Groundwater Sustainability Plan

Monterey Subbasin

Marina Coast Water District Groundwater Sustainability Agency

Salinas Valley Basin Groundwater Sustainability Agency

DRAFT Chapter 6

Water Budget Information

September 2021

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Appendices

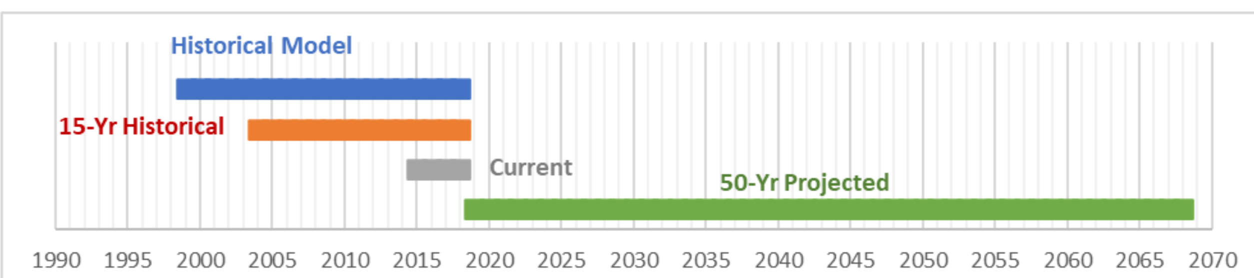
6 WATER BUDGET INFORMATION

On August 25, 2021 the SVBGSA Monterey Subbasin Planning Committee received an updated presentation on the potential relationship between groundwater elevations and arsenic concentrations in the Corral de Tierra Area. The committee discussed new options for the groundwater elevations Sustainable Management Criteria (SMCs), and passed a motion to raise the minimum thresholds and measurable objectives in the Corral de Tierra Area to 2008 and 2004/2005 elevations respectively. These changes have not yet been incorporated into the modeling results, or the rest of the GSP. This statement is here as a placeholder for the reader, and as a reminder to the GSP process that stakeholder input is valuable to the development and implementation of sustainable management of groundwater resources. No changes to the SMCs for the Marina-Ord Area are proposed.

This section presents information on the water budget for the Monterey Subbasin (Subbasin). Consistent with the Groundwater Sustainability Plan (GSP) Regulations (23-California Code of Regulations [CCR] Division 2 Chapter 1.5 Subchapter 2) and California Department of Water Resources' (DWR) Water Budget Best Management Practices (BMP) (DWR, 2016b), this water budget provides an accounting of the total annual volume of water entering and leaving the Subbasin for historical, current, and projected future conditions.

Three water budget time periods are presented herein:

- A historical water budget period representing 15 years of historical hydrology for the period Water Year[1] (WY) 2004-2018 and calibrated to historical data[2];
- A current conditions water budget period representing average conditions over a recent four-year period (WY 2015-2018), validated against recent data; and
- A 50-year projected water budget period (WY 2019-2068), which results presented as averages for comparison to historical and current conditions.



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[1] The DWR-defined Water Year runs from October of the previous year to September of the current year (e.g. Water Year 2015 is October 1, 2014 – September 30, 2015.

[2] The historical model spans the 20-year period WY 1999-2018 and includes a five-year equilibration period (WY 1999 – 2003) before historical water budget information is reported. The historical model is calibrated to observed water levels within the Basin from October 1999 – September 2018.

As discussed in Section 6.1 below, detailed historical and current water budgets are presented for both the land surface system (e.g., precipitation, applied water, and plant evapotranspiration [ET]) and groundwater system (e.g., pumping, cross-boundary flows). To facilitate planning for future sustainability, this GSP also assesses potential future groundwater conditions under various scenarios.

Water budgets for each timeframe are presented for the basin as a whole. In addition, zone budgets are presented for each management area. The Reservation Road portion of the Corral de Tierra has, however, been grouped with the Marina-Ord Area zone budget as it has similar hydrostratigraphy and groundwater from the Marina-Ord Area flows through this area into the 180/400 Foot aquifer subbasin, without a significant change in storage. As such, zone water budgets are presented for the following areas, as shown on Figure 6-1:

- A basin-wide water budget encompassing the entire subbasin;
- The Marina-Ord Area – water budget zone (WBZ) includes the Marina-Ord Area as well as well as the Reservation Road portion of the Corral de Tierra Area, as they share the same principal aquifers;
- The Corral de Tierra Area - Water Budget Zone includes the main portion of the Corral de Tierra Area underlain by the El Toro Primary Aquifer System.

A breakout of the water budget for the Reservation Road portion of the Corral de Tierra Area is included in the Appendix 6A for informational purposes.

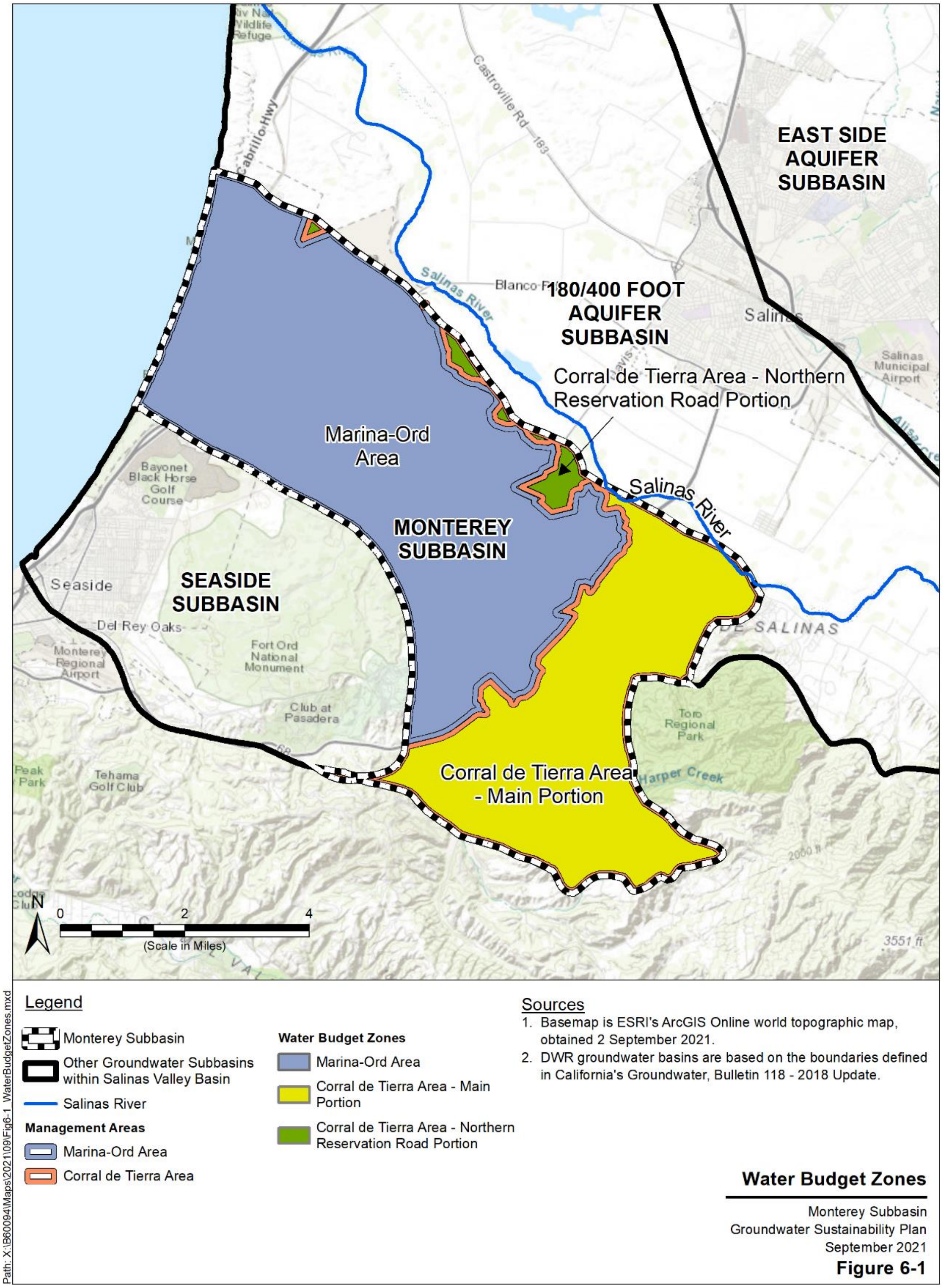

Figure 6-1. Water Budget Zones

6.1 Water Budget Method

The water budget information presented herein is based on the use of a numerical groundwater flow model developed for the subbasin, the Monterey Subbasin Groundwater Flow Model (herein referred to as “Monterey Subbasin Model” or “MBGWFM”). The MBGWFM uses the United States Geological Survey (USGS) Newton formulation of the Modular Three-Dimensional Groundwater Modeling platform (MODFLOW-NWT) platform to solve the governing groundwater flow equations. The MBGWFM divides the spatial model domain of the subbasin into a gridded network of cells, applies data-driven assumptions of groundwater system properties at those cells, applies stresses such as recharge and pumping, and calculates groundwater levels in the cells and groundwater fluxes between cells by solving a system of equations based on groundwater flow principles. Figure 6-2 shows the active extent of the MBGWFM grid.

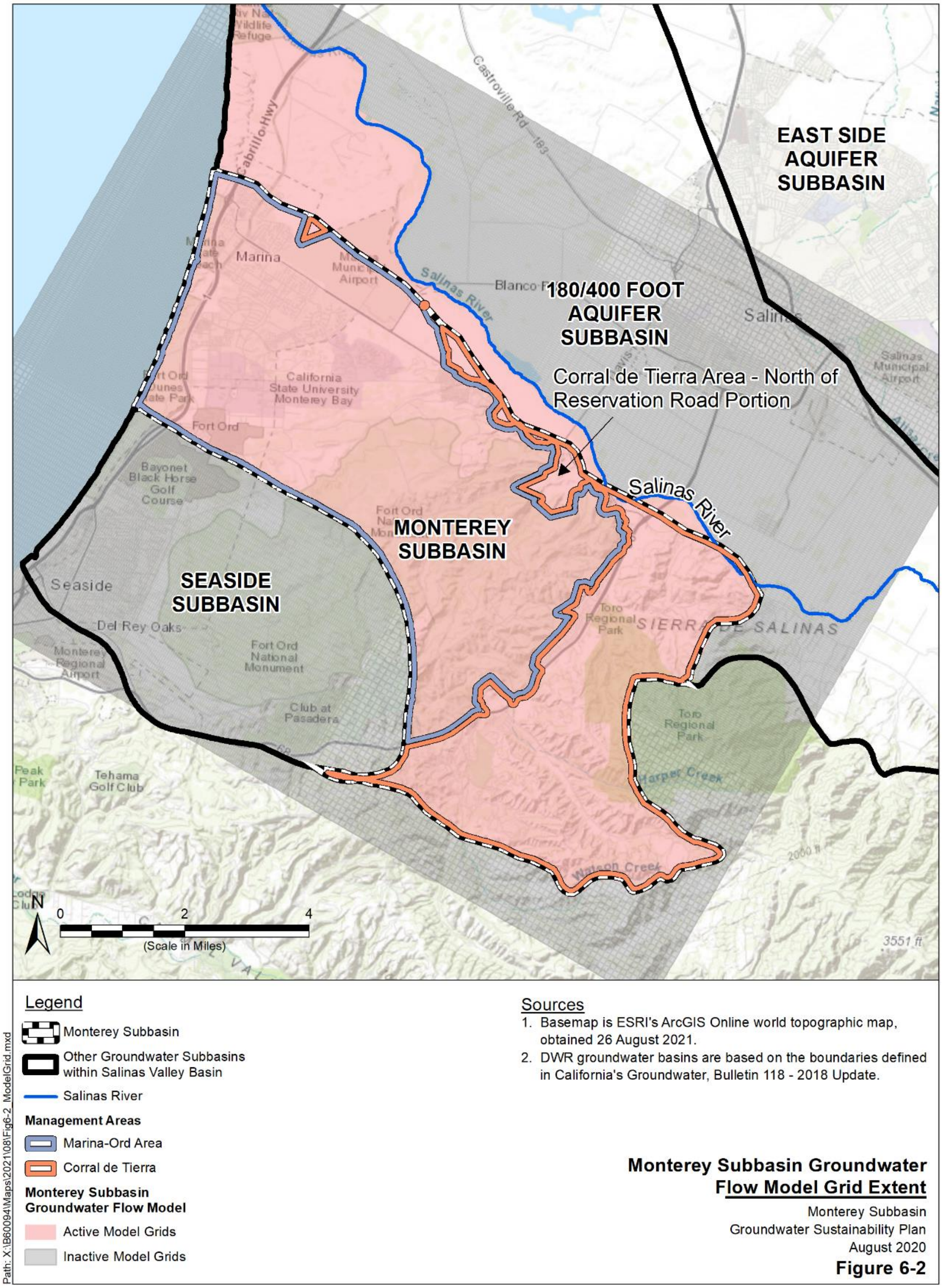

Figure 6-2 Monterey Subbasin Groundwater Flow Model Grid Extent

Details on the MBGWFM development are provided in Appendix 6B. Key aspects of the MBGWFM include:

- Grid whose active extent covers the entire extent of the subbasin, as defined by DWR, as well as a small portion of the 180/400 Foot Aquifer Subbasin south of the Salinas River;
- Eight model layers representing the primary aquifer and aquitards in the subbasin consistent with the subbasin's Hydrogeological Conceptual Model (HCM), which includes the Dune Sand Aquifer, Salinas Valley Aquitard, Upper 180-Foot Aquifer, 180-Foot Aquitard, Lower 180-Foot Aquifer, 180/400-Foot Aquitard, 400-Foot Aquifer, and Deep Aquifers (the latter two layers together represent the El Toro Primary Aquifer System within the Corral de Tierra Area);
- Transient boundary conditions tied to historical water level observations (within the 180/400 Foot Aquifer Subbasin), simulated water levels from existing groundwater flow models (within the Seaside Area Subbasin), and freshwater equivalent sea levels (along the Monterey Coast);
- Transient simulation of Salinas River flows and surface water-groundwater interactions using MODFLOW's River (RIV) package;
- Spatially variable groundwater recharge based on the soil moisture budget accounting model (SMB); and
- Groundwater pumping from Marina Coast Water District (MCWD) production wells based on pumping records, Corral de Tierra Area wells estimated by the Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA), and other production wells in the active portion of the 180/400 Foot Aquifer Subbasin based on Monterey County Water Resources Agency (MCWRA) pumping records.

Model calibration is an assessment of how a model simulates observed historical conditions. Generally, a model's calibration is evaluated through calibration error statistics – statistics of the normalized magnitude of the error between simulated water levels and observed water levels. A general rule of thumb in assessing model calibration is that the model is considered calibrated when the normalized calibration error statistics[3] are less than 10%. As discussed in Appendix 6B, the MBGWFM has been calibrated against 30,354 historical water level measurements to achieve normalized calibration error statistics of less than 2% and thus adequately represents the historical conditions of the Basin. Therefore, it is appropriate to use the MBGWFM to estimate water budgets for the Monterey Subbasin.

[3] Calibration error statistics include mean absolute residual, residual standard deviation, root mean squared error (RMSE), and coefficient of determination (R-squared).

Water budget information is extracted from simulated model results for the spatial and temporal domain of interest. The land surface processes (e.g., precipitation, applied water, and plant evapotranspiration [ET]) are simulated by the SMB. The SMB calculates deep percolation on a grid cell basis, which is then specified as recharge in the MBGWFM. Similarly, the SMB calculates the demand that is unmet by District water deliveries and precipitation, which is specified as private irrigation well pumping in the MBGWFM. Therefore, the land surface processes are integrated into the groundwater system processes. To quantify all required water budget components as specified in the GSP Emergency Regulations (CCR § 354.18(b)), this GSP presents results from both the SMB for the land surface system and the MBGWFM for the groundwater system.

6.1.1 Data Sources

Per 23-CCR §354.18(e), the best-available data were used to evaluate the water budget for the Basin and include the following:

- Precipitation records, mapped to the MBGWFM grid, from the 4-kilometer Parameter-elevation Regressions on Independent Slopes Model (PRISM)[4] dataset, *Daily, October 1998 – September 2018*
- Reference ET Data from California Irrigation Management Information System (CIMIS) Salinas North #116 and Laguna Seca #229 stations; *Daily, October 1998 – September 2018*
- Spatial Land Use Data including:
    - MCWD current land use survey from the District's 2020 Water Master Plan, *Static, March 2020*
    - DWR historical land use survey, *Static, Fall 2014.*[5]
    - U.S. Department of Agriculture (USDA) Forest Service Region 5 Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG)[6] dataset for Zone 5 (Central Valley), *Static, March 2020*
- Pumping Records including:
    - MCWD pumping volumes from District-owned production wells from the District's internal operations records, *Monthly, October 1998- September 2018*.
    - MCWRA pumping volumes from production wells within the active model portion of the 180/400 Foot Aquifer Subbasin, *Monthly, October 1998- September 2018*.

[4] https://prism.oregonstate.edu/recent/
[5] Available online at https://gis.water.ca.gov/app/CADWRLandUseViewer/
[6] Available online at https://www.fs.usda.gov/detail/r5/landmanagement/resourcemanagement/?cid=stelprdb5347192

  - Estimated Corral de Tierra pumping based on extraction reported to MCWRA and State Water Resources Control Board (SWRCB) where available, and approximated based on the number of households to account for small water systems connections and *de minimis* pumpers

- Historical Groundwater Level Records from selected wells within the Monterey and 180/400 Foot Aquifer Subbasins; *Seasonal, Fall 1998 – Spring 2018 (data availability varies by well)*
- Delivery Records including:
  - MCWD delivery volumes from the District's internal operations records, *Monthly, October 1998 – September 2018*
  - Delivery volumes for the Cal-Am and California Water Service (CWS) service areas within the Basin, compiled by the Seaside Watermaster, *Monthly, October 1998 – September 2018*
- Salinas River Flow Data from the USGS Spreckels Gauge #11152500, *Monthly, October 1998 – September 2018*
- Various SMB input datasets, including:
  - Soil properties (i.e., hydrologic group, wilting point, field capacity, soil porosity, saturated hydraulic conductivity, and depth) from the United States Department of Agriculture (USDA) Soil Survey Geographic Database (SSURGO)
  - Curve numbers for runoff for agriculture, urban, and native vegetation classifications including conifer forest/woodland, hardwood forest/woodland, mixed conifer and hardwood forest/woodland, shrub, herbaceous, and barren from USDA, 1989, and
  - Crop coefficients and canopy storage properties for native, agricultural, and urban land use types from California Polytechnic State University's Irrigation Training and Research Center (ITRC)
- Model outputs from the Seaside Basin Groundwater Flow Model (Hydrometrics 2009 & 2018), used to simulate cross-boundary subsurface flows with the Seaside Area Subbasin.

6.2 Water Budget Components

Principal components of the Basin water budget have been classified into (1) land surface system and (2) groundwater system categories, and are described in detail below.

6.2.1 Land Surface System Water Budget Components

The SMB accounts for most processes relevant to the land surface system budget quantification, including the following:

Precipitation within the Basin is available as a 4-kilometer gridded dataset from PRISM. Precipitation falling on Basin lands serves to wet the near surface soil and then either evaporates, contributes to crop or natural vegetation water demand, or when intense enough, percolates through the root zone to eventually recharge groundwater. The SMB uses daily precipitation rates estimated by PRISM, which provides a representation of the spatial distribution of precipitation over the entire extent of the Basin.

Applied Water is a combination of (1) MCWD deliveries of groundwater pumped from MCWD-owned wells into their distribution system, (2) CWS and Cal-Am deliveries of groundwater pumped from CWS and Cal-Am wells into their distribution systems, and (3) applied water from private irrigation wells which provide groundwater directly to crops and/or golf courses. MCWD, CWS, and Cal-Am deliveries comprise a large majority of total applied water in the Basin, and are estimated from the water agencies' local operations records. As outdoor deliveries were not specifically tabulated in the operations records, it was assumed that 25% of total deliveries during the summer irrigation period (i.e., April through September) were used to meet outdoor demands, consistent with information provided in the MCWD Urban Water Management Plan (UWMP) (Schaff & Wheeler, 2021). Private irrigation pumping is limited to the ~230 acres of agricultural lands north of the Monterey Subbasin boundary and in the Reservation Road portion of the Corral de Tierra Area, as well as the Corral de Tierra Country Club, and is calculated by the SMB as the residual crop water demand during the summer irrigation period after accounting for contributions from precipitation.

ET is estimated by the SMB for all land use classes using a crop coefficient method, where reference ET data from the two CIMIS stations proximate to the Basin are scaled by land-use specific, monthly crop coefficients. The SMB also incorporates an ET stress function that reduces ET when soil moisture is low (i.e., at the wilting point). The SMB calculates an actual ET rate based on the potential ET and with consideration of the available soil moisture. See Appendix 6B for details.

Runoff is calculated as the amount of precipitation and applied water that does not infiltrate the soil, but rather drains off the land. The SMB calculates rainfall excess runoff based on the U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) curve number method, with curve numbers a function of land use type, soil hydrologic group, and antecedent moisture. The SMB also calculates saturation excess runoff based on soil depth and porosity, although the occurrence of this type of runoff is very rare (i.e., only occurs on thin, low permeability soils during times of high deliveries of applied water or after intense rainfall events).

Root zone storage is calculated on a running basis throughout each SMB daily time step. It is increased by precipitation and applied water and decreased by ET and recharge. Soil moisture also feeds back into the calculation of curve number runoff and ET, as described above.

Recharge to the groundwater system is calculated by the SMB to occur when soil moisture exceeds the field capacity of the soil, after infiltration of the precipitation remaining after curve number runoff and after ET. Recharge is limited to a fraction of the saturated hydraulic conductivity of soil, and when the soil is unable to recharge the entire amount of soil moisture in excess of field capacity, the soil moisture can exceed field capacity, eventually building up to reach soil porosity and causing saturation excess runoff, although such occurrence is very rare, as mentioned above.

Stream-groundwater interactions is calculated by the MBGWFM based on Salinas River stage, assumed streambed properties and the surrounding model-calculated groundwater levels. More information is provided under the groundwater system below.

6.2.2 Groundwater System Water Budget Components

The MBGWFM accounts for all water flow processes relevant to groundwater system budget quantification. Some values originate from the SMB, whereas others are direct inputs to or outputs from the MBGWFM.

Recharge from excess precipitation and applied water is calculated by the SMB, as described above. Additionally, leakage from water distribution systems contributes to groundwater recharge. Consistent with information provided in the MCWD UWMP (Schaaf & Wheeler, 2021), leakage is estimated as 5% of the total delivered water to MCWD, CWS, and Cal-Am service areas, which are entirely supplied by groundwater.

Groundwater pumping includes pumping from MCWD-owned wells and pumping from other water system and private wells in the Corral de Tierra Area. Groundwater pumping from MCWD-owned wells is based on MCWD reported data. Groundwater pumping from wells in the Corral de Tierra Area was estimated by SVBGSA. Using 2019 as an example historical year, 78% of pumped groundwater in the Corral de Tierra is used by municipal and mutual water systems. The Groundwater Extraction Management System (GEMS) maintained by the Monterey County Water Resources Agency only covers part of the Corral de Tierra. Therefore, these pumping estimates were calculated also using 2019 pumping reported by public water systems to the state, as well as estimates based on land use type, acreage, parcels, and de minimis use. For parcels that are not included in mutual water systems or municipal water systems, analysis of aerial imagery and engineering judgement were used to estimate irrigated areas fed by private wells.

Inter-Basin Cross-Boundary Flow

- Subsurface exchanges with the 180/400 Foot Aquifer Subbasin are calculated by the MBGWFM using a general head boundary condition. The MBGWFM calculates subsurface flow based on observed historical groundwater elevations at wells within the 180/400 Foot Aquifer Subbasin proximate to the northern active model boundary, distances from those wells to the active model boundary, and lateral hydraulic conductivities at boundary cells.

- Subsurface exchanges with the Seaside Area Subbasin are calculated by the MBGWFM using a general head boundary condition. The MBGWFM calculates subsurface flow based on modeled groundwater head outputs at the Seaside boundary from the historical Seaside Basin Groundwater Flow Model (Hydrometrics 2009 & 2018) and lateral hydraulic conductivities at boundary cells.

- Subsurface exchanges with the Pacific Ocean are calculated by the MBGWFM using a constant head boundary condition. The MBGWFM calculates subsurface flow based on freshwater equivalent sea levels along the Monterey Coast[7]. This subsurface flow exchange with the ocean may consist of seawater or freshwater and is not explicitly distinguished within the model.

- Because the subbasin is bounded on the east and southeast by mostly metamorphic bedrock formations, they are treated as no-flow boundaries and therefore it is assumed that the subbasin does not receive subsurface inflows from these areas.

Stream-groundwater interactions are calculated by the MBGWFM based on Salinas River stage, assumed streambed properties, and the surrounding model-calculated groundwater levels. Salinas River stage is directly provided as input to the RIV package of the MBGWFM based on monthly flow measurements recorded at the USGS Spreckels Gauge (Site #11152500). Corresponding stream-groundwater exchanges are calculated based on modeled hydraulic gradients between the streambed and underlying groundwater system. The Salinas River is the only major surface water body explicitly modeled in the MBGWFM. All other contributing streams to the Basin are ephemeral in nature and either flow into the Salinas River during precipitation events or otherwise dry up before leaving the Basin, likely contributing to additional groundwater recharge.

[7] Freshwater equivalent sea levels are calculated based on the Ghyben-Herzberg Relation, which states that for every foot of freshwater above sea level there is approximately 40 feet of freshwater below sea level (Barlow 2003). The depths and distances at which principal aquifer units (namely, the Aromas Sand and Paso Robles Formations) outcrop along the seafloor were estimated to inform corresponding freshwater equivalent heads at the aquifer-seafloor interface.

Change in groundwater storage is calculated by the MBGWFM by solving the groundwater flow equation. The groundwater storage inflows and outflows extracted from the MBGWFM are referenced to the groundwater storage domain instead of the groundwater system domain. For the purposes of this GSP, change in groundwater storage is calculated as the groundwater system inflows minus the groundwater system outflows. Therefore, a positive change in storage indicates an increase in groundwater storage and a negative change in storage indicates a decrease in groundwater storage.

Water budget information for the historical and current water budget periods is presented in Section 6.4 below and water budget information for the projected future scenarios is presented in Section 6.5 below.

6.3 Water Budget Time Frames

Time periods must be specified for each of the three required water budgets. The Sustainable Groundwater Management Act (SGMA) regulations require water budgets for historical conditions, current conditions, and projected conditions.

6.3.1 Historical Water Budget Time Period

23-CCR §354.18(c)(2) requires quantification of historical water budget components for at least the past 10 years. Additionally, per DWR's Water Budget BMP, the water budget should represent average hydrology, with both wet and dry years (DWR, 2016b).

The historical water budget is intended to evaluate how past land use and water supply availability has affected aquifer conditions and the ability of groundwater users to operate within the sustainable yield. GSP Regulations require that the historical water budget include at least the most recent 10 years of water budget information. DWR's Water Budget BMP document further states that the historical water budget should help develop an understanding of how historical conditions concerning hydrology, water demand, and surface water supply availability or reliability have impacted the ability to operate the basin within the sustainable yield. Accordingly, historical conditions should include the most reliable historical data that are available for GSP development and water budgets calculations.

As shown on Figure 6-3, the long-term average precipitation on subbasin lands based on PRISM records was 15.46 inches per year (in/yr) between the period of 1896 through 2019. Using these historical rainfall records, a 15-year period representing WY 2004-2018 was defined as the historical water budget period. The average precipitation based on PRISM data over the historical water budget period (WY 2004-2018) is 15.50 in/yr and is similar to the long-term average. This historical water budget time period contains a variety of water year types and therefore adequately represent average hydrologic conditions for purposes of quantifying the historical subbasin water budget.

In addition to the historical water budget and calibration period, a five-year preconditioning period (WY 1998-2003) was established to allow the model to stabilize from initial conditions, resulting in a total 20-year model evaluation period.

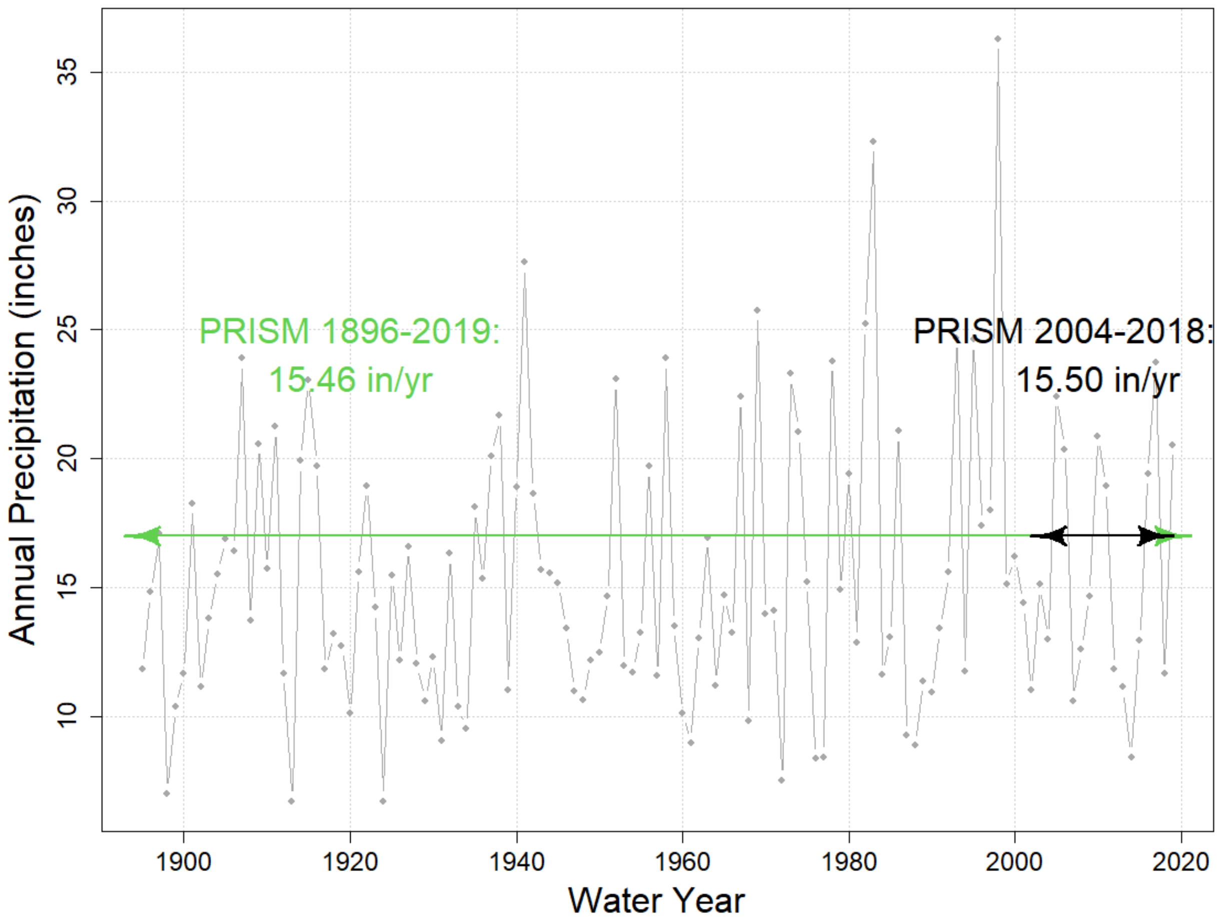

Figure 6-3. Monterey Subbasin Long-Term Precipitation Records

6.3.2 <u>Current Water Budgets Time Period</u>

A four-year period representing WY 2015-2018 was defined as the current water budget period, which is reflective of recent patterns of climate, groundwater use, and boundary conditions. As shown on Figure 6-3, the average precipitation falling on subbasin lands based on PRISM data between WY 2015-2018 was 16.94 in/yr.

The current water budget is intended to allow the Groundwater Sustainability Agencies (GSAs) and DWR to understand the existing supply, demand, and change in storage under the most recent population, land use, and hydrologic conditions. Current conditions are generally the most recent conditions for which adequate data are available and that represent recent climatic and hydrologic conditions. Current conditions are not well defined by DWR but can include an average over a few recent years with various climatic and hydrologic.

6.3.3 Projected Water Budgets Time Period

Per 23-CCR § 354.18(e)(2)(A), the projected water budgets must use 50 years of historical precipitation, evapotranspiration, and streamflow information as the basis for evaluating future conditions under baseline and climate-modified scenarios. To develop the required 50 years of projected hydrologic input information, an "analog period" was created by repeating select sequences of the historical hydrologic record in a way that maintains long-term historical average hydrologic conditions, as detailed below.

The projected water budget is intended to quantify the estimated future baseline conditions. The projected water budget estimates the future baseline conditions concerning hydrology, water demand, and surface water supply over a 50-year planning and implementation horizon. It is based on historical trends in hydrologic conditions which are used to project forward 50 years while considering projected climate change and sea level rise if applicable.

To develop the required 50 years-worth of hydrologic input information, first an "analog period" was created from 20 years-worth of historical information (WY 1999-2018) by combining the years in a specific way that, on average, maintained the long-term average hydrologic conditions. This approach allowed for the creation of a complete 50-year period to inform the projected water budget analysis, even when certain component datasets were not available for that length of time. The sequence of actual years that were combined to create the 50-year analog period is as follows:

- Analog Years 1-20: Based on actual years 1999-2018
- Analog Years 21-40: Based on actual years 1999-2018
- Analog Years: 41-50: Based on actual years 1999-2008

The above mapping of actual years to analog years within the required 50-year projected water budget period applies to precipitation and ET datasets.

6.4 Historical and Current Water Budget

This section presents water budget results from the calibrated MBGWFM and associated SMB. Results are presented below in terms of both annual values and averages during the historical water budget period (WY 2004–2018) and the current water budget period (WY 2015-2018).

Historical and current water budget information is presented for the following areas as shown on Figure 6-4 through Figure 6-6:

- The basin-wide water budget encompassing the entire subbasin (Section 6.4.1);

- The Marina-Ord Area – Water Budget Zone ("Marina-Ord Area WBZ) which includes the Marina-Ord Area as well as well as the Reservation Road portion of the Corral de Tierra Area (Section 6.4.2); and
- The Corral de Tierra Area - Water Budget Zone (Corral de Tierra Area WBZ) which includes the main portion of the Corral de Tierra Area underlain by the El Toro Primary Aquifer System (Section 6.4.3).

6.4.1 Basin-Wide Water Budget

Table 6-1 summarizes inflows to and outflows from the basin-wide groundwater system by water source type during the historical water budget period (WY 2004–2018) and current water budget period (WY 2015-2018). Water budget components include: recharge, well pumping, net inter-basin flow, and net river exchange. Positive values indicate a net inflow to the Monterey subbasin and negative values indicate a net outflow from the subbasin. Further description regarding the modeling of each of these water budget components is described Section 6.2 and provided in Appendix 6B.

Table 6-1. Historical and Current Groundwater Water Budget Results, Monterey Subbasin

Net Annual Groundwater Flows (AFY) (a)	Historical Annual Inflows/Outflows WY 2004 - 2018	Current Annual Inflows/Outflows WY 2015 - 2018
Recharge		
● Rainfall, leakage, irrigation	10,055	12,060
	10,055	**12,060**
Well Pumping		
● Well Pumping	-5,641	-5,274
	-5,641	**-5,274**
Net Inter-Basin Flow (Presumed Freshwater) (b)		
● Seaside Subbasin	918	1,334
● 180/400 Foot Aquifer Subbasin	-9,393	-9,307
● Ocean	-524	-574
	-8,999	**-8,547**
Net Inter-Basin Flow (Presumed Seawater) (b)		
● 180/400 Foot Aquifer Subbasin	-2,872	-3,258
● Ocean	2,872	3,258
	0	**0**
Net Surface Water Exchange		
● Salinas River Exchange	151	153
	151	**153**
NET ANNUAL CHANGE IN GROUNDWATER STORAGE	**-4,434**	**-1,609**

Notes:

(a) Positive values indicate a net inflow and negative values indicate a net outflow.
(b) All seawater inflows from the ocean are presumed to leave the Monterey Subbasin across the 180/400 Foot Aquifer Subbasin boundary, as evidenced by no observed expansion of the seawater intrusion front in the Monterey Subbasin over the historical time period.

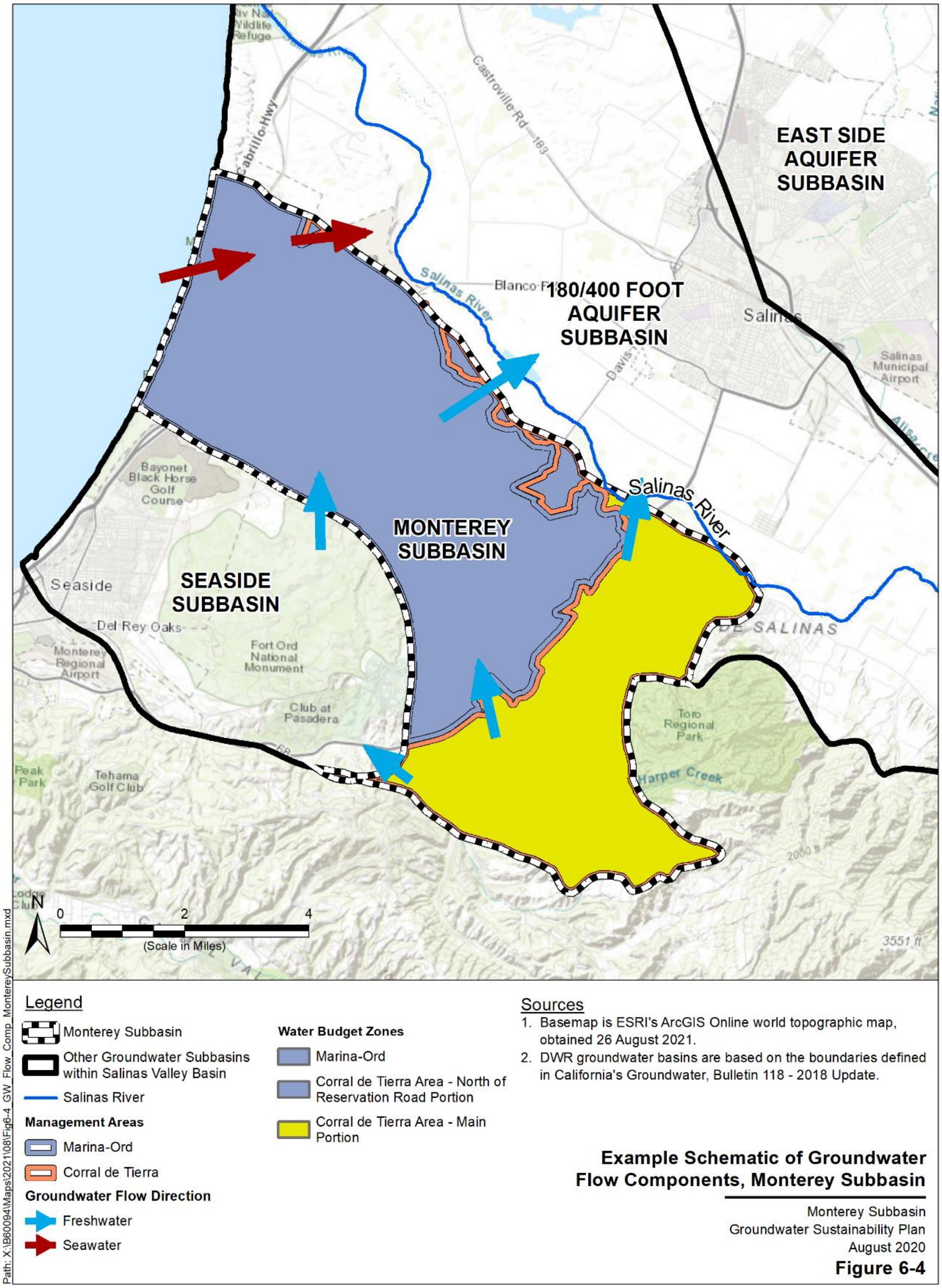

Figure 6-4. Example Schematic of Groundwater Flow Components, Monterey Subbasin

6.4.1.1 Historical Water Budget

6.4.1.1.1 Recharge

Estimated average annual recharge to the basin during the historical period was 10,055 AFY. This recharge is was estimated utilizing the SMB and incorporates land surface system processes and estimated leakage of total delivered water by MCWD. Outputs from the SMB are included in the Appendix 6A.

6.4.1.1.2 Well Pumping

The estimated average annual well pumping in the basin during the historical period was 5,641 AFY. It includes pumping from MCWD-owned wells and pumping from other water system and private wells in the Corral de Tierra Area.

This value is significantly less than the estimated annual recharge to the basin (10,055 AFY) during the historical period. The annual well pumping value is negative in Table 6-1 as it represents and outflow from the subbasin.

6.4.1.1.3 Net Inter-basin Flows

Net annual inter-basin flows represent the sum of inflows and outflows along the entire boundary of each adjacent subbasin and the ocean. They represent the aggregate groundwater flow in all principal aquifers across a given boundary. The basis for calculating these flows and calibrating conditions along each of the model boundaries during the historical and current period is outlined in Section 6.2.2 and described in Appendix 6B.

Estimated net inter-basin flows include:

- Subsurface groundwater flows between the Monterey Subbasin and the adjacent subbasins including the Seaside Subbasin and the 180/400 Foot Aquifer Subbasin and
- Subsurface groundwater flows between the Monterey Subbasin and the ocean.

They are further subdivided by type (i.e., presumed freshwater and presumed seawater). Although the MBGWFM does not specifically distinguish between seawater and freshwater, freshwater and seawater inflow and outflow components can be estimated based on the following assumptions:

- Inflows into the Monterey Subbasin across the ocean boundary are 100% seawater, as ocean water is presumed to saline.
- Outflows from the Monterey Subbasin across the ocean boundary are 100% freshwater, because outflows to the ocean generally only occur within the Dune Sand aquifer which contains freshwater (see Appendix 6A and Section 5.3.3).

- Seawater inflows into the Monterey Subbasin during the historical period were equivalent to seawater outflows to the 180/400 Foot Aquifer Subbasin, as (1) there has been no observed expansion of the seawater intrusion front within the Monterey Subbasin over the historical period and (2) groundwater from the coastal portion of the Monterey Subbasin flows toward the 180/400 Foot Aquifer Subbasin in the lower 180-and 400-Foot aquifers where seawater intrusion has been observed.

Figure 6-4 depicts the general direction of inter-basin cross boundary flows between the subbasins and the ocean, including the direction of presumed freshwater and seawater inflows and outflows from the subbasin. The estimated magnitude of each of these inter-basin cross boundary flows are itemized in Table 6-1 and described below.

Based on the assumptions above, it is estimated that net annual freshwater outflows from the Monterey Subbasin averaged 8,999 AFY during the historical period. These net annual freshwater outflows consisted of the following inter-basin flows:

- 918 AFY of net annual inflows from the Seaside Subbasin into the Monterey Subbasin. These flows are represented as positive in Table 6-1 because they represent and inflow from the Seaside basin into the Monterey Subbasin. The estimated magnitude of these inflows is generally consistent with those estimated by the Seaside Basin Groundwater Flow Model (Hydrometrics 2009 & 2018).

- 9,393 AFY of net outflows from the Monterey Subbasin into the 180/400 Foot Aquifer Subbasin. These flows are identified as negative in Table 6-1 as they represent an outflow from the Monterey Subbasin. These estimated outflows are very significant and are reflective of the large inland gradients that exist between the Monterey subbasin and the 180/400 Foot Aquifer Subbasin. As discussed in Chapter 5, groundwater levels in the 180/400 Foot Aquifer Subbasin are more than 40 feet below sea level in the 180- and 400-Foot Aquifers and have recently declined to over 100 feet below sea level in the Deep Aquifers.

- 524 AFY of net outflows from the Monterey Subbasin into the ocean. These outflows generally occur within the Dune Sand Aquifer (see Appendix 6A), which contains fresh water and has seaward hydraulic gradients.

Estimated net annual seawater inter-basin flows averaged 0 AFY. Based on model results, the magnitude of these net annual seawater flows consisted of the following:

- 2,872 AFY of net seawater inflows into the Monterey Subbasin from the ocean. The majority of these inflows occur within the Lower 180- and 400-Foot Aquifers where seawater intrusion is occurring.

- 2,872 AFY of net seawater outflows from the Monterey Subbasin into the 180/400 Foot Aquifer subbasin. The magnitude of these presumed seawater inter-basin outflows are assumed to be equivalent based on estimated inflows into the Monterey Subbasin across the ocean boundary, given that that there has been no observed expansion of the seawater intrusion front within the Monterey Subbasin over the historical period.

6.4.1.1.4 Net River Exchange

The estimated annual net river exchange was 151 AFY over the historical period. It represents inflows to the subbasin that occur along the Salinas River, which intersects the Subbasin in a small portion of the Corral De Tierra Area.

6.4.1.1.5 Net Annual Change in Groundwater Storage

Change in groundwater storage is the sum of all flow components pertaining to the groundwater system as shown in Table 6-1. Although estimated groundwater recharge (10,055 AFY) exceeded pumping in the Monterey Subbasin (5,651 AFY) during the historical period, the net estimated annual change in groundwater storage in the Monterey Subbasin was -4,434 AFY. This value is negative indicating a loss of storage during the historical period. Inter-basin outflows accounted for the majority of the subbasin's groundwater outflow over the historical period. Net inter-basin outflows (8,999 AFY) well exceeded groundwater pumping and were close to total estimated recharge in the Subbasin. These estimated outflows are reflective of the large inland gradients that exist between the Monterey subbasin and the 180/400 Foot Aquifer Subbasin. As discussed in Chapter 5, groundwater levels in the 180/400 Foot Aquifer Subbasin are more than 40 feet below sea level in the 180- and 400-Foot Aquifers and have recently declined to over 100 feet below sea level in the Deep Aquifers. These results demonstrate the relationship and interdependence between inter-basin inflows, outflows, and the basin water budget and the need for coordinated sustainable groundwater management in all of these subbasins.

The loss in storage is reflected in the groundwater level declines that have been observed in the 400-Foot Aquifer and Deep Aquifers within the Marina-Ord Area and within the El Toro Primary Aquifer in the Corral de Tierra Area. The negative net annual change in storage indicates that the Monterey Subbasin was in overdraft during the historical period.

6.4.1.2 Current Water Budget

The current basin-wide water budget is based upon water years 2015 through 2018 and is also presented in Table 6-1. The current water budget includes the same water budget components as the historical water budget (see Section 6.2) but characterizes basin conditions over a much shorter period of time. The current period includes one wet year (2017), two above normal years (2016 and 2018), and one dry year (2015). Although the current water budget includes both dry and wet years, average precipitation during this period (16.94 in/yr) was higher than the historical period (15.50 in/yr). As such, recharge was much higher than during the historical period. The magnitude of other groundwater budget components including: well pumping, net freshwater inter-basin flows and net river exchange stayed relatively constant with historic values, which resulted in a much smaller net annual change in groundwater storage (-1,609 AFY) during the current period. However, this value is likely not representative of long-term conditions as it is not reflective of the long-term hydrologic cycle.

6.4.2 The Marina-Ord Area – Water Budget Zone

Table 6-2 summarizes the Marina-Ord Area WBZ budget during the historical water budget period (WY 2004–2018) and current water budget period (WY 2015-2018). Similar to the basin-wide budget, water budget components included in the Marina-Ord Area WBZ include: recharge, well pumping, and net inter-basin flow. In addition, the Marina-Ord Area WBZ includes estimated net intra-basin flows from the Corral de Tierra Area. There is no surface water exchange component as the Salinas river does not extend into the Marina-Ord Area WBZ.

Positive values in Table 6-2 indicate a net inflow to the Marina-Ord Area WBZ and negative values indicate a net outflow from the Marina-Ord Area WBZ. Further description regarding the modeling of each of these water budget components is described Section 6.2 and provided in Appendix 6B.

Table 6-2. Historical and Current Groundwater Water Budget Results, Marina-Ord Area

Net Annual Groundwater Flows (AFY) (b)	Historical Annual Inflows/Outflows WY 2004 - 2018	Current Annual Inflows/Outflows WY 2015 - 2018
Recharge		
● Rainfall, leakage, irrigation	6,144	7,624
	6,144	**7,624**
Well Pumping		
● MCWD (180-Foot and 400-Foot Aquifers)	-1,797	-773
● MCWD (Deep Aquifers)	-2,262	-2,445
● Reservation Road Portion	-287	-285
	-4,346	**-3,503**
Net Inter-Basin Flow (Presumed Freshwater) (c)		
● Seaside Subbasin	1,310	1,715
● 180/400 Foot Aquifer Subbasin	-5,761	-6,450
● Ocean	-524	-574
	-4,975	**-5,308**
Net Inter-Basin Flow (Presumed Seawater) (c)		
● 180/400 Foot Aquifer Subbasin	-2,872	-3,258
● Ocean	2,872	3,258
	0	**0**
Net Intra-basin Flow		
● From Corral de Tierra Area WBZ	1,544	1,397
	1,544	**1,397**
NET ANNUAL CHANGE IN GROUNDWATER STORAGE	**-1,632**	**209**

Notes:

(a) The Marina-Ord Area Zone Budget includes inflows to and outflows from the portion of Corral de Tierra that is north of Reservation Rd.
(b) Positive values indicate a net inflow and negative values indicate a net outflow.
(c) All seawater inflows from the ocean are presumed to leave the Monterey Subbasin across the 180/400 Foot Aquifer Subbasin boundary, as evidenced by no observed expansion of the seawater intrusion front in the Monterey Subbasin over the historical time period.

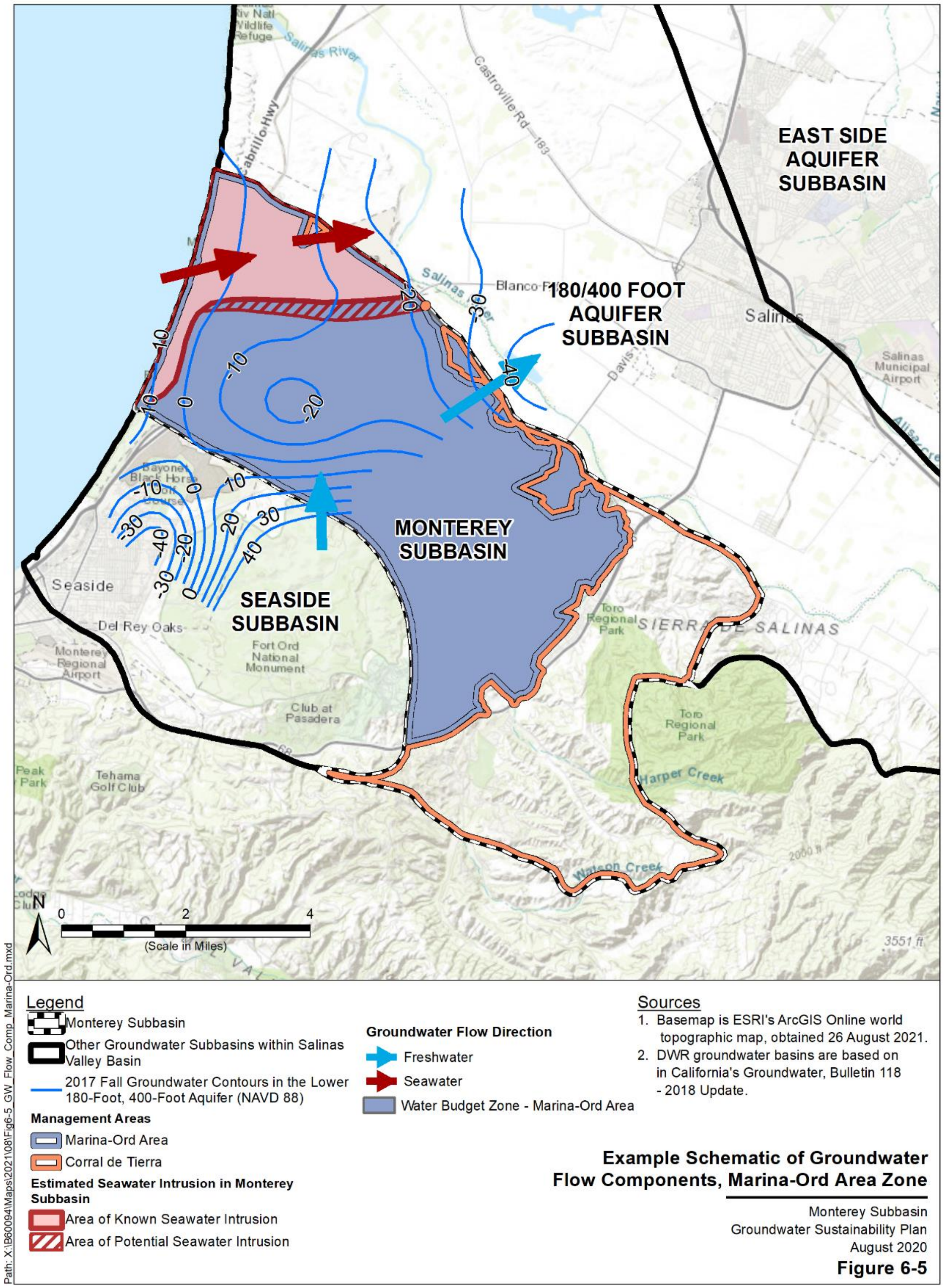

Figure 6-5. Example Schematic of Groundwater Flow Components, Marina-Ord Area Zone

6.4.2.1 Historical Water Budget

6.4.2.1.1 Recharge

Estimated average annual recharge to the Marina-Ord Area WBZ during the historical period was 6,144 AFY. This recharge is was estimated utilizing the SMB and incorporates land surface system processes and estimated leakage of total delivered water by MCWD. Outputs from the SMB are included in the Appendix 6A.

6.4.2.1.2 Well Pumping

Estimated average annual well pumping in the Marina-Ord Area WBZ was 4,346 AFY and included:

- 1,797 AFY by MCWD from the 180- and 400-Foot aquifers;
- 2,262 AFY by MCWD from the Deep aquifers; and
- 287 AFY from Corral de Tierra North of Reservation Rd.

The estimated well pumping in the Marina-Ord Area WBZ was significantly lower than the average annual recharge during the historical period. The well pumping values are negative in Table 6-2 as they represent an outflow from the Marina-Ord Area WBZ.

6.4.2.1.3 Net Inter-basin and Intra-basin Flows

Figure 6-5 depicts the general direction of presumed freshwater and seawater cross-boundary flows to and from the Marina-Ord Area WBZ within the Lower 180- and 400- Foot Aquifer zone where the majority of seawater intrusion is occurring. Net inter-basin and intra-basin flows from the Marina-Ord Area WBZ include:

- Presumed freshwater and seawater inter-basin flows between the Marina-Ord Area WBZ, the ocean and adjacent subbasins; and
- Presumed freshwater intra-basin flows between the Marina-Ord Area WBZ and the Corral de Tierra Area WBZ.

The estimated magnitude of each of these inter- and intra- basin cross boundary flows are itemized in Table 6-2 and described below.

Estimated net annual freshwater inter-basin outflows from the Marina-Ord Area WBZ averaged 4,975 AFY during the historical period. These net annual freshwater outflows consisted of the following inter-basin flows:

- 1,310 AFY of net annual inflows from the Seaside Subbasin into the Marina-Ord Area WBZ.

- 5,761 AFY of net outflows from the Marina-Ord Area WBZ into the 180/400 Foot Aquifer Subbasin.

- 524 AFY of net outflows from the Marina-Ord Area WBZ into the ocean. These outflows generally occur within the Dune Sand Aquifer (see Appendix 6A), which contains fresh water and has seaward hydraulic gradients.

Estimated net annual seawater inter-basin flows from the Marina-Ord Area WBZ averaged 0 AFY. Based on model results, the magnitude of these net annual seawater flows consisted of: :

- 2,872 AFY of net seawater inflows from the Marina-Ord Area WBZ from the ocean. The majority of these inflows occur within the Lower 180- and 400-Foot Aquifers where seawater intrusion is occurring.

- 2,872 AFY of net seawater outflows from the Marina-Ord Area WBZ into the 180/400 Foot Aquifer subbasin. The magnitude of these presumed seawater inter-basin outflows are assumed to be equivalent based on estimated inflows into the Marina-Ord Area WBZ across the ocean boundary, given that that there has been no observed expansion of the seawater intrusion front within the Marina-Ord Area WBZ over the historical period.

Further quantification of these net cross boundary flows by principal aquifer are provided in Appendix 6A.

Estimated net annual freshwater intra-basin inflows from the Corral de Tierra Area WBZ into the Marina-Ord Area WBZ averaged 1,544 AFY over the historical period. As discussed in Section 6.4.3, the Corral de Tierra Area WBZ is located in the Santa Lucia range where groundwater naturally flows toward lower lying coastal areas of the Monterey subbasin and the 180/400 Foot Aquifer Subbasin.

6.4.2.1.4 Net Annual Change in Groundwater Storage

Similar to basin-wide water budget results, groundwater recharge (6,144 AFY) exceeded pumping in the Marina-Ord Area WBZ (4,346 AFY) during the historical period. However, the net estimated annual change in groundwater storage in the Marina-Ord Area WBZ was -1,632 AFY. Net inter-basin outflows from the Marina-Ord Area WBZ (4,975 AFY) were very significant. These results demonstrate the relationship and interdependence between inter-basin inflows, outflows, and the Marina-Ord Area WBZ water budget and the need for coordinated sustainable groundwater management in all subbasins.

6.4.2.2 Current Water Budget

The current water budget for the Marina-Ord Area WBZ is based upon water years 2015 through 2018 and is also presented in Table 6-2. The current water budget includes the same water budget components as the historical water budget (see Section 6.2) but characterizes basin conditions over a much shorter period of time. The current period includes one wet year (2017), two above normal years (2016 and 2018), and one dry year (2015). Although the current water budget includes both dry and wet years, precipitation during this period (16.94 in/yr) was higher than the historical period (15.50 in/yr). As such, recharge was much higher than during the historical period. In addition, due to MCWD's water conservation efforts groundwater pumping in the Marina-Ord Area WBZ has decreased since the beginning of the historical period. Average pumping during the current period (3,503 AFY) was lower than average pumping during the historical period (4,346 AFY). These factors resulted in a net increase in groundwater storage (209 AFY) during the current period. However, this value is likely not representative of long- term conditions as it is not reflective of the long-term hydrologic cycle.

The current water budget results also quantify net annual inter-basin flows into the Marina-Ord Area WBZ. These net annual inter-basin flows represent the sum of inflows and outflows along the entire boundary with each adjacent subbasin and the ocean. They represent the aggregate groundwater flow in all principal aquifers across a given boundary.

These water budget results indicate that total net freshwater and seawater annual outflows from the Marina-Ord Area WBZ into to the 180/400 Foot Aquifer subbasin during the current period were 9,709 AFY. These total net freshwater and seawater annual outflows are substantially higher than those averaged during the historical period (8,633 AFY). This increase in outflows is consistent with observed declines in groundwater levels within the 180/400 Foot Aquifer subbasin between 2004 and 2018 (see chapter 5). Increased annual outflows from the Marina-Ord Area WBZ to the 180/400 Foot Aquifer subbasin during the current period resulted in increased inflows from the ocean and the Seaside basin during this period. These results demonstrate the relationship and interdependence between inter-basin inflows and outflows in the Marina-Ord Area and the need for coordinated sustainable groundwater management in all of these subbasins.

6.4.3 The Corral de Tierra Area – Water Budget Zone

Table 6-3 summarizes the Corral de Tierra Area WBZ budget during the historical water budget period (WY 2004–2018) and current water budget period (WY 2015-2018). Similar to the basin-wide budget, water budget components included in the Corral de Tierra Area WBZ include: recharge, well pumping, net inter-basin flow, and net river exchange. In addition, the Corral de Tierra Area WBZ includes estimated net intra-basin flows to the Marina-Ord Area. Positive values indicate a net inflow to the Corral de Tierra Area WBZ and negative values indicate a net outflow from the Corral de Tierra Area WBZ. Further description regarding the modeling of each of these water budget components is described Section 6.2 and provided in Appendix 6B.

Table 6-3. Historical and Current Groundwater Water Budget Results, Corral de Tierra Area Zone

Net Annual Groundwater Flows (AFY) (b)	Historical Annual Inflows/Outflows WY 2004 - 2018	Current Annual Inflows/Outflows WY 2015 - 2018
Recharge		
● Rainfall, leakage, irrigation	3,910	4,435
	3,910	**4,435**
Well Pumping		
● El Toro Primary Aquifer System	-1,295	-1,771
	-1,296	**-1,771**
Net Inter-Basin Flow (Presumed Freshwater) (c)		
● Seaside Subbasin	-392	-381
● 180/400 Foot Aquifer Subbasin	-3,632	-2,857
● Ocean	0	0
	-4,024	**-3,238**
Net Intra-basin Flow		
● From Marina-Ord Area WBZ	-1,544	-1,397
	-1,544	**-1,397**
Net Surface Water Exchange		
● Salinas River Exchange	151	153
	124	**118**
NET ANNUAL CHANGE IN GROUNDWATER STORAGE	**-2,803**	**-1,818**

Notes:

(a) The Corral de Tierra Area Zone Budget does not include inflows to and outflows from the portion of Corral de Tierra Area that is north of Reservation Rd.
(b) Positive values indicate a net inflow and negative values indicate a net outflow.
(c) Net cross boundary flows are reflective of 100% freshwater as no seawater inflows to the subbasin reach the Corral de Tierra Management Area.

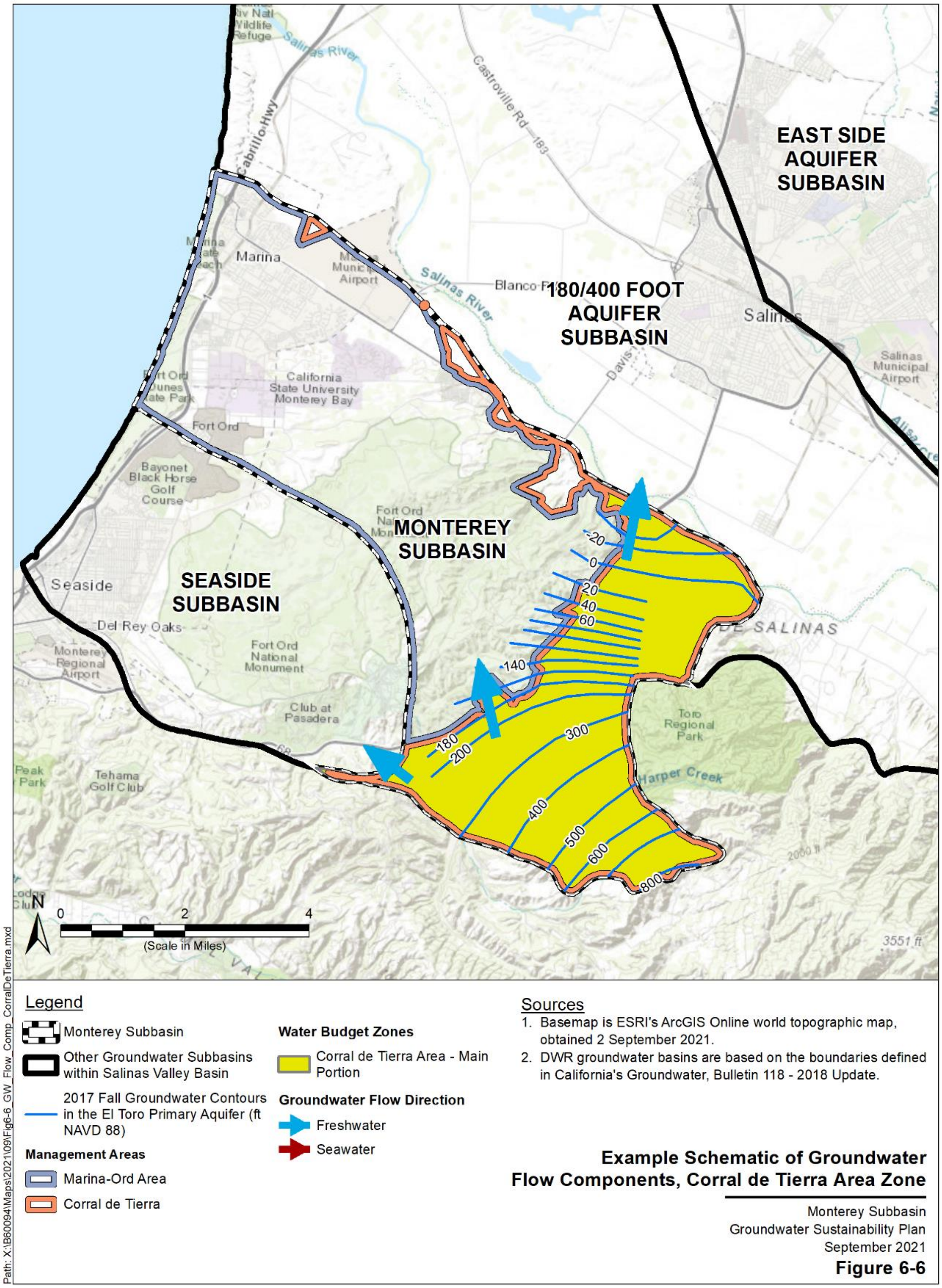

Figure 6-6. Example Schematic of Groundwater Flow Components, Corral de Tierra Area Zone

6.4.3.1 Historical Water Budget

6.4.3.1.1 Recharge

Estimated average annual recharge to the Corral de Tierra Area WBZ during the historical period was 3,910 AFY. This recharge is was estimated utilizing the SMB and incorporates land surface system processes. Outputs from the SMB are included in the Appendix 6A.

6.4.3.1.2 Well Pumping

Estimated average annual well pumping in the Corral de Tierra Area WBZ during the historical period which was 1,295 AFY. The well pumping values are negative in Table 6-3. as the represent and outflow from the Corral de Tierra Area WBZ. It is important to note this area is characterized by many domestic wells and small water systems, which have different reporting requirements than other groundwater extractors. This means that pumping in the Corral de Tierra Area is estimated using the known data, and may be missing a significant amount of pumping. This is a data gap that will be addressed during implementation as described in Chapter 10.

6.4.3.1.3 Net Inter-basin and Intra-basin Flows

Table 6-3 depicts the general direction of groundwater cross-boundary flows to and from the Corral de Tierra Area WBZ. These cross-boundary flows consists of freshwater flows:

- Between the El Toro Primary Aquifer System in the Corral de Tierra Area WBZ and the multiple principal aquifers in adjacent subbasins; and
- Between the principal aquifers in the Marina-Ord Area WBZ and the El Toro Primary Aquifer System in the Corral de Tierra Area WBZ.

The estimated magnitude of each of these inter- and intra- basin cross boundary flows are itemized in Table 6-3 and described below. These

Estimated net annual freshwater inter-basin outflows from the Corral de Tierra Area WBZ averaged 4,024 AFY during the historical period. These net annual freshwater outflows consisted of the following inter-basin flows:

- 392 AFY of net annual outflows from the Corral de Tierra Area WBZ into the Seaside Subbasin.
- 3,602 AFY of net annual outflows from the Corral de Tierra Area WBZ into the 180/400 Foot Aquifer Subbasin.

Estimated net annual freshwater intra-basin inflows from the Corral de Tierra Area WBZ into the Marina-Ord Area WBZ averaged 1,544 AFY over the historical period. As shown on Figure 4-5, the Corral de Tierra Area WBZ is located in the Santa Lucia range and land surface elevations ranges from 300 feet to 1,900 feet above mean sea level. Groundwater from this area naturally flows toward lower lying coastal areas of the Monterey subbasin where the Marina-Ord Area is located and the El Toro Creek Canyon which connects to lower lying areas of the 180/400 Foot Aquifer Subbasin.

6.4.3.1.4 Net Annual Change in Groundwater Storage

Similar to basin-wide water budget results, groundwater recharge (3,910 AFY) exceeded pumping in the Corral de Tierra Area WBZ (1,295 AFY) during the historical period. It is important to note that recharge is not immediately available to the locations and depths of the principal aquifer that are experiencing the most pumping. Recharge and pumping are also not always occurring within the same time periods. In addition, the net estimated annual change in groundwater storage in the Corral de Tierra Area WBZ was -2,803 AFY based on groundwater modeling results, which is over twice the amount of groundwater pumping during this period. This discrepancy is partly due to the data gap related to pumping from small water system and *de minimis* wells which characterize the area, and have different reporting requirements than larger water systems and agricultural users. Net inter-basin outflows from the Corral de Tierra Area WBZ (4,024 AFY) were very significant and close to the area's groundwater recharge. These results demonstrate that extraction data and estimates may underestimate actual extraction in the area and the interdependence of groundwater budgets between subbasins.

6.4.3.2 Current Water Budget

The current water budget for the Corral de Tierra Area WBZ is based upon water years 2015 through 2018 and is also presented in Table 6-3. The current water budget includes the same water budget components as the historical water budget but characterizes basin conditions over a much shorter period of time. Although the current water budget includes both dry and wet years, precipitation during this period (16.94 in/hr) was higher than the historical period (15.50 in/yr). The increased precipitation during this period are the result of higher than average precipitation in the years following the 2012-2016 drought period. As such, recharge was much higher than during the historical period. As shown in Table 6A-3 in Appendix 6A, groundwater pumping in the Corral de Tierra Area WBZ increased during the period of WY 2004-2018. Therefore, average pumping during the current period (1,771 AFY) was higher than average pumping during the historical period (1,296 AFY). The net change in groundwater storage during the current period (-1,818 AFY) was smaller than that of the historical period (-2,803 AFY).

The current results also indicate that net annual outflows from the Corral de Tierra Area WBZ into to the 180/400 Foot Aquifer Subbasin and the Marina-Ord Area WBZ during the current period were 3,238 AFY and 1,397 AFY, respectively. These total net freshwater annual outflows are lower than those averaged during the historical period. These results indicate that increased groundwater pumping and observed groundwater elevation declines between 2004 and 2018 (see Chapter 5) have resulted in less groundwater leaving the Corral de Tierra Area WBZ. These results demonstrate that extraction data and estimates may underestimate actual extraction in the area, and the degree of interdependence of groundwater budgets between subbasins.

6.5 Projected Water Budget

Per 23-CCR § 354.18(e)(2), projected water budgets are required as a way to estimate future conditions of water supply and demand within a basin, as well as the aquifer response to implementation of the Plan over the planning and implementation horizon. To develop the projected water budget, the same tools and methodologies that were used for the historical and current water budget were used, with updated inputs for climate variables (i.e., precipitation and ET), land use (water demand), and future subbasin boundary conditions.

The chief purpose of this projected water budget analysis is to assess the magnitude of the net water supply deficit that would need to be addressed through Projects and Management Actions to prevent Undesirable Results (discussed further in Chapters 8 and 9) and achieve the Sustainability Goal. This section describes the development and results of the projected water budget for the entire subbasin and by water budget zones.

6.5.1 Projected Scenarios Data Sources

Per the GSP Emergency Regulations 23-CCR §354.18(c)(3), the projected water budgets must use "50 years of historical precipitation, evapotranspiration, and streamflow" for estimating future hydrology, "the most recent land use, evapotranspiration, and crop coefficient information" for estimating future water demand. To develop the required 50 years of projected hydrologic input information, an "analog period" was created by repeating select sequences of the historical hydrologic record in a way that maintains long-term historical average hydrologic conditions. The analog period used for projected water budget simulations is discussed in detail in Section 6.3.3.

Per 23-CCR §354.18(e), the best-available data were used to develop the projected water budgets for the subbasin and include the following:

- Monthly Precipitation, ET, and Salinas River flows from the historical simulation period. See Section 6.1.1. for details on the historical data sources.
- Monthly climate change factors for precipitation and ET, and for the 2030 and 2070 Central Tendency scenarios (DWR, 2020). Precipitation and ET climate change factors are spatially variable and mapped to a variable infiltration capacity (VIC) grid. Climate change factors for the VIC grid cells which intersect the Basin were used to vary historical precipitation and ET estimates.
- Future MCWD land use from the District's 2020 Water Master Plan. The historical urban footprint within MCWD was adjusted to include future planned urban developments.
- Future MCWD demands from the District's 2020 UWMP (Schaff & Wheeler, 2021). Projected demands from 2020-2040 were used to adjust groundwater pumping assumptions within MCWD-owned wells and subsequent deliveries of irrigation water in the MCWD service area.

- Water Augmentation Alternatives Study for Former Fort Ord Area (EKI, 2020). Projected recycled water or other augmented supply availability within MCWD was used to develop a "Project" based scenario where future MCWD groundwater demands are partially offset by augmented surface water supplies, as described in detail in Section 6.5.5.
- Water Level Sustainability Criteria for the 180/400 Foot Aquifer Subbasin Representative Monitoring Network. Minimum Thresholds and Measurable Objectives defined for nearby representative monitoring sites (RMS) included in the 180/400 Foot Aquifer Subbasin GSP were used to develop projected groundwater elevations along the northern active model boundary.
- Projected Sea Level Conditions from the 180/400 Foot Aquifer Subbasin GSP were used to develop projected sea levels along the Monterey Coast.
- Seaside Basin Groundwater Flow Model. Final (September 2018) historical groundwater elevations output from the Seaside model (Hydrometrics 2009 & 2018) were used to develop projected groundwater elevations at the Seaside Area Subbasin boundary.

There is less information regarding projected future water demands and land use data available for the Corral de Tierra management area, and as such a few assumptions needed to be made for the model development and projected water budget runs associated with these inputs. Further description regarding each of the assumptions included in projected model simulations is provided below.

6.5.1.1 Projected Water Demands and Land Use

Projected basin-wide water demand and land use are based on (a) projected urban development within MCWD's projected future service area through 2040, and (b) current land use and continued pumping in the Corral de Tierra Area at estimated 2018 extraction rates. The 2018 pumping (i.e., 2,474 AFY) is taken from the very end of the current period to best encapsulate the known maximum amount of pumping in the Corral de Tierra Area. It includes ongoing extraction of 286 AFY from the Reservation Road portion and 2,188 AFY from the remainder of the Corral de Tierra Area.

MCWD's projected service area is located within the Marina-Ord Area and portions of the Seaside Subbasin and 180/400 Foot Aquifer Subbasin. Based on information provided in Table 4.10 of MCWD's 2020 UWMP (Schaff & Wheeler, 2021), water demand within the MCWD service area are anticipated to increase from 3,367 AFY in 2020 to 8,314 AFY by 2040[8]. For the purposes of these projected water budgets, it has been assumed that potable water demands for the entire MCWD future service area would be supplied by pumping from existing MCWD wells in the

[8] An additional 1,270 AFY are anticipated to be met by recycled water or other augmented surface water supplies, to meet a total demand of 9,584 AFY by 2040.

Marina-Ord Area. This groundwater pumping has been divided roughly evenly between the 180/400-Foot Aquifer and Deep Aquifers based on the pumping distributions inferred from MCWD's historical operations.

Projected basin-wide land use was adjusted from historical land use to reflect projected development within MCWD's projected future service area. Land use information was obtained from MCWD's 2020 Water Master Plan, consistent with local land use plans and approved development. As discussed above in Section 6.2.1, this projected land use data serves as an input to the SMB that calculates projected runoff and recharge as a result of land use changes.

6.5.1.2 Projected Hydrology and Variable Climate Scenarios

Projected water budget results are presented for three alternative sets of hydrology and climate conditions which have been identified as:

- Baseline (Historical Analog) Conditions
- 2030 ("Near future") Climate Conditions, and
- 2070 ("Late future") Climate Conditions

To develop the required 50 years-worth of hydrologic input information, first an "analog period" was created from 20 years-worth of historical information (WY 1999-2018) by combining the years in a specific way that, on average, maintained the long-term average hydrologic conditions. This approach allowed for the creation of a complete 50-year period to inform the projected water budget analysis, even when certain component datasets were not available for that length of time. The analog period used for projected water budget simulations is discussed in detail in Section 6.3.3.

- Baseline Climate Scenario: As discussed in Section 6.3.3, an 50-year analog period was created to inform the project water budget analysis. These hydrologic input information were developed using a sequence of historical hydrologic input information that reflects the Subbasin's long-term average hydrologic conditions.
- 2030 Climate Change Scenario: In order to estimate the potential effects on the projected water budget of climate change during the GSP implementation period (i.e., between 2020 and 2040), a water budget scenario based on 2030 climate change factors published by DWR was developed. For this scenario, precipitation and ET were both adjusted using the monthly 2030 change factors published by DWR. Constant head boundary conditions along the Monterey Coast are adjusted using projected 2030 sea levels.
- 2070 Climate Change Scenario: In order to estimate the potential effects on the projected water budget of climate change towards the end of the planning and implementation horizon (i.e., 50 years out into the future), a water budget scenario based on 2070 "central tendency" climate change factors published by DWR was developed. It should be noted that estimates of climate change impacts on water supplies this far into the future have

significant uncertainty. For this scenario, precipitation and ET were both adjusted using the monthly 2070 "central tendency" change factors published by DWR. Constant head boundary conditions along the Monterey Coast are adjusted using projected 2070 sea levels.

6.5.1.3 Projected Subbasin Boundary Conditions

Historical water budget results demonstrate that conditions in the Monterey Subbasin are highly sensitive to conditions in adjacent subbasins. As such, projected water budget results are presented for three alternative sets of boundary conditions, which have been identified as:

- Minimum Threshold (MT) Boundary Conditions
- Measurable Objective (MO) Boundary Conditions, and
- Seawater Intrusion (SWI) Protective Boundary Conditions.

Each of these boundary condition scenarios are predicated on the assumption that (a) the 180/400 Foot Aquifer subbasin will be managed to its SMCs over the 50-year projected model period and (b) Seaside subbasin, which is an adjudicated subbasin, will be managed sustainably such that groundwater levels remain stable into the future.

The 180/400 Foot Aquifer Subbasin has been designated as a critically over drafted subbasin by DWR, and is subject to SGMA. The GSP for the 180/400 Foot Aquifer Subbasin establishes MTs and MOs for both groundwater levels and seawater intrusion. These SMCs have been utilized to simulate potential future boundary conditions along the 180/400 Foot Aquifer Subbasin for the projected water budget. Groundwater levels along the northern active model boundary (just north of the Monterey Subbasin boundary) were established as follows over the 50-year projected model period for each boundary condition scenarios:

- MT Boundary Condition: Groundwater levels in RMS wells located near the Monterey Subbasin are raised from 2018 model predicted values to water level MTs established in the 180/400 Foot Aquifer GSP during the 20-year GSP implementation period (i.e., between 2020 and 2040) and then kept constant for the following 30 years of the projected model period.
- MO Boundary Condition: Groundwater levels in RMS wells located near the Monterey Subbasin raised from 2018 model predicted values to water level MOs following their five year interim milestone (IM) trajectories established in the 180/400 Foot Aquifer GSP during the 20-year GSP implementation period (i.e., between 2020 and 2040) and then kept constant for the following 30 years of the projected model period.
- SWI Protective Boundary Condition: Groundwater levels along the entire boundary of the Monterey Subbasin and 180/400 Foot Aquifer Subbasin are raised from 2018 model predicted values to levels protective against further seawater intrusion within the 180- and 400- Foot aquifers. These SWI protective elevations are projected over the 20-year

GSP implementation period (i.e., between 2020 and 2040). In the absence of the installation of a hydraulic injection and/or extraction barrier, these SWI protective elevations represent the minimum groundwater elevations that would be needed in the coastal portions of the 180/400 Foot Aquifer subbasin to stop further seawater intrusion consistent with the MTs for seawater intrusion established in the 180/400 Foot Aquifer Subbasin GSP. In the Deep Aquifer seawater intrusion has not been observed to date. As such groundwater levels in Deep Aquifer RMS wells located near the Monterey Subbasin are set at water level MOs established in the 180/400 Foot Aquifer GSP, consistent with the MO Boundary Condition.

The Seaside basin is subject to adjudication requirements that require that rates of groundwater extraction within the Subbasin not exceed the estimated basin safe yield. As such, in all three boundary conditions scenarios, groundwater levels in the adjudicated Seaside basin are assumed to remain stable into the future. Water levels along the Seaside Subbasin boundary have been set to model predicted values at the end of the Historical Period (i.e., September 2018) in the Marina-Ord Area or at the established MTs (i.e. based on 2015 water levels) in the Corral de Tierra Area wherever they were below MTs at the end of the Historical Period.

The SVBGSA Subbasin Committee updated their groundwater levels SMCs at the August 25, 2021 special meeting. This will be changed in the next version.

6.5.2 Projected Water Budget Scenarios

All of these scenarios are based upon projected future water demands and land use changes described in Section 6.5.1 above. They assume that, in the absence of any projects, these projected water demands will be met though groundwater pumping from the Monterey Subbasin.

The "No Project" scenarios do not incorporate the potential benefits of any new projects or management actions. However, these projected water budgets do assume that benefits from the following on-going projects/management actions will continue into the future:

- *Stormwater Recharge Management* within the Marina-Ord Area (Section 9.4.4, project M1); and
- *MCWD Demand Management Measures* within the Marina-Ord Area (Section 9.4.5, project M2).

Further description of the anticipated benefits of these projects are included in Chapter 9.

6.5.2.1 *"No Project" Scenarios*

Projected water budgets for two "No Project" scenarios have been developed. These projected water budgets assess basin inflows and outflows under a range of potential future boundary conditions and climate conditions described in Section 6.5.1 above. They include:

- "No Project" Scenario with Variable Boundary Conditions: This scenario estimates the projected water budget under variable boundary conditions with the 180/400 Foot Aquifer Subbasin as described in Section 6.5.1.2 including:
    - MT Boundary Conditions;
    - MO Boundary Conditions, and
    - SWI Protective Boundary Conditions.

  As described in Section 6.5.1.3, boundary conditions with the Seaside subbasin are kept constant as part of this projected water budget scenario. This water budget scenario does not include the implementation of any new projects. It assumes 2030 Climate Conditions versus Baseline climate conditions, as 2030 Climate conditions (i.e., recharge and seawater level rise) fall within the middle of the range of projected climate scenarios used to estimate basin recharge and seawater level rise. An overview of projected budget results for this scenario is included in Section 6.5.4. Additional details regarding specific inflows and outflow components are detailed in Appendix 6B.

- "No Project" Scenario with Variable Climate Conditions: This scenario estimates the projected water budget under the variable climate conditions described in Section 6.5.1.3 including:
    - Baseline Climate conditions
    - 2030 Climate Conditions;
    - 2070 Climate Conditions

  This water budget scenario does not include the implementation of any new projects. It assumes MO boundary conditions at the 180/400-Foot Aquifer Subbasin boundary, as these boundary conditions fall within the middle of the range of projected boundary conditions. As described in section 6.5.1.3, boundary conditions with the Seaside subbasin are kept constant. An overview of projected budget results for this scenario included in Section 6.5.4. Additional details regarding specific inflows and outflow components are detailed in Appendix 6B.

6.5.2.2 *"Project" Scenarios*

Projected Water budgets are provided for one "Project" based scenario, which includes:

- Marina-Ord Water Augmentation Project Scenario with Variable Boundary Conditions: This scenario assumes that a portion of MCWD's projected water demand will be satisfied through some form of water supply augmentation. For evaluation purposes, this projected water budget assumes that all recycled water generated by MCWD will be used to augment water supplies within its service area. This project is consistent with the *Recycled Water Reuse Through Landscape Irrigation and Indirect Potable Reuse* project described in Chapter 9 (Section 9.4.6, project M3). It simulates an incremental increase in augmented water supplies beginning at 600 AFY in 2023 and up to 5,495 AFY by 2040. These augmented water supplies are currently modeled as "in-lieu" of groundwater pumping, i.e. through direct, proportional reductions in groundwater pumping from MCWD-owned wells relative to the "no project" pumping demands described in Sections 6.5.1.1 and 6.5.2.1.

An overview of projected budget results for this "Project" based scenario included in Section 6.5.5. Additional details regarding specific inflows and outflow components are detailed in Appendix 6B.

No project scenarios were run for the Corral de Tierra area at this time.

6.5.3 Projected Water Budget Scenario Results

Consistent with historical and current water budget results, projected water budget information for each scenario is assessed for:

- The entire Monterey Subbasin;
- The Marina-Ord Area WBZ; and
- The Corral de Tierra Area WBZ.

An overview of these projected budget results are summarized in the following sections and tables.

Section 6.5.4: "No Project" Scenario Results:

- Table 6-4 through Table 6-6: "No Project" Scenario with Variable Boundary Conditions and 2030 Climate Condition for Monterey Subbasin, Marina-Ord Area WBZ, and Corral de Tierra Area WBZ;
- Table 6-7: "No Project" Scenario with Variable Climate Conditions and Measurable Objective Boundary Condition for the Monterey Subbasin;

Section 6.5.5: "Project" Scenario Results:

- Table 6-8: Marina-Ord Water Augmentation "Project" Scenario with Variable Boundary Conditions and 2030 Climate Condition.

These tables summarize the magnitude of water budget components associated with each projected water budget scenario. The water budget components include: recharge, well pumping, net inter-basin flow, net intra-basin flow[9], and net river exchange. Similar to historical and current water budget results, positive values identified in these tables indicate a net inflow to the subbasin or WBZ and negative values indicate a net outflow from the subbasin or WBZ. However, unlike historical and current water budget results, only ocean inter basin flows are characterized as freshwater or seawater. Net inter-basin flows between subbasins are not subdivided between those that are presumed to be freshwater versus seawater, as it is difficult to predict if seawater inflows from the ocean will continue to pass through the Monterey Subbasin into the 180/400 Foot Aquifer subbasin as they did during the historical period. It is anticipated that the magnitude and direction of seawater flows could change as the magnitude and direction of inter-basin flows and gradients change. In particular, any inflows within the 180-Foot and 400-Foot Aquifers from the 180/400 Foot Aquifer Subbasin into the Monterey Subbasin are likely to be saline and could cause expansion of the seawater intrusion front in the Monterey Subbasin. As such, projected water budgets should be viewed with caution and cannot be used to assess actual changes in fresh water storage in the subbasin. However, they can be used to assess overall inflows and outflows from the Subbasin and predict the relative magnitude of seawater inflows from the ocean under each scenario.

In addition, Figure 6-7 though Figure 6-11 identify average projected changes in groundwater elevations at RMS wells within the identified management area WBZs under “No Project” and “Project” scenarios. The figures also identify the average change in water levels required to reach MTs and MOs at RMS wells within the identified management area WBZs. Although not well specific, these graphs indicate if water level MTs and MOs will be reached within the associated management area WBZ under these “No Project” and “Project” scenarios.

6.5.4 “No Project” Scenario Results

Due to the strong interdependence of conditions within the Monterey Subbasin and conditions in adjacent subbasins, water budget results are presented for three alternative sets of boundary conditions including:

- MT Boundary Conditions;
- MO Boundary Conditions, and
- SWI Protective Boundary Conditions.

These alternative boundary conditions are further described in Section 6.5.1.2 above. Each of these conditions are predicated on the assumption that the adjacent Seaside Subbasin and 180/400 Foot Aquifer Subbasin will be managed sustainably as determined in in their respective planning documents over the projected 50-year analog period.

[9] Intra-basin flows are only included in WBZ water budget tables as they are not relevant to basin-wide results.

For comparison purposes, these results are presented along with the basin-wide water budget for the historical period (WY 2004-2018). 2030 climate conditions have been assumed for all projected water budget boundary condition scenarios. 2030 climate conditions fall within the middle of the range of projected climate scenarios, which are used to estimate basin recharge and seawater level rise. Impacts of climate variability are also assessed based on baseline, 2030, and 2070 climate Scenarios. However, the projected water budget results indicate that the climate scenarios have a much smaller impact on changes in storage and groundwater levels within the subbasin than the identified boundary conditions.

The magnitude of each of the budget components is generally described on a basin-wide basis. Predicted net annual changes in storage and changes in groundwater levels are also discussed by management area WBZ, as each management area has its own RMS wells and sustainable management criteria.

Table 6-4. Comparison of Projected Water Budget Results Under "No Project" Scenarios with Variable Boundary Conditions and 2030 Climate Condition, Monterey Subbasin

Net Annual Groundwater Flows (a) (AFY)	Historical Annual Inflows/Outflows (WY 2004-2018)	Projected Annual Inflows/Outflows 2030 Climate Conditions		
		Minimum Threshold Boundary Conditions	Measurable Objective Boundary Conditions	Seawater Intrusion Protective Boundary Conditions
Recharge				
● Rainfall, leakage, irrigation	10,055	10,928	10,928	10,928
	10,055	**10,928**	**10,928**	**10,928**
Well Pumping				
● Well Pumping	-5,641	-10,955	-10,955	-10,955
	-5,641	**-10,955**	**-10,955**	**-10,955**
Net Inter-Basin Flow				
● Seaside Subbasin	918	2,414	1,258	-453
● 180/400 Foot Aquifer Subbasin	-12,265	-5,583	-3,412	-295
● Ocean (Presumed Freshwater)	-524	-725	-752	-794
● Ocean (Presumed Seawater)	2,872	2,939	2,369	1,308
	-8,999	**-955**	**-537**	**-234**
Net Surface Water Exchange				
● Salinas River Exchange	151	261	254	279
	151	**261**	**254**	**279**
NET ANNUAL CHANGE IN GROUNDWATER STORAGE	**-4,434**	**-721**	**-310**	**18**

Notes:

(a) Positive values indicate a net inflow and negative values indicate a net outflow.

Table 6-5. Comparison of Projected Water Budget Results Under "No Project" Scenarios with Variable Boundary Conditions and 2030 Climate Condition, Marina-Ord Area WBZ

Net Annual Groundwater Flows (a) (AFY)	Historical Annual Inflows/Outflows (WY 2004-2018)	Projected Annual Inflows/Outflows (b) 2030 Climate Conditions		
		Minimum Threshold Boundary Conditions	Measurable Objective Boundary Conditions	Seawater Intrusion Protective Boundary Conditions
Recharge				
● Rainfall, leakage, irrigation	6,144	6,823	6,823	6,823
	6,144	**6,823**	**6,823**	**6,823**
Well Pumping				
● Well Pumping	-4,346	-8,767	-8,767	-8,767
	-4,346	**-8,767**	**-8,767**	**-8,767**
Net Inter-Basin Flow				
● Seaside Subbasin	1,310	2,513	1,361	-347
● 180/400 Foot Aquifer Subbasin	-8,633	-3,849	-1,927	1,171
● Ocean (Presumed Freshwater)	-524	-725	-752	-794
● Ocean (Presumed Seawater)	2,872	2,939	2,369	1,308
	-4,975	**878**	**1,051**	**1,338**
Net Intra-basin Flow				
● From Corral de Tierra Area	1,544	923	1,026	985
	1,544	**923**	**1,026**	**985**
Net Surface Water Exchange				
● Salinas River Exchange	0	0	0	0
	0	**0**	**0**	**0**
NET ANNUAL CHANGE IN GROUNDWATER STORAGE	**-1,632**	**-143**	**133**	**379**

Notes:

(a) The Marina-Ord Area Zone Budget includes inflows to and outflows from the portion of Corral de Tierra that is north of Reservation Rd.
(b) Positive values indicate a net inflow and negative values indicate a net outflow.

Table 6-6. Comparison of Projected Water Budget Results Under "No Project" Scenarios with Variable Boundary Conditions and 2030 Climate Condition, Corral de Tierra Area WBZ

Net Annual Groundwater Flows (a) (AFY)	Historical Annual Inflows/Outflows (WY 2004-2018)	Projected Annual Inflows/Outflows (b) 2030 Climate Conditions		
		Minimum Threshold Boundary Conditions	Measurable Objective Boundary Conditions	Seawater Intrusion Protective Boundary Conditions
Recharge				
● Rainfall, leakage, irrigation	3,910	4,105	4,105	4,105
	3,910	**4,105**	**4,105**	**4,105**
Well Pumping				
● Well Pumping	-1,296	-2,188	-2,188	-2,188
	-1,296	**-2,188**	**-2,188**	**-2,188**
Net Inter-Basin Flow				
● Seaside Subbasin	-392	-99	-103	-107
● 180/400 Foot Aquifer Subbasin	-3,632	-1,734	-1,485	-1,466
	-4,024	**-1,833**	**-1,588**	**-1,573**
Net Intra-basin Flow				
● From Marina-Ord Area	-1,544	-923	-1,026	-985
	-1,544	**-923**	**-1,026**	**-985**
Net Surface Water Exchange				
● Salinas River Exchange	151	261	254	279
	151	**261**	**254**	**279**
NET ANNUAL CHANGE IN GROUNDWATER STORAGE	**-2,803**	**-578**	**-443**	**-362**

Notes:

(a) The Corral de Tierra Area Zone Budget does not include inflows to and outflows from the portion of Corral de Tierra Area that is north of Reservation Rd.

(b) Positive values indicate a net inflow and negative values indicate a net outflow.

Table 6-7. Comparison of Projected Water Budget Results Under "No Project" Scenarios with Variable Climate Conditions and Measurable Objective Boundary Condition, Monterey Subbasin

Net Annual Groundwater Flows (a) (AFY)	Historical Annual Inflows/Outflows (WY 2004-2018)	Projected Annual Inflows/Outflows (b) (c) Measurable Objective Boundary Conditions		
		Baseline Climate Conditions	2030 Climate Conditions	2070 Climate Conditions
Recharge				
• Rainfall, leakage, irrigation	10,055	10,152	10,928	11,952
	10,055	**10,152**	**10,928**	**11,952**
Well Pumping				
• Well Pumping	-5,641	-10,955	-10,955	-10,955
	-5,641	**-10,955**	**-10,955**	**-10,955**
Net Inter-Basin Flow				
• Seaside Subbasin	918	1,527	1,258	885
• 180/400 Foot Aquifer Subbasin	-12,265	-3,071	-3,412	-3,901
• Ocean (Presumed Freshwater)	-524	-721	-752	-804
• Ocean (Presumed Seawater)	2,872	2,288	2,369	2,534
	-8,999	**24**	**-537**	**-1,286**
Net Surface Water Exchange				
• Salinas River Exchange	151	259	254	249
	151	**259**	**254**	**249**
NET ANNUAL CHANGE IN GROUNDWATER STORAGE	**-4,434**	**-520**	**-310**	**-40**

Notes:

(a) Positive values indicate a net inflow and negative values indicate a net outflow.

6.5.4.1 Projected Annual Basin-Wide Inflows/Outflows

Table 6-4 and Table 6-7 summarize projected annual inflows and outflows from the basin-wide groundwater system by water source type for the "No Project" scenario under variable boundary and climate scenarios.

6.5.4.1.1 Projected Recharge

Table 6-4 and Table 6-7 indicates that estimated average annual recharge to the basin during the projected 50-year analog period (10,152 AFY) is generally consistent with the historical period under the baseline climate conditions. Projected recharge in the basin increases by approximately 7.6 percent under 2030 Climate Conditions and by approximately 17.7 percent under 2070 Climate Conditions.

6.5.4.1.2 Projected Well Pumping

The projected recharge is generally consistent with, or exceeds projected average annual well pumping, in the subbasin (10,955 AFY) under the "No Project" scenario. As discussed in Section 6.5.1.1, this well pumping reflects (a) projected water demands within MCWD's projected future service area through 2040, and (b) current land use and continued pumping in the Corral de Tierra Area WBZ at estimated 2018 extraction rates (i.e., 2,188 AFY) and in the Corral de Tierra North of Reservation Portion (i.e. 268 AFY). Total projected pumping rates are higher than pumping rates estimated over the historical period (5,641 AFY).

6.5.4.1.3 Projected Net Inter-Basin Flows

Projected net annual inter-basin outflows range up to 1,286 AFY for all identified boundary and climate change scenarios presented on Table 6-4 and Table 6-7. These projected net annual inter-basin outflows are significantly below those estimated for the historical period (8,999 AFY). The decrease in net inter-basin outflows principally reflects a reduction in outflows to the 180/400 Foot Aquifer Subbasin. This reduction in outflows is primarily the result of the projected increases in water levels at the boundary of the 180/400-Foot Aquifer subbasin as this basin reaches its determined MTs, MOs and/or SWI protective elevations. The magnitude of these outflows sequentially decreases as water levels at this boundary increase from MTs, to MOs, to SWI protective elevations.

As expected, ocean inflows into the basin also decrease as water levels at this boundary increase from MTs, to MOs, and to SWI protective elevations (see Table 6-7). However, there is little reduction in net ocean inflows between the historical water budget and the projected baseline water budgets under MT boundary conditions or MO boundary conditions. Consistent with historical groundwater flow patterns, it is anticipated that a substantial percentage of ocean inflows will pass through the Monterey Subbasin into the 180/400 Foot Aquifer Subbasin under the MT and MO boundary condition scenarios, as MTs and MOs in the 180/400 Foot Aquifer subbasin are below sea level near the coast and are generally lower than MT and MOs established within the Monterey Subbasin along the basin boundary. Further, projected water budgets also indicate that substantial groundwater outflows from the Monterey Subbasin continue to occur into the 180/400-Foot Aquifer Subbasin under MT and MO boundary condition scenarios. Estimated ocean inflows are significantly reduced under the SWI protective boundary conditions (i.e., 1,308 AFY under 2030 climate scenario). Variable climate condition results presented in Table 6-7 indicate that ocean inflows generally increase under 2030 and 2070 climate conditions relative to baseline conditions, due to sea level rise.

All model estimated ocean inflows should, however, be viewed with caution as the MBGWFM is not a dual density model and therefore cannot accurately assess the seawater/freshwater interface. Monitoring will be used to verify that expansion of the seawater intrusion front does not occur in the Monterey Subbasin consistent with established SMCs.

Projected net annual inflows from the Seaside basin into the Monterey subbasin also appear to be influenced by projected 180/400 Foot Aquifer boundary conditions. As shown in Table 6-4 and Table 6-7, these net annual inflows:

- Increase relative to historical inflows in the projected water budget for the MT boundary condition scenario;
- Stay in the same range as historical inflows under MO conditions depending future climate conditions (see Table 6-7Figure 6-10); and
- Become slightly negative, (i.e., become outflows) under SWI Intrusion Boundary Conditions and 2030 climate conditions.

However, inflows from the Seaside Basin will also be significantly influenced by groundwater levels in the Seaside basin, which have been assumed to stay constant at 2018 levels[10]. Further analysis of potential inflows and outflows along the Seaside subbasin boundary is proposed as part of proposed future modeling efforts identified in implementation action Future Modeling of Seawater Intrusion and Projects, Section 9.5.6.

Further quantification of projected net cross boundary flows by management area WBZ are provided in Section 6.5.4.1.3 and are further discussed in Appendix 6B. Net annual changes in storage and groundwater levels are described by management area WBZ in Sections 6.5.4.2 and 6.5.4.3 below.

[10] Or at the established MTs (i.e. based on 2015 water levels) in the Corral de Tierra Area wherever they were below MTs at the end of the Historical Period.

6.5.4.1.4 Projected Net River Exchange

The projected estimated annual net river inflows ranges between 261 and 279 AFY for the variable boundary condition and climate change scenarios presented in Table 6-4 and Table 6-7. These inflows occur in the Corral de Tierra Area WBZ and are slightly higher than those estimated during the historical period (151 AFY) and are a relative small component of the Subbasin's water budget.

6.5.4.1.5 Basin-wide Projected Net Annual Change in Groundwater Storage

The net annual change in basin-wide groundwater storage ranges between -721 and 18 AFY for the "No Project" scenario projected boundary condition and climate scenarios presented in Table 6-4 and Table 6-7. The net annual change in groundwater storage is significantly lower than that calculated for the historical period (-4,434 AFY), and indicates that inflows and outflows to the subbasin would be slightly negative to balanced under this range of boundary and climate conditions. However, further assessment by management area is required to evaluate where overdraft is occurring in the subbasin and to compare projected water levels with management area specific SMCs to assess the basin sustainable yield. Projected net annual changes in groundwater storage and groundwater levels in the Marina-Ord and Corral de Tierra Area WBZ's, are provided in Sections 6.5.4.2 and 6.5.4.3, respectively.

6.5.4.2 Marina-Ord Area WBZ Projected Net Annual Change in Storage and Projected Changes in Water Elevations Relative to SMCs

Table 6-5 summarizes projected annual inflows, outflows, and net change in storage within the Marina-Ord Area WBZ under variable boundary conditions. As shown on this table, the projected net annual change in groundwater storage ranges between -143 and 379 AFY for the "No Project" scenario within the Marina-Ord Area WBZ. The net annual change in groundwater storage is significantly lower than that calculated for the historical period (-1,632 AFY), and indicates that the Marina-Ord Area WBZ inflows and outflows would be essentially balanced under any of these boundary condition scenarios. Review of climate scenario results presented in Appendix 6A, indicates that this conclusion is true under all of the identified climate change scenarios. As such, these projected water budget results indicate that this management area will not be in overdraft if adjacent basins are managed sustainably and SMCs are achieved.

However, the potential for expansion of the seawater intrusion front within the Marina-Ord Area WBZ must be considered under projected water budget scenarios. Although ocean (i.e., seawater) inflows into the Marina-Ord Area WBZ are generally equal to or lower than those observed during the historical period, it is difficult to predict if (a) these seawater inflows will continue to pass through the Monterey Subbasin into the 180/400 Foot Aquifer subbasin as they did during the historical period or if (b) changes in boundary conditions and increased extraction in the subbasin could cause saline groundwater from the 180/400 Foot Aquifer subbasin or ocean to flow further inland within the Monterey subbasin. It is noted that MCWD has significant operational flexibility regarding rates of extraction from its wells and could potentially modify the location and depth at which groundwater is extracted to limit such impacts. Further assessment and monitoring is required pursuant to this GSP to verify that expansion of the seawater intrusion front, which has been identified as an undesirable result, does not occur under all future scenarios.

In addition, projected water level elevations for the "No Project" scenario must be compared to water level MTs and MOs established in the Marina-Ord Area WBZ, to determine if projects and management actions need to be implemented to meet these sustainability criteria. Figure 6-7 depicts average projected changes in groundwater elevations at RMS wells in the Marina-Ord Area WBZ under the "No Project" scenario with variable boundary conditions. This figure also identifies the average change in water levels required to reach MTs and MOs at RMS wells in the Marina-Ord Area WBZ.[11] As shown on Figure 6-7, groundwater elevations are projected to stabilize under all boundary conditions scenarios within the first 10 years of GSP implementation. However, the resulting average groundwater elevation varies significantly between the various boundary scenarios. The under baseline "no project" scenario results imply that groundwater elevations in RMS wells within the Marina-Ord Area WBZ will:

- generally reach MTs under MT Boundary Conditions, but fall below MTs during drought periods;
- be below MOs under MO Boundary Conditions, and
- be well above MOs and MTs at SWI Protective boundary conditions.

Figure 6-8 presents the effects of variable climate scenarios on groundwater elevations within Marina-Ord Area WBZ under the "No Project" scenario with MO Boundary conditions. This figure indicates that variable climate conditions have limited impacts on projected water levels in RMS wells relative to boundary condition scenarios.

In aggregate, these results suggest that projects and/or management actions may be required to consistently maintain water levels above MTs and to achieve MOs within the Marina-Ord Area unless SWI protective boundary conditions are achieved in the adjacent subbasins.

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[11] This figure shows average projected groundwater elevation changes in the 35 RMS wells in the Marina-Ord Area with respect to those modeled at the end of the historical period (i.e. 2018). The MT and MO elevations shown on this graph reflects their average elevations with respect to 2018 water levels at the RMS wells. For example, MTs, which are set based on 2015 water levels, are on average 2 feet higher than 2018 water levels in these RMS wells.

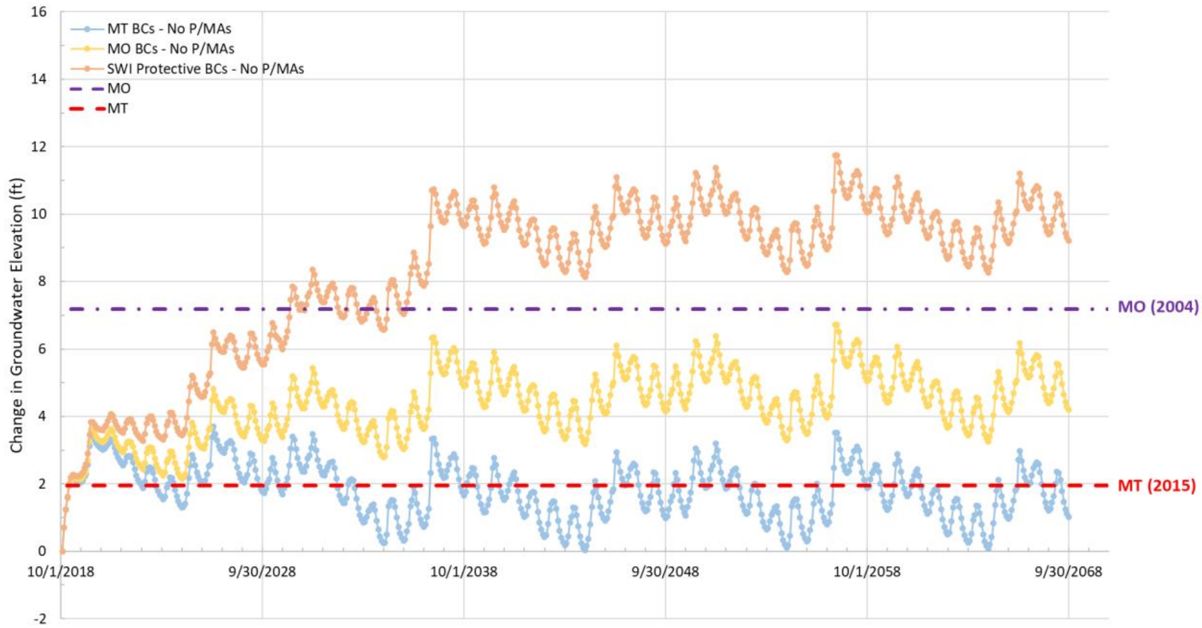

Figure 6-7. Comparison of Groundwater Elevation Changes Under "No Project" Scenario with Various Boundary Conditions and 2030 Climate Condition, Marina-Ord Area WBZ

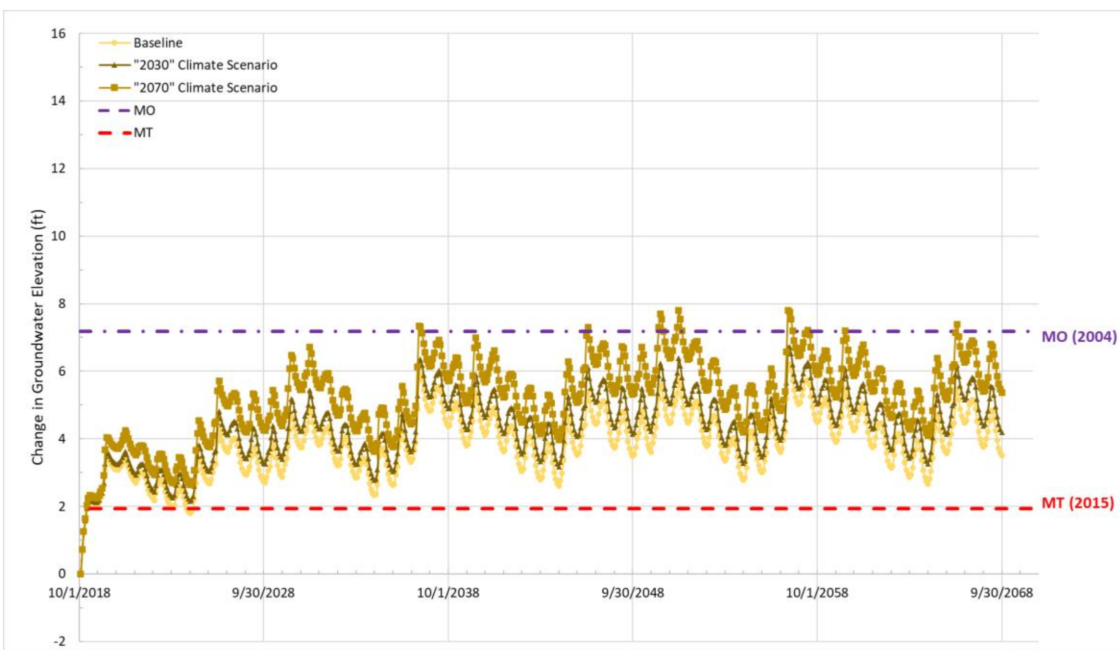

Figure 6-8. Comparison of Groundwater Elevation Changes Under "No Project" Scenario with Various Climate Condition and Measurable Objective Boundary Condition, Marina-Ord Area WBZ

6.5.4.3 *Corral de Tierra Area WBZ Net Annual Change in Groundwater Storage and Projected Changes in Groundwater Elevations relative to SMCs*

Table 6-6 summarizes projected annual inflows and outflows from the Corral de Tierra Area WBZ under identified variable boundary conditions. The projected net annual change in groundwater storage ranged between -578 and -362 AFY in the Corral de Tierra Area WBZ for the "No Project" scenario under variable boundary conditions. The net annual change in groundwater storage is significantly lower than that calculated for the historical period (-2,803 AFY), but is still in slight overdraft over the entirety of the 50-year analog period. Review of climate scenario results presented in Appendix 6A, indicates that this conclusion is true under all of the identified climate change scenarios. As such, these projected water budget results indicate that this management area will be in overdraft even if adjacent basins are managed to their MOs and no projects are undertaken.

Figure 6-9 depicts average projected changes in groundwater elevations at RMS wells in the Corral de Tierra Area WBZ under the "No Project" scenario with variable boundary conditions. This figure also identifies the average change in water levels required to reach MTs and MOs at RMS wells in the Corral de Tierra Area WBZ. As shown on Figure 6-9, groundwater elevations in RMS wells within the Corral de Tierra Area WBZ appear to stabilize in the last 10 years of the 50 year analog period. However, they stabilize at levels that are on average 17 to 25 feet lower than groundwater elevation MTs and 28 to 36 feet lower than groundwater elevations MOs even if SMCs are achieved in adjacent subbasins under these boundary condition scenarios.

Figure 6-10 presents the effects of variable climate scenarios on groundwater elevations within Corral de Tierra Area WBZ under the "No Project" scenario with MO Boundary conditions. This figure indicates that variable climate conditions have limited impacts on projected water levels in RMS wells relative to boundary condition scenarios.

In aggregate, these results suggest that projects and/or management actions will be required to raise water levels above MTs and to achieve MOs within the Corral de Tierra Area WBZ.

On August 25, 2021 the SVBGSA Monterey Subbasin Planning Committee received an updated presentation on the potential relationship between groundwater elevations and arsenic concentrations in the Corral de Tierra area. The committee discussed new options for the groundwater elevations SMCs specific to the Corral de Tierra Management area, and passed a motion to raise the minimum thresholds and measurable objectives to 2008 and 2004/2005 elevations respectively. These changes have not yet been incorporated into the modeling results, or the rest of the GSP. This statement is here as a placeholder for the reader, and as a reminder to the GSP process that stakeholder input is valuable to the development and implementation of sustainable management of groundwater resources.

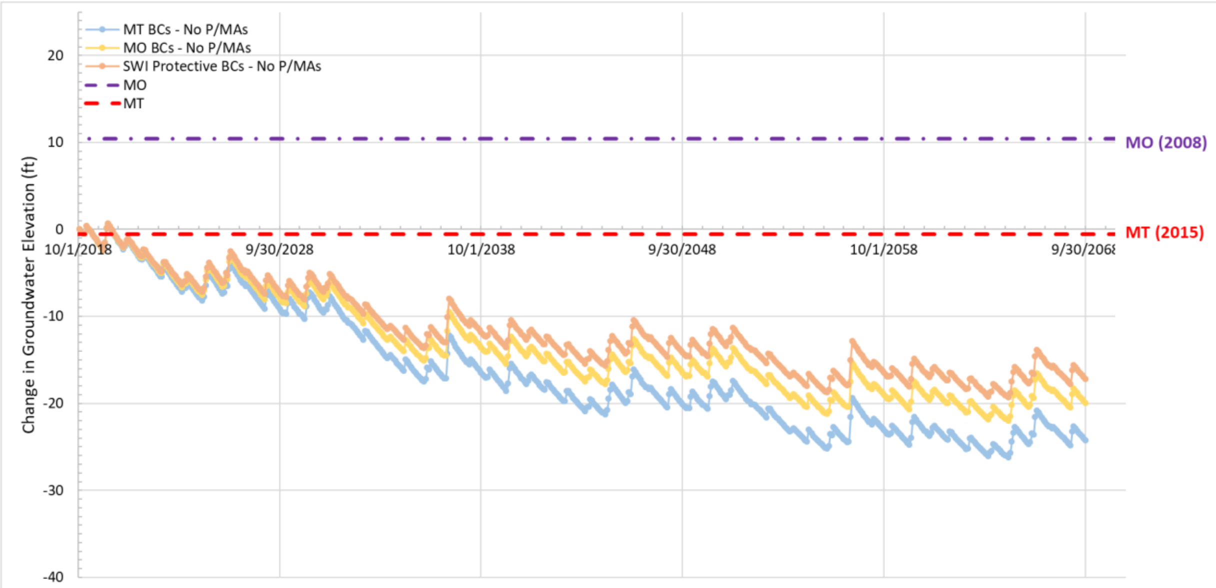

Figure 6-9. Comparison of Groundwater Elevation Changes Under "No Project" Scenario with Various Boundary Conditions and 2030 Climate Condition, Corral de Tierra Area WBZ

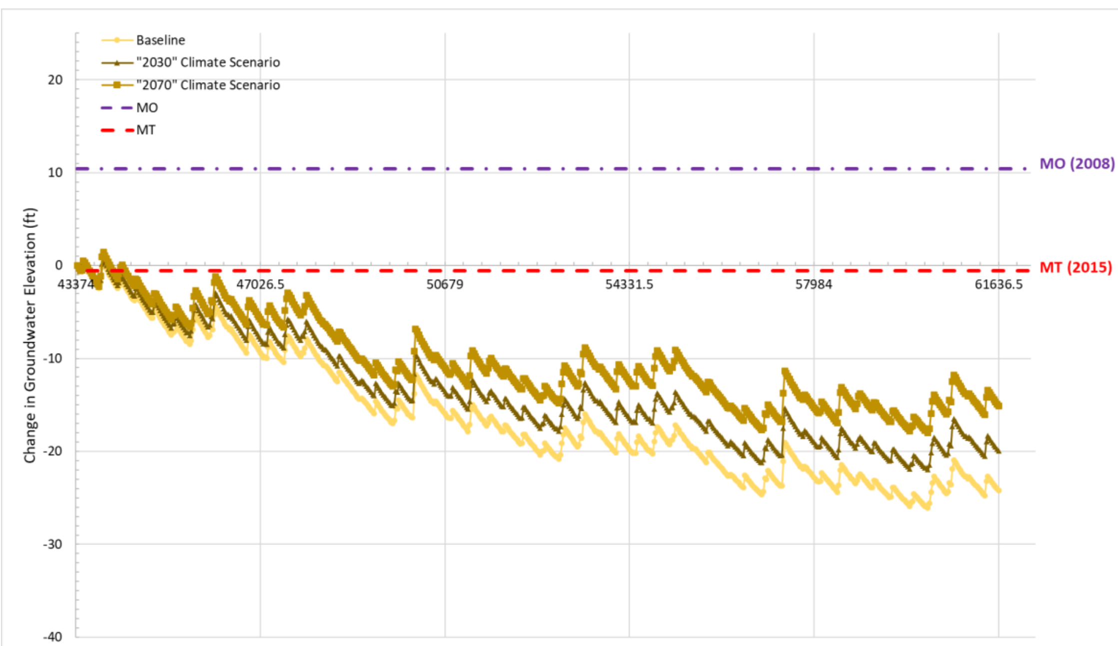

Figure 6-10. Comparison of Groundwater Elevation Changes Under "No Project" Scenario with Various Climate Condition and Measurable Objective Boundary Condition, Corral de Tierra Area WBZ

6.5.5 "Project" Scenario Results

Table 6-8 summarizes projected water budget results for the Marina-Ord Water Augmentation "Project" scenario with variable boundary conditions. The Marina-Ord water augmentation scenario is described in Section 6.5.2.2. It results in an average annual pumping rate over the 50-year analog period of 4,488 AFY within the Marina-Ord Area WBZ. This average annual pumping rate is below the estimated average annual recharge within the Subbasin under all projected climate scenarios, which range between (6,356 AFY and 7,509 AFY)[12]. This average annual pumping rate represents a 4,279 AFY reduction in projected pumping from the "No Project" scenario".

The project does not however result in a similar net annual increase in groundwater storage over the "No Project" scenario (see Table 6-5). Net annual changes in groundwater storage for this project only average 200 AFY more than the "No Project" scenario. The limited increase in net groundwater storage is the result of projected increases in net outflows to the 180/400-Foot Aquifer Subbasin and decreases in net inflows from the Seaside Subbasin and ocean under this "Project" scenario.

Consistent with the "No Project" scenario the projected water budget for this "Project" scenario results in a positive net increase in storage over the 50-year analog period, under all identified boundary condition and climate condition scenarios. As such, these projected water budget results indicate that this management area will not be in overdraft under this "Project" scenario if adjacent basins are managed sustainably and SMCs are achieved. This "Project" scenario also results in a decrease in inflows from the ocean and inflows from 180/400 foot Aquifer subbasin to the lower 180-Foot Aquifer and 400-Foot Aquifer, which are seawater intruded. Therefore this "Project" scenario likely reduces the risk of expansion of the seawater intrusion front over the "No Project" scenario.

Figure 6-11 depicts (a) average projected changes in groundwater elevations at RMS wells in the Marina-Ord Area WBZ under the "Project" scenario with variable boundary conditions and (b) average change in water levels required to reach MTs and MOs at RMS wells in the Marina-Ord Area WBZ. Projected groundwater elevations under this "Project" scenario also stabilize within the first 10 years of GSP implementation for all boundary conditions and are constant over the 30-year post-GSP implementation period during which groundwater rates of extraction are 4,376 AFY. However, the resulting average groundwater elevation varies significantly between the various boundary scenarios. The results indicate that under the "Project" scenario groundwater elevations in RMS wells within the Marina-Ord Area WBZ will:

- reach MTs if MT Boundary Conditions are met,

[12] See Tables 6A-4 and 6A-5 in Appendix 6A.

- reach MOs if MO Boundary Conditions are met; and
- reach MOs and MTs if SWI Protective boundary conditions are met.

These results suggest, however, that even under this “Project” scenario, groundwater elevations in RMS wells will not meet MOs in the Marina-Ord Area WBZ if MO boundary conditions are not achieved in adjacent subbasins. As described in Section 8.7.4, such conditions could lead to increases in seawater intrusion within the Monterey Subbasin and lead to undesirable results. As such, a coordinated approach to sustainable groundwater management will be required between subbasins within the Salinas Valley Basin.

Table 6-8. Comparison of Projected Water Budget Results Under Marina-Ord Area Water Augmentation "Project" Scenario with Variable Boundary Conditions and 2030 Climate Condition

Net Annual Groundwater Flows (a) (AFY)	Historical Annual Inflows/Outflows (WY 2004-2018)	Projected Annual Inflows/Outflows (b) 2030 Climate Conditions		
		Minimum Threshold Boundary Conditions	Measurable Objective Boundary Conditions	Seawater Intrusion Protective Boundary Conditions
Recharge				
● Rainfall, leakage, irrigation	6,144	6,823	6,823	6,823
	6,144	**6,823**	**6,823**	**6,823**
Well Pumping				
● Well Pumping (c)	-4,346	-4,488	-4,488	-4,488
	-4,346	**-4,488**	**-4,488**	**-4,488**
Net Inter-Basin Flow				
● Seaside Subbasin	1,310	1,776	612	-1,115
● 180/400 Foot Aquifer Subbasin	-8,633	-6,833	-4,901	-1,788
● Ocean (Presumed Freshwater)	-524	-738	-764	-806
● Ocean (Presumed Seawater)	2,872	2,617	2,047	989
	-4,975	**-3,178**	**-3,006**	**-2,721**
Net Intra-basin Flow				
● From Corral de Tierra Area	1,544	898	1,001	958
	1,544	**898**	**1,001**	**958**
Net Surface Water Exchange				
● Salinas River Exchange	0	0	0	0
	0	**0**	**0**	**0**
NET ANNUAL CHANGE IN GROUNDWATER STORAGE	**-1,632**	**55**	**330**	**572**

Notes:

(a) The Marina-Ord Area Zone Budget includes inflows to and outflows from the portion of Corral de Tierra that is north of Reservation Rd.
(b) Positive values indicate a net inflow and negative values indicate a net outflow.

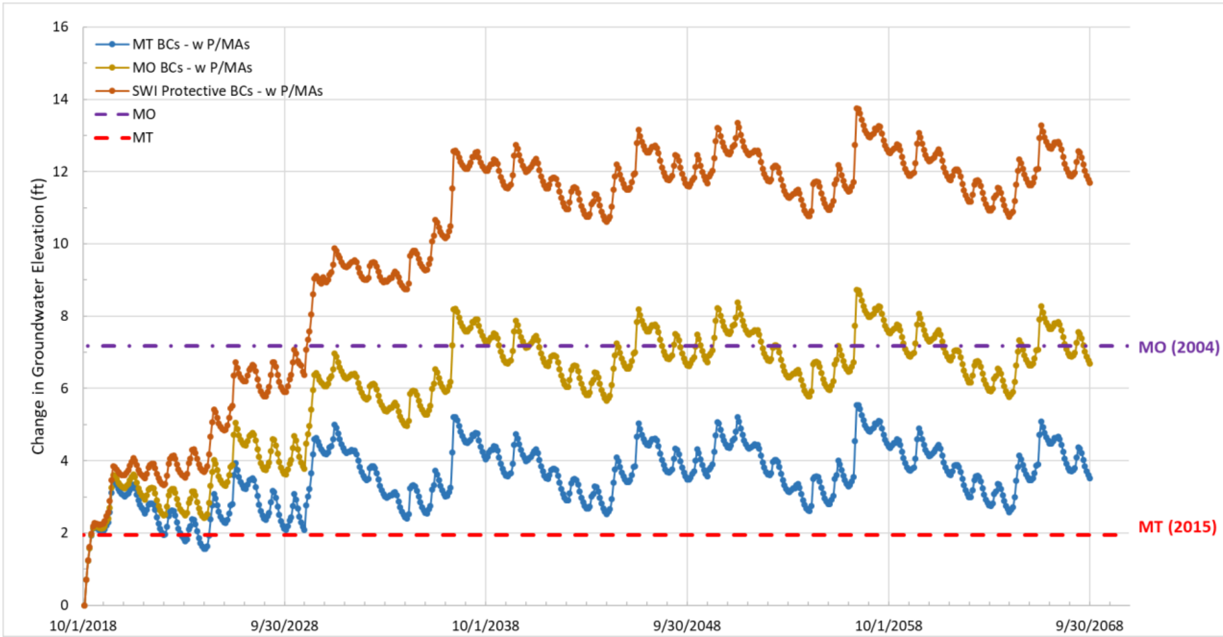

Figure 6-11. Comparison of Groundwater Elevation Changes Under Marina-Ord Water Augmentation "Project" Scenario with Various Boundary Conditions and 2030 Climate Condition, Marina-Ord Area WBZ

6.6 Historical, Current, and Projected Overdraft and Sustainable Yield

SGMA defines sustainable yield 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" (CWC § 10721(w)). DWR's Water Budget BMP (DWR, 2016b), further states that "Water budget accounting information should directly support the estimate of sustainable yield for the basin and include an explanation of how the estimate of sustainable yield will allow the basin to be operated to avoid locally defined undesirable results. The explanation should include a discussion of the relationship or linkage between the estimated sustainable yield for the basin and local determination of the sustainable management criteria (sustainability goal, undesirable results, minimum thresholds, and measurable objectives)."

A key part of the codified definition and the BMP statement is the avoidance of undesirable results, defined as "significant and unreasonable" effects for any of the six SGMA sustainability indicators. For example, with regard to groundwater levels, declining levels during a drought do not constitute an Undesirable Result for Chronic Lowering of Groundwater Levels if extractions and groundwater recharge are managed as necessary to ensure that reduction in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods (CWC § 10721(x)(1)). Therefore, while the water budget should provide support for sustainable yield, determination of the sustainable yield for the subbasin ultimately depends upon whether undesirable results are avoided within the time-frames required by SGMA.

The sustainable yield of the Monterey Subbasin is significantly affected by recharge, pumping, and conditions in adjacent subbasins. As such, the sustainable yield established on the basis of historical overdraft has significant uncertainty and does not address all undesirable results. Groundwater conditions in adjacent subbasins are projected to change as these subbasins move toward sustainability. A first order estimate of the sustainable yield is estimated by subtracting overdraft from extraction; however, since sustainable management criteria were not established historically, the sustainable yield does not reflect sustainability as it is defined in this GSP. Projected water budget results have been used to estimate the projected sustainable yield. The sustainable yield has been evaluated by Management Area (i.e. water budget zone) as conditions vary and independent SMCs have been established for each area.

6.6.1 Marina-Ord Area WBZ

A estimate of the three sustainable yields of the groundwater system underlying the Marina-Ord Area WBZ can be made on the basis of the water budget data presented in Table 6-2, and the "No Project" water budget results presented in Section 6.5.4.

The simplifying assumptions for estimating historical sustainable yield is that a first-order estimate can be developed by subtracting the historical average overdraft from the historical average extractions. Data in Table 6-2, show that the historical pumping in the Marina-Ord Area WBZ was 4,346 AFY, and the historical overdraft was 1,632 AFY. This calculation leads to an estimated historical sustainable yield in the WBZ of 2,714 AFY.

Data in Table 6-2 additionally show that the average annual pumping in the current time period is 3,503 AFY, and average annual overdraft in the current time period is 209 AFY. This calculation leads to an estimated current sustainable yield in the WBZ of 3,294 AFY. The current time period represent only a few years, and is not indicative of long-term groundwater conditions. Therefore, the current sustainable yield and overdraft estimates should not be used for developing long-term groundwater management strategies.

The projected water budget for the "No project" scenario results in a positive net increase in storage over the 50-year analog period, under all identified boundary condition and climate condition scenarios. Further, projected groundwater level data presented in Section 6.5.4.2 indicate that groundwater levels stabilize within the first 10 years of GSP implementation and are constant over the 30-year post-GSP implementation period under all identified boundary scenarios and climate conditions. Annual rates of groundwater extraction during this 30-year post-GSP implementation period average 9,870 AFY. As such, these projected water budget results support the conclusion that 9,870 AFY can be pumped from the Marina-Ord Area WBZ with no long term loss in storage, and provide the first-order estimate of the sustainable yield of the Marina-Ord Area WBZ. They also support the conclusion that the Marina-Ord Area WBZ will not be in overdraft in the future if adjacent subbasins are managed sustainably and the 180/400 Foot aquifer Subbasin reaches its SMCs.

These calculations provide only first-order estimates of the magnitude of the Marina-Ord Area WBZ sustainable yield. The historical and current sustainable yield estimates are for information only, and do not guide groundwater management activities in this GSP. The projected sustainable yield provides a first-order estimate of anticipated sustainable pumping if no projects are implemented. However, simply reducing pumping to within the sustainable yield is not proof of sustainability under SGMA, which must be demonstrated by avoiding undesirable results for all 6 sustainability indicators.

Comparison of projected groundwater levels within the Marina-Ord Area WBZ under the “no project” and “project” scenarios with established MTs and MOs provides significant insight regarding the projected sustainable yield as defined under SGMA. As discussed above, the attainment of MTs and MOs, which are established to avoid undesirable results and achieve basin sustainability, should be considered in the estimation of sustainable yield under SGMA. As discussed in Sections 6.5.4.2 and 6.5.5, projected groundwater level data indicate that:

- Under the “no project” scenario groundwater levels in RMS wells stabilize and are generally higher than MTs during non-drought periods under all identified boundary conditions and climate scenarios, and reach MOs if SWI protective boundary conditions are achieved in adjacent subbasins.

- Under the “Project” scenario, groundwater levels stabilize and are higher than MTs and reach MOs in RMS wells within the Marina-Ord Area WBZ, if MT and MO boundary conditions are achieved in adjacent subbasins, respectively.

These results indicate that the future projected sustainable yield of the Marina-Ord Area WBZ ranges between approximately 4,400 AFY[13] and 9,900[14] AFY if adjacent basins subbasins are managed sustainably and the 180/400 Foot Aquifer Subbasin reaches its SMCs.

Although these projected budget results provide potential insight into the sustainable yield of the Marina-Ord Area, confirmation that these quantities could be extracted without inducing seawater intrusion has to be verified.

[13] Groundwater levels stabilize and annual rates of pumping during the 30-year GSP implementation period average 4,376 AFY for the “project” scenario.
[14] Groundwater levels stabilize and annual rates of pumping during the 30-year GSP implementation period average 9,870 AFY for the “no project” scenario.

6.6.2 Corral de Tierra Area WBZ

Information regarding the sustainable yield of the groundwater system underlying the Corral de Tierra can be garnered on the basis of projected water budget for the historical water budget data presented in Table 6-3, and the "No Project" scenario presented in Section 6.5.4.

The simplifying assumptions for estimating historical sustainable yield is that a first-order estimate can be developed by subtracting the historical average overdraft from the historical average extractions. Data in Table 6-3, show that the historical pumping in the Corral de Tierra Area WBZ was 1,296 AFY, and the historical overdraft was 2,803 AFY. This calculation leads to an estimated sustainable yield in the WBZ of -1,507 AFY. While this is only a rough first-order estimate, the negative sustainable yield suggests that no amount of pumping reduction in the WBZ could have historically brought the area into balance. The outflows to adjacent subbasins and the Marina-Ord Area WBZ result in overdraft that is independent of the WBZ pumping. Using the same method to estimate the current sustainable yield, the annual pumping during the current period in the Corral de Tierra Area WBZ was 1,771 AFY, and the historical overdraft was 1,818 AFY. This leads to an estimated sustainable yield in the WBZ of -47 AFY.

The baseline projected water budget, which includes no projects, with boundary conditions set at measurable objectives in adjacent subbasins results in an annual average storage decrease of 89 AFY over the 30-year of the analog period that represents stabilized boundary conditions. Under "No Project" scenario, annual rates of groundwater extraction over the 30-year analog period average 2,189 AFY. Subtracting the average annual overdraft from the average annual pumping yields a long-term sustainable yield of the Corral de Tierra Area WBZ of 2,100 AFY. This is a first-order estimate, and further analysis is needed to assess if this sustainable yield avoids all undesirable results.

This estimate of sustainable yield would be the sustainable yield to hold groundwater levels where they are after the first 20 years of GSP implementation if there are no projects undertaken. Since groundwater levels are declining, this level would be significantly below current groundwater levels, and below the MTs. Therefore, this sustainable yield estimate of 2,100 AFY. is likely an overestimate of the true sustainable yield when all undesirable results are avoided.

The historical and current sustainable yield estimates are for information only, and do not guide groundwater management activities in this GSP. The projected sustainable yield provides a first-order estimate of anticipated sustainable pumping if no projects are implemented. However, simply reducing pumping to within the sustainable yield is not proof of sustainability, which must be demonstrated by avoiding undesirable results for all 6 sustainability indicators. Further analysis is necessary to refine estimates of where pumping should be reduced to address all sustainability indicators.

6.7 Water Budget Uncertainty and Limitations

Models are mathematical representations of physical systems. They have limitations in their ability to represent physical systems exactly and due to limitations in the data inputs used. There is also inherent uncertainty in groundwater flow modeling itself, since mathematical (or numerical) models can only approximate physical systems and have limitations in how they compute data. However, DWR (2018) recognizes that although models are not exact representations of physical systems because mathematical depictions are imperfect, they are powerful tools that can provide useful insights. As mentioned in Section 6.1 and described in detail in Appendix 6B, the MBGWFM was developed using established scientific practices and principals for groundwater flow simulation, and calibrated using the best available data within the Basin. Inputs to the models 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 models are the best available tools for estimating water budgets and simulating projected groundwater conditions. As demonstrated by the calibration error statistics summarized in Section 6.1. and presented in detail in Appendix 6B, the MBGWFM reasonably represents historical groundwater conditions within the Subbasin.

As is the case with any numerical groundwater flow model, the MBGWFM is subject to uncertainties and data gaps in hydrogeologic conceptualization (e.g., depth and extent of principal aquifer units), model parameterization (e.g., aquifer transmitting and storage properties) and calibration data (i.e., historical water level monitoring data), and simulated stresses (e.g., recharge, pumping, and boundary conditions). Here, "uncertainty" refers to the incomplete understanding of the physical setting, characteristics, and current conditions that significantly affect calculation of the water budgets presented above. "Data gaps" refer to limitations in the spatial coverage of measured data, or periods of time when no data are available. Each of these main categories of uncertainty and/or data gaps contribute to overall uncertainty in the water budget outputs from MBGWFM.

The following list groups water budget components in increasing order of uncertainty.

(a) Measured: metered municipal, agricultural, and some small water system pumping

(b) Estimated: domestic pumping, including depth, rate, and location

(c) Simulated primarily based on climate data: precipitation, evapotranspiration, irrigation pumping

(d) Simulated based on calibrated model: all other water budget components

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.

As part of MBGWFM development and calibration, model uncertainty was evaluated by performing a sensitivity analysis on simulated stresses and aquifer parameters. A detailed description of the model sensitivity and uncertainty analysis is provided in Appendix 6B. A summary of the main limitations of the model and corresponding water budgets identified from this analysis is provided below.

- Uncertainty in Simulated Boundary Conditions. As described in Section 6.2.2., inter-basin cross-boundary flows were simulated at the 180/400 Foot Aquifer Subbasin boundary based on historical groundwater elevation measurements from nearby wells, at the Seaside Area Subbasin boundary based on outputs from the historical Seaside Basin Groundwater Flow Model (Hydrometrics 2009 & 2018), and at the Monterey Coast based on freshwater equivalent sea levels. The datasets and assumptions used to model boundary conditions at each Subbasin boundary are subject to their own uncertainties, data gaps, and limitations, including:
    - *Lack of Deep Aquifer wells with historical data in the 180/400 Foot Aquifer Subbasin.* Only a small number of wells exist in the Deep Aquifers within the 180/400 Foot Aquifer Subbasin with observed water level data spanning the full duration of the Historical Period. As such, simulated Deep Aquifers heads along the northern model boundary are subject to the limitations in available data to the north of the boundary, which may impact resulting calculations of 180/400 Foot Aquifer Subbasin exchanges within the water budget.
    - *Incomplete conceptualization of Principal Aquifer units in the Seaside Basin Groundwater Flow Model.* The Seaside model does not explicitly simulate groundwater flow from each principal aquifer unit defined in the Monterey Subbasin GSP, but rather uses a unique conceptualization of aquifer units that is primarily based on the main geologic formations encountered in the Seaside Area Subbasin (i.e., the Aromas Sands, Paso Robles Formation, and Santa Margarita/Purisima Formations). As such, there is considerable uncertainty surrounding the assumptions employed to link outputs from the Seaside model to individual layers of the MBGWFM[15], which may impact resulting calculations of Seaside Area Subbasin exchanges within the water budget.
    - *Uncertainty in freshwater equivalent head calculations at the Monterey Coast.* As discussed in Section 6.2, freshwater equivalent sea levels at the Monterey Coastline are calculated based on the Ghyben-Herzberg Relation. The depths and distances at which principal aquifer units outcrop along the seafloor were estimated to inform corresponding freshwater equivalent heads at the aquifer-seafloor interface. There is considerable uncertainty surrounding the depths and distances at which each principal aquifer unit comes in contact with the sea floor,

[15] See Appendix 6B for further details.

which may impact resulting calculations of Ocean exchanges within the water budget.

- Uncertainty in Pumping Estimates within the Corral de Tierra (CDT) Management Area. Very limited historical groundwater pumping data are available for the CDT Management Area. As such, CDT groundwater pumping demands were estimated for small water systems and domestic wells by SVBGSA using extraction reported to MCWRA and SWRCB where available, and approximated based on number of households to account for small water systems connections and *de minimis* pumpers. Therefore, the accuracy of CDT groundwater pumping estimates included in the water budget is limited by the lack of available pumping data and uncertainty in the CDT pumping estimates provided by SVBGSA.

- Uncertainty in Deep Aquifers Representation. Groundwater elevation data collected from the Deep Aquifers and the El Toro Primary Aquifer System (both represented by model Layer 8) show heterogeneous conditions in the upper and lower portions of these aquifers. As discussed in Section 5.1.4 and shown on Figure 5-12, a vertical gradient exists between the Paso Robles and Santa Margarita formations of the El Toro Primary Aquifer System. In addition, heterogeneous groundwater elevations were observed in the shallow and deep screens of Deep Aquifer well clusters as shown on Figure 5-14. However, currently there is not enough spatial coverage of data to characterize the upper and lower portions of these aquifers as separate aquifers. Refining representation of the Deep Aquifers and the El Toro Primary Aquifer System will facilitate connectivity between the MBGWFM and the Seaside Subbasin Model, and therefore refine calculation of inter-basin flows. Additional data is needed within both (a) the Monterey Subbasin to characterize and calibrate upper and lower portions of these aquifers and (b) the adjacent subbasins to establish boundary conditions.

- Lack of Water Level Calibration Data. Though the MCWD service area, former Fort Ord Site, and CWS/Cal-Am water service areas within CDT are well monitored, very limited historical groundwater elevation data exists in other portions of the Basin including near the Reservation Rd area, in the Fort Ord Hills, and within the Deep Aquifer unit. As such, MBGWFM calibration in these areas is limited by the lack of available calibration data to quantify model error and inform localized adjustments to model parameterization.

- Climate Change Uncertainty. As described in Section 6.5.1., climate change scenarios were developed based on DWR's 2030 and 2070 Central Tendency climate modeling scenarios (DWR, 2020). These climate scenarios provide a standard framework for defining what might be considered the most likely future climate conditions within the Basin; however, they are inherently subject to considerable uncertainty. As stated in DWR (2018):

- o *"Although it is not possible to predict future hydrology and water use with certainty, the models, data, and tools provided [by DWR] are considered current best available* science *and, when used appropriately should provide GSAs with a reasonable* point *of reference for future planning.*

- o *All models have limitations in their interpretation of the physical system and the types of data inputs used and outputs generated, as well as the interpretation of outputs. The climate models used to generate the climate and hydrologic data for use in water budget development were recommended by [the DWR Climate Change Technical Advisory Group] for their applicability to California water resources planning."*

- Uncertainty in Aquifer Parameters. As mentioned above and described in detail in Appendix 6B, a sensitivity analysis was performed to identify the most sensitive aquifer parameters that will impact model-calculated water levels, and was subsequently used to direct further calibration efforts. In general, it was discovered that the model was most sensitive to specific storage and lateral hydraulic conductivity parameters in each principal aquifer unit. These aquifer parameters were further calibrated using a combination of *Model-Independent Parameter Estimation and Uncertainty Analysis* (PEST) calibration procedures and professional judgement. As described in Appendix 6B, all final calibrated aquifer parameters fell within their respective ranges reported in available pumping test data collected from wells within the Basin.

As discussed in Chapter 10, MCWD GSA and SVBGSA are planning data gap filling activities and monitoring network expansion within the Monterey Subbasin and in the adjacent 180/400-Foot Aquifer Subbasin. These activities are informed by the uncertainties and data gaps identified above and include:

- Monitoring network expansion and aquifer investigations in the 400-Foot Aquifer and Deep Aquifers near the Seaside Subbasin boundary;
- Monitoring network expansion and aquifer investigations in the Corral de Tierra Area near the 180/400-Foot Aquifer Subbasin boundary including the Reservation Road portion and CWS/Cal-Am service areas; and
- GEMS expansion and enhancement as well as a well registration program that intends to cover the entire Monterey Subbasin.

As additional groundwater elevation, aquifer properties, and groundwater extraction data become available, they will be used to refine representation of these aquifers as part of future modeling efforts during the first 5-years of GSP implementation.