservoir), Table 6-6 summarizes the annual average, minimum, and maximum values for these inflows.

Table 6-6. Estimated Current (2012-2016) Annual Surface Water Inflows to Basin

Surface Water Inflow Component	Average	Minimum[2]	Maximum[2]
Inflow to Basin including the Salinas River and Tributaries[1]	5,600	1,300	9,000
Imported (Nacimiento Water Project)	2,158	731	4,792
Total	7,800		

notes:

All values in acre-feet

[1] - Tributaries include Santa Margarita Creek, Paloma Creek, Atascadero Creek, Graves Creek, and Paso Robles Creek

[2] – Minimum and maximum values are not totaled because the values for each component may have occurred in different years.

The estimated average total inflow from both precipitation runoff and reservoir releases over the current water budget period was approximately 7,800 AFY, or about 9 percent of the average annual 90,600 AFY inflow during the historical base period. The substantial reduction in surface water inflows reflects the drought conditions that prevailed during the current water budget period.

6.4.1.3 Current Surface Water Outflows

The estimated annual average, minimum, and maximum surface water outflow leaving the Basin as flow in the Salinas River and percolation into the groundwater system over the current base period is summarized in Table 6-7. Reductions in surface water outflow for the current water budget period were similar to those reported above for the surface water inflows.

Table 6-7. Estimated Current (2012-2016) Annual Surface Water Outflows from Basin

Surface Water Outflow Component	Average	Minimum[1]	Maximum[1]
Salinas River Outflow from Basin	4,200	100	7,600
Streamflow Percolation	1,400	1,200	1,500
Nacimiento Water Project Percolation	2,158	731	4,792
Total	7,800		

notes:

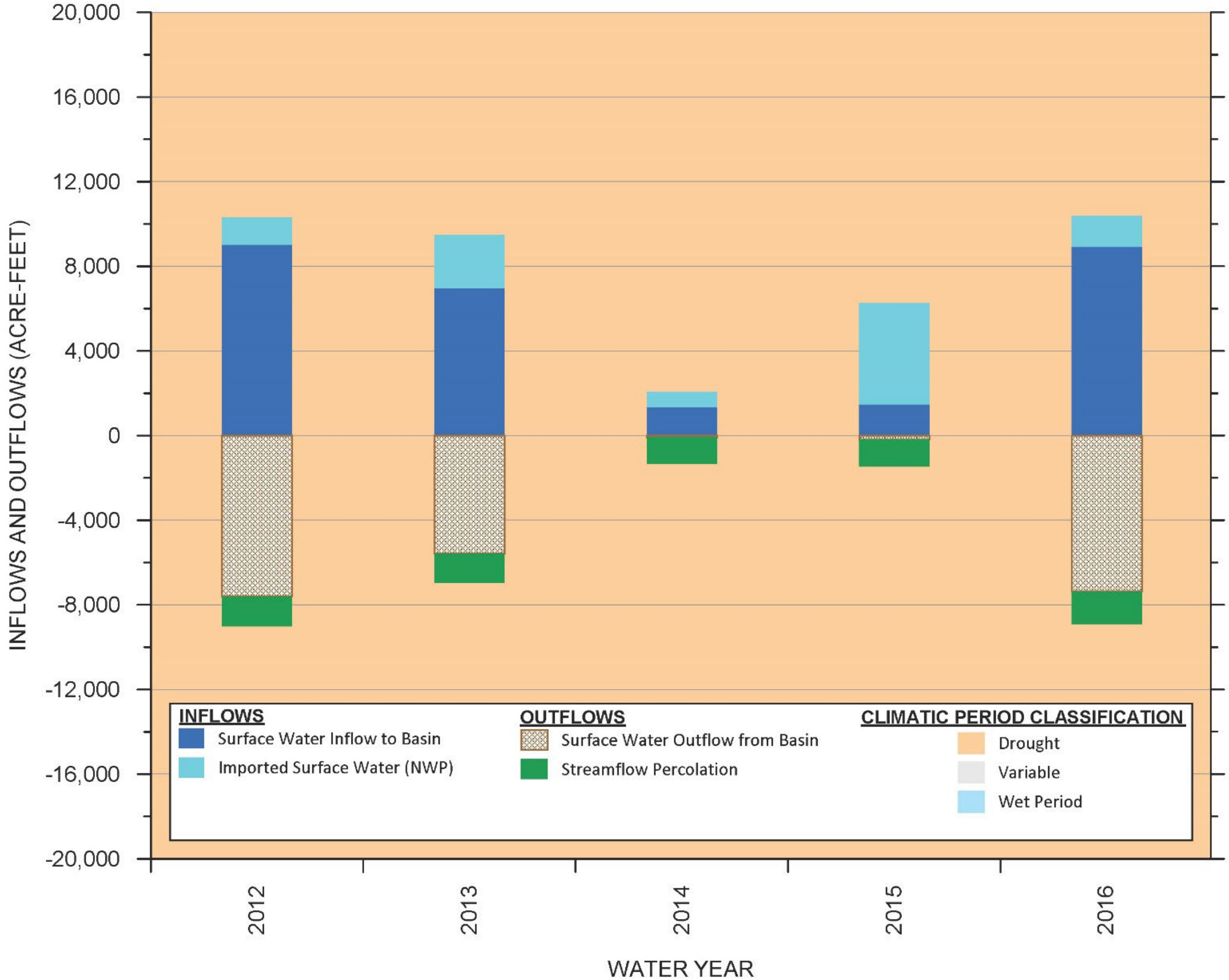
All values in acre-feet

[1] – Minimum and maximum values are not totaled because the values for each component may have occurred in different years.

6.4.1.4 Current Surface Water Budget

Figure 6-5 summarizes the current surface water budget for the Basin. Figure 6-5 shows the effects of the drought conditions that prevailed during the period 2012 through 2016. During this period, precipitation was well below average, which resulted in very little surface water flow.

Figure 6-5. Current (2012 – 2016) Surface Water Inflows and Outflows



6.4.2 *Current Groundwater Budget*

Groundwater supplied most of the water used in the basin during the current water budget period. The current water budget includes a summary of the estimated groundwater inflows, groundwater outflows, and change in groundwater in storage.

6.4.2.1 **Current Groundwater Inflows**

Groundwater inflow components include streamflow percolation, agricultural irrigation return flows, deep percolation of direct precipitation, subsurface inflow into the Basin, imported surface water percolation, wastewater pond percolation, and urban irrigation return flow. Estimated annual groundwater inflows for the current water budget period are summarized in Table 6-8.

Table 6-8. Estimated Current (2012-2016) Annual Groundwater Inflows to Basin

Groundwater Inflow Component[1]	Average	Minimum[2]	Maximum[2]
Streamflow Percolation	1,400	1,200	1,500
Agricultural Irrigation Return Flow	1,000	700	1,200
Deep Percolation of Direct Precipitation	600	300	1,400
Subsurface Inflow into Basin	400	0	1,200
Wastewater Pond Percolation	2,520	2,460	2,570
Nacimiento Water Project Percolation	2,158	731	4,792
Urban Irrigation Return Flow	2,700	2,400	2,900
Total	10,800		

notes:

All values in acre-feet

[1] - Percolation from septic systems is not directly accounted for because it is subtracted from the total estimated rural-domestic pumping to simulate a net rural-domestic pumping amount

[2] – Minimum and maximum values are not totaled because the values for each component may have occurred in different years.

For the current water budget period, estimated total average groundwater inflow ranged from 8,900 AFY to 13,000 AFY, with an average inflow of 10,800 AFY. Notable observations from the summary of groundwater inflows for the current water budget period included:

- Average total inflow during the current water budget period was about 62 percent of the historical base period.
- Unlike the historical base period, when the largest inflow component was streamflow percolation, the largest groundwater inflow component for the current water budget is agricultural and urban irrigation return flows, which together account for approximately 34 percent of the total average inflow.
- The relatively small difference between the minimum and maximum inflows reflects the drought condition that prevailed during the current water budget period, when precipitation and runoff were continuously low.

- Total annual average streamflow percolation in the current water budget period was approximately 20 percent of the streamflow percolation in the historical base period. This reflects the very low streamflows during the drought. The low streamflows had a significant impact on the groundwater basin because streamflow percolation was the most significant source of groundwater recharge during the historical period.
- Total annual average recharge from direct precipitation for the current water budget period was about 16 percent of the recharge from direct precipitation for the historical base period.

6.4.2.2 Current Groundwater Outflows

Groundwater outflow components include total groundwater pumping from all water use sectors and riparian evapotranspiration. Estimated annual groundwater outflows for the current water budget period are summarized in Table 6-9.

Table 6-9. Estimated Current (2012-2016) Annual Groundwater Outflow from Basin

Groundwater Outflow Component	Average	Minimum[1]	Maximum[1]
Total Groundwater Pumping	12,900	11,400	14,500
Subsurface Flow Out of Basin	-200	-300	-100
Riparian Evapotranspiration	500	500	500
Total	13,200		

notes:
All values in acre-feet
[1] – Minimum and maximum values are not totaled because the values for each component may have occurred in different years.

For the current water budget period, estimated total average groundwater outflows ranged from 11,800 AFY to 14,700 AFY, with an average annual outflow of 13,200 AF. A notable observation from a comparison of the historical (Table 6-4) and current groundwater outflows is:

- Total annual average groundwater pumping was about 16 percent lower during the current water budget period.

The largest groundwater outflow component from the Basin in the current water budget period is pumping. Estimated annual groundwater pumping by water use sector for the current water budget period is summarized in Table 6-10.

Table 6-10. Estimated Current (2012-2016) Annual Groundwater Pumping by Water Use Sector from Basin

Water Use Sector	Average	Minimum[1]	Maximum[1]
Agricultural	2,600	2,200	3,100
Municipal	9,200	7,800	10,800
Rural Domestic	500	500	500
Small Public Water Systems	600	600	600
Total	12,900		

notes:
All values in acre-feet
[1] – Minimum and maximum values are not totaled because the values for each component may have occurred in different years.

For the current water budget period, estimated total average groundwater pumping ranged from 11,400 AFY to 14,500 AFY, with an average pumping of 12,900 AFY. Municipal pumping was the largest component of total groundwater pumping and accounts for about 72 percent of total pumping during the current water budget period. Agricultural, rural-domestic, and small commercial pumping account for 20 percent, 4 percent, and 5 percent, respectively, of total average pumping during the current water budget period.

Notable observations from a comparison of the historical (Table 6-5) and current total annual average groundwater pumping include:

- Total annual average agricultural groundwater pumping was about 53 percent less during the current water budget period when compared to the historical period (decrease of 2,900 AFY).
- Total annual average municipal groundwater pumping was about 4 percent higher during the current water budget period when compared to the historical period (increase of 340 AFY).

6.4.2.3 Current Groundwater Budget and Change in Groundwater Storage

Groundwater inflows and outflows for the current base period are summarized on Figure 6-6. This graph shows inflow and outflow components for every year of the current water budget period. Inflow components are graphed above the zero line and outflow components are graphed below the zero line. Groundwater outflow by pumping (green crosshatched bars) includes pumping from all water use sectors (Table 6-10).

Figure 6-7 shows annual and cumulative change in groundwater storage during the current water budget period. Annual decreases in groundwater storage are graphed below the zero line. The red line shows the cumulative change in groundwater storage over the historical base period.

Figure 6-6. Current (2012-2016) Groundwater Inflows and Outflows

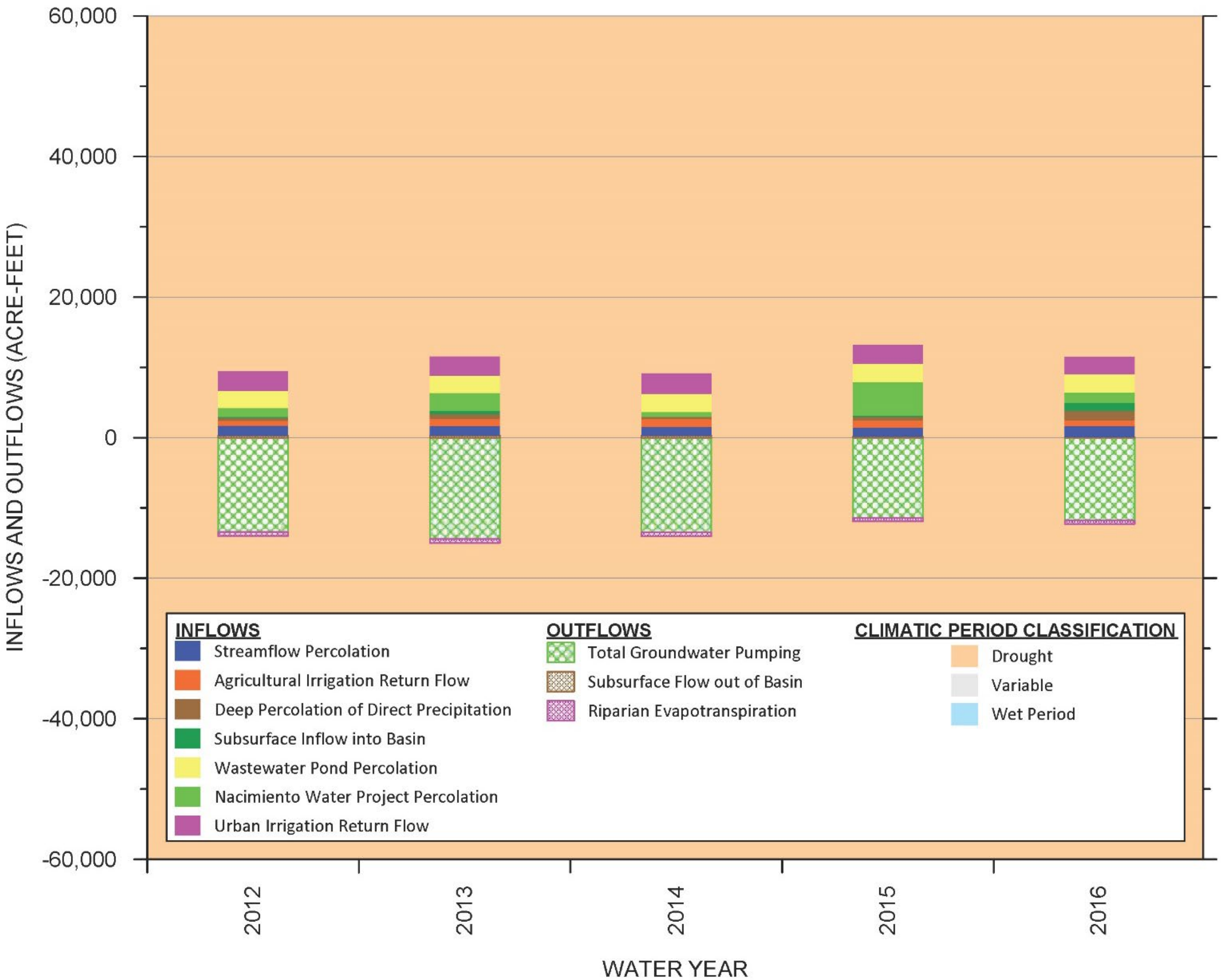
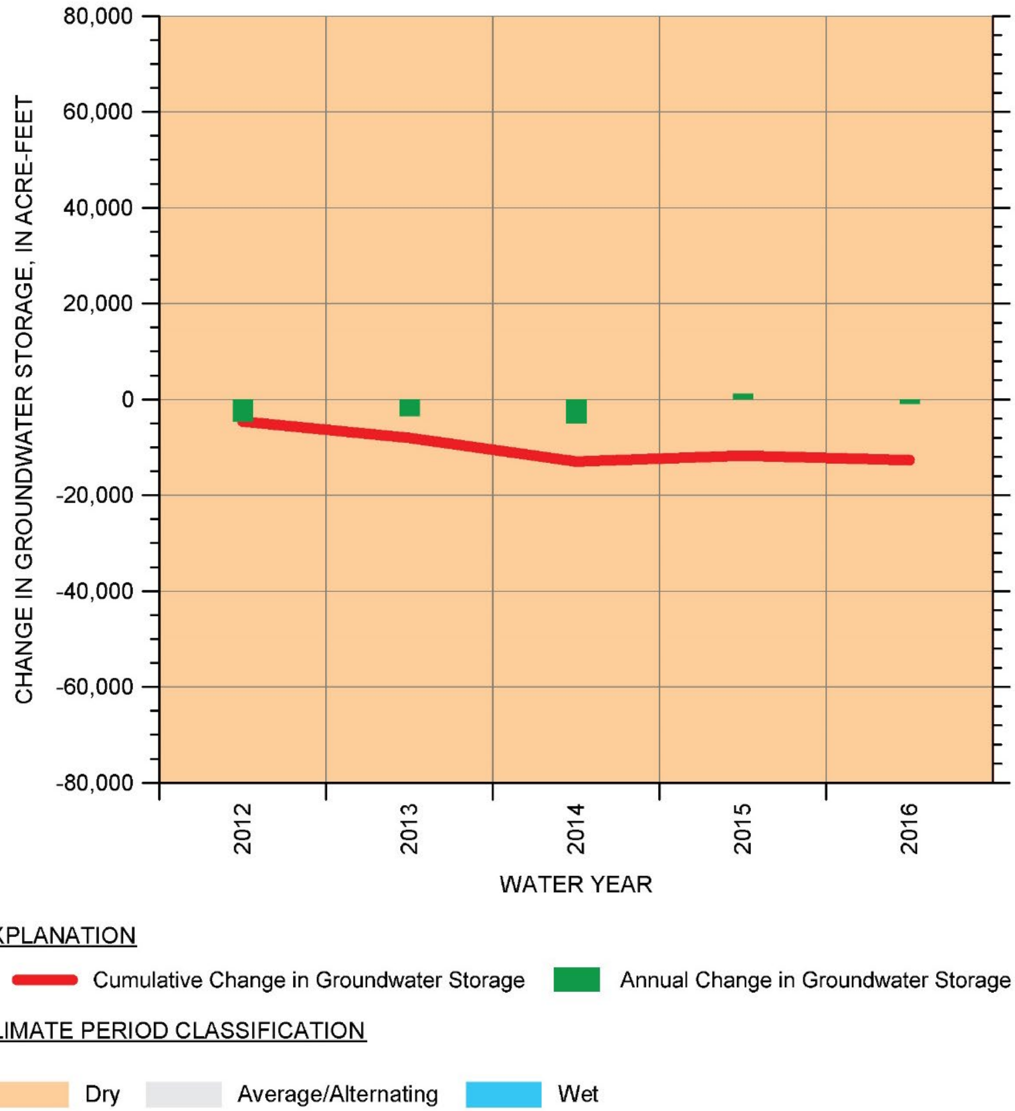


Figure 6-7. Current (2012-2016) Annual and Cumulative Change in Groundwater Storage



The current groundwater budget is strongly influenced by the drought. During the current water budget period, the amounts of streamflow percolation and percolation of direct precipitation were very low and the average amount of total pumping was only slightly less than the historical water budget period. Percolation of imported surface water from the NWP, which had barely come online in the final year of the historical water budget period, played a significant role in mitigating the effects of the recent drought. Over the five-year current water budget period, an estimated net loss of groundwater in storage of about 12,600 AF occurred (Figure 6-7). The annual average groundwater storage loss, or the difference between outflow and inflow to the Basin, was approximately 2,500 AFY.

6.4.2.4 Current Water Balance

The short-term depletion of groundwater in storage indicates that total groundwater outflows exceeded the total inflows over the current water budget period. As summarized in Table 6-9, total groundwater pumping averaged approximately 12,900 AFY during the current period. A quantification of the safe yield for the Basin during the current time period is be estimated by subtracting the average groundwater storage deficit (2,500 AFY) from the total average amount of groundwater pumping (12,900 AFY) to yield about 10,400 AFY. Due to the drought conditions, the current water budget period is not appropriate for long-term sustainability planning.

6.5 Future Water Budget

SGMA Regulations require the development of a future surface water and groundwater budget to estimate future baseline conditions of supply, demand, and aquifer response to GSP implementation. The future water budget provides a baseline against which management actions will be evaluated over the GSP implementation period from 2022 to 2042. Future water budgets were developed using the GSP model.

In accordance with Section 354.18 (c)(3)(A) of the SGMA Regulations, the future water budget should be based on 50 years of historical precipitation, evapotranspiration, and streamflow information. The GSP model includes only 36 years of historical precipitation, evapotranspiration, and streamflow data. Therefore, the future water budget is based on 36 years of historical data rather than 50 years of historical data. It is believed that this time period is representative and is the best available information for groundwater sustainability planning purposes.

6.5.1 *Assumptions Used in Future Water Budget Development*

Assumptions about future groundwater supplies and demands are described in the following subsections.

Future water budgets were developed using the GSP model. During the update process for the GSP model, all model components (e.g., groundwater pumping) of the entire original 2016 GSSI model area were updated, including components within Monterey County and the Paso Robles

Subbasin. However, information provided for the future water budget only pertains to the Atascadero Basin (Figure 1-1), thus do not include areas within Monterey County or the Paso Robles Subbasin.

6.5.1.1 Future Municipal Water Demand and Wastewater Discharge Assumptions

Future municipal water demands and wastewater discharge were estimated for AMWC, TCSD, and the city of Paso Robles based on the following available planning documents:

- Atascadero Mutual Water Company 2015 Urban Water Management Plan (UWMP) (MKN & Associates, 2016),
- Templeton Community Services District Water Supply Buffer Model 2019 Update (TCSD, 2019),
- Paso Robles 2015 Urban Water Management Plan (Todd Groundwater, 2016)

Portions of AMWC's, TCSD's, and the city of Paso Robles' future groundwater demand[3] will be offset by imported NWP water. Total municipal demand in the Basin is projected to increase from about 10,500 AFY in 2020 to about 12,900 AFY in 2042.

Discharge of treated wastewater to the Salinas River provides a source of recharge to the Alluvial Aquifer. Rates of future wastewater discharge were estimated as a percentage of total water demand based on the planning documents listed above for AMWC and TCSD[4]. Wastewater discharge as a percentage of water demand was calculated separately for each water provider. Total wastewater discharge in the Basin is projected to increase from about 2,300 AFY in 2020 to about 3,100 AFY in 2042.

Future municipal water demands and/or wastewater discharge volumes will be adjusted during the implementation of the GSP should they be found to differ from the volumes used in the GSP model.

6.5.1.2 Future Agricultural and other Non-Municipal Water Demand Assumptions

In accordance with Section 354.18 (c)(3)(B) of the SGMA Regulations, the most recently available land use (in this case, crop acreage) and crop coefficient information should be used as the baseline condition for estimating future agricultural irrigation water demand. For the GSP, the most recent crop acreage data was obtained from the office of the San Luis Obispo County Agricultural Commissioner. To account for irrigation efficiency in the future water budget, the reported crop coefficient information from GSSI (GSSI, 2016) was used.

Projections for agricultural irrigation water demand are not available. Agricultural water demand was assumed to increase at a 1 percent annual growth rate. This assumed growth rate is

[3] Note that the city of Paso Robles operates production wells in both the Basin and the Paso Robles Subbasin. Only the portion produced from the Basin is included here.

[4] The city of Paso Robles wastewater discharge occurs outside the Basin (within the Paso Robles Subbasin) and is therefore not included.

considered a conservative estimate. Total agricultural groundwater demand in the Basin is projected to increase from about 2,800 AFY in 2020 to about 3,400 AFY in 2042.

Projections for rural domestic wells and smaller commercial groundwater users, were also not available. Water demand for these users was assumed to increase at a 1 percent annual growth rate. Total rural domestic and smaller commercial users groundwater demand in the Basin is projected to increase from about 1,300 AFY in 2020 to about 1,600 AFY in 2042.

Future agricultural and/or other non-municipal water demands will be adjusted during the implementation of the GSP should they be found to differ from the volumes used in the GSP model.

6.5.1.3 Future Climate Assumptions

The SGMA Regulations require incorporating future climate estimates into the future water budget. To meet this requirement, DWR developed an approach for incorporating reasonably expected, spatially gridded changes to monthly precipitation and reference evapotranspiration (ETo) (DWR, 2018). The approach for addressing future climate change developed by DWR was used in the future water budget modeling for the Basin. The changes are presented as separate monthly change factors for both precipitation and ETo, and are intended to be applied to historical time series within the climatological base period through 2011. Specifically, precipitation and ETo change factors were applied to historical climate data for the period 1981 to 2011 for modeling the future water budget.

DWR provides several sets of change factors representing potential climate conditions in 2030 and 2070. DWR recommends using the 2030 change factors to evaluate conditions over the GSP implementation period (DWR, 2018). Consistent with DWR recommendations, datasets of monthly 2030 change factors for the Atascadero area were applied to precipitation and ETo data from the historical base period to develop monthly time series of precipitation and ETo, which were then used to simulate future hydrology conditions.

6.5.2 *Modifications to Modeling Platform to Simulate Future Conditions*

The existing modeling platform was modified to simulate future conditions, and the results of these simulations are used to develop the future water budget

6.5.2.1 Modification to Soil Water Balance Model

The soil water balance model operates on a daily time scale and tracks daily variations in soil water storage for different agricultural areas in the model domain. For consistency with the monthly climate change factors provided by DWR, the daily model was used to develop monthly soil water balance calculations. These calculations compute irrigation demand as the residual crop evapotranspiration demand unsatisfied by effective precipitation.

These calculations use monthly precipitation and ETo, rescaled by the monthly climate change factors provided by DWR, and the same monthly crop coefficients used in the historical water budget analysis. Empirical relationships were developed to account for soil moisture carryover from the winter into the spring based on results from the daily soil water balance model.

Monthly applied irrigation water was determined over the future base period from computed monthly crop demand and the crop-specific irrigation efficiencies. The future agricultural irrigation water demand assumptions described above in Section 6.5.1.2 was incorporated into this analysis. Agricultural irrigation return flow is then computed as the difference between the applied irrigation water and the crop demand. Results were then averaged to provide average monthly rates of applied irrigation water and irrigation return flow that would be expected under future climate conditions.

6.5.2.2 Modifications to the Watershed Model

The watershed model operates on a daily time scale and simulates streamflow and infiltration of direct precipitation. The watershed model was modified to account for climate change by rescaling daily precipitation and ETo with the monthly climate change factors provided by DWR. The watershed model was then re-run using the modified precipitation and ETo values.

Results from the modified historical base period simulation were then averaged to provide average monthly rates of infiltration of direct precipitation and streamflow under future climate conditions.

6.5.2.3 Modifications to the Groundwater Model

The groundwater model operates at a semi-annual time scale, with stress periods representing six-month periods. The groundwater model was extended and modified to simulate the period 2020 to 2042. Starting groundwater levels for the future simulation were set to groundwater levels at the end of Water Year (WY) 2016, extracted from the updated groundwater model.

Future groundwater recharge components were computed using the modified soil water balance model and watershed model, as described above. Future streamflow generated both inside and outside the Basin was computed using the modified watershed model.

Future groundwater recharge and streamflow are specified in the groundwater model as repeating average time-series, based on average monthly calculation of excess irrigation water, recharge of direct precipitation, and streamflow. This approach was adopted to simplify the future water budget and allow reporting of average future conditions accounting for climate change. Future pumping and wastewater return flows are the only inputs to the groundwater model that exhibit a long-term trend over the implementation period.

6.5.3 *Projected Future Water Budget*

Future surface water and groundwater budgets were projected.

6.5.3.1 Future Surface Water Budget

The future surface water budget includes average inflows from local imported supplies, average inflows from local supplies, average stream outflows, and average stream percolation to groundwater. Table 6-11 and Table 6-12 summarize the average components of the projected surface water budget.

Table 6-11. Projected Future Annual Surface Water Inflows to Basin

Surface Water Inflow Component	Average
Inflow to Basin including the Salinas River and Tributaries[1]	96,400
Imported (Nacimiento Water Project)	2,600
Total	99,000

notes:

All values in acre-feet

[1] - Tributaries include Santa Margarita Creek, Paloma Creek, Atascadero Creek, Graves Creek, and Paso Robles Creek

Table 6-12. Projected Future Annual Surface Water Outflows from Basin

Surface Water Outflow Component	Average
Salinas River Outflow from Basin	92,000
Streamflow Percolation	4,400
Nacimiento Water Project Percolation	2,600
Total	99,000

notes:

All values in acre-feet

6.5.3.2 Future Groundwater Budget

Projected groundwater budget components are computed using the modified groundwater flow model to simulate average conditions over the implementation period. Table 6-13 summarizes projected annual groundwater inflows. In contrast to the historical groundwater budget, which accounted for month-to-month variability, the projected groundwater budget is based on average monthly inflows. Therefore, variability in simulated groundwater budget components is minor, and minimum and maximum values are not included in Table 6-13.

Table 6-13. Projected Future Annual Groundwater Inflows to Basin

Groundwater Inflow Component[1]	Average
Streamflow Percolation	4,400
Agricultural Irrigation Return Flow	900
Deep Percolation of Direct Precipitation	3,700
Subsurface Inflow into Basin	1,600
Wastewater Pond Percolation	2,800
Nacimiento Water Project Percolation	2,600
Urban Irrigation Return Flow	1,900
Total	18,000

notes:

All values in acre-feet

1 - Percolation from septic systems is not directly accounted for because it is subtracted from the total estimated rural-domestic pumping to simulate a net rural-domestic pumping amount

The total average annual groundwater inflow is 500 AF greater during the future period than during the historical base period. Although, annual stream percolation is projected to be 2,700 AF less during the future period than during the historical base period, the increased imported surface water percolation nearly makes up for it. Lesser increases in urban irrigation return flow and wastewater percolation offset minor reductions in agricultural irrigation return flow and subsurface inflow between the historical base period and the projected future period. Reduction in agricultural irrigation return flow is due partly to changes in historical cropping patterns and partly to improvements in vineyard irrigation efficiency.

Table 6-14 summarizes projected annual groundwater outflows.

Table 6-14. Projected Future Annual Groundwater Outflow from Basin

Groundwater Outflow Component	Average
Total Groundwater Pumping	16,400
Subsurface Flow Out of Basin	200
Riparian Evapotranspiration	600
Total	17,200

notes:

All values in acre-feet

The total average annual groundwater outflow is estimated to be 1,100 AF greater during the future period than during the historical base period. Future total annual groundwater pumping is projected to increase by about 1,100 AF compared to the historical base period.

6.5.3.3 Future Safe Yield

The projected future groundwater budget shows the Basin to be generally in balance, with projected groundwater inflows of about 18,000 AFY and projected groundwater outflows of about 17,200 AFY. The projected future surplus indicates an average annual increase in groundwater in storage of 800 AFY. A calculated annual volume for the projected future safe yield of the Basin was estimated by adding the average groundwater storage surplus of 800 AFY to the total projected future average amount of groundwater pumping of 16,400 AFY, therefore the future safe yield for the Basin is estimated to be approximately 17,200 AFY.

The estimated future safe yield of 17,200 AFY is 500 AFY greater than the estimated safe yield for the historic base period. This close comparison of safe yield values between the two periods indicates that projected future climate change is not expected to have a substantial impact on the safe yield.

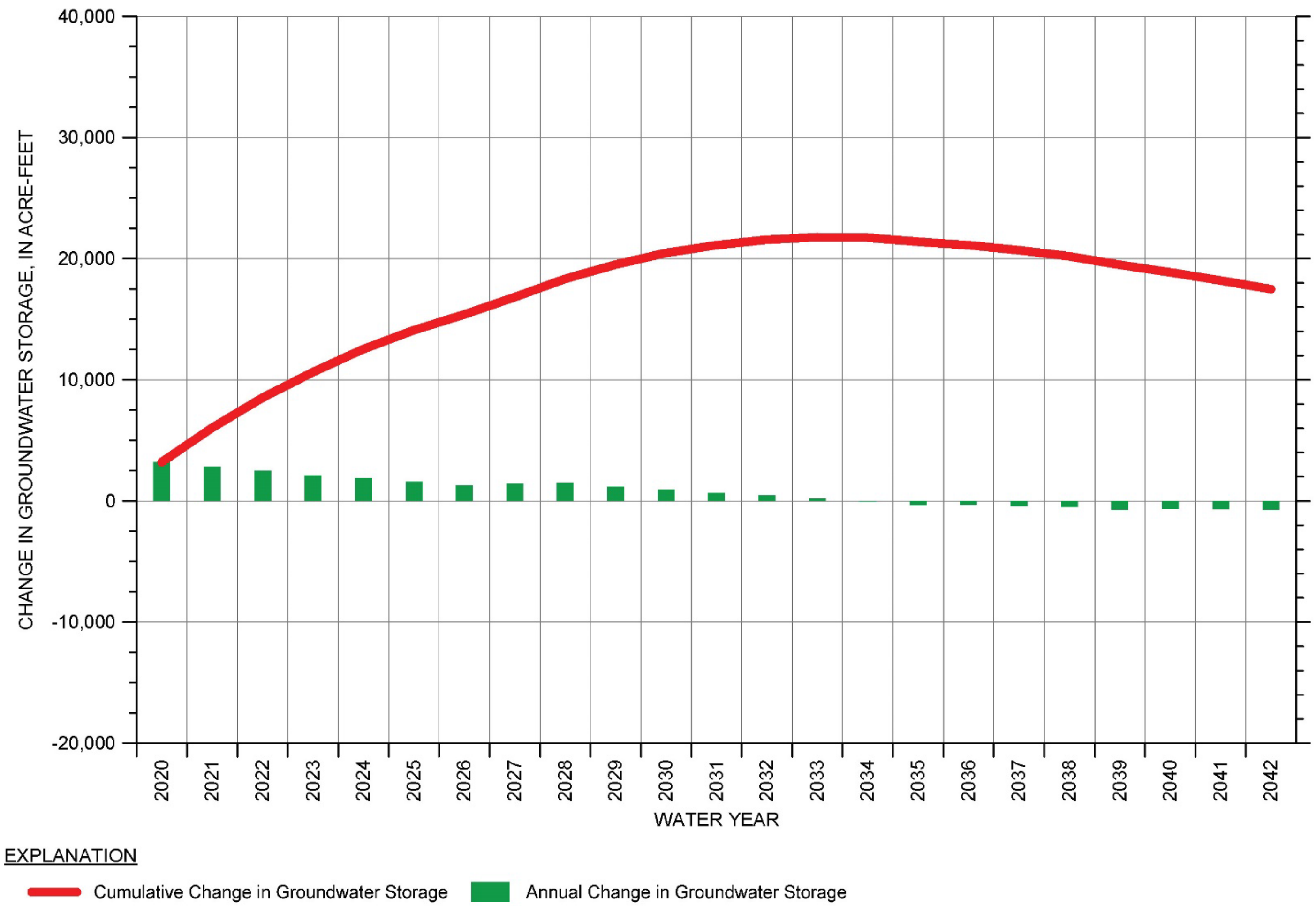
The primary reason that the average safe yield increases in the future compared to the historical period, even coupled with the assumed climate change modifiers and increased projected pumping from all users, is the added beneficial component of increased future use of the NWP water. However, as demonstrated by the projected cumulative change in storage curve presented on Figure 6-8, the benefits of increased NWP utilization is expected to be overtaken by the assumed 1 percent annually increasing pumping demands by the year 2034.

The cumulative change of groundwater in storage is projected to remain well above zero by the year 2042, however its downward trend in later years suggests the possibility of a groundwater storage deficit in the distant future (well beyond 2042) without further mitigation measures.

It is likely that the 1 percent annual growth rate assumption for non-municipal pumping is overly conservative. Adjusting this to a lower or a flat growth rate at some future date would be one such potential mitigation measure. Regardless, the imported NWP supply augments the natural basin recharge components and provides the municipal purveyors a water resource management tool that allows for effective management of the Basin for the foreseeable future.

The calculated safe yield of the Basin is a reasonable estimate of the long-term pumping that can be maintained without a long-term lowering of groundwater levels. The sustainable yield of the Basin, which will be estimated after an assessment of the sustainable management criteria and identification of potential undesirable results, will be estimated later. Sustainable yield looks to the presence or absence of undesirable results, not strictly inflows and outflows. The definitive sustainable yield can only be determined once undesirable results have been shown to have not occurred. The sustainable yield estimate may be revised in the future as new data become available during GSP implementation.

Figure 6-8. Projected Future Cumulative Change in Groundwater Storage



6.6 References

California Department of Water Resources (DWR) (2016a), Best Management Practices for the Sustainable Management of Groundwater – Water Budget BMP. December, 2016.

DWR (2016b), California's Groundwater: Bulletin 118 Interim Update.

DWR (2018), Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development. July 2018.

Fugro West, Inc., and Cleath and Associates (Fugro) (2002), Final Report, Paso Robles Groundwater Basin Study: unpublished consultant report prepared for the County of San Luis Obispo Public Works Department, August 2002.

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GSSI (2016), Refinement of the Paso Robles Groundwater Basin Model and Results of Supplemental Water Supply Options Predictive Analysis, December 2016.

MKN & Associates, (2016), 2015 Urban Water Management Plan for the Atascadero Mutual Water Company, Draft for Public Review: May 2016.

Montgomery and Associates (M&A) (2020), Paso Robles Subbasin Groundwater Sustainability Plan. Prepared for the Paso Robles Subbasin Cooperative Committee and the Groundwater Sustainability Agencies. November 13, 2019.

Templeton Community Services District (TCSD) (2019), Water Supply Buffer Model 2019 Update.

Todd Groundwater (Todd) (2016), City of Paso Robles 2015 Urban Water Management Plan, Final: July 2016.

Appendix 6A: Model Update and Modifications

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Tables

Figures

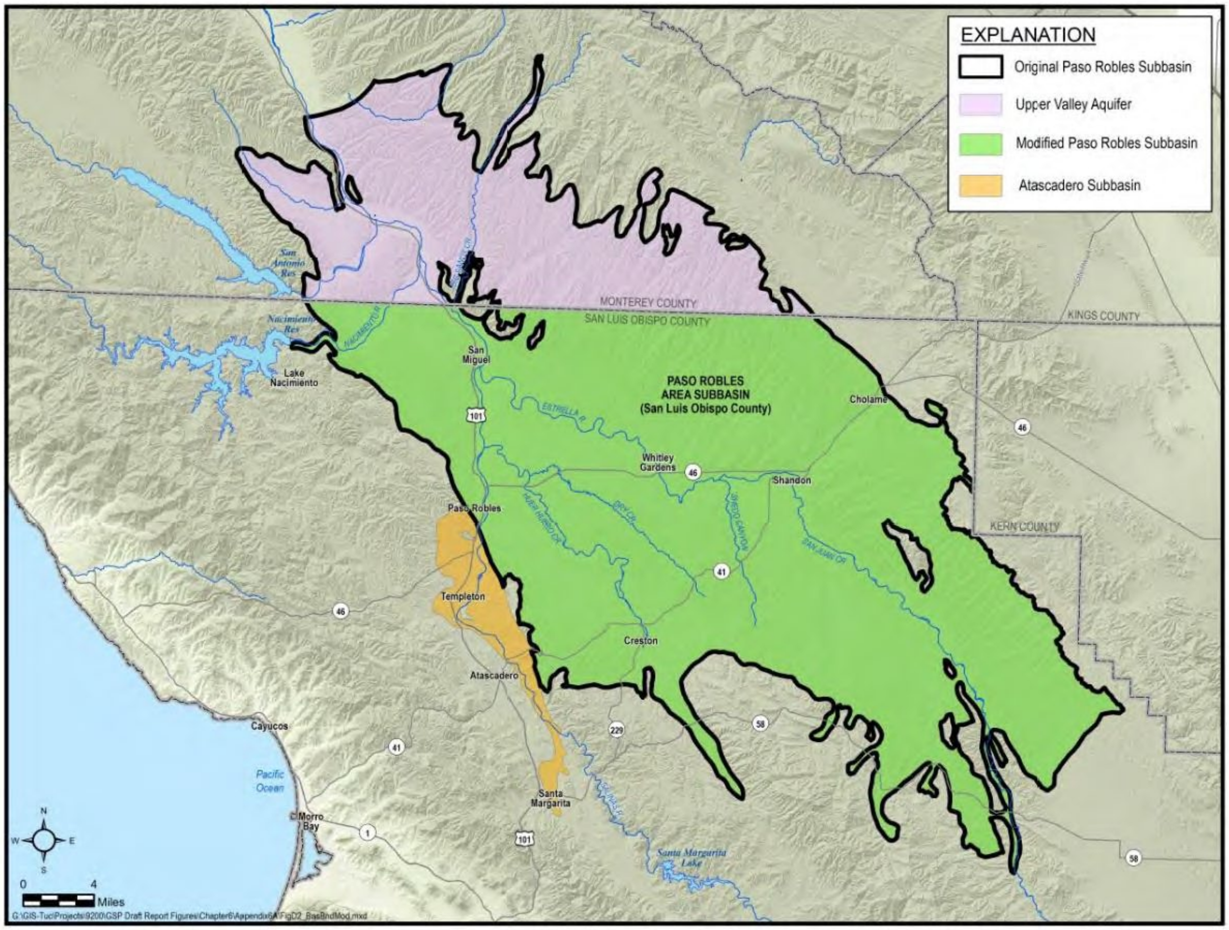
Introduction

This appendix briefly summarizes modeling work done for the Groundwater Sustainability Plan (GSP). As described in Section 6, the hydrologic modeling platform was developed for the Paso Robles Subbasin by various authors during the period from 2005 through 2020. Montgomery and Associates (M&A) performed the final modifications and updates to the modeling platform that were utilized for both this Atascadero Basin GSP and the Paso Robles Subbasin GSP (M&A, 2020). Work conducted by M&A included the following activities:

- Updating the platform with recent hydrologic information,
- Modifying certain components of the platform to address computational issues identified during the update process,
- Adapting the water budgeting process to be consistent with new boundaries, including segregation of the Atascadero Subbasin (Atascadero Basin, or Basin) and the Paso Robles Subbasin. Segregation of the portion of the Paso Robles Subbasin north of the San Luis Obispo County line was previously performed by M&A. Figure 1 shows the Basin boundary (in orange) and the new Paso Robles Subbasin boundary (in green); the GSP only applies to the Atascadero Basin, thus, water budgets reported in the GSP do not include areas within the newly defined Paso Robles Subbasin or areas that lie north of the San Luis Obispo County line.

This appendix is substantially similar to Appendix E of the Paso Robles Subbasin GSP, prepared by M&A (2020). It has been modified to include work performed during development of the Atascadero Basin GSP.

Figure 9. Map Showing Original and Modified Paso Robles Subbasin Boundaries and the Atascadero Subbasin (Source: M&A, 2020)



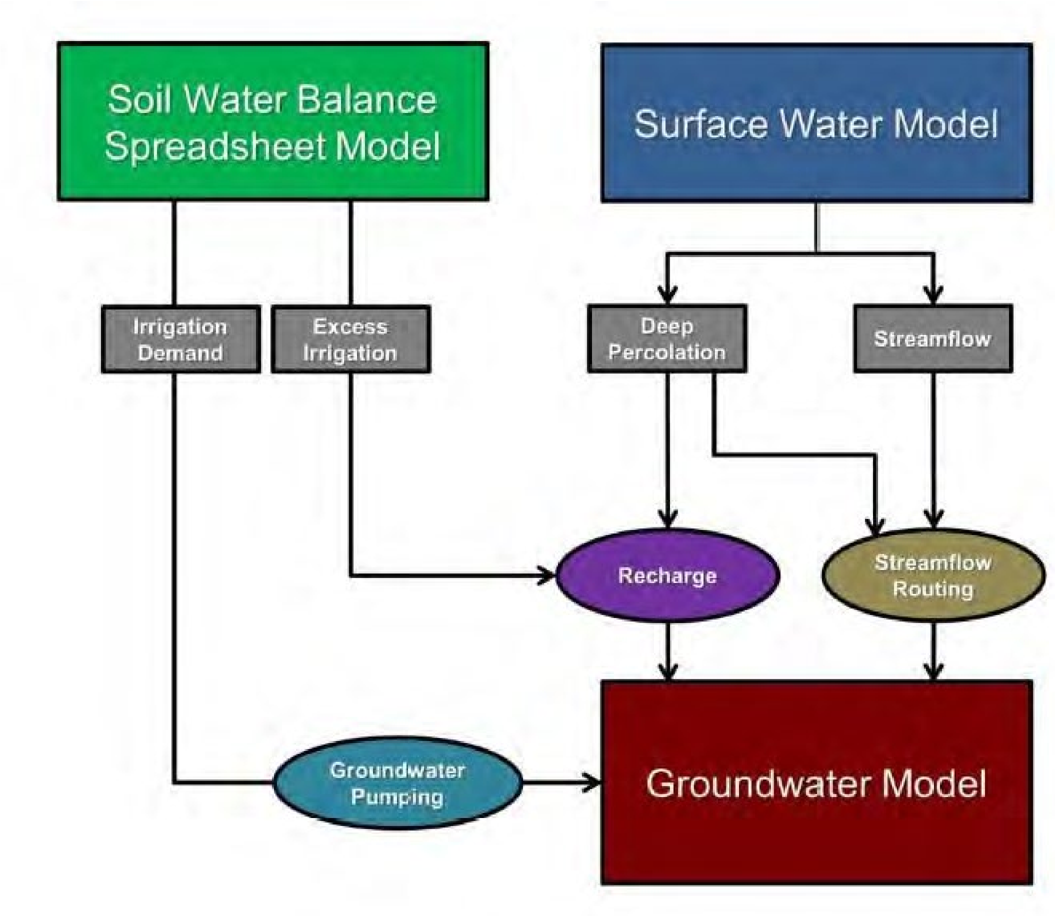
This appendix summarizes the model update process and effects of changes to the modeling platform and boundaries on computed groundwater budgets.

The appendix is subdivided into the following sections.

- Description of GSP Model
- Model Update
- Model Modifications

The hydrologic modeling platform includes a numerical groundwater flow model and two additional models that are used to compute groundwater model input data for streamflow, recharge, and groundwater pumping [Geoscience Support Services, Inc. (GSSI), 2014 and 2016]. The two additional models consist of a Soil Water Balance (SWB) spreadsheet model and a surface water model. The interrelationship between the groundwater model, SWB model, and surface water model are shown on Figure 2. Hereafter in this appendix, the original hydrologic modeling platform developed by GSSI is referred to as “the GSSI model.”

Figure 10. Schematic for Modeling Platform (Source: M&A, 2020)



The GSSI model was updated by M&A for the GSP. The M&A model update process included compiling hydrologic data and preparing model input files to extend the simulation time period from 2012 through 2016. Model modifications included changes to model structure, input/output processing routines, and model assumptions. Modifications were made to address issues that had a potentially significant impact on the computed water budget and groundwater storage calculations.

The GSP model was not recalibrated by M&A. In lieu of recalibration, a focused comparison of model-projected and observed groundwater elevations at wells and stream flows at selected stream gages was conducted. Results of this comparison indicated that the calibration of the GSP model was similar to the GSSI model, thus, the model was considered appropriate for use on both this Atascadero Basin GSP and the Paso Robles Subbasin GSP.

Description of GSP Model

Soil Water Balance Spreadsheet Model

The SWB model uses rainfall, evapotranspiration, soil, and crop data to estimate groundwater irrigation demand for crops in the Basin. Irrigated crops are assigned to seven crop categories (Carollo and others, 2012), including alfalfa, nursery, pasture, citrus, deciduous, vegetables, and vineyard. For the GSP model, geospatial crop datasets compiled by the Agricultural Commissioner's Office of San Luis Obispo County were intersected with different climate zones and soil types within the Basin and the surrounding watersheds. For each of the seven crop categories, existing discrete SWB models were extended in time for each unique intersection of crop acreage, climate zone, and soil type to cover the current period (2012-2016).

The underlying structure and data requirements are identical for all of the SWB spreadsheet models, except vineyards. All of the SWB models operate on a daily time step and require daily precipitation and reference evapotranspiration rates as input. SWB models developed for vineyards also require daily minimum temperature data to estimate frost prevention groundwater pumping during March and April.

The SWB model computes daily irrigation demand rates in inches. Groundwater pumping to satisfy the irrigation demand is higher than the actual crop demand due to excess irrigation losses, which depend on assumed irrigation efficiency. The study documented by GSSI (2014) defined irrigation efficiency for each of the seven crop categories, and those efficiency values were also used by M&A. The difference between groundwater pumping and crop irrigation demand is assumed to percolate past the base of the root zone, ultimately becoming groundwater recharge. This recharge is referred to as irrigation return flow in GSP Section 6.

Surface Water Model

A surface water model was developed by GSSI (2014) for contributing watersheds. The surface water model was developed using the Hydrologic Simulation Program – Fortran (HSPF) code. The model simulates land surface processes and surface water flow at the subwatershed scale (Bicknell and others, 2001). The surface water model simulates daily time steps, and requires daily precipitation, reference evapotranspiration, and reservoir releases as input. Historical watershed simulations developed by GSSI (2014) used land use data for 1985, 1997, and 2011 in the surface water model. The 2011 land use data were used by M&A to update the GSP model.

The surface water model simulates deep percolation of precipitation past the base of the root zone and streamflow leaving the outlet of each subwatershed. The amount of deep percolation of precipitation computed by the surface water model was included in the recharge assigned to the groundwater model, and simulated streamflow at the subwatershed outlet was used to compute surface flow rates for stream segments simulated in the groundwater model.

Groundwater Model

The groundwater flow model for the Paso Robles Subbasin and subsequent use for the Atascadero Basin uses the MODFLOW-2005 code (GSSI, 2014 and 2016). The extent and structure of the GSSI model are based on an earlier version of the groundwater flow model developed by Fugro (2005). Groundwater inflows simulated in the model include areal recharge, subsurface inflow at the model boundaries, and streambed percolation. Areal recharge includes both recharge from precipitation and irrigation return flow. Groundwater outflows simulated in the model include subsurface outflow, groundwater pumping, and riparian evapotranspiration.

Areal recharge and subsurface inflow are computed based on excess irrigation from the SWB model and deep percolation of precipitation from the surface water model. Streambed percolation depends on both simulated water table elevation and simulated streamflow, which in turn is based on simulated streamflow from the surface water model. Agricultural groundwater pumping is specified based on irrigation demand computed in the SWB model.

Model Update

SGMA regulations require estimation of surface water and groundwater budgets for both a historical base period and current period. For the Basin, the historical base period covers Water Years (WY) 1981 through 2011 and the current period covers WY 2012 through 2016. The GSSI model covered only the historical base period (GSSI, 2014; GSSI, 2016). To comply with SGMA regulations for developing a current water budget, M&A updated the 2016 version of the GSSI model to include hydrologic data from 2012 through 2016.

Each of the three components of the modeling platform were updated to include the current period. Table 1 lists datasets used for the model update, along with the source for each dataset.

Table 15. Data Sources for Model Update (modified from Paso Robles Subbasin GSP Appendix E (M&A, 2020))

Dataset	Responsible Agency or Entity	Type of Data	Data Source
Meteorological Data			
Paso Robles Station (46730); Santa Margarita Booster Station (47933)	NOAA[1]	Daily precipitation	https://www.ncdc.noaa.gov
San Miguel Wolf Ranch (47867)	NOAA[1]	Daily precipitation	https://www.ncdc.noaa.gov/
Oak Shores WWTP (201)	San Luis Obispo County	Daily precipitation	Electronic transmittal from SLO County
Paso Robles	WWG[2]	Daily reference evapotranspiration	Electronic transmittal
Atascadero (163)	CIMIS[3]	Daily reference evapotranspiration	https://cimis.water.ca.gov/WSNReportCriteria.aspx
Hydrologic Data			
Nacimiento Reservoir	Monterey County Water Resources Agency	Daily reservoir releases	https://www.co.monterey.ca.us/government/government-links/water-resources-agency

Dataset	Responsible Agency or Entity	Type of Data	Data Source
San Antonio Reservoir	Monterey County Water Resources Agency	Daily reservoir releases	https://www.co.monterey.ca.us/government/government-links/water-resources-agency
Salinas Dam	San Luis Obispo County	Daily reservoir releases	https://wr.slocountywater.org/site.php?site_id=25&site=2d50a617-2e23-4efc- a9be-e3a2c4a7100b
Water Use Data			
San Miguel CSD	San Miguel CSD	Monthly groundwater pumping	Excel file (Paso_Water_Use_Tables_v7.xlsx) received from GEI Consultants on 14 June 2018; data provided to GEI by San Miguel CSD
City of Paso Robles	City of Paso Robles	Monthly groundwater pumping	Historical based on Excel file (Paso_Water_Use_Tables_v7.xlsx) received from GEI Consultants on 14 June 2018; data provided to GEI by City of Paso Robles. Projected based on Paso Robles 2015 Urban Water Management Plan.
Templeton CSD	Templeton CSD	Annual groundwater pumping	Templeton Community Services District Water Supply Buffer Model 2019 Update
Atascadero MWC	Atascadero MWC	Annual groundwater pumping	Atascadero MWC 2015 Urban Water Management Plan
Small commercial pumping	N/A	Annual groundwater pumping	Paso Robles portion of model: For pumping that started before 2010, projected based on historic use in 2016 model (linear regression trend). For water use that began in 2010; assume 1% annual increase through 2016. Atascadero portion of model: Assumed 1% annual increase.
Domestic pumping	N/A	Annual groundwater pumping	Paso Robles portion of model: Projected based on historic use in 2016 model (linear regression trend). Atascadero portion of model: Assumed 1% annual increase.
Agricultural pumping	N/A	Annual groundwater pumping	Pumping based on groundwater demand from soil water-balance spreadsheets. Atascadero portion of model: Projected demand based on 1% annual increase.
Imported Surface Water			

Dataset	Responsible Agency or Entity	Type of Data	Data Source
Imported Surface Water Recharge (including Nacimiento Water Project and State Water Project)	N/A	Annual recharge to groundwater from imported sources	Historical based on records provided by contract holders. Projected based on Agency planning documents.
Wastewater Recharge			
Wastewater recharge (all utilities)	N/A	Annual recharge to groundwater from wastewater	Projected based on Agency planning documents.
Crop Data			
San Luis Obispo County, 2013-2016	San Luis Obispo County	Geospatial data attributed with acreage and crop group	Electronic transmittal from SLO County
State of California, 2014	CA DWR4	Geospatial data attributed with acreage and crop group	https://gis.water.ca.gov/app/CADWRLandUseViewer/

Notes:
(1) National Oceanic and Atmospheric Administration
(2) Western Weather Group
(3) California Irrigation Management Information System
(4) California Department of Water Resources

Model Modifications

Modifications to Model Components

Groundwater budgets for the Basin were derived from the groundwater flow model, which depends on the SWB models and surface water model for key input data. During the model update process for the GSP model, M&A made several modifications to the individual models to improve two computational aspects of the model.

Modifications to Agricultural Irrigation Routing

In the model input files developed by GSSI, irrigation return flow was routed to the surface water model. This irrigation return flow was treated as an external lateral surface inflow to the land surface. The surface water model combines this water with all direct precipitation that was not intercepted by the crop canopy. Some of the water accumulating at the land surface becomes streamflow. The remaining water enters the soil root zone. In the GSSI model, excess irrigation return flow water accumulating in the upper and lower soil root zones was subject to evapotranspiration. However, excess irrigation return flow represents water that has moved past the root zone and should not be subject to evapotranspiration. Thus, irrigation return flow was inadvertently subjected to soil evaporation twice. The net effect of double-counting soil evaporation was to underestimate the quantity of water that ended up as deep percolation to groundwater.

The models were modified so that irrigation return flow calculated in the SWB models was routed to groundwater recharge in the groundwater flow model instead of routed to the surface water model. As a result, areal recharge specified in the GSP model is greater than areal recharge specified in the GSSI model (M&A, 2020).

Modifications to Streamflow Routing Outside the Paso Robles Subbasin

In the GSSI model, subsurface inflow was computed as the sum of irrigation return flow, deep percolation of direct precipitation, and streambed percolation occurring outside the Subbasin boundaries. Streambed percolation was computed by HSPF as an outflow from each stream reach. The streambed percolation was computed using reference information from the HSPF Best Management Practices toolkit developed by the U.S. Environmental Protection Agency (GSSI, 2014).

Modifications were made to the process described above to ensure consistency in the simulated water balance. In HSPF, stream outflows and streambed percolation are routed to the next downstream stream reach. Consequently, when a stream enters the margin of the groundwater model, HSPF routes all of the streamflow and streambed percolation into the stream network within the groundwater model domain. However, in the GSSI model, the streambed percolation water was also being added to the groundwater model as subsurface inflow. This means percolating water through streambeds in the watershed outside of the Subbasin was being double counted: as both stream inflow and subsurface inflow.

To avoid double counting the inflow, M&A modified the groundwater model input files so that subsurface inflow no longer included HSPF model-computed streambed percolation outside groundwater model domain. The primary effect of this change was a reduction in subsurface inflow into the groundwater model. A secondary effect of this change was a reduction in inflow to streams inside the groundwater model domain due to excess subsurface inflow.

Reduction in stream inflows as a result of modifications described above is due to an input processing procedure developed by GSSI (2016). Specifically, the 2016 version of the GSSI model included an empirical procedure for re-assigning computed subsurface inflow above a threshold value as surface water inflow to streams inside the Subbasin boundaries. The GSP model uses the same procedure; however, streambed percolation is no longer double counted, thus computed subsurface inflow in excess of the threshold is lower in the GSP model than compared to the GSSI (2016) model.

Summary of Effects of Model Modifications

The net effect of correcting excess agricultural irrigation routing was to increase areal recharge. The net effect of removing streambed percolation computed by the surface water model from subsurface inflow to the groundwater model was to reduce both subsurface inflow and surface water inflow to streams in the groundwater flow model. The combined effect of these two modifications was to reduce the amount of water recharging the groundwater system.

Change in Subbasin Boundary

The boundary of the Paso Robles Subbasin changed between completion of the 2016 GSSI model and the GSP model update. In 2018, the California Department of Water Resources (DWR) redefined the Paso Robles Subbasin boundary in response to two basin boundary modification requests. As a result of this modification, the Atascadero Subbasin (Basin), and all land north of the Monterey County line are no longer included in the Paso Robles Subbasin (Figure 1). Groundwater budgets for the Atascadero Basin GSP are reported for the smaller Basin area only. Previous groundwater budgets using the 2016 GSSI model were reported for the entire original Paso Robles Groundwater Subbasin, which included the Atascadero Basin (GSSI, 2016).

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Appendix 6B: Tabulated Water Budget Data for the Historical Base Period and the Current Period

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Water Budget	Water Year	INFLOW (Acre Feet per Year)								OUTFLOW (Acre Feet per Year)								Difference between inflow and outflow (Acre-feet)	Cumulative Change (Acre-feet)	Estimated Safe Yield (Acre-feet per year)
		Treated Wastewater Discharge	NWP Perc	Perc of Precip	Urban Irrigation Return Flow	Ag Irrigation Return Flow	Stream Infiltration	Sub-surface Inflow	Total Inflow	Municipal Pumping	Ag Irrigation Pumping	Rural Domestic Pumping	Small Commercial Pumping	Total Pumping	Riparian Evapo-transpiration	Outflow to Paso Robles Subbasin	Total Outflow			
Historical Water Budget	**1981**	1,570	0	1,400	100	2,700	3,200	2,900	11,900	4,900	12,900	200	700	18,700	500	400	19,700	-7,800	-7,800	
	1982	1,600	0	3,600	100	2,300	7,200	5,000	19,900	4,900	10,900	200	600	16,600	500	1,100	18,300	1,500	-6,300	
	1983	1,630	0	13,000	100	2,500	27,200	5,400	49,800	5,100	10,800	300	600	16,800	500	1,400	18,500	31,300	25,000	
	1984	1,660	0	700	100	2,700	2,300	2,100	9,600	6,800	12,600	300	700	20,400	500	400	21,300	-11,800	13,200	
	1985	1,690	0	500	100	2,400	1,900	1,800	8,400	6,900	11,500	300	700	19,400	500	300	20,100	-11,700	1,500	
	1986	1,730	0	6,000	100	2,100	15,700	4,500	30,100	7,400	10,400	300	700	18,800	500	600	19,800	10,300	11,800	
	1987	1,760	0	300	100	2,200	1,500	1,300	7,100	8,100	9,500	300	700	18,600	500	600	19,700	-12,700	-900	
	1988	1,790	0	600	100	1,800	2,000	1,400	7,700	8,400	8,500	300	600	17,800	500	500	18,900	-11,200	-12,000	
	1989	1,820	0	1,100	100	1,700	2,800	1,900	9,500	8,100	8,500	300	700	17,600	500	400	18,600	-9,100	-21,100	
	1990	1,860	0	100	100	1,800	1,100	800	5,700	7,600	7,800	300	700	16,400	500	300	17,200	-11,400	-32,600	
	1991	1,890	0	2,000	1,000	1,000	2,300	2,100	10,300	6,200	4,600	300	700	11,800	500	400	12,800	-2,500	-35,100	
	1992	1,930	0	2,600	900	900	3,400	3,000	12,700	7,000	4,200	300	700	12,200	500	500	13,200	-500	-35,600	
	1993	1,960	0	9,600	1,100	1,000	16,500	3,100	33,300	7,600	3,900	300	700	12,500	500	800	13,800	19,400	-16,100	
	1994	1,990	0	400	1,100	900	1,400	500	6,200	8,600	3,600	300	600	13,100	500	200	13,800	-7,600	-23,700	
	1995	2,030	0	10,600	1,100	800	25,500	3,100	43,100	9,000	3,300	300	600	13,200	500	600	14,400	28,700	5,000	
	1996	1,700	0	3,400	900	600	5,900	3,600	16,100	9,800	3,100	300	700	13,900	500	200	14,600	1,600	6,600	
	1997	2,120	0	7,800	1,100	600	18,100	4,100	33,800	10,500	2,700	300	700	14,200	500	400	15,200	18,600	25,200	
	1998	2,040	0	11,400	1,000	500	21,800	3,400	40,200	9,200	2,400	300	600	12,500	500	600	13,700	26,600	51,800	
	1999	1,770	0	700	1,000	500	1,300	700	6,000	10,300	2,600	400	600	13,900	500	0	14,500	-8,400	43,300	
	2000	1,720	0	2,900	900	500	3,700	2,800	12,600	11,200	2,800	400	600	15,000	500	0	15,500	-2,900	40,400	
	2001	2,080	0	2,600	1,000	600	2,600	2,300	11,200	10,600	3,100	400	600	14,700	500	-100	15,100	-3,900	36,500	
	2002	2,280	0	400	2,800	800	1,600	300	8,200	10,900	3,100	400	600	15,000	500	-200	15,400	-7,100	29,300	
	2003	2,340	0	2,300	2,300	600	2,300	1,900	11,700	11,100	2,800	400	600	14,900	500	-300	15,100	-3,400	26,000	
	2004	2,340	0	500	2,800	800	1,400	300	8,100	10,300	3,300	400	700	14,700	500	-200	14,900	-6,800	19,200	
	2005	2,320	0	10,400	2,200	800	19,800	3,100	38,600	9,900	3,300	400	600	14,200	500	300	15,000	23,700	42,800	
	2006	2,370	0	3,500	2,100	700	2,900	1,900	13,600	11,300	3,300	400	600	15,600	500	-300	15,900	-2,300	40,600	
	2007	2,270	0	100	2,800	1,000	1,200	0	7,400	12,000	2,900	400	700	16,000	500	-500	16,000	-8,500	32,000	
	2008	2,380	0	3,200	2,400	800	3,600	2,400	14,800	11,500	2,900	400	700	15,500	500	-300	15,700	-900	31,100	
	2009	2,280	0	500	2,700	900	1,500	300	8,100	10,400	2,800	400	600	14,200	500	-400	14,400	-6,300	24,800	
	2010	2,450	0	4,800	2,500	700	7,300	2,100	19,800	10,100	2,400	500	600	13,600	500	-100	13,900	5,900	30,700	
	2011	2,540	70	6,700	2,300	600	9,900	3,300	25,300	10,000	2,100	500	600	13,200	500	0	13,700	11,700	42,300	
	Average	**2,000**	**0**	**3,700**	**1,200**	**1,200**	**7,100**	**2,300**	**17,500**	**8,900**	**5,500**	**300**	**600**	**15,300**	**500**	**300**	**16,100**	**1,400**		**16,700**
	Min	1,570	0	100	100	500	1,100	0	5,700	4,900	2,100	200	600	11,900	500	-500	12,800	-12,700		
	Max	2,540	70	13,000	2,800	2,700	27,200	5,400	49,800	12,000	12,900	500	700	20,400	500	1,400	21,300	31,300		
Current Water Budget	**2012**	2,460	1,270	400	2,800	700	1,400	100	9,200	10,200	2,200	500	600	13,500	500	-300	13,700	-4,600	-4,600	
	2013	2,490	2,530	700	2,700	1,000	1,400	500	11,200	10,800	2,600	500	600	14,500	500	-300	14,700	-3,500	-8,000	
	2014	2,520	730	300	2,900	1,200	1,200	0	8,900	9,300	3,100	500	600	13,500	500	-300	13,800	-4,900	-13,000	
	2015	2,550	4,790	500	2,700	1,100	1,300	200	13,000	7,800	2,500	500	600	11,400	500	-100	11,800	1,200	-11,700	
	2016	2,570	1,460	1,400	2,400	800	1,500	1,200	11,400	8,000	2,600	500	600	11,700	500	-100	12,200	-900	-12,600	
	Average	**2,520**	**2,160**	**600**	**2,700**	**1,000**	**1,400**	**400**	**10,800**	**9,200**	**2,600**	**500**	**600**	**12,900**	**500**	**-200**	**13,200**	**-2,500**		**10,400**
	Min	2,460	730	300	2,400	700	1,200	0	8,900	7,800	2,200	500	600	11,400	500	-300	11,800	-4,900		
	Max	2,570	4,790	1,400	2,900	1,200	1,500	1,200	13,000	10,800	3,100	500	600	14,500	500	-100	14,700	1,200		

Notes: NWP = Nacimiento Water Project, Perc = percolation, Ag = agricultural, PWS = public water system