# CHAPTER 3 – BASIN SETTING Groundwater Sustainability Plan for the Marina GSA Area of the 180/400 Foot Aquifer Subbasin

City of Marina Groundwater Sustainability Agency Marina, California



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# **3 BASIN SETTING**

# **Regulation Requirements:**

# §354.12 Introduction to Basin Setting

This Subarticle describes the information about the physical setting and characteristics of the basin and current conditions of the basin that shall be part of each Plan, including the identification of data gaps and levels of uncertainty, which comprise the basin setting that serves as the basis for defining and assessing reasonable sustainable management criteria and projects and management actions. Information provided pursuant to this Subarticle shall be prepared by or under the direction of a professional geologist or professional engineer.

This chapter describes the basin setting of the City of Marina Groundwater Sustainability Agency (MGSA) Area of the 180/400 Foot Subbasin (MGSA Area), a 372-acre area at the western end of the 180/400 Foot Aquifer Subbasin (Subbasin). It includes information regarding the hydrogeologic conceptual model, current and historical groundwater conditions, and historical, current, and projected water budgets. The Subbasin is subject to significant and unreasonable seawater intrusion due largely to long-term groundwater extraction in the inland portions of the Subbasin in excess of the sustainable yield, and has been identified by the Department of Water Resources (DWR) as being in a critical condition of overdraft (DWR 2016a). The purpose of this Groundwater Sustainability Plan (GSP) is to support regional efforts to address this undesirable result and return to Subbasin to sustainable groundwater management within 20 years, as required by the Sustainable Groundwater Management Act (SGMA). MGSA will achieve this by supporting the projects and management actions that will be implemented by Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA) under its regional GSP, and by assuring that local groundwater resources are managed sustainably to protect local and regional beneficial uses and users.

The MGSA Area occupies a relatively small area in the larger Subbasin. The basin setting information in the SVBGSA's GSP provides the necessary regional context for Subbasin-wide sustainable groundwater management; however, MGSA has developed this locally focused GSP to provide the framework necessary to ensure sustainable groundwater management in this portion of the Subbasin. The subsequent sections of this chapter provide the necessary local data to support development of a GSP that complies with the requirements of the Sustainable Groundwater Management Act (SGMA) and supports sustainable groundwater management. Information from or references to the SVBGSA's GSP are included where appropriate. In addition, information regarding SVBGSA's regional groundwater budget for the basin is adopted in this GSP, and supplemented with local data as appropriate.

# 3.1 Hydrogeologic Conceptual Model

# **Regulation Requirements:**

§354.14(a) Each Plan shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterizes the physical components and interaction of the surface water and groundwater systems in the basin.

# 3.1.1 Introduction

The 372-acre MGSA Area is approximately 7,850 feet long by 2,200 feet wide and is located entirely within the City of Marina (City or Marina) city limits. The Subbasin is at the northern, down-gradient end of the Salinas Valley Groundwater Basin – an approximately 90-mile-long alluvial basin underlying the elongated, intermountain valley of the Salinas River. The Subbasin is oriented southeast to northwest along the coast, with the Salinas River draining toward the northwest into the Pacific Ocean at Monterey Bay. The Salinas River watershed drains approximately 4,600 square miles of land in Monterey and San Luis Obispo Counties, and is the dominant riparian corridor along the central coast of California (RCDMC 2019a). Originating in the Los Padres National Forest, the Salinas River flows northwesterly for about 150 miles through the Salinas Valley and empties into Monterey Bay north of the MGSA Area. The valley is nestled between two sets of mountain ranges, the Gabilan Range to the east and the Santa Lucia Range and Sierra de Salinas to the west, both of which are part of the California Coast Range geomorphic province. The watershed includes 200,000 acres of irrigated farmland. Besides providing aquifer recharge for the irrigation water for Monterey County's agricultural industry, the river and its tributaries provide fish and wildlife habitat.

# 3.1.2 GSP AREA EXTENT

# **Regulation Requirements:**

§354.14(b)(2) The hydrogeologic conceptual model shall be summarized in a written description that includes lateral basin boundaries, including major geologic features that significantly affect groundwater flow.

§354.14(b)(3) The hydrogeologic conceptual model shall be summarized in a written description that includes the definable bottom of the basin.

The MGSA Area lies within the western portion of the 180/400 Foot Aquifer Subbasin, and is one of nine subbasins of the Salinas Valley Groundwater Basin, of which six subbasins are being managed in part or in whole by SVBGSA. The Subbasin extents are defined by the DWR and are documented in Bulletin 118 (DWR 2003; DWR 2016a). Figure 3-1 illustrates the extent of the MGSA Area within the Subbasin. It is bounded to the south by the Monterey Subbasin, and to the west by the Pacific Ocean.

# 3.1.2.1 LATERAL SUBBASIN AND GSP AREA BOUNDARIES

The 180/400 Foot Aquifer Subbasin is bounded by a combination of inter-subbasin boundaries within the Salinas Valley Groundwater Basin, and outer boundaries of the Salinas Valley Basin:

- Inter-subbasin boundaries surrounding the 180/400 Foot Aquifer Subbasin generally do not
  follow physical or hydrologic boundaries, but delineate areas with generally different aquifer
  characteristics, uses or management requirements. These include inter-subbasin boundaries
  with the Forebay Subbasin, Eastside Subbasin, Langley Subbasin and Monterey Subbasin.
- Basin boundaries surrounding the 180/400 Foot Aquifer Subbasin that coincide with the Salinas Valley Groundwater Basin follow physical basin and aquifer boundaries or prominent hydrologic features. These include:

- The Monterey Bay Shoreline to the west;
- Elkhorn Slough to the north (which separates the Subbasin from the Pajaro Valley Subbasin; and
- The Sierra de Salinas, which forms the basin and aquifer boundary along the southern half of the southwest Subbasin boundary.

The MGSA Area lateral limits are the City of Marina city limits on the north, west and east, and the Monterey Subbasin boundary on the south. The western boundary coincides with the mean high tide line of the Pacific Ocean (Figure 3-2).

#### 3.1.2.2 VERTICAL SUBBASIN AND MGSA AREA BOUNDARIES

The sedimentary sequence in the Salinas Valley structural trough is 10,000 to 15,000 feet thick. However, the productive drinking water aquifers are only at shallower depths, with the effective thickness of the groundwater Subbasin being approximately 1,500 feet (Durbin *et al.* 1978). The base of the Subbasin is not a sharp interface between permeable sediments and lower-permeability basement rock, but a general transition to less productive and more saline aquifers that may vary in depth by location. With increasing depth, increased consolidation and cementation of the sediments decreases the well yield, and deeper marine formations contain poor-quality saline groundwater unsuitable for most uses.

Figure 3-3 shows a contour map of the estimated depth to the base of the aquifers in the basin (Durbin *et al.* 1978). In the vicinity of the MGSA Area, the aquifers above a depth of approximately 700 feet are seawater intruded, and water supply wells extract groundwater from the "Deep Aquifer," which is a system of aquifers that occurs between approximately 900 and 2,000 feet below ground surface (Hanson *et al.* 2002) within the Pliocene marine Purisima Formation. The wells completed in this aquifer system near the MGSA Area provide the water supply for Marina Coast Water District (MCWD), which serves the City of Marina and the adjacent Ord Community. These wells are completed at depths ranging from approximately 900 to approximately 1,950 feet below ground level. This GSP has adopted the base of the Deep Aquifer system and the vertical boundary of the MGSA Area as 2,000 feet below ground level.

# 3.1.3 Topographic Information

# **Regulation Requirements:**

**§354.14(d)(1)** Physical characteristics of the basin shall be represented on one or more maps that depict topographic information derived from the U.S. Geological Survey or another reliable source.

The Subbasin and MGSA Area are located at the northern, seaward end of the Salinas Valley. The valley trends north-northwestward between two sets of mountain ranges, the Gabilan Range to the east and the Santa Lucia and Sierra de Salinas to the west, both of which are part of the Pacific Coast Range.

Elevations in the Subbasin range from approximately 500 feet above mean sea level (msl) along the Sierra de Salinas to sea level at Monterey Bay, and fall northwestward at an average grade of approximately 5 feet/mile to the northwest. The Salinas River carries sand along the valley into the Pacific Ocean, where it is transported southward along the coast by longshore currents. The sand is blown onshore by coastal winds, forming a series of coastal dunes along the shore south the Salinas River. The MGSA Area encompasses an area of unique Flandrian coastal dunes at the seaward edge of Salinas Valley on the north side of the City of Marina and south of the Salinas River. The elevation within the MGSA Area ranges from about 100 feet above msl near the top of the coastal dunes to sea level at Monterey Bay. The colored bands on Figure 3-4 show the topography of the Subbasin, derived from the United States Geological Survey (USGS) Digital Elevation Model (DEM).

#### **3.1.4 Surface Water Features**

#### **Regulation Requirements:**

§354.14(d)(5) Physical characteristics of the basin shall be represented on one or more maps that depict surface water bodies that are significant to the management of the basin.

The Salinas River watershed drains approximately 4,600 square miles of land in Monterey and San Luis Obispo Counties, and is the dominant riparian corridor along the central coast of California (RCDMC 2019a) and the primary surface water body in the Subbasin. The river runs through the entire length of the Subbasin and is fed by local tributaries (Figure 3-5). The Salinas River watershed includes 200,000 acres of irrigated farmland. Originating in the Los Padres National Forest, the Salinas River flows northwesterly for about 150 miles through the Salinas Valley and empties into Monterey Bay approximately 4,000 feet north of the MGSA Area. Besides providing aquifer recharge for the irrigation water for Monterey County's agricultural industry, the river and its tributaries provide fish and wildlife habitat. The mouth of the Salinas River forms a lagoon; its outflow to Monterey Bay is blocked by sand except during winter high-water flows. MCWRA operates a slide-gate to transfer water through a culvert from the lagoon northward into Old Salinas River during the wet season for flood control (MCWRA 1994). The Old Salinas River discharges through tide gates at Potrero Road into Moss Landing Harbor and ultimately the Monterey Bay.

The only surface water features within the MGSA Area are four artificial process ponds on the CEMEX plant site that were constructed to support industrial sand mining and processing operations on the site. These include a dredge pond and three percolation ponds, which are generally devoid of vegetation.

Regionally, the following surface water bodies are located outside of the Subbasin but are important controls on the rate and timing of Salinas River discharges:

 Two reservoirs constructed to control flooding and to increase recharge from Salinas River to groundwater:

- Lake Nacimiento, in San Luis Obispo County, was constructed in 1957 and has a storage capacity of 335,000 acre-feet (MCWRA 2018).
- Lake San Antonio, in Monterey County, was constructed in 1967 and has a storage capacity of 377,900 acre-feet.
- Arroyo Seco, a tributary with a 275-square-mile drainage area that has no dams in its drainage basin and is characterized by both very high flood flows and extended dry periods.

#### 3.1.5 REGIONAL GEOLOGIC AND STRUCTURAL SETTING

# **Regulation Requirements:**

**§354.14(b)(1)** The hydrogeologic conceptual model shall be summarized in a written description that includes the regional geologic and structural setting of the basin including the immediate surrounding area, as necessary for geologic consistency.

The Subbasin was formed through periods of structural deformation and periods of marine and terrestrial sedimentation in a tectonically active area on the eastern edge of the Pacific Plate. Figure 3-6 presents a geologic map of the Salinas Valley Basin and vicinity, illustrating both the locations of faults and the geologic formations present at ground surface. The legend in Figure 3-7 presents the age sequence of the geologic materials from the youngest unconsolidated Quaternary sediments to the oldest basement rock.

Salinas Valley is a structural basin filled with Quaternary alluvial sediments and Tertiary marine and continental deposits. In the vicinity of the MGSA Area Quaternary dune sands generally occur on a terrace south of the Salinas River, and alluvial and flood plain basin deposits occur north of the river (Figure 3-8). There are no known structural features that restrict groundwater flow inside or immediately surrounding the MGSA Area, or within the 180/400 Foot Aquifer Subbasin.

# 3.1.5.1 GEOLOGIC FORMATIONS

# **Regulation Requirements:**

§354.14(b)(4)(a) Formation names, if defined.

Major geologic units present in the subsurface and on the flanks of the 180/400 Foot Subbasin are described below from youngest to oldest. The corresponding designation on Figure 3-6 is provided in parenthesis. This discussion on the Subbasin geology is derived from the SVBGSA GSP (SVBGSA 2020).

Aromas Sand (QPc) – This Pleistocene unit is composed of cross-bedded sand containing some clayey layers (Harding ESE 2001). This unit was deposited in a combination of eolian, high-energy alluvial, alluvial fan, and shoreline environments (Harding ESE 2001; Greene 1970; and Dupre 1990). The Aromas Sand may be up to 300 feet thick (Harding ESE 2001) in the adjacent Monterey Subbasin (Harding ESE 2001) and likely extends into the northern portion of the

180/400 Foot Aquifer Subbasin (MCWRA [Monterey County Water Resources Agency] 2017a), but it is not found in other portions of the basin.

- Paso Robles Formation (Tc) This Pliocene to lower Pleistocene unit is composed of lenticular beds of sand, gravel, silt, and clay from terrestrial deposition (Thorup 1976, Durbin 1978). The depositional environment is largely fluvial (Durbin 1973) but also includes alluvial fan, lake, and floodplain deposition (Harding ESE 2001, Thorup 1976, Greene 1970). The alternating beds of fine and coarse materials typically have bed thicknesses of 20 to 60 feet (Durbin 1978). The Paso Robles Formation overlies the Purisima Formation and underlies all of the Subbasin but is rarely exposed at the surface. Durham (1974) reports that the thickness is variable due to erosion of the upper part of the unit and that the Formation is approximately 1,500 feet thick near Spreckels and 1,000 feet thick near Salinas. Through most of the subbasin, this is the deepest unit and the underlying marine deposits typically do not yield high rates of low total dissolved solids (TDS) groundwater.
- Purisima Formation (P) This Pliocene unit consists of intercalated siltstone, sandstone, conglomerate (Greene 1977), clay, and shale (Harding ESE 2001) deposited in a shallow marine environment. The Purisima Formation is found in the subsurface in the Subbasin and ranges from 500 to 1,000 feet in thickness (WRIME 2003). It is the youngest consolidated sedimentary unit encountered in the Subbasin vicinity and for the most part underlies the basin.
- Santa Margarita Sandstone and Monterey Formation (M) These Miocene units consist of friable arkosic sandstone (Santa Margarita) and shale/mudstone (Monterey) deposited in a shallow marine environment (Harding ESE 2001, Greene 1977). In some areas, Santa Margarita Sandstone directly underlies the Paso Robles Formation where the Purisima Formation is absent (Greene 1977). These units typically underlie the basin.

# 3.1.5.2 SURFICIAL GEOLOGY

# **Regulation Requirements:**

§354.14(d)(2) Physical characteristics of the basin shall be represented on one or more maps that depict surficial geology derived from a qualified map including the locations of cross-sections required by this Section.

A local geologic map showing surficial geologic units is presented as Figure 3-8. Surficial geologic units present in the 180/400 Foot Subbasin and MGSA Area consist of Holocene and Quaternary alluvial, dune sand and flood basin deposits, as shown on Figure 3-6 and Figure 3-8. The descriptions below were derived from the SVBGSA GSP (SVBGSA 2020) and other references as noted. Surficial geologic deposits consist of the following from youngest to oldest:

Marine and Nonmarine Sands (Qs) – This unit includes recent (Holocene), active dunes (Qd in Figure 3-6) and old (Pleistocene), vegetated dunes (Qod in Figure 3-8). Active, wind-blown dunes generally extend less than 0.5 mile inland, and older dune sand deposits extend up to 4

miles inland as well as offshore. The active dune areas typically consist of elevated rolling hills composed of loose to moderately consolidated, fine to medium grained, well sorted sand (Ninyo & Moore, 2005; PCE, 2014). Younger, sparsely vegetated, active dunes are present along the coastline and intergrade with well sorted beach sand deposits at the coast. Older, more consolidated, and sometimes weakly cemented dune deposits with more established vegetation are present in the inland areas and underlie most of the area south of the Salinas River near the coast, as well as portions of the offshore area.

- Alluvium (Q and Qs) This Holocene unit predominately consists of unconsolidated layers of mixed sand, gravel, silt, and clay that were deposited in a fluvial environment by the Salinas River and its tributaries. As shown on Figure 3-6, these deposits include active riverbed alluvium, alluvium, and overbank or basin deposits. In the Subbasin, this unit also includes extensive clay layers that were deposited in a shallow marine to brackish-water estuarine environment during periods when sea level rise caused submergence of the northern portion of the basin (Durham 1974). The estuarine deposits extend throughout much of the Subbasin and form prominent aquitards that define the aquifer system discussed in Section 3.1.6. The thickness is not well established because the alluvium is difficult to distinguish from underlying units, but it is likely 100 to 300 feet thick along the axis of the valley (Durham 1974).
- Older Alluvium (Qoa) This Pleistocene unit is composed of alternating, interconnected beds of fine-grained and coarse-grained deposits predominately associated with alluvial fan depositional environments. The Older Alluvium underlies the Qa throughout the Subbasin but is not exposed at the ground surface. The alluvial fan deposits have an estimated maximum saturated thickness of 500 feet (Durham 1974).

#### 3.1.5.3 SOIL CHARACTERISTICS

# **Regulation Requirements:**

§354.14(d)(3) Physical characteristics of the basin shall be represented on one or more maps that depict soil characteristics as described by the appropriate Natural Resource Conservation Service soil survey or other applicable studies.

Regionally, the soils of the Subbasin are derived from the underlying geologic formations and influenced by the historical and current patterns of climate and hydrology. Productive agriculture in the Subbasin is supported by deep, dark, fertile soils. The arable soils of Subbasin historically were classified into four groups (Carpenter and Cosby 1925): residual soils, old valley-filling soils, young valley-filling soils, and recent-alluvial soils. In addition, five classes of miscellaneous soils were mapped that included tidal marsh, peat, coastal beach, and dune sands.

Because the dunes underlying the MGSA Area are active, no significant soil formation has taken place in this area. The soils of the MGSA Area are dune sands (Figure 3-9) listed by USDA Natural Resources Conservation Service (NRCS) as the Dune land (Df) unit (NRCS 2019). More recent surveys classify the soils into categories based on detailed soil taxonomy (U.S. Department of Agriculture [USDA] 2018).

Figure 3-10 is a composite soil map of soils in and near the MGSA Area from NRCS and the Gridded Soil Survey Geographic (gSSURGO) Database that is produced by National Cooperative Soil Survey (NCSS). The soils in the terrace area south of the Salinas River where the MGSA Area is located are generally sandy and well drained to excessively drained with high saturated hydraulic conductivities (Table 3-1). The City of Marina reports that since the soils in the city are dominated by dune sand with a high percolation rate, stormwater runoff from the built environment percolates into the subsurface at a very rapid rate, resulting in little excess runoff and no need for stormwater discharge infrastructure to surface water (City of Marina 2014a).

TABLE 3-1. SUMMARY OF SOIL CHARACTERISTICS IN THE VICINITY OF THE MGSA AREA

Soil Name	Map Symbol	Percent of Area	Drainage Class	Hydrologic Soil Group	Saturated Hydraulic Conductivity (in/hr)
Corducci-Typic Xerofluvents	300	0.1	Somewhat excessively drained	А	19.3
Alviso silty clay loam	Ac	1.3	Very poorly drained	C/D	2.9
Baywood sand	BbC	20.8	Somewhat excessively drained	А	13.0
Clear Lake clay	Cg	7.5	Poorly drained	D	0.8
Coastal beaches	Cm	0.8	Not defined	$D^1$	13.0
Cropley silty clay	CnA	0.6	Well drained	С	0.1
Dune land	Df	6.8	Excessively drained	NA <sup>2</sup>	NA
Metz loamy sand	Me	1.0	Somewhat excessively drained	В	2.7
Metz fine sandy loam	Mf	4.2	Somewhat excessively drained	В	1.6
Metz complex	Mg	4.7	Somewhat excessively drained	В	2.7
Mocho silt loam	MnA	3.5	Well drained	В	1.3
Mocho silty clay loam	MoA	0.9	Well drained	С	5.0
Oceano loamy sand	OaD	30.7	Excessively drained	А	13.0
Pacheco clay loam	Pa	10.9	Poorly drained	С	0.6
Pico fine sandy loam	Pf	0.7	Well drained	А	3.3
Salinas clay loam	SbA	1.7	Well drained	С	4.5
Water	W	2.5	Not available	NA	NA
Xerorthents, dissected	Xd	1.2	Well drained	С	0.4

#### Notes:

#### NA = Data not available.

Hydrologic Group A: Soils having high infiltration rate (low runoff potential) when thoroughly wet.

Hydrologic Group B: Soils having moderate infiltration rate when thoroughly wet.

Hydrologic Group C: Soils having a slow infiltration rate when thoroughly wet.

Hydrologic Group D: Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet.

Source: USDA NRCS Web Soil Survey, https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

<sup>&</sup>lt;sup>1</sup> Beach sand is assigned Hydrologic Group D because it is assumed to be saturated at a very shallow depth.

<sup>&</sup>lt;sup>2</sup> Dune land are not assigned a Hydrologic Group; however, are assumed to have low runoff potential.

#### 3.1.5.4 REGIONAL CROSS-SECTIONS

#### **Regulation Requirements:**

§354.14(c) The hydrogeologic conceptual model shall be represented graphically by at least two scaled cross-sections that display the information required by this section and are sufficient to depict major stratigraphic and structural features in the basin.

Three regional cross-sections along and across the Subbasin are shown in Figure 3-11, Figure 3-12, and Figure 3-13 (Kennedy-Jenks 2004). These cross sections are adopted from the SVBGSA Subbasin GSP (SVBGSA 2020). The locations of these cross-sections are depicted in Figure 3-6. The hydrogeologic cross-sections are based on geologic logs provided in California DWR Water Well Drillers Reports (DWR-188 forms) filed by the well drillers, and depict the general stratigraphic distribution and lithology of the principal water supply aquifers in the Subbasin. Geologic log descriptions were grouped into hydrologic units as follows:

- Fine-grained sediments (e.g., clay, silt, sandy clay, and gravelly clay) are shown as aquitards;
- Coarse-grained sediments (e.g., sand, gravel, and sand-gravel mixtures) are shown as aquifers;
- Sediments logged as gravel/clay, sand/clay, and sand/gravel/clay are interpreted to consist of interbedded coarse-grained and fine-grained deposits and are included with aquifer materials.

The cross sections show the extent of the 180-Foot Aquifer and 400-Foot Aquifer and aquitards (Salinas Valley Aquitard and 180/400 Foot Aquitard) throughout the Salinas Valley basin, and illustrate the heterogeneity of these aquifers units and the aquitards that separate them. The major aquitards are discontinuous at various locations, most importantly near the coast, where the MGSA Area is located. Locally important shallow aquifers are not identified at the scale of these cross sections.

# 3.1.6 AQUIFER SYSTEM

#### **Regulation Requirements:**

**§354.14(b)(4)** The hydrogeologic conceptual model shall be summarized in a written description that includes the principal aquifers and aquitards.

§354.14(b)(4)(c) Structural properties of the basin that restrict groundwater flow within the principal aquifers, including information regarding stratigraphic changes, truncation of units, or other features.

Previous hydrogeological studies in and around the region of interest provide detailed background information about the regional hydrostratigraphy (Fugro West Inc. 1995, Harding ESE 2001, Kennedy/Jenks Consultants 2004, MACTEC 2005; Geoscience Support Services 2014, Hopkins Groundwater Consultants 2016). Historically, in hydrostratigraphic investigations, the region that lies north of the Salinas River, which comprises most of the Salinas Valley basin, has been discussed separately from the region south of the Salinas River, which includes the Marina and Fort Ord areas. While there are geological and geographic differences between the two regions, most of the equivalent aquifers produced for beneficial uses in each region are believed to be hydraulically connected. Here, we

present a brief review of the hydrostratigraphy in the coastal region of interest, noting major differences between the regions north and south of the Salinas River. The units are discussed roughly in order of highest to lowest elevation. Much of this discussion is adapted from Gottschalk *et al.* (2018). Though these aquifer-system units are referred to here as "aquifers," they generally constitute heterogenous assemblages of fine- and coarse-grained deposits (Hanson *et al.* 2002).

#### 3.1.6.1 DUNE SAND AQUIFER

The Dune Sand Aquifer is present south of the Salinas River, and is the predominant unconfined aquifer in the Marina and Fort Ord areas. It is composed of fine to medium grained, well sorted aeolian sand of Pleistocene to Recent age that extends offshore and up to 4 miles inland, and extends to depths up to 85 to 95 feet beneath the ground surface at the coast in the MGSA Area. While the Dune Sand Aquifer is laterally continuous at and in the vicinity of the MGSA Area, it is not commonly used for drinking water or agricultural irrigation. However, as discussed later in this chapter, the Dune Sand Aquifer is connected to surface water systems and yields significant quantities of groundwater to groundwater-dependent ecosystems (GDE), stores a substantial quantity of low-TDS groundwater with designated beneficial uses, is an important source of low-TDS groundwater recharge to aquifers below it, and contains low-TDS groundwater in equilibrium with an intruding saline water wedge deeper in the aquifer system. Therefore, in this GSP, the Dune Sand Aquifer is considered a principal aquifer because of its local importance.

Within much of the Marina and Fort Ord areas, the Dune Sand Aquifer overlies a clay layer known in Fort Ord groundwater investigations as the Fort Ord- Salinas Valley Aquitard (FO-SVA) and known more regionally as part of the Salinas Valley Aquitard (SVA). When underlain by the SVA, the Dune Sand Aguifer is also referred to as the Perched Dune Sand Aguifer (Hopkins Groundwater Consultants 2016), or the A-Aquifer (Ahtna Environmental Inc. 2017). The underlying SVA or other aguitards, where present, are considered to create a perched or semi-perched condition for the Dune Sand Aquifer. Near the coast and south of the Salinas River, the SVA thins out, bringing the Dune Sand Aquifer and the underlying 180-Foot Aquifer into hydraulic connection. The thinning of the SVA is coincident with a drop in the hydraulic head in the Dune Sand Aquifer. Here the groundwater enters the underlying Upper 180-Foot Aquifer, and flows southeastward, according to the hydraulic gradient (Ahtna Environmental Inc. 2017). In the MGSA Area, the Dune Sand Aquifer is seawater intruded; however, high recharge rates have resulted in a large zone of groundwater containing lower concentrations of TDS immediately east of, and extending into the eastern portion of, the MGSA Area. The seaward discharge of low TDS groundwater from this area, and the flow of groundwater from the Dune Sand Aquifer to the Upper 180-Foot Aquifer, appears to mound groundwater in the Dune Sand and Upper 180-Foot Aquifers near the coast, creating a local groundwater barrier against encroaching seawater intrusion.

As a result of the relatively high permeability of the Dune Sand Aquifer, it supports high recharge rates and has little to no runoff. It is notable that south of the Salinas River, there are no major creeks, streams or rivers that drain at and in the vicinity of the MGSA Area (Figure 3-5), which relates to the high

permeability, high recharge rate of the Dune Sand Aquifer. Groundwater occurs at depth beneath the tall, active dunes at the coast, but can be relatively shallow further inland and beneath hollows and depressions. As discussed in Section 3.2.6.2, near the MGSA Area, the Dune Sand Aquifer is hydraulically connected to, and supports, local groundwater-dependent ecosystems (GDEs), including palustrine and emergent wetlands which support protected species.

# 3.1.6.2 SALINAS VALLEY AQUITARD (SVA)

The Salinas Valley Aquitard is a laterally extensive clay and sandy clay layer covering much of the Salinas Valley basin, east of Fort Ord, and from the Monterey Bay south past Salinas. It is approximately 100 feet thick west of Salinas (Kennedy/Jenks 2004). South of the Salinas River, a similar unit of clay is locally called the FO-SVA as discussed previously. Harding ESE (2001) concluded that the SVA and the FO-SVA are "either the same or at least hydraulically equivalent." Within this GSP, the two units are referred to collectively as the SVA. In the Salinas Valley basin, the SVA is thicker and relatively flat, while in the Fort Ord area, the SVA is higher in elevation and dips more steeply toward the coast (*ibid*). Near the coast and south of the Salinas River, the SVA thins out, bringing the Dune Sand Aquifer and the underlying 180-Foot Aquifer into hydraulic connection.

#### 3.1.6.3 180-FOOT AQUIFER

The 180-Foot Aquifer underlies the SVA and is the uppermost regional aquifer that has historically been used as a groundwater supply. Near the MGSA area, it is seawater intruded; however, due to recharge from the overlying Dune Sand Aquifer, it contains a zone of groundwater with relatively low concentrations of TDS east of the MGSA Area. The aquifer ranges from 50 to 150 feet in thickness, and within the Salinas Valley basin, the top is often encountered 100 to 150 feet below ground surface (ft bgs) (Kennedy/Jenks 2004). The 180-Foot Aquifer extends across more than one stratigraphic or geologic unit, and various interpretations have correlated it to different combinations of stratigraphic units depending on the investigator, the area under study, and the investigator's interpretation. In the MGSA Area, it has been correlated with the lower portions of the Quaternary Alluvium and the upper portions of the Aromas Sand (ESA 2018). The Upper 180-Foot Aquifer, believed to be 20 to 60 feet thick (Harding ESE 2001), is considered to be in hydraulic connection with the Dune Sand Aquifer near the coast, as the SVA thins out. The Intermediate 180-Foot Aquitard, a sequence of silty and clayey beds, hydraulically separates the sandy Upper 180-Foot Aquifer from the gravelly Lower 180-Foot Aquifer in the Marina and Fort Ord area. Geophysical studies reported by Gottschalk *et al.* (2018) have confirmed this aquitard is discontinuous in the vicinity of the MGSA Area.

# 3.1.6.4 180/400-FOOT AQUITARD

This 180/400-Foot Aquitard separates the 180-Foot Aquifer from the underlying 400-Foot Aquifer throughout much of the Subbasin. It is a zone of "discontinuous aquifers and aquitards," of which the aquitards, where present, comprise an aquitard that separates the 180-Foot Aquifer from the underlying 400-Foot Aquifer (Geoscience 2014). The discontinuous nature of the 180/400-Foot Aquitard was

documented first by Monterey County Flood Control and Water Conservation District (MCFCWCD 1960) and was a subject of focused studies by Kennedy/Jenks (2004) north of the Salinas River. South of the Salinas River, the 180/400-Foot Aquitard is relatively thin and has been recorded to pinch out at the Main Garrison area of the former Fort Ord (Harding ESE 2001). Geophysical studies reported by Gottschalk *et al.* (2018) have confirmed this aquitard is discontinuous in and near the MGSA Area, and its hydraulic connection to the overlying 180-Foot Aquifer in the vicinity of the MGSA area is substantiated by available hydrographs (Section 3.2.1.3).

# 3.1.6.5 400-FOOT AQUIFER

This aquifer is regionally extensive and is composed of sand and gravel packages and is typically encountered between 275 and 460 ft bgs (Kennedy/Jenks, 2004). It is correlated with the Aromas Sand and the upper portion of the Paso Robles Formation (ESA 2018). The thickness and depth of the aquifer are variable throughout the Subbasin. Near Salinas, the aquifer is largely continuous; whereas, near Castroville, it is comprised of multiple sandy packages, separated by thin clay layers. South of the Salinas River, the 400-Foot Aquifer consists mostly of sand. In regions where the 180/400-Foot Aquitard thins out or is absent, the 180-Foot Aquifer and the 400-Foot Aquifer are in direct hydraulic communication. Hydraulic connection allows groundwater to flow unhindered from the aquifer with higher hydraulic head to the aquifer with lower hydraulic head in these areas. Generally speaking, the 400-Foot Aquifer has a lower hydraulic head than the 180-Foot Aquifer. In areas of hydraulic connection between these two aquifers, saline groundwater in the 180-Foot Aquifer, which has been recorded farther inland than in the 400-Foot Aquifer, has been documented to migrate vertically into the 400-Foot Aquifer, deteriorating water quality in the 400-Foot Aquifer (MCWRA 2017).

# 3.1.6.6 400-FOOT/DEEP AQUITARD

Beneath the 400-Foot Aquifer is an aquitard that can be up to "several hundred feet thick" (Kennedy/ Jenks 2004). Logging of a boring in the City of Marina conducted by the USGS interpreted a zone of silty clay and mudstone from about 700 to 900 feet below the ground surface (Hanson *et al.* 2002). More variable lithology has been interpreted from other deep well geophysical logs in the area (MCWRA 2017), and as discussed below, the USGS acknowledged the stratigraphic interval in which this aquitard was encountered has also been identified as containing transmissive units locally referred to as the 900-Foot Aquifer. As such, while substantial units of low permeability appear to exist within and beneath the lower portions of the upper aquifer system in the Paso Robles Formation, their regional continuity and competence are not well understood.

# 3.1.6.7 DEEP AQUIFER

The Deep Aquifer has received different definitions from various reports and consists of a system of aquifers. Kennedy/Jenks (2004) define the Deep Aquifer as the group of deep aquifers located between the depths of approximately 780 and 1,500 ft msl. Previous investigators delineated the Deep Aquifer system as the interval between 1,300 and more than 2,000 feet below ground surface (Geoconsultants,

Inc. 1993) based on data from the MCWD deep-aquifer system water-supply wells. USGS (Hanson *et al.* 2002) states the basal part of the upper aquifer system, encountered from approximately 670 to 955 feet below ground surface at a deep boring in the City of Marina, is locally referred to as the 900-Foot Aquifer, which is generally considered part of the Deep Aquifer system. They conclude this part of the Deep Aquifer system may constitute terrestrial sediments of the Plio-Pleistocene Paso Robles Formation (stratigraphically equivalent to the aquitard described above). ESA (2018) states that in the MGSA Area, the 900-Foot Aquifer correlates with the Paso Robles Formation. The majority of the Deep Aquifer system appears to consist of interbedded sands, silts and clays of the Mio-Pliocene Purisima Formation that were deposited in a marine shelf environment (Hanson *et al.* 2002, ESA 2018). Aquifers within this formation are known to extend to a depth of approximately 2,000 feet. The basal, or lowermost, unit of the Purisima Formation is reported to consist of relatively impermeable clay and shale (ESA 2018). Portions of the Purisima Formation that correlate with the Deep Aquifer system crop out in the submarine Monterey Canyon several miles offshore.

To date, seawater intrusion has not been documented in the Deep Aquifer, even though groundwater elevations in the Deep Aquifer are consistently below sea level. This lack of seawater intrusion in the Deep Aquifer may be due, at least in part, to the geologic setting (Feeney and Rosenberg 2003). groundwater pumping from wells in the Deep Aquifer is thought to be supported primarily by leakance from the overlying aquifer system (*i.e.*, the 180-Foot Aquifer and 400-Foot Aquifer). Some groundwater pumping is derived from depletion of groundwater storage, but hydraulic properties of the Deep Aquifer (specifically storage coefficients) suggest that while some groundwater may come from storage immediately following the onset of pumping a well, very little groundwater is removed from storage over time. Therefore, increases in groundwater pumping in the Deep Aquifer are likely supported by increased leakance from the overlying aquifers (Feeney and Rosenberg 2003). As a result of these findings, the Monterey County Board of Supervisors voted on May 18, 2018 to place a moratorium on the construction of new wells in the Deep Aquifer as a preventive measure because, at present, seawater intrusion has not been observed in the Deep Aquifer.

# **3.1.7 AQUIFER PROPERTIES**

#### **Regulation Requirements:**

§354.14(b)(4)(b) Physical properties of aquifers and aquitards, including the vertical and lateral extent, hydraulic conductivity, and storativity, which may be based on existing technical studies or other best available information.

#### **3.1.7.1 GENERAL AQUIFER PROPERTIES**

There are two general types of aquifer properties relevant to groundwater management:

• **Groundwater transmission properties** - These properties control the relationship between hydraulic gradients and the rate of groundwater movement or flow; and

• Aquifer storativity properties - These properties control the relationship between the volume of groundwater stored in the aquifer and the water elevation measured in the aquifer.

**Groundwater transmission properties:** Hydraulic conductivity measures the ability of an aquifer to transmit water. Hydraulic conductivity is measured in units of feet per day (ft/day). Units with higher hydraulic conductivities, such as sands and gravels, transmit groundwater more easily than units with lower hydraulic conductivities. Another common measurement of the ability of an aquifer to transmit water is transmissivity. Transmissivity is equivalent to the hydraulic conductivity of an aquifer times the thickness of an aquifer. Unfortunately, very few estimates of hydraulic conductivity or transmissivity exist for the Subbasin.

**Aquifer storativity properties**: The aquifer properties that characterize the relation between water elevation and aquifer storage volume are "specific yield" for unconfined aquifers and "specific storage" for confined aquifers. The units are dimensionless.

- Specific yield is the amount of water that drains from pores when an unconfined aquifer is dewatered. An example is water draining from the voids between sand grains, but leaving behind water sticking to the grains as a film of water. The pores dewater, they are not dried out. Typical specific yield values for unconfined alluvial systems range from 10% to 30% or 0.1 to 0.3 (Lohman 1972).
- Specific storage (also referred to as storage coefficient) is the amount of water derived from a cubic foot of confined aquifer due to a unit loss of pressure head in the aquifer. Specific storage is effectively a pressure response and is a combination of compression of the aquifer and compression or expansion of water. Specific storage in confined alluvial aquifers typically ranges from about 10<sup>-3</sup> to 10<sup>-5</sup> (Lohman 1972).

# 3.1.7.2 AQUIFER PROPERTIES NEAR THE MGSA AREA

Although there is limited information on aquifer properties at and in the vicinity of the MGSA Area, the CEMEX model used for the MPWSP site investigation assigned aquifer properties to the aquifers and aquitards from the Dune Sand Aquifer down to the Deep Aquifer. While this model is based on a simplified version of the site-specific stratigraphy and initial water elevation conditions that does not consider all of the locally available data, it does provide a reasonable initial estimate of aquifer properties. A list of the assigned aquifer and aquitard parameters adopted in the CEMEX model is listed below (the Deep Aquifer is referred to as the 900-Foot Aquifer in the CEMEX model).

- Dune Sand Aquifer Hydraulic conductivity 210 to 340 ft/day; Specific yield 0.065;
- Salinas Valley Aquitard Hydraulic conductivity and storage not simulated near MGSA Area;
- 180-Foot Aguifer Hydraulic conductivity 160 ft/day; Specific storage 4x10<sup>-3</sup>;
- 180/400-Foot Aguitard Hydraulic conductivity 3.1 to 5.4 ft/day; Specific storage 1x10<sup>-5</sup>;
- 400-Foot Aquifer Hydraulic conductivity 50 to 90 ft/day; Specific storage 4x10<sup>-4</sup> to 2x10<sup>-3</sup>;

- 400/900-Foot Aquitard Hydraulic conductivity 1.8 ft/day; Specific storage 1x10<sup>-5</sup> to 2x10<sup>-5</sup>; and
- 900-Foot Aquifer Hydraulic conductivity 25 ft/day; Specific storage 1x10<sup>-5</sup>.

USGS is developing the Salinas Valley Integrated Hydrologic Model (SVIHM) to simulate surface and groundwater conditions and flow in the Salinas Valley basin and serve as a tool to assess historical, current, and future groundwater conditions. SVBGSA utilized a pre-publication version of this model to support development of its GSP. The above aquifer properties will be updated as more data become available and the USGS SVIHM model is published. Refinement of these aquifer properties and of the local stratigraphic relationships, dimensions, and heterogeneity within and surrounding the MGSA Area will allow a more accurate assessment of groundwater flow and solute transport as the GSPs are implemented.

# 3.1.8 AQUIFER USES

# **Regulation Requirements:**

§354.14(b)(4)(e) Identification of the primary use or uses of each aquifer, such as domestic, irrigation, or municipal water supply.

The Dune Sand Aquifer is not currently used as a water supply, but does support surface water systems and does yield water to GDEs in the immediate vicinity of the MGSA Area (Section 3.2.6.2). Groundwater extraction from the 180-Foot and 400-Foot Aquifers within the Castroville Seawater Intrusion Project (CSIP) service area in the seawater-intruded area on the west side of the Subbasin is regulated by the MCWRA, and groundwater extraction is prohibited in a portion of this area. The SVBGSA's GSP includes a management action to expand the CSIP service area and prohibit new groundwater wells throughout this area. As a result, groundwater extraction in this area is limited. MCWD operates five municipal supply wells that are completed in the 180/400-Foot Aquifer and Deep Aquifer to provide water to the Ord Community, about 4 miles southeast of the MGSA Area (Schaaf & Wheeler 2016, MCWD 2019c). Small non-transient water systems reliant on groundwater are located near Neponset, near the Marina Airport and near the regional wastewater treatment plant located east of the MGSA Area.

Groundwater within the MGSA Area is currently being used by the CEMEX plant for industrial process supply (ESA 2018). CEMEX produces groundwater from a well completed in the 180-Foot and 400-Foot Aquifers. The well was constructed in the 1960s, and currently extracts approximately 305 acre-feet per year (AFY). The amount of groundwater produced from the lower TDS zone in the upper 180-Foot Aquifer vs. saline groundwater from the deeper portions of the 180-Foot Aquifer and the underlying 400-Foot Aquifer is not known. The CEMEX permitted operations will end by December 31, 2020 due to the agency enforcement actions described in Chapter 2, and pumping for the facility will cease by that time (Powder & Bulk Solids 2017) or, at the latest in December 2024, when CEMEX removes the well.

One proposed future use of the aquifers in the MGSA Area is extraction of groundwater for the proposed MPWSP desalination plant. Makeup water for the MPWSP would be pumped from five slant

wells (plus two standby wells) close to the coast. The wells would extract water radially from the DSA and 180-Foot Aquifer near the coast. Groundwater captured by the wells would include saline groundwater originating outside the western (seaward) Subbasin boundary, saline groundwater from aquifers within the Subbasin, and low-TDS groundwater from aquifers within the Subbasin. The amount of makeup water proposed to be pumped from these slant wells under the preferred alternative is approximately 17,400 AFY (HWG 2017).

South of the MGSA Area, MCWD pumps groundwater from three supply wells completed in the Deep Aquifer in the eastern portion of the City for distribution to the Central Marina service area and Armstrong Ranch (Wells #10, #11 and #12). The combined extraction from these wells was approximately 1,823 AFY in 2015, and is forecast to increase to 3,905 AFY by 2035, including supply for development in the Armstrong Ranch area, which was annexed to the City in 2007 (Schaaf & Wheeler 2016). The MCWD wells are located in the Monterey Subbasin in the eastern part of the City of Marina as shown on Figure 3-14.

# 3.1.9 GENERAL GROUNDWATER QUALITY

# **Regulation Requirements:**

§354.14(b)(4)(d) General water quality of the principal aquifers, which may be based on information derived from existing technical studies or regulatory programs.

Native groundwater in the 180-Foot and 400-Foot Aquifers that is not affected by seawater intrusion is characterized as calcium-sodium bicarbonate water (MCWRA 2017). Groundwater in the Deep Aquifer is characterized as a sodium bicarbonate water (MCWRA 2017). Seawater intrusion into 180-Foot and 400-Foot Aquifers at and in the vicinity of the MGSA Area has created more saline water that is characterized as a sodium chloride water. Figure 3-15 presents a Piper diagram from a report prepared by MCWRA (2017) that plots major ion data from the principal aquifers within and near the Subbasin. The diagram provides a means of representing the proportions of major anions and cations in water samples and thereby can be used to illustrate the character of the water quality.

As discussed further in Section 3.2.3, seawater intrusion into the 180-Foot and 400-Foot Aquifers is monitored by the MCWRA. MCWRA uses a standard of 500 milligrams per liter (mg/L) chloride to define the areas affected by seawater intrusion and inform its management decisions (MCWRA 2017). Based on this standard, seawater intrusion has progressed inland from the coast over a distance of approximately 4 to 7 miles in the 180-Foot Aquifer, and 3 to 4 miles in the 400-Foot Aquifer. In addition, several "chloride islands" have formed in the 400-Foot Aquifer beyond the main intrusion front as a result of downward migration of groundwater containing over 500 mg/L chloride from the 180-Foot Aquifer into the 400-Foot Aquifer in areas where the aquitard separating the two aquifers is thin or absent. Vertical movement of saline groundwater into the 400-Foot Aquifer at "islands" could be due to both downward migration in areas where the aquitard thins or is heterogeneous, or at locations where wells are improperly constructed or abandoned, forming a conduit through which vertical migration may occur.

It is important to note that groundwater in the areas affected by seawater intrusion still has actual and potential beneficial uses. Under State Water Resources Control Board (SWRCB) Resolution No. 88-63, the state considers all groundwater containing TDS at concentrations less than 3,000 mg/L as having a potential beneficial use as a domestic and municipal supply. For water containing TDS or chloride in excess of drinking water standards, treatment would be required prior to use. The Federal Clean Water Act defines groundwater containing less than 10,000 mg/L TDS as an Underground Source of Drinking Water. In addition, there are zones of higher quality, less saline groundwater, which contain lower concentrations of TDS, present at various locations and depths within the seawater-intruded area. As discussed further in Section 3.1.12, a prominent zone of higher quality groundwater extends approximately from the eastern portion of the MGSA Area eastward through the area underlain by the Dune Sand Aquifer, and extends vertically downward into the 180-Foot Aquifer (Gottschalk *et al.* 2018).

Nitrate impacts from historical agricultural uses are widespread in the Subbasin. As discussed further in Section 3.2.4.2, nitrate concentrations detected in wells within the MGSA Area are well below the Maximum Contaminant Level (MCL), except for one outlier of 13 historical sampling events of the CEMEX process water supply well; however, this well produces saline groundwater and is not being used as a source of drinking water. Shallow monitoring wells in the agricultural area east of the MGSA Area generally contain nitrate at concentrations near or exceeding the MCL.

In the vicinity of the MGSA Area, elevated TDS and chloride are the primary constituents of concern due to seawater intrusion. Figure 3-16, Figure 3-17, and Figure 3-18 present the TDS and chloride concentrations detected in the Dune Sand Aquifer, 180-Foot Aquifer, and 400-Foot Aquifer, respectively, in samples collected in April 2019.

#### 3.1.10 Source and Point of Delivery of Imported Water

# **Regulation Requirements:**

§354.14(d)(6) Physical characteristics of the basin shall be represented on one or more maps that depict the source and point of delivery for imported water supplies.

There is no water imported into either the MGSA Area or the 180/400 Foot Aguifer Subbasin.

#### 3.1.11 RECHARGE AND DISCHARGE AREAS

#### **Regulation Requirements:**

§354.14(d)(4) Physical characteristics of the basin shall be represented on one or more maps that depict delineation of existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas, including significant active springs, seeps, and wetlands within or adjacent to the basin.

# 3.1.11.1 NATURAL RECHARGE AREAS

Monterey County maps the area immediately east of the MGSA Area as a recharge area (Figure 3-19). The area is underlain by the Older Dune Sands (Figure 3-8) and soils in the arear are highly permeable. The City of Marina uses an infiltration rate of 1 foot/hour as a stormwater management design standard

in this area. The active coastal dunes that extend from the Salinas River southward through and past the City of Marina possess similar properties. Although the Dune lands (Df) soils underlying these areas, including the MGSA Area, are not mapped by the County as a recharge area, they are assumed to have similar properties. It is assumed that all rainfall on the Df soil that is not lost to evapotranspiration is recharged to the subsurface aquifer(s). As was noted earlier in Section 3.1.6, south of the Salinas River, there are no major creeks, streams or rivers that drain at and in the vicinity of the MGSA Area (Figure 3-5), which relates to the high permeability, high recharge rate of the Dune Sand Aquifer.

An additional source of recharge is deep percolation of applied irrigation water in the agricultural areas east and northeast of the MGSA Area. This area receives water from the CSIP, and has undergone an expansion of agricultural development by approximately 1,000 acres over the last 10 years. Given the very high permeability of the underlying soils, it is assumed that any applied irrigation water that is not consumptively used by crops recharges the underlying aquifer(s).

The Salinas River is reported to be a "losing" stream in the area near Marina (MCWRA 2018); therefore, it is expected to be a regional source of recharge north and east of the MGSA Area. Salinas River losses per river mile were estimated by MCWRA based on measurements at eight gaging stations (MCWRA 2018) extending upstream from Spreckels. Spreckels is located approximately 13.5 river miles upstream from the river mouth, south of Salinas. Measured river losses ranged from 4.5 cubic feet per second (cfs) to 12.2 cfs per river mile. It should be noted that these river measurements were conducted following a 5-year drought. Assuming these measurements are representative of river losses over a typical year, this would be equivalent to a loss of approximately 3,300 to 8,840 AFY per river mile to groundwater recharge. Assuming half the recharge contributes to recharge on each side of the river and that these measurements apply to the lower reach of the river between Spreckels and the river mouth, this would equate to recharge rates from the river to the Dune Sand and 180-Foot Aquifers of about 1,650 to 4,420 AFY per river mile near the MGSA Area. Recharge derived from infiltration of river water contributes to the subsurface inflow to the MGSA Area, but it is not directly connected to the MGSA Area, as the river passes approximately 4,000 feet to the north and 2 miles to the east.

#### 3.1.11.2 NATURAL DISCHARGE AREAS

Groundwater discharge in the area near the MGSA Area occurs by evapotranspiration (ET) from GDEs and discharge to the Pacific Ocean.

As discussed in Section 3.2.6.2, no GDEs are located within the boundaries of the MGSA Area; however, several GDEs are located in the immediately surrounding area. These GDEs utilize shallow groundwater from the Dune Sand Aquifer to meet a significant portion of their water demand. The amount of consumptive use by these GDEs has not been estimated. The total annual ET from these GDEs will be assessed as part of future groundwater budget updates during GSP implementation.

Three GDEs near the MGSA Area are included in the *Coastal/Vernal Ponds Comprehensive Management Plan* that was developed by the City in 1994 (The Habitat Restoration Group and Michael Swanson and

Associates 1994): Pond 6 – Armstrong Ranch Complex Ponds are immediately to the east of the MGSA Area; Pond 5 – Marina Cost Water District Pond is south of the MGSA Area; and Pond 3 – Marina Landing Pond is south east of the MGSA Area. These features are characterized as emergent or palustrine wetlands in the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset developed by The Nature Conservancy in cooperation with DWR.

Potentiometric surface maps prepared for the vicinity of the MGSA Area indicate the groundwater flow direction in the Dune Sand Aquifer is toward the coast. In addition, there is an upward gradient between the 180-Foot Aquifer and the Dune Sand Aquifer at the monitoring well cluster that is nearest to the coast (Section 3.1.12). This is consistent with seaward discharge of groundwater from the Dune Sand Aquifer and upper 180-Foot Aquifer under Ghyben-Herzberg dynamics (Section 3.1.12).

# 3.1.12 CONCEPTUAL UNDERSTANDING

When preparing seawater intrusion maps for 2015, MCWRA (2017) noted, for the first time, the existence of three isolated plumes of saline groundwater in the 400-Foot Aquifer inland from the contiguous seawater intrusion front (referred to in the report as "chloride islands"). The existence of these chloride islands suggested that migration of saline groundwater may be occurring downward through gaps in the 180/400-Foot Aquitard. Vertical movement of saline water into the 400-Foot Aquifer at "islands" could be due to both downward migration in areas where the aquitard thins or is heterogeneous, or at locations where wells are improperly constructed or abandoned, forming a conduit through which vertical migration may occur. In response to this finding, MCWRA conducted a detailed review of 187 wells in an effort to better understand the potential pathways for seawater intrusion into the chloride islands. It was found that of the 187 wells evaluated, there are at least 74 wells for which adequate hydraulic separation could not be confirmed of the 400-Foot Aquifer from the overlying, seawater-intruded 180-Foot Aquifer. The MCWRA (2017) report identifies 15 locations where gaps in the 180/400-Foot Aquitard were confirmed to exist. Figure 3-20 presents a map view illustration of the "area of impact" as mapped by MCWRA and the identified aquitard gaps.

In addition to the extensive dataset developed from prior hydrogeologic investigations in the area, from 2011 to 2018, a research team from Stanford University investigated the hydrostratigraphy and seawater intrusion in the upper aquifer system (the Dune Sand, 180-Foot and 400-Foot Aquifers) along the Monterey Bay coast in Santa Cruz and Monterey Counties. The investigations utilized Electrical Resistance Tomography (ERT) and Airborne Electromagnetics (AEM) to investigate variations in subsurface conductivity that were used to interpret stratigraphic and water quality variations by correlating them to the electrical logs of borings drilled near the coast.

Electrical and electromagnetic geophysical techniques provide an efficient means of collecting sufficient data for two- and three-dimensional conceptualization of complex subsurface systems in a way that is not practical with the use of conventional boreholes and monitoring wells alone, and are a widely used and well established investigation technique for characterization of seawater intrusion into coastal

aquifers (Viezzoli, Munday and Cooper 2012, Herckenrath *et al.* 2013, Mills et al. 1988, Kazkis *et al.* 2016, Hazreek *et al.* 2018). The northward extension of the AEM dataset compiled by the Stanford team is currently being used in the preparation of a GSP for the Santa Cruz Mid-County Subbasin and is proposed to perform long term monitoring of seawater intrusion in that area. While the AEM data are not collected using direct measurements (such as, drilling a well bore), using indirect measurement geophysics in subsurface investigations has a long history in groundwater investigations dating back to 1926 when the Schlumberger brothers developed borehole resistivity logging tools (Hilche 1990). Further, airborne electromagnetic surveys are an integral part of the SWRCB Regional Monitoring Program for groundwater monitoring in areas of oil and gas well stimulation for salinity mapping conducted by USGS (SWRCB 2019).

The AEM data provides one snapshot in time covering much of MGSA Area and nearby area of interest. The data are extensive and provide a broader three-dimensional understanding of the subsurface hydrostratigraphy and water quality distribution than well-based data alone.

In 2011 and 2012, ERT profiles were collected along 6.8 kilometers (km) of shoreline along the Monterey Bay near Marina, and in 2014, 40 km of ERT profile data were collected along the Monterey Bay shoreline in Monterey and Santa Cruz Counties (Pidlisecky et al. 2016, Goebel et al. 2017). In 2017, 395 miles of AEM data were acquired in the northern Salinas Valley near the shore and extending inland across the mapped areas of seawater intrusion (Gottschalk et al. 2018). The AEM data were calibrated using electrical well logs and used to refine the previous hydrostratigraphic models developed using borehole data and the North Marina Groundwater Model, and to assess the extent of saline and low-TDS groundwater in the aquifer system. The data were made available in a three-dimensional geologic data visualization package called leapfrog<sup>©</sup> that is extensively used in the petroleum and mining industries. Figure 3-21 and Figure 3-22 present hydrostratigraphic and water quality cross sections of the data across the MGSA Area and vicinity, and Figure 3-23 presents an oblique block section of the area and a conceptual model drawing taken from the seawater intrusion literature that illustrates the Ghyben-Herzberg relationship of saline-freshwater interfaces. The lithologic and conductivity interpretations were developed as discussed in Gottschalk et al. (2018), and the lithologic interpretation presented in the cross sections is based on interpretation of boring logs and modified using the AEM data (Gottschalk's "Model A"). Our findings are summarized below in light of the data presented in the previous sections.

The three-dimensional view of the hydrostratigraphy in the MGSA Area indicates that is more complex than has been previously conceptualized. This is not unexpected given the number of additional data points derived using a geophysical approach. The AEM profiles show the Dune Sand Aquifer extends westward beneath the older and recent dune deposits south and west of the Salinas River, which have been recognized as an area with high recharge rates. The Dune Sand Aquifer lies on top of the Salinas Valley Aquitard, which thins and pinches out toward the west. Beneath the MGSA Area, the Dune Sand Aquifer is in direct hydraulic communication with the underlying 180-Foot Aquifer because the Salinas

Valley Aquitard is not present. The 180-Foot Aquifer is shown as a series of tabular and lenticular bodies, and consists of an upper and a lower member that are partially separated by discontinuous clay layers. The 180/400-Foot Aquitard is discontinuous and notably absent beneath a portion of the MGSA Area and in a large area located just east of the MGSA Area. This occurs in the vicinity of an area where the aquitard was previously judged to be thin or absent by MCWRA (see Figure 3-20). The 400-Foot Aquitard is uneven, and the Deep Aquifer occurs at some locations as shallow as depths of approximately 650 feet below the ground surface.

The water quality data show a prominent saline groundwater wedge (> 10,000 mg/L TDS) which dives downward from the coast through the Dune Sand and 180-Foot Aquifers, and extends downward into the 400-Foot Aquifer through a large gap in the 180/400 Foot Aquitard. This saline groundwater wedge is juxtaposed against a zone of lower TDS groundwater (< 3,000 mg/L TDS) that has developed as a result of freshwater recharge through the high permeability dune sand deposits that occur between the MGSA Area and the Salinas River. This low TDS zone extends downward into the 180-Foot Aquifer east of the MGSA Area.

The saline groundwater wedge and low TDS zone have the geometry of a typical seawater intrusion interface as first characterized by Ghyben and Herzberg, after whom this relationship is named (Ghyben 1889, Herzberg 1901). Seawater interfaces in coastal aquifers have been extensively characterized, and follow what has been termed the Ghyben-Herzberg model, which is illustrated in Figure 3-23. Under equilibrium conditions, the ratio between the depth to the interface below sea level to the height of the water table above sea level remains constant and is proportional to the difference in density between the overlying low TDS native aquifer groundwater and the underlying seawater. This ratio often approximates 40:1, but is dependent on the actual salinity and density contrast. Groundwater flow is seaward in the overlying low TDS zone and discharges to the ocean, and flow is landward in the intruding saline groundwater wedge. At the saline/low-TDS groundwater interface, the saline groundwater circulates and mixes with the over-riding low TDS groundwater and flows back along the interface to discharge at the ocean (Cooper et al., 1964). This pattern is consistent with the water quality distribution interpreted from the AEM data and the water elevation data discussed in Sections 3.1.12 and 3.3.7. Although this equilibrium may have been somewhat disturbed at the MGSA Area by pumping of CEMEX well and the test slant well, and by recharge of saline water in the CEMEX ponds, the geometry of a saline groundwater wedge dipping beneath an over-riding low-TDS zone is clearly identifiable and consistent with the Ghyben-Herzberg model.

# 3.1.13 IDENTIFICATION OF DATA GAPS

#### **Regulation Requirements:**

§354.14(b)(5) Identification of data gaps and uncertainty within the hydrogeologic conceptual model.

The following data gaps and uncertainties have been identified in the hydrogeologic conceptual model for the MGSA Area:

- The period of record for monitoring groundwater elevations and water quality in and near the MGSA Area is limited to 2015 to present, with few exceptions. As such, potential current and historical trends in groundwater elevations and flow, low-TDS groundwater distribution and saline groundwater distribution, are not well understood. Similarly, because monitoring started shortly before a long-term pumping test that was initiated during a historic drought, the effects of pumping and climatic stress on the groundwater system are not well understood. With the exception of the test slant well pumping test, which was conducted from April 2015 to February 2018, the CEMEX well has been the only groundwater development in the MGSA Area since the 1960s. In this GSP, it is therefore assumed that current and historical groundwater conditions as well as the spatial groundwater quality distribution (i.e., extent of seawater intrusion) are generally similar; however, the data to demonstrate this conclusively are not available. MCWRA is planning to add five new monitoring well clusters with wells completed in the Dune Sand Aguifer, 180-Foot Aguifer, and 400-Foot Aguifer (Feeney and Zidar 2019). The Mitigation Monitoring and Reporting Program (MMRP) for the proposed MPWSP includes monitoring of these wells, the existing MPWSP monitoring wells, and a number of other existing wells in the vicinity by MCWRA. During preparation of its GSP for the Monterey Subbasin (due 2022), MCWD GSA plans to assess the adequacy of this monitoring network. MGSA will review the results of this analysis and update the monitoring networks for this GSP as needed to maintain a consistent monitoring approach across GSPs.
- Little information is available regarding the nature and hydraulic properties of the Deep Aquifer system, which includes multiple aquifer units spanning a vertical interval of approximately 1,300 feet. Specifically, the interconnection between the disparate aquifer units in this system, how they are recharged, and the extent of potential leakance from the overlying upper aquifer system are not well understood. Groundwater flow patterns within the Deep Aquifer are not well characterized. The competence of the system of aquitards overlying the Deep Aquifer is of particular concern, as is the aquifer's potential connection to seawater offshore in Monterey Canyon. MCWRA, SVBGSA and MCWD GSA are discussing plans to further investigate the Deep Aquifer system. Although no investigations have been scheduled at this time, there is consensus that better characterization of the Deep Aquifer system is needed early during the GSP implementation process. MGSA will review the results of this investigation and refine the approach to management of the Deep Aquifer consistent with the pertinent findings.
- The available data suggest that the vicinity of the MGSA Area has not experienced significant subsidence. However, the data are insufficient to assess the potential vulnerability of this area to future subsidence if groundwater extractions are increased. MGSA will work with SVBGSA to address this data gap during GSP implementation.
- While projected groundwater elevations in the Dune Sand Aquifer are less than 20 feet below the thalweg in the lower reach of the Salinas River, which suggests the river and aquifer may be

hydraulically interconnected, the nature and degree of the interconnection is not known. SVBGSA is planning to conduct an evaluation of surface water – groundwater interaction, which would include the use of existing shallow wells near the river, and installation of new monitoring wells at up to two locations. After SVBGSA's well construction and data analysis has been conducted, the need for additional information regarding surface water – groundwater interaction will be evaluated by MGSA.

- The response and susceptibility of GDEs to groundwater elevation declines varies depending on local hydrology, soil conditions, the plant species involved and other factors. A correlation between groundwater elevations and GDE stress or habitat quality has not been established.
- The nested monitoring wells installed in and near the MGSA Area for the potential MPWSP have relatively long screen intervals: screen lengths in the Dune Sand Aquifer average 36 feet, screen lengths in the 180-Foot Aquifer average 110 feet, and screen lengths in the 400-Foot Aquifer average 59 feet. While this provides useful aggregate data, depth discreet measurements may be needed to better understand the vertical distribution of lower TDS groundwater in the shallow portions of the 180-Foot Aquifer at and near the MGSA Area. Depth discrete data could be collected either with the installation of new monitoring wells with shorter screen intervals, using passive diffusion bags, induction logs, or other sampling techniques on existing monitoring wells.
- The AEM geophysical surveys provided a snapshot in time of subsurface conditions. Additional geophysical surveys may be needed to evaluate changes in the saltwater wedge over time in the vicinity of the MGSA Area.
- The USGS SVIHM model is being developed, in part, to assist with establishing water budgets for areas within the 180/400 Foot Subbasin. The calibrated model report has not been released to date. Once the SVIHM model is published, the model output will be used to update the current and projected regional water budgets by the SVBGSA. Because MGSA has adopted the SVBGSA water budgets for the MGSA GSP, the SVIHM model will also be used to update the MGSA GSP water budgets.
- A groundwater model that can simulate solute transport and density-driven flow, and that incorporates the heterogeneity of the aquifer system in the Marina area is not available at this time. As such, the potential impacts of significant and prolonged pumping, such as for the proposed MPWSP, on the local water budget, water quality and seawater intrusion cannot be adequately evaluated. Before substantial groundwater extraction is implemented in the MGSA Area, there would be a need for a locally refined groundwater flow model that is able to simulate solute transport and density-driven flow, and for additional targeted investigation for data gaps. MCWD GSA is currently planning to conduct such studies for the area that includes their GSA boundaries and the surrounding region, including the MGSA Area and beyond. MGSA

will collaborate with and review these studies, and update the HCM, sustainable management criteria, monitoring networks and management actions in this GSP to assure the sustainability goals are met.

# 3.2 CURRENT AND HISTORICAL GROUNDWATER CONDITIONS

#### **Regulation Requirements:**

**§354.16** Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:

This section describes current and historical groundwater conditions in the MGSA Area and the broader 180/400 Foot Aquifer Subbasin. In accordance with the SGMA regulations (23 CCR § 354.16), current conditions are representative conditions occurring after January 1, 2015. By implication, historical conditions are any conditions occurring prior to January 1, 2015. This chapter focuses on summarizing information required by the SGMA regulations, and that provides the necessary context for developing an effective GSP. Little data are available in the MGSA Area and its vicinity prior to 2015; however, as discussed in Section 3.1.13, it is reasonable to assume that historical conditions prior to this time were similar to current conditions. Therefore, the data discussed in this Section is assumed to represent both historical and current conditions. Data from prior to 2015 are discussed to the extent available.

#### 3.2.1 Groundwater Level Data

#### **Regulation Requirements:**

**§354.16(a)** Groundwater elevation data demonstrating flow directions, lateral and vertical gradients, and regional pumping patterns, including:

- 1. Groundwater elevation contour maps depicting the groundwater table or potentiometric surface associated with the current seasonal high and seasonal low for each principal aquifer within the basin.
- 2. Hydrographs depicting long-term groundwater elevations, historical highs and lows, and hydraulic gradients between principal aquifers.

Groundwater elevations in the Salinas Valley are highly dependent on two sources of climatic variability:

- Annual variation between wet season and dry season that is reinforced and amplified by agricultural irrigation; and
- Wet and dry climatic cycles, characterized by multi-year drought and wet cycles, with a complete cycle often lasting a decade or more.

#### 3.2.1.1 DATA SOURCES

Groundwater elevation data have been collected by the MCWRA on a regional scale since 1944; however, until the installation of monitoring wells to support the MPWSP slant well pumping test in 2015, very little water elevation data is available in the vicinity of the MGSA Area.

The MCWRA regularly collects groundwater elevation measurements from 166 locations in the 180/400 Foot Aquifer Subbasin for various monitoring programs (Section 2.2.1.1). The groundwater elevation

data are primarily from privately-owned wells and are subject to confidentiality agreements between the well owners and MCWRA. Only one well currently monitored by MCWRA is located southwest of the Salinas River within about 2 miles of the MGSA Area, and data from this well is publicly available through other programs. Therefore, confidential MCWRA data are considered in this GSP only in the assessment of regional groundwater elevations and flow direction and are not individually mapped or reported.

MCWRA collects groundwater elevation data at specific times of the year to understand seasonal changes and monitor longer term trends in specific areas. Some of the wells actively monitored for water elevations are equipped with pressure transducers that take automated measurements hourly. Other wells are measured monthly or annually during each fall season to inform the regional measurement program, and/or annually in August to assess maximum drawdown to assess conditions at the end of the irrigation season in the area north and east of Salinas where the greatest drawdowns have occurred (MCWRA 2018a). The fall monitoring program is implemented from mid-November to mid-December. MCWRA conducts their fall measurement program to observe groundwater elevations after the irrigation season ends but before the rainy season begins (Brown and Caldwell 2015), and is believed to provide the most representative year-to-year regional comparison because groundwater elevations have recovered somewhat from the height of irrigation pumping, and are generally not yet greatly influenced by near-term recharge events during the rainy season.

MCWRA recently became the primary local Monitoring Entity for the Salinas Valley Basin under the California Statewide Groundwater Elevation Monitoring Program (CASGEM). Created by the state in 2009, CASGEM is a statewide program to collect groundwater elevations and make the data accessible to the public to support groundwater resource management. In the 180/400 Foot Aquifer Subbasin, 23 wells are monitored under the CASGEM program. Wells were selected for the CASGEM program based on their distribution throughout the basin, the availability of detailed and reliable well construction data, and access considerations (MCWRA 2015). Fifteen wells are equipped with transducers that record groundwater elevations hourly; 8 others are monitored manually on a monthly basis (MCWRA 2015). The average period of record for these wells is 10 years. The earliest groundwater elevations were recorded in 2003. One CASGEM well is located within 2 miles of the MGSA Area as shown on Figure 2-12.

The primary monitoring well network of interest for evaluation of historical groundwater elevation data near the MGSA Area includes 24 monitoring wells installed to assess the effects of test slant well pumping for the proposed MPWSP. These wells were installed in eight multi-depth clusters of three wells each completed in the Dune Sand Aquifer, 180-Foot Aquifer, and 400-Foot Aquifer. The locations of these well clusters are shown on Figure 3-24, and additional details regarding the wells are discussed in Section 5.2.1 and summarized in Table 5-1. These wells were constructed in 2015 and 2016, and include three clusters within the MGSA Area (wells MW-1, MW-3, and MW-4), and five clusters that are

about ½ mile to 4 miles from the MGSA Area boundary. Water elevation data are collected using transducers and hand measurements, and are documented in monthly reports.

The nearest long-term water elevation data collection programs in this area prior to 2015 are associated with the compliance monitoring program associated with the Monterey Peninsula Class III landfill (about 2 miles east of the MGSA Area), the site cleanup program for Fort Ord Operable Unit (OU)-1 Off-Site Plume (about 1.5 to 2.5 miles to the southeast of MGSA), and the cleanup program for the Fort Ord Carbon Tetrachloride Plume (OUCTP) (about 1 to 1.5 miles southeast of the MGSA). The locations of these wells are shown on Figure 3-25. As discussed below, the shallow monitoring wells associated with these programs appear to be completed in locally distinct shallow aquifer areas within the footprint of the Dune Sand Aquifer, but data from the wells was considered in the assessment of groundwater elevation and flow conditions. A few wells associated with the Fort Ord OU-1 Off-Site Plume were apparently completed in the 180-Foot Aquifer; however, these wells were destroyed in 2011.

Monitoring of the remaining Fort Ord wells was discontinued in 2014 and 2015. The Fort Ord OUCPT wells continue to be monitored, and several are completed in the 180-Foot Equivalent Aquifer.

#### 3.2.1.2 GROUNDWATER ELEVATION CONTOURS AND HORIZONTAL GROUNDWATER GRADIENTS

To assess groundwater elevation contours, regional contour maps prepared by MCWRA for 2015 and 2017 were reviewed, and local conditions were assessed by preparing several groundwater elevation maps for the MGSA Area and its vicinity. For the MGSA Area, groundwater elevation maps were developed using data from local groundwater monitoring wells during times when data were available. Water elevation maps were prepared for three periods:

- Prior to test pumping of the test slant well to document conditions at the end of the period when only the CEMEX well was being pumped in the MGSA Area (March 20, 2015);
- During the period of test pumping of the test slant well (March 12, 2017); and
- After the cessation of test slant well pumping, during a period with no pumping except by the CEMEX well (April 2, 2018).

Groundwater elevation maps were prepared for each of the three monitored zones on each of these three dates for a total of nine water elevation maps:

- Dune Sand Aquifer (Figure 3-25, Figure 3-26, and Figure 3-27);
- 180-Foot Aquifer (Figure 3-28, Figure 3-29, and Figure 3-30); and
- 400-Foot Aquifer (Figure 3-31, Figure 3-32, and Figure 3-33).

#### **REGIONAL GROUNDWATER LEVELS AND GRADIENTS**

Regionally, MCWRA publishes groundwater elevation contour maps for the Salinas Valley Groundwater Basin in odd-numbered years using data from the fall measurement programs. In the 180/400 Foot

Aquifer Subbasin, MCWRA produces separate contour maps for the 180-Foot and 400-Foot Aquifers. The maps extend from Chualar to the mouth of the Salinas River and include both the East Side Aquifer Subbasin and the 180/400-Foot Aquifer Subbasin. Contour maps cover 1994 through 2017 (after 1994 the maps were published in odd numbered years). Proximal to the MGSA Area, depending on the year, the closest contours for the 180-Foot Aquifer are typically drawn 1 to 2 miles from the northeastern edge of the MGSA Area, and the closest 400-Foot Aquifer contours are typically drawn within 2,000 feet of the MGSA Area. The contour intervals are generally about 10 feet, and provide a regional understanding of groundwater flow in the area. For confidentiality reasons, the maps do not plot the wells or groundwater elevation data used to construct the contours. The 1994, 2007, 2015, and 2017 contour maps are included in Appendix 3.A.

The primary feature documented in both the 180-Foot/Shallow East Side Aquifers and 400-Foot/Deep East Side Aquifer maps is a groundwater depression located north of Salinas with groundwater elevations generally -80 to -120 feet msl. Groundwater elevations are generally below sea level for most of the area covered by the maps extending back to 1994. East of the MGSA Area groundwater elevations are generally interpreted to be -10 to -20 feet msl with some years as low as -30 feet msl (for example 2007). The 2017 contour map for the 180-Foot Aquifer indicates an inland flow direction over a broad region surrounding the MGSA Area with a gradient of 0.0014. A similar flow pattern is interpreted for the 400-Foot Aquifer, with a gradient of 0.0013. These groundwater flow data are based on widely spaced wells, and should be considered generalizations for the MGSA Area.

Insufficient data currently exist to map flow directions and groundwater elevations in the Deep Aquifer, and MCWRA does not produce groundwater elevation maps of the Deep Aquifer.

# **LOCAL DUNE SAND AQUIFER GROUNDWATER LEVELS AND GRADIENTS**

For the Dune Sand Aquifer, the March 20, 2015 groundwater elevation contour map includes data for the individual MPWSP wells installed prior to that time (MW-1S, MW-3S, MW-4S and MW-5S), monitoring wells at the Monterey Peninsula Class III Landfill ("Minus 2-Foot Aquifer") about 2 miles east of the MGSA Area, and monitoring wells for the Fort Ord OU-1 Off-Site Plume ("A-Aquifer") southeast of the MGSA Area. Based on the groundwater elevation data, the Fort Ord A-Aquifer monitoring wells appear to be completed in a local perched aquifer with groundwater elevations that are about 30 to 40 feet higher than groundwater elevations in the surrounding area. At the landfill, groundwater elevations in the landfill area may be affected by multiple perched layers, the drainage control systems for landfill hydraulic containment, and other factors (RMC Geoscience, Inc., 2019), and are lower than expected. Groundwater flow direction and gradient are influenced by the Salinas River and by pumping from the landfill water supply wells. Groundwater flow is also locally influenced by surface water recharge associated with the storm water percolation pond, the relatively poor drainage conditions south of the landfill whereby water is routed around the landfill in unlined surface channels, and by pumping from the site water supply wells (RMC Geoscience, Inc. 2019).

Due to the sparsity of datapoints to extrapolate groundwater elevations in the Dune Sand Aquifer on this date, the available data were posted, but were not contoured. For the remaining Dune Sand Aquifer groundwater elevation contour maps (March 12, 2017 and April 2, 2018), it was found that groundwater elevations measured in well MW-5S differed from the surrounding wells and may be representative of a local perched zone. Well MW-9S is located north of the Salinas River. Groundwater elevations in this well are generally consistent with what would be expected based on the other wells to the south of the river; however, to avoid conjecture about the effect of river seepage on groundwater elevations in this area, the contours were terminated south of the river. Finally, well MW-6S is located approximately 3.5 to 4 miles southeast of the MGSA Area next to the Salinas River. The pronounced difference between the March 2017 and March 2018 groundwater elevations in this well suggest it may be affected by river stage. In addition, it is located a considerable distance from the MGSA Area. For these reasons, only water elevation data for MW-1S, MW-3S, MW-4S, MW-7S, and MW-8S were contoured.

The direction of groundwater movement in the Dune Sand Aquifer was toward the ocean to the west-northwest in March 2017 with a gradient of about 0.0005, and toward the ocean to the northwest with a gradient of about 0.0006 in April 2018 (Figure 3-25 through Figure 3-27). Near the coast in wells MW-1S and MW-3S, groundwater elevations increased by approximately 7 feet and 1 foot, respectively between March 2017 and April 2018. This may indicate the re-establishment of a seepage face at the shoreline after the cessation of the test slant well pumping program.

# **LOCAL 180-FOOT AQUIFER GROUNDWATER LEVELS AND GRADIENTS**

For the 180-Foot Aquifer, the March 20, 2015 map includes groundwater elevation data for MPWSP wells MW-1M. MW-3M, MW-4M and MW-5M, only. Wells MW-6M, MW-7M, MW-8M, and MW-9M had not yet been installed in March 2015. Due to the sparsity of data, groundwater elevations were not contoured. For the remaining maps (March 12, 2017 and April 2, 2018), groundwater elevation data for wells MW-1M, MW-3M, MW-4M, MW-5M, MW-7M, MW-8M, MW-9M were contoured. Well MW-6M is located a considerable distance from the MGSA Area with no intervening wells; therefore, data for these wells were posted but were not considered in contouring.

The direction of groundwater movement in the 180-Foot Aquifer was landward in March 2017 with an apparent groundwater divide (mound) beneath the agricultural land east of the MGSA. Groundwater gradients were northeast and southeast away from the divide. The March 2017 gradient near the MGSA Area was about 0.0006. In April 2018, an apparent mound was again observed east of the MGSA area, but its southeastern flank was not resolved by the data. The gradient was about 0.0009 in in a landward direction in the vicinity of the MGSA Area (Figure 3-28 through Figure 3-30).

Please note that proposed SVBGSA Priority Management Actions and Preferred Projects include in lieu recharge and direct recharge projects with expected benefits including "arresting the decline, or raising, groundwater elevations" (SVBGSA 2019). For the 180-Foot Aquifer, SVBGSA has estimated a groundwater elevation rise of about 3.5 feet in the vicinity of the Salinas River and 2 feet in the vicinity

of the MGSA as a result of implementing the projects and management actions in their GSP (SVBGSA 20219). Raising groundwater elevations could change groundwater flow gradients, and potentially flow directions in the 180-Foot Aquifer.

#### **LOCAL 400-FOOT AQUIFER GROUNDWATER LEVELS AND GRADIENTS**

For the 400-Foot Aquifer, the March 20, 2015 groundwater elevation map includes data for MPWSP wells MW-1D. MW-3D, MW-4D and MW-5D, and State well 14S02E08M002M (located near Neponset, where Highway 1 crosses the Salinas River). Wells MW-6M(L), MW-7D, MW-8D and MW-9D had not yet been installed in March 2015. Due to the sparsity of data, groundwater elevations were not contoured. For the remaining maps (March 12, 2017 and April 2, 2018), groundwater elevation data for wells MW-1D, MW-3D, MW-4D, MW-5D, MW-7D, MW-8D, MW-9D were contoured. Well MW-6M(L) is located a considerable distance from the MGSA Area with no intervening wells and was determined to be within the lower 180-Foot Aquifer, rather than the 400-Foot Aquifer (HWG 2017). In addition, groundwater elevations in State well 14S02E08M002M were different than expected based on the surrounding wells, suggesting it is reflective of different hydrostratigraphic intervals than the MPWSP monitoring wells. For these reasons, data for these two wells (MW-6M(L) and State well 14S02E08M002M were posted but were not considered in contouring. For March 2017 and April 2018, the direction of groundwater flow was landward. The gradient was east with a magnitude of approximately 0.0008 in March 2017, and east-southeast with a magnitude of 0.0006 in April 2018. A slight groundwater mound was present beneath the agricultural land east of the MGSA Area (Figure 3-31 through Figure 3-33).

As noted above, proposed SVBGSA Priority Management Actions and Preferred Projects include *in lieu* recharge and direct recharge projects with expected benefits including "arresting the decline, or raising, groundwater elevations" (SVBGSA 2019). For the 400-Foot Aquifer the SVBGSA has estimated a groundwater elevation rise of about 3.5 feet in the vicinity of the Salinas River and 3 feet in the vicinity of MGSA as a result of implementing the projects and management actions in their GSP (SVBGSA 2019). Raising groundwater elevations could change groundwater flow gradients, and potentially flow directions in the 400-Foot Aquifer.

#### 3.2.1.3 AQUIFER HYDROGRAPHS

Representative temporal trends in groundwater elevations can be assessed with hydrographs – graphs that plot changes in groundwater elevations in a well over time. Groundwater-elevation data from wells within the Subbasin are available from monitoring conducted and reported by MCWRA and in many cases span a period of decades. Hydrographs for the eight MPWSP monitoring wells are available from monitoring reports published for that project. The MPWSP well hydrographs cover the period from early 2015, prior to initiation of test slant well pumping, to the present.

#### **REGIONAL HYDROGRAPHS**

MCWRA measures water elevations at more than 90 wells on a monthly basis throughout the Salinas Valley to monitor seasonal groundwater elevation fluctuations. Data from approximately 50 of these

wells are compiled in MCWRA quarterly reports (included in MCWRA 2015, 2016, 2017, 2018). The water elevation measurements are categorized by hydrologic subarea, averaged, and graphed (average hydrographs) to compare current water elevations with selected past conditions. Hydrographs for individual subareas (such as the 180-Foot Pressure and the 400-Foot Pressure subareas) are prepared showing the current year's water elevation conditions, the previous year's conditions, and reference dry conditions. Beginning in 1985, MCWRA produced composite hydrographs showing groundwater elevations for five wells in the 180-Foot Aquifer and 11 wells in the 400-Foot Aquifer to provide perspectives general seasonal and inter-annual groundwater elevation trends. The MCWRA annual reports for 2015 through 2017 compared these composite hydrographs to monthly averages for 1985, and the 2018 annual report included a comparison to monthly averages over 30 years (WY1987-WY2017). A summary table is provided below.

TABLE 3-2. COMPOSITE HYDROGRAPHS SUMMARY FOR THE PRESSURE 180-FOOT AND 400-FOOT AQUIFERS

Area	Water Year	September Average Depth to Water (feet)	September Average Groundwater Elevation* (feet msl)	One-Year Average Change (feet)	Change from WY 1985 (feet)	Difference from 30 Year Average* (feet)	1 Month Change (feet)
	2015	69	NA	down 7	down 18	NA	up 1
Pressure 180-Foot	2016	68	NA	no change	down 17	NA	up 1
Aquifer	2017	58	NA	up 11	down 6	NA	up 1
	2018	NA	5	up <1	NA	down 1	up 4
	2015	59	NA	down 4	down 2	NA	up 2
Pressure 400-Foot Aquifer	2016	57	NA	up 1	down 1	NA	up 2
	2017	49	NA	up 8	up 7	NA	up 3
	2018	NA	-9	down 1	NA	up 4	up 3

Compared to 30-year averages, September 2018 groundwater elevations in the 400-Foot Aquifer were 4 feet higher, and the September 2018 groundwater elevations in the 180-Foot Aquifer were less than 1 foot lower, indicating average stable to somewhat recovering conditions. The composite hydrographs are included in Appendix 3.B.

Hydrographs for eight individual wells in the 180/400 Foot Aquifer Subbasin monitored by MCWRA within approximately 7 miles of the MGSA Area that are not limited by confidentiality agreements are included in Appendix 3.C. The hydrographs provide information on specific wells in the northern 180/400 Foot Aquifer Subbasin and provide subregional information about groundwater elevation trends surrounding the MGSA Area. The locations of these wells are shown in the Appendix. A summary of the individual well hydrographs is provided in Table 3-3.

TABLE 3-3. SUMMARY OF WELL HYDROGRAPHS IN THE NORTHERN 180/400 FOOT AQUIFER SUBBASIN

Well	Period of Record	Aquifer	Difference between Lowest and Highest Elevation (feet)	General Water Level Trend
13S/02E-21Q01	2004 to present	180-Foot	4	stable
14S/02E-03F04	2004 to present	180-Foot	21	declining since 2006
14S/02E-04G02	2000 to present	400-Foot	28	stable to slightly declining
14S/02E09D04	1999 to present	400-Foot	16	stable to slightly declining
14S/02E-15A01	1983 to present	400-Foot	68	declining since 1999
14S/02E-17B03	1999 to present	400-Foot	14	stable
14S/02E-22L01	1993 to present	400-Foot	44	declining since 1999
14S/02E-26H01	2004 to present	180-Foot	44	declining since 2006

Based on the data presented in Appendix 3.C, groundwater elevations in six of eight MCWRA wells within 7 miles of MGSA Area are generally declining over the period of record.

For the Deep Aquifer, MCWRA currently monitors groundwater elevations at 13 locations with varying frequency. Five of the groundwater elevation data collection points are monitoring wells equipped with continuously-recording pressure transducers, and the remaining eight groundwater elevation data collection points are production wells manually monitored on either a monthly (seven wells) or annual (one well) basis. MCWRA analysis of average Deep Aquifer groundwater elevation changes in a subset of wells near the coast indicates that average groundwater elevations generally declined and fell below sea level until the Castroville Seawater Intrusion Project (CSIP) began operations in 1998. Following startup of the CSIP, average groundwater elevations rapidly increased and rose above sea level, then leveled off until approximately 2006. After 2006, average groundwater elevations began to decline once again and are currently below sea level (Figure 3-34).

#### LOCAL HYDROGRAPHS IN AND NEAR THE MGSA AREA

Appendix 3.D provides copies of the groundwater elevation hydrographs and specific conductance plots for the 24 monitoring wells constructed for the proposed MPWSP. The hydrograph plots group the shallow, middle, and deep wells in each cluster, providing both time-series and vertical gradient information from February 2015 through May 2019. The shallow wells are generally designated Dune Sand Aquifer wells, the middle wells are generally 180-Foot Aquifer wells, and the deep wells are generally 400-Foot Aquifer wells. Well hydrographs are provided for wells MW-1, MW-3, and MW-4 within the MGSA Area, and wells MW-5, MW-6, MW-7, MW-8, and MW-9 located to the east.

Conclusions from review of the hydrographs are provided below:

- Well MW-5S is located at a higher elevation and displays groundwater elevations that are substantially higher than other wells in the surrounding area. This well appears to be associated with a perched aquifer within the footprint of the Dune Sand Aquifer.
- There is little difference in the groundwater elevations for wells MW-6M and MW-6D. The designation for the latter was changed to well MW-6M(L) in recent MPWSP reports, recognition of the fact that it is completed in the lower 180-Foot Aquifer.
- In well clusters MW-7, MW-8 and MW-9, there is less separation between the hydrographs for the middle (M) lower (D) wells than in well clusters MW-1, MW-3, and MW-4, indicating the 180/400-Foot Aquitard may be less competent or absent in this area, as also documented by the AEM surveys in this area (Section 3.1.12).
- In well clusters MW-1 and MW-3, there is less separation between the shallow (S) and middle (M) hydrographs than in well located further east, reflecting the previously documented lack of the SVA in this area.
- In wells MW-6S, MW-8S, and MW-9S there is a groundwater elevation spike in late 2016 and early 2017, with the biggest rise observed at MW-6S (from about 7 feet msl to 17 feet msl). This rise in groundwater elevations occurs at about the same time as a significant stage height increase in Salinas River measured at the USGS Spreckels gaging station (#11152500) from less than 2 feet to 20 feet (web site <a href="https://waterdata.usgs.gov/ca/nwis/uv?site\_no=11152500">https://waterdata.usgs.gov/ca/nwis/uv?site\_no=11152500</a>). These three wells, especially MW-6S, appear to respond to changes in the stage height of the Salinas River. This indicates that, at least during major rainfall events, the Salinas River is a losing river at MW-6, MW-8 and MW-9 which recharges the shallow aquifer. The immediacy of the response suggests a surface-groundwater interconnection.
- There is a cyclical pattern of high groundwater elevations in the winter/spring and low elevations in the summer/fall. Differences between seasonal high (spring) and low (summer/fall) groundwater elevations vary by completion interval and generally increase in

- amplitude with depth. The average amplitude of the seasonal groundwater elevation fluctuation is approximately 0 to 4 feet in the Dune Sand Aquifer, 1.5 to 10 feet in the 180-Foot Aquifer, and 10 to 24 feet in the 400-Foot Aquifer. These seasonal changes are consistent with regional temporal recharge and pumping patterns.
- To further assess the seasonal and inter-annual variability in groundwater levels related to different water year types, groundwater level data from spring and fall 2017 and spring and fall 2018 were compared. The 2017 data represent a wet year (23.0 inches of precipitation compared to the long-term average of 16.9 inches) during pumping of the test slant well, and 2018 data represent a dry year (12.6 inches of precipitation) after shut down of the slant test well pumping in February 2018. Summer/fall groundwater level declines were within the general ranges noted above for both years. In some cases, seasonal groundwater level declines were greater in 2017 than in 2018, but average declines were within were within 1 foot of each other. Spatially, for the 180- and 400-Foot Aquifers, average groundwater level declines were approximately 5 to 6 feet greater in the more easterly wells (MW-5, 6 and 9) than in wells further to the west (MW-4, 7 and 8), leading to greater landward gradients in the summer/fall in these aquifers than in the spring. The interpreted groundwater flow directions for the 180-Foot and 400-Foot Aquifers in the fall of 2017 and 2018 were generally consistent with the spring 2017 and 2018 flow directions discussed in Section 3.3.1.2. In the Dune Sand Aquifer, a consistent pattern in the spatial differences between spring and summer/fall groundwater levels was not evident during either year, and interpreted groundwater flow directions were consistently seaward.
- Groundwater elevations noticeably declined in the Dune Sand Aguifer and 180-Foot Aguifer near the test slant well in the MGSA Area during the pumping test between April 2015 and February 2018. Groundwater elevations declined by approximately 8 feet in MW-1S and MW-1M, and by 3 feet in MW-3S and MW-3M, but recovered after the long-term test was discontinued in February 2018 and have remained relatively stable since then. For the remaining monitoring wells (1,920 to 21,500 feet from the test slant well) pumping-related drawdown was too gradual to be readily distinguishable; however, groundwater elevations in most of these wells appeared to show a relatively abrupt recovery (or rebound) when long-term pumping was temporarily discontinued in March of 2016 and at the end of the long-term test pumping in April 2018, indicating these wells were subject to drawdown related to the test. Recovery in all of the 180-Foot Aquifer and 400-Foot Aquifer monitoring wells was abrupt and distinct, and ranges from approximately 2 to 5 feet in the 400-Foot Aquifer, and 1 to 4 feet in the 180-Foot Aquifer. This observation is consistent with a hydraulic connection between the 180-Foot and 400-Foot Aguifer systems and lower storativities in the 400-Foot Aguifer system compared to the 180-Foot Aquifer system. Recovery in the six Dune Sand Aquifer wells located east of the MGSA Area was generally more muted and approximately 1.5 feet or less. An abrupt response was observed in two wells during the first recovery event (MW-8S and MW-9S), a

muted/slight response was observed in one monitoring well during both recovery events (MW-4S) and one monitoring well during the first recovery event (MW-6S), and no response was observed in to monitoring wells (MW-6 and MW-7). Although these muted responses are more difficult to distinguish from recovery related to other causes, such as recharge events or the cessation of other pumping, their observed correlation with the cessation of pumping at the test slant well and responses in deeper aquifers is a strong indicator the Dune Sand Aquifer is hydraulically influenced by the underlying aquifer system and was affected by pumping the test slant well. This is consistent with modeling for the proposed MPWSP, which indicates pumping from the Dune Sand and 180-Foot Aquifers to supply water for the project from the MGSA Area is expected to result in drawdown ranging from 1 to 5 feet in the Dune Sand Aquifer between the MPWSP and the Salinas River (ESA 2018).

Seasonal high groundwater elevations in some of the shallow monitoring wells in the agricultural areas east of the MGSA Area occur later than in deeper wells in the same cluster. For example, seasonal high groundwater elevations in well MW-7S occur approximately 80 to 120 days later than in wells MW-7M and MW-7D. A similar, less pronounced pattern is observed for well MW-8S. This shift may be related to recharge from the deep percolation of irrigation water near these well locations.

### 3.2.2 ESTIMATE OF GROUNDWATER STORAGE CHANGES

### **Regulation Requirements:**

**§354.16(b)** A graph depicting estimates of the change in groundwater in storage, based on data, demonstrating the annual and cumulative change in the volume of groundwater in storage between seasonal high groundwater conditions, including the annual groundwater use and water year type.

A graph depicting regional groundwater storage change in the 180/400 Foot Aquifer Subbasin presented in the SVBGSA's regional GSP (SVBGSA 2020) is presented as Figure 3-35. Although groundwater storage, as plotted on the figure, has shown both decreasing and increasing short term trends since the 1940s, overall, Subbasin storage has displayed a decreasing trend. During the recent drought between 2012 and 2016, groundwater storage is estimated in SVBGSA's graph to have decreased by approximately 54,000 AF, to a cumulative maximum depletion since 1940 of 115,000 AF. In 2017, storage recovered by approximately 24,000 AF, indicating that, as had occurred on several past occasions during the period of record, that significant storage recovery is possible within a relatively short period of time.

In the MGSA Area, groundwater elevation data are only available since 2015, and during the period for which data are available, a long-term pumping test of the test slant well for the potential MPWSP was conducted. During this test, approximately 5,450 acre-feet (AF) of groundwater were extracted through September 21, 2017 from the DSA and 180-Foot Aquifer (HWG, 2017), consisting of saline groundwater originating beneath the Pacific Ocean outside the Subbasin boundaries, and a significant but unknown quantity of saline groundwater and low TDS groundwater from the landward side of the Dune Sand and

180-Foot Aquifers within the Subbasin. With the exception of MW-5S, MW-5M and MW-5D, groundwater elevations for the area east of the MGSA are unavailable prior to the pumping test, so an estimate of saline and low-TDS groundwater storage reduction in this area as a result of test slant well pumping is not possible. Since the cessation of test slant well pumping in February 2018, groundwater elevations in some of the monitoring wells east of the MGSA Area have increased slightly; whereas others have decreased, so no clear trends indicating long term storage recovery is evident.

Gottschalk *et al.* (2018) estimated the amount of low-TDS groundwater (defined as "potential drinking water" based on an interpreted TDS concentration less than 3,000 mg/L) in storage in the AEM-surveyed area as 550,000 AF. This includes 188,000 AF in the Dune Sand Aquifer, 291,000 AF in the upper 180-Foot Aquifer, 47,000 AF in the lower 180-Foot Aquifer, and 21,000 AF in the 400-Foot Aquifer. This includes low TDS groundwater identified within the MGSA Area, east of the MGSA Area in the 180-Foot Aquifer Subbasin, southeast of the MGSA Area in the Monterey Subbasin, and north of the area of seawater intrusion in the 180-Foot Aquifer Subbasin. It does not include potential low TDS groundwater in a large area of Dune Sand Aquifer within the Monterey Subbasin southeast of the MGSA Area that could not be surveyed by AEM methods because helicopter overflights were not permitted. These estimates represent a single snapshot in time, but could be used as a baseline to estimate future low TDS groundwater storage changes if the geophysical surveys are updated.

### 3.2.3 SEAWATER INTRUSION

### **Regulation Requirements:**

§354.16(c) Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.

#### 3.2.3.1 BACKGROUND

Regionally, the 180-Foot and 400-Foot Aquifers have been subject to seawater intrusion for more than 75 years and the 400-Foot Aquifer for 60 years, as demonstrated by increased salt content in wells near the Monterey Bay coastline. The negative impact of seawater intrusion on local water resources and the agricultural economy has been the primary motivation for many studies dating back to 1946 (DWR 1946). MCWRA and others have implemented a series of engineering and management projects including well construction moratoriums, developing the CSIP system, and implementing the Salinas Valley Water Project (SVWP), among other actions to halt seawater intrusion. Although those actions have managed to slow the advance of intrusion and reduce its impacts, seawater intrusion remains an ongoing threat.

The definition of seawater intrusion is generally based on a chloride concentration threshold and is dependent on local beneficial uses and groundwater protection strategies. In the Salinas Valley Groundwater Basin, MCWRA has defined the seawater intrusion threshold as 500 mg/L of chloride. This chloride concentration is significantly lower than the 19,000 mg/L chloride concentration typical of seawater, but it represents a concentration that may begin to impact use of the water. However, the

500 mg/L chloride definition has limited applicability in other circumstances. First, it is entirely possible that in an aquifer area where seawater intrusion has occurred at 500 mg/L chloride, that there will be large groundwater areas within the 500 mg/L impacted area that have higher quality groundwater than at the leading edge. For example, the chloride concentrations detected in wells MW-5M and 6M(L), located within the mapped seawater intrusion zone of the 180-Foot Aquifer, and well MW-9D, located within the mapped seawater intrusion zone of the 400-Foot Aquifer, contain chloride concentrations wells below the 500 mg/L threshold (see Figures 3-17, 3-18, 3-36 and 3-37). Second, although this definition may represent a practical standard for identifying groundwater affected by seawater intrusion, the affected groundwater quality may well be sufficient for many beneficial uses. In other words, the seawater intrusion front defined using the 500 mg/L chloride threshold is a useful guideline for identifying when some seawater affect may be detected, this does not mean that the groundwater within the affected region is no longer suitable for any current or potential beneficial uses.

Specifically, the following beneficial use standards apply to groundwater within the seawater intruded area of the Subbasin:

- Under SWRCB Resolution No. 88-63, the state considers all groundwater containing TDS at
  concentrations less than 3,000 mg/L as having a potential beneficial use as ("suitable for") a
  domestic and municipal supply. This Resolution is adopted as part of RWQCB's Water Quality
  Protection Plan for the region.
- SWRCB Resolution No. 68-16, also known as the Antidegradation Policy, requires that the
  existing high quality of waters be maintained to the maximum extent possible, and allows
  degradation only if it is consistent with maximum benefit to the people of the state, will not
  unreasonably affect present and potential beneficial uses, and will not result in water quality
  lower than applicable standards.
- For water containing TDS or chloride in excess of drinking water standards, treatment would be required prior to use. It should be noted is not uncommon for municipal or domestic supply systems to treat water prior to potable use. The State of California has adopted an upper Secondary Maximum Contaminant Level (SMCL) of 1,000 mg/L TDS and 500 mg/L chloride, and a short-term maximum SMCL of 1,500 mg/L TDS and 600 mg/L chloride. United States Environmental Protection Agency's (EPA's) and California's recommended maximum secondary limit is 500 mg/L TDS and 250 mg/L chloride. TDS and chloride concentrations in groundwater ranging to the "upper" contaminant level are acceptable if it is neither reasonable nor feasible to provide more suitable water sources. However, for purposes of determining whether groundwater is suitable for domestic and municipal water purposes, SWRCB Resolution No. 88-63, which is incorporated in the RWQCB's Basin Plan, governs over all other standards.
- The Federal Clean Water Act defines groundwater containing less than 10,000 mg/L TDS as an Underground Source of Drinking Water.

An additional important consideration is that the salt concentration at which seawater intrusion is defined in the Subbasin is much lower than the TDS concentration in seawater, which is approximately 35,000 mg/L, and is much lower than the concentration at which gravity-driven flow following Ghyben-Herzberg dynamics would occur (Section 3.1.12). The gravity-driven interface dynamics which occur near the MGSA Area differ from the advective solute transport that characterizes seawater intrusion in more inland areas, where the intruding water has a much lower TDS concentration and density. In these inland areas, dissolved solids essentially behave as a tracer that follows groundwater flow. The "seawater intrusion front" defined by the 500 mg/L chloride isoconcentration contour in the inland area is not expected to follow Ghyben-Herzberg dynamics. It is also important to note that the potential migration of the Ghyben-Herzberg interface in the nearshore environment, which cannot be defined using a 500 mg/L chloride contour, can nevertheless have important implications on the stability and migration of the 500 mg/L chloride isoconcentration contour in the inland areas.

### 3.2.3.2 EXTENT AND ADVANCE OF SEAWATER INTRUSION

The extent and advance of seawater intrusion over time has been well-monitored and reported by MCWRA. Monitoring seawater intrusion has been ongoing since the Agency formed in 1947 and currently includes a network of 96 agricultural wells and 25 dedicated monitoring wells that are sampled twice annually: in June and August. The water samples are analyzed for general minerals; the analytical results are used by MCWRA to analyze and report the following:

- Maps and graphs of historical chloride and specific conductivity trends;
- Stiff diagrams and Piper diagrams; and
- Plots of chloride concentration vs. sodium chloride molar ratio trends.

MCWRA publishes estimates of the extent of seawater intrusion every two years based on the inferred location of the 500 mg/L chloride concentration. MCWRA has developed regional maps of the current and historical extent of seawater intrusion for the 180-Foot Aquifer and the 400-Foot Aquifer. Maps showing the progression of the seawater intrusion front over time up to 2015 in the 180-Foot and 400-Foot Aquifers are presented as Figure 3-36 and Figure 3-37, respectively. These maps were augmented by MGSA to include approximate outlines of the zones of "low TDS groundwater" identified during the AEM survey (Gottschalk *et al.* 2018) on top of MCWRA seawater intrusion maps. Using a standard of 3,000 mg/L TDS to define seawater intrusion into the Dune Sand Aquifer, these figures also show the advance of seawater intrusion into the Dune Sand Aquifer. In each of the two figures, the extent of the color shaded contours represents the extent of groundwater with chloride exceeding 500 mg/L during the referenced year. The maps indicate that seawater intrusion has migrated inland (eastward) in a bilobate zone. In the northern lobe, approximately centered between the current mouth of the Salinas River and Elkhorn Slough, seawater intrusion has progressed inland for a distance of approximately 7.5 miles in the 180-Foot Aquifer and 3 miles in the 400-Foot Aquifer. In the southern lobe, approximately centered on the City of Marina, seawater intrusion has progressed inland approximately 4.5 miles in the

180-Foot Aquifer and 4 miles in the 400-Foot Aquifer. Several "chloride islands were first observed in the 400-Foot Aquifer on the landward side of the previously identified seawater intrusion front, and reflect the vertical migration of seawater intrusion through gaps in the 180/400-Foot Aquitard where the 180-Foot Aquifer and the 400-Foot Aquifer are in direct connection, and/or where vertical migration takes place through wells that have been improperly constructed or boring have been improperly abandoned and serve as conduits that connect the aquifer systems.

Continued seawater intrusion is driven by a large trough north and northeast of Salinas where groundwater elevations have fallen below sea level. SVBGSA estimates of groundwater storage losses due to continued seawater intrusion in the Subbasin range from 8,000 to 14,000 AFY (SVBGSA 2019). As discussed in Chapter 2 and Chapter 6, several projects are being implemented and/or proposed by SVBGSA and others to address ongoing overdraft and seawater intrusion through *in lieu* recharge and direct recharge to reverse this trend. These projects are intended to increase the water elevation in the 180-Foot Aquifer and 400-Foot Aquifer to slow seawater intrusion. Groundwater level rises ranging from approximately 2 to 4 feet are projected between the Salinas River and the MGSA Area, decreasing to the west. Water elevation rise from future projects will decrease landward groundwater gradients, and could potentially reverse the groundwater flow direction in the 180-Foot Aquifer, and 400-Foot Aquifer depending on the extent and success of future projects and other factors.

The distribution of water quality in the Dune Sand Aquifer, 180-Foot Aquifer and 400-Foot Aquifer near the MGSA Area is discussed in Section 3.1.12, and shown graphically in Figure 3-21 to Figure 3-23. Maps showing the distribution of TDS and chloride concentrations detected in monitoring wells near the MGSA Area are shown in Figure 3-16, Figure 3-17, and Figure 3-18 for the Dune Sand, 180-Foot and 400-Foot Aquifers, respectively. As shown in these figures and discussed in Section 3.1.12, a zone of low TDS groundwater (TDS < 3,000 mg/L) exists in an approximately 8,300-acre area that is locally recharged through the Dune Sand Aquifer (Gottschalk *et al.* 2018). TDS concentrations detected in groundwater samples collected from this area in April 2019 range from 896 to 3,000 mg/L, and chloride concentrations range from 112 to 950 mg/L (Figure 3-16). This zone appears to be in a relatively stable state of equilibrium with a saline groundwater intrusion wedge whose upper contact cuts through the eastern side of the MGSA Area. Under Ghyben-Herzberg dynamics, this wedge should remain stable as long as the thickness of the overlying low TDS groundwater zone is maintained.

To date, seawater intrusion has not been reported in the Deep Aquifer. However, due to concern about the potential competence of aquitards separating this aquifer from the overlying seawater-intruded aquifers, MCWRA recommended a moratorium on further development of groundwater supplies in this aquifer (MCWRA 2017). Subsequently, the county adopted Ordinance 5302, prohibiting the construction of new wells in the Deep Aquifer beneath the areas impacted by seawater intrusion.

# 3.2.4 GROUNDWATER QUALITY

# **Regulation Requirements:**

**§354.16(d)** Groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes.

This section presents a summary of current groundwater quality conditions that are not related to seawater intrusion. MGSA does not have regulatory authority over groundwater quality and is not charged with improving groundwater quality in the Subbasin. Projects and actions implemented by MGSA are not required to improve groundwater quality; however, they must not further degrade groundwater quality. Locally, RWQCB, DTSC and Monterey County Environmental Health Bureau oversee and enforce compliance with environmental health and water quality protection regulations in the county.

#### **3.2.4.1** Point Sources of Groundwater Pollutants

There are no reported contamination incidents, waste discharge sites, underground storage tank sites or other potential point sources of groundwater pollutants within the MGSA Area. There are no active point-sources of water quality pollutants or contamination plumes located within 1 mile from the MGSA; therefore, contamination plumes and point sources of pollutants are discussed narratively below, but a map is not included.

In the vicinity of the MGSA Area, there are three closed underground storage tank cleanup cases located within approximately 1 mile of the MGSA Area (SWRCB 2019). Based on their distance from the MGSA Area (at least 2,500 fee) and the fact that these cases are closed, it is unlikely that management actions or projects within the MGSA Area would result in the capture or spread of contamination from these properties. The MCWD wastewater collection facility, reclamation plant and desalination facility are located approximately 2,000 feet south of the MGSA Area and operate under Waste Discharge Requirements issued by the RWQCB. No violations or releases have been reported at these facilities.

The Ford Ord Superfund Site Operational Unit Carbon Tetrachloride Plume (OUCTP) area is located southeast of the MGSA Area. The OUCTP plume extends off the former army post into the City of Marina and the western extent of the carbon tetrachloride plume is approximately 7,000 feet southeast of the MGSA Area (Ahtna, 2019a). Recent monitoring for September 2018 (Ahtna, 2019b) includes water level and water quality monitoring: water quality monitoring is conducted at four remediation injection wells, 19 remediation extraction wells, and 56 monitoring wells. The September 2018 sampling was conducted in A-Aquifer wells, and carbon tetrachloride was present in 37 of the 56 monitoring wells at concentrations up to 5.8 micrograms per liter (ug/L). The A-Aquifer plume extends north from the post approximately 1 mile, then west northwest into the City of Marina approximately 2 miles. The plume currently appears to be contained by ongoing remediation efforts.

Groundwater elevation data for the 180-Foot Aquifer are also measured at OUCTP, and the direction of groundwater flow for the four quarterly events reported (Q4 2017 to Q3 2018) was generally an

eastward direction for the area within the City of Marina. The 180-Foot Aquifer is not impacted by the OUCTP plume.

Groundwater extraction in the MGSA Area has the potential to affect groundwater gradients near the OUCTP area, potentially causing a change in the direction or rate of plume migration, and interfering with ongoing cleanup efforts. The impacted A-Aquifer in this area is reported to be perched on the Fort Ord/Salinas Valley Aquitard, which may effectively separate it from regional drawdown in the DSA and 180-Foot Aquifer; however, this has not been determined conclusively. The MMRP for the MPWSP requires review of potential changes in OUCTP plume migration that could be induced by MPWSP pumping (CPUC 2018), if the MPWSP is approved and implemented. These evaluations would be reported under MCWRA's monitoring program, which has been incorporated into this GSP.

### 3.2.4.2 DISTRIBUTION AND CONCENTRATIONS OF DIFFUSE OR NATURAL GROUNDWATER CONSTITUENTS

With the exception of seawater intrusion, there are no known or reported sources of diffuse or natural groundwater pollutants in the MGSA Area.

Within the 180/400 Foot Aquifer, the Regional Board monitors and regulates activities and discharges that can contribute to non-point pollutants, which are constituents that are released to groundwater over large areas. In the Subbasin, the most prevalent non-point source water quality concern is nitrate. The current distribution of nitrate was extensively monitored and evaluated by the CCGC and documented in a report submitted to the Regional Board (LSCE 2015).

Six agricultural sites within 1 mile of the MGSA Area are enrolled in the Irrigated Lands Program, which monitors and regulates nitrate discharges to groundwater. Two sources of water quality data were reviewed for the MGSA Area with respect to nitrate (based on prior investigations in the Salinas Valley Basin that identified nitrate as a chemical of concern): data from monitoring wells sampled in support of the MPWSP and groundwater quality data and data posted to the SWRCB GeoTracker GAMA site (SWRCB 2019). Nitrate as nitrogen was detected in three monitoring wells in the MGSA Area at concentrations ranging from less than 1 mg/L to approximately 5 mg/L. Water quality data posted for the CEMEX well indicate 13 samples were collected between 2000 and 2014 and analyzed for nitrate, with reported concentrations ranging from less than 2 mg/L (reporting limit) to 77 mg/L. None of the MPWSP on-site well samples exceeded the Maximum Contaminant Level (MCL) for nitrate as nitrogen in drinking water of 10 mg/L, and only one of the CEMEX well samples exceeded the nitrate MCL of 45 mg/L; however, water produced from this well contains TDS at a concentration of 19,000 mg/L and is not suitable as a source of drinking water.

Groundwater sampled east of the MGSA Area from monitoring wells MW-5S(P), MW-5M, MW-7S, and MW-8S was found to contain nitrate as nitrogen concentrations greater than the 10 mg/L MCL. These wells are located approximately 3,300 to 7,200 feet east of the MGSA Area, in agriculturally developed areas.

## 3.2.4.3 GROUNDWATER QUALITY SUMMARY

Based on the water quality information presented in the previous sections, the following constituents will be considered for inclusion in the monitoring program adopted in this GSP:

- · Chloride; and
- TDS.

The monitoring network is further defined in Chapter 5. The constituents listed above are the constituents of concern for all aquifers in MGSA Area. Nitrate is not proposed to be included because there are no potential nitrate sources within the MGSA Area.

## 3.2.5 LAND SUBSIDENCE

## **Regulation Requirements:**

§354.16(e) The extent, cumulative total, and annual rate of land subsidence, including maps depicting total subsidence, utilizing data available from the Department, as specified in Section 353.2, or best available information.

Land subsidence is not closely monitored in the Monterey Bay region and has not been reported in Salinas Valley. In 2014, DWR reported that continuous monitoring stations located near the coast in the Pajaro Valley and Santa Cruz areas displayed a declining trend, but recorded total cumulative subsidence less than 1 inch (DWR 2014). DWR estimated the potential for future land subsidence in each groundwater basin based on groundwater elevations, previous subsidence studies, borehole extensometer data, and continuous GPS data. It was reported that there was insufficient data in the Salinas Valley Basin to assess its vulnerability to future subsidence.

The DWR SGMA Data Viewer includes estimates of vertical ground surface displacement in Salinas Valley between June 2015 and June 2018 based on satellite data (<a href="https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#landsub">https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#landsub</a>). Vertical displacement estimates are derived from Interferometric Synthetic Aperture Radar (InSAR) data collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by TRE ALTAMIRA Inc. (TRE) under contract with the DWR. The total ground surface displacement reported in and near the MGSA Area during this time period ranged from approximately 0.01 to 0.025 foot. During the first two years of this time period, the test slant well-constructed for the MPWSP project in the MGSA Area was pumped at a rate of approximately 2,000 gallons per minute.

The available data suggest that the vicinity of the MGSA Area has not experienced significant subsidence. However, the data are insufficient to assess the potential vulnerability of this area to future subsidence if groundwater extractions are increased. MGSA will work with SVBGSA to address this data gap during GSP implementation.

## 3.2.6 INTERCONNECTED SURFACE WATER SYSTEMS

### **Regulation Requirements:**

**§354.16(f)** Identification of interconnected surface water systems within the basin and an estimate of the quantity and timing of depletions of those systems, utilizing data available from the Department, as specified in Section 353.2, or best available information.

The MGSA Area is approximately 4,000 feet from the Salinas River. Little information is available to directly assess the potential interaction between the river and the Dune Sand Aquifer and underlying 180-Foot Aquifer at this location; however, the following data suggest that they are interconnected:

- Measured groundwater elevations in wells in this area range from 6 to 8 feet above mean sea level, which is less than 20 feet below the elevation of the Salinas River thalweg in this area;
- In early 2016, groundwater elevations measured in the shallow wells completed at the MW-6, MW-8 and MW-9 clusters near the Salinas River showed a rapid and pronounced rise up to approximately 7 feet that was closely correlated with a rise in the Salinas River stage at the Spreckels gaging station from 2 to 20 feet.
- Geophysical data collected in 2017 indicate that groundwater elevations in the Dune Sand Aquifer are close to the river stage elevation, and decline away from the river, suggesting a losing condition (Figure 3-22).
- Within approximately ½ mile of the river mouth, the geophysical data suggest that seawater intrusion is occurring through the riverbed and into the Dune Sand Aquifer and underlying 180-Foot Aquifer (Figure 3-22).
- Projected groundwater elevations in the spring of 2018 were within less than 2 to 5 feet of several mapped "vernal ponds" (palustrine and emergent wetlands) located east of the MGSA Area that are designated as environmentally sensitive habitat areas designated for protection under the California Coastal Act (Section 2.1.2).

Further inland, near the Spreckels gaging station approximately 13.5 river miles upstream from the Pacific Ocean, groundwater elevations have historically been much deeper than Salinas River, indicating that the river may be hydraulically disconnected from the regional groundwater aquifers at this location.

This analysis of surface-groundwater interaction along the Salinas River is based on limited data and is therefore uncertain. Additional groundwater elevation data collection using monitoring wells completed in the Dune Sand Aquifer and the 180-Foot Aquifer near the river, and further evaluation through groundwater modeling would help to address this data gap. MGSA will work in coordination with the SVBGSA to help address this data gap in the lower reach of the river near the MGSA Area.

#### 3.2.6.1 Groundwater-Dependent Ecosystems

### **Regulation Requirements:**

**§354.16(g)** Identification of groundwater dependent ecosystems within the basin, utilizing data available from the Department, as specified in Section 353.2, or best available information.

Figure 3-38 shows the location of potential groundwater-dependent ecosystems (GDEs) in the vicinity of the MGSA Area based on the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset (<a href="https://gis.water.ca.gov/app/NCDatasetViewer/">https://gis.water.ca.gov/app/NCDatasetViewer/</a>) developed by The Nature Conservancy in collaboration with DWR. The process for assessing whether these potential GDEs are in fact GDEs is discussed below. No potential GDEs are mapped in the MGSA Area, but several potential GDEs are located nearby. Potential GDEs near the MGSA Area include riverine wetlands and riparian habitat along the banks of the Salinas River, and palustrine and emergent wetland areas that are seasonally flooded in depressions a short distance east of the MGSA Area, north in the Salinas River National Wildlife Refuge, and south in the City of Marina.

Several of the potential GDEs identified near the MGSA Area are included in the *Coastal/Vernal Ponds Comprehensive Management Plan* that was developed by the City in 1994 (The Habitat Restoration Group 1994). Despite their sometimes seasonal nature, they are considered coastal wetlands and that provide habitat and cover for migratory waterfowl and a number of animals, including the endangered black legless lizard. Table 3-4 lists the location and current ownership/management of several of the vernal ponds in the City of Marina. The plan was developed to identify guidelines for the preservation, management and enhancement of Marina's wetland resources, and the plan identifies specific measures to be conducted at each pond to preserve, protect, and enhance sensitive resources.

TABLE 3-4. VERNAL PONDS IN MARINA

Pond	Location	Current Ownership/Management
Pond 1	West of Lake Drive	City of Marina
Pond 2	Reservation Road and Seaside Avenue	City of Marina
Pond 3	Reservation Road and Beach Road	Private/City
Pond 4	North of Reservation Road West of Hwy 1	Marina Water District
Pond 5	South of Reservation Road West of Hwy 1	CA Department of Parks and Recreation
Pond 6	West of Hwy 1	Private (unincorporated land outside City of Marina Limits)
Pond 7	West of Lake Drive	City of Marina

Source: City of Marina Local Coastal Program Land Use Plan (City of Marina 2014a)

Ponds 3, 5, and 6 are located closest to the MGSA Area: Pond 6 – Armstrong Ranch Complex Ponds are immediately to the east of the MGSA Area; Pond 5 – Marina Cost Water District Pond is south of the MGSA Area; and Pond 3 – Marina Landing Pond is south east of the MGSA Area. They are described in

City of Marina planning documents as "vernal ponds," which are areas where water pools that expand during the wet season and support marshy wetlands that provide habitat for plants and animals much of the year (City of Marina 2014a). These fresh and brackish water ponds are unique along the California coast and are present when a combination of circumstances (*i.e.*, a depression within the fast-draining sandy soils, a lens of less pervious soil, and a high water table) occur simultaneously.

To evaluate whether these potential GDEs are in fact groundwater dependent and whether they may be affected by groundwater extraction in the MGSA Area, the following information was considered. The Dune Sand Aquifer is the uppermost aquifer in the area and is hydraulically connected to the 180-Foot Aquifer in the MGSA Area (Section 3.1.6). Modeling of potential groundwater resources effects associated with the proposed MPWSP indicates pumping from the Dune Sand and 180-Foot Aquifers to supply water for the project from the MGSA Area is expected to result in drawdown ranging from 1 to 5 feet in the Dune Sand Aquifer in the area between the MPWSP and the Salinas River (ESA 2018). While the actual amount of drawdown is uncertain, the results of this analysis support the interpretation of a nexus between groundwater extraction in the MGSA area and groundwater elevations in the Dune Sand Aquifer in the surrounding area. Consistent with guidance developed by The Nature Conservancy (TNC 2019), an evaluation was conducted to assess the connection of the potential GDEs identified near the MGSA Area (Pond 6) and the Dune Sand Aquifer. Groundwater elevations interpolated from monitoring data in the Dune Sand Aquifer in an area within and east of the MGSA Area (Pond 6) were subtracted from land surface elevations derived from the USGS digital elevation model to determine the depth to groundwater beneath areas where potential GDEs were mapped. In the area where groundwater elevation data were available, it was found that the mapped palustrine and emergent wetlands (coastal vernal ponds) occurred in the areas where the shallowest groundwater elevations were found to exist (0 to 5 feet below ground level), strongly suggesting that these features are groundwater connected and dependent. The results of this analysis are presented as Figure 3-38.

The Armstrong Ranch Ponds are located approximately 300 to 1,000 feet southeast of the MGSA Area and include a series of seasonal wetlands with ponded water in the winter and wet herbaceous meadows likely subsisting on shallow groundwater during the dry season (The Habitat Restoration Group 1994). A representative analysis of evapotranspiration (ET) from one of these ponds is presented in Figure 4-1. Summer (June, July, and August) evapotranspiration was calculated using the surface energy balance method (Paul *et al.* 2018) from remote sensing data generated by the Landsat Satellite mission by Formation Environmental under contract to the Department of Water Resources (DWR). The results indicate summer ET ranged from approximately 5 to 10 inches from 2010 to 2013, then decreased to approximately 1 to 5 inches in 2014 and 2015, and 1 to 3 inches in 2016. In 2017, ET increased to approximately 3 to 10 inches, and in 2018, ET was approximately 5 to 12 inches. The decline in ET from 2014 to 2016 occurred during a period of severe drought; however, the test slant well pumping test was also conducted from April 2015 to February 2018 (Geoscience Support Services 2019). Hydrographs for well MW-4S indicate that the seasonal fluctuation in groundwater elevations in this well was approximately 2 feet, and suggest that pumping-induced drawdown was approximately 1 foot.

The lowest groundwater elevations were observed in the summer of 2016 and averaged about 2 feet higher in summer 2017 and summer 2018.

The above ET analysis demonstrates the correlation between groundwater levels and ET from this wetland, and illustrates its sensitivity to groundwater level declines. The existence of a GDE at this location is therefore considered confirmed, and the remaining vernal ponds are also assumed to be GDEs for the purposes of this GSP. ET, and by correlation biomass productivity, rebounded with groundwater levels; however, it is not known whether the stress induced in the GDE resulted in a change in the vegetation community, habitat degradation, or habitat succession that is not readily reversible. Based on this data, it is not possible to determine the extent to which the drawdown induced during the test slant well pumping test resulted in significant and unreasonable impacts to the GDE, or whether the results were temporary and reversable. The correlation between groundwater elevations and GDE responses is identified as a data gap.

# 3.3 WATER BUDGET INFORMATION

### 3.3.1 Introduction

## **Regulation Requirements:**

§354.18(a) Each Plan shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form.

The MGSA Area represents a relatively small area within the 180/400 Foot Aquifer Subbasin, for which historical, current, and projected water budgets have been prepared by SVBGSA and presented in their GSP (SVBGSA 2020). Since the MGSA Area is hydraulically connected with the surrounding portions of the Subbasin and part of the already developed water budgets, this GSP adopts the SVBGSA's regional historical, current, and future water budgets for the Subbasin (SVBGSA, 2020). Tables summarizing these water budgets are included as Appendix 3.E, and the details and assumptions regarding their derivation are described in the SVBGSA's GSP. The water budget discussion in this GSP focuses on augmenting the SVBGSA's regional water budgets with local water budget information as needed to prepare a locally focused GSP that complies with the requirements of 23 CCR § 354.18, conveys an adequate understanding of local groundwater conditions, and informs local sustainable groundwater management decisions.

Data to assess local water budget components near the MGSA Area are limited. Up to the present time, land use in the MGSA Area was limited to open space and a sand plant with a single saline process water supply well and little attention was paid to groundwater conditions beneath the area, except as part of more regional studies. The sand plant permit to operate and pump water expires on December 31, 2020, which should result in improved groundwater conditions within the MGSA Area.

In order to help assess potential impacts associated with construction of the MPWSP slant makeup water wells for the proposed MPWSP within the MGSA Area, monitoring wells were first installed in 2015 along with the test slant well. As a result, there is little data for development of a local historical water budget prior to 2015. Similarly, while recent investigations focused on this area have revealed the nature and complexity of local subsurface stratigraphic and water quality conditions, the tools to evaluate the response of the low-TDS/saline groundwater interface and the aquifers in this area to pumping to substantial pumping at a local level do not, as yet, exist. This GSP relies on the regional water budget analysis completed by SVBGSA, supplemented by a local water budget under current conditions, and qualitative information regarding local historical and projected water budget conditions. We believe this approach complies with the requirements of 23 CCR § 354.18 and will support sustainable management of groundwater resources in and around the MGSA Area when coupled with appropriate sustainable management criteria, monitoring and management actions discussed in Chapters 4, 5 and 6, respectively.

SVBGSA used a pre-publication version of the USGS SVIHM to evaluate and develop regional water budgets for the Subbasin. The approach, assumptions, and resulting water budgets are described in detail in Chapter 6 of SVBGSA's GSP (SVBGSA 2020). After the SVIHM is publicly released, MGSA will use it as needed during GSP implementation in collaboration with SVBGSA to develop a more refined understanding of the local water budget, flow conditions and project effects, and their integration with regional conditions, and to inform sustainable groundwater management decisions. Chapter 6 includes specific requirements for development of a locally refined groundwater flow model that is able to simulate solute transport and density-driven flow that can be used to evaluate and develop corrective actions if water quality monitoring indicates that significant and unreasonable seawater intrusion or water quality degradation may occur. MCWD GSA is currently planning to conduct such studies for the area that includes their GSA boundaries and the surrounding region, including the MGSA Area and beyond. With these measures in place, the water budget and basin characterization tools that are currently available are sufficient to assure the sustainable management objectives of this GSP and the adjacent GSPs are met.

### 3.3.2 LIMITATIONS

Several significant data limitations affect the approach to water budget development in this GSP and the interpretation and application of the water budget data. Appropriate care should be taken when applying these data to assess inter-basin flows and the regional effects of seawater intrusion and proposed regional projects, as such assessments will likely require additional focused evaluation. Once the SVIHM groundwater model is made available by the USGS, updated assessments of the historical, current, and future water budgets for the MGSA Area and surrounding regions will be undertaken as needed during GSP implementation in coordination with SVBGSA and MCWD GSA. The following specific data limitations have been identified.

- Groundwater elevation, flow direction and gradient data There are limited data describing the groundwater elevation and flow conditions within and near the MGSA Area. Water elevation data are available for the Dune Sand Aquifer, 180-Foot Aquifer and 400-Foot Aquifer only after early 2015, which limits the ability to assess trends and historical water budget data. The closest Deep Aquifer monitoring well is more than 2 miles south of the MGSA Area. Further, the available Deep Aquifer wells are completed in various aquifer horizons between about 700 and 2,000 feet below ground surface, and are at present insufficient numbers to establish a groundwater gradient; therefore, the subsurface inflow/outflow cannot be estimated for the Deep Aquifer at this time.
- **Upper aquifer system data** Known heterogeneities in the upper aquifer system (the Dune Sand, 180-Foot and 400-Foot Aquifers), aquitards and groundwater density contacts have not yet been conceptualized in available groundwater models at the local scale.
- Lower aquifer system data The properties of the 400 Foot/Deep Aquitard and Deep Aquifer are not well understood. Refinement of the available modeling tools may be needed during GSP implementation to assess potential future water budget changes.
- Recharge and vertical leakances data Based on regional information and site-specific water elevation data, recharge occurs from deep percolation of precipitation and applied irrigation water. The 180-Foot, 400-Foot and Deep Aquifers all receive recharge from the overlying aquifers in the form of vertical leakance. The lateral extent, thickness and properties of the aquitards separating these aquifers is variable, and the vertical leakance between these aquifers has not been quantified at the local level.
- Subsurface inflow/outflow data Groundwater moves into and out of the MGSA Area as subsurface flow. Under pre-development conditions in the Salinas Valley, the groundwater gradient in all four aquifers is presumed to have been seaward (in a generally westerly direction from the land to the sea). Due to inland pumping, the groundwater gradient has changed, and saltwater has intruded under the land within a portion of Dune Sand, 180-Foot and 400-Foot Aquifers. Developing subsurface inflow/outflow budgets is complicated by the landward flow direction in the 400-Foot Aquifer and at least the lower portions of the 180-Foot Aquifer. With the implementation of in lieu and direct discharge projects in the future, as described in Chapter 6, these gradients are expected to lessen in the future, and water budgets would change as a result of decreasing and potentially even reversed gradients.
- Groundwater mixing in multiple aquifers Pumping from the CEMEX well, MPWSP test slant
  well and proposed MPWSP slant wells occurs from multiple aquifers, and the contribution from
  individual aquifers or differing water quality zones is not known. In addition, density-driven
  convection of saline groundwater in the intruding wedge underlying the MGSA Area likely
  results in the mixing of saline and low-TDS groundwater in the upper portion of the intruding

wedge, which discharges seaward. Mixing of aquifer water complicates developing inflow and outflow water budgets and the prediction of future water budget effects.

## 3.3.3 APPROACH

## **Regulation Requirements:**

§354.18(e) Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population, climate change, sea level rise, groundwater and surface water interaction, and subsurface groundwater flow. If a numerical groundwater and surface water model is not used to quantify and evaluate the projected water budget conditions and the potential impacts to beneficial uses and users of groundwater, the Plan shall identify and describe an equally effective method, tool, or analytical model to evaluate projected water budget conditions.

Due to the limitations described in Section 3.3.2, only a current water budget is developed for the MGSA Area, and qualitative water budget information is provided for the historical water budget and predicted water budget to cover the budget components that can be evaluated at this time. However, for planning purposes, it is reasonable to assume that the historic water budget was similar to the current water budget, as there has not been a significant change in land use or groundwater development within the MGSA Area for decades, with exception of the recent test slant well pumping. The current water budget was calculated using average annual data from Water Year (WY) 2015 through WY 2018.

Section 3.3 organized in subsections that develop the supplemental water budget information for the MGSA Area in a methodical fashion using the following approach:

- 1. Define the water budget boundary.
- 2. Identify the water budget components to be estimated for the water budget.
- 3. Identify the source data and quantify each of the groundwater budget components. Separate sections are included quantifying the surface water budget and groundwater inflows and outflows. Component quantification is mainly for the current water budget, with additional information discussed to provide perspective on the historical and projected water budgets.
- 4. Estimate the change in groundwater in storage.
- 5. Combine the individual components into a water budget summary in tabulated and graphical form.
- 6. Discuss the uncertainties in the water budgets.

Development of the supplemental water budget for the MGSA Area is based on the following data:

- 24 years of precipitation data from Monterey airport summarized in Table 3-5 (1995 to 2018);
- Eight years of evapotranspiration data summarized in Table 3-6 (2010 to 2018);

- Four years of water elevation data from MPWSP monitoring wells summarized in Table 3-7 (February 2015 to April 2019);
- Aquifer properties summarized in Section 3.1.7.1; and
- Reported pumpage by the CEMEX and test slant well test.

TABLE 3-5. MONTHLY PRECIPITATION (INCHES) FOR MONTEREY WEATHER FORECAST OFFICE (WFO), CA

14/2424													Water
Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
real													Total
1996	0.16	0.05	1.61	4.16	6.05	2.87	0.70	1.30	0.03	0.01	Т	0.02	16.96
1997	0.76	2.07	5.93	7.67	0.05	0.12	0.18	0.12	0.10	Т	0.15	0.00	17.15
1998	0.57	6.06	3.46	7.55	13.73	3.79	2.98	2.25	0.09	0.06	Т	0.10	40.64
1999	0.61	2.46	1.19	2.67	3.14	3.39	2.17	0.03	0.20	0.01	0.04	0.40	16.31
2000	0.12	1.00	0.16	5.27	5.77	2.44	0.73	0.41	М	0.02	0.00	0.23	16.15
2001	3.89	М	0.20	3.55	3.70	1.67	1.78	0.01	0.06	Т	0.03	0.11	15.00
2002	0.17	2.28	4.78	1.08	0.97	1.04	0.40	0.66	0.03	Т	0.01	Т	11.42
2003	0.01	1.89	6.19	1.02	1.88	0.99	2.15	0.79	0.02	0.01	0.05	0.02	15.02
2004	0.35	1.66	5.33	1.34	4.05	0.53	0.01	Т	0.06	0.03	0.01	0.08	13.45
2005	3.34	1.02	4.92	4.44	4.16	4.15	1.56	0.79	0.28	0.04	0.00	0.00	24.70
2006	0.15	1.09	3.62	3.18	0.91	7.11	2.77	0.63	0.00	0.04	0.00	0.00	19.50
2007	0.07	1.34	2.30	1.07	3.12	0.52	1.04	0.15	0.06	0.02	0.00	0.44	10.13
2008	1.13	0.46	1.07	6.34	2.61	0.52	0.25	0.00	0.01	0.01	0.01	Т	12.41
2009	0.16	1.32	2.70	2.21	4.96	2.32	0.33	0.20	0.03	0.04	0.08	0.15	14.50
2010	2.43	0.25	2.18	5.88	2.87	3.24	3.01	0.55	0.00	0.00	0.15	0.05	20.61
2011	0.85	2.15	4.04	2.01	4.52	4.83	0.20	0.86	0.78	0.02	0.07	0.01	20.34
2012	1.86	1.44	0.20	1.31	0.74	3.51	2.23	0.13	0.30	0.03	0.03	0.00	11.78
2013	0.63	3.45	3.87	0.86	0.79	1.05	0.31	Т	0.06	Т	0.11	0.04	11.17
2014	0.45	0.39	0.30	0.10	3.75	2.63	1.22	0.09	0.01	Т	0.06	0.33	9.33
2015	1.44	1.39	8.55	Т	1.26	0.29	0.89	0.29	0.01	0.13	0.05	0.05	14.35
2016	0.13	3.58	3.73	6.40	1.34	5.16	0.59	0.24	0.01	0.00	0.03	0.00	21.21
2017	2.73	1.32	1.51	7.49	6.18	2.33	1.24	0.03	0.08	0.00	0.01	0.07	22.99
2018	0.14	1.21	0.20	3.44	0.35	4.74	2.33	0.11	0.00	0.02	0.01	0.00	12.55
Mean	0.96	1.65	2.96	3.44	3.34	2.58	1.26	0.42	0.10	0.02	0.04	0.09	16.86

TABLE 3-6. MONTHLY EVAPOTRANSPIRATION DATA FROM CALETA

Water Year	Units	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
	Inches	0.57	0.41	0.26	0.42	0.39	0.68	0.93	0.91	0.81	0.76	0.64	0.68	7.47
WY2011	Acre- Feet	18.84	13.65	8.74	14.03	13.02	22.57	30.88	30.19	27.03	25.07	21.40	22.57	248.00
	Inches	0.64	0.44	0.48	0.53	0.60	0.78	0.98	1.00	0.92	0.78	0.76	0.58	8.50
WY2012	Acre- Feet	21.25	14.59	15.89	17.50	20.04	26.04	32.49	33.24	30.61	26.04	25.20	19.31	282.19
	Inches	0.58	0.48	0.32	0.46	0.51	0.81	0.96	0.87	0.81	0.64	0.65	0.69	7.77
WY2013	Acre- Feet	19.29	15.88	10.51	15.25	17.02	27.03	31.75	29.00	26.78	21.15	21.45	22.77	257.88
	Inches	0.45	0.35	0.34	0.35	0.32	0.60	0.77	0.84	0.65	0.70	0.61	0.48	6.46
WY2014	Acre- Feet	14.81	11.69	11.30	11.77	10.70	20.00	25.44	27.73	21.61	23.08	20.36	15.97	214.48
	Inches	0.44	0.30	0.23	0.42	0.55	0.78	0.71	0.64	0.76	0.84	0.72	0.48	6.85
WY2015	Acre- Feet	14.51	9.92	7.71	13.92	18.21	25.79	23.52	21.39	25.17	27.78	23.75	15.90	227.59
	Inches	0.45	0.34	0.32	0.39	0.86	0.98	1.00	0.89	0.89	0.80	0.44	0.63	8.01
WY2016	Acre- Feet	14.85	11.45	10.65	13.10	28.43	32.47	33.35	29.53	29.70	26.70	14.66	20.94	265.82
	Inches	0.58	0.47	0.41	0.53	0.66	1.09	1.12	1.18	1.00	0.93	0.67	0.67	9.30
WY2017	Acre- Feet	19.40	15.54	13.45	17.72	21.76	36.11	37.33	39.14	33.12	30.79	22.19	22.30	308.85
	Inches	0.77	0.49	0.37	0.45	0.64	0.76	0.88	0.91	1.11	1.00	0.65	0.51	8.55
WY2018	Acre- Feet	25.59	16.15	12.25	16.51	23.95	28.51	33.37	34.85	42.02	38.32	26.23	20.62	318.36
														Total
	Inches	0.56	0.41	0.34	0.44	0.57	0.81	0.92	0.91	0.87	0.80	0.64	0.59	7.86
Average	Acre- Feet	18.57	13.61	11.31	14.97	19.14	27.31	31.02	30.63	29.51	27.37	21.90	20.05	265.40

TABLE 3-7. GROUNDWATER LEVEL AND VERTICAL GRADIENT DATA FROM MPWSP MONITORING WELLS

Well Name	Top of Casing	Measurement	Groundwater Elevation	Vertical Head Difference between Zones	Relative Vertical Flow Direction
	(ft NAVD88)	Date and Time	(ft NAVD88)	(ft)	
MW-1S	30.51	4/2/2018 12:00	6.05		
				-0.31	up
MW-1M	29.86	4/2/2018 12:00	6.36		
				7.99	down
MW-1D	29.68	4/2/2018 12:00	-1.63		
MW-1S	30.51	3/12/2017 12:00	-1.26		
				-2.97	up
MW-1M	29.86	3/12/2017 12:00	1.71		
		- 4 4		3.91	down
MW-1D	29.68	3/12/2017 12:00	-2.2		
MW-1S	30.19	3/20/2015 12:00	4.42	0.55	
	20.00	2/20/2045 42 00	5.07	-0.65	up
MW-1M	29.86	3/20/2015 12:00	5.07	0.50	d a
MW-1D	29.39	3/20/2015 12:00	2.52	8.59	down
MW-3S	37.16		-3.52		
IVIVV-33	37.10	3/20/2015 12:00	5.81	2.56	down
MW-3M	37.35	3/20/2015 12:00	3.25	2.30	down
IVIVV-SIVI	37.33	3/20/2013 12.00	3.23	5.97	down
MW-3D	36.93	3/20/2015 12:00	-2.72	3.37	uo
MW-3S	37.16	3/12/2017 12:00	5.38		
	37.10	3/12/2017 12:00	3.33	1.76	down
MW-3M	37.35	3/12/2017 12:00	3.62	-	
				5.88	down
MW-3D	36.93	3/12/2017 12:00	-2.26		
MW-3S	37.16	4/2/2018 12:00	6.32		
				1.6	down
MW-3M	37.35	4/2/2018 12:00	4.72		
				6.27	down
MW-3D	36.93	4/2/2018 12:00	-1.55		
MW-4S	41.96	3/20/2015 12:00	3.43		
				2.81	down
MW-4M	41.99	3/20/2015 12:00	0.62		
				5.08	down
MW-4D	41.95	3/20/2015 12:00	-4.46		

TABLE 3-7. GROUNDWATER LEVEL AND VERTICAL GRADIENT DATA FROM MPWSP MONITORING WELLS

MW-4S	41.96	3/12/2017 12:00	6.91		
				4.06	down
MW-4M	41.99	3/12/2017 12:00	2.85		
				4.97	down
MW-4D	41.95	3/12/2017 12:00	-2.12		
MW-4S	41.96	4/2/2018 12:00	6.3		
				3.37	down
MW-4M	41.99	4/2/2018 12:00	2.93		
				4.02	down
MW-4D	41.95	4/2/2018 12:00	-1.09		
MW-5S	80.06	3/20/2015 12:00	36.63		
				35.35	down
MW-5M	80.1	3/20/2015 12:00	1.28		
				7.59	down
MW-5D	80.06	3/20/2015 12:00	-6.31		
MW-5S	80.25	3/12/2016 12:00	37.12		
				43.51	down
MW-5D	80.06	3/12/2017 12:00	-6.39		
				-8.54	up
MW-5M	80.48	3/12/2017 12:05	2.15		
MW-5S	80.25	4/2/2018 12:00	40.04		
				38.2	down
MW-5M	80.48	4/2/2018 12:00	1.84		
				4.66	down
MW-5D	80.06	4/2/2018 12:00	-2.82		
MW-6S	35.89	3/12/2017 12:00	20.9		
				28.22	down
MW-6M	35.68	3/12/2017 12:00	-7.32		
				0.88	down
MW-6M(L)	35.82	3/12/2017 12:00	-8.2		
MW-6S	35.89	4/2/2018 12:00	7.89		
				14.42	down
MW-6M	35.68	4/2/2018 12:00	-6.53		
				1.28	down
MW-6M(L)	35.82	4/2/2018 12:00	-7.81		
MW-7S	50.64	3/12/2017 12:00	8.32		
	30.01	-,,, 12.00	3. <b>0.</b>	7.26	down
MW-7M	50.29	3/12/2017 12:00	1.06	20	0.0 1111
	33.23	0,, -01, 12.00	2.30	3.51	down
MW-7D	50.24	3/12/2017 12:00	-2.45	5.51	33 1111
	30.27	5/12/2017 12:00	<u> ۲۰</u> -۲ <i>J</i>		

TABLE 3-7. GROUNDWATER LEVEL AND VERTICAL GRADIENT DATA FROM MPWSP MONITORING WELLS

50.64	4/2/2018 12:00	8.62		
			6.83	down
50.29	4/2/2018 12:00	1.79		
			2.24	down
50.24	4/2/2018 12:00	-0.45		
19.96	3/12/2017 12:00	6.85		
			5.56	down
19.99	3/12/2017 12:00	1.29		
			5.67	down
20.08	3/12/2017 12:00	-4.38		
19.96	4/2/2018 12:00	5.56		
			4.59	down
19.99	4/2/2018 12:00	0.97		
			2.68	down
20.08	4/2/2018 12:00	-1.71		
18.42	3/12/2017 12:00	8.14		
			10.4	down
18.32	3/12/2017 12:00	-2.26		
			4.62	down
18.32	3/12/2017 12:00	-6.88		
18.42	4/2/2018 12:00	7.02		
			9.39	down
18.32	4/2/2018 12:00	-2.37		
			-0.82	up
18.32	4/2/2018 12:00	-1.55		
	50.29 50.24 19.96 19.99 20.08 19.99 20.08 18.42 18.32 18.32 18.32	50.29	50.29       4/2/2018 12:00       1.79         50.24       4/2/2018 12:00       -0.45         19.96       3/12/2017 12:00       6.85         19.99       3/12/2017 12:00       1.29         20.08       3/12/2017 12:00       -4.38         19.96       4/2/2018 12:00       5.56         19.99       4/2/2018 12:00       0.97         20.08       4/2/2018 12:00       -1.71         18.42       3/12/2017 12:00       8.14         18.32       3/12/2017 12:00       -2.26         18.32       3/12/2017 12:00       -6.88         18.42       4/2/2018 12:00       7.02         18.32       4/2/2018 12:00       -2.37	50.29       4/2/2018 12:00       1.79         2.24       50.24       4/2/2018 12:00       -0.45         19.96       3/12/2017 12:00       6.85         19.99       3/12/2017 12:00       1.29         5.67       20.08       3/12/2017 12:00       -4.38         19.96       4/2/2018 12:00       5.56         19.99       4/2/2018 12:00       0.97         20.08       4/2/2018 12:00       -1.71         18.42       3/12/2017 12:00       8.14         18.32       3/12/2017 12:00       -2.26         18.32       3/12/2017 12:00       -6.88         18.42       4/2/2018 12:00       7.02         9.39       18.32       4/2/2018 12:00       -2.37         -0.82

Notes:

NAVD88 = North American Vertical Datum of 1988

ft = feet

References:

Monthly Groundwater Monitoring Report No. 3

Test Slant Well Long-Term Pumping Monitoring Report No. 97

Test Slant Well Long-Term Pumping Monitoring Report No. 148

## **3.3.4 WATER BUDGET BOUNDARIES**

The supplement water budget information for the MGSA Area is calculated inside the following boundaries that lie within the water budget boundaries for SVBGSA's regional water budget for the Subbasin:

- The lateral boundaries for the water budget calculations are the perimeter of the MGSA Area.
- The bottom boundary for the water budget calculations is the top of the Deep Aquifer. As discussed in Section 3.3.1, data are insufficient to perform water budget calculations for the Deep Aquifer, but a discussion of water budget components for the Deep Aquifer is presented.
- The top boundary of the water budget calculations is above the ground surface; precipitation infiltration and evapotranspiration are included in the water budget.

## **3.3.5 WATER BUDGET COMPONENTS**

# 3.3.5.1 Surface Water Budget Components

Within the boundaries discussed above, the surface water budget inflows include:

- Precipitation and runoff; and
- Process water discharge to the four man-made ponds that are part of the CEMEX operation.

The surface water budget outflows include:

- Evapotranspiration (ET); and
- Evaporation from the CEMEX ponds.

Due to the high permeability of the dune sands, there is no surface water inflow to the MGSA area. Runon and runoff are negligible.

### 3.3.5.2 Groundwater Budget Components

Within the boundaries discussed above, the groundwater budget inflows include:

- Deep percolation of precipitation;
- Deep percolation of CEMEX pond water; and
- Subsurface inflows from adjacent areas within the Subbasin.

The groundwater budget outflows include:

Groundwater pumping;

- Subsurface outflows; and
- Deep percolation.

There are no GDEs in the MGSA Area, so ET of groundwater is not considered an outflow component.

## 3.3.6 Surface Water Inflow and Outflow

## **Regulation Requirements:**

**§354.18(b)** The water budget shall quantify the following, either through direct measurements or estimates based on data: (1) Total surface water entering and leaving a basin by water source type.

Surface water inflows under current and historical conditions are similar and include the following components:

- **Precipitation** Precipitation at the Marina Airport weather station has been measured since 1995, and the mean annual precipitation is reported as 16.90 inches. Marina Airport precipitation data are compiled in Table 3-5. For the MGSA Area (398 acres), this equates to an annual average precipitation input volume of 561 AFY.
- Process water discharge The CEMEX operation discharges saline process water to three
  infiltration ponds. As discussed in Section 3.3.6, the total process water demand of the CEMEX
  plant is 305 AFY. The amount of consumptive use is not known, but is assumed to be negligible
  for the purposes of this water budget; therefore, process water discharge is assumed to be 305
  AFY.

Surface water outflows under current and historical conditions are assumed to be similar and include the following components:

- Evapotranspiration Actual ET data for the MGSA Area is available for the period from WY 2011 to WY 2018 from the CalETa data set developed for DWR by Formation Environmental (Paul *et al.* 2018 and 2011). The data set consists of daily evapotranspiration calculated at a resolution of 30 meters by analyzing Landsat satellite and climatic data using the Surface Energy Balance Approach. The mean annual ET between 2010 and 2017 was 7.9 inches, for a total of 265 AFY from the MGSA Area. MGSA Area ET data from WY 2010 to WY 2017 are compiled in Table 3-6.
- Evaporation from CEMEX ponds Evaporation from the four CEMEX ponds is estimated to be less than 5 AFY.

The projected future surface water budget would include the following changes:

• **Precipitation** – Precipitation is forecast to increase statewide by 2.9 percent in and after 2030 and by 5.3 percent in and after 2070 due to climate change (DWR 2018). Projected increases in the Central Coast hydrologic region are projected to be 2.8% by 2030 and 6.5% by 2070. The

precipitation inflow volume is therefore forecast to increase from 512 AFY to 526 AFY in 2030 and to 545 AFY in 2070.

- **Process water discharge** The CEMEX sand mining facility will cease operation by December 31, 2020. After this time, saline process water discharges to the CEMEX ponds will cease.
- Evapotranspiration ET is forecast to increase by approximately 6% by 2070 (SCMCGA 2020) due to climate change (DWR 2018). The ET outflow volume during this time is therefore forecast to increase from 265 AFY to 281 AFY.

## 3.3.7 GROUNDWATER INFLOW

## **Regulation Requirements:**

§354.18(b) The water budget shall quantify the following, either through direct measurements or estimates based on data: (2) Inflow to the groundwater system by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as lakes, streams, rivers, canals, springs and conveyance systems.

This section quantifies each of the groundwater inflow components of the supplemental water budget information for the MGSA Area listed in Section 3.3.5.2. These local supplemental water budget components are assumed to be included in the regional water budget adopted for the Subbasin by the SVBGSA and this GSP.

## 3.3.7.1 Historical and Current Groundwater Inflow Components

Historical data are limited and assumed to be similar to the current water budget, as discussed in Section 3.3.3. Current and historical groundwater inflow components include the following:

- **Deep percolation of precipitation** Since there is no surface runoff from the MGSA Area, deep percolation of precipitation is equal to total precipitation minus ET. Therefore, the deep percolation from precipitation under current and historical conditions is equal to 512 AFY 265 AFY = 247 AFY. This is a relatively high recharge rate, and reflects the high permeability and recharge potential of the Dune Sand and Older Dune Sand that underlie the MGSA Area and area southwest of the Salinas River. The deep percolation is assumed to contribute to the low TDS groundwater zone within the Dune Sand Aquifer and the 180-Foot Aquifer noted in Sections 3.1.12 and 3.2.3.
- Deep percolation of process water The CEMEX ponds receive approximately 305 AFY and
  evaporation is relatively limited and expected to exceed about 5 AFY; therefore, deep
  percolation of saline CEMEX process water is assumed for current and historical purposes to be
  approximately 300 AFY.

- Subsurface inflow from adjacent areas. Subsurface inflow was estimated using 1) hydraulic gradients derived from groundwater elevations measured on March 12, 2017, 2) hydraulic conductivity values from the CEMEX model (ESA 2018, Geoscience Support Services 2017), and 3) estimated aquifer thicknesses based on monitoring well screen intervals for the Dune Sand Aquifer and the 180-Foot Aquifer, and the estimated aquifer thickness of the 400-Foot Aquifer (Gottschalk, 2018). For current conditions (at the approximately 2,000-foot by 8,000-foot MGSA Area) the calculated subsurface inflows at the MGSA Area boundaries are as follows:
  - 435 AFY in the Dune Sand Aquifer (across the eastern boundary in a seaward direction);
  - 556 AFY in the 180-Foot Aquifer (net saline groundwater flow across the western boundary in a landward direction<sup>2</sup>);
  - 1,333 AFY in the 400-Foot Aquifer (saline groundwater flow across the western boundary in a landward direction); and
  - Groundwater elevation data are insufficient to calculate groundwater inflow and outflow in the Deep Aquifer beneath the MGSA Area.
- Inter-aquifer fluxes include the following: Based on the vertical gradients measured in the monitoring well clusters installed in and near the MGSA Area (Table 3-7) the 180-Foot Aquifer receives recharge by vertical leakance from the Dune Sand Aquifer, and the 400-Foot Aquifer receives recharge by vertical leakance from the 180-Foot Aquifer. The only exception occurs at the seaward edge of the 180-Foot Aquifer, where discharge likely occurs upward to the Pacific Ocean from both the Dune Sand and 180-Foot Aquifers. Recharge to the Deep Aquifer is believed to occur via leakance from the 400-Foot Aquifer; however, the data are insufficient to assess the distribution and rate of recharge (MCWRA 2017). The inter-aquifer fluxes have not been assessed through measurement or modeling. For the purposes of this water budget, it is assumed that the leakance rate into and out of each aquifer is equal to the rate of recharge from precipitation to the Dune Sand Aquifer, or 247 AFY.

Under current conditions groundwater flow in the vicinity of the MGSA Area in the upper aquifer system is generally toward or away from the Pacific Ocean, parallel to the boundary between the 180/400 Foot Aquifer Subbasin and the Monterey Subbasin. Significant cross boundary inflows in the upper aquifer system are not anticipated based on the available data; however, the groundwater flow direction in the Deep Aquifer, and the potential for cross boundary inflows, is not known.

<sup>&</sup>lt;sup>1</sup> Note that as discussed in Section 3.2.1.3, the magnitude of landward gradients in the 180-Foot and 400-Foot Aquifers increases seasonally in the summer and fall, and groundwater inflow and outflow is likely greater at this time.

<sup>&</sup>lt;sup>2</sup> As discussed in Section 3.1.12, the flow in the upper, lower TDS portion of the 180-Foot Aquifer may be seaward, but this is offset by landward flow in the saline groundwater wedge that intrudes the aquifer from the west.

# 3.3.7.2 Projected Changes in Groundwater Inflow Components

Recharge from deep percolation of precipitation is projected to increase (both precipitation and evapotranspiration will increase with precipitation increasing more than evapotranspiration) with a net change from the current conditions (247 AFY) to the year 2070 (264 AFY). Recharge inflow from the CEMEX infiltration ponds will be eliminated at the end of 2020, decreasing inflow by 300 AFY. As noted above, proposed SVBGSA Priority Management Actions and Priority Projects include *in lieu* recharge and direct recharge projects with expected benefits including "arresting the decline, or raising, groundwater elevations" (SVBGSA 2019). Raising groundwater elevations in the future could change groundwater flow gradients, and potentially flow directions in the 180-Foot Aquifer and the 400-Foot Aquifer. This would change subsurface inflows into the water budget area. Groundwater flow directions and gradients will be reevaluated during the Five-Year Review, and the water budgets will be updated.

# 3.3.8 OUTFLOWS FROM GROUNDWATER SYSTEM

### **Regulation Requirements:**

§354.18(b) The water budget shall quantify the following, either through direct measurements or estimates based on data: (3) Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow.

This section quantifies each of the groundwater outflow components of the supplemental water budget for the MGSA Area listed in Section 3.3.5.2. These supplemental water budget components are assumed to be included in the regional water budget adopted for the Subbasin by the SVBGSA and this GSP.

### 3.3.8.1 Historical and Current Groundwater Outflow Components

Historical data are limited and assumed to be similar to the current water budget, as discussed in Section 3.3.3. Current and historical groundwater outflow includes the following components:

### Groundwater pumpage

- CEMEX well Process water for the CEMEX operation is extracted from a well on the east side of the MGSA Area. Based on the DWR well log, the well was constructed in 1968 with seven perforated intervals from 200 to 632 feet below ground level in the 180-Foot and 400-Foot Aquifers (included in Appendix 3-5). The well operates 20 hours a day for 255 days a year, with a pumping rate of 325 gallons per minute (gpm) (HWG 2017). Total pumpage from the CEMEX well in the MGSA Area therefore equals 305 AFY. The amount of groundwater drawn by the well from each aquifer is not known.
- MPWSP test slant well Test pumping of the MPWSP test slant well occurred from April 2015 through February 2018. From October 27, 2015, to September 21, 2017, the test slant well average pumping rate was 2,056 gpm, so the total extracted groundwater volume was approximately 5,450 AF, which would average about 2,860 AFY (HWG

2017). A total volume of approximately 6,000 AF was pumped from the well for the entire test. The test slant well is completed in the Dune Sand Aquifer and the 180-Foot Aquifer. A small portion of the test slant well screen lies outside the MGSA Area and the Subbasin, as the MGSA Area and Subbasin western boundary is the mean high tide mark. The test slant well extracted groundwater from the DSA and the 180-Foot Aquifer in a radial pattern, including saline groundwater from outside the Subbasin boundaries beneath the Pacific Ocean, as well as low-TDS groundwater from the inland portions of DSA and 180-Foot Aquifer within the Subbasin. Specific conductance monitoring during the test indicates that salinity increased after the well pump was turned on, and decreased after it was turned off, suggesting that the amount of lower salinity groundwater captured by the test slant well decreases over time. It has not been established how much groundwater was extracted by the test slant well from the Subbasin aquifers underlying the MGSA Area (including the low-TDS zone) as opposed to saline groundwater originating outside the Subbasin to the west. ESA (2018) estimated an "Ocean Water Percentage" of approximately 90 percent using the CEMEX model during the first year of test slant well pumping for the full MPWSP raw water makeup system; however, the modeling assumed a landward gradient in the DSA. The actual gradient in the DSA is seaward, so the amount of groundwater captured from the DSA from the inland portions of the aquifer would be larger than simulated. The conceptual groundwater budget summaries presented in Table 3-10 and Table 3-11 therefore include alternative budgets based on an estimated 10 percent and 30 percent of the extracted test slant well groundwater being produced from the aquifers underlying the MGSA Area.

- **Subsurface outflow.** The relatively stable groundwater elevations measured in and near the MGSA Area since the cessation of test slant well pumping (Table 3-7, Appendix 3.D) indicate that subsurface outflow is approximately the same as inflow. Based on the observed groundwater gradients, the following outflows are interpreted:<sup>3</sup>
  - Discharge from the Dune Sand Aquifer to the Pacific Ocean is approximately 435 AFY (seaward direction out of the western MGSA boundary). This assumes vertical leakance from the Dune Sand Aquifer into the 180-Foot Aquifer is equal to the rate of recharge from precipitation. This estimate may be refined in the future as additional data and the SVIHM become available.
  - Net saline groundwater discharge in a landward direction through the eastern boundary
    of the 180-Foot Aquifer is approximately 556 AFY. This assumes vertical leakance from
    the Dune Sand Aquifer into the 180-Foot Aquifer is approximately equal to vertical
    leakance out of the 180-Foot Aquifer into the 400-Foot Aquifer. This estimate may be

<sup>&</sup>lt;sup>3</sup> Note that as discussed in Section 3.2.1.3, the magnitude of landward gradients in the 180-Foot and 400-Foot Aquifers increases seasonally in the summer and fall, and groundwater inflow and outflow is likely greater at this time.

refined in the future as additional data and the SVIHM become available. Note that this outflow estimate is a simplified net value. Under Ghyben-Herzberg dynamics, we would expect that some discharge of mixed saline and low TDS groundwater to the Pacific Ocean would occur in the upper portion of this aquifer; however, the screen lengths of the monitoring wells in the 180-Foot Aquifer do not allow evaluation of vertical variation in water quality or gradient directions to be resolved.

- Landward discharge of saline groundwater from the 400-Foot Aquifer through the
  eastern MGSA Area boundary is estimated to be 1,333 AFY. This assumes vertical
  leakance from the 180-Foot Aquifer into the 400-Foot Aquifer is approximately equal to
  vertical leakance out of the 400-Foot Aquifer into the Deep Aquifer. This estimate may
  be refined in the future as additional data and the SVIHM become available.
- Groundwater elevation data are insufficient to calculate groundwater inflow and outflow in the Deep Aquifer beneath the MGSA Area.

Under current conditions groundwater flow in the vicinity of the MGSA Area in the upper aquifer system is generally toward or away from the Pacific Ocean, parallel to the boundary between the 180/400 Foot Aquifer Subbasin and the Monterey Subbasin. Significant cross boundary inflows in the upper aquifer system are not anticipated based on the available data; however, the groundwater flow direction in the Deep Aquifer, and the potential for cross boundary outflows, is not known.

### 3.3.8.2 Projected Changes in Groundwater Outflow Components

Expected increases in inflow (recharge) resulting from changes in climatic conditions over the next 50 years would result in corresponding changes in outflows. In addition, as noted in Section 3.3.7.2, proposed SVBGSA Priority Management Actions and Priority Projects include *in lieu* recharge and direct recharge projects with expected benefits including "arresting the decline, or raising, groundwater elevations" (SVBGSA 2019). Raising groundwater elevations in the future could change groundwater flow gradients, and potentially flow directions in the 180-Foot Aquifer and the 400-Foot Aquifer. Consequently, this could affect the rate and direction of outflows. Groundwater flow directions and gradients will be reevaluated during the 5-Year Review, and the water budgets will be updated.

When groundwater extraction from the CEMEX well ends in 2020, this outflow will be eliminated. If the MPWSP project is implemented, groundwater extraction from the DSA and the 180-Foot Aquifer would increase. In addition, as was noted in Section 3.2.1.3, the 400-Foot Aquifer did experience drawdown during test slant well pumping; therefore, the 400-Foot Aquifer would also be affected by groundwater extraction from the proposed MPWSP pumping. The rate of local proposed groundwater extraction (17,400 AFY) would be greater than the other components of this water budget analysis, indicating significant regional groundwater budget changes would occur, which may affect ET outflow to GDEs and interaction with the Salinas River. Evaluating the potential effects of this proposed groundwater extraction on the MGSA Area and regional water budgets would require the development of a refined local groundwater flow, solute transport, and density-driven flow model. As discussed in Chapter 6,

MCWD GSA plans to develop such a model to evaluate the local groundwater flow, water budgets, seawater intrusion and water quality effects to support preparation of its GSP. MGSA will review the results of this analysis and update this GSP as appropriate.

# 3.3.9 CHANGE IN GROUNDWATER STORAGE

### **Regulation Requirements:**

**§354.18(b)** The water budget shall quantify the following, either through direct measurements or estimates based on data: (4) The change in the annual volume of groundwater in storage between seasonal high conditions.

During the test slant well test, groundwater elevations noticeably declined in the Dune Sand and 180-Foot Aquifer near the test slant well in the MGSA Area as groundwater was removed from storage during the pumping test between April 2015 and February 2018. Groundwater elevations declined by approximately 8 feet in MW-1S and MW-1M, and by 3 feet in MW-3S and MW-3M, but recovered relatively quickly to pre-pumping conditions after the long-term test was discontinued, and have remained relatively stable since then. The observed seasonal groundwater elevation fluctuation increases with aquifer depth, and averages approximately 0 to 4 feet in the Dune Sand Aquifer, 1.5 to 10 feet in the 180-Foot Aguifer, and 10 to 24 feet in the 400-Foot Aguifer, indicating a seasonal storage change that is consistent with regional recharge and pumping patterns. However, the available groundwater elevation data (2015 to present) suggest that there is no long-term inter-annual change in storage between seasonal high conditions. Thus, although the Subbasin as a whole has experienced a significant decrease in groundwater storage as described in Section 3.2.2, and the MGSA Area experienced a short-term decline in storage due to the 3-year test slant well test, based on available monitoring data since 2015, the groundwater storage beneath the MGSA Area does not appear to be decreasing at the present. This implies that conditions at the seaward edge of the saline intrusion front in the Subbasin are relatively stable; however, significant changes in groundwater pumping in this area could upset this equilibrium and have both local and inland implications for future seawater intrusion.

# 3.3.10 SUMMARY OF SUPPLEMENTAL MGSA AREA WATER BUDGETS

### **Regulation Requirements:**

### For current water budgets:

§354.18 (c) Each Plan shall quantify the current, historical, and projected water budget for the basin as follows:

- (1) Current water budget information shall quantify current inflows and outflows for the basin using the most recent hydrology, water supply, water demand, and land use information.
- (d) The Agency shall utilize the following information provided, as available, by the Department pursuant to Section 353.2, or other data of comparable quality, to develop the water budget:
- (2) Current water budget information for temperature, water year type, evapotranspiration, and land use.

#### For historical water budgets:

§354.18 (c) Each Plan shall quantify the current, historical, and projected water budget for the basin as follows:

- (2) Historical water budget information shall be used to evaluate availability or reliability of past surface water supply deliveries and aquifer response to water supply and demand trends relative to water year type. The historical water budget shall include the following:
  - (A) A quantitative evaluation of the availability or reliability of historical surface water supply deliveries as a function of the historical planned versus actual annual surface water deliveries, by surface water source and water year type, and based on the most recent ten years of surface water supply information.
  - (B) A quantitative assessment of the historical water budget, starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the tools and methods used to estimate and project future water budget information and future aquifer response to proposed sustainable groundwater management practices over the planning and implementation horizon.
  - (C) A description of how historical conditions concerning hydrology, water demand, and surface water supply availability or reliability have impacted the ability of the Agency to operate the basin within sustainable yield. Basin hydrology may be characterized and evaluated using water year type.
- (d) The Agency shall utilize the following information provided, as available, by the Department pursuant to Section 353.2, or other data of comparable quality, to develop the water budget:
- (1) Historical water budget information for mean annual temperature, mean annual precipitation, water year type, and land use.

### For projected water budgets:

§354.18 (c) Each Plan shall quantify the current, historical, and projected water budget for the basin as follows:

- (3) Projected water budgets shall be used to estimate future baseline conditions of supply, demand, and aquifer response to Plan implementation, and to identify the uncertainties of these projected water budget components. The projected water budget shall utilize the following methodologies and assumptions to estimate future baseline conditions concerning hydrology, water demand and surface water supply availability or reliability over the planning and implementation horizon:
- (A) Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology. The projected hydrology information shall also be applied as the baseline condition used to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change and sea level rise.
- (B) Projected water demand shall utilize the most recent land use, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand. The projected water demand information shall also be applied as the baseline condition used to evaluate future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate.
- (C) Projected surface water supply shall utilize the most recent water supply information as the baseline condition for estimating future surface water supply. The projected surface water supply shall also be applied as the baseline condition used to evaluate future scenarios of surface water supply availability and reliability as a function of the historical surface water supply identified in Section 354.18(c)(2)(A), and the projected changes in local land use planning, population growth, and climate.
- (d) The Agency shall utilize the following information provided, as available, by the Department pursuant to Section 353.2, or other data of comparable quality, to develop the water budget:
- (3) Projected water budget information for population, population growth, climate change, and sea level rise.

The following sections present a summary of the supplemental water budgets for the MGSA Area. This information is presented as a supplement to the regional water budget developed for the Subbasin by

SVBGSA to support development of a locally focused GSP within the Subbasin for the MGSA Area. The water budget information presented should be considered preliminary, and is subject to the assumptions and limitations discussed in the preceding sections. Together with the regional water budget, it is intended to fulfill the requirements of 23 CCR § 354.18 and support achievement and maintenance of the sustainability goals identified in this GSP. The water budget was developed based on the data and tools available at this time. During GSP implementation, the water budget will be updated as needed, and as new data and tools become available, in collaboration with SVBGSA and MCWD GSA. SVBGSA will use the SVIHM when it is released to evaluate regional water budgets and surface-groundwater interaction. MCWD GSA proposes to develop a locally refined groundwater flow model that is able to simulate solute transport and density-driven flow. As discussed in Chapters 6 and 7, MGSA will review the results of these efforts and collaborate with SVBGSA and MCWD GSA to update the local and regional water budgets presented in this GSP.

# 3.3.10.1 Summary of Surface Water Budget

The surface water budget summarized below in Table 3-8 is representative of both historical and current conditions. Inflows and outflows were calculated for years that data for all components were available. The limiting factor was evapotranspiration, for which data were available for WY 2011 through WY 2018 (Table 3-6). Precipitation data were available for 1995 through 2018 (Table 3-5), but only the data from WY 2011 to WY 2018 were used.

Although the period for which sufficient information was available to calculate supplemental water budgets for the MGSA Area is limited, the four years do cover one below average year which was preceded by two drought years (2015), two years with above average precipitation (2016 and 2017), and one below average year (2018). The precipitation during these years was 14.25, 21.21, 21.99, and 12.55 inches of rain, respectively, compared to a 24-year average of 16.86 inches. Thus, especially the surface water budgets provide some perspective on climatic variability and its influence on the water budget.

TABLE 3-8. SUMMARY OF CURRENT AND HISTORICAL SURFACE WATER BUDGET

Surface Budget Component	Annual Minimum	Annual Maximum	Annual Average	Average % (rounded)
Inflows (acre-feet per year)				
Precipitation (2011 to 2018)	309	763	512	63%
Discharge of process water to CEMEX Ponds	305	305	305	37%
Total Inflow	817			
Outflows (acre-feet per year)				
Evapotranspiration (2011 to 2018)	215	318	265	32%
Deep Percolation of Precipitation	94 (2014)	454 (2017)	247	30%
Percolation of CEMEX Pond discharge	300	300	300	37%
Evaporation of CEMEX Pond discharge	5	5	5	1%
Total Outflow	817			

The projected future surface water budget through 2070 is presented in Table 3-9. Projected future changes include an increase in precipitation and ET, as well as cessation of CEMEX operations and restoration of the ponds, as discussed in Section 3.3.6. As shown in below, deep percolation to groundwater is projected to increase slightly during this time period. No changes to the surface water budget within the MGSA Area are anticipated if the MPWSP is implemented; however, drawdown could decrease the amount of surface water discharge via ET or to the Salinas River.

TABLE 3-9. SUMMARY OF PROJECTED FUTURE SURFACE WATER BUDGET

Surface Water Budget Component	Current Average	2030 Projection	2070 Projection
Inflows (acre-feet per year)			
Precipitation	512	526	545
Discharge of process water to CEMEX Ponds	305	0	0
Total Inflows	817	526	545
Outflows (acre-feet per year)			
Evapotranspiration	265	273	281
Deep Percolation of Precipitation	247	253	264
Percolation of CEMEX Pond discharge	300	0	0
Evaporation of CEMEX Pond discharge	5	0	0
Total Outflow	817	526	545

## 3.3.10.2 Summary of Current Groundwater Budget Supplement

To provide perspective into the current and historical local groundwater budget components, and insight into and how they may change in the future, the following conceptual water budgets were prepared.

- Table 3-10 presents a water budget based on the assumption that 10 % of the groundwater produced by the test slant well was pulled into the well from the aquifers underlying the MGSA Area (as opposed to saline groundwater originating from outside the Subbasin Boundary to the west, which is not included in this water budget assessment). Although this groundwater would have been extracted from both the DSA and the 180-Foot Aquifer, because of the seaward gradient in the DSA, all of the extraction was assigned to the DSA.
- Table 3-11 presents a water budget based on the assumption that 30 % of the groundwater produced by the test slant well was pulled into the well from the aquifers underlying the MGSA Area (as opposed to saline groundwater originating from outside the Subbasin Boundary to the west, which is not included in this water budget assessment). Although this groundwater would have been extracted from both the DSA and the 180-Foot Aquifer, because of the seaward gradient in the DSA, all of the extraction was assigned to the DSA.

 Table 3-12 presents a WY 2018 water budget for summarizing conditions after the cessation of test slant well pumping.

A graphical representation of these water budget supplement is presented as Figure 3-40. The evaluation of different assumptions regarding the percentage of groundwater that is extracted from aquifers within the Subbasin indicates that during test slant well pumping, much of the inflow into the DSA from the landward side of the MGSA Area was captured by the test slant well, and the amount of inflow captured increased with the proportion of groundwater that the well extracted from the Subbasin Aquifers. The actual amount of groundwater produced from the aquifers within the Subbasin vs. saline groundwater west of the Subbasin and infiltrating seawater cannot be adequately evaluated without a suitable groundwater flow model that can simulate solute transport and density driven flow, and may be different from the above assumptions.

Development of a future groundwater budget also is not possible without a refined groundwater flow model; however, the above conceptual water budgets provide useful perspective. Given that the proposed extraction rate for the MPWSP, if implemented, would be approximately 17,400 AFY, it is readily apparent that even if only a small percentage were derived from the aquifers underlying the MGSA Area and the Subbasin, the local groundwater budget would be significantly changed. A large volume of groundwater would be removed from the DSA as well as the 180-Foot Aquifer. At the same time, a large amount of seawater would be drawn in to replace the aquifer water that is removed from storage. The analysis underscores the need for locally refined groundwater model that can simulate both solute transport and density-driven flow.

TABLE 3-10. WY 2017 CONCEPTUAL GROUNDWATER BUDGET WITH TEST SLANT WELL 10 PERCENT AQUIFER CAPTURE

Groundwater Budget Component	WY2017	Average %	Basis and Assumptions	
Inflows (acre-feet per year)				
Recharge from Precipitation	454	15%	WY 2017 precipitation minus evapotranspiration.	
Recharge from CEMEX Ponds	300	10%	305 AFY minus nominal evaporation and other losses.	
Subsurface Inflow into Dune Sand Aquifer (DSA)	435	14%	Calculated using 3/12/2017 gradient, average screen length, CEMEX model hydraulic conductivity, and transverse length of MGSA.	
Subsurface Inflow into 180-Foot Aquifer	657	21%	Equals outflow plus 1/3 CEMEX well pumping volume.	
Subsurface Inflow into 400-Foot Aquifer	1,537	50%	Equals outflow plus 2/3 CEMEX well pumping volume.	
Total Inflow	3,383			
Outflows (acre-feet per year)				
Pumping CEMEX Well	305	10%	Reported annual CEMEX pumping from HWG 2017	
Pumping Test Slant Well			The second secon	
Groundwater Extraction from Dune Sand Aquifer (Assumed to be 10% of extraction rate)	286	9%	Assumed 10 % of extracted water is derived from Subbasin aquifers. Actual rates may be different than assumed. DSA accounts for 45% of well transmissivity; however, because the gradient is seaward in March 2017, most of the captured aquifer water would be from this aquifer. Therefore, assumed all of slant well aquifer water contribution derives from this aquifer.	
Groundwater Extraction from the 180-Foot Aquifer	0	0%	Accounts for 55% of well transmissivity; however, gradient is landward in March 2017. Therefore, assumed no aquifer water contribution from this aquifer to slant well pumping.	
Subsurface Outflow Dune Sand Aquifer	740	24%	Equals inflow plus recharge from precipitation plus recharge from CEMEX ponds, minus test slant well extraction minus leakance to Deep Aquifer.	
Subsurface Outflow 180-Foot Aquifer	556	18%	Calculated using 3/12/2017 gradient, average screen length, CEMEX model hydraulic conductivity, and transverse length of MGSA.	
Subsurface Outflow 400-Foot Aquifer	1,333	43%	Calculated using 3/12/2017 gradient, aquifer thickness from Gottschalk <i>et al.</i> , 2018, CEMEX model hydraulic conductivity, and transverse length of MGSA.	
Subsurface Leakance to Deep Aquifer	163	5%	Steady state leakance to Deep Aquifer (assumed equal to recharge from precipitation) minus test slant well aquifer capture volume.	
Total Outflow	3,383			

TABLE 3-11. WY 2017 CONCEPTUAL GROUNDWATER BUDGET WITH TEST SLANT WELL 30 PERCENT AQUIFER CAPTURE

Groundwater Budget Component	WY2017	Average %)	Basis and Assumptions	
Inflows (acre-feet per year)				
Recharge from Precipitation	454	15%	WY 2017 precipitation minus evapotranspiration.	
Recharge from CEMEX Ponds	300	10%	305 AFY minus nominal evaporation and other losses.	
Subsurface Inflow into Dune Sand Aquifer (DSA)	435	14%	Calculated using 3/12/2017 gradient, average screen length, CEMEX model hydraulic conductivity, and transverse length of MGSA.	
Subsurface Inflow into 180-Foot Aquifer	657	21%	Equals outflow plus 1/3 CEMEX well pumping volume.	
Subsurface Inflow into 400-Foot Aquifer	1,537	50%	Equals outflow plus 2/3 CEMEX well pumping volume.	
Total Inflow	3,383			
Outflows (acre-feet per year)				
Pumping CEMEX Well	305	10%	Reported 305 AFY annual CEMEX pumping	
Pumping Test Slant Well	1		, , ,	
Groundwater Extraction from Dune Sand Aquifer (Assumed to be 10% of extraction rate)	858	28%	HWG OWP estimate assumed landward gradient in DSA; therefore, a lower OWP (higher aquifer water capture percentage) is a reasonable assumption. Actual rates may be different than the assumed 30%. DSA accounts for 45% of well transmissivity; however, because the gradient is seaward in March 2017, most of the captured aquifer water would be from this aquifer. Therefore, assumed all of slant well aquifer water contribution derives from this aquifer.	
Groundwater Extraction from the 180-Foot Aquifer	0	0%	Accounts for 55% of well transmissivity; however, gradient is landward in March 2017. Therefore, assumed no aquifer water contribution from this aquifer to slant well pumping.	
Subsurface Outflow Dune Sand Aquifer	331	11%	Equals inflow plus recharge from precipitation plus recharge from CEMEX ponds, minus test slant well extraction minus leakance to Deep Aquifer.	
Subsurface Outflow 180-Foot Aquifer	556	18%	Calculated using 3/12/2017 gradient, average screen length, CEMEX model hydraulic conductivity, and transverse length of MGSA.	
Subsurface Outflow 400-Foot Aquifer	1,333	43%	Calculated using 3/12/2017 gradient, aquifer thickness from Gottschalk <i>et al.</i> , 2018, CEMEX model hydraulic conductivity, and transverse length of MGSA.	
Subsurface Leakance to Deep Aquifer	0	0%	Steady state leakance to Deep Aquifer (assumed equal to recharge from precipitation) minus test slant well aquifer capture volume.	
Total Outflow	3,383			

TABLE 3-12. WY 2018 CONCEPTUAL GROUNDWATER BUDGET

Groundwater Budget Component	WY2018 (Acre-Feet)	Average % (rounded)					
Inflows (acre-feet per year)							
Recharge from Precipitation	98	18%					
Recharge from CEMEX Ponds	300	9%					
Subsurface Inflow into Dune Sand Aquifer	500	12%					
Subsurface Inflow into 180-Foot Aquifer	1,059	19%					
Subsurface Inflow into 400-Foot Aquifer	1,032	41%					
Total Inflow	2,989						
Outflows (acre-feet per year)							
Pumping CEMEX Well	305	9%					
Subsurface Outflow Dune Sand Aquifer	500	12%					
Subsurface Outflow 180-Foot Aquifer	1,059	19%					
Subsurface Outflow 400-Foot Aquifer	1,032	41%					
Subsurface Leakance to Deep Aquifer	93	18%					
Total Outflow	2,989						
Change in Storage (acre-feet per year)	0						

Groundwater flow in the vicinity of the MGSA Area in the upper aquifer system is generally toward or away from the Pacific Ocean, parallel to the boundary between the 180/400 Foot Aquifer Subbasin and the Monterey Subbasin. Significant cross boundary outflows in the upper aquifer system are not anticipated based on the available data; however, the groundwater flow direction in the deep aquifer, and the potential for cross boundary outflows, is not known.

#### 3.3.10.3 Summary of Historical Groundwater Budget Supplement

Due to a lack of local groundwater elevation data prior to 2015, it was not possible to prepare a complete local historical groundwater budget to supplement the regional historical groundwater budget prepared by SVBGSA. However, as discussed in Section 3.3.3, for planning purposes, it is reasonable to assume that the historic water budget for the MGSA Area is similar to the current WY 2018 water budget, as there has not been a significant change in land use or groundwater development within the MGSA Area for decades, with exception of the recent test slant well pumping.

#### 3.3.10.4 Summary of Projected Groundwater Budget Supplement

The projected surface water budget presented in Table 3-11 indicates that recharge from precipitation may be expected to increase slightly over the next 50 years. Several *in lieu* recharge projects are planned to be implemented in the portions of the basin located east of the MGSA Area, and are projected to lead to an increase in local groundwater elevations by several feet in the 180-Foot and 400-

Foot Aquifers (Chapter 6). However, sea level is projected to rise by approximately 17 inches during this time period, increasing the driver for seawater inflow into the saline groundwater wedge underlying the MGSA Area and its vicinity. This will at least partially offset the gains from additional recharge and groundwater elevation rise in the area. The effects of sea level rise on the local water budget and saline wedge intrusion will be evaluated during GSP implementation once a model capable of simulating density-driven flow is developed by MCWD GSA.

Pumping of the CEMEX well is expected to cease in December 2020 or, at the latest in December 2024, when CEMEX removes the well, resulting in the *in lieu* recharge of approximately 300 AFY of groundwater to the 180-Foot and 400-Foot Aquifers, and the loss of approximately 300 AFY of groundwater recharge to the DSA from saline water discharged to the CEMEX percolation ponds, which will be restored. The partitioning of extraction from the CEMEX well between the 180-Foot and 400-Foot Aquifers, and whether any low-TDS groundwater is currently being withdrawn from this well, is not known.

The proposed pumping of 17,400 AFY of feed water for the MPWSP, if permitted and implemented, would extract saline groundwater from beneath the ocean and saline as well as low-TDS groundwater from the Dune Sand and 180-Foot Aquifers in the Subbasin. In the Monterey Subbasin, groundwater demand from the Deep Aquifer by MCWD to supply the City of Marina is expected to increase as discussed in Chapter 2; however, the increase is projected to be within MCWD's allocated pumping rights. Given that land use in the MGSA Area is designated as open space and conservation land use, other significant land use and groundwater demand changes are not anticipated.

As described in Sections 3.3.2 and 3.3.11, several key data elements needed to evaluate the water budget effects of the above climatic, *in-lieu* recharge and groundwater extraction changes are not available at this time. The available data are insufficient for the evaluation of water budgets for the Deep Aquifer at this time; however, groundwater extraction from the Deep Aquifer is not anticipated in the MGSA Area. For the upper aquifer system (the Dune Sand, 180-Foot, and 400-Foot Aquifers), data gaps include the relatively short period of available groundwater elevation monitoring data, interaction of existing and proposed wells with the aquifer system, vertical flow and leakance rates, and the dynamics of density-driven flow of saline groundwater.

The MGSA Area is relatively small and included within the existing regional groundwater budget developed for the Subbasin by SVBGSA, and future groundwater development focuses primarily on a single large project. Given these facts, reliance of the existing regional water budget as augmented above is an appropriate and adequate basis for implementation of the sustainable management criteria, monitoring program and management actions described in Chapters 4, 5 and 6, respectively. A locally refined groundwater flow model that is able to simulate solute transport and density-driven flow is currently under consideration by MCWD GSA for the area that includes their GSA boundaries and the surrounding region, including the MGSA Area and beyond. MGSA will collaborate with and review these

studies, and update the HCM, sustainable management criteria, monitoring networks and management actions in this GSP to assure the sustainability goals are met.

#### 3.3.10.5 WATER YEAR TYPES ASSOCIATED WITH THE WATER BUDGET

#### **Regulation Requirements:**

**§354.18(b)** The water budget shall quantify the following, either through direct measurements or estimates based on data: (6) The water year type associated with the annual supply, demand, and change in groundwater stored.

Although the period for which sufficient information was available to calculate supplemental water budgets for the MGSA Area, the four years analyzed do cover one below average year which was preceded by two drought years (2015), two years with somewhat above average precipitation (2016 and 2017), and one below average year (2018). The precipitation during these years was 14.25, 21.21, 21.99, and 12.22 inches of rain, respectively, compared to a 24-year average of 16.86 inches.

The CEMEX well was operating during the WY 2015 to WY 2018 period. The test slant well was also pumping during the majority of this period. Therefore, demand was effectively constant and did not change with water year type.

The MPWSP monitoring wells east of the MGSA Area (especially the shallow wells completed in the Dune Sand Aquifer) did not show a direct response to Slant Well pumping during the water budget period; therefore, these wells are suitable for evaluating the climatic (dry-, normal-, and wet-year) and extraction-related groundwater elevation trends during the supplemental water budget period of record. Review of the five shallow monitoring wells located east of the MGSA Area (Appendix 3.D) indicates there is a general upward trend (increasing water elevations) from April 2015 to April 2019. Groundwater elevation trends in wells MW-7S, MW-8S and MW-9S were evaluated for the period from April 2016 to April 2019. Groundwater elevations generally increased at MW-7S, were stable in MW-8S, and appeared to decline slightly in MW-9S. The available data generally reflect a slight increase in groundwater elevations and storage during the transition from a year with below average precipitation at the end of a drought in WY 2015, to two years with above average precipitation in WY 2016 and WY 2017. Groundwater gradients calculated from the Dune Sand Aquifer March 2017 groundwater level map (during a wet year and pumping of the pilot slant well) and April 2018 groundwater level map (during a dry year and after the pilot slant well was shutdown) were similar. In addition, the gradient directions remained similar during the fall of each year; however, the magnitudes of the landward gradients in the 180- and 400-Foot Aguifers increased in the summer and fall.

#### 3.3.11 Uncertainties in Supplemental MGSA Area Water Budget Information

The level of accuracy and certainty is highly variable between water budget components. The water budget uncertainty will be reduced over time as the GSP monitoring programs are implemented and the resulting data are used to check and improve the water budgets. Refinement of the water budget will be performed in collaboration with SVBGSA and MCWD GSA as necessary, or as required to implement management actions described in Chapter 6.

- **Groundwater elevation data** The period of record for groundwater elevation data is relatively short and is limited to four years from 2015 through 2019. This prevents development of a quantified historical groundwater budget to supplement the regional historical water budget in this area; however, based on the available data, it is reasonable to infer for planning purposes that historical conditions were likely similar to current conditions.
- **Deep Aquifer water elevation data** There are no Deep Aquifer wells in the MGSA Area, and a minimum of three would be needed to estimate a groundwater gradient for water budget calculations. Regional data are insufficient to interpolate groundwater flow directions in the Deep Aquifer due to its thickness and heterogeneous nature, and relative paucity of wells.
- **Deep Aquifer recharge and characteristics** The hydrologic characteristics of the Deep Aquifer and the overlying 400-Foot/Deep Aquitard have not been well characterized and as a result recharge to and flow within this aquifer is uncertain.
- **Vertical leakance** The vertical leakance between aquifers is not known and is assumed to be equal to recharge at the ground surface.
- Slant well pumping The amount of landward saline and low TDS groundwater from the Subbasin aquifers captured by test slant well pumping is not known. A large portion of the groundwater pumped by the test slant well was saline groundwater originating from beneath the ocean outside the western boundary of the Subbasin; however, a significant volume of saline and low-TDS groundwater was also withdrawn from the aquifers within the Subbasin underlying the MGSA Area and its vicinity. The MPWSP test slant well salinity data and groundwater elevations in the DSA indicate that some groundwater was derived from a low-TDS groundwater source in the Dune Sand and 180-Foot Aquifer. Conceptual water budgets are provided assuming 10 percent of the test slant well groundwater was captured Subbasin groundwater, and 30 percent of the test slant well groundwater was captured Subbasin groundwater; however, the actual percentage of Subbasin groundwater extracted from the Subbasin by the test slant well is not known.
- **CEMEX well pumping** The CEMEX well is completed in both the 180-Foot Aquifer and the 400-Foot Aquifer, and it is not clear what fraction of the groundwater produced by the well originates from each aquifer. Without this information, it is not possible to predict the effect that the planned shut-down of this well at the end of 2020 will have on the low-TDS zone in the Dune Sand Aquifer and the 180-Foot Aquifer.
- Local groundwater and density-driven flow model A groundwater model that can simulate solute transport and density-driven flow, and that incorporates the heterogeneity of the aquifer system in the Marina area is not available at this time. As such, the potential impacts of a high rate of groundwater extraction in the MGSA Area, such as by the proposed MPWSP, on the local water budget, water quality and seawater intrusion cannot be adequately evaluated. Prior to

initiating rates of groundwater extraction that are substantially higher than historical rates, there would be a need for a locally refined groundwater flow model that is able to simulate solute transport and density-driven flow. MCWD GSA is currently planning to conduct such studies for the area that includes their GSA boundaries and the surrounding region, including the MGSA Area and beyond. MGSA will collaborate with and review these studies, and update the HCM, sustainable management criteria, monitoring networks and management actions in this GSP to assure the sustainability goals are met.

#### 3.3.12 QUANTIFICATION OF OVERDRAFT

#### **Regulation Requirements:**

**§354.18(b)** The water budget shall quantify the following, either through direct measurements or estimates based on data: (5) If overdraft conditions occur, as defined in Bulletin 118, the water budget shall include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions.

The 180/400 Foot Aquifer Subbasin (Subbasin) is subject to seawater intrusion due largely to long-term groundwater extraction in the inland portions of the Subbasin in excess of the sustainable yield, and has been identified by the Department of Water Resources as being in a critical condition of overdraft (DWR 2016a). In keeping with the objectives of this GSP to support regional efforts that address this overdraft condition by supporting the projects and management actions that will be implemented by SVBGSA under its regional GSP, this section provides an assessment of local overdraft conditions.

The available data to support evaluation of the existing water budget are limited to the time period after 2015. During this time, groundwater elevations declined near the test slant well located on the west side of the MGSA Area during the long-term pumping test from April 2015 to February 2018, and then recovered. The groundwater quality and level monitoring data indicates that some groundwater from the low-TDS zone in the DSA and 180-Foot Aquifer was drawn into the test slant well from the east; however, the data are insufficient to determine whether there was a significant and unreasonable impact to these resources during the test time period, and whether the saline groundwater intrusion wedge advanced inland or thickened as a result.

In the absence of the test slant well pumping test, it would be expected that the saline groundwater intrusion wedge and low TDS groundwater zone currently exist in a relative state of equilibrium since there have been no land use changes that would cause a change in recharge or groundwater pumping near the MGSA Area. The CEMEX well may have contributed to seawater intrusion historically; however, conditions in the nearshore environment were likely stable as of the adoption of SGMA in early 2015. The recovery of groundwater elevations to pre-slant well test elevations shortly after the test suggests the MGSA Area is not currently being overdrafted, and that groundwater conditions are relatively stable. As such, there is no evidence that current activities in the MGSA Area are contributing to the critical conditions of overdraft that are driving seawater intrusion in the inland areas.

The proposed implementation of the MPWSP could change the local water budget and has the potential to impact GDEs, reduce groundwater storage in the low-TDS groundwater zone, induce seawater intrusion and cause groundwater quality degradation. As such, it has the potential to create a future overdraft condition locally and to contribute to regional overdraft conditions. The sustainable management criteria, monitoring program and management actions described in Chapters 4, 5 and 6 are intended to identify and address any overdraft in the MGSA Area (from any cause) before it results in significant and unreasonable impacts.

#### 3.3.13 ESTIMATE OF SUSTAINABLE YIELD

#### **Regulation Requirements:**

**§354.18(b)** The water budget shall quantify the following, either through direct measurements or estimates based on data: (7) An estimate of sustainable yield for the basin.

Regionally, based on a water budget analysis, SVBGSA has estimated the historical sustainable yield of the Subbasin as 96,950 AFY and the long-term projected sustainable yield as 112,000 AFY (SVBGSA 2019). SVBGSA states this is an estimate only, and that the sustainable yield estimate for the Subbasin will be modified and updated as more data are collected and more analyses are performed, including evaluation of the SVIHM, which is expected to be released in late 2020. This GSP adopts the regional sustainable yield as estimated for the 180/400 Foot Aquifer Subbasin in SVBGSA's GSP (SVBGSA 2019).

As described further in Chapter 4, locally, the contribution to the sustainable yield from groundwater extraction in the MGSA Area is the amount of groundwater that can be withdrawn annually over a period of time without causing undesirable results within or near the MGSA Area. Undesirable results include, but may not be limited to, the following significant and unreasonable impacts beyond a 2015 baseline condition:

- Chronic groundwater level decline in the DSA that adversely effects GDEs;
- Further seawater intrusion into the Dune Sand, 180-Foot, 400-Foot, and/or Deep Aquifers; or
- Degradation of the low TDS groundwater zone within the Dune Sand, 180-Foot and/or 400-Foot Aquifers.

Pumping of saline groundwater from the CEMEX well (possibly including a mix of saline and low-TDS groundwater from the 180-Foot and 400-Foot Aquifers) has been ongoing since the 1960's at a rate of approximately 300 AFY. Although it is not known if this pumping contributed to historical seawater intrusion in the area, the available data suggest this level of pumping currently coexists with a stable distribution of water quality and groundwater elevations in the area, and is therefore sustainable relative to SGMA's 2015 baseline and the regional sustainable yield estimate.

Water quality trends and groundwater elevations during test slant well pumping at a rate of 2,860 AFY from April 2015 to February 2018 indicate that low TDS groundwater (< 3,000 mg/L TDS) from the inland

portion of the Dune Sand and 180-Foot Aquifers was likely being captured during the test, and that the equilibrium between the saline groundwater wedge and low TDS groundwater zone within and east of the MGSA Area may have been at least temporarily affected. ET from nearby GDEs decreased significantly during this test, due to a combination of drawdown and drought conditions. The ET from this GDE has since recovered, but it is not known whether vegetative stress resulted in longer-term changes to the habitat community composition or quality. For these reasons, without additional data and modeling tools, it is not possible to assess whether continued pumping at the rate of the test slant well would be sustainable in the long term. If the MPWSP is fully approved and implemented, the proposed increased source water pumping rate of 17,400 AFY would have a greater effect on the local groundwater budget, potentially further stressing sustainability indicators including groundwater level decline (and impacts to GDEs), water quality degradation and seawater intrusion.

As discussed further in Chapters 5 and 6, water quality monitoring will be conducted and trigger thresholds are established in this GSP for management actions to require further assessment and corrective action (as appropriate) to help assure protection of GDEs, prevention of further seawater intrusion, and prevention of groundwater quality degradation. The required assessments described in Chapter 6 would aid in the refinement of the estimate of the local contribution to sustainable yield beyond the current rate of 300 AFY, and corrective actions would be implemented as needed to prevent the occurrence of undesirable results.

## 3.4 WATER SUPPLY AVAILABILITY FOR AUGMENTATION

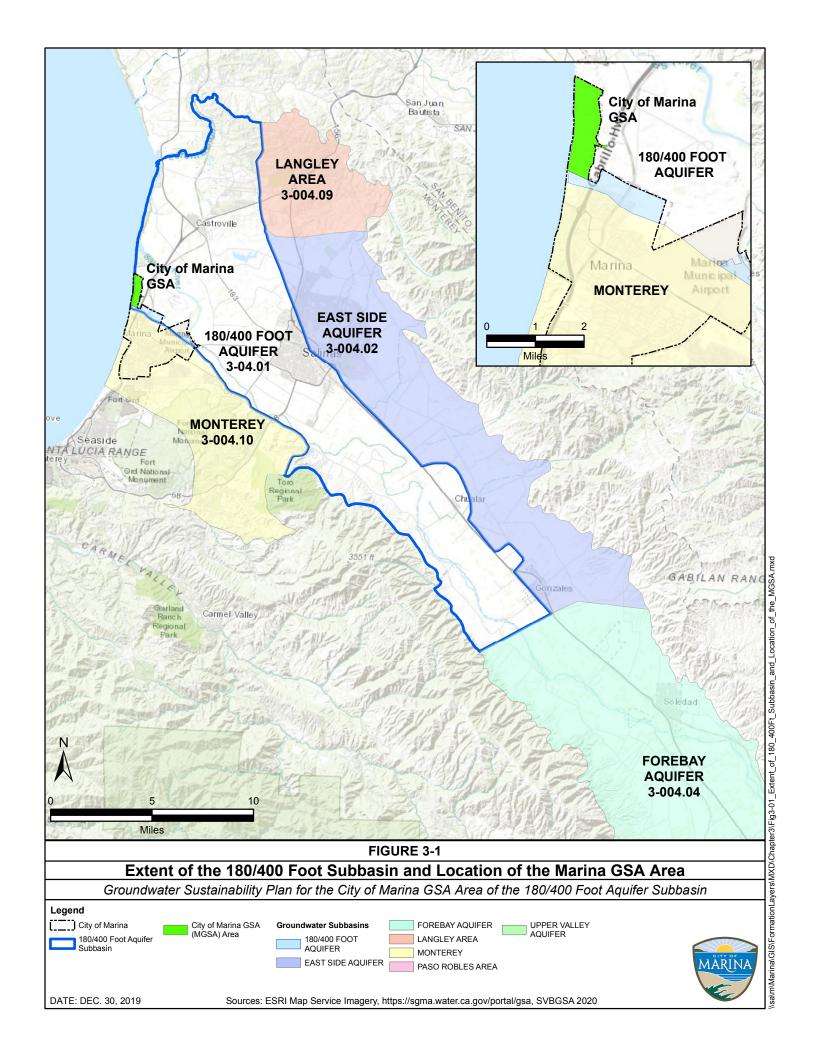
There are currently no alternative sources of water supply within the MGSA Area. If future development in the MGSA Area were to require a potable water supply, annexation of the MGSA Area into MCWD could be considered.

#### 3.5 MANAGEMENT AREAS

#### **Regulation Requirements:**

**§354.20** (a) Each Agency may define one or more management areas within a basin if the Agency has determined that creation of management areas will facilitate implementation of the Plan. Management areas may define different minimum thresholds and be operated to different measurable objectives than the basin at large, provided that undesirable results are defined consistently throughout the basin.

There are no management areas within the MGSA Area.



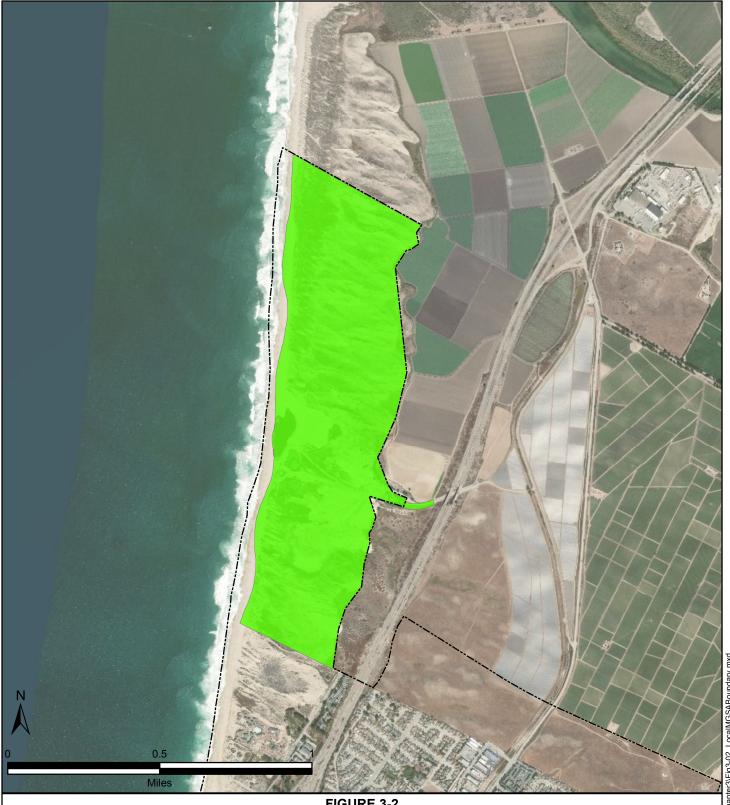
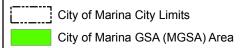


FIGURE 3-2

## City of Marina GSA Area

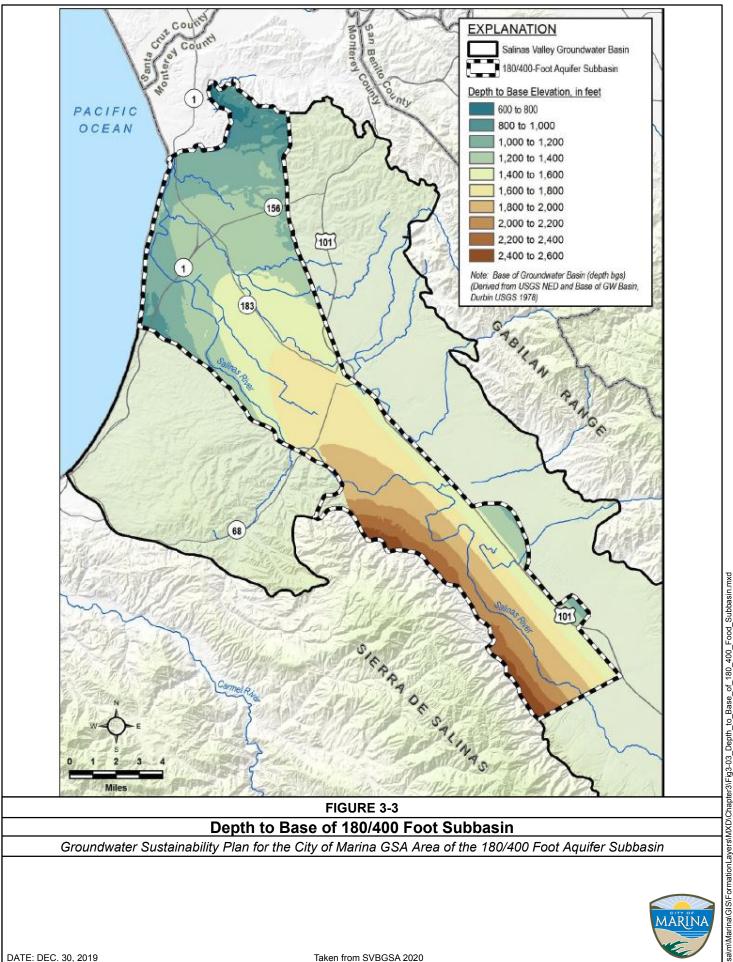
Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

## Legend



Sources: ESRI Map Service Imagery, https://sgma.water.ca.gov/portal/gsa, https://montereycountyopendata-12017-01-13t232948815zmontereyco.opendata.arcgis.com, SVBGSA 2020

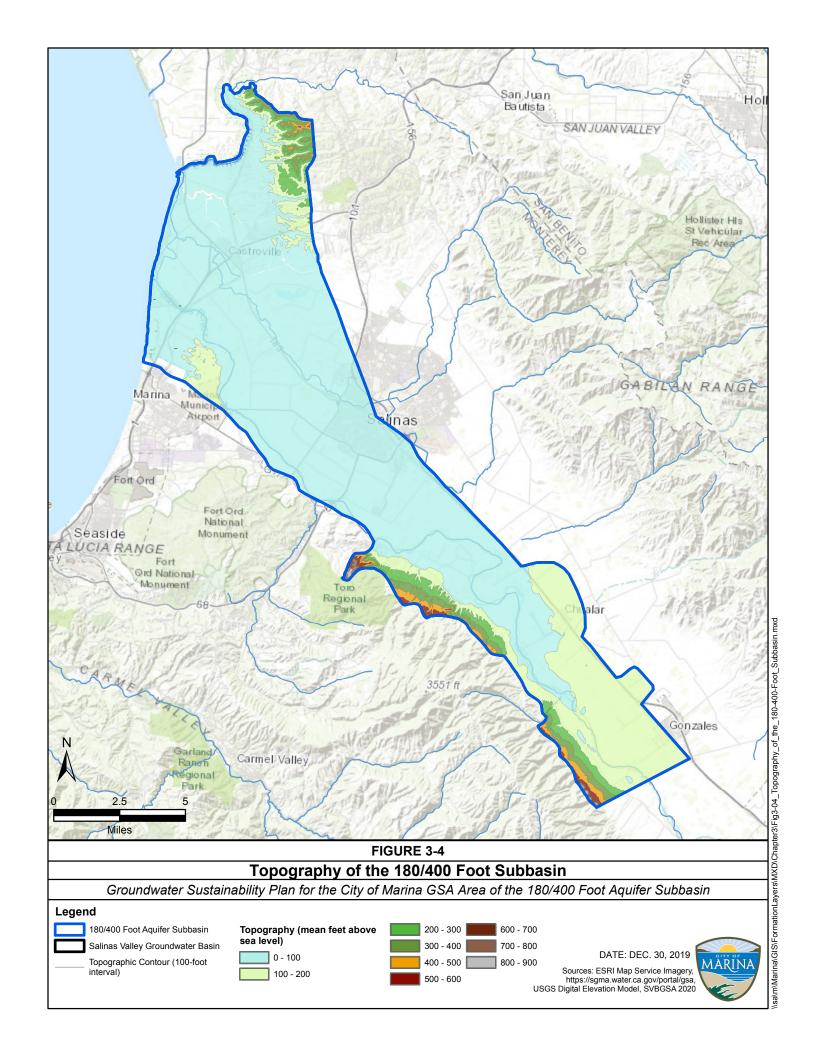


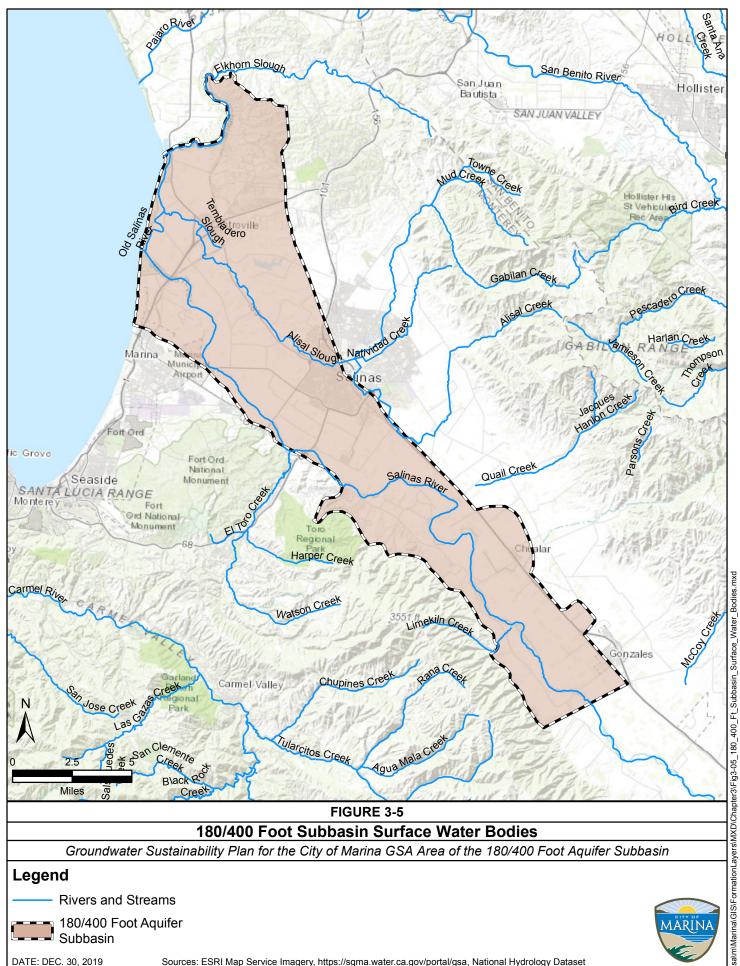


# Depth to Base of 180/400 Foot Subbasin

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin





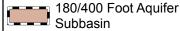


## 180/400 Foot Subbasin Surface Water Bodies

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

#### Legend

Rivers and Streams



DATE: DEC. 30, 2019

Sources: ESRI Map Service Imagery, https://sgma.water.ca.gov/portal/gsa, National Hydrology Dataset



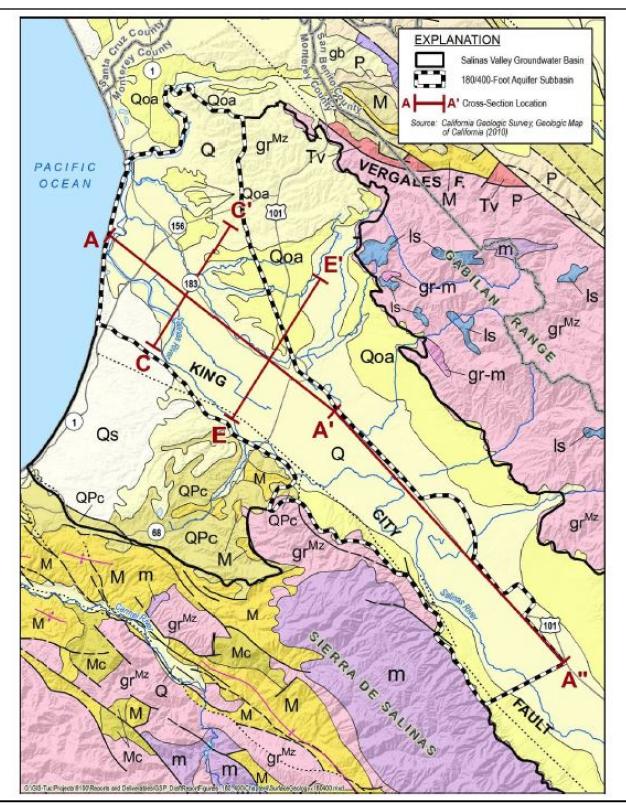


FIGURE 3-6

## Geologic Map of the 180/400 Foot Subbasin

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin



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#### TERTIARY VOLCANIC ROCKS

mostly well consolidated

Tv Tertiary volcanic flow rocks, minor pyroclastic deposits

# MESOZOIC SEDIMENTARY AND METASEDIMENTARY ROCKS

Limestone, dolomite, and marble whose age is uncertain but probably Paleozoic or Mesozoic

#### MESOZOIC MIXED ROCKS

gr-m Mesozoic to Precambrian granitic and metamorphic rocks, mostly gneiss and other metamorphic rocks injected by granitic rocks

#### MESOZOIC PLUTONIC ROCKS

grMz

Mesozoic granite, quartz monzonite, granodiorite, and quartz diorite

gb

Gabbro and dark dioritic rocks, chiefly Mesozoic

#### PALEOZOIC MIXED ROCKS

Undivided pre-Cenozoic metasedimentary and metavolcanic rocks of great variety. Mostly slate, quartzite, hornfels, chert, phyllite, mylonite, schist gneiss, and minor marble

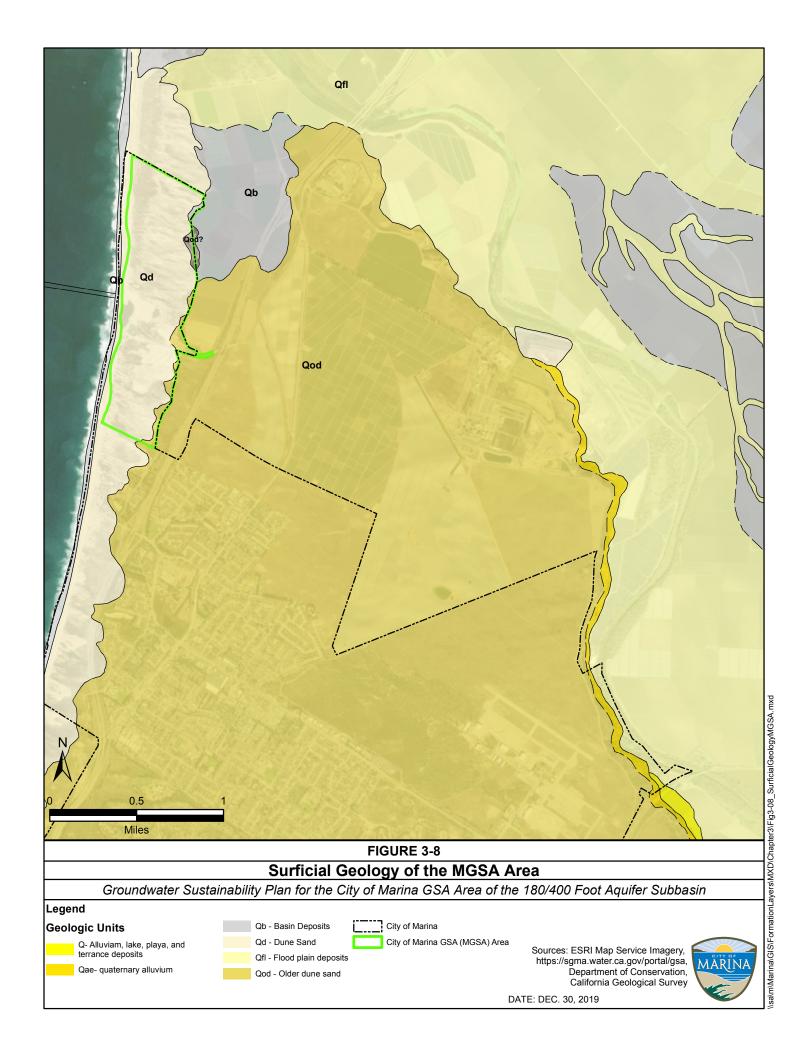
#### FIGURE 3-7

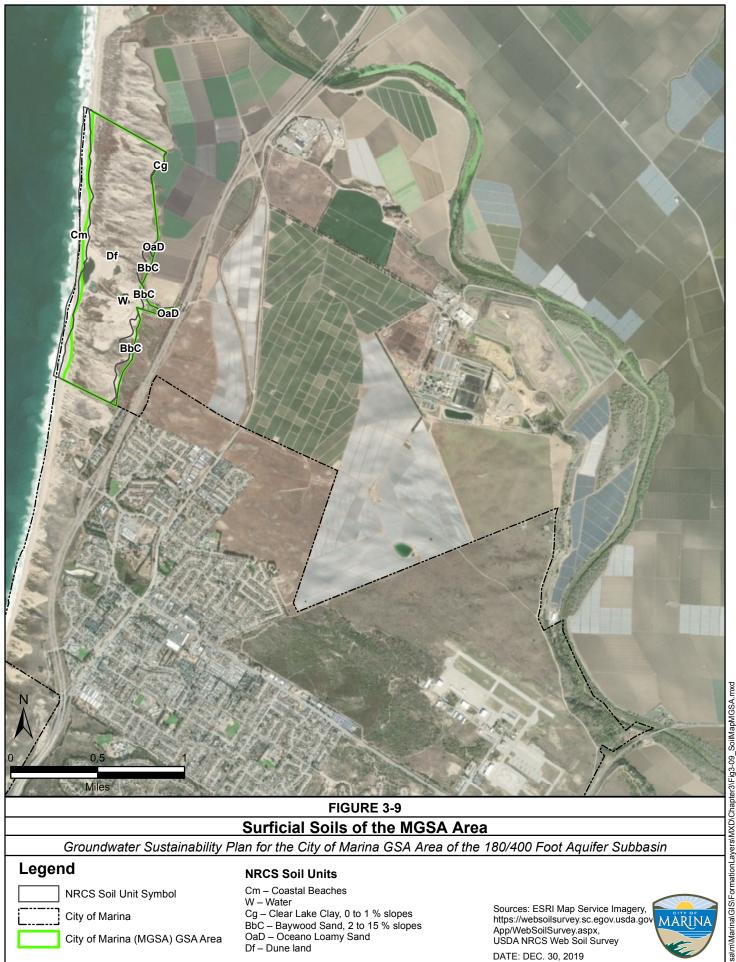
#### Legend for the Geologic Map of the 180/400 Foot Subbasin

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin



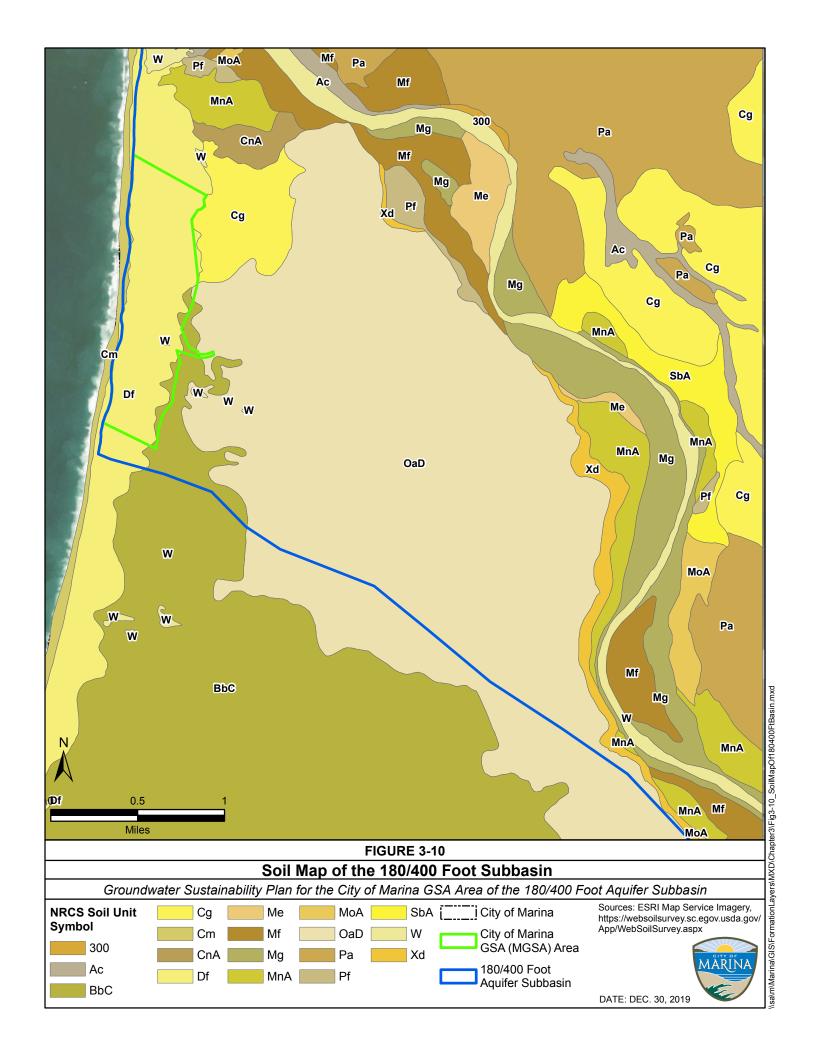
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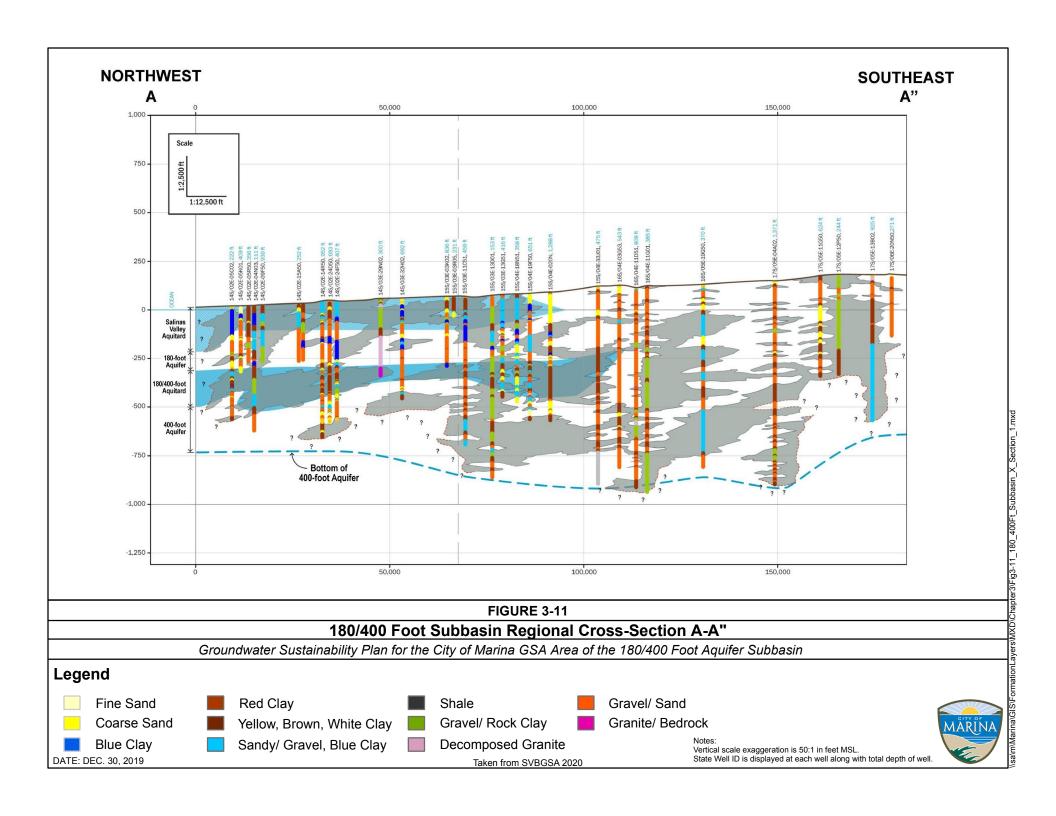


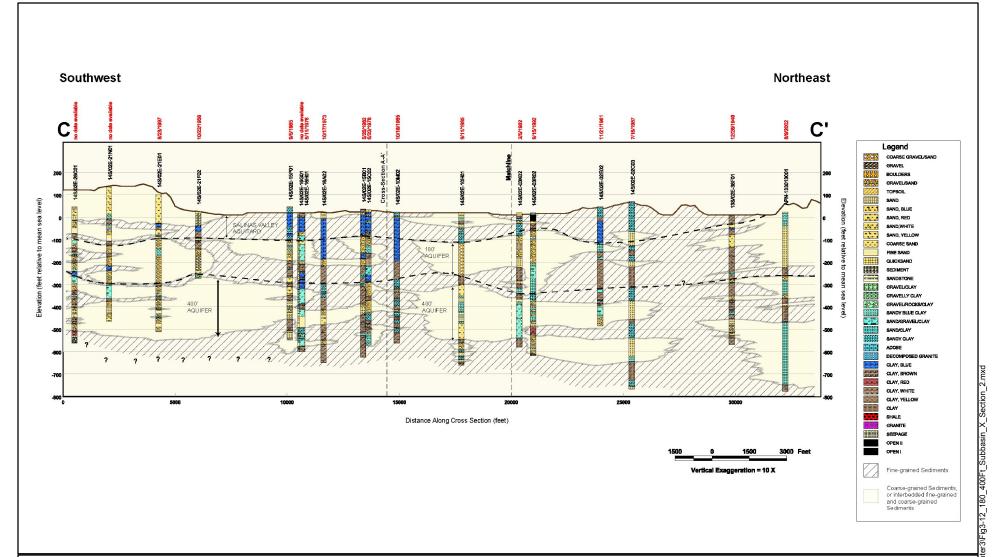


BbC – Baywood Sand, 2 to 15 % slopes OaD – Oceano Loamy Sand Df – Dune land

City of Marina (MGSA) GSA Area





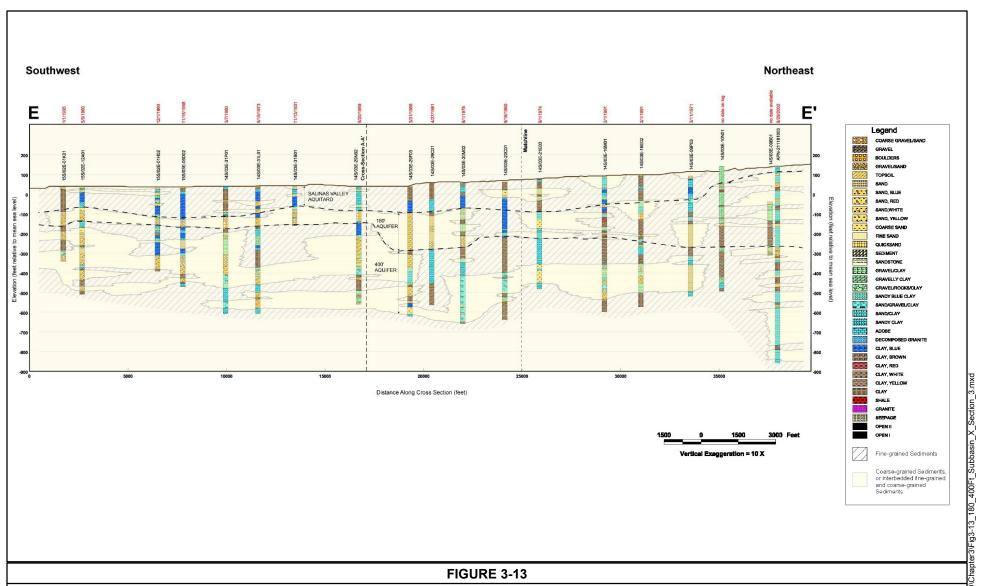


#### **FIGURE 3-12**

## 180/400 Foot Subbasin Regional Cross-Section C-C'

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

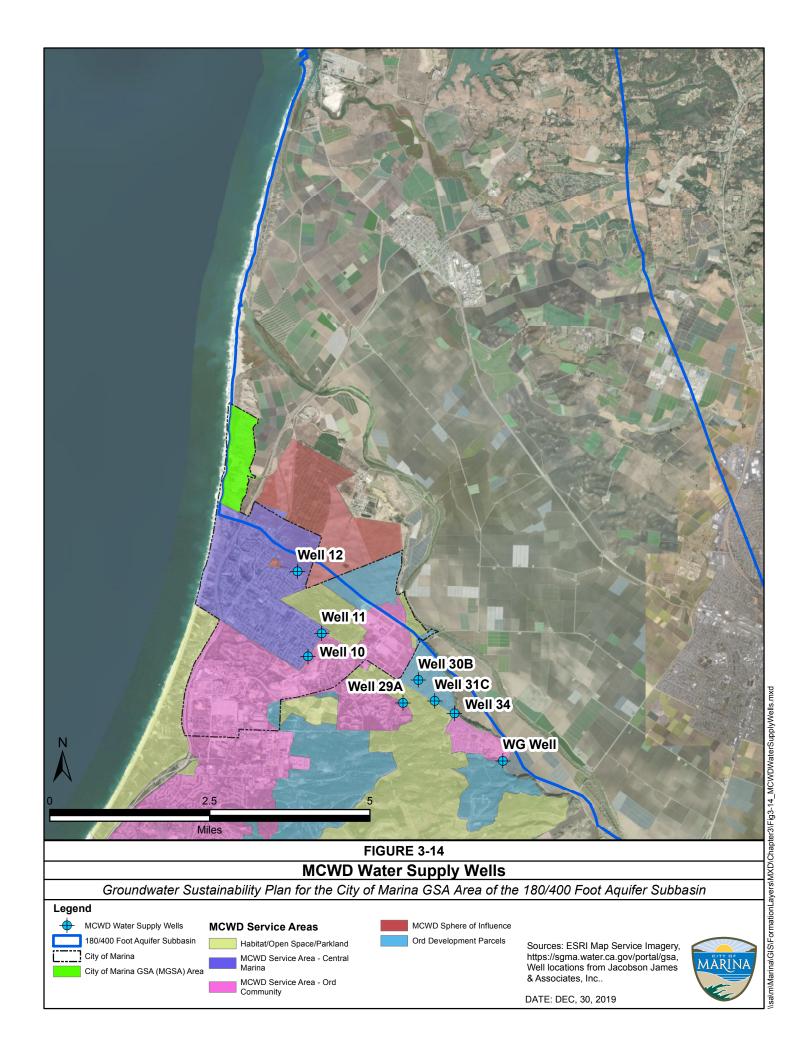


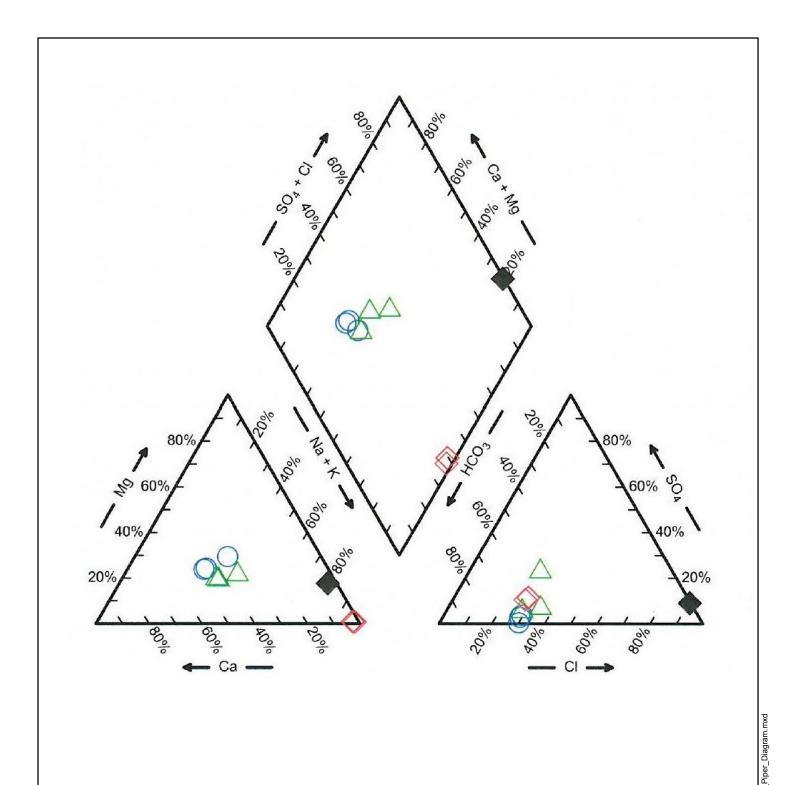


## 180/400 Foot Subbasin Regional Cross-Section E-E'

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin







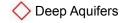
**FIGURE 3-15** 

# Regional Water Quality in Principal Supply Aquifers; Piper Diagram

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

## Legend

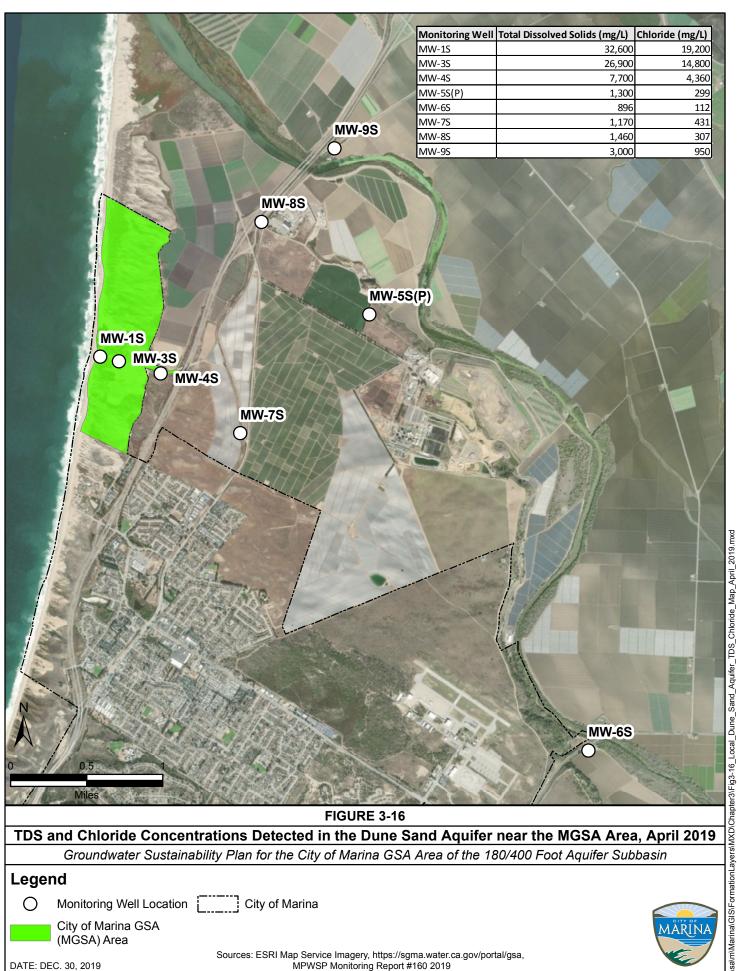
O Pressure 180-Foot Aquifer O Deep Aquifers

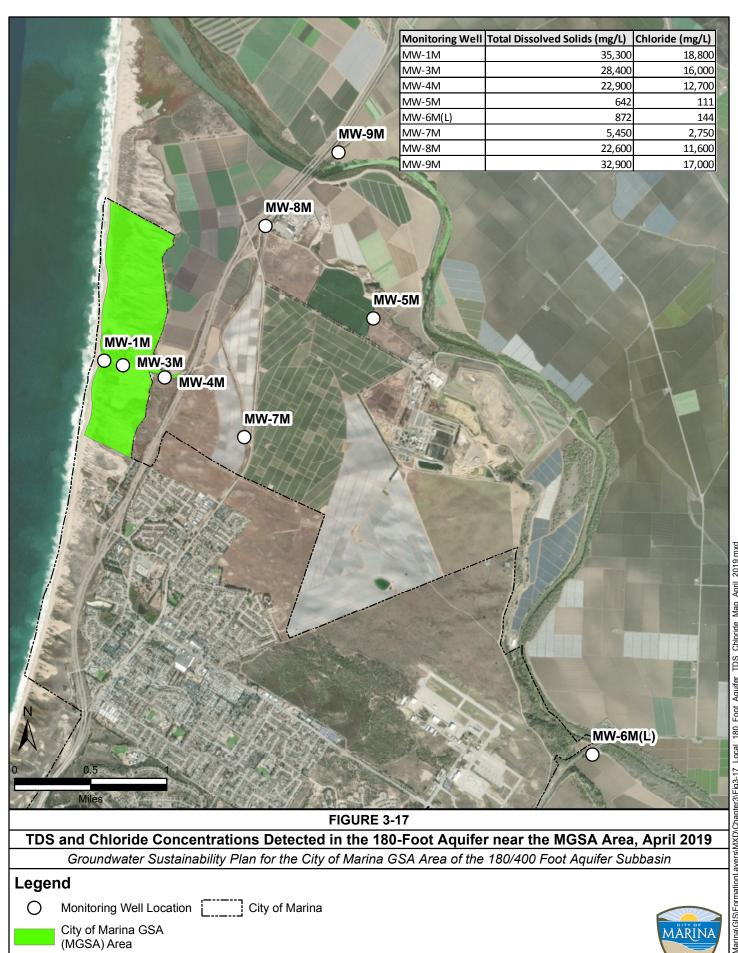


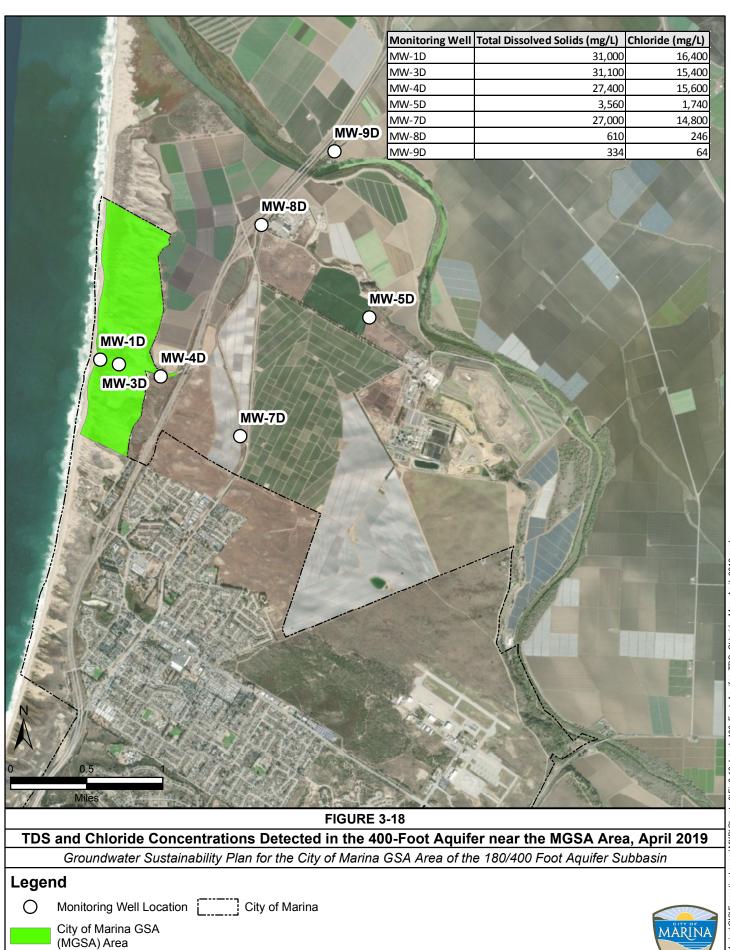
△ Pressure 400-Foot Aquifer

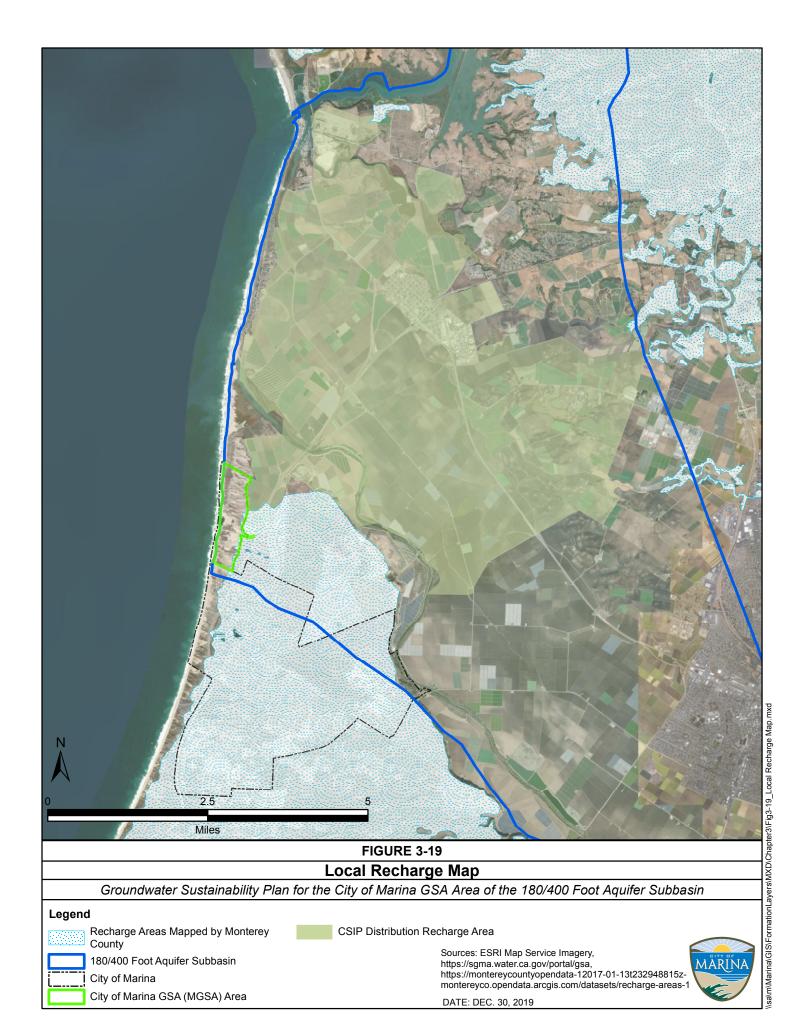


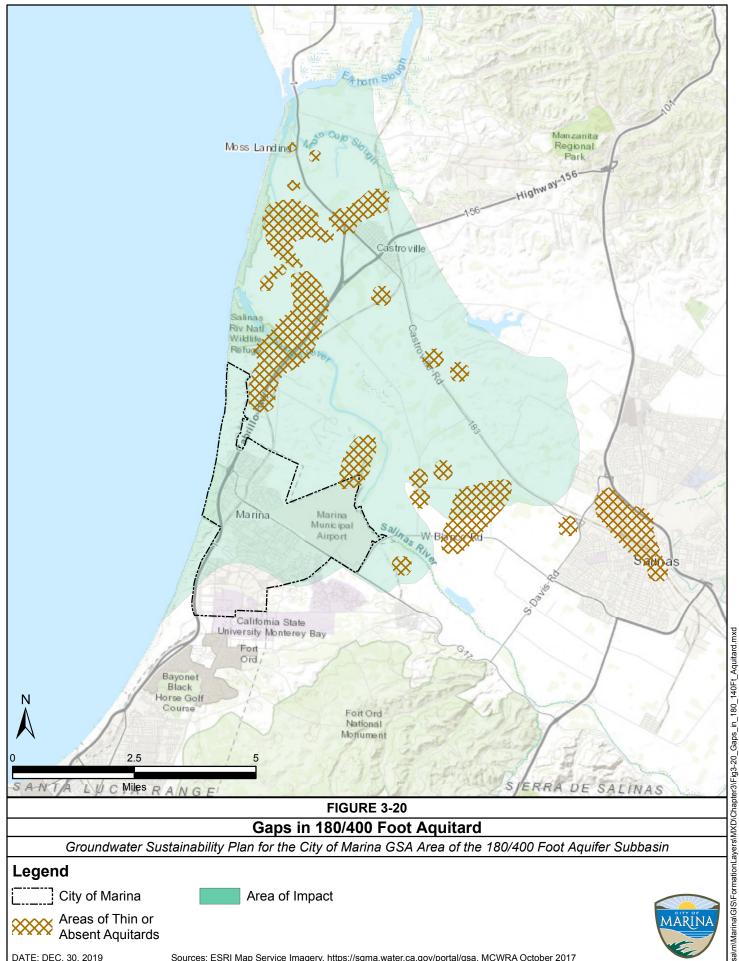








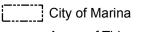


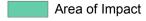


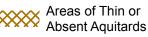
Gaps in 180/400 Foot Aquitard

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

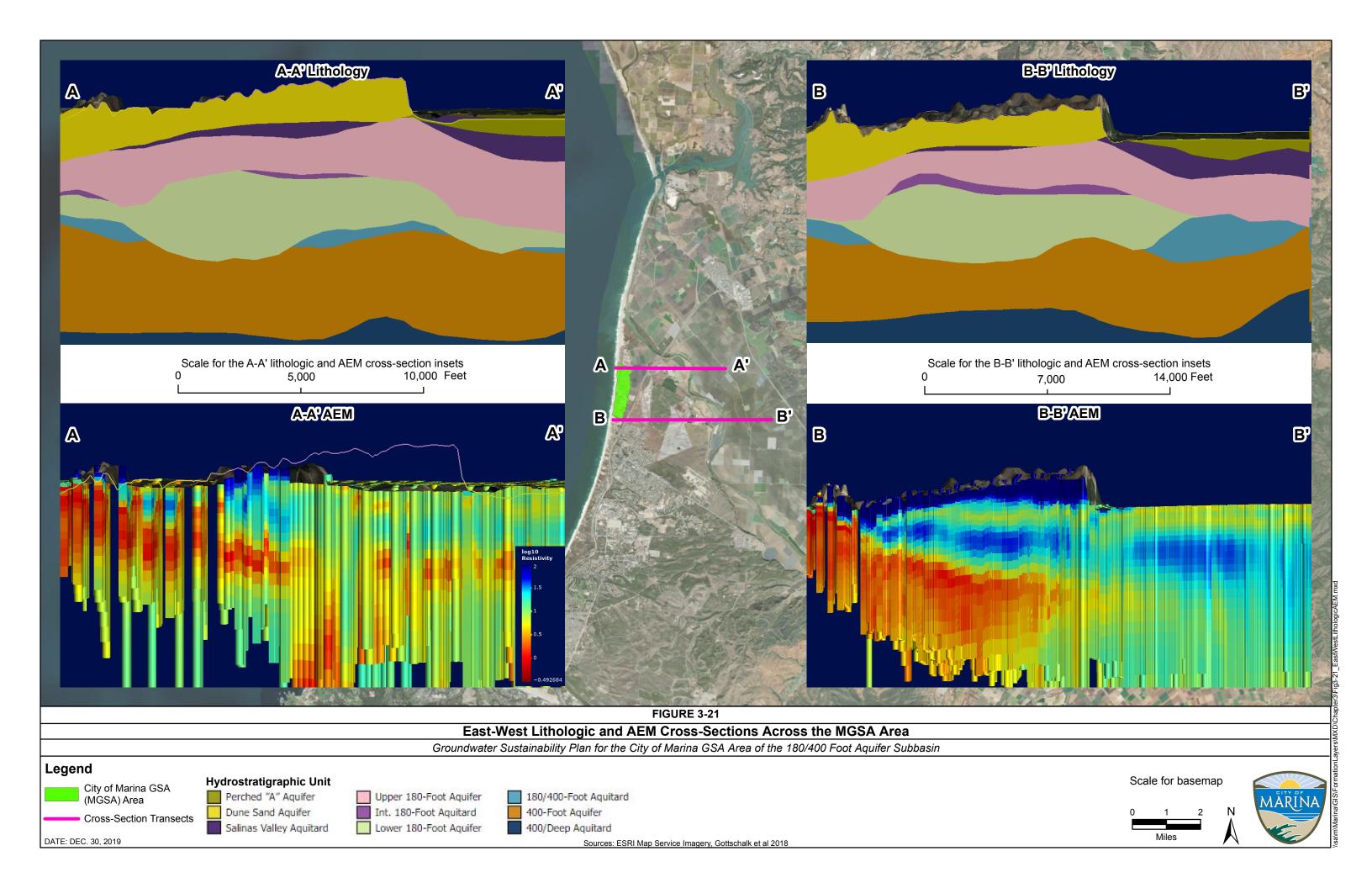
## Legend

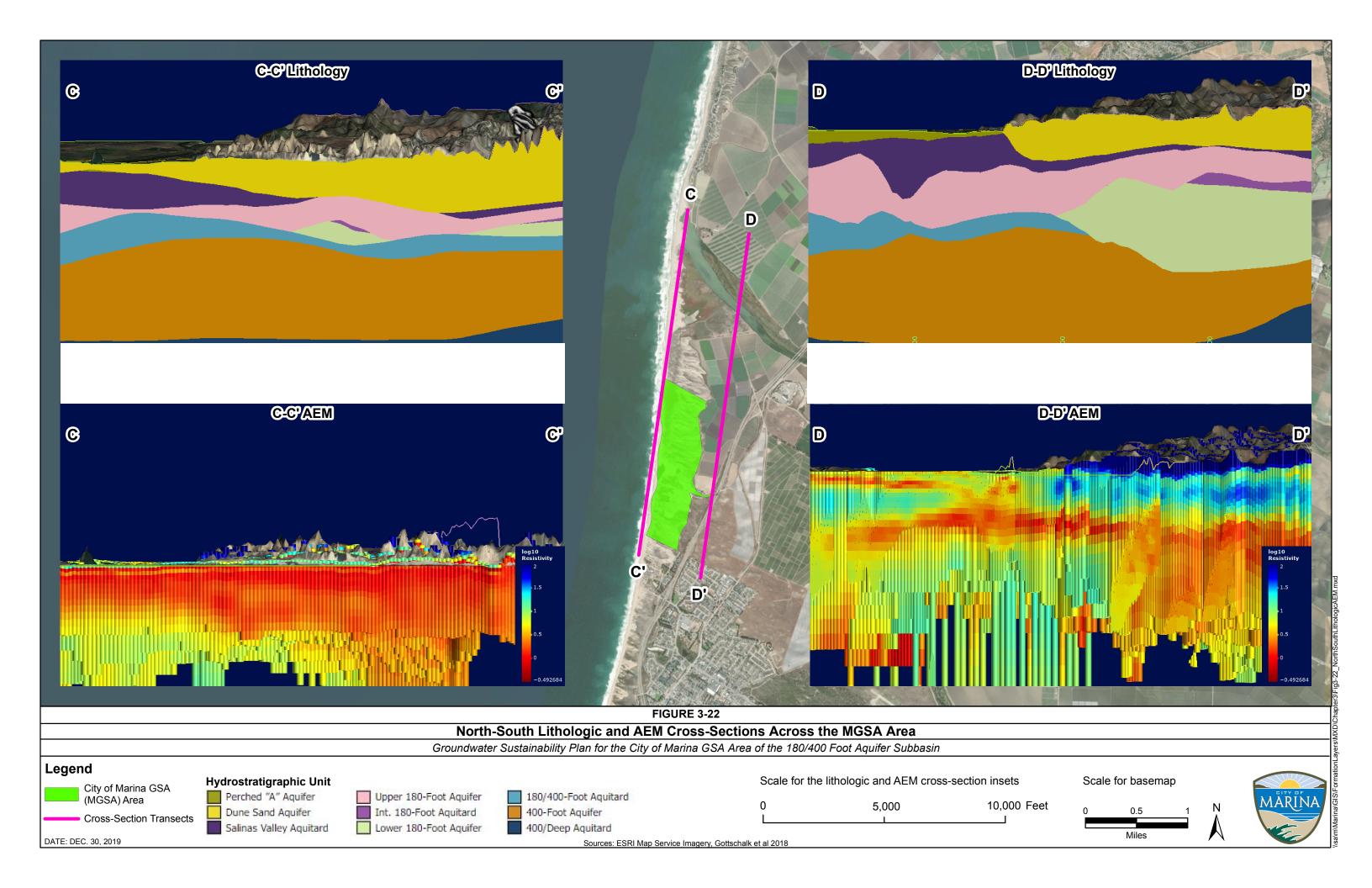


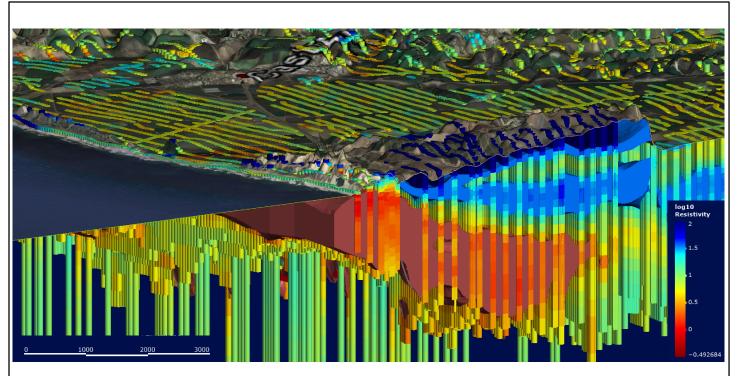


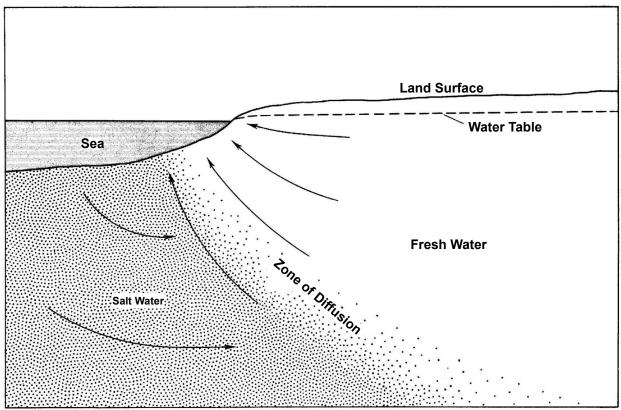












**FIGURE 3-23** 

Oblique View of Seawater Intrusion Front and Low TDS Zone with Ghyben-Herzberg Model Inset

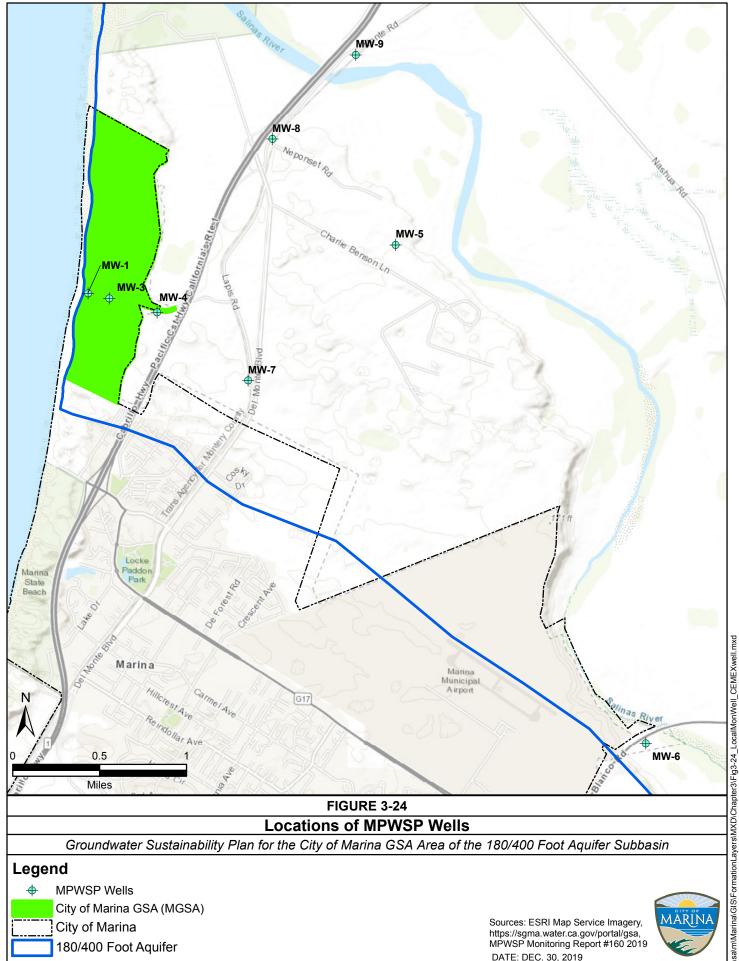
Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin



Sources: Gottschalk et al 2018

DATE: DEC. 30, 2019

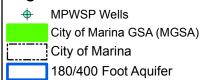
salm\Marina\G\S\FormationLayers\MXD\Chapter3\Fig3-23\_Oblique\TewOfSeawaterIntrusionFrontLowTDSModel.mxd



**Locations of MPWSP Wells** 

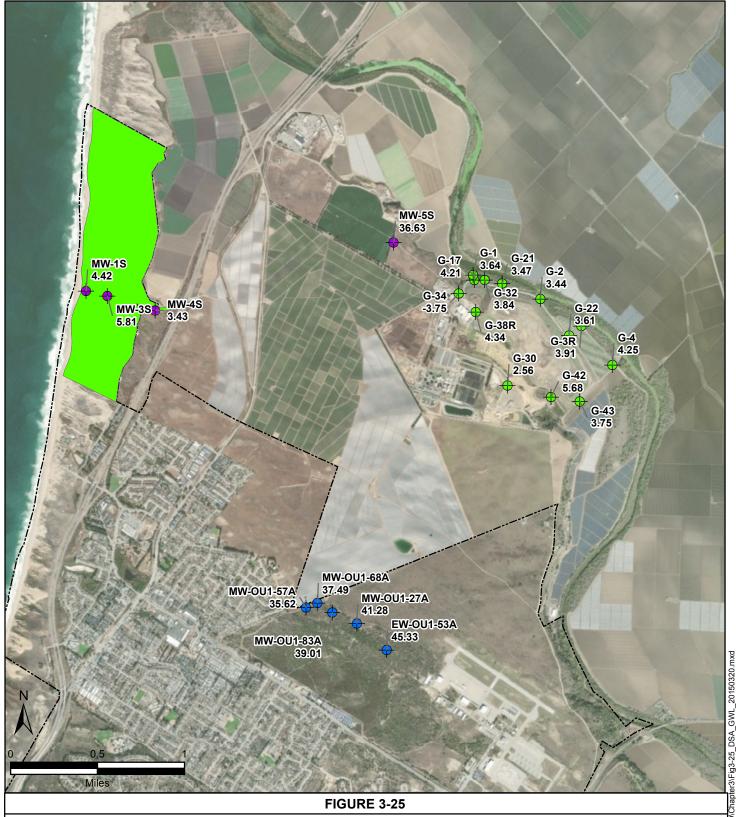
Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

### Legend



Sources: ESRI Map Service Imagery, https://sgma.water.ca.gov/portal/gsa, MPWSP Monitoring Report #160 2019 DATE: DEC. 30, 2019





## Local Dune Sand Aquifer Water Level Map, March 20, 2015

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

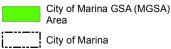
#### Legend

MPWSP Monitoring Well

DATE: DEC. 30, 2019

Monterey Peninsula Landfill Monitoring Well

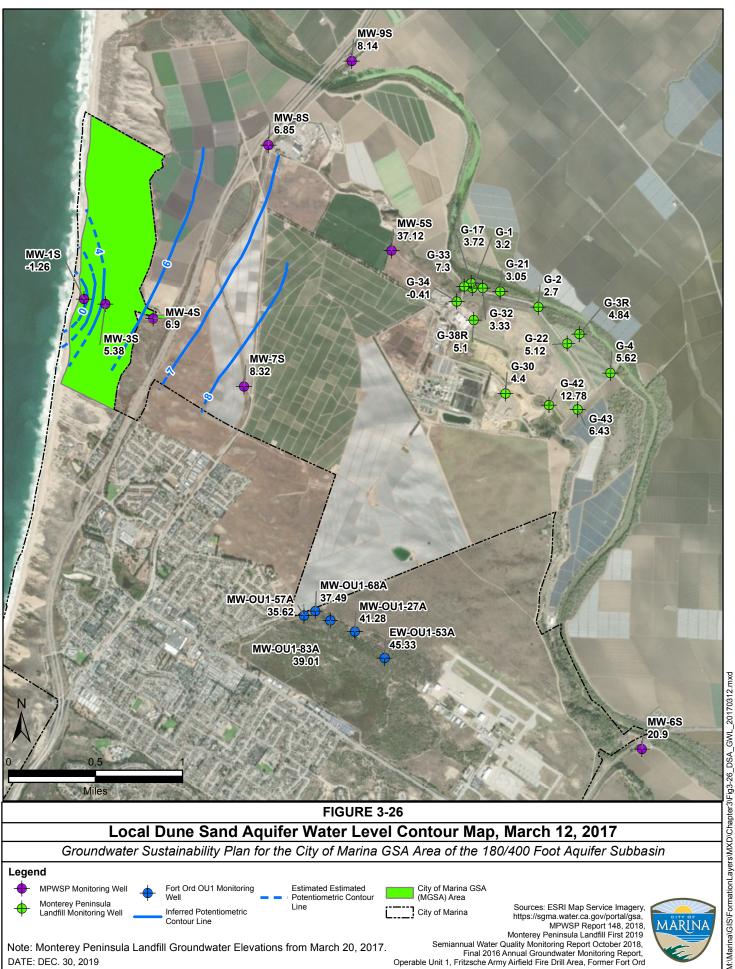
Fort Ord OU1 Monitoring Well



Note: Monterey Peninsula Landfill water levels from March 23-24, 2015. Fort Ord OU1 water levels from July 1, 2015.

Sources: ESRI Map Service Imagery,
https://sgma.water.ca.gov/portal/gsa,
MPWSP Report 148, 2018,
Monterey Peninsula Landfill First 2019
Semiannual Water Quality Monitoring Report October 2018,
Final 2016 Annual Groundwater Monitoring Report,
Operable Unit 1, Fritzsche Army Airfield Fire Drill Area, Former Fort Ord

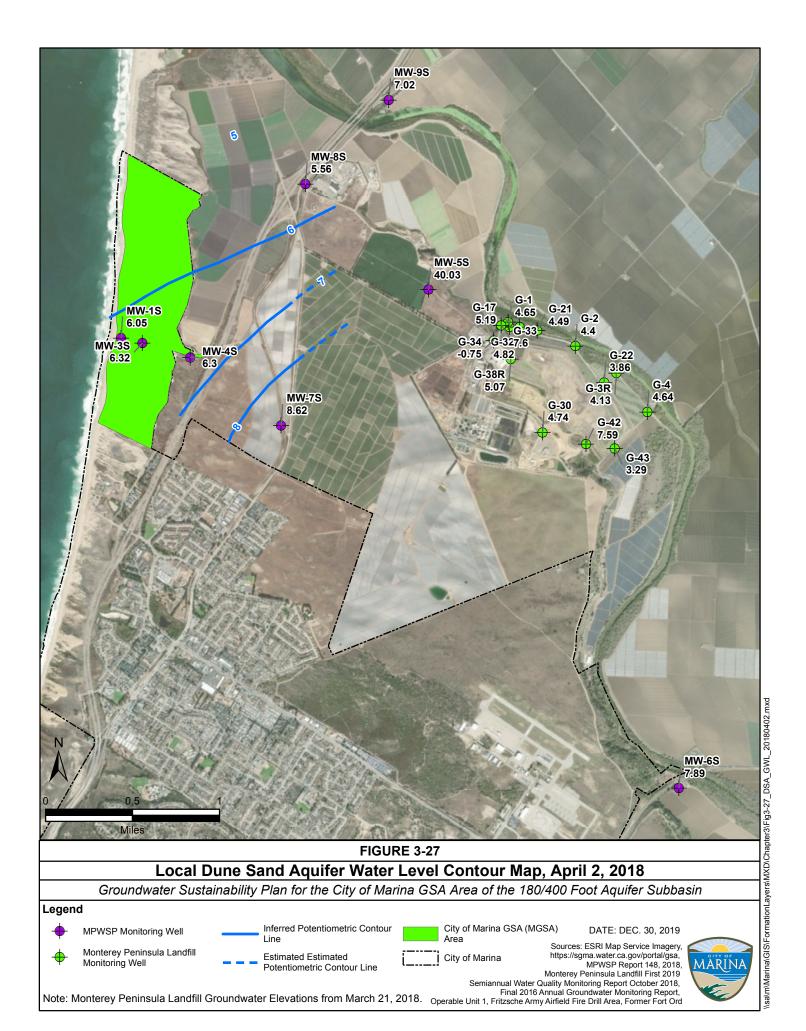


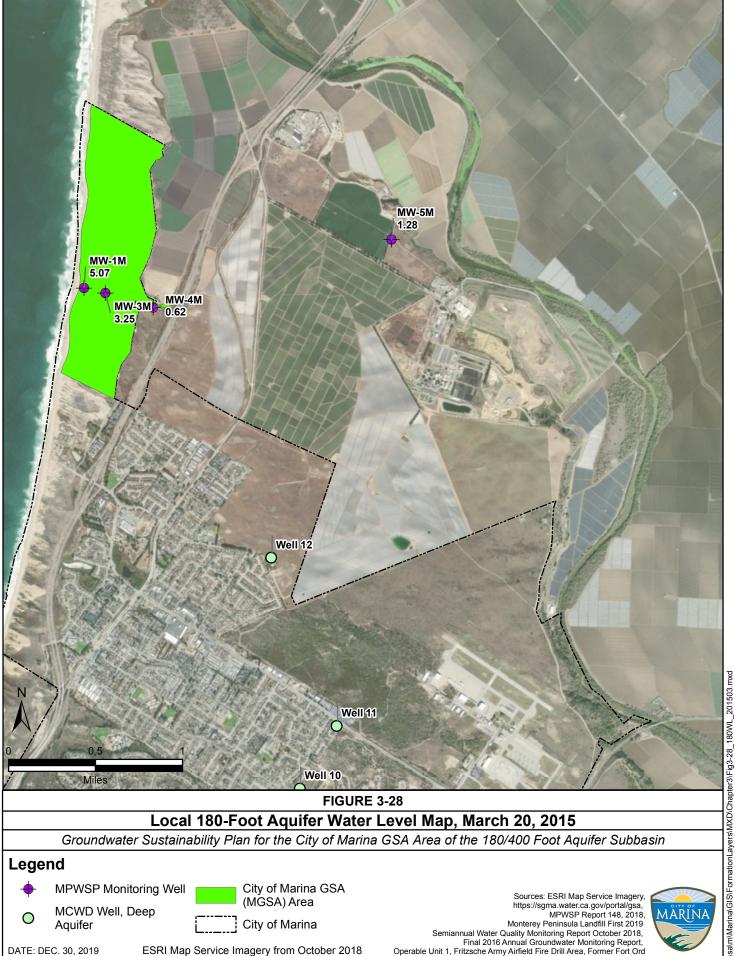


Note: Monterey Peninsula Landfill Groundwater Elevations from March 20, 2017. DATE: DEC. 30, 2019

MPWSP Report 148, 2018, Monterey Peninsula Landfill First 2019 Semiannual Water Quality Monitoring Report October 2018, Final 2016 Annual Groundwater Monitoring Report, Operable Unit 1, Fritzsche Army Airfield Fire Drill Area, Former Fort Ord

MARIN





**FIGURE 3-28** 

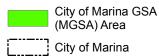
### Local 180-Foot Aquifer Water Level Map, March 20, 2015

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

### Legend

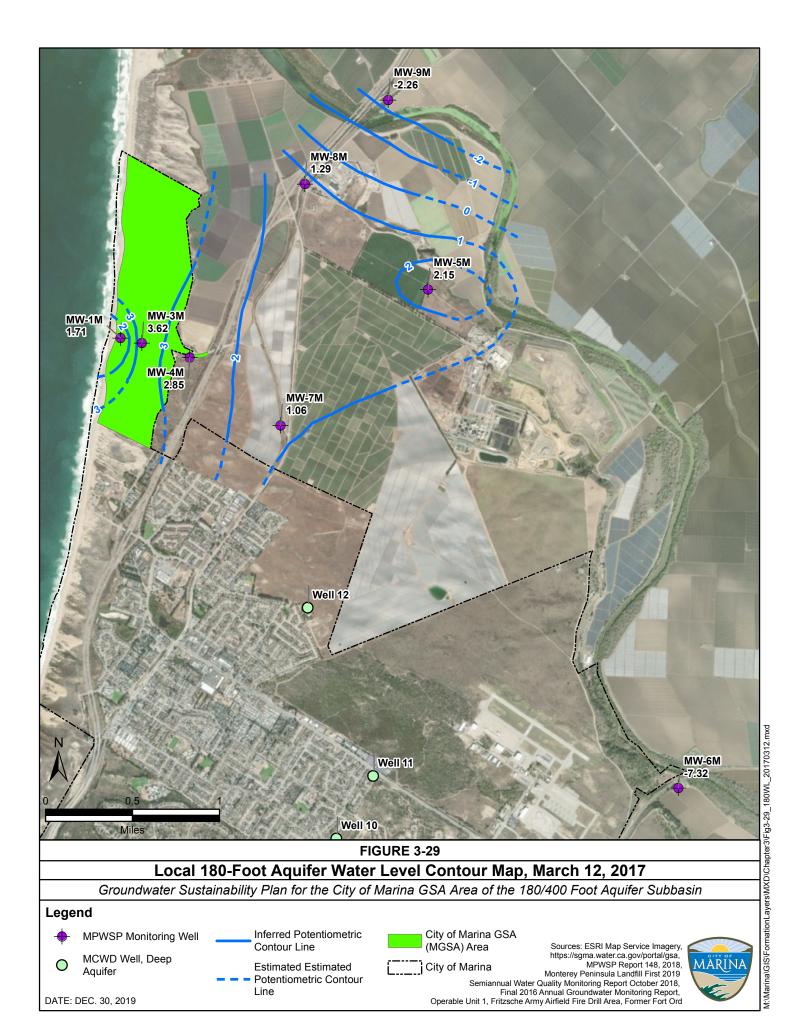
MPWSP Monitoring Well

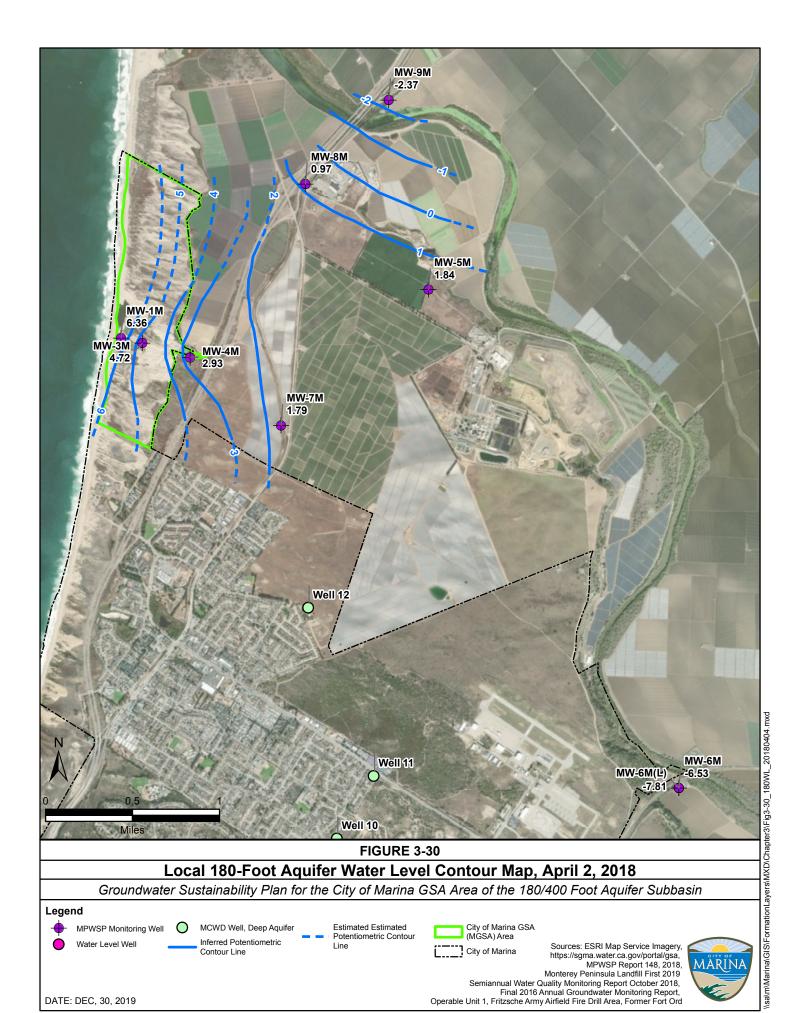
MCWD Well, Deep Aquifer

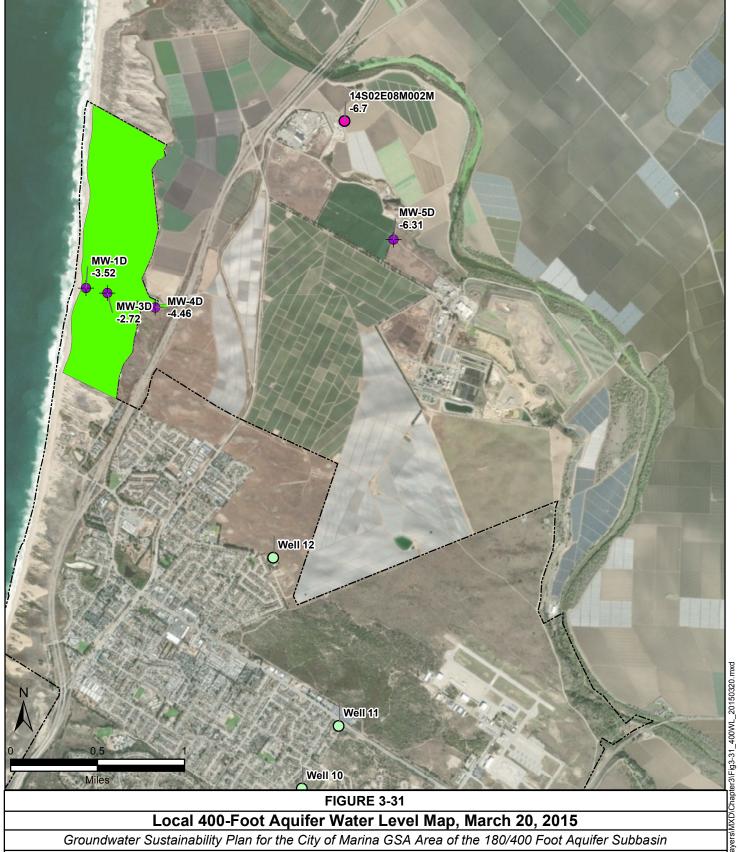


Sources: ESRI Map Service Imagery,
https://sgma.water.ca.gov/portal/gsa,
MPWSP Report 148, 2018,
Monterey Peninsula Landfill First 2019
Semiannual Water Quality Monitoring Report October 2018,
Final 2016 Annual Groundwater Monitoring Report,
Operable Unit 1, Fritzsche Army Airfield Fire Drill Area, Former Fort Ord









**FIGURE 3-31** 

### Local 400-Foot Aquifer Water Level Map, March 20, 2015

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

### Legend

Water Level Well

DATE: DEC, 30, 2019

MPWSP Monitoring Well



MCWD Well, Deep Aquifer



City of Marina GSA (MGSA) Area

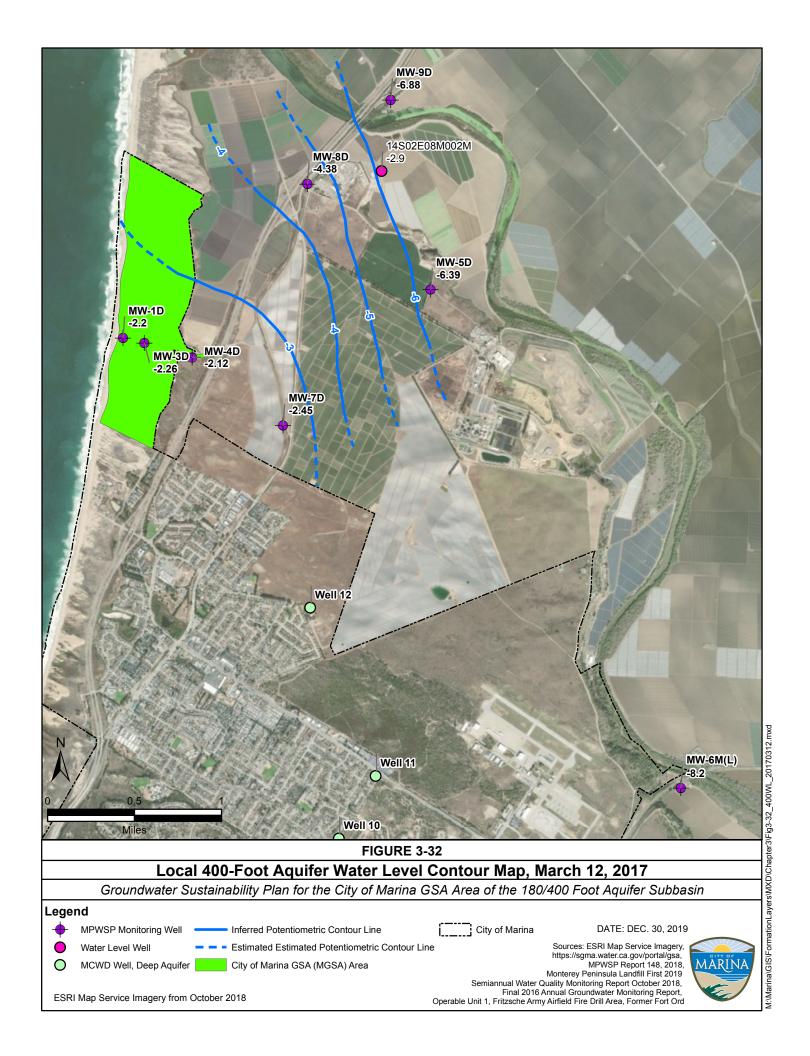


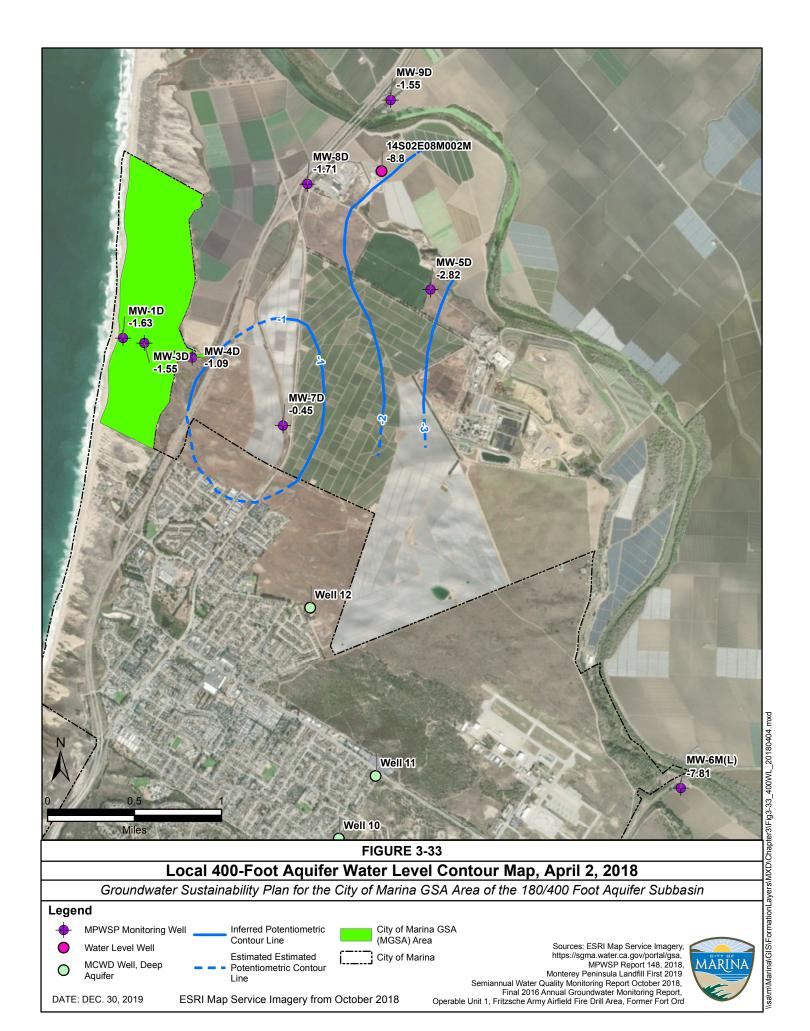
ESRI Map Service Imagery from October 2018

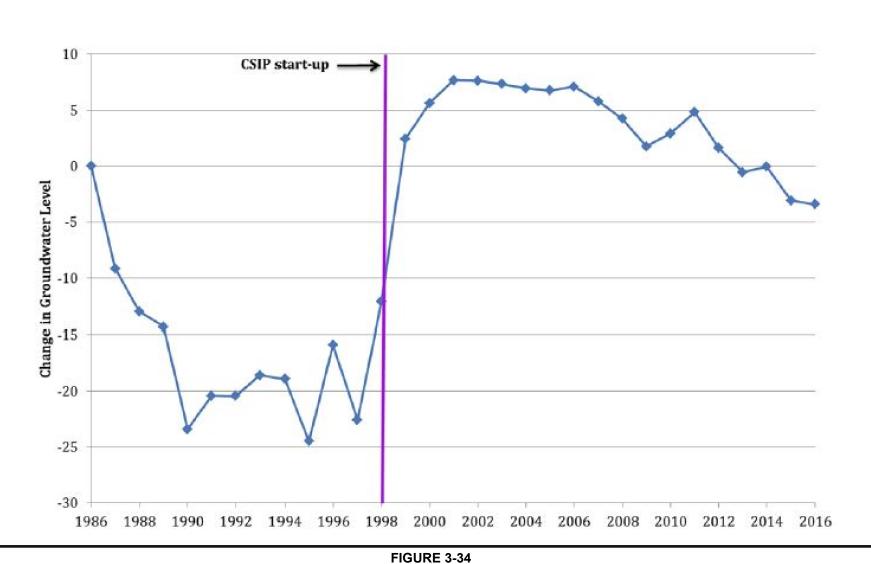
City of Marina

A) Area Sources: ESRI Map Service Imagery,
https://sgma.water.ca.gov/portal/gsa,
Marina MPWSP Report 148, 2018,
Monterey Peninsula Landfill First 2019
Semiannual Water Quality Monitoring Report October 2018,
Final 2016 Annual Groundwater Monitoring Report,
Operable Unit 1, Fritzsche Army Airfield Fire Drill Area, Former Fort Ord









Average Groundwater Level Changes in the Deep Aquifers

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin



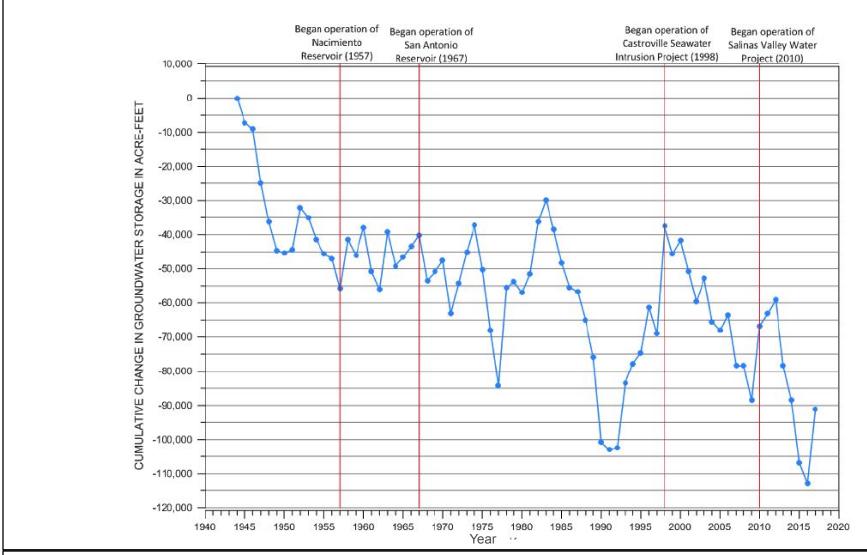
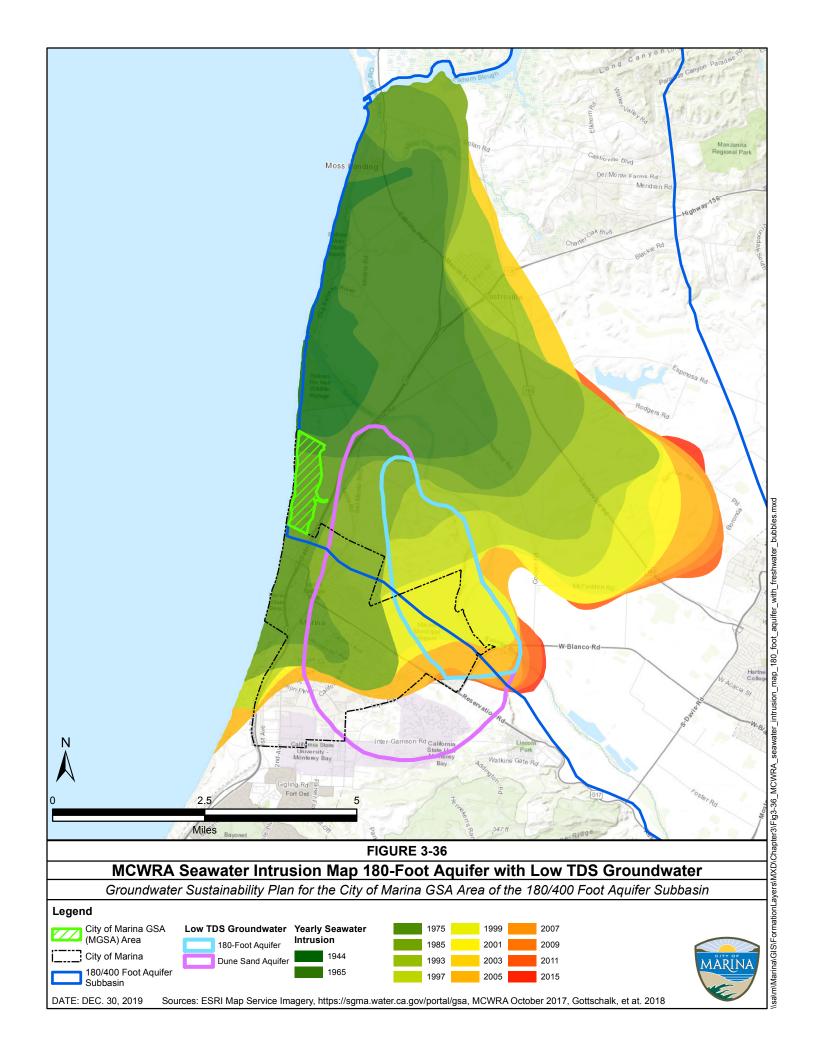


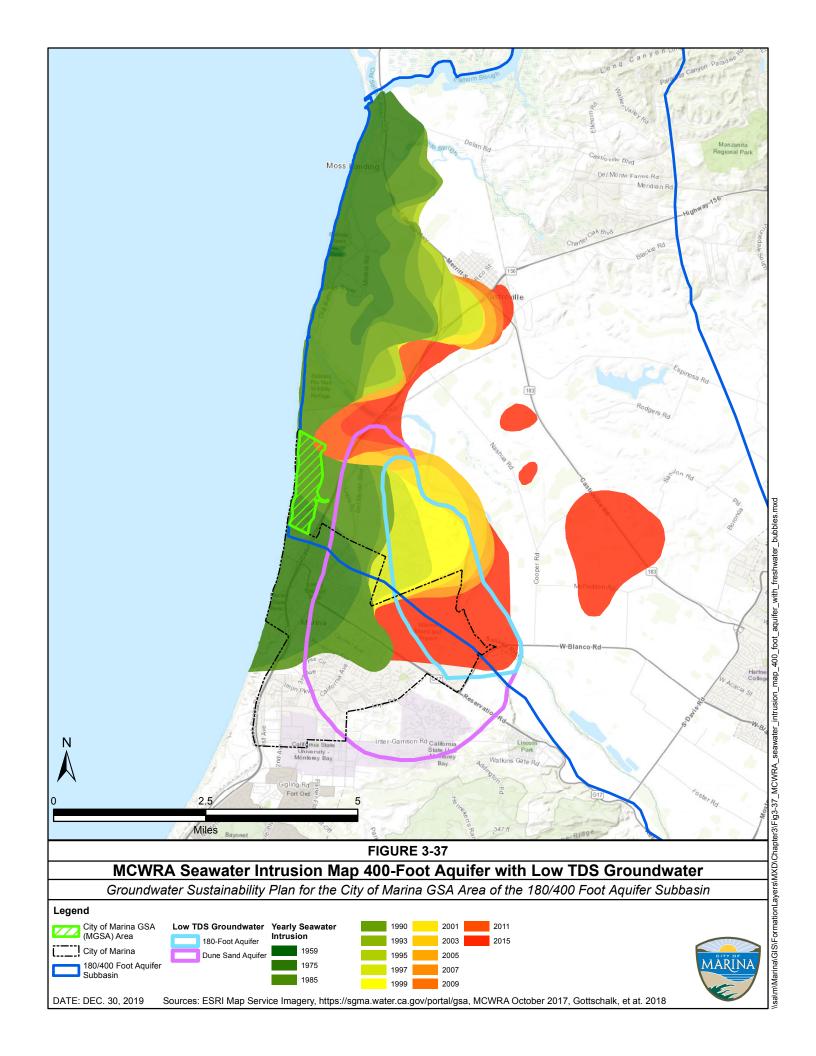
FIGURE 3-35

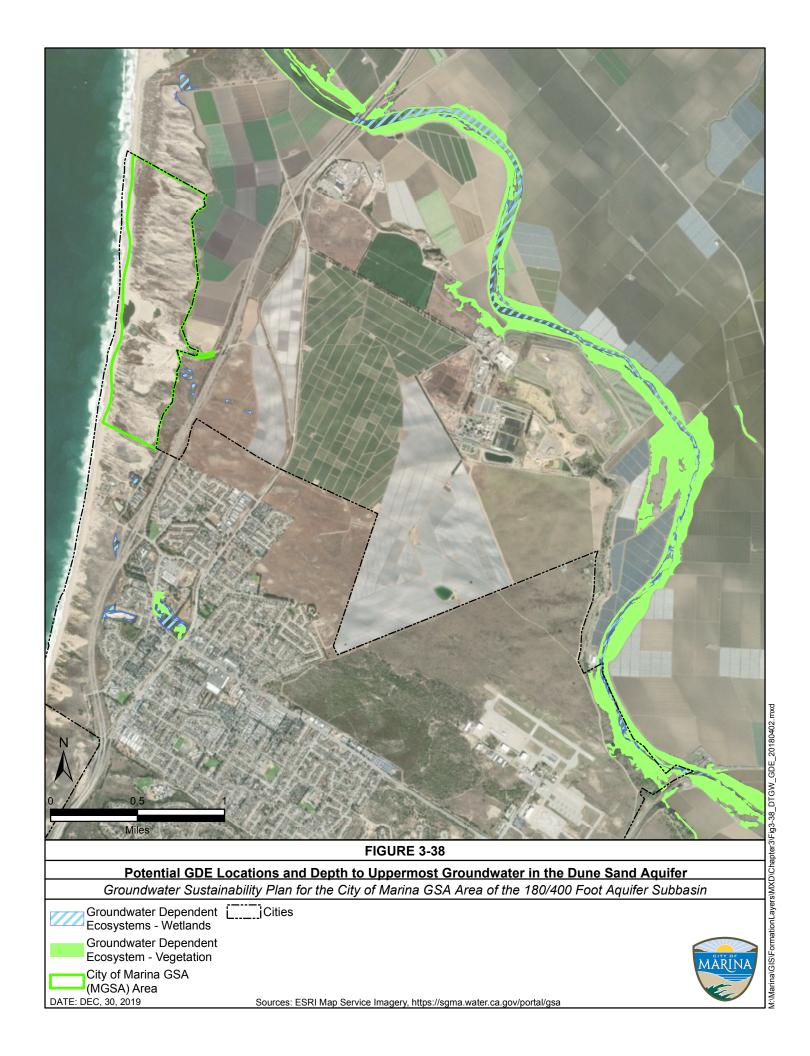
### **Cumulative Change in Groundwater Storage Based on Groundwater Elevations**

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin









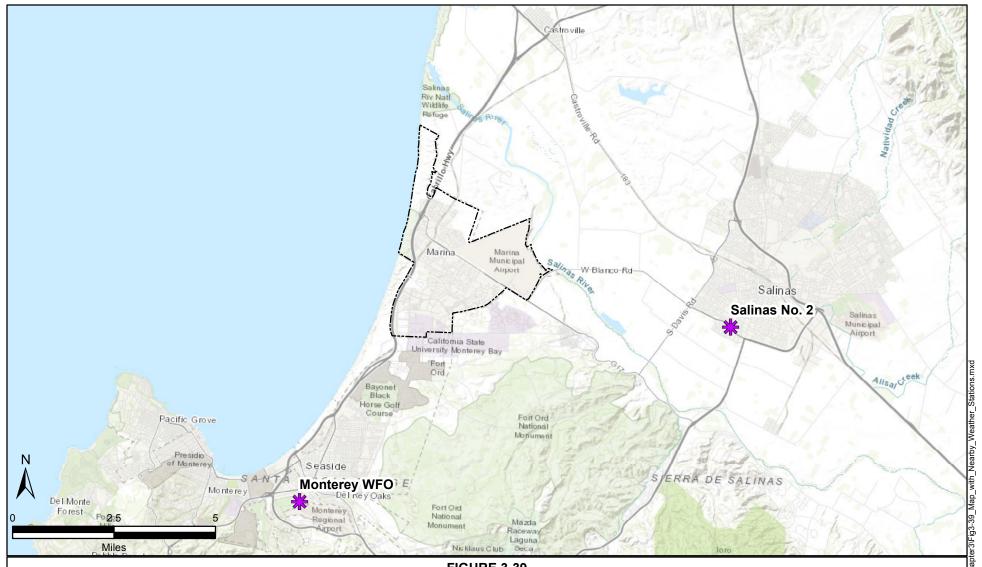


FIGURE 3-39

### **Nearby Weather Stations**

Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

### Legend



Weather Stations

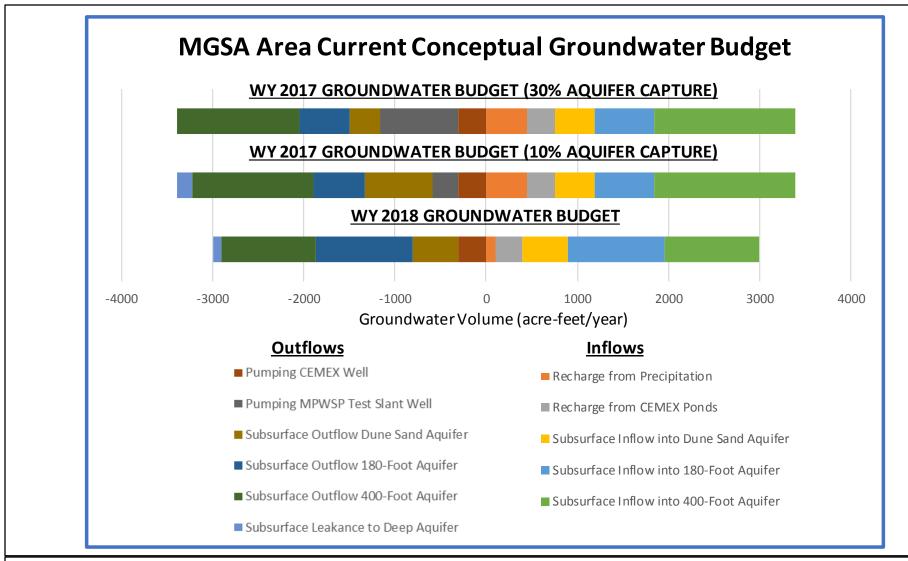


City of Marina

DATE: DEC. 30, 2019

Sources: http://goto.arcgisonline.com/maps/World\_Topo\_Map, National Weather Service - NWS San Francisco/Monterey Bay Area





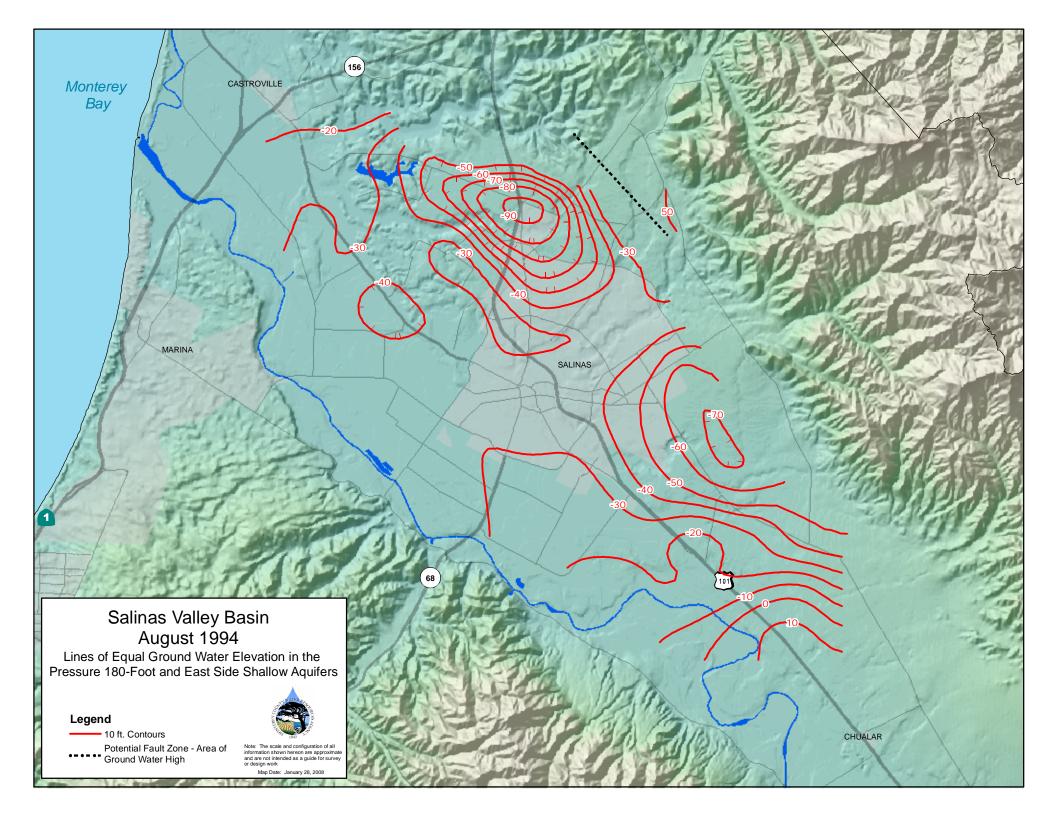
#### **FIGURE 3-40**

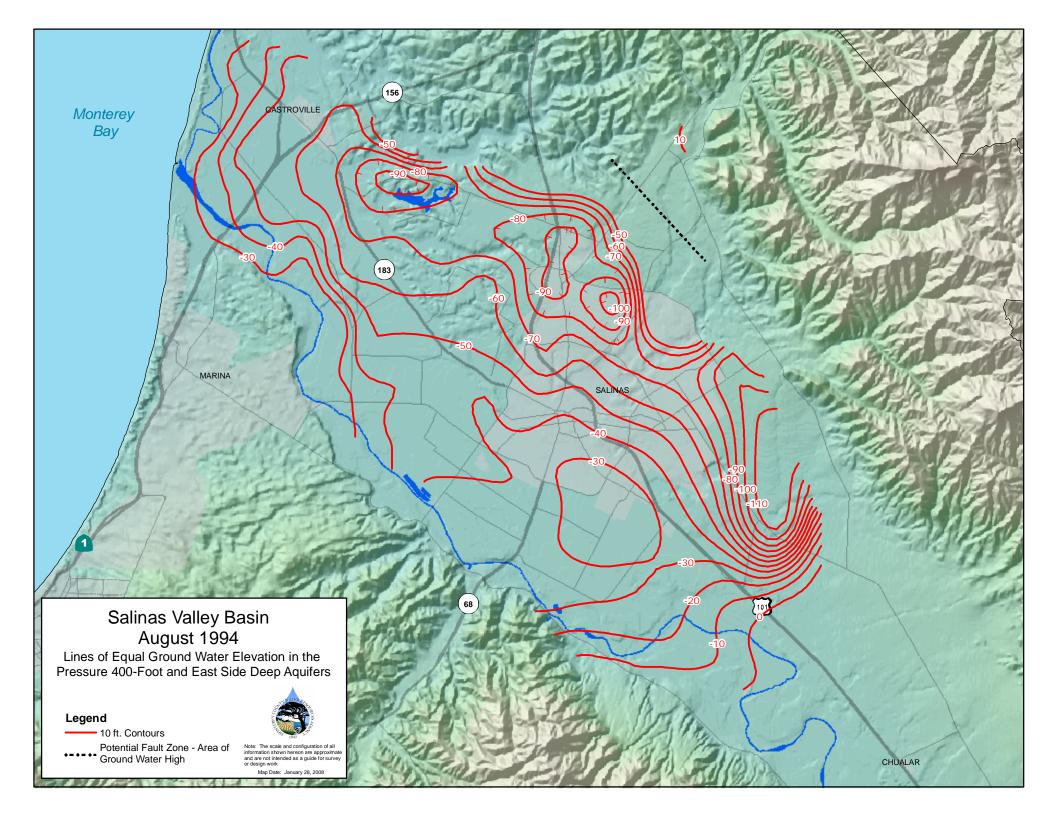
### MGSA Area Current Conceptual Groundwater Budget

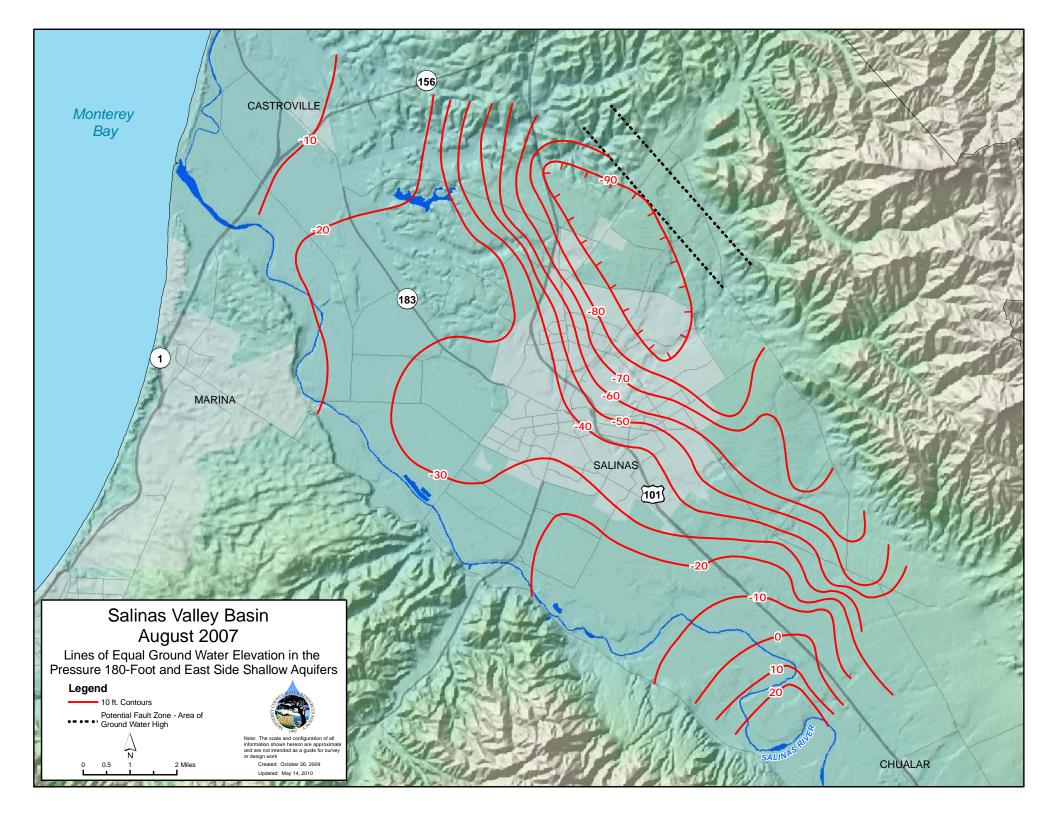
Groundwater Sustainability Plan for the City of Marina GSA Area of the 180/400 Foot Aquifer Subbasin

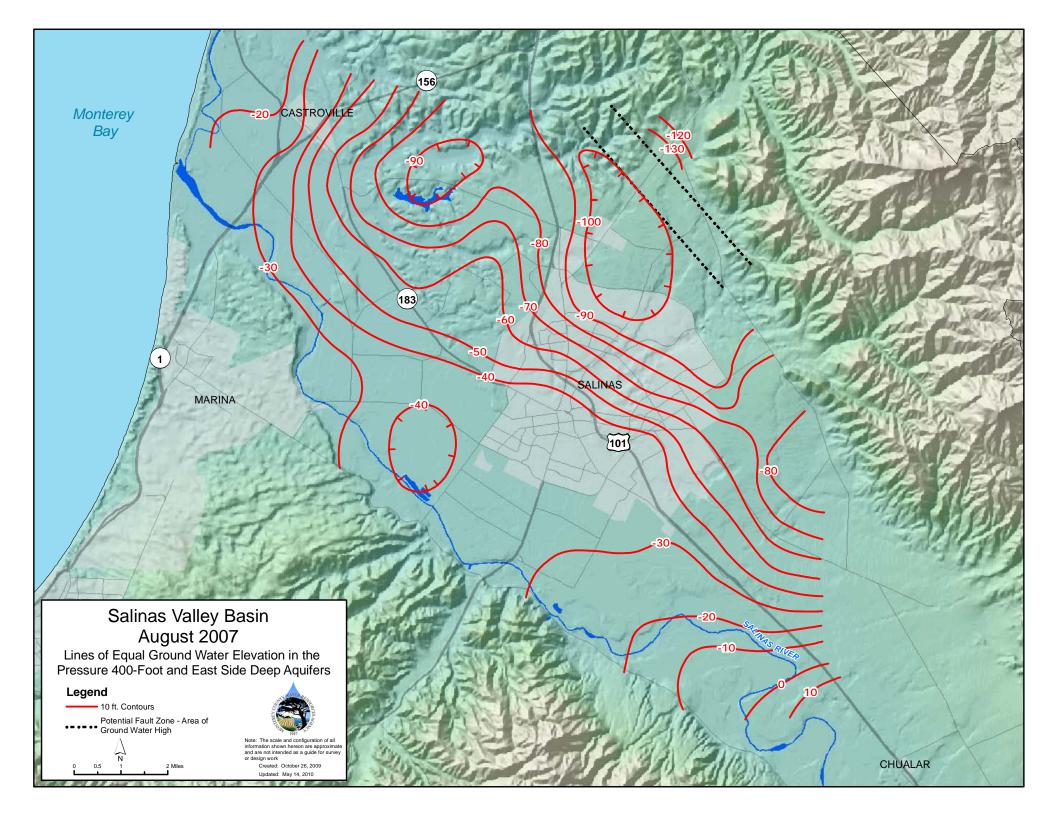


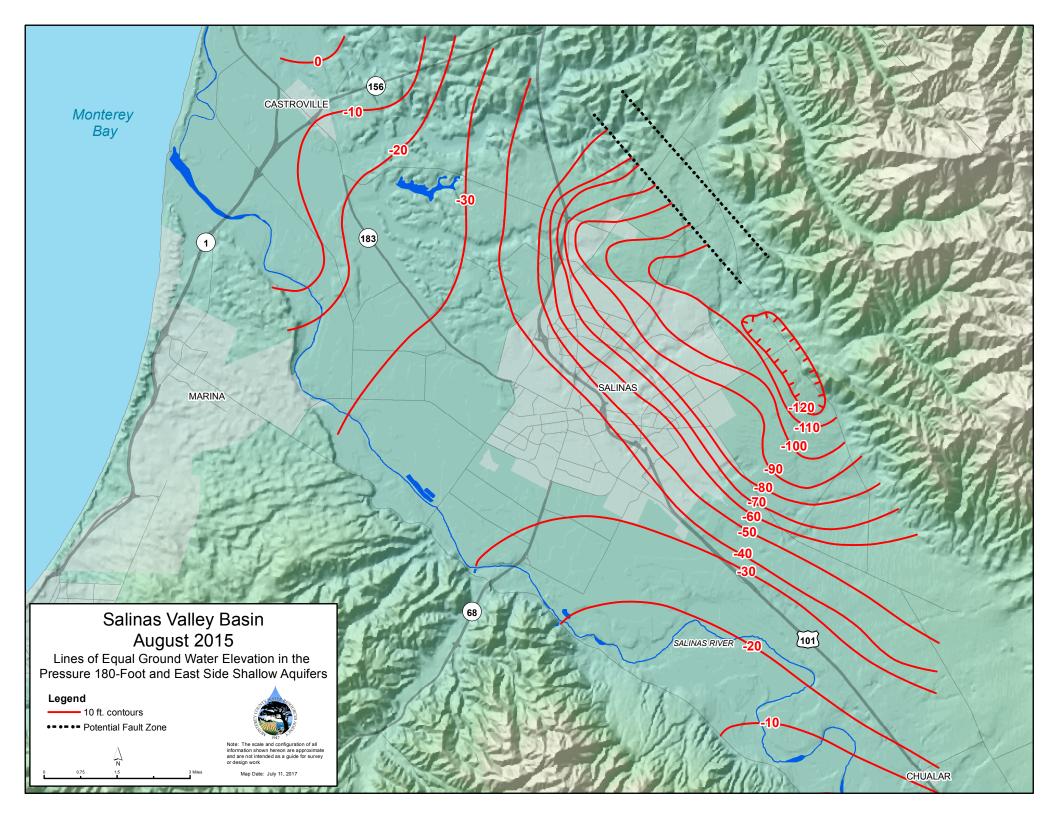
### **APPENDIX 3.A – 1994, 2007, 2015, AND 2017 CONTOUR MAPS**

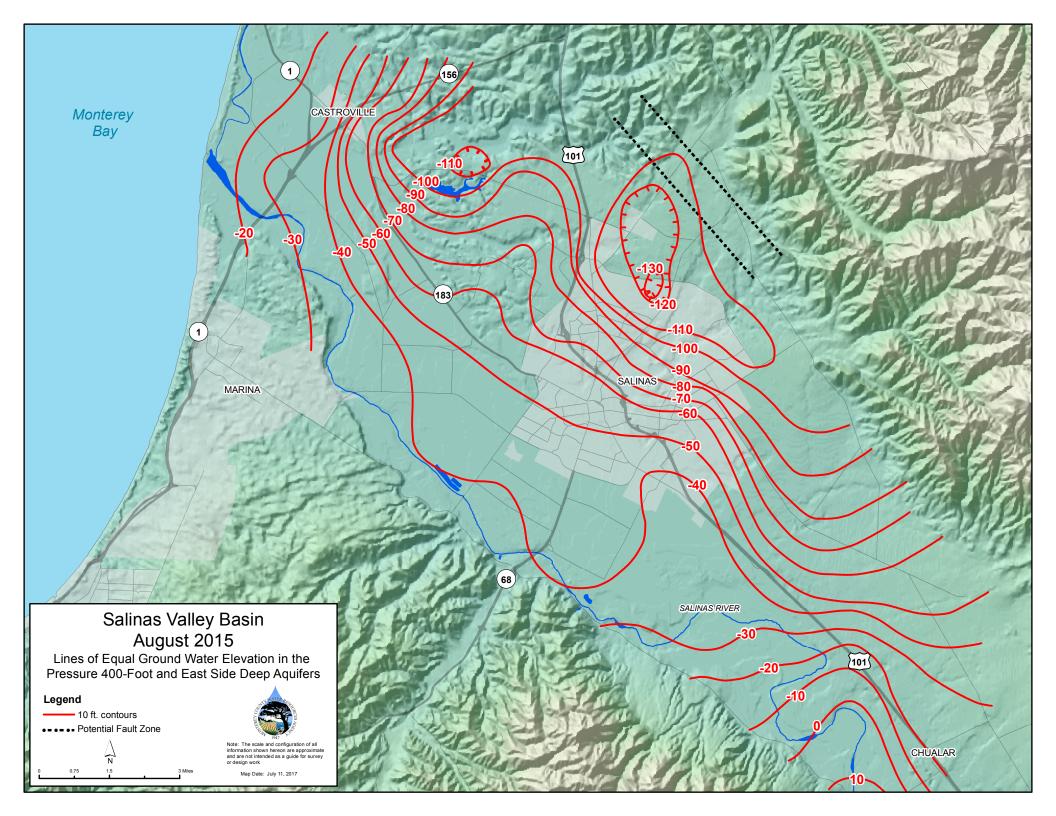


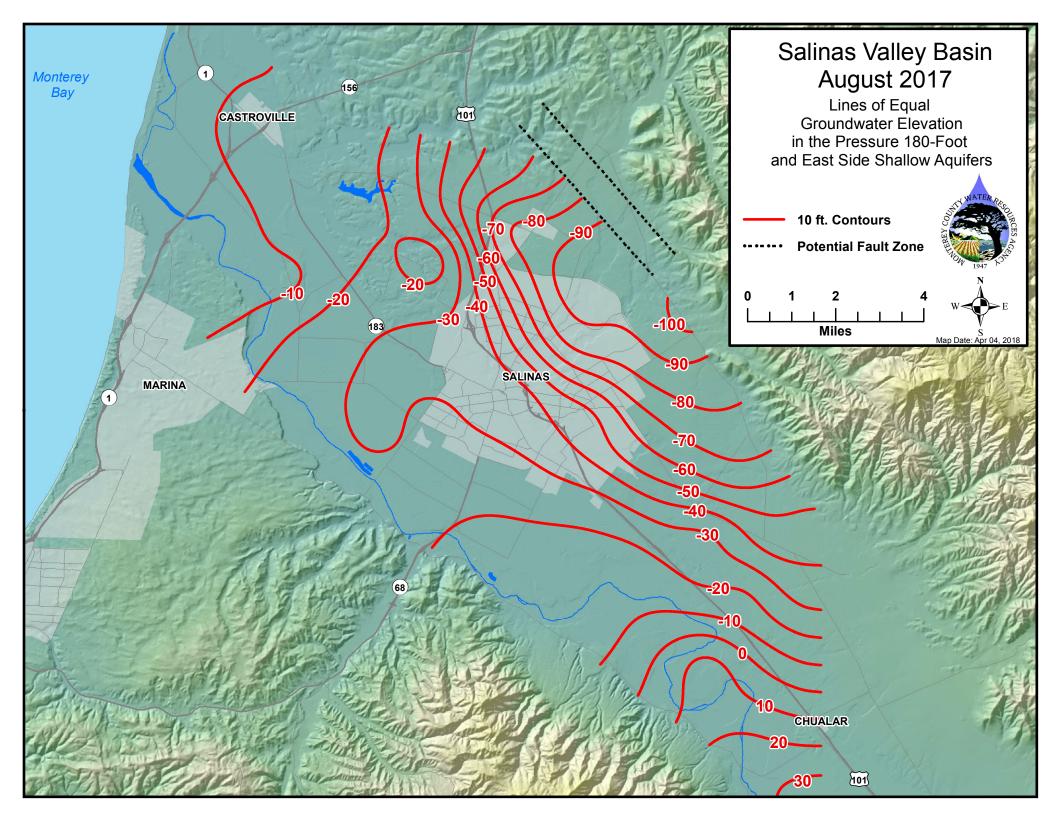


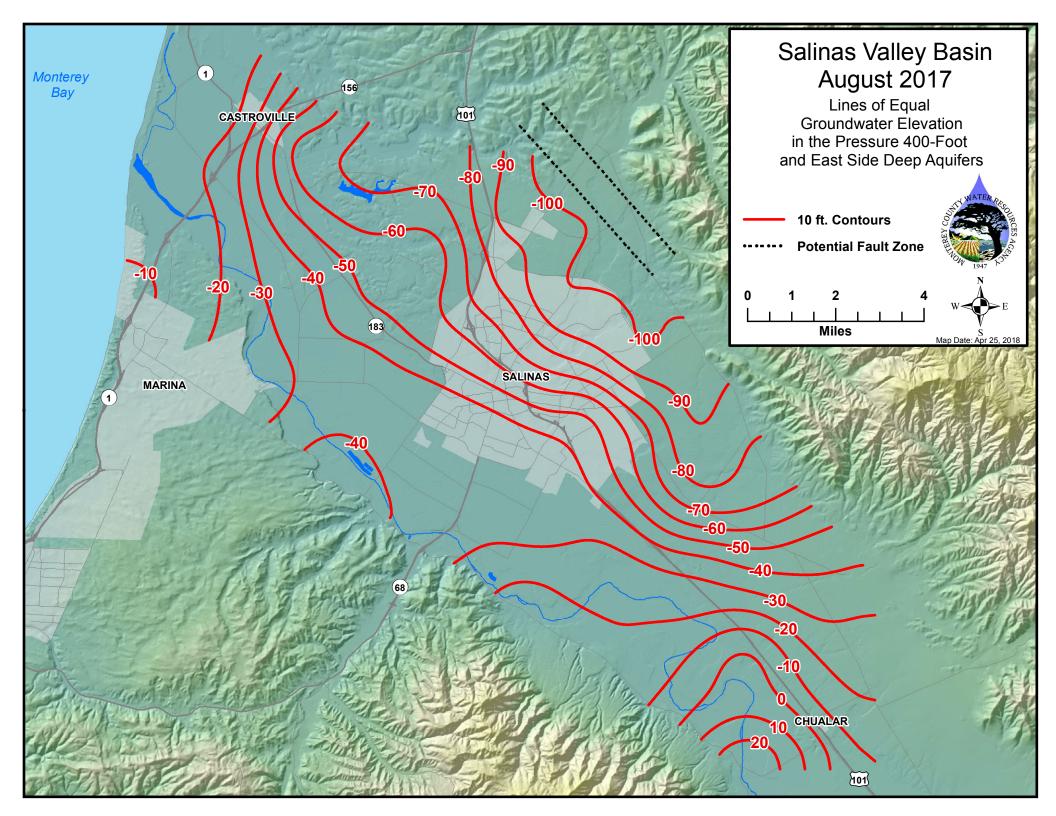






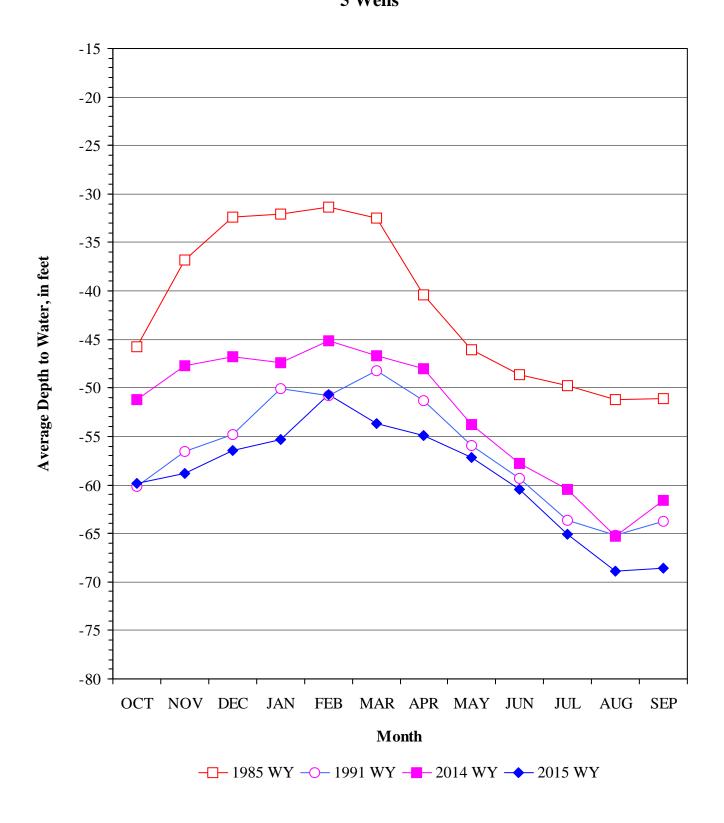




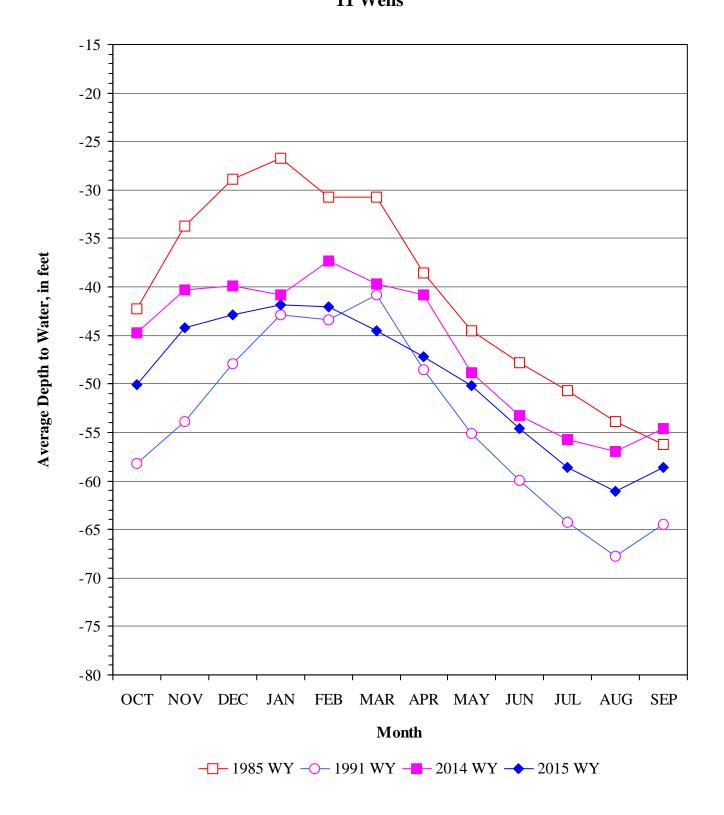


### **APPENDIX 3.B – MCWRA COMPOSITE HYDROGRAPHS**

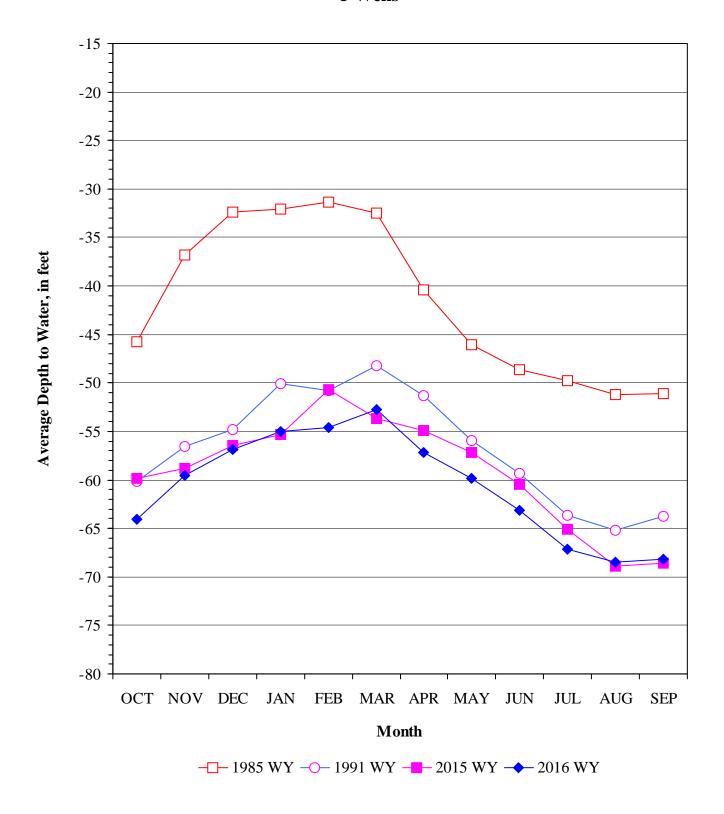
# HISTORIC GROUNDWATER TRENDS PRESSURE 180-FOOT AQUIFER 5 Wells



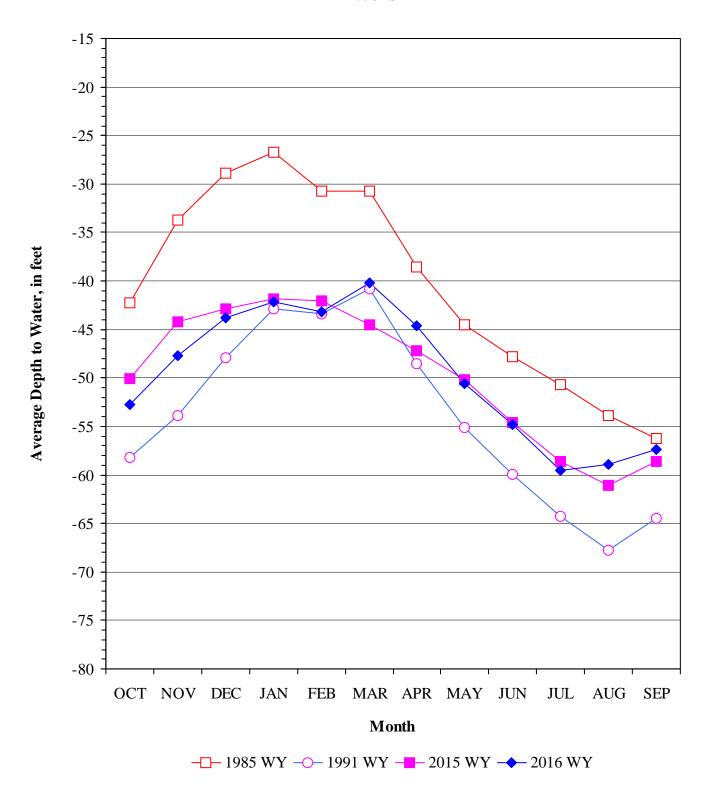
# HISTORIC GROUNDWATER TRENDS PRESSURE 400-FOOT AQUIFER 11 Wells



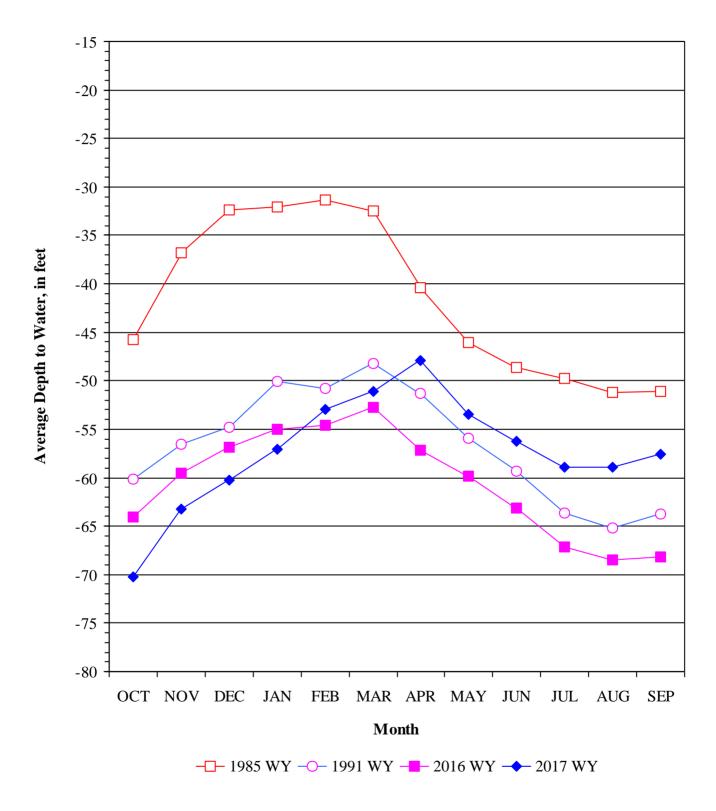
# GROUNDWATER TRENDS PRESSURE 180-FOOT AQUIFER 5 Wells



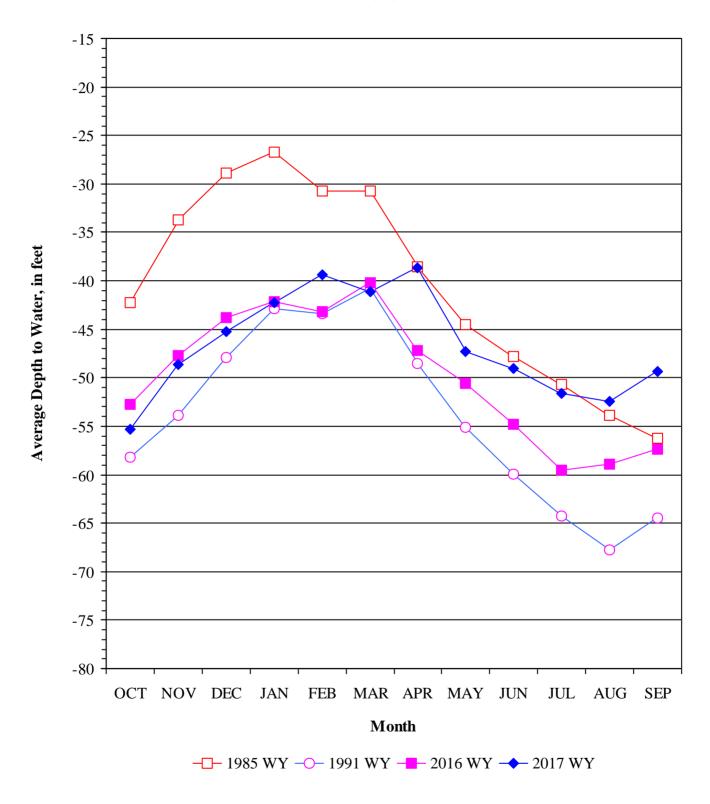
# GROUNDWATER TRENDS PRESSURE 400-FOOT AQUIFER 11 Wells



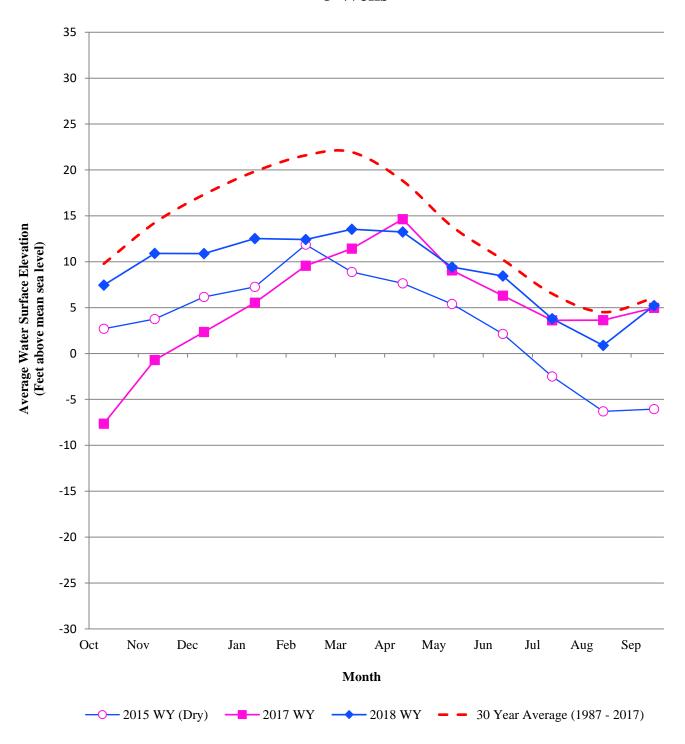
# GROUNDWATER TRENDS PRESSURE 180-FOOT AQUIFER 5 Wells



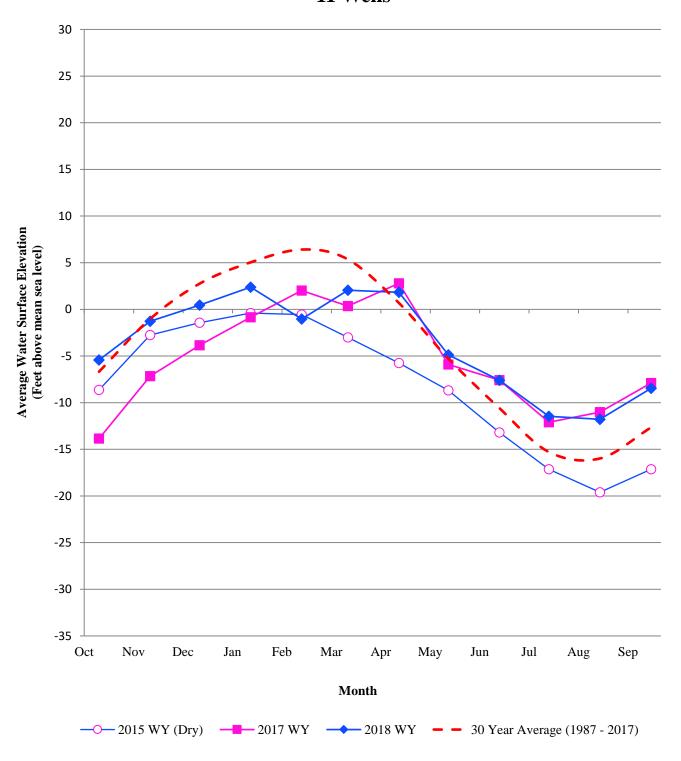
# GROUNDWATER TRENDS PRESSURE 400-FOOT AQUIFER 11 Wells



### GROUNDWATER TRENDS PRESSURE 180-FOOT AQUIFER 5 Wells

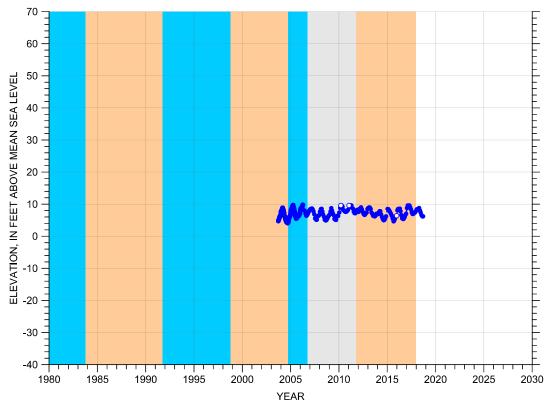


### GROUNDWATER TRENDS PRESSURE 400-FOOT AQUIFER 11 Wells



### **APPENDIX 3.C – SELECTED MCWRA HYDROGRAPHS**

### HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 13S/02E-21Q01



### **EXPLANATION**

--- GROUNDWATER ELEVATION ESTIMATED ELEVATION

### **CLIMATE PERIOD CLASSIFICATION**

AVERAGE/ALTERNATING

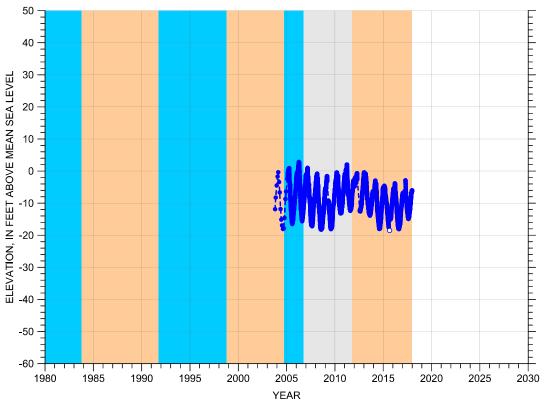
Subbasin: 180/400-Foot Aquifer Subbasin (180-Foot Aquifer) Well Depth: 157.4 feet

Screened Interval: 105-155 feet below land surface

 $S:\projects \ensuremath{\mbox{9}}\projects \ensuremath{\mbox$ 



### HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 14S/02E-03F04



### **EXPLANATION**

--- GROUNDWATER ELEVATION **ESTIMATED ELEVATION** 

### **CLIMATE PERIOD CLASSIFICATION**

AVERAGE/ALTERNATING

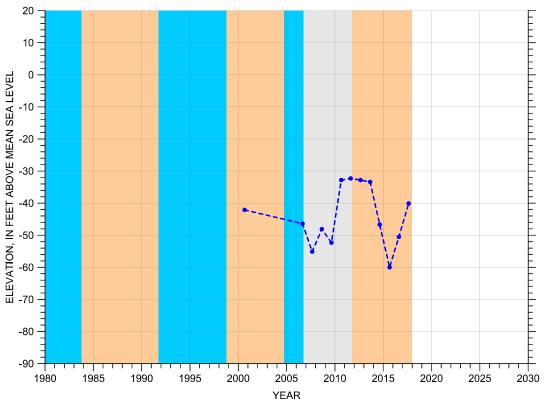
Subbasin: 180/400-Foot Aquifer Subbasin (180-Foot Aquifer) Well Depth: 205 feet

Screened Interval: 154-204 feet below land surface

 $S:\projects \ensuremath{\mbox{9}} 100\_Salinas\_GSP\analysis \ensuremath{\mbox{water\_levels}} Hydrographs\_MCWRA\pasoDroughtIndex\grf14S\_02E-03F04.grf$ 



### HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 14S/02E-04G02



### **EXPLANATION**

--- GROUNDWATER ELEVATION **ESTIMATED ELEVATION** 

**CLIMATE PERIOD CLASSIFICATION** 

AVERAGE/ALTERNATING

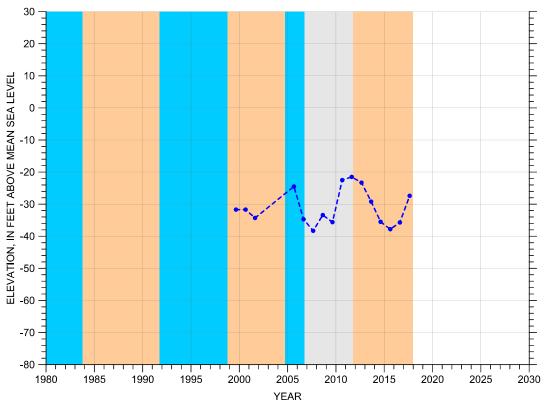
Subbasin: 180/400-Foot Aquifer Subbasin (400-Foot Aquifer) Well Depth: 620 feet

Screened Interval: 370-610 feet below land surface

 $S:\projects \ensuremath{\mbox{9}}\projects \ensuremath{\mbox$ 



### HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 14S/02E-09D04



### **EXPLANATION**

--- GROUNDWATER ELEVATION **ESTIMATED ELEVATION** 

**CLIMATE PERIOD CLASSIFICATION** 

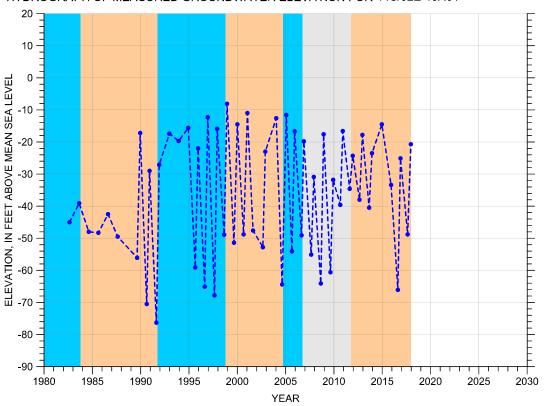
AVERAGE/ALTERNATING

Subbasin: 180/400-Foot Aquifer Subbasin (400-Foot Aquifer) Well Depth: 610 feet

Screened Interval: 350-600 feet below land surface



#### HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 14S/02E-15A01



#### **EXPLANATION**

--- GROUNDWATER ELEVATION **ESTIMATED ELEVATION** 

## **CLIMATE PERIOD CLASSIFICATION**

AVERAGE/ALTERNATING WET

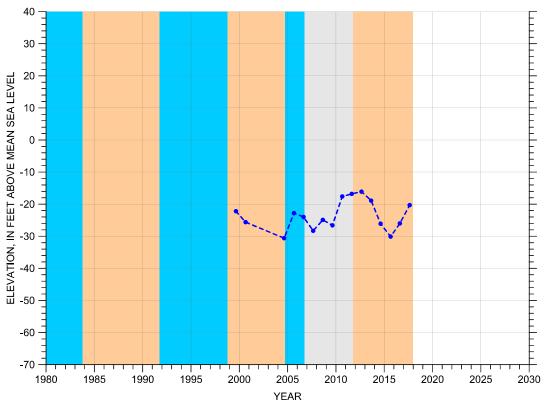
Subbasin: 180/400-Foot Aquifer (400-Foot Aquifer) Well Depth: 623 feet

Screened Interval: 386-608 feet below land surface

 $S:\projects \ensuremath{\mbox{9}}\projects \ensuremath{\mbox$ 



#### HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 14S/02E-17B03



#### **EXPLANATION**

--- GROUNDWATER ELEVATION **ESTIMATED ELEVATION** 

## **CLIMATE PERIOD CLASSIFICATION**

AVERAGE/ALTERNATING

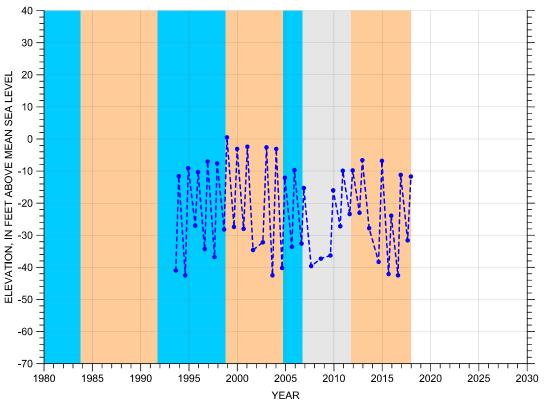
Subbasin: 180/400-Foot Aquifer Subbasin (400-Foot Aquifer) Well Depth: 615 feet

Screened Interval: 330-600 feet below land surface

 $S:\projects \ensuremath{\mbox{9}}\projects \ensuremath{\mbox$ 



#### HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 14S/02E-22L01



#### **EXPLANATION**

--- GROUNDWATER ELEVATION **ESTIMATED ELEVATION** 

**CLIMATE PERIOD CLASSIFICATION** 

AVERAGE/ALTERNATING WET

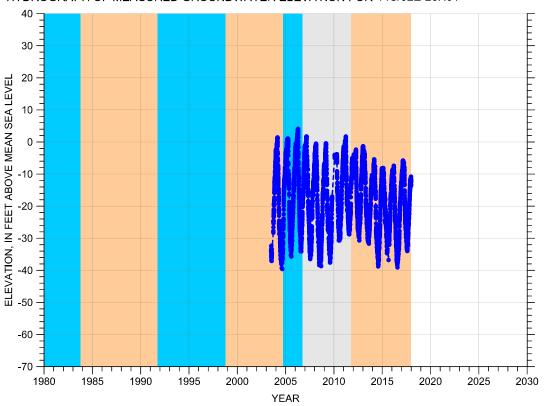
Subbasin: 180/400-Foot Aquifer Subbasin (400-Foot Aquifer) Well Depth: 680 feet

Screened Interval: 420-680 feet below land surface

 $S:\projects\parb=MCWRA\pasoDrought\parb=McW$ 



#### HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 14S/02E-26H01



#### **EXPLANATION**

--- GROUNDWATER ELEVATION **ESTIMATED ELEVATION** 

## **CLIMATE PERIOD CLASSIFICATION**

AVERAGE/ALTERNATING

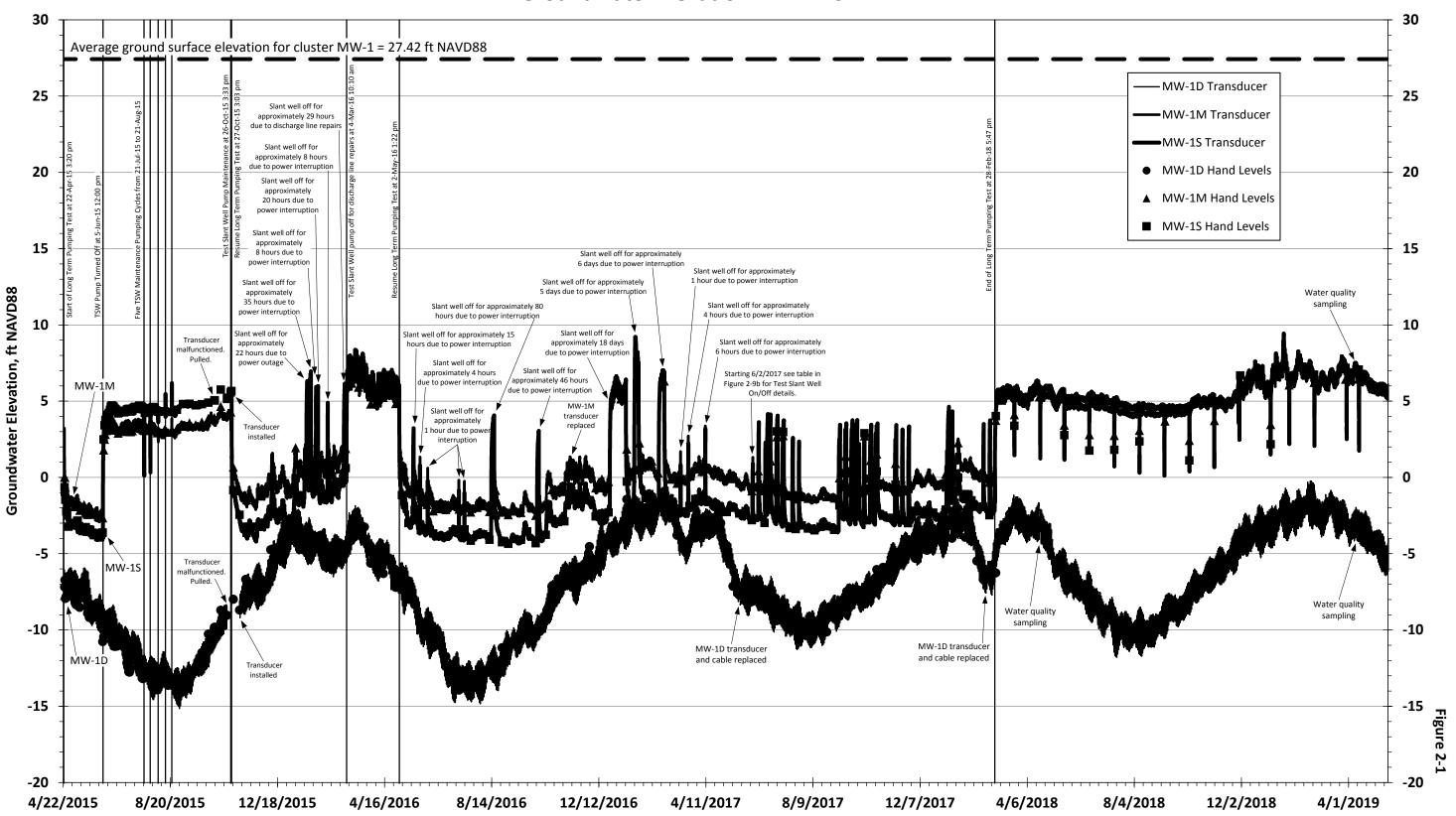
Subbasin: 180/400-Foot Aquifer Subbasin (180-Foot Aquifer) Well Depth: 339.3 feet

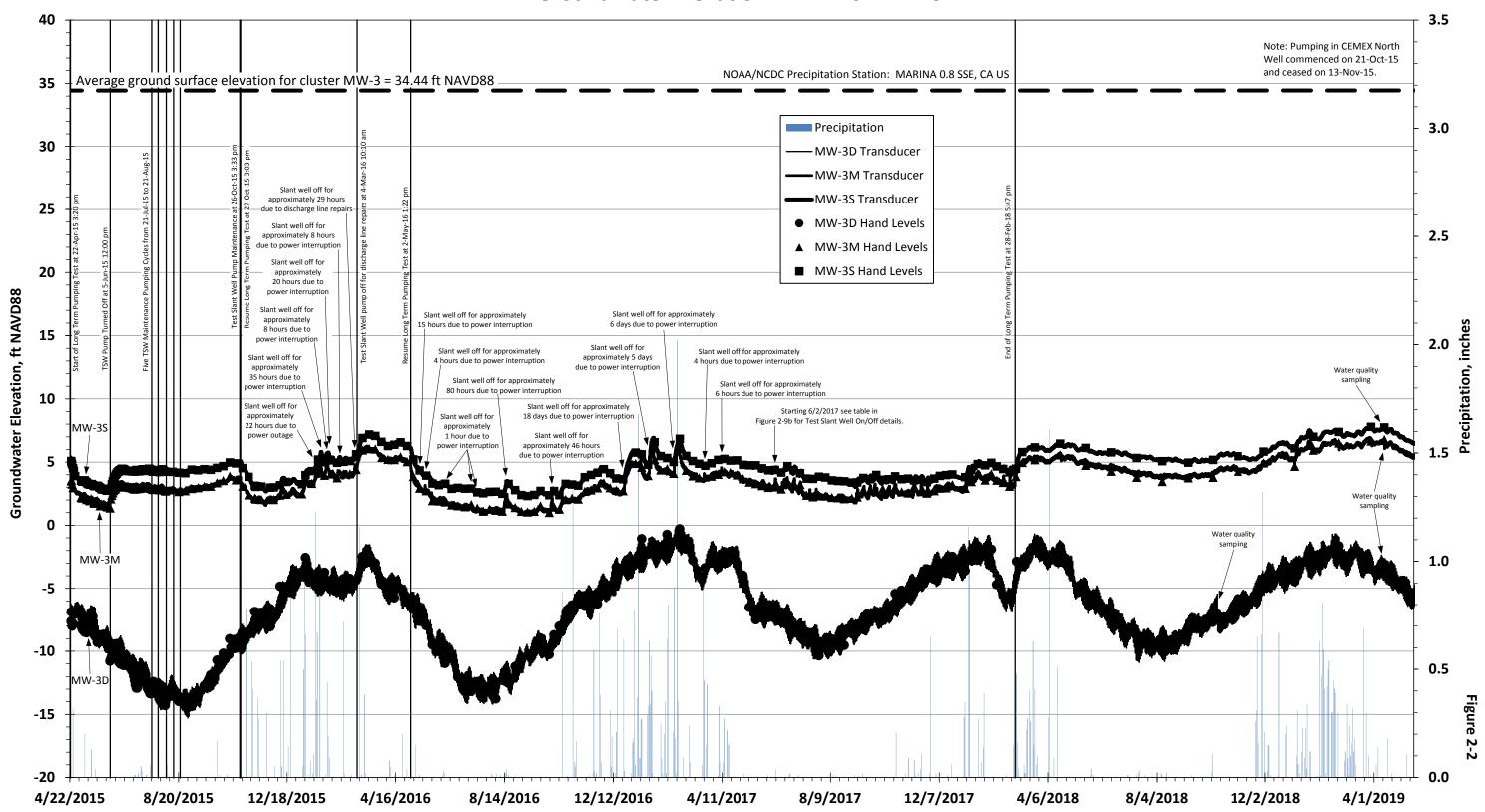
Screened Interval: 287-337 feet below land surface

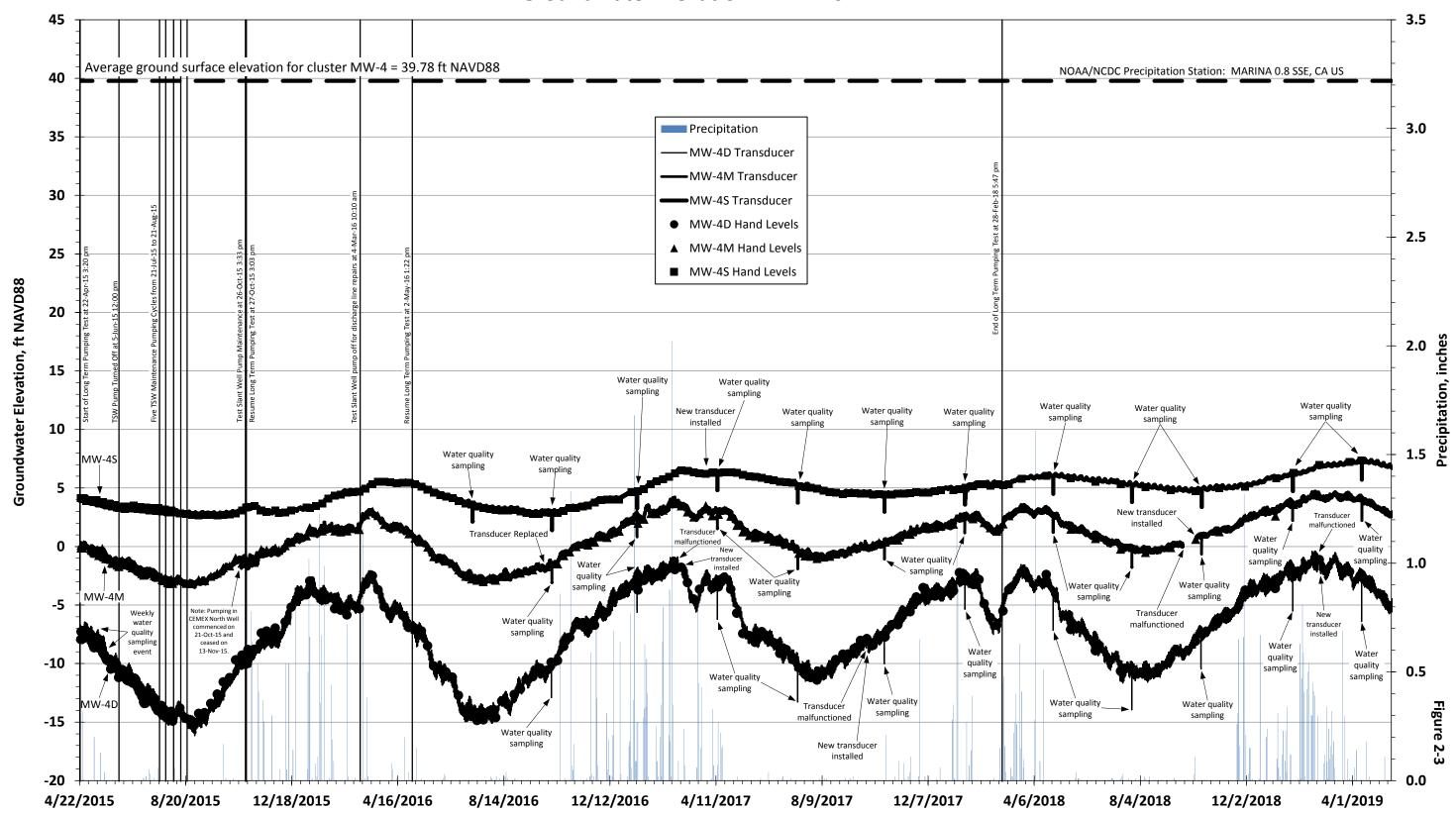
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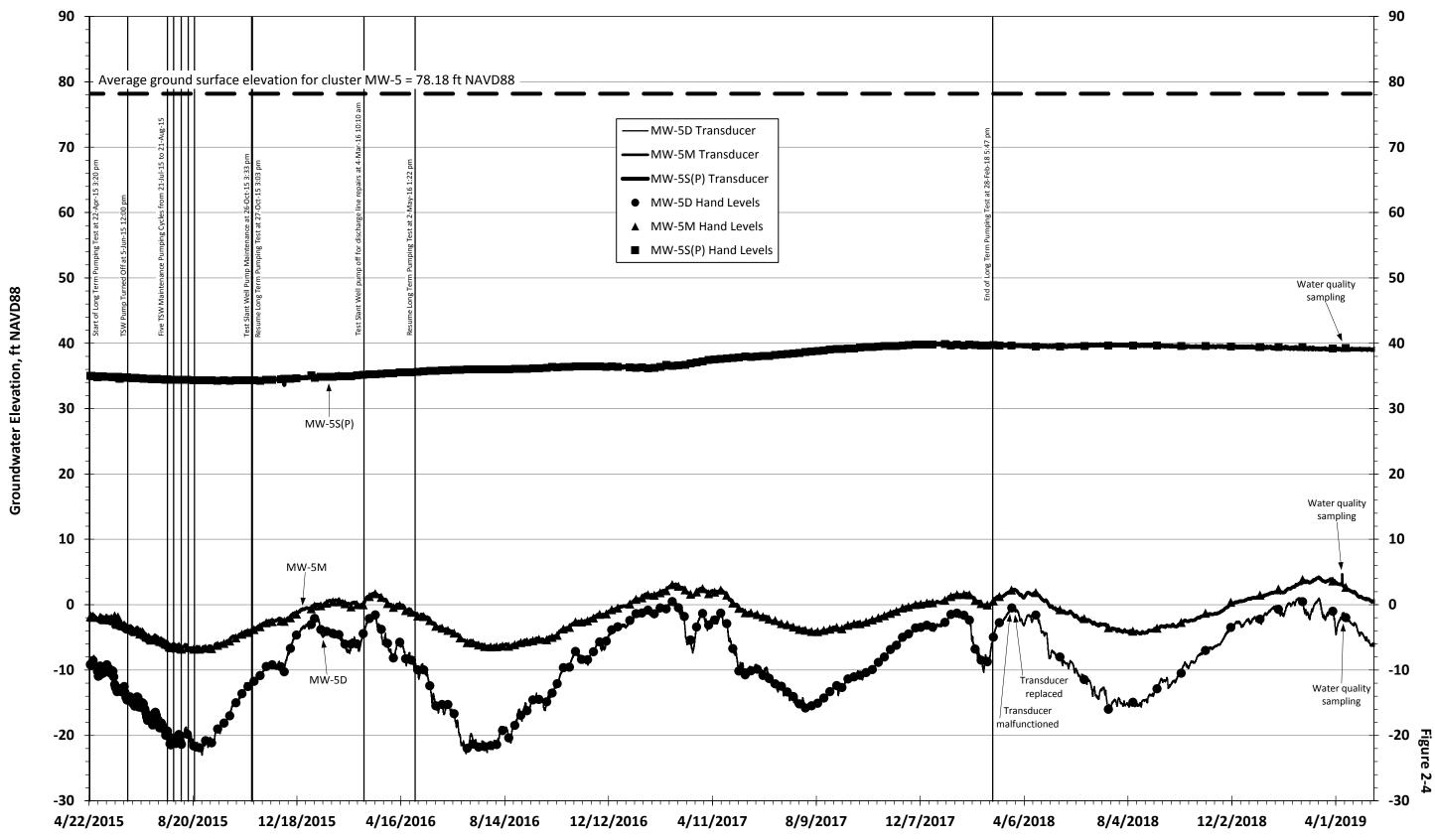


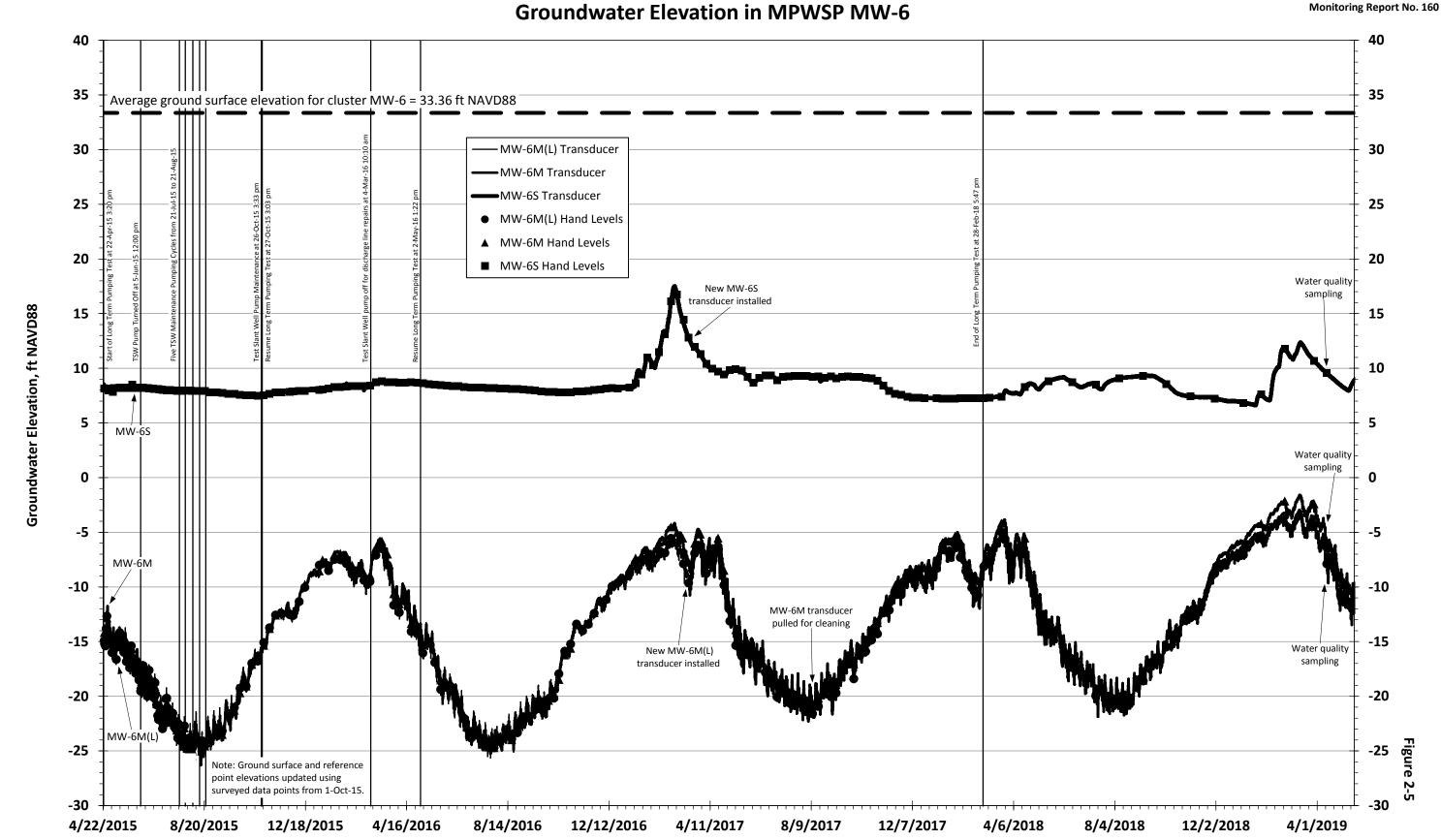
# APPENDIX 3.D – GW ELEVATION HYDROGRAPHS AND SPECIFIC CONDUCTANCE PLOTS FOR MPWSP WELLS

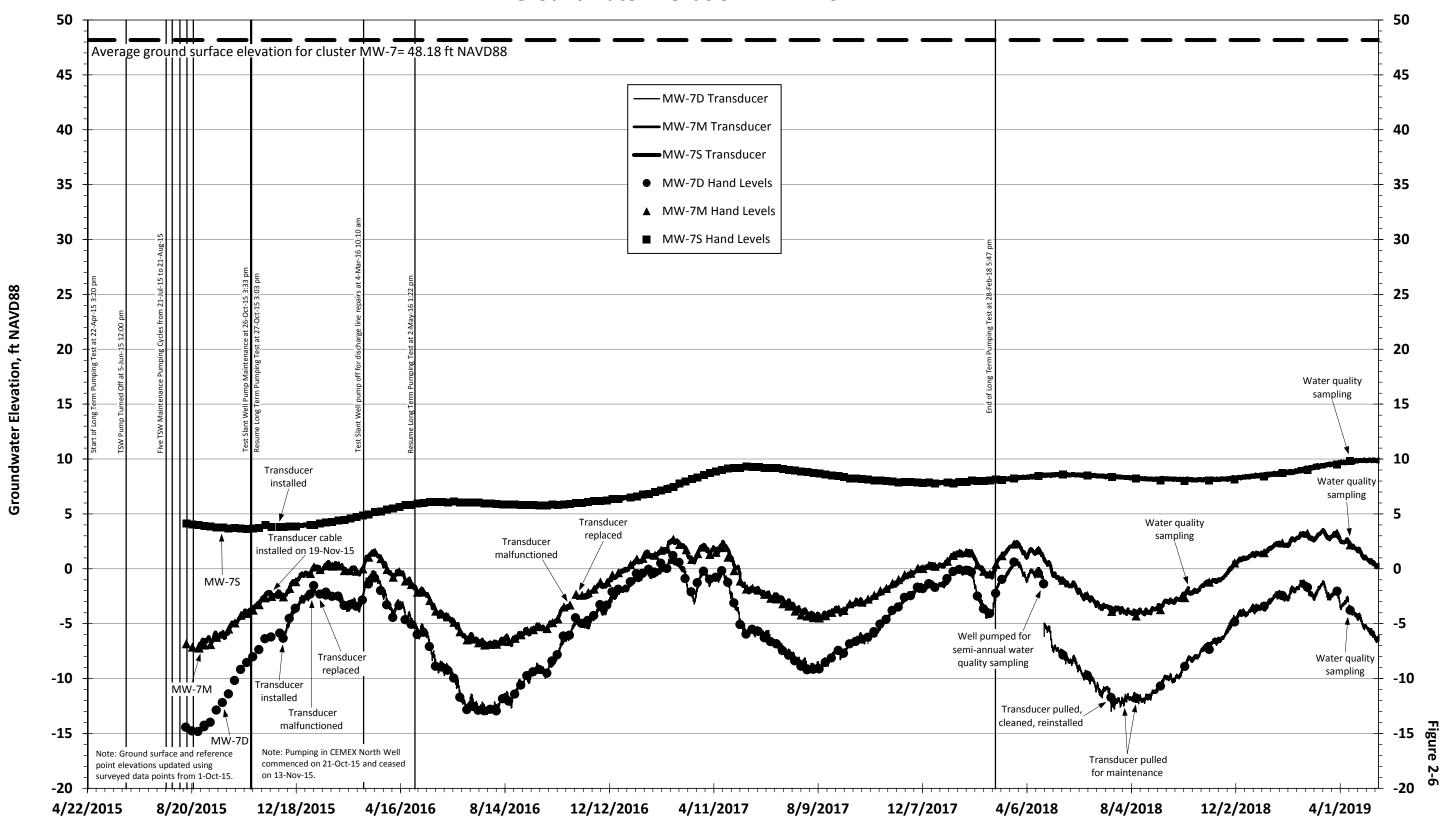


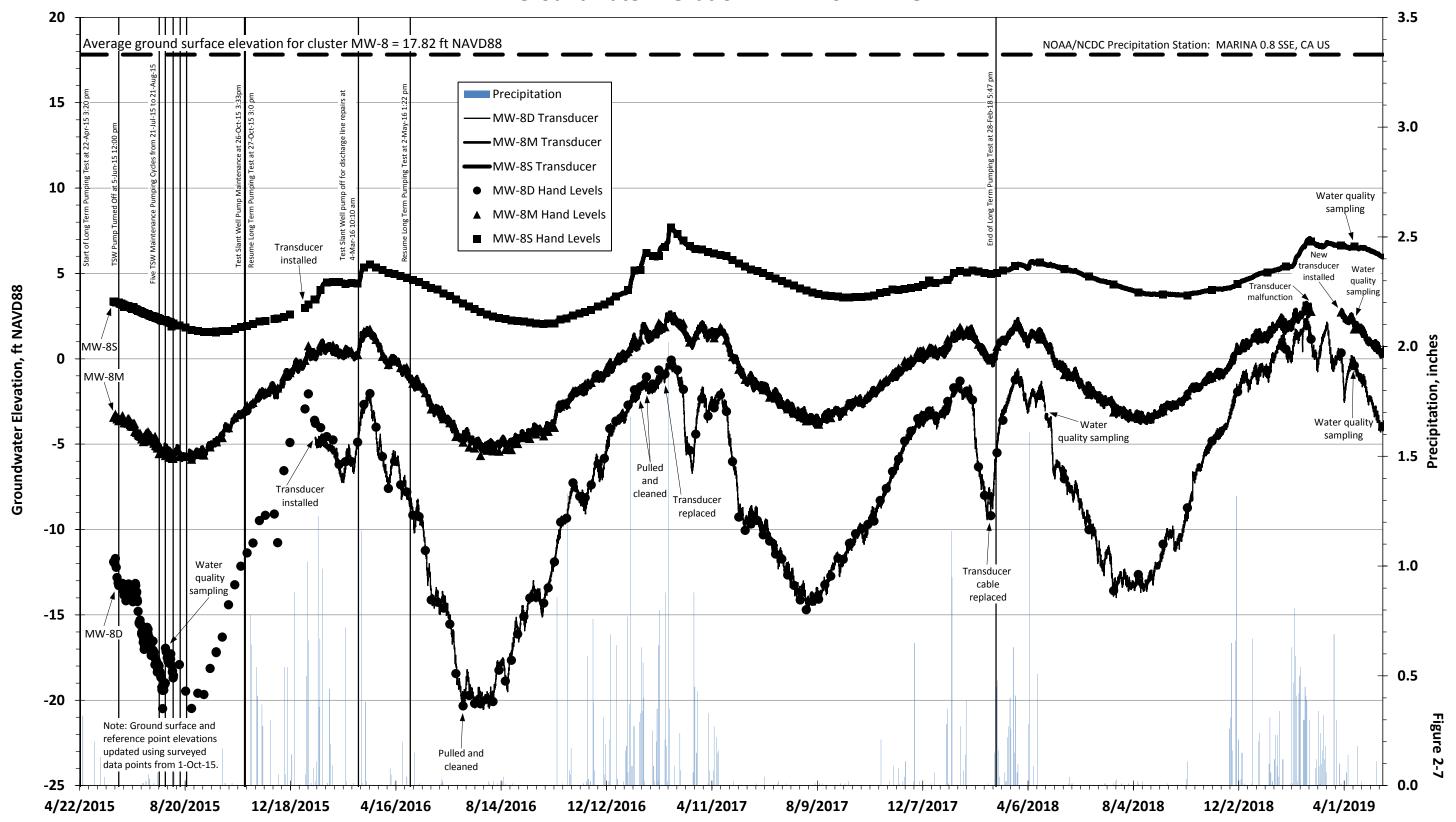


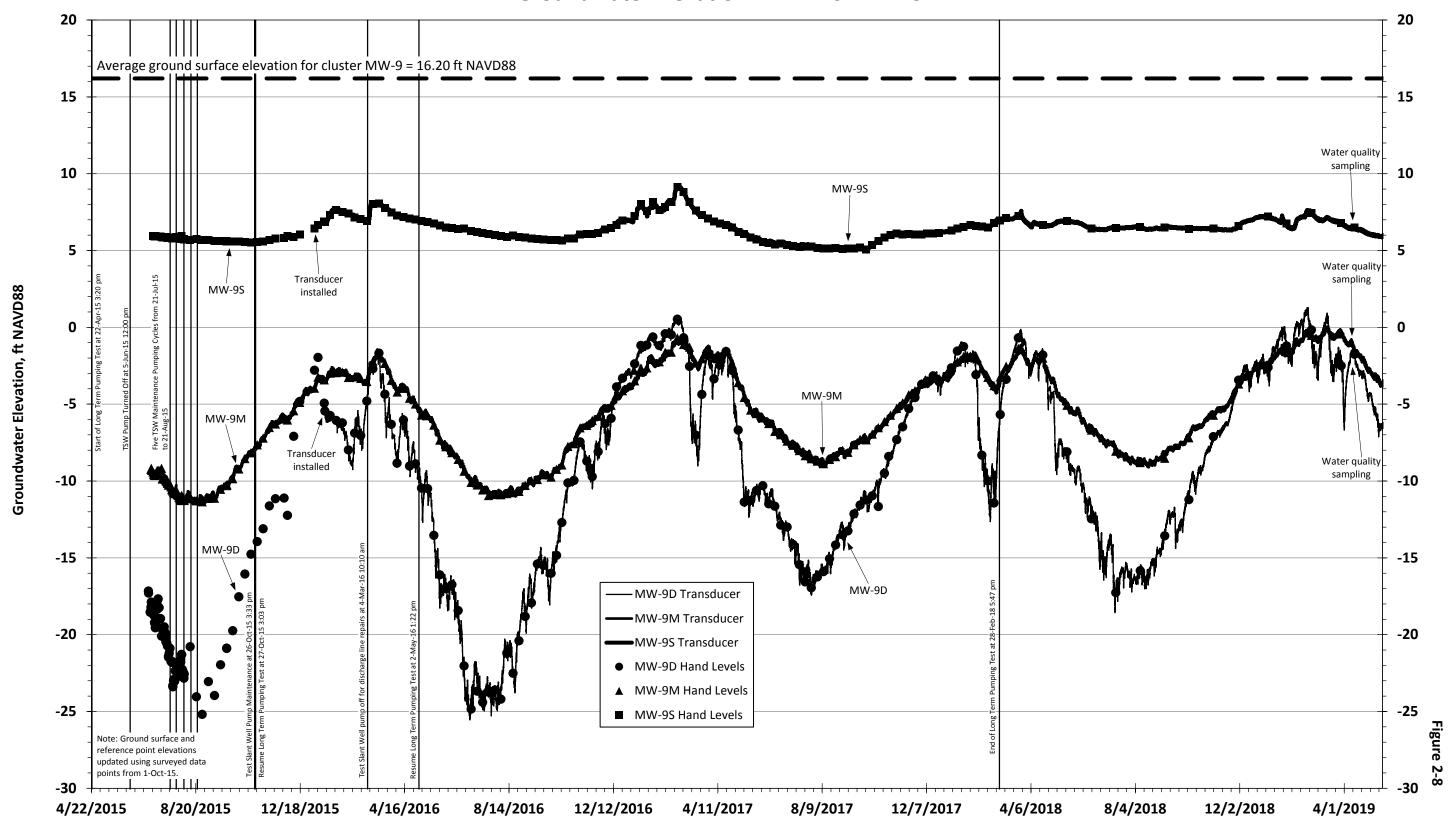




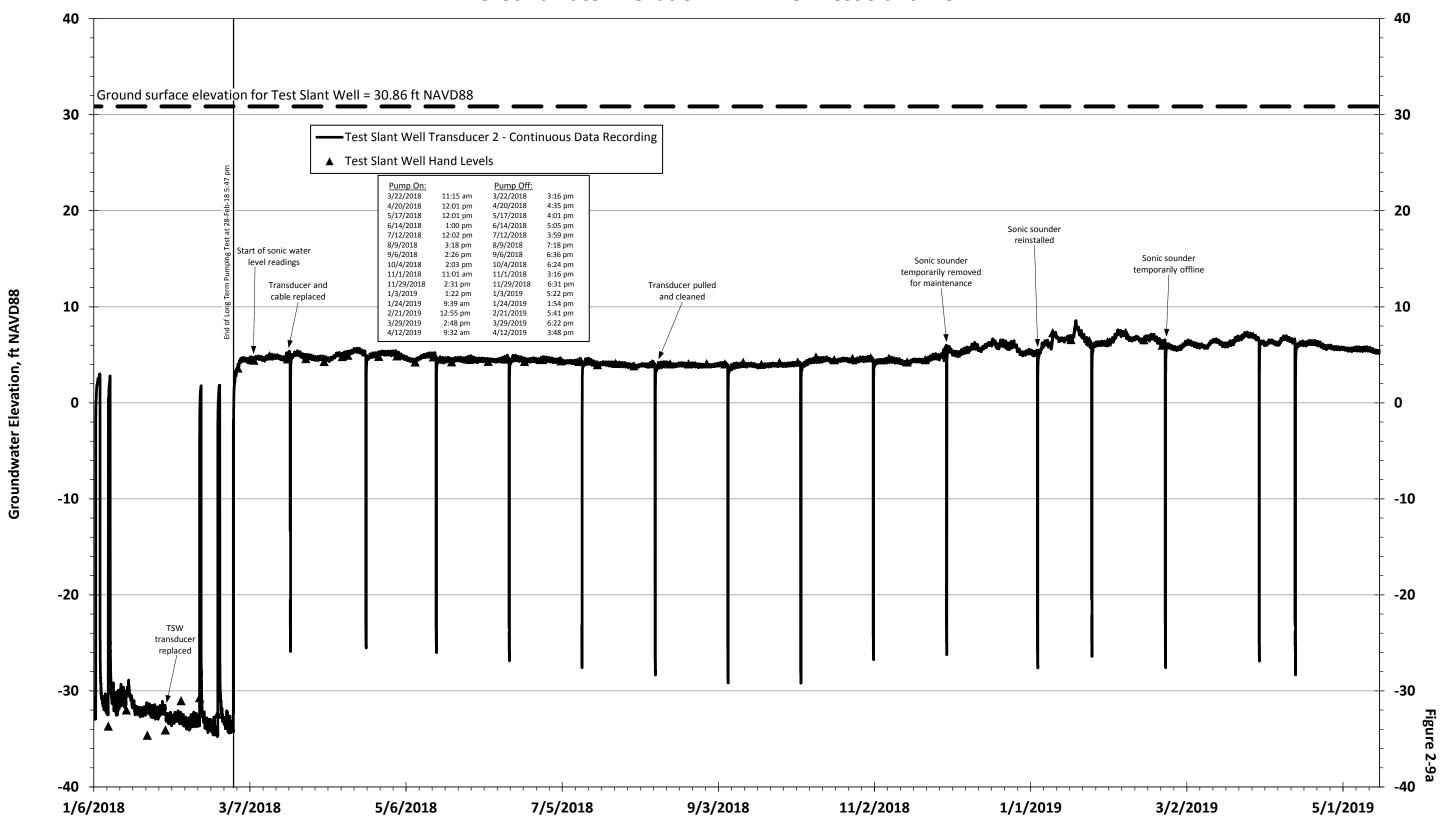




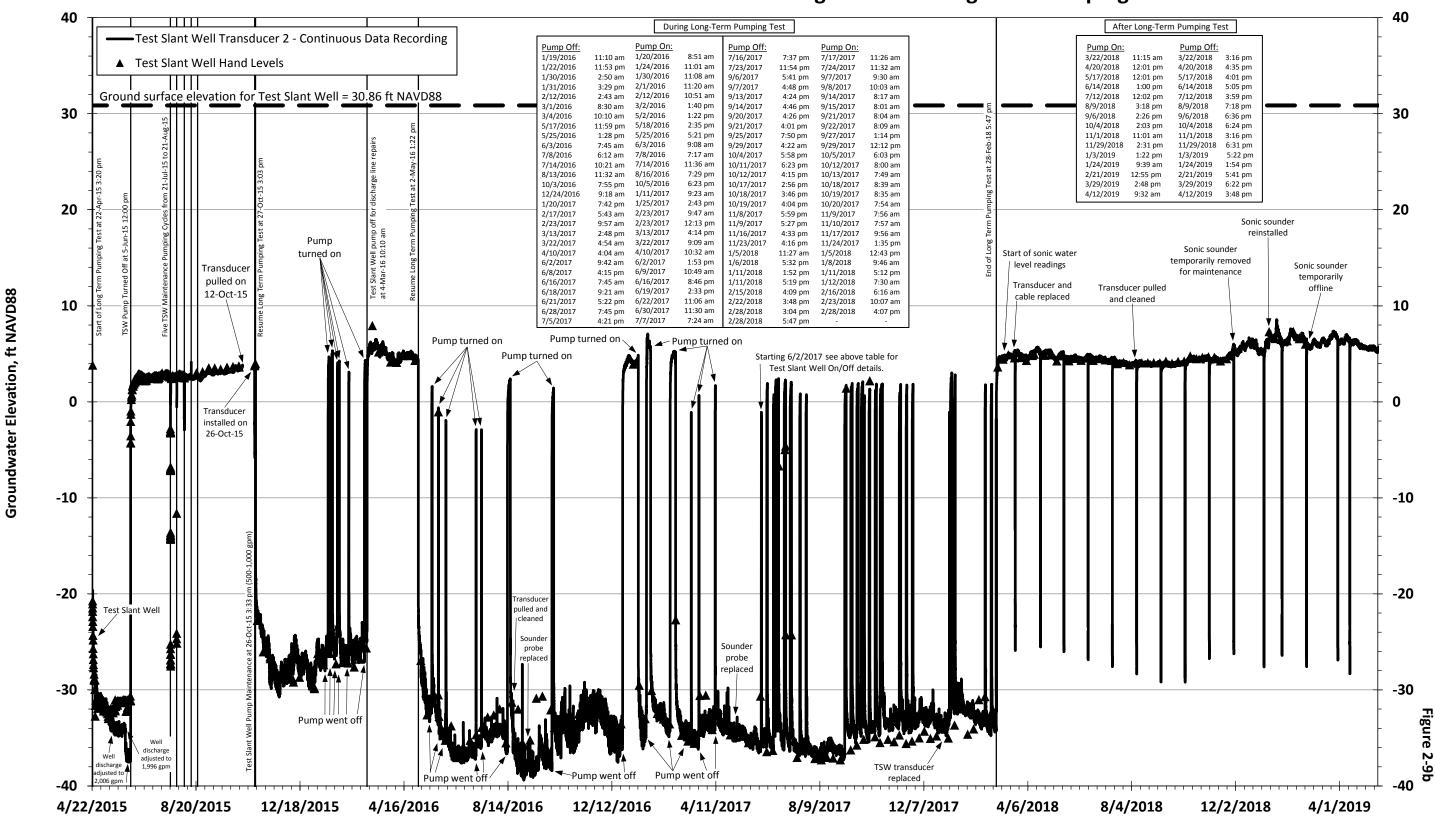


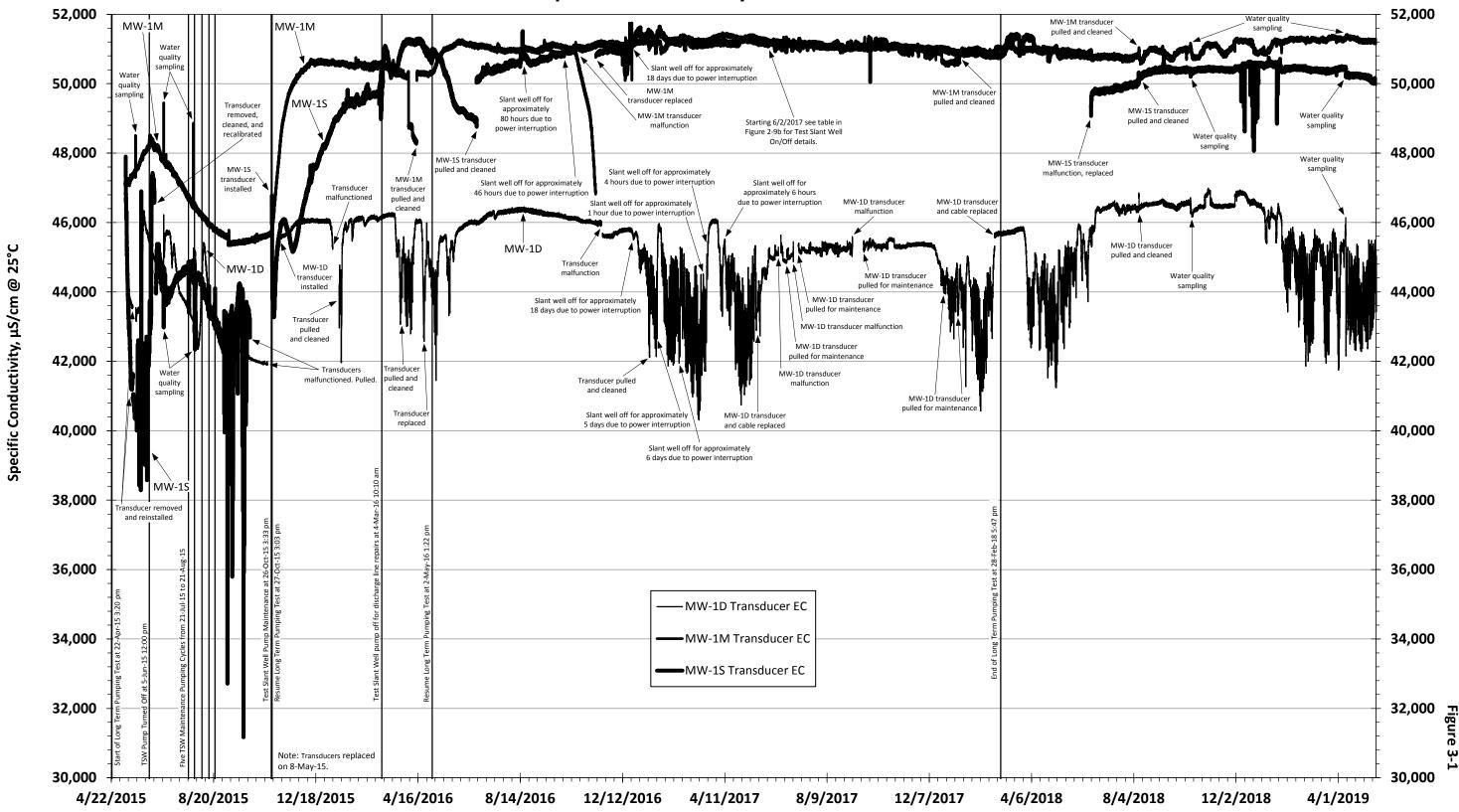


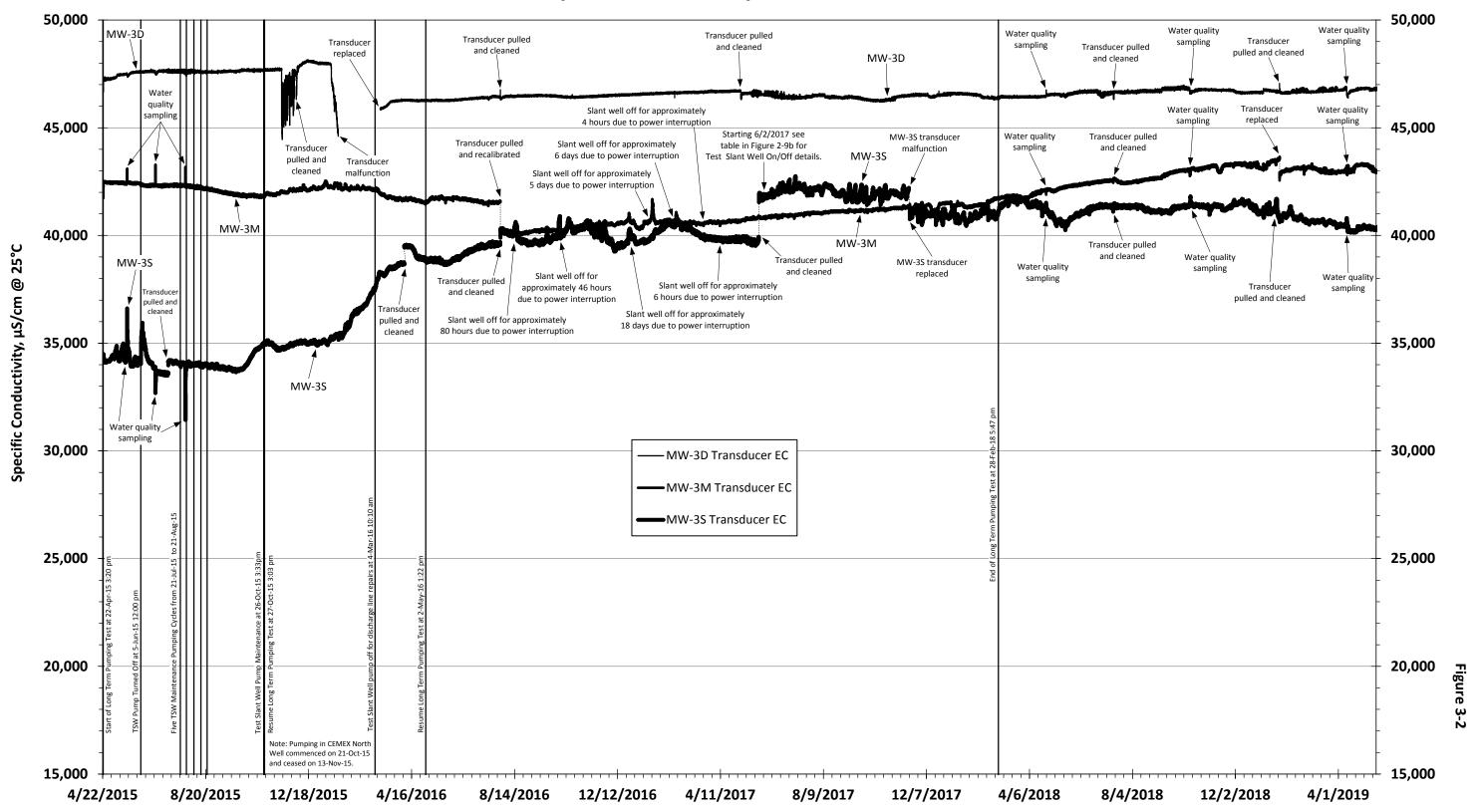
## **Groundwater Elevation in MPWSP Test Slant Well**

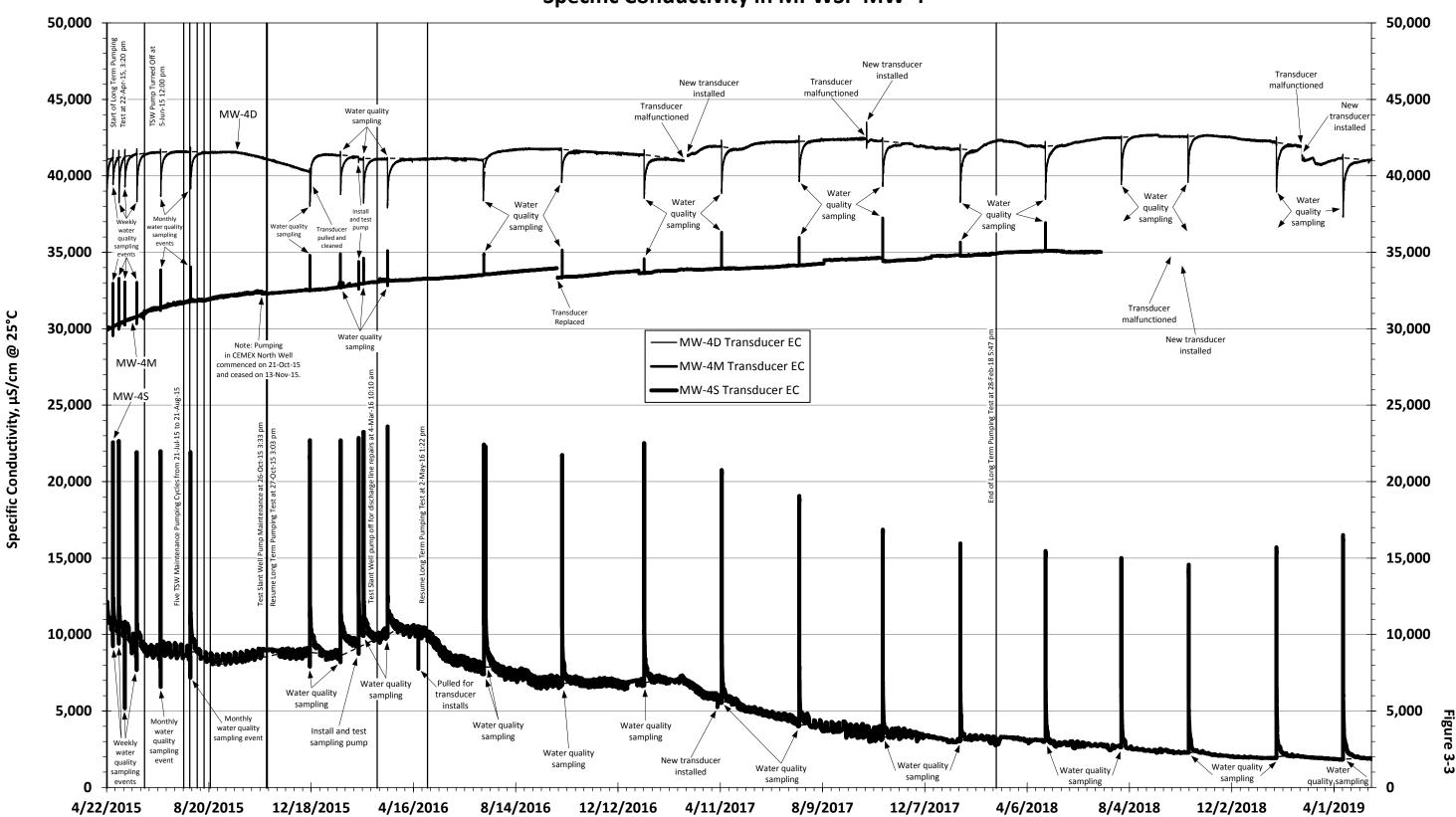


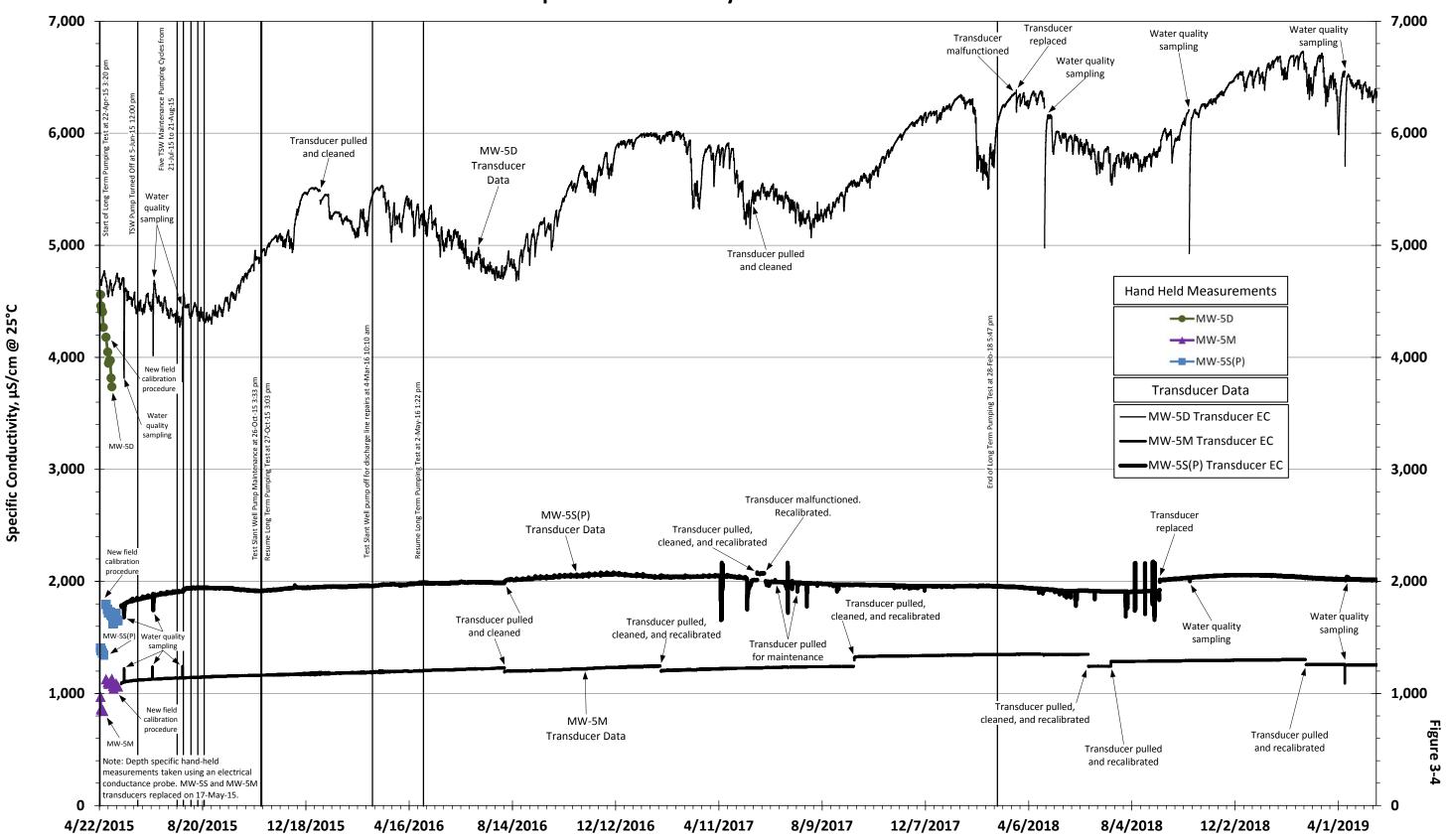
## **Groundwater Elevation in MPWSP Test Slant Well During and After Long-Term Pumping Test**

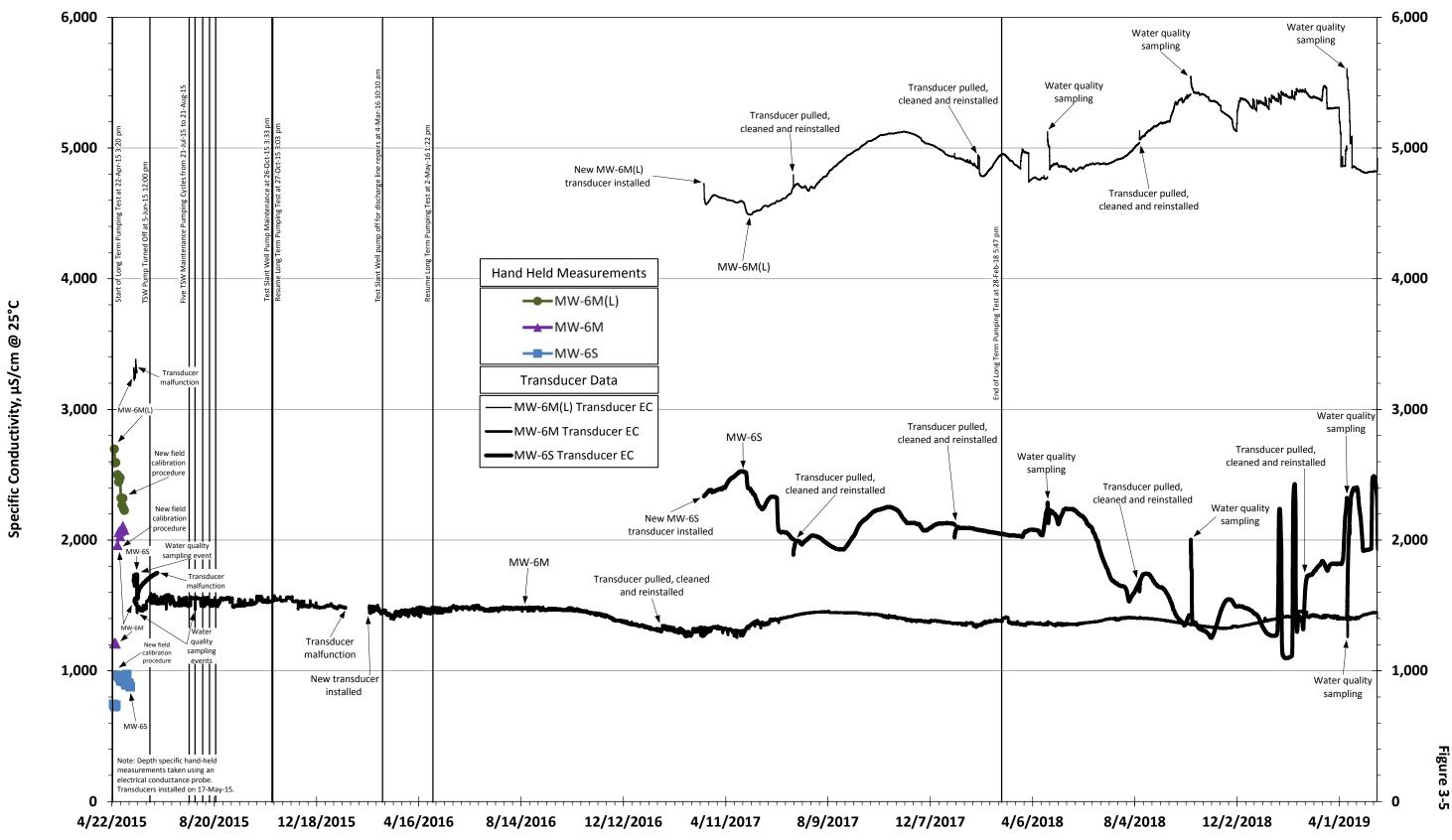


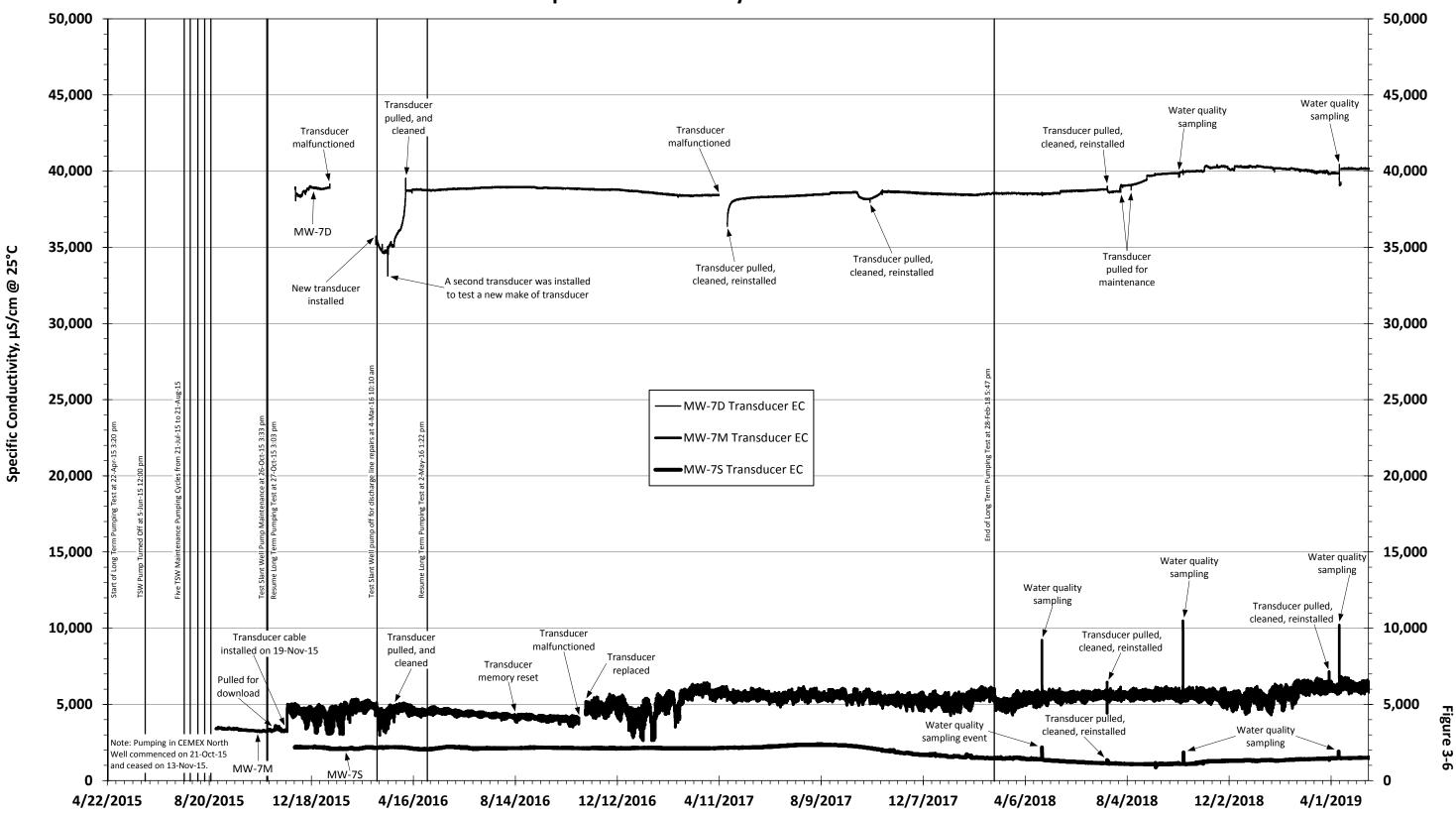


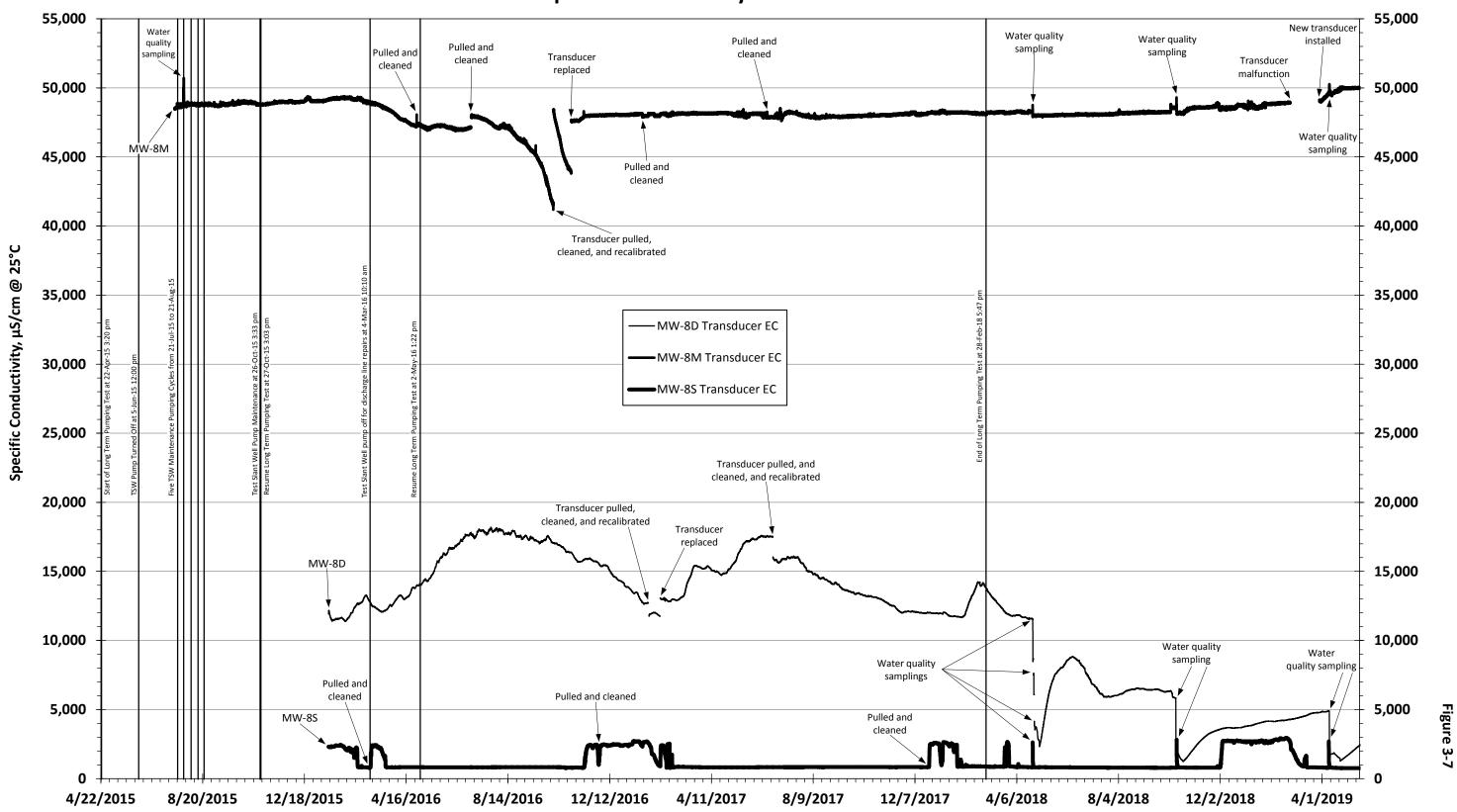


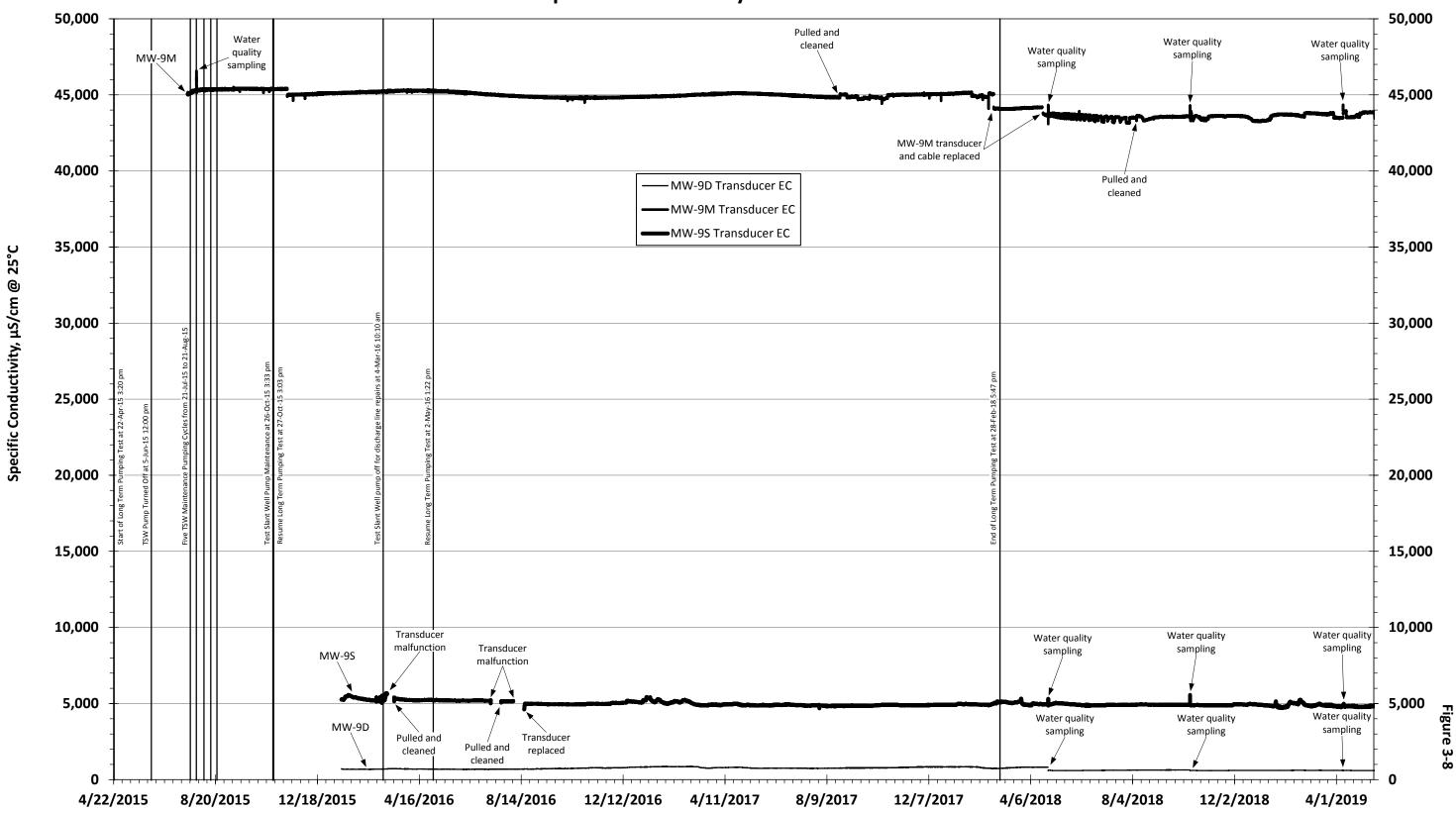




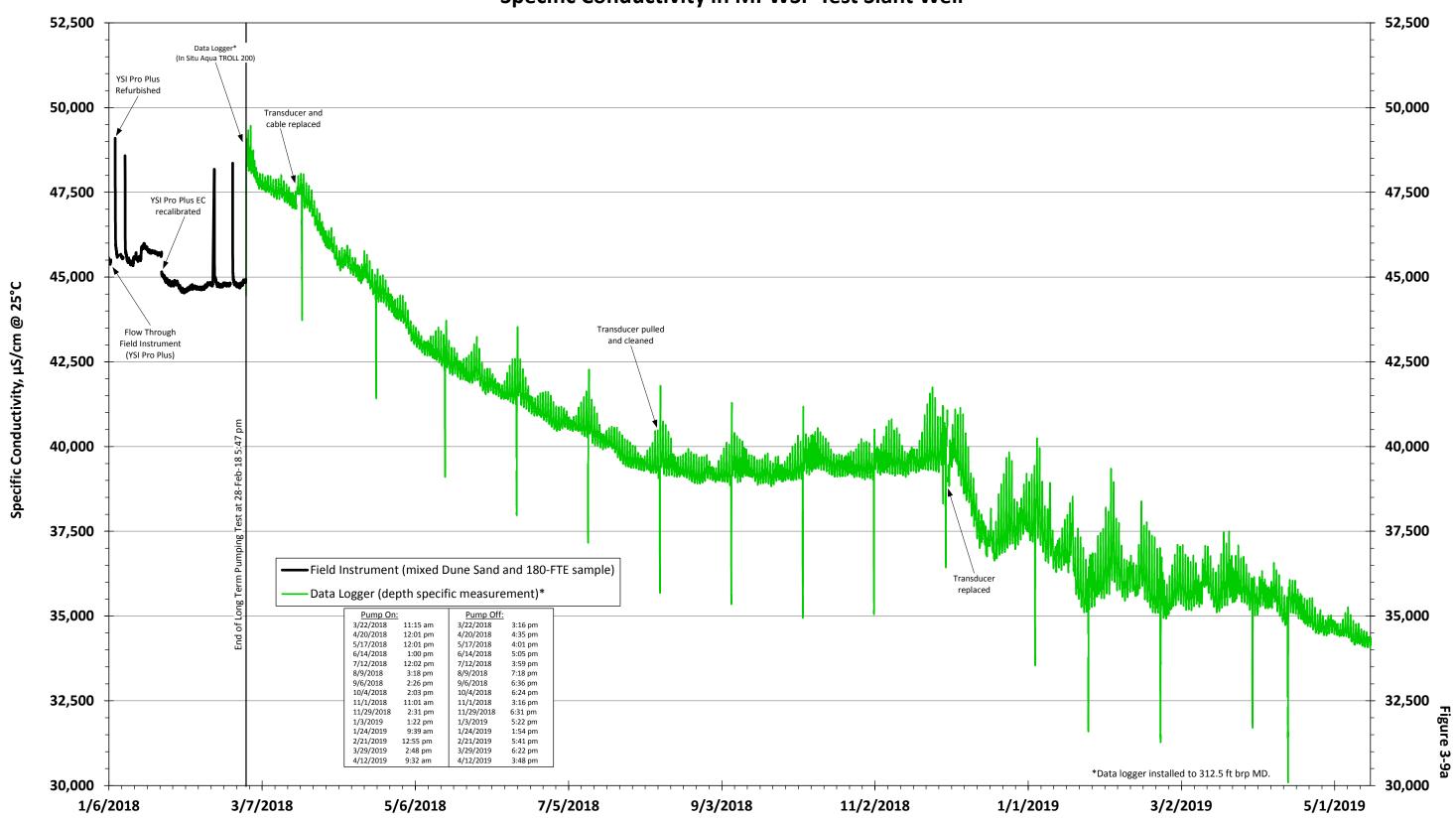




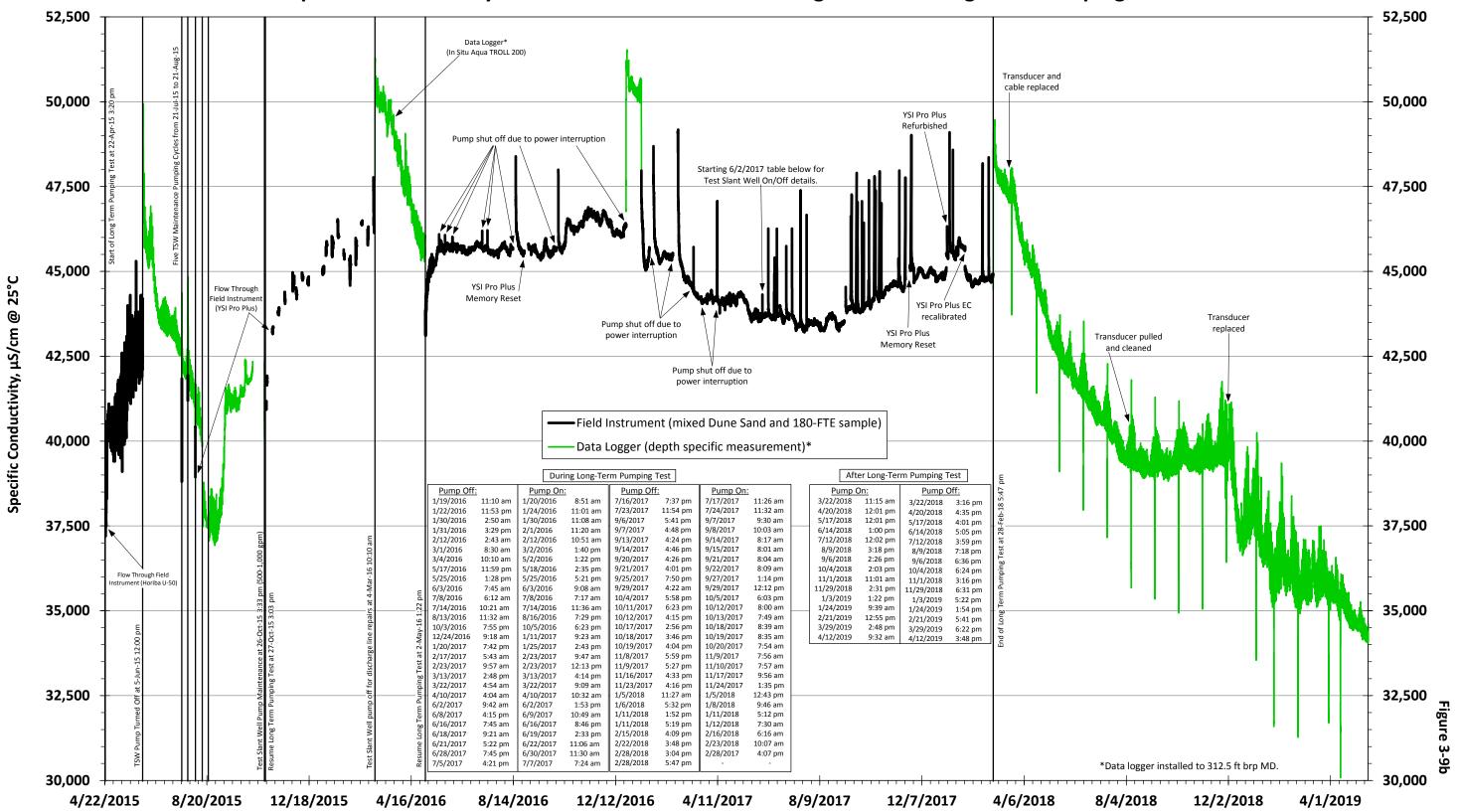




# **Specific Conductivity in MPWSP Test Slant Well**



# Specific Conductivity in MPWSP Test Slant Well During and After Long-Term Pumping Test



# **APPENDIX 3.E – SVBGSA WATER BUDGETS**

Table 6-19: Summary of Current Groundwater Budget

31,100 6,500 4,500 20,000	3,300 0 -9400¹ 20,000	80,000 10,800 15,500
4,500	-9400 <sup>1</sup>	•
		15.500
20.000	20,000	,
,	20,000	20,000
62,100	38,700	101,400
Average (AF/yr.)	Minimum (AF/yr.)	Maximum (AF/yr.)
109,300	108,400	111,000
91,900	89,000	97,700
17,000	12,900	19,000
400	400	400
12,000	12,000	12,000
9,500	9,500	9,500
130,800	129,900	132,600
	Average (AF/yr.) 109,300 91,900 17,000 400 12,000 9,500	Average (AF/yr.) (AF/yr.)  109,300 108,400  91,900 89,000  17,000 12,900  400 400  12,000 12,000  9,500 9,500

Storage		Average (AF/yr.)	Minimum (AF/yr.)	Maximum (AF/yr.)
	Change in Storage	-68,700	-28,500	-93,800

<sup>&</sup>lt;sup>1</sup>Negative percolation due to extremely high flows in the Rec ditch in 2017, which is all subtracted from irrigation. Some Rec Ditch flows should be subtracted from precipitation. The total recharge from both irrigation and precipitation is correct

The annual groundwater budget components are variable, although not as variable as the surface water budget components. Figure 6-4 illustrates the annual inflow and outflow components for the historical budget period. The diagram uses stacked bar height to illustrate the magnitude of budget components for each year, with inflows shown on the positive y-axis and outflows on the negative y-axis. The inflow and outflow components for each year are tabulated in Appendix 6A.

Table 6-27: Average Annual Groundwater Budget for Projected Climate Change Conditions (acre-ft/year)

Projected Climate Change Timeframe	2030 (AF/yr.)	2070 (AF/yr.)
Net GW Extraction	-115,00	-120,600
Net Drain Flow	-7,100	-8,000
Net Stream Exchange	69,700	69,800
Net Deep Percolation	41,200	45,100
Ocean Outflow	-800	-700
Net flow from Monterey	5,500	6,200
Net flow to Eastside	-7,200	-6,200
Net flow from Forebay	5,000	5,000
Net flow from Langley	1,600	1,600
Net mountain front recharge	1,700	1,800
Net flow to Pajaro	-800	-800
Net Storage Change	-4,600	-4,700

Table 6-28: Total Groundwater Inflows and Outflows for Projected Groundwater Budgets

Projected Climate Change Timeframe	2030 (AF/yr.)	2070 (AF/yr.)
Total In	295,700	308,600
Total Out	294,200	307,100
In-Out	1,500	1,600
%Error	0.50%	0.51%

Combining the land surface and groundwater budgets, groundwater pumping by water use sector can be summarized, as shown in Table 6-29.

Table 6-29: Projected Annual Groundwater Pumping by Water Use Sector

Water Use Sector	2030	2070 Average
	Average	
Agricultural	94,800	99,500
Urban (total pumping minus agricultural)	20,500	21,100
Rural-Domestic (not simulated in model, considered minimal)	0	0
Total Pumping	135,800	141,600