RECOMMENDATIONS TO ADDRESS THE EXPANSION OF SEAWATER INTRUSION IN THE SALINAS VALLEY GROUNDWATER BASIN

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Water Resources Agency

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Monterey County Water Resources Agency

Mission Statement

The Water Resources Agency manages, protects, stores, and conserves water resources in Monterey County for beneficial and environmental use, while minimizing damage from flooding to create a safe and sustainable water supply for present and future generations.

Vision Statement

To become a recognized and respected leader in the community we serve through demonstrated knowledge, integrity, and the quality of our actions.

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Section 1 - Introduction

1.1 Previous Activity

At a Special Joint Meeting of the Board of Supervisors of Monterey County, Board of Supervisors of the Monterey County Water Resources Agency (Agency), and the Water Resources Agency Board of Directors (Joint Boards) on July 11, 2017 staff presented the 2015 coastal Salinas Valley seawater intrusion contours (Figure 1 and Figure 2); 2015 groundwater elevation contours (Appendix A); an update on the Salinas Valley Groundwater Basin Investigation; and a presentation of the historical Salinas Valley Integrated Hydrologic Model (SVIHM-2014).[1] The updated extent of seawater intrusion depicted in the seawater intrusion maps and discussion of pathways of seawater intrusion indicated by the current data prompted a request from the Joint Boards that staff provide recommendations for actions to consider that, if implemented, would slow or halt further expansion of seawater intrusion.

1.2 Objective of this Report

This report provides a discussion of the current knowledge and related background information surrounding seawater intrusion pathways and potential impacts thereof on the Salinas Valley Groundwater Basin. This document also serves as a body of evidence to catalogue the findings used to support the recommendations presented herein.

Staff is making six recommendations, with each focused on a component that influences, or could be impacted by, the advancement of seawater intrusion. The recommendations are being presented in an order that builds upon the foundational knowledge laid out in the background section of this report, rather than in an order of priority.

Each recommendation can be implemented on its own or in concert with the others, and the relative importance of each will be discussed individually in this report. However, the recommendations have been conceptualized as a comprehensive solution that, along with continued operation of projects that have been constructed for the same purpose, have the strongest potential to ensure success in slowing or halting further seawater intrusion when implemented simultaneously.

[1] The 2015 seawater intrusion maps are available on the Water Resources Agency website at http://www.co.monterey.ca.us/government/government-links/water-resources-agency/documents/seawater-intrusion-maps#wra and the 2015 groundwater elevation contour maps are available at http://www.co.monterey.ca.us/government/government-links/water-resources-agency/documents/groundwater-elevation-contours#wra.

1.3 Recommendations

Staff makes the following six recommendations with the aim to slow or halt seawater intrusion, and impacts related thereto, in the Salinas Valley Groundwater Basin.

In no particular order of priority:

1. An immediate moratorium on groundwater extractions from new wells[2] in the Pressure 400-Foot Aquifer[3] within an identified Area of Impact[4], except for the following use categories:
    a. Wells operating under the auspices of the Castroville Seawater Intrusion Project; and,
    b. Monitoring wells owned and maintained by the Agency or other water management agencies.

2. Enhancement and expansion of the Castroville Seawater Intrusion Project (CSIP) Service Area. The expansion should include, at a minimum, lands served by wells currently extracting groundwater within the Area of Impact.

3. Following expansion of the CSIP Service Area, termination of all pumping from existing wells Pressure 180-Foot or Pressure 400-Foot Aquifer wells within the Area of Impact, except for the following use categories:
    a. Municipal water supply wells;
    b. Wells operating under the auspices of the Castroville Seawater Intrusion Project; and,
    c. Monitoring wells owned and maintained by the Agency or other water management agencies.

4. Initiate and diligently proceed with destruction of wells in Agency Zone 2B, in accordance with Agency Ordinance No. 3790, to protect the Salinas Valley Groundwater Basin against further seawater intrusion.

5. An immediate moratorium on groundwater extractions from new wells within the entirety of the Deep Aquifers of the 180/400 Foot Aquifer and Monterey Subbasins until such time

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[2] "New well" is not intended to include (a) any well for which a construction permit has been issued by the Monterey County Health Department or (b) any well for which drilling or construction activities have commenced in accordance with a well construction permit issued by the Monterey County Health Department.

[3] Aquifer means: a water-bearing or saturated formation that is capable of serving as a groundwater reservoir supplying enough water to satisfy a particular demand, as in a body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs (Poehls and Smith, 2009).

[4] See Section 1.5 for a description of the Area of Impact. The Area of Impact is also depicted in Figure 4.

as an investigation of the Deep Aquifers is completed and data pertaining to the hydraulic properties and long-term viability of the Deep Aquifers are available for knowledge-based water resource planning and decision making.

a. Monitoring wells, public agency wells, municipal water supply wells, wells for which a construction permit has already been issued, and well repairs should be considered for exemption from this recommendation.
b. The moratorium should include a prohibition of:
    i. Replacement wells, unless it can be demonstrated that the installation of such a well will not result in further expansion of the seawater intrusion front; and,
    ii. Deepening of wells from overlying aquifers into the Deep Aquifers, deepening of wells within the Deep Aquifers, and other activities that would expand the length, depth, or capacity of an existing well.

6. Initiate and diligently proceed with an investigation to determine the hydraulic properties and long-term viability of the Deep Aquifers.

Implementation of these recommendations will require close consultation with the County Counsel and, depending on the actions pursued, additional work by Agency staff and cooperation with Resource Management Agency (RMA) – Planning staff to ensure compliance with California Environmental Quality Act (CEQA) and other applicable procedures and policies. Some of the recommendations, such as a moratorium[5] relating to the well ordinance, might require implementation under the Government Code and coordination between Agency and County staff, and the Board of Supervisors of the Monterey County Water Resources Agency and Board of Supervisors of Monterey County.

[5] Certain moratoria may have consequences for a "taking" where the moratorium deprives an owner of all reasonable economic use of the owner's property. Whether there is a taking is an issue that would require further review and analysis on a case-by-case basis for each affected property.

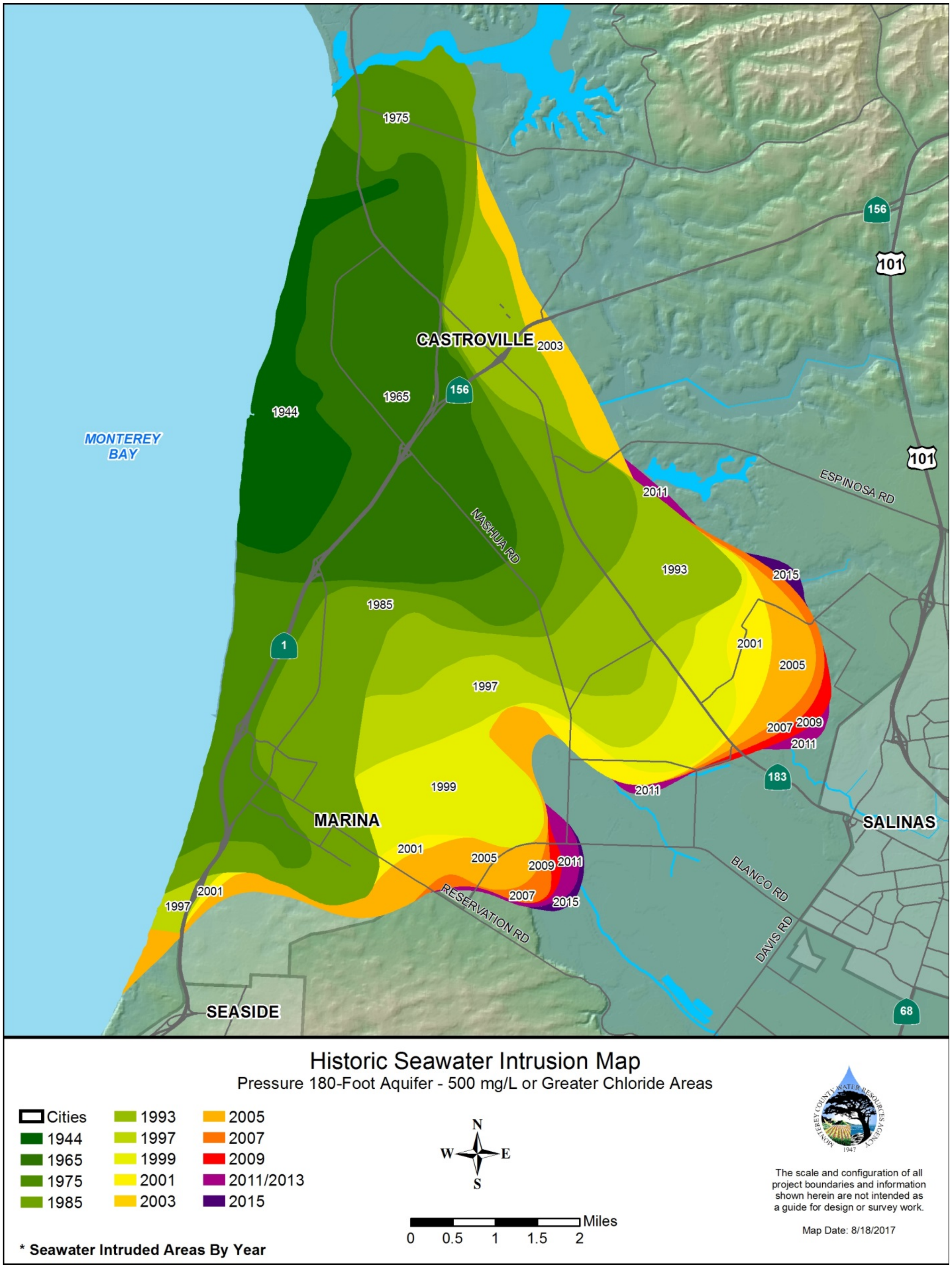

Figure 1 - Map of Historical Seawater Intrusion in the Pressure 180-Foot Aquifer

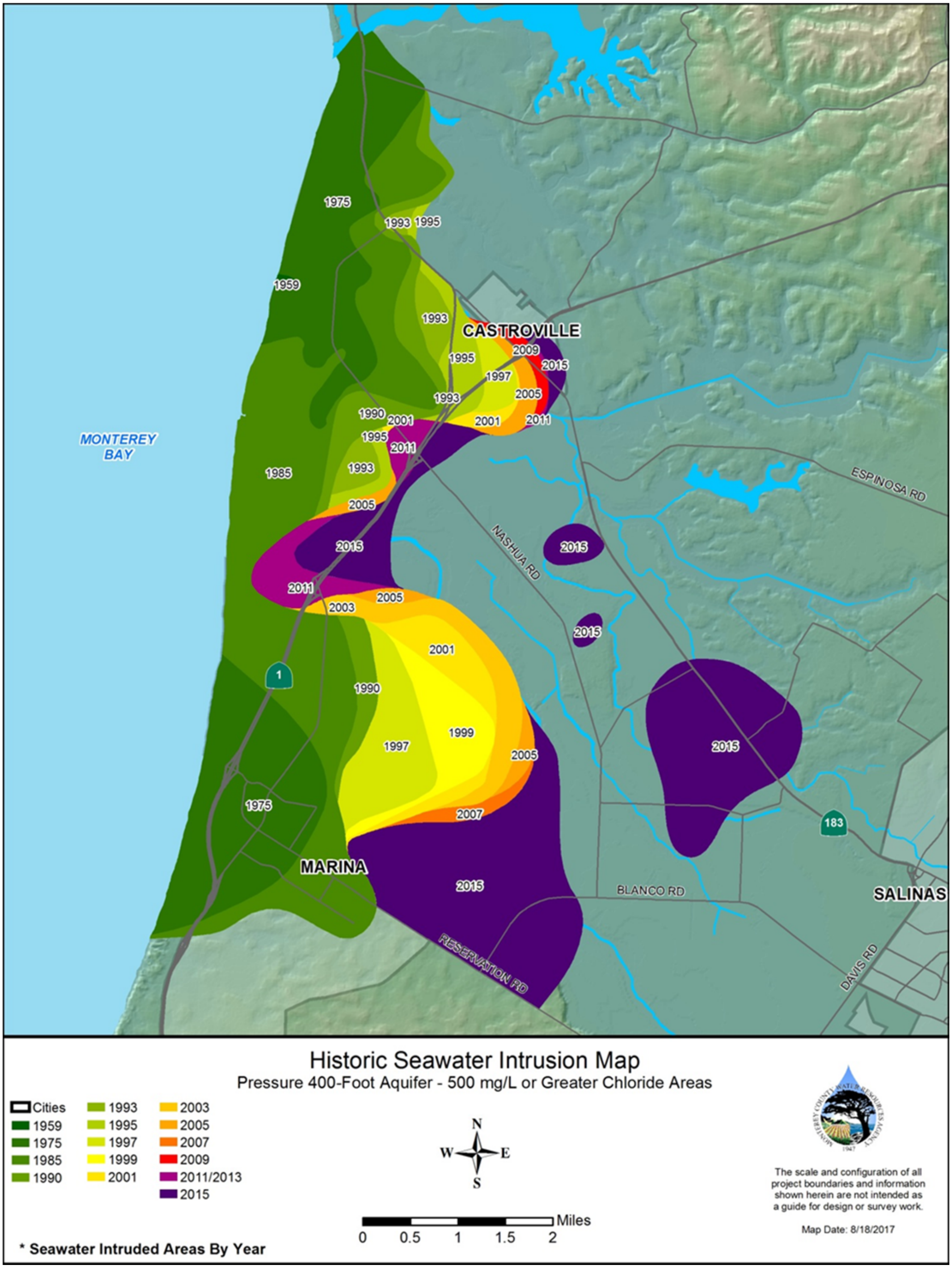

Figure 2 - Map of Historical Seawater Intrusion in the Pressure 400-Foot Aquifer

1.4 Explanation of Exemptions

1.4.1 Municipal water supply wells

The continued operation and expansion of municipal water supply wells within the identified Area of Impact must be carefully evaluated within the scope and context of the recommendations of this report. Pumping from municipal water supply wells in the Area of Impact represented an annual average of 23% of all groundwater extractions from 1995 to 2015 (17% in 2015). Groundwater extractions from the Area of Impact for municipal purposes ranged from 3,271 acre-feet (af) in 2015 to 5,714 af in 2000 (Figure 3). Annually, an average of 41% of all municipal pumping in the Area of Impact occurs from the Deep Aquifers.

This report recommends an immediate moratorium on groundwater extractions from new wells, including municipal wells, in the Pressure 400-Foot Aquifer (recommendation 1, Section 1.3). This report also recommends consideration of an exemption for new municipal water supply wells in the entirety of the Deep Aquifers (recommendation 5, Section 1.3a). Staff is of the opinion that these exemptions be considered only when weighed against the potential of risk to human health and safety.

The intent of these recommendations is to slow or halt the advancement of seawater intrusion in order to ensure the viability of current and future water supplies. To that end, staff views the continued pursuit of municipal water supply projects which reduce or eliminate the reliance on groundwater extractions as preferable to an exemption for new municipal water supply wells in the Deep Aquifers.

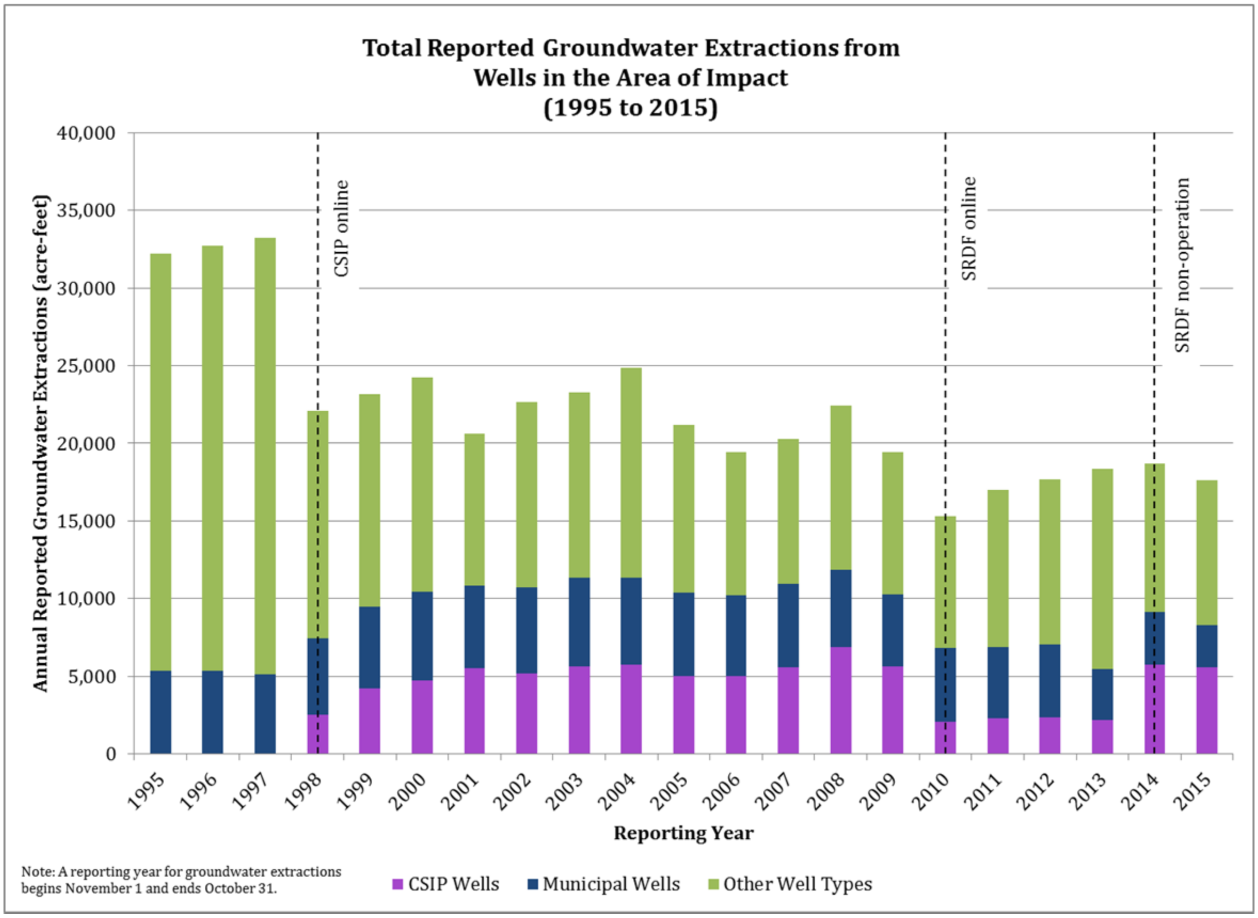

Figure 3 - Total Reported Groundwater Extractions from Wells in the Area of Impact (1995 to 2015)

1.4.2 CSIP wells

As discussed in more detail in Section 2.3 of this report, the water supply for CSIP is derived from recycled water, treated surface water from the Salinas River, and groundwater pumped from supplemental wells. Groundwater pumped from supplemental wells is required in order to meet demands in the CSIP area. However, because this pumping occurs as part of an Agency project, the volume and distribution of the groundwater pumping within the Area of Impact for CSIP can be closely monitored and managed. Furthermore, because groundwater pumping from private wells is generally prohibited in the CSIP area, the Agency is obligated under Ordinance No. 3790 to provide a substitute water supply.[6]

The ability to regulate this source of groundwater pumping and the necessity of having water available for CSIP support this exemption from the recommendations.

[6] Additional discussion of Agency Ordinance No. 3790 occurs in Sections 4 and 6.5 of this report.

1.4.3 Monitoring wells

Monitoring wells have been installed in the Pressure 180-Foot, Pressure 400-Foot, and Deep Aquifers within the Area of Impact for the purpose of facilitating periodic observation and sampling of groundwater levels and quality. While the measurement of groundwater levels does not require groundwater pumping, some groundwater pumping does occur during the process of collecting groundwater samples for water quality analysis. However, the total volume is on the order of fractions of an acre-foot per sampling event at each well.[7] Due to the relatively minimal amount of water extracted during groundwater sampling, and the importance of ongoing data collection to managing the resource, staff suggests that monitoring wells be exempt from the recommendations.

1.4.4 Well repairs

The intent of an exemption for well repairs is to allow ongoing use of wells that were installed prior to implementation of any of the recommendations if the repair will result in the well's construction enhancing aquifer protections, reducing the potential for expansion of seawater intrusion. Well repairs typically involve changes to the existing structure of a well that are intended to return the well to a state that closely resembles how it performed when it was first installed; to prolong the operable lifespan of a well that has deteriorated in production; or to fix a problem that is physically endangering continued use of the well (for example, a hole in the well casing).

Replacement wells are exempt from some policies of the 2010 Monterey County General Plan. In order to maintain consistency with existing County policies, staff is suggesting the same exemption from these recommendations be considered for existing wells within the Deep Aquifers when it can be demonstrated that the installation of a replacement well will not result in further expansion of the seawater intrusion front.

1.5 Defining the Area of Impact

The Agency has identified an Area of Impact (Figure 4), encompassing an area of the 180/400 Foot Aquifer and Monterey Subbasins that meets the following criterion:

- That portion of the 180/400 Foot Aquifer and Monterey Subbasins in which chloride concentrations in either the Pressure 180-Foot Aquifer or the Pressure 400-Foot Aquifer are 250 milligrams per liter (mg/L) or greater.

The location of areas where chloride concentrations in groundwater are 250 mg/L chloride concentration or greater will be defined by the most recently published data from the Agency;

[7] Standard procedures call for removing three casing volumes of water from a well before collecting a water quality sample in order to ensure that the sample is representative of aquifer water, rather than of water that has been stagnant in the well. Casing volume is dependent on the diameter and length of the casing. Using an average casing diameter of four inches (common for a monitoring well) and a depth of 1,370 feet (the average depth of a monitoring well in the Deep Aquifers), three casing volumes is approximately 2,930 gallons or 0.009 acre-feet. (One acre-foot equals 325,851 gallons.) Sampling of monitoring wells in the Pressure 180-Foot or Pressure 400-Foot Aquifers would result in even less groundwater pumping per sampling event because the wells are shallower.

currently this is data from 2015. The use of the 250 mg/L threshold is applicable only to identifying the Area of Impact as it pertains to these recommendations. The Agency will continue to define the extent of seawater intrusion as the area in which chloride concentrations are 500 mg/L or greater (Figure 1 and Figure 2).

The recommendations in this report are intended as a way to proactively manage, and take steps toward halting, the advancement of seawater intrusion. Groundwater within the Area of Impact is considered to be vulnerable due to the presence of pathways and conduits for seawater intrusion, all of which will be discussed in more detail in Sections 2 and 3 of this report.

Using the scientifically-based metric of 250 mg/L to delineate the vulnerable portion of the 180/400 Foot Aquifer and Monterey Subbasins allows the Agency to implement recommendations in the areas of incipient seawater intrusion with the aim of preventing the water quality in those areas from declining further.

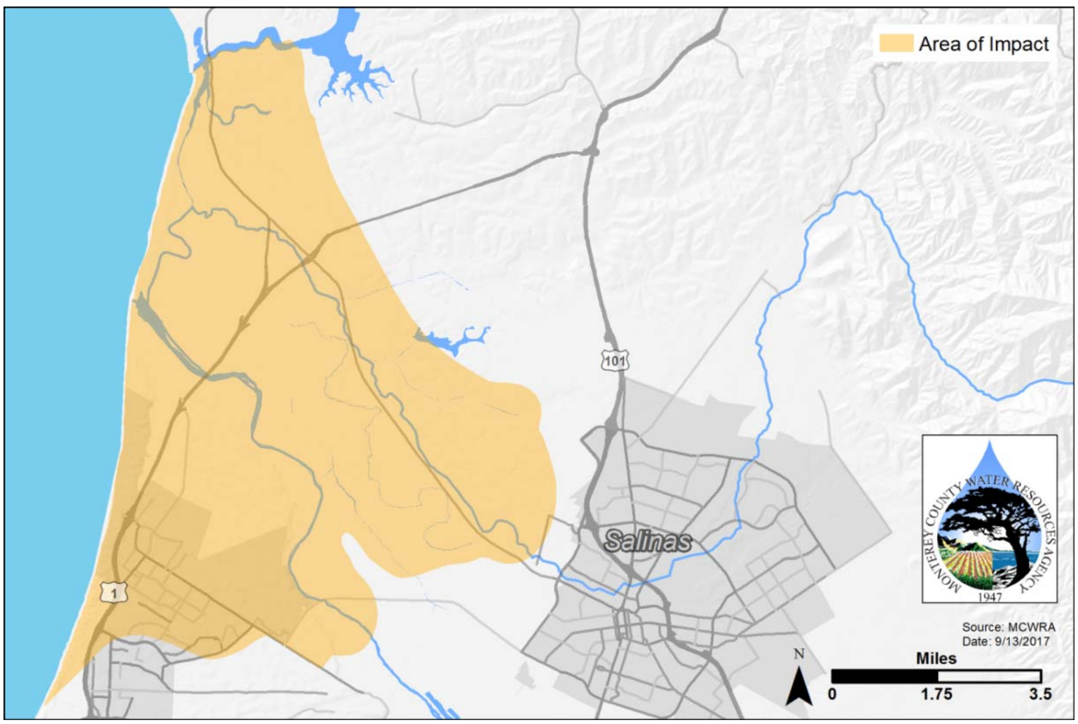

Figure 4 - Area of Impact

Section 2 – Background

2.1 Geology and Hydrogeology

2.1.1 Geology and Geologic Setting

Over millions of years, a succession of sea level fluctuations, uplift, and various types of sediment deposition created the geologic formations that are found in Monterey County today (Table 1). Monterey County lies entirely within the California Coast Range Geomorphic Province and is underlain by two fundamentally different basement terranes[8]: the Franciscan Complex and the Salinian Block (Rosenberg, 2001). The Salinian Block is primarily composed of granitic and metamorphic rocks that formed under high temperatures and was subsequently tectonically transported northward along its boundaries, now the San Andreas, San Gregorio, and Sur/Nacimiento faults (Figure 5). The Franciscan Complex consists mainly of oceanic crustal material and sedimentary rocks which formed under high pressure and relatively low temperatures and were transported on a tectonic plate moving toward North America (Lopez, 2006 and Rosenberg, 2001). Tectonic activity associated with the faults listed above continues to form the mountain ranges of Monterey County: the Santa Lucia Range, Sierra de Salinas, Gabilan Range, and Diablo Range (Rosenberg, 2001).

The Salinas Valley is a structural, inter-montane alluvial[9] basin on the eastern edge of the Pacific Plate. It is defined by the tectonically active Gabilan and Diablo Mountains to the northeast and Santa Lucia Mountains to the southwest. Over time, the Salinas Valley has been filled with 10,000 to 15,000 feet of marine and terrestrial sediments, of which up to 2,000 feet is now saturated alluvium (DWR, 2003).

Within the northern portion of the Salinas Valley Groundwater Basin, approximately from the City of Gonzales to the coast, thick alternating sequences of coarse and fine sediments deposited over millions of years by Plio-Pleistocene marine and terrestrial sedimentation form the 180/400 Foot Aquifer Subbasin. Bordering the 180/400 Foot Aquifer Subbasin to the east is the East Side Aquifer Subbasin (DWR, 2003).

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[8] Terrane means: a large block of the earth's crust with a distinct geologic character, originally part of the same crustal plate (Harden, 2004).

[9] Alluvial means: pertaining to material or processes associated with transportation and/or subaerial deposition by concentrated running water (USDA).

Table 1 - Geologic time scale highlighting events in Monterey County
From Rosenberg (2001) with age estimates from Hansen (1991)

<table>
<tr><th>Era</th><th colspan="2">Period, System, Subsystem</th><th>Epoch</th><th>Age estimates of boundaries in millions of years</th><th>Monterey County Geologic events, features, and deposits</th></tr>
<tr><td rowspan="7">Cenozoic (Age of mammals)</td><td colspan="2" rowspan="2">Quaternary</td><td>Holocene</td><td>0 – 0.010</td><td>Floodplain deposits, landslides, beach deposits</td></tr>
<tr><td>Pleistocene</td><td>0.010 – 1.6</td><td>Sea level fluctuates, sand dunes, marine terraces, Salinas Valley deposits</td></tr>
<tr><td colspan="2" rowspan="5">Tertiary</td><td>Pliocene</td><td>1.6 – 5</td><td>Uplift of Santa Lucia Range</td></tr>
<tr><td>Miocene</td><td>5 – 24</td><td>Seas advanced and retreated</td></tr>
<tr><td>Oligocene</td><td>24 – 38</td><td>Seas retreated, lava flows</td></tr>
<tr><td>Eocene</td><td>38 – 55</td><td>Uplift, deep basins, and isolated islands</td></tr>
<tr><td>Paleocene</td><td>55 – 66</td><td>Seas advanced</td></tr>
<tr><td rowspan="3">Mesozoic (Age of reptiles)</td><td colspan="2">Cretaceous</td><td></td><td>66 – 138</td><td>Salinian granitic rocks intruded</td></tr>
<tr><td colspan="2">Jurassic</td><td></td><td>138 – 205</td><td rowspan="2">Franciscan rocks subducted and accreted</td></tr>
<tr><td colspan="2">Triassic</td><td></td><td>205 – 240</td></tr>
<tr><td rowspan="8">Paleozoic (Age of fishes)</td><td colspan="2">Permian</td><td></td><td>240 – 290</td><td rowspan="8">Sur Complex formed hundreds of miles south of Monterey County</td></tr>
<tr><td rowspan="2">Carboniferous Systems</td><td>Pennsylvanian</td><td></td><td>290 – 330</td></tr>
<tr><td>Mississippian</td><td></td><td>330 – 360</td></tr>
<tr><td colspan="2">Devonian</td><td></td><td>360 – 410</td></tr>
<tr><td colspan="2">Silurian</td><td></td><td>410 – 435</td></tr>
<tr><td colspan="2">Ordovician</td><td></td><td>435 – 500</td></tr>
<tr><td colspan="2">Cambrian</td><td></td><td>500 – 570</td></tr>
<tr><td>Pre-Paleozoic</td><td colspan="2">pre-Cambrian</td><td></td><td>570 – 4600</td><td>--</td></tr>
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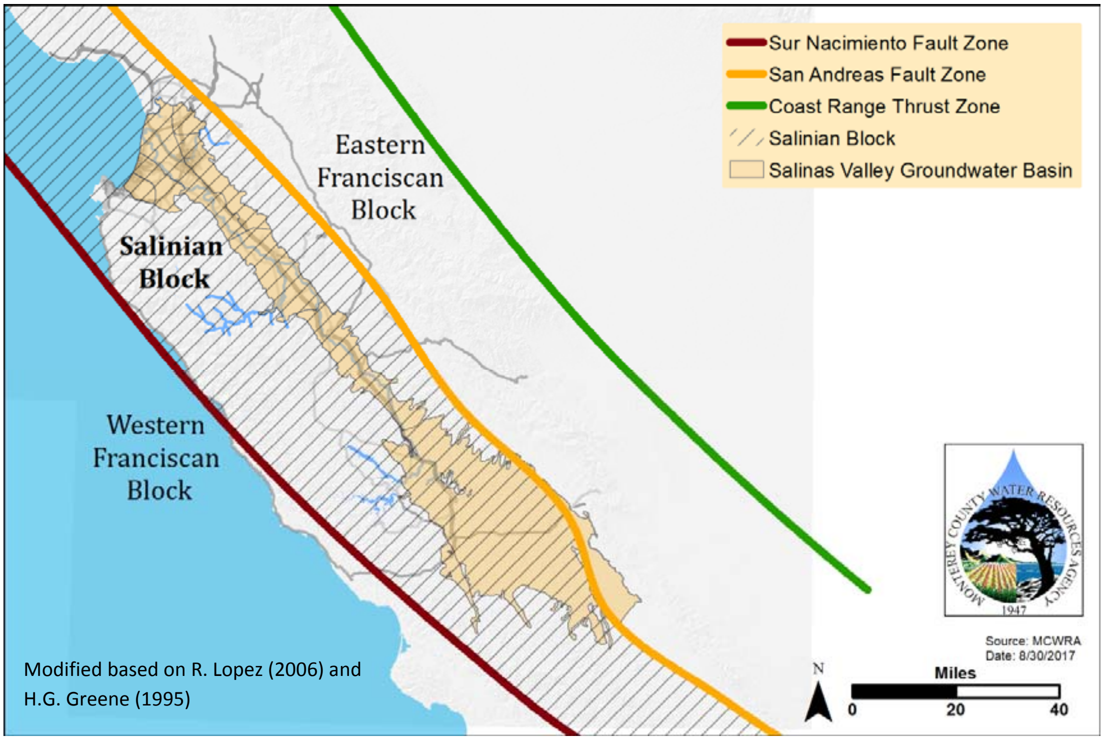

Figure 5 - Monterey County Geologic Setting

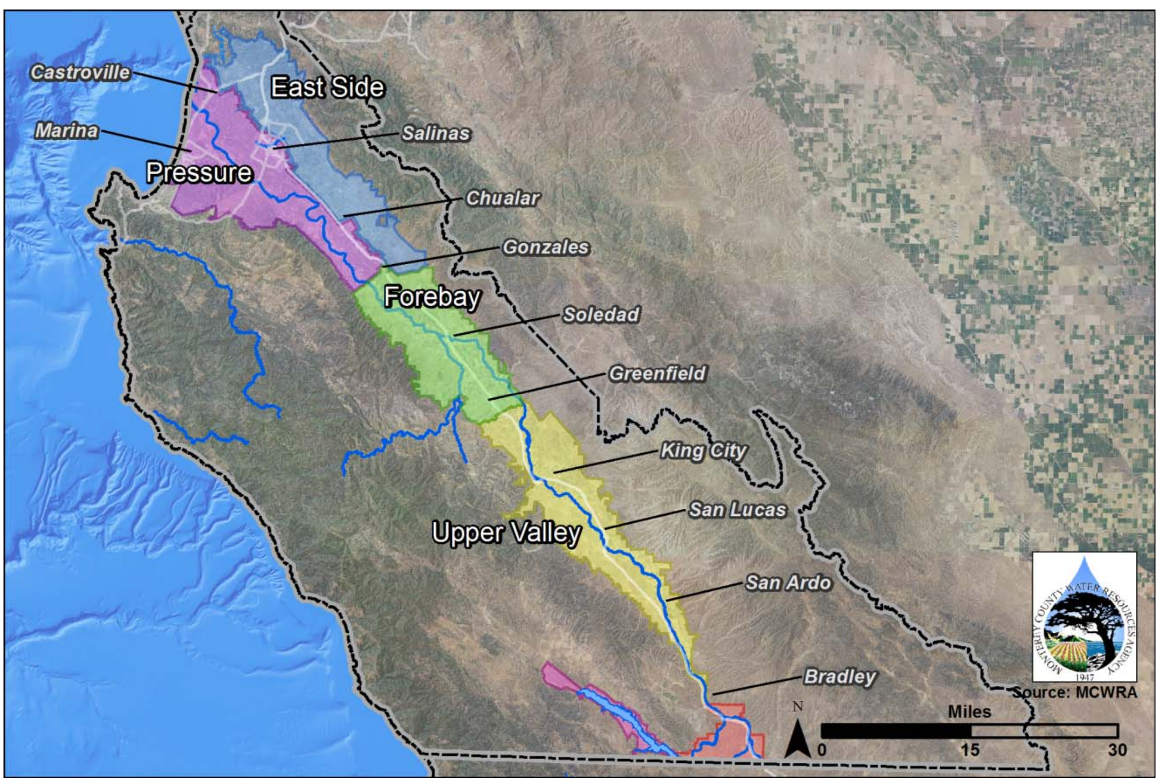

Figure 6 - Zone 2C Subareas

2.1.1.1 180/400 Foot Aquifer Subbasin

The 180/400 Foot Aquifer Subbasin of the Salinas Valley Groundwater Basin is defined by the Department of Water Resources (DWR) on the basis of groundwater flow boundaries; however, it is generally coincident with the Pressure Subarea as defined by the Agency (Brown and Caldwell, 2015; Figure 6). The northwestern boundary of the 180/400 Foot Aquifer Subbasin is defined by the Monterey Bay and the western edge is shared with the Monterey Subbasin. The Corralitos-Pajaro Valley Groundwater Basin is found on the northern edge of the Subbasin while the southern border is shared with the Forebay Subbasin beginning near the city of Gonzales.

The 180/400 Foot Aquifer Subbasin contains three primary aquifer units, as discussed below: the Pressure 180-Foot Aquifer, Pressure 400-Foot Aquifer, and Deep Aquifers (Figure 6 and Figure 7). There is also a fourth aquifer unit, referred to as the Shallow Aquifer, located at or near the ground surface but it is considered to be limited in both the quantity and quality of water available.

The stratigraphy of the 180/400 Foot Aquifer Subbasin generally consists of eight geologic units, listed here from shallowest to deepest, though not all units are present throughout the subbasin:

1. Surficial deposits (recent alluvium and valley fill)
2. Aromas Sands
3. Paso Robles Formation
4. Purisima Formation
5. Santa Margarita Sandstone
6. Monterey Formation
7. Unnamed Sandstone
8. Granitic basement

Older portions of the surficial deposits and the upper portion of the Aromas Sands correlate with the Pressure 180-Foot Aquifer, while the Pressure 400-Foot Aquifer is associated with the lower portion of the Aromas Sands and the upper part of the Paso Robles Formation (DWR, 2003 and Figure 7). The Aromas Sands are present only in the northern portion of the subbasin, gradually transitioning to the Paso Robles Formation to the south.

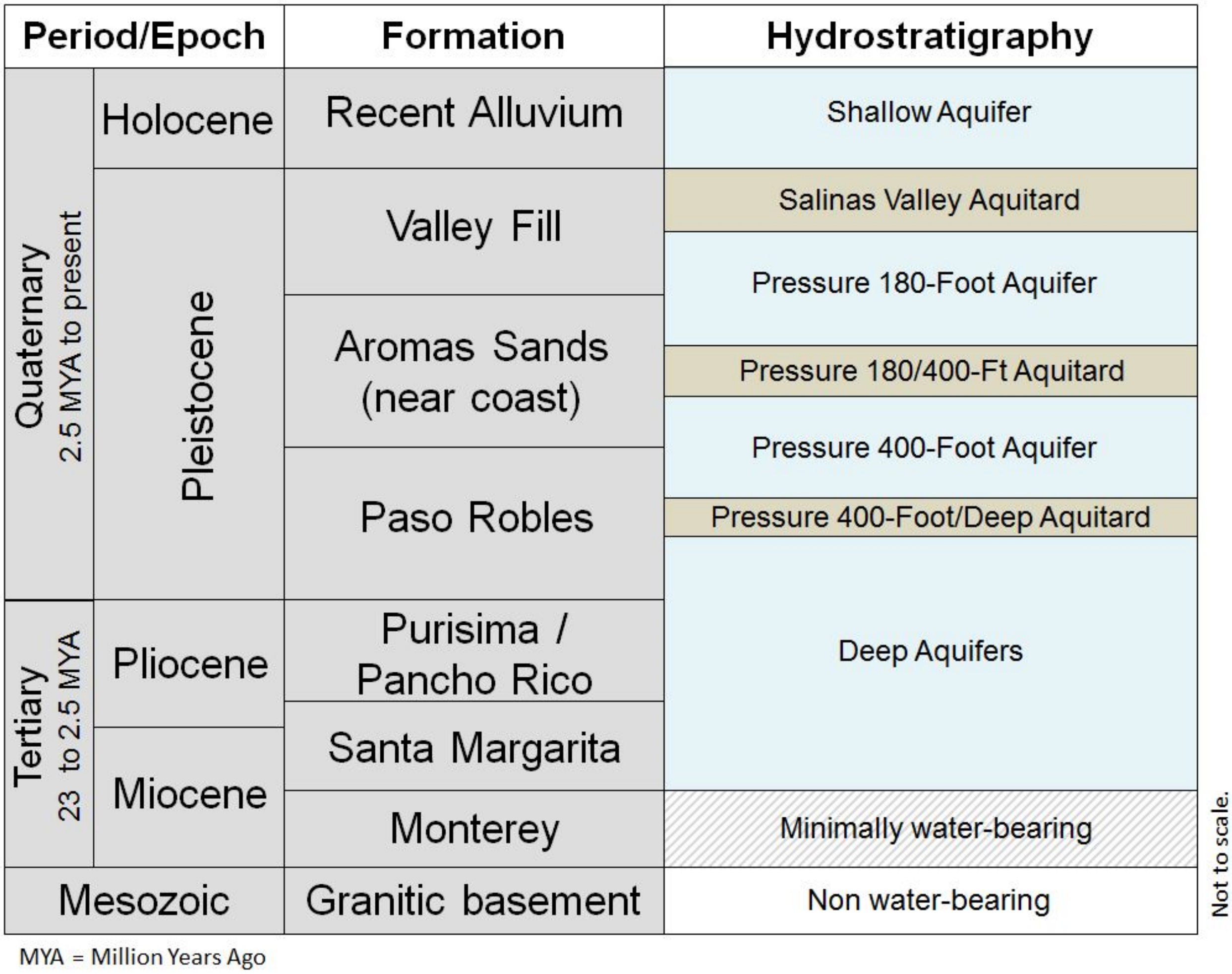

Figure 7 - Stratigraphy and Hydrostratigraphy of the 180/400 Foot Aquifer Subbasin of the Salinas Valley Groundwater Basin

2.1.1.2 East Side Aquifer Subbasin

The East Side Aquifer Subbasin lies to the east of the 180/400 Foot Aquifer Subbasin, extending from the town of Gonzales in the south to the city of Salinas, and is bounded by the Gabilan Range on the east (DWR, 2003). Stratigraphy of the East Side Aquifer Subbasin generally consists of a poorly bedded sequence of gravel, sand, silt, sandy and gravelly clay, and clay. Decomposed granite is also characteristic of sediments in the East Side Aquifer Subbasin, reflecting their origin in the Gabilan Range (Kennedy/Jenks, 2004).

While the fluvially[10] generated aquifers of the 180/400 Foot Aquifer Subbasin are not observed in the East Side Aquifer Subbasin, there is hydraulic communication between the aquifers and sediments of both subbasins can be correlated by zones that are stratigraphically equivalent (Kennedy/Jenks, 2004). However, the near-surface confining unit present in the 180/400 Foot

[10] Fluvial means: of or pertaining to rivers and streams, existing, growing, or living in or near a stream (Poehls and Smith, 2009).

Aquifer, the Salinas Valley Aquitard[11], does not extend into the East Side Aquifer Subbasin (DWR, 2003).

The boundary between the 180/400 Foot Aquifer and East Side Aquifer subbasins is significant to the discussion of seawater intrusion advancement. Originally, subbasin boundaries were defined by the Department of Water Resources (DWR) based on the source of aquifer recharge (Kennedy/Jenks, 2004). However, Kennedy/Jenks has defined an area of transition between the two subbasins based on the shift from predominantly alluvial facies to predominantly fluvial facies (2004). This change in depositional environment results in variable hydraulic properties along the transition zone between the two subbasins (Figure 8).[12]

Historically, the lateral advancement of seawater intrusion has occurred preferentially along geologic pathways that allow for easier movement of water. The discontinuous and layered nature of the sediments in the transition zone between the 180/400 Foot Aquifer Subbasin and the East Side Aquifer Subbasin result in a situation that restricts (but does not preclude) the flow of groundwater across this area.

A prominent and persistent groundwater feature within the East Side Aquifer Subbasin is the large groundwater depression referred to as the East Side trough. Decades of groundwater level monitoring data documents the presence of the trough, where groundwater levels vary seasonally in the range of 80 to 120 feet below mean sea level (Appendix A).

Persistent dewatering of the East Side Aquifer Subbasin, as revealed by the trough, is also a mechanism for land subsidence.[13] Preliminary data from the U.S. Geological Survey (USGS) indicates that land subsidence is occurring in the East Side Aquifer Subbasin in the area around Salinas (Personal communications with R. Hanson, 2017). Land subsidence results in an irreversible loss of aquifer storage and potential damage to infrastructure.

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[11] Aquitard means: a confining unit that retards but does not prevent the flow of water to or from an adjacent aquifer (Poehls and Smith, 2009).

[12] In Figure 8, the terminology “Pressure Subarea” and “East Side Subarea” are used in lieu of 180/400 Foot Aquifer Subbasin and East Side Subbasin, respectively.

[13] Subsidence refers to differential settlements or sinking resulting from excessive groundwater withdrawals (based on Poehls and Smith, 2009).

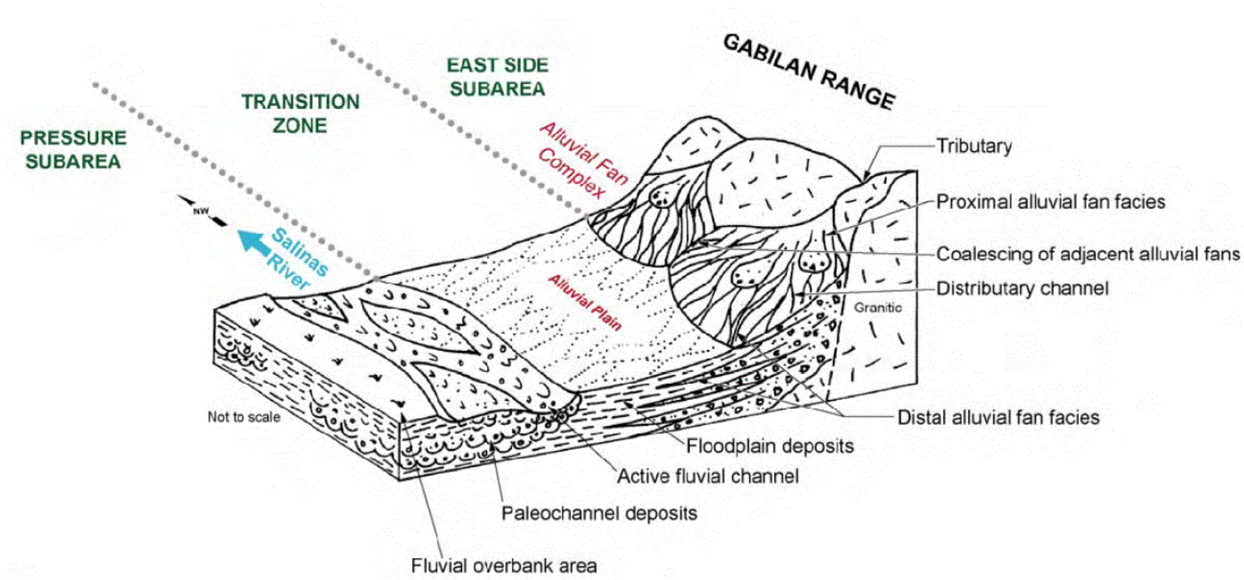

Figure 8 - Generalized Fluvial and Alluvial Fan Facies of the Northern Salinas Valley
(Kennedy/Jenks, 2004)

2.1.2 Hydrogeology

The 180/400 Foot Aquifer Subbasin of the Salinas Valley Groundwater Basin consists of a complex sequence of water-bearing sediments, characterized by alternating aquifers and aquitards (Figure 7). Historically, the sequence of strata has been grouped by major hydrostratigraphic units and represented from top to bottom as follows:

1. Shallow Alluvial Aquifer
2. Salinas Valley Aquitard
3. Pressure 180-Foot Aquifer
4. Pressure 180/400-Foot Aquitard
5. Pressure 400-Foot Aquifer
6. Pressure 400-Foot/Deep Aquitard
7. Deep Aquifers

2.1.2.1 Shallow Alluvial Aquifer

The Shallow Alluvial Aquifer, which is the same unit where the "Dune Sand" aquifer is found near the coast, contains perched groundwater in some areas overlying the Salinas Valley Aquitard.

2.1.2.2 Salinas Valley Aquitard

The Salinas Valley Aquitard consists of a series of blue or yellow sandy clay layers that overlies and confines the underlying Pressure 180-Foot Aquifer. The Salinas Valley Aquitard ranges in thickness from approximately 100 feet in the area west of Salinas, thinning to approximately 25 feet near Salinas, and pinches out east of Salinas (Kennedy/Jenks, 2004).

2.1.2.3 Pressure 180-Foot Aquifer

The Pressure 180-Foot Aquifer is the uppermost laterally extensive aquifer in the northern Salinas Valley and is named for the depth at which it is typically encountered (DWR, 1946). The Pressure 180-Foot Aquifer ranges from 50 to 150 feet in thickness and spans multiple stratigraphic units (Figure 6) (Kennedy/Jenks, 2004).

2.1.2.4 Pressure 180/400-Foot Aquitard

The Pressure 180-Foot and Pressure 400-Foot Aquifers are separated by a zone of clay, or clay and sand layers, referred to as the Pressure 180/400-Foot Aquitard. This hydraulic barrier is widespread in the 180/400 Foot Aquifer Subbasin and varies in thickness, continuity, and quality (Kennedy/Jenks, 2004 and MCFCWCD, 1960). Further discussion of the Pressure 180/400-Foot Aquitard follows in Section 3 of this report.

2.1.2.5 Pressure 400-Foot Aquifer

This areally extensive layer of sand and gravel typically encountered between 270 and 470 feet below ground surface is referred to as the Pressure 400-Foot Aquifer (Kennedy/Jenks, 2004). The depth to the top of the aquifer, the thickness of the aquifer, and the degree of complete interbedding with clay layers is variable between wells (Thorup, 1976 and Kennedy/Jenks, 2004).

2.1.2.6 Pressure 400-Foot/Deep Aquitard

The Deep Aquifers of the 180/400 Foot Aquifer Subbasin are separated from overlying strata and confined by an aquitard that can be several hundred feet thick (Kennedy/Jenks, 2004).

2.1.2.7 Deep Aquifers

The Deep Aquifers of the 180/400 Foot Aquifer Subbasin include aquifer units that have been referred to as the 800-Foot Aquifer, 900-Foot Aquifer, 1,000-Foot Aquifer, and the 1,500-Foot Aquifer (Harding ESE, 2001).

The Deep Aquifers are discussed in more detail in Section 5 of this report.

2.2 Seawater Intrusion

2.2.1 Defining seawater intrusion

Seawater intrusion was first documented in the Salinas Valley Groundwater Basin in 1946 (Dept. of Public Works). Today, the Agency monitors the movement and extent of seawater intrusion by collecting groundwater samples from a series of wells located in the coastal northwestern portion of Monterey County.

The Agency defines the seawater intrusion front as the inland extent at which the concentration of chloride in groundwater is at least 500 mg/L. A chloride concentration of 500 mg/L represents a level that is twice the National Secondary Drinking Water Regulation (250 mg/L) and which exceeds the concentration for water considered to be of "Class III - injurious or unsatisfactory" quality for agricultural irrigation (350 mg/L) (USDA).

2.2.2 Monitoring groundwater

2.2.2.1 Groundwater levels

The Agency has been monitoring groundwater levels in the coastal area since the 1940s. The Agency's groundwater level monitoring program consists of surveys to determine fluctuations in groundwater levels as measured predominantly in privately-owned agricultural production wells. The Agency owns twenty-seven dedicated monitoring wells that augment this effort.

Surveys are conducted on a monthly basis at approximately 94 wells and on an annual basis at approximately 400 wells. An additional survey is conducted each August at approximately 130 wells, with the intent of capturing conditions during the period of seasonal maximum pumping.

Groundwater level data collected during the August and annual surveys are used to produce two sets of maps showing groundwater elevation contour lines for (1) the Pressure 180-Foot and East Side Shallow aquifers and (2) the Pressure 400-Foot and East Side Deep aquifers (Appendix A). Groundwater level data collected for the monthly survey are used to produce quarterly reports on groundwater conditions in the Salinas Valley Groundwater Basin.[14]

Groundwater level measurements are also used as a tool to understand the scale and geographic extent of conditions leading to a reversal of the normal seaward hydraulic gradient. An understanding of the dynamic configuration of the hydraulic gradients within the basin contributes to the Agency's understanding of pathways for seawater intrusion, which will be discussed further in Section 2.2.3 of this report.

[14] Agency reports on Quarterly Salinas Valley Water Conditions are available on the Agency's website at: http://www.co.monterey.ca.us/government/government-links/water-resources-agency/documents/quarterly-salinas-valley-water-conditions#wra

2.2.2.2 Groundwater quality

The Agency conducts two groundwater sampling events each year during the period of peak groundwater pumping, typically in June and August, in order to monitor water quality in the coastal region of the Salinas Valley. Each sampling event consists of collecting groundwater from 121 wells (96 agricultural production wells and 25 monitoring wells), which is then analyzed for general minerals, conductivity, and pH.

The Agency uses chloride concentration as an indicator of seawater intrusion.[15] A suite of geochemical tools, including Piper diagrams, Stiff diagrams, and an evaluation of chloride versus sodium/chloride molar ratios, are used to evaluate laboratory results. These geochemical tools allow the Agency to discern whether seawater intrusion is the source of chloride concentrations in a well or if the result is due to another source such as soil amendments, for example.

2.2.3 Pathways of seawater intrusion

2.2.3.1 Regional Seawater Intrusion

In the Salinas Valley Groundwater Basin, the Pressure 180-Foot and Pressure 400-Foot Aquifers are in direct hydraulic communication with the Pacific Ocean, a condition that provides a pathway for seawater intrusion (Kennedy/Jenks, 2004). A secondary contributor to seawater intrusion into the Pressure 180-Foot and Pressure 400-Foot Aquifers is the persistent reversal of the seaward groundwater gradient, driven by inland groundwater levels that are below sea level (Kennedy/Jenks, 2004). The combination of these two factors is referred to as regional seawater intrusion (Figure 9).

In the case of regional seawater intrusion, seawater infiltrates the Pressure 180-Foot and Pressure 400-Foot Aquifers through the submarine outcrops of the aquifers offshore of Monterey Bay (Kennedy/Jenks, 2004). Seawater moves inland, infiltrating portions of the aquifers that contain fresh water, because groundwater pumping has resulted in groundwater levels that are below sea level in both aquifers (DWR, 1973; Kennedy/Jenks, 2004; Todd, 1989).

As shown in Figure 9, regional seawater intrusion results in the formation of a transition zone between native fresh water (50 mg/L chloride) and seawater (19,000 mg/L), where groundwater quality deteriorates with proximity to the coast.

A study conducted in the Marina area using conductivity profiles within a well also suggests that saline groundwater is likely to travel preferentially along pathways with coarse grained materials like sands and gravels (Staal, Gardner & Dunne, Inc., 1994). Traditional methods of sampling wells result in samples that represent composites of water quality throughout the water column; however, there may be concentrations of higher salinity water in certain zones around a well.

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[15] Maps of the extent of seawater intrusion in the Pressure 180-Foot and Pressure 400-Foot Aquifers are created biennially, in odd-numbered years (e.g. 2013 and 2015).

2.2.3.2 Inter-Aquifer Seawater Intrusion

A second pathway for seawater intrusion, termed inter-aquifer seawater intrusion, has been discussed in previous reports and was recently documented in the 2015 Historic Seawater Intrusion Map for the Pressure 400-Foot Aquifer (Figure 2) (DWR, 1973; Kennedy/Jenks, 2004; Brown and Caldwell, 2015). Inter-aquifer seawater intrusion occurs when groundwater that has already been intruded with seawater migrates vertically between aquifers. Each of the following conditions contributes to the likelihood of inter-aquifer seawater intrusion:

- thin or discontinuous aquitards;
- wells with screens across multiple aquifer units (multi-aquifer wells);
- improperly constructed or abandoned wells;
- wells in poor condition; or,
- a vertical hydraulic gradient wherein groundwater levels are deeper in the underlying aquifer, either due to the naturally occurring piezometric heads in the aquifer or pumping-induced groundwater level differentials.

Varying combinations of these conditions are present at many locations throughout the 180/400 Foot Aquifer Subbasin. The implications will be discussed further in Sections 3 and 4 of this report, but all are potential conduits for inter-aquifer seawater intrusion (Figure 10).

2.2.4 Rates of seawater intrusion

Rates of seawater intrusion can be determined using a variety of methods, as discussed by Kennedy/Jenks (2004). The rates of advancement have historically been variable and have been discussed in terms of both linear rates (e.g., feet per year) and the areal expansion of distinct lobes, (e.g., acres of ground surface underlain by the defined seawater intrusion extent). The linear rate of seawater intrusion over a given time interval is the distance moved by the 500 mg/L chloride contour divided by that time interval (conventionally reported in years). The number of acres advanced is calculated from the change in intruded area, as exhibited in Figure 1 and Figure 2(Brown and Caldwell, 2015).

Expansion of seawater intrusion into an area may result from increased pumping or prolonged droughts, when groundwater level withdrawals exceed available recharge. Similarly, short-term reductions in the seawater intrusion rate may be observed during wet periods. As demonstrated in Kennedy/Jenks (2004), seawater intrusion data suggest that preferential “travel paths” may exist along which seawater intrusion could progress at a faster rate due to the underlying geology. In some cases, there may be no advancement along the fringes of a seawater intrusion lobe.

With each contouring event, the Agency determines the number of acres over which seawater intrusion has advanced (Table 2). Historical data on estimated acreage overlying seawater intrusion from 1999 to 2015 was used to determine that seawater intrusion is advancing at a rate of approximately 265 acres per year in the Pressure 180-Foot Aquifer since CSIP began operation in 1998. For the same time period, seawater intrusion has advanced at a rate of 414 acres per year in the Pressure 400-Foot Aquifer.

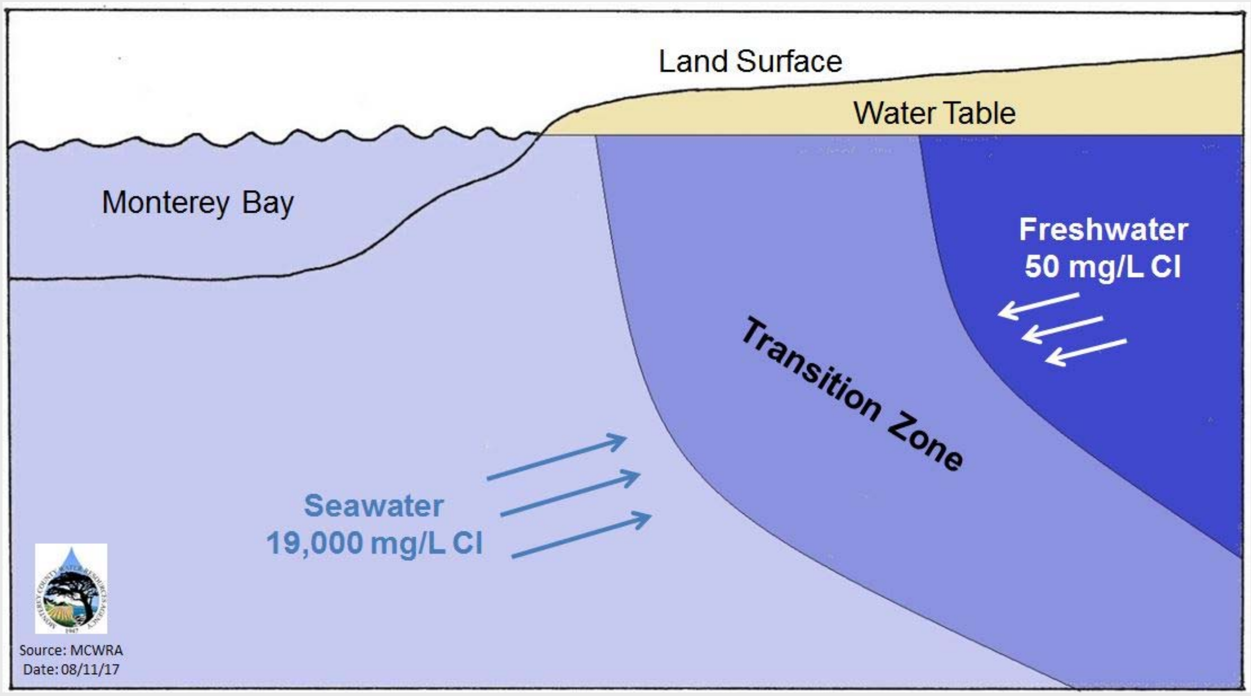

Figure 9A. As seawater intrudes into an aquifer there is a transition zone where seawater and fresh water mix.

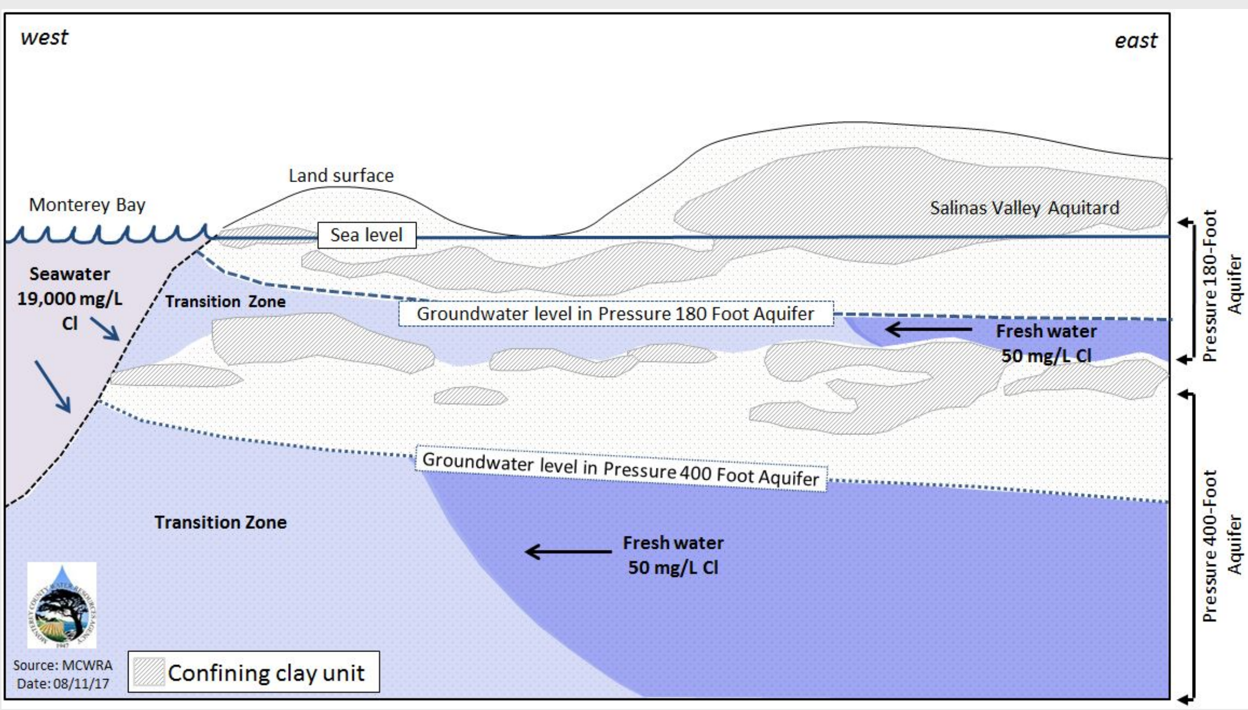

Figure 9B. With regional seawater intrusion, seawater moves inland because there are submarine outcrops of the geologic formations and a landward groundwater gradient.

Figure 9 - Illustration of Regional Seawater Intrusion

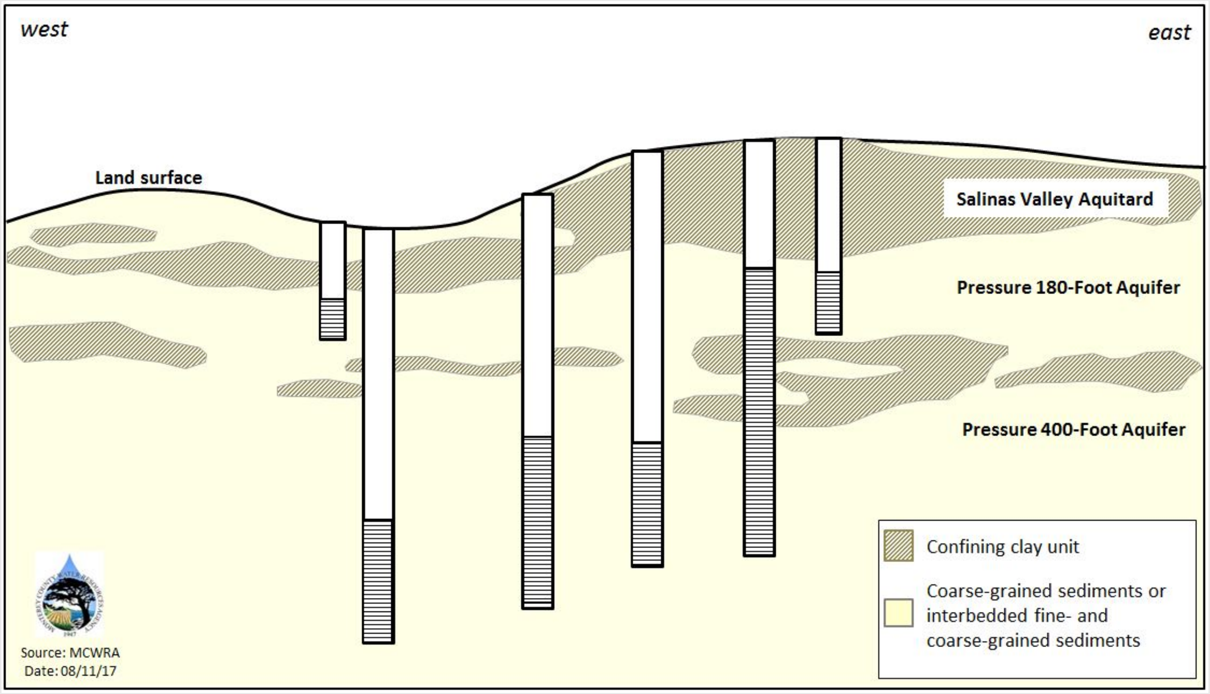

Figure 10A. The 180/400 Foot Aquifer Subbasin contains multiple layers of water-bearing zones interspersed with confining clay units.

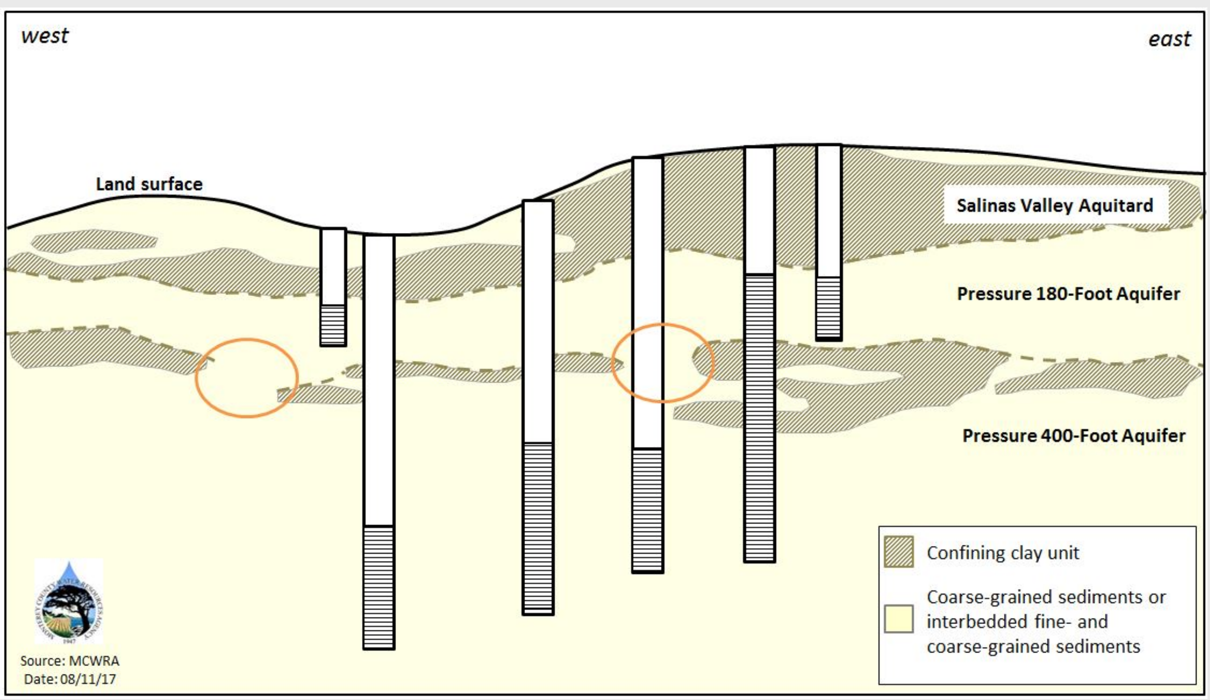

Figure 10B. In some areas of the 180/400 Foot Aquifer Subbasin, the confining clay unit is missing or very thin.

Figure 10 - Illustration of Inter-Aquifer Seawater Intrusion

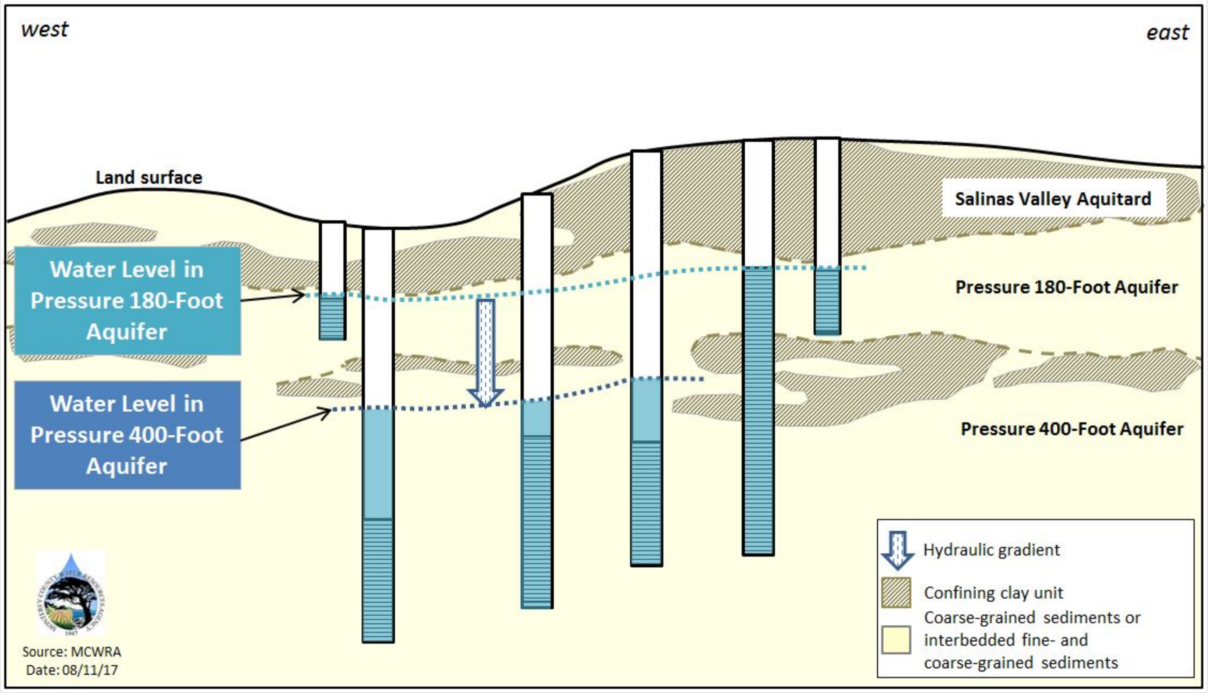

Figure 10C. Water levels in the Pressure 400-Foot Aquifer are lower than in the overlying Pressure 180-Foot Aquifer. This results in a downward hydraulic gradient.

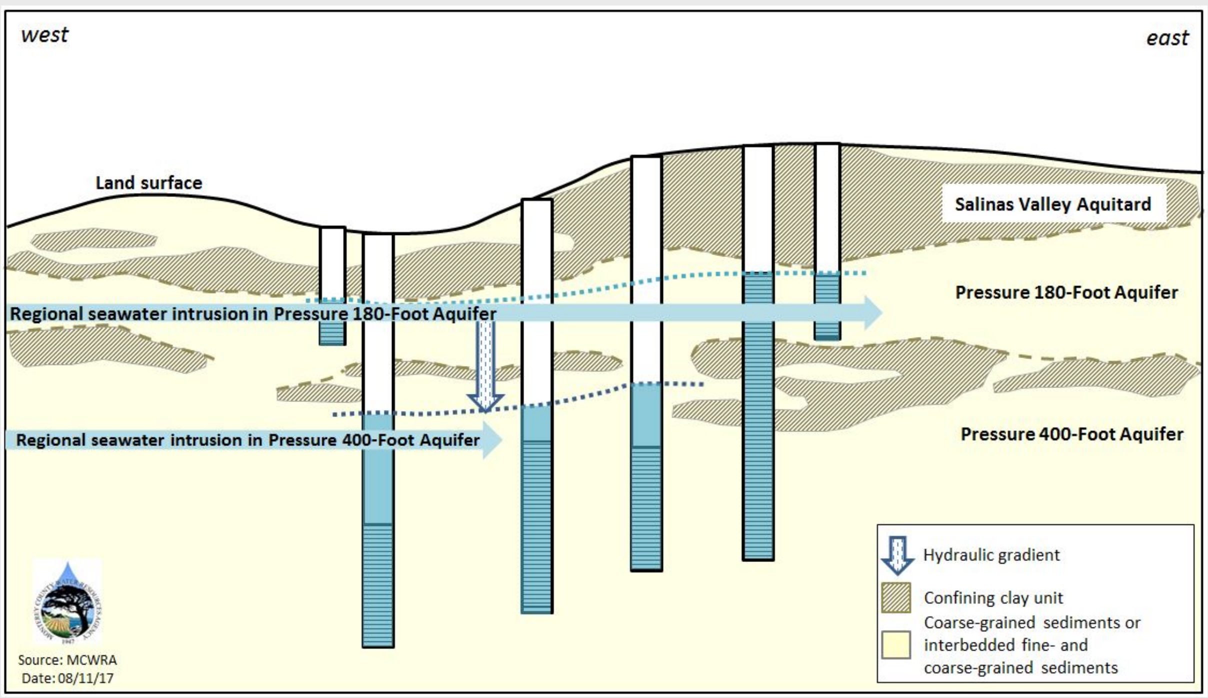

Figure 10D. Regional seawater intrusion has occurred in both the Pressure 180-Foot and Pressure 400-Foot Aquifers, but seawater intrusion extends further inland in the Pressure 180-Foot Aquifer.

Figure 10 (continued) – Illustration of Inter-Aquifer Seawater Intrusion

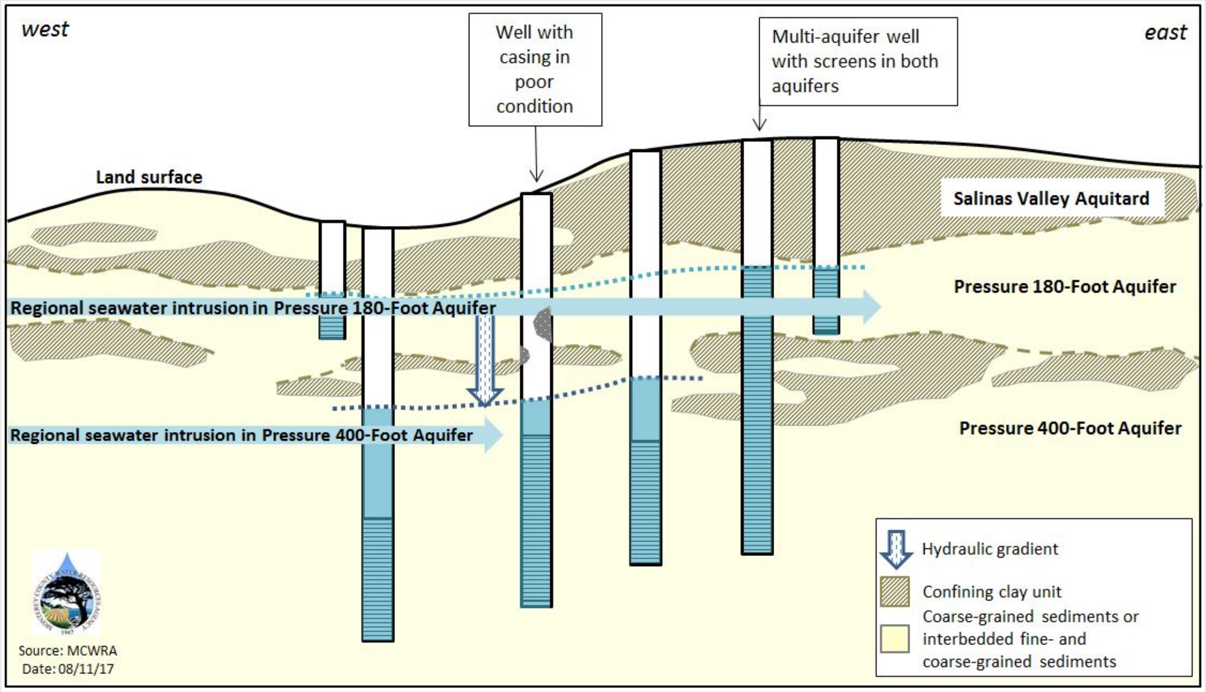

Figure 10E. Some wells in the 180/400 Foot Aquifer Subbasin are installed in multiple aquifers, have casings that are in poor condition, or have been improperly constructed or abandoned.

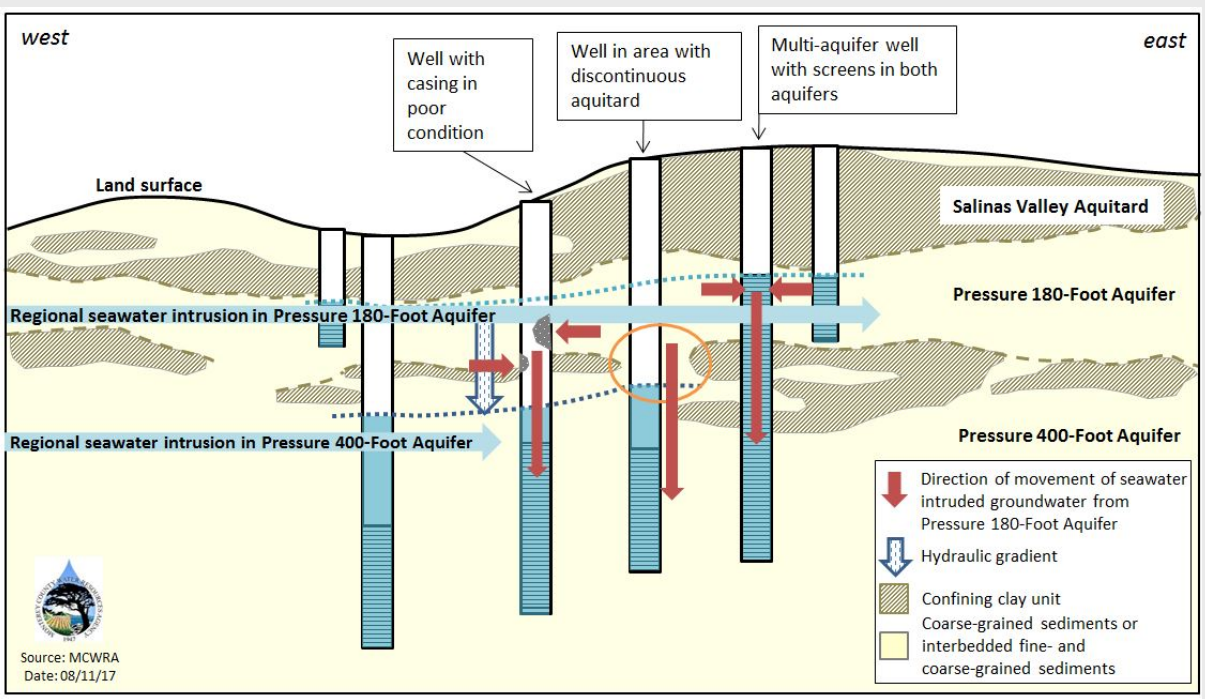

Figure 10F. A combination of the geology, hydraulic gradient, overlying intrusion, groundwater pumping, and well construction/condition allows for inter-aquifer seawater intrusion.

Figure 10 (continued) – Illustration of Inter-Aquifer Seawater Intrusion

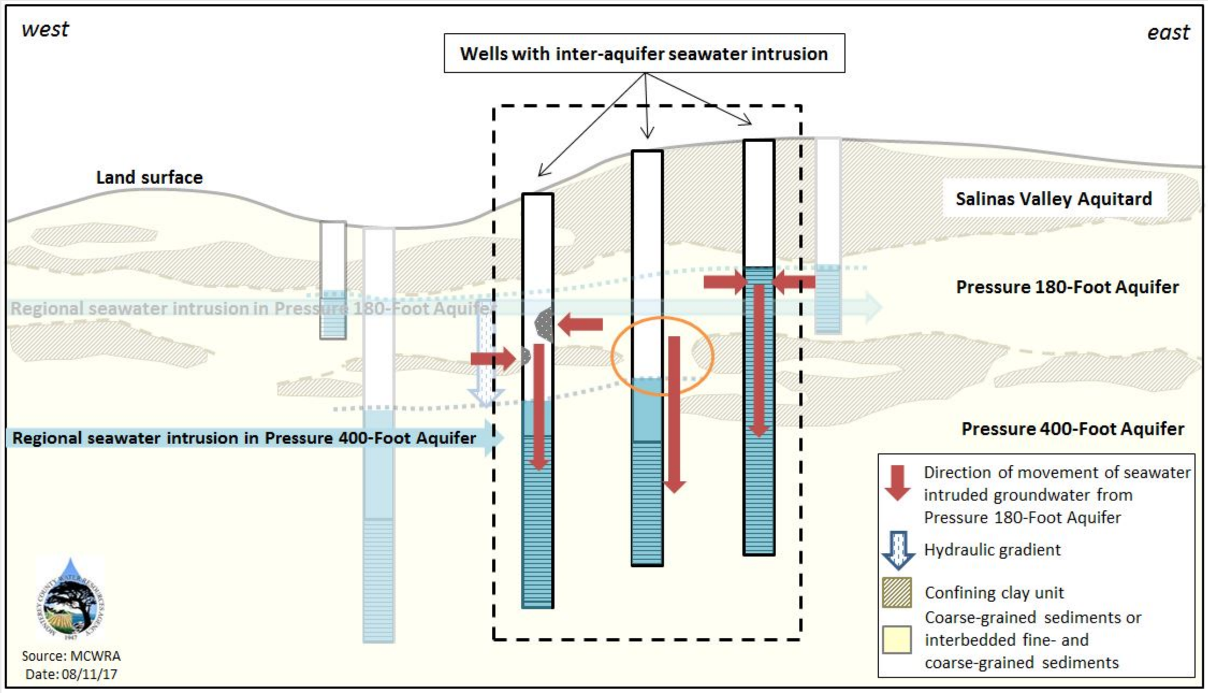

Figure 10G. Seawater intrusion would be detected at the three highlighted wells in the Pressure 400-Foot Aquifer, even though the regional seawater intrusion front has not yet reached them, as a result of movement of seawater intruded groundwater through conduits.

Figure 10 (continued) – Illustration of Inter-Aquifer Seawater Intrusion

Table 2 - Historical Estimated Acreage Overlying Seawater Intrusion

Water Year	Pressure 180-Foot Aquifer (acres advanced)	Total Acres Advanced in Pressure 180-Foot Aquifer	Pressure 400-Foot Aquifer (acres advanced)	Total Acres Advanced in Pressure 400-Foot Aquifer
1944	1,833	1,833	NAD*	NAD*
1959	NAD*	1,833	22	22
1965	5,839	7,672	NAD*	22
1975	3,973	11,645	3,695	3,717
1985	4,576	16,221	3,804	7.521
1990	NAD*	16,221	826	8,347
1993	3,596	19,817	311	8,658
1994	NOC†	19,817	NOC†	8,658
1995	NOC†	19,817	407	9,065
1997	1,802	21,619	896	9,961
1999	2,400	24,019	543	10,504
2001	761	24,780	499	11,033
2003	627	25,407	520	11,523
2005	1,768	27,175	359	11,882
2007	425	27,600	122	12,004
2009	191	27,791	93	12,097
2011	351	28,142	476	12,573
2013	NOC†	28,142	NOC†	12,573
2015	115	28,257	4,552	17,125

[a] The seawater intrusion front did not change discernably between 2011 and 2013, based on the coincidental position of the 2011 and 2013 500 mg/L chloride contours.
* = No Available Data (NAD)
† = No Observed Change (NOC)

2.3 Castroville Seawater Intrusion Project

The Castroville Seawater Intrusion Project (CSIP) is one component of the Monterey County Water Recycling Projects, the other being the Salinas Valley Reclamation Project, which began construction in 1995. CSIP started delivering recycled water and groundwater pumped from supplemental wells to agricultural fields in the Castroville area in 1998 (Figure 11). Beginning with operation of the Salinas River Diversion Facility (SRDF)[16] in 2010, CSIP also delivers treated surface water from the Salinas River. The water provided through CSIP allows for decreased pumping of groundwater near the coast.

A discussion of possible enhancements and expansion of CSIP is presented in Section 3 of this report.

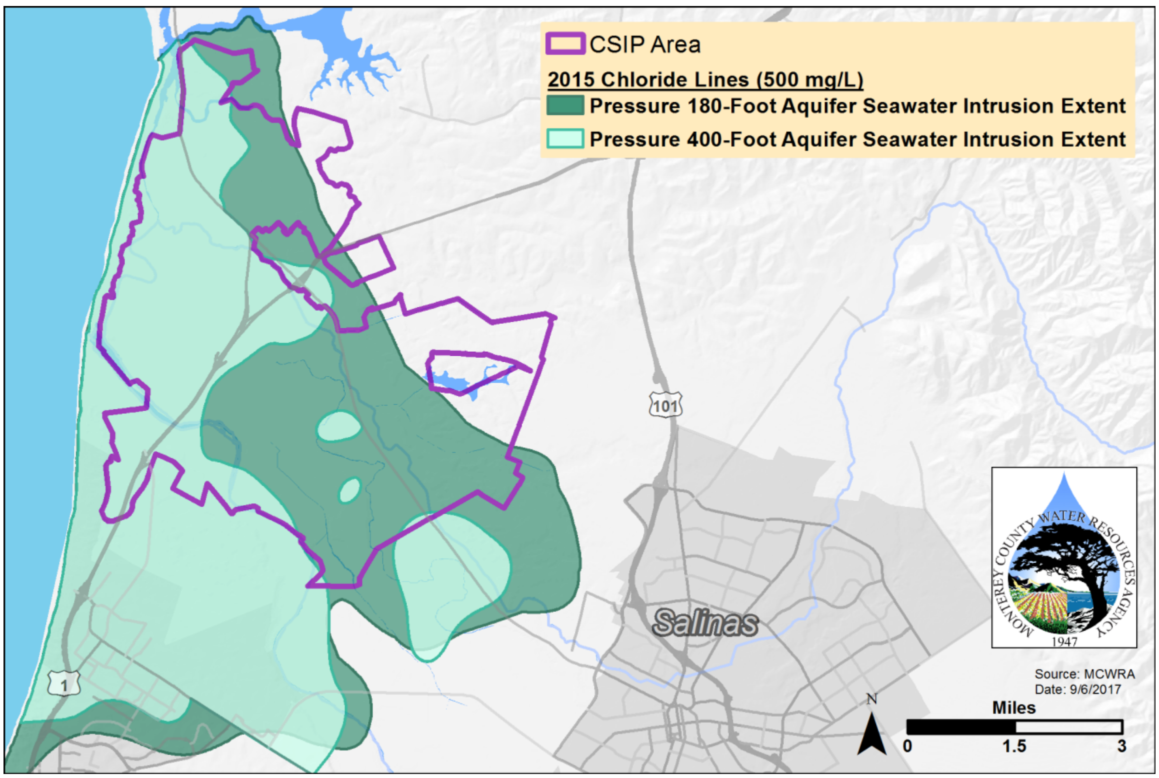

Figure 11- Boundary of the Castroville Seawater Intrusion Project Service Area (Zone 2B)

[16] The Salinas River Diversion Facility is a component of the Salinas Valley Water Project, along with the modification of Nacimiento Spillway and reoperation of the reservoirs.

Recommendations

Sections 3, 4, and 5 of this report discuss the six recommendations that staff is making with the aim to slow or halt seawater intrusion, and related impacts, in the Salinas Valley Groundwater Basin. The recommendations are grouped not in order of priority but by the primary aquifer or project area that will be influenced by the recommendation, as follows: Pressure 400-Foot Aquifer (Section 3); Well Destruction (Section 4); and, Deep Aquifers (Section 5).

Section 3 – Pressure 400-Foot Aquifer

3.1 Recommendations

The following three recommendations aim to cease activities having a strong likelihood of expanding the intrusion of seawater into remaining usable portions of the Pressure 400-Foot Aquifer:

1. An immediate moratorium on groundwater extractions from new wells[17] in the Pressure 400-Foot Aquifer[18] within an identified Area of Impact[19], except for the following use categories:
    a. Wells operating under the auspices of the Castroville Seawater Intrusion Project; and,
    b. Monitoring wells owned and maintained by the Agency or other water management agencies.

2. Enhancement and expansion of the Castroville Seawater Intrusion Project (CSIP) Service Area. The expansion should include, at a minimum, lands served by wells currently extracting groundwater within the Area of Impact.

3. Following expansion of the CSIP Service Area, termination of all pumping from existing Pressure 180-Foot or Pressure 400-Foot Aquifer wells within the Area of Impact, except for the following use categories:
    a. Municipal water supply wells;
    b. Wells operating under the auspices of the Castroville Seawater Intrusion Project; and,
    c. Monitoring wells owned and maintained by the Agency or other water management agencies

[17] "New well" is not intended to include (a) any well for which a construction permit has been issued by the Monterey County Health Department or (b) any well for which drilling or construction activities have commenced in accordance with a well construction permit issued by the Monterey County Health Department.

[18] Aquifer means: a water-bearing or saturated formation that is capable of serving as a groundwater reservoir supplying enough water to satisfy a particular demand, as in a body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs (Poehls and Smith, 2009).

[19] See Section 1.5 for a description of the Area of Impact. The Area of Impact is also depicted in Figure 4.

3.1.1 Area of Impact

As discussed in Section 1.5 of this report, the Agency has identified an Area of Impact. Non-intruded groundwater within the Area of Impact is considered to be vulnerable due to the presence of pathways and conduits for seawater intrusion (Figure 4).

There is a portion of the Area of Impact that is considered to be especially vulnerable because of the overlying seawater intrusion and the presence of conduits for inter-aquifer seawater intrusion. This is the portion of the Pressure 400-Foot Aquifer where seawater intrusion has not been detected but where it is overlain by seawater intrusion in the Pressure 180-Foot Aquifer. This focus area within the Area of Impact will be discussed further in the remainder of Section 3.

3.2 Background and Discussion

3.2.1 Hydrogeology

As discussed in Section 2.1.2, the Pressure 400-Foot Aquifer is one in a series of hydrogeologic units within the Area of Impact. Also of key importance to understanding conditions within the Pressure 400-Foot Aquifer are the Pressure 180-Foot Aquifer and the Pressure 180/400-Foot Aquitard.

In areas where groundwater within the Pressure 180-Foot Aquifer has become impaired due to seawater intrusion, the viability and sustainability of the underlying Pressure 400-Foot Aquifer depends in part upon the existence and integrity of hydraulic separation provided by the Pressure 180/400-Foot Aquitard. Figure 12 illustrates that the continuity of the Pressure 180/400-Foot Aquitard within the Area of Impact is highly variable and there are documented areas where the aquitard is thin or missing altogether (Todd, 1989 and Kennedy/Jenks, 2004). Within these areas of discontinuous aquitards the Pressure 180-Foot and Pressure 400-Foot Aquifers can be characterized as a single hydraulically continuous water-bearing unit lacking a separating aquitard.

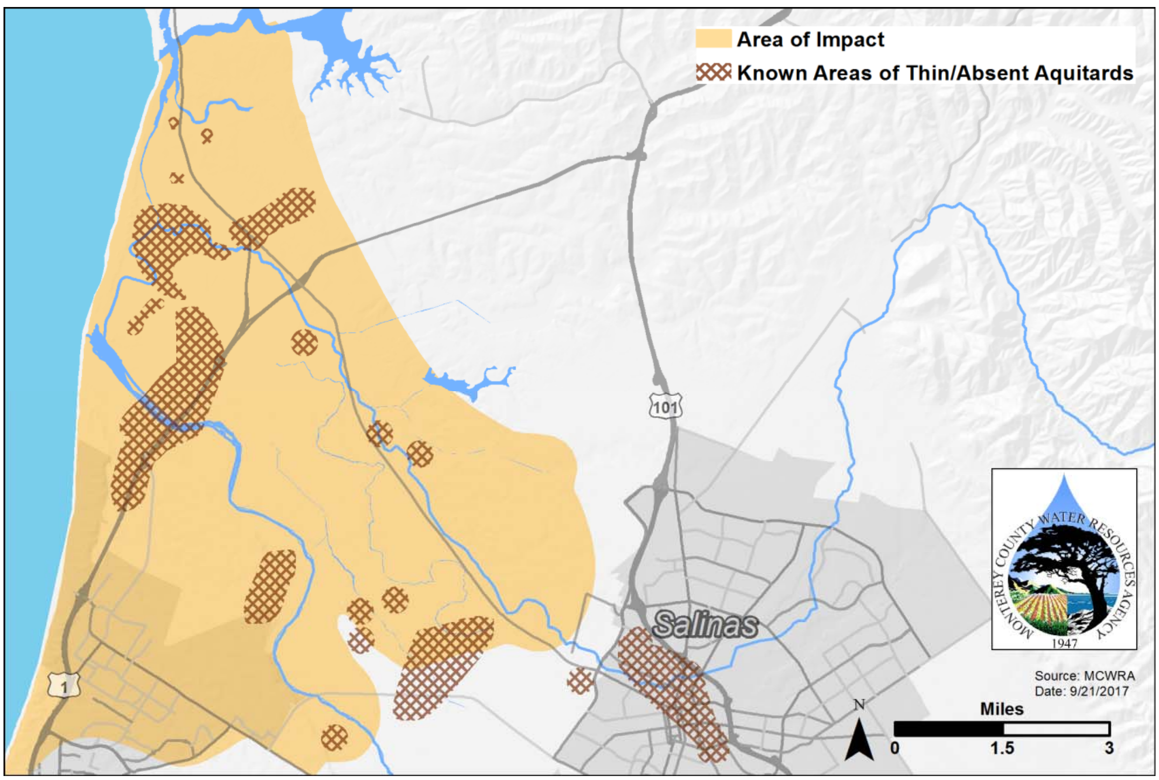

Figure 12 - Areas of Discontinuities in the Pressure 180/400 Foot Aquitard

3.2.2 Groundwater Extractions in the Pressure 400-Foot Aquifer

Groundwater extractions (pumping) have been reported to the Agency since 1993; however, the dataset is most comprehensive beginning in 1995.[20] Groundwater extraction data is available for 202 wells within the Area of Impact (Figure 4), with varying periods of record for the data at each well.

As shown in Table 3, groundwater extraction data is available for 123 wells that have reported groundwater extractions from the Pressure 400-Foot Aquifer. Another five wells within the Area of Impact are screened both in the Pressure 180-Foot and Pressure 400-Foot Aquifers, meaning that water from these wells comes from both aquifers. Some of the wells shown in Table 3 as "unknown" are likely pumping from the Pressure 400-Foot Aquifer as well. Figure 13 summarizes reported groundwater pumping totals from the Pressure 400-Foot Aquifer for wells in the Area of Impact since 1995.

Table 3 - Aquifer Assignments for Wells in the Area of Impact that Report Groundwater Extractions

Aquifer Unit	Number of Wells in Area of Impact Reporting Groundwater Extractions
Pressure 180-Foot Aquifer	36
Pressure 400-Foot Aquifer	123
Pressure 180-Foot and 400-Foot Aquifers	5
Deep Aquifers	12
Unknown[21]	26
TOTAL	**202**

Since 1995, annual pumping totals from wells in the Pressure 400-Foot Aquifer within the Area of Impact ranged from approximately 9,808 acre-feet in 2010, the first year of operation of the Salinas River Diversion Facility (SRDF), to 19,853 acre-feet in 1997, the year prior to the beginning of CSIP operations (Figure 13). Annual average reported pumping for the period 1995 to 2015 was 14,713 acre-feet; this annual average decreases to 13,905 acre-feet for the CSIP operational period (1998 to 2015).

The groundwater extraction totals shown in Figure 13 represent a reasonable minimum approximation of pumping from the Pressure 400-Foot Aquifer in the Area of Impact. Of note is the period of reduced pumping from 2010 through 2013 when the SRDF was operational.

[20] The Groundwater Extraction Management System (GEMS) program was initiated in 1993 with the adoption of Agency Ordinances No. 3663 and No. 3717. The first full year of the program (1994) did not have the same level of participation as has occurred in subsequent years, making 1995 a good starting point for analyzing long-term extraction data in Zones 2, 2A, and 2B.

[21] The Agency does not have well construction details for all wells that report groundwater extractions. It is impossible to know which aquifer a well is extracting water from without knowing the depth and screened/perforated interval(s) of the well.

Extractions from CSIP supplemental wells in the Pressure 400-Foot Aquifer account for an average of 30% of the annual pumping total in the Area of Impact. Groundwater from the Pressure 400-Foot Aquifer CSIP supplemental wells is blended with recycled water for distribution to subscribing water users within the CSIP area as a means of alleviating groundwater pumping near the coast (Figure 11). During the operational period of the Salinas River Diversion Facility (2010-2013), CSIP also used treated water from the Salinas River, which was combined with recycled water and groundwater extracted from the CSIP Supplemental wells. During the SRDF operational period, pumping from CSIP supplemental wells constituted an average of 20% of the overall pumping in the Area of Impact.

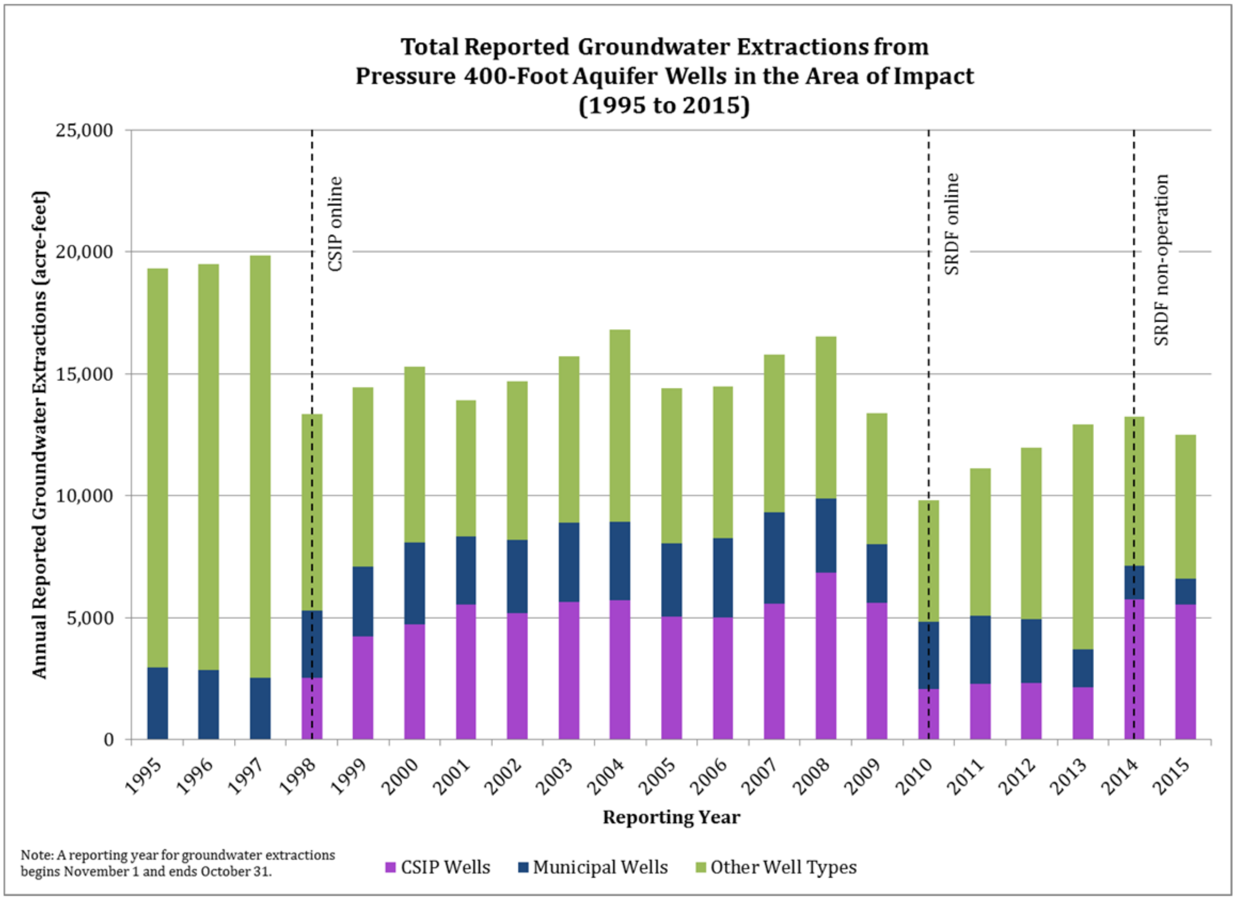

Figure 13 - Annual Groundwater Extractions from Pressure 400-Foot Aquifer Wells in the Area of Impact

3.2.3 Water Quality in the Pressure 400-Foot Aquifer

Historically, groundwater within the Pressure 400-Foot Aquifer was predominantly of superior quality, reflecting its recharge sources of deep percolation of rainfall, seasonal flows within the Salinas River and its tributaries, agricultural return flows, and its residence time as interflow within the alluvium of the Salinas Valley Groundwater Basin.

Historical groundwater extractions from the Pressure 400-Foot Aquifer exceed natural recharge and have created a landward hydraulic gradient, resulting in a pathway for regional seawater intrusion. Decades of seawater intrusion have resulted in increasing chloride concentrations near the coast in both the Pressure 180-Foot and Pressure 400-Foot Aquifers.

Native groundwater within the Pressure Subarea typically contains chloride at concentrations of about 50 mg/L and seawater has an average chloride concentration of 19,400 mg/L. The intruded portions of the Pressure 180-Foot and Pressure 400-Foot Aquifers can be thought of as transition zones within which seawater has encroached inland from the coast and mixed with native groundwater, resulting in an overall pattern of gradually increasing chloride concentrations, from approximately the landward edge of the Area of Impact to the coast.

Since the late 1940s the Agency has monitored and mapped a "seawater intrusion front," that is, the location in the transition zone at which intruding seawater has elevated chloride levels to 500 mg/L or greater. The newly published 2015 Seawater Intrusion map of the Pressure 400-Foot Aquifer illustrates the presence, for the first time, of three isolated areas or "islands" of intruded groundwater, beyond the contiguous seawater intrusion front (Figure 2 and Figure 14).

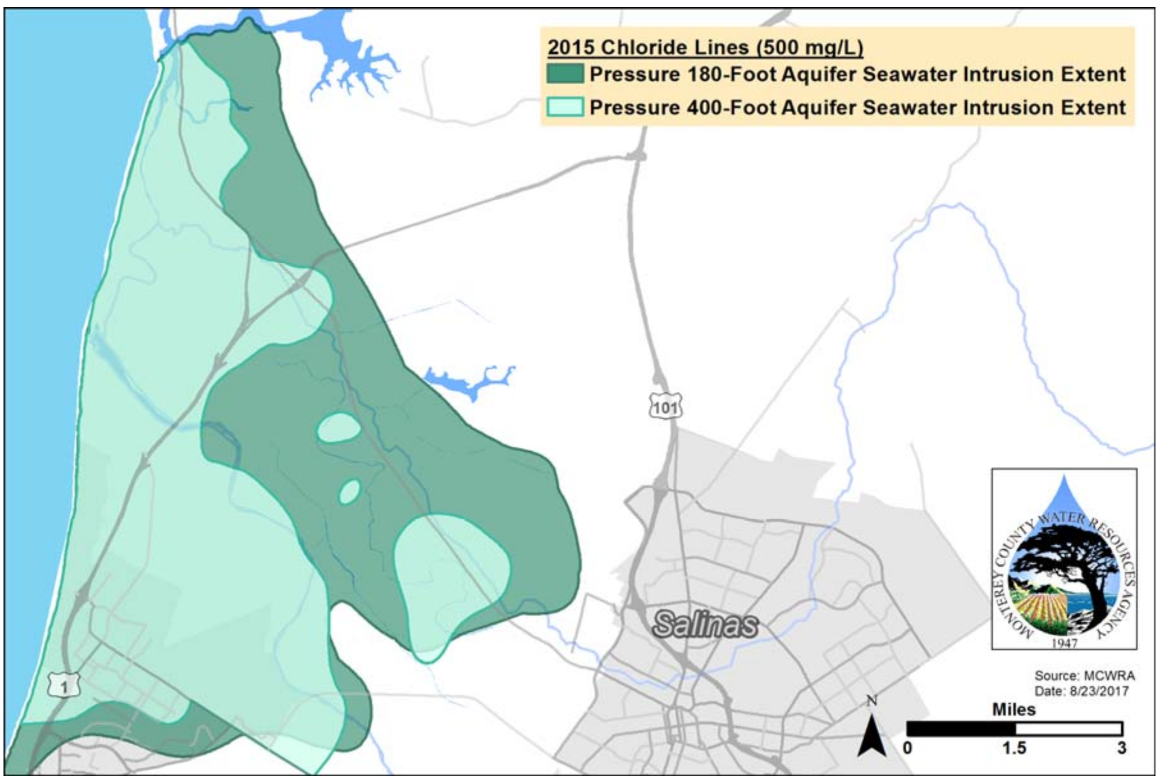

Figure 14 - 2015 Extent of Seawater Intrusion

3.2.4 Hydraulic Conditions Giving Rise to Seawater Intrusion

Groundwater elevation contour maps published by the Agency spanning the last two decades document a landward groundwater gradient from the coast towards Salinas and Spreckels in the

Pressure 400-Foot Aquifer.[22] Derived from depth-to-groundwater-level data collected by the Agency, these gradients persist not only during the peak pumping season (as revealed in August Trough Groundwater Level Contour Maps) but at times of reduced aquifer stress (as is evident in Fall Groundwater Level Contour maps). These seawater intrusion-inducing patterns of landward sloping groundwater levels are seen during periods of drought, such as in the groundwater contour maps created using data from 2013 and 2015, as well as during the full range of climatic year types, including wet periods (e.g. 1995 and 2011). These groundwater level patterns have continued into the operational period of the Salinas River Diversion Facility, as reflected in the 2011 and 2013 groundwater elevation contour maps (Appendix A).

Groundwater levels in the vicinity of the Area of Impact also exhibit a persistent vertical pattern in which water levels in the Pressure 400-Foot Aquifer are consistently lower than those in the Pressure 180-Foot Aquifer. This pattern defines a vertical downward gradient, a condition that encourages downward migration of groundwater through available conduits, and which is enhanced by groundwater pumping in the Pressure 400-Foot Aquifer.

3.3 Wells and Vertical Migration of Groundwater

3.3.1 Well Inventory

Agency well records that include location coordinates primarily consist of data that predates 1998. Based on a query of this data from the Area of Impact, staff was able to identify and locate 187 wells within and near the Area of Impact (Figure 15). Other wells have been installed in the Area of Impact since the last effort by the Agency to collect location data in the mid-1990s; however, many of these newer wells are not depicted in Figure 15 because the specific location of the wells is unknown. An Agency effort to obtain GPS coordinates for new wells has not been completed since the mid-1990s due to resource constraints.

Of the 187 wells with known locations, 10 are domestic, 3 are municipal water supply wells, and 4 are dedicated monitoring wells; the remaining wells are agricultural production wells. The majority of these wells draw water from the Pressure 400-Foot Aquifer, although 66 of the wells lack definitive information on aquifer of extraction or screen depth.

[22] Maps depicting groundwater elevation contours are available on the Water Resources Agency website here: http://www.co.monterey.ca.us/government/government-links/water-resources-agency/documents/groundwater-elevation-contours#wra

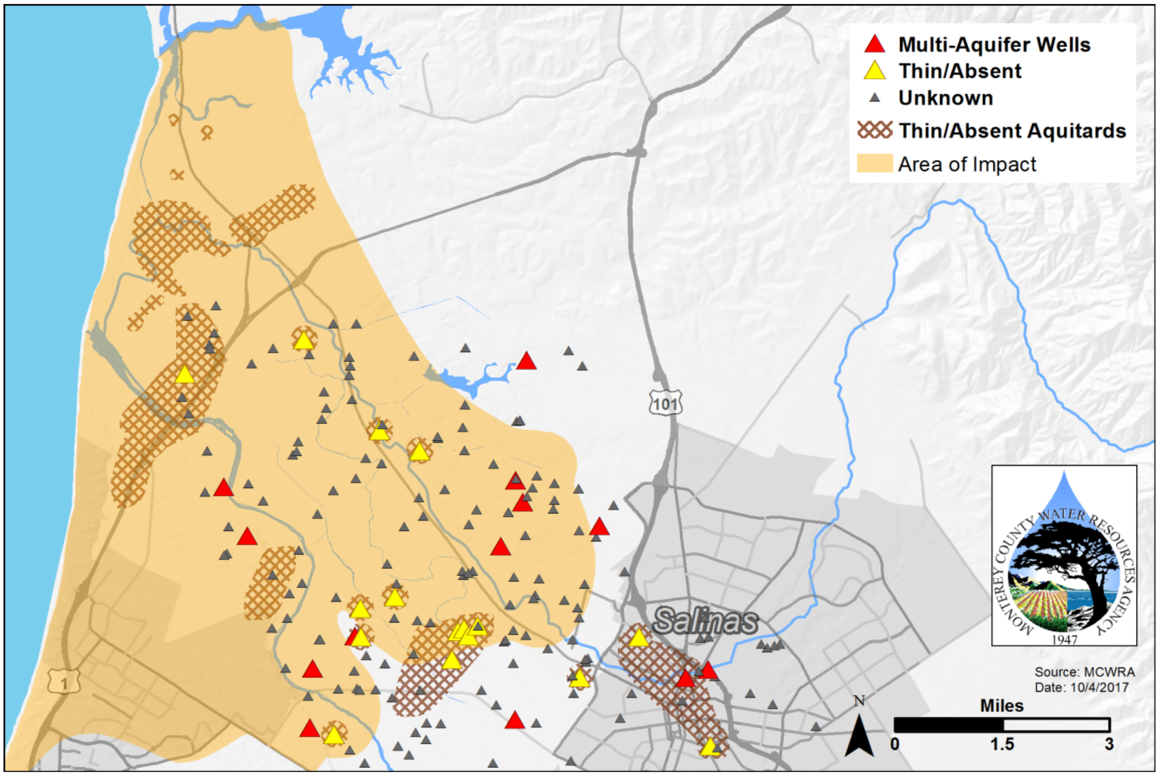

Figure 15 - Degree of Hydraulic Separation in Wells within and near the Area of Impact

3.3.2 Interpreting Hydraulic Separation

The 2015 Pressure 400-Foot Aquifer seawater intrusion map is the first published documentation by the Agency of isolated areas or "islands" of intruded waters beyond the seawater intrusion front (Figure 2). The presence of chloride concentrations less than 500 mg/L in groundwater between the seawater intrusion front and the islands, as well as between the islands themselves, and the documented presence of conduits as discussed in Section 2, suggest vertical migration of groundwater between the intruded Pressure 180-Foot Aquifer and the underlying Pressure 400-Foot Aquifer as a dominant pathway of seawater intrusion in these isolated areas of the Pressure 400-Foot Aquifer. Chloride concentrations in wells within and nearby the islands have been increasing for the past ten to fifteen years and reached the 500 mg/L threshold for the first time in 2015.

As part of the Agency's analysis of chloride data during development of the 2015 seawater intrusion maps, a detailed review of the 187 wells known to be located within the Area of Impact was conducted in an effort to fully understand potential pathways of seawater intrusion into the "chloride islands." That review, which focused on the vulnerable portion of the Area of Impact where the Pressure 400-Foot Aquifer is currently unintruded, revealed that there are at least 74 wells for which adequate hydraulic separation between the intruded Pressure 180-Foot and the Pressure 400-Foot Aquifers cannot be confirmed (Table 4).

Of these 74 wells, eight have lithologic logs indicating poor or no hydraulic separation; another seven have lithologic logs that have an inconclusive determination of hydraulic separation; and three others have well completion reports that document multiple aquifer construction enabling direct hydraulic communication between the intruded Pressure 180-Foot and the Pressure 400-Foot Aquifers. For the remaining 56 wells within this group, neither lithologic nor well construction data were available to determine the degree of separation between the aquifers at these locations.

An additional 25 Pressure 400-Foot Aquifer wells in the northern portion of the Area of Impact, near Castroville, have yet to be evaluated for hydraulic separation. At least one of these is an active well known to be screened in both the intruded Pressure 180-Foot Aquifer and in the Pressure 400-Foot Aquifer.

Continued pumping of wells contributes to the ongoing landward gradient of the groundwater levels. Additionally, with known conduits between the Pressure 180-Foot and Pressure 400-Foot Aquifers within the Area of Impact, downward migration of impaired Pressure 180-Foot Aquifer is exacerbated by groundwater pumping from Pressure 400-Foot Aquifer wells.

The newly mapped "intrusion islands" evident in the Pressure 400-Foot Aquifer, coupled with evidence of known conduits within and in close proximity to the Area of Impact, will result in the continued spatial and temporal spreading of impaired water within the Pressure 400-Foot Aquifer.

In some locations this will mean rapidly deteriorating water quality. Current groundwater level and chloride concentration trends suggest that without protective steps, the continued viability of the Pressure 400-Foot Aquifer in and near the Area of Impact is endangered.

Table 4 - Summary of Degree of Uncertainty Observed in Hydraulic Separation for Wells within the Area of Impact

Hydraulic Separation Category	Well Count in Area of Impact**	Well Count within 0.5 miles seaward of 2015 500 mg/L contour line	Well count within 0.5 miles landward of 2015 500 mg/L contour line	Total
No separation	4	1	1	6
Poor	4	1	2	7
Multi-aquifer well	3	1	2	6
Unknown*	56	10	24	90
Inconclusive	7	3	1	11
TOTAL	**74**	**16**	**30**	**120**

* "Unknown" includes wells for which a well log has not been located.

** The analysis of hydraulic separation at well locations was conducted only for wells in the portion of the Area of Impact where the intruded Pressure 180-Foot Aquifer overlies the unintruded Pressure 400-Foot Aquifer. This portion of the Area of Impact is considered to be particularly vulnerable.

3.3.3 Efforts to Limit Inter-Aquifer Hydraulic Communication

Through its role as a technical consultant to the Monterey County Health Department (Environmental Health Bureau) in the well permitting process, the Agency seeks to mitigate inter-aquifer migration of groundwater through implementation of well construction standards. Specifically, the Agency does not recommend construction of any production well (domestic, municipal, or agricultural) in an area where there is no hydraulic separation between the Pressure 180-Foot and Pressure 400-Foot Aquifers. Furthermore, at well sites where the aquitard is present, the Agency recommends that wells be constructed in a manner that ensures that water can be extracted from only one aquifer. This is achieved by the Agency providing review of site-specific geologic and geophysical data and well construction designs.

Despite these efforts, water quality data now show that regional impacts from groundwater pumping are overriding the preventative measures implemented on the basis of site-specific hydrogeology, allowing for continued inter-aquifer migration of groundwater and advancement of seawater intrusion.

3.4 Enhancement and Expansion of CSIP

The Castroville Seawater Intrusion Project (CSIP) delivers recycled water from the Salinas Valley Reclamation Project (SVRP), treated Salinas River water from the Salinas River Diversion Facility (SRDF), and groundwater from twelve supplemental wells to 12,000 acres of irrigated land in the Castroville Area in order to reduce groundwater pumping near the coast (Figure 11).

CSIP delivered 17,363 acre-feet of water in fiscal year 2016-2017[23] and, since deliveries began in 1998, an average of approximately 19,500 acre-feet has been delivered annually (Appendix B).

3.4.1 Enhancement of CSIP

Enhancement of CSIP involves optimization within the current service area boundary (Zone 2B, Figure 11) and would take the form of installing storage tanks capable of retaining water from the SRDF. Storage tanks would optimize operation of the SRDF by allowing surface water to be pumped during low-demand times and stored for later delivery, when demands are high. The installation of storage tanks would also assist with maintaining pressure in the CSIP delivery system and would reduce the need for the installation of any new supplemental wells.

Enhancement of CSIP would allow for more flexibility in the timing of SRDF deliveries and would provide the potential to reduce groundwater pumping from supplemental wells.

3.4.2 Expansion of CSIP

Expansion of CSIP could take many forms, all of which would involve enlarging the boundary of the service area. One possibility for expansion is the installation of new supplemental wells near Chualar, which would replace the groundwater pumping that, currently, occurs from supplemental wells in the Castroville and Salinas areas. Groundwater from the Chualar supplemental wells would

[23] Fiscal Year 2016-2017 covers the time period from July 1, 2016 to June 30, 2017.

be delivered via a pipeline, to meet irrigation demands in the expanded CSIP area. Irrigated lands between Chualar and the current Zone 2B boundary would simultaneously be brought into the expanded service area, offsetting groundwater pumping from those lands.

CSIP could also be expanded with a progressive build-out from the current service area toward Chualar, effectively "chasing" groundwater of good quality and moving south-southeast down the Salinas Valley ahead of the seawater intrusion front. Additional irrigated lands would be brought into the CSIP service area in a step-wise fashion with this approach.

Expansion of CSIP would have the benefits of further reducing groundwater pumping near the coast, stabilizing groundwater levels in and around the current service area, and building upon the benefits that have already been realized by CSIP, further contributing to the effort of slowing or halting the advancement of seawater intrusion.

3.5 Findings in Support of Recommendations

The recommendation for an immediate moratorium on new well construction in the Pressure 400-Foot Aquifer is necessary for the following reasons:

- Islands of high chloride concentrations (500 mg/L or greater) in the Pressure 400-Foot Aquifer have been documented.
- Water quality data collected in 2016 and 2017 show evidence of areal expansion of the islands of high chloride concentrations.
- Evidence of communication between the Pressure 180-Foot Aquifer and the Pressure 400-Foot Aquifer via conduits has been documented, including:
    - Areas of discontinuous aquitards;
    - Wells screened in multiple aquifers enabling vertical mixing;
    - Wells with potentially compromised casings penetrating both the Pressure 180-Foot and the Pressure 400-Foot Aquifers; and,
    - Uncertainty in the integrity of hydraulic separation within the Area of Impact at existing wells for which no construction or hydrostratigraphic information has been located.
- A persistent inland groundwater gradient exists, which allows for lateral or regional seawater intrusion.
- A constant downward groundwater gradient from the Pressure 180-Foot Aquifer toward the Pressure 400-Foot Aquifer exists within an area where the Pressure 400-Foot Aquifer is overlain by the intruded Pressure 180-Foot Aquifer. This downward gradient acts as a driving force for vertical migration or inter-aquifer seawater intrusion.
- Variation in the hydrogeology of the 180/400 Foot Aquifer Subbasin results in pathways within the Pressure 400-Foot Aquifer along which intruded water can flow.
- Groundwater pumping directly impacts the severity and areal extent of seawater intrusion, diminishing the quality and quantity of the usable groundwater supply in the Salinas Valley.

Enhancement and expansion of CSIP, the second recommendation, will improve the resiliency of the existing CSIP delivery system and allow for continued decreases in groundwater pumping near the coast. Implementing this recommendation, along with the third recommendation to terminate pumping in the Area of Impact following expansion of CSIP, will further reduce groundwater pumping in the Pressure 400-Foot Aquifer. The combination of these three recommendations has a high potential to positively impact the goal of slowing or halting seawater intrusion.

Section 4 – Destruction of Wells in the CSIP Area

4.1 Recommendation

The following recommendation aims to slow or halt seawater intrusion in the Pressure 180-Foot and Pressure 400-Foot Aquifers:

4. Initiate and diligently proceed with destruction of wells in Agency Zone 2B, in accordance with Agency Ordinance No. 3790, to protect the Salinas Valley Groundwater Basin against further seawater intrusion.

4.2 Background

4.2.1 Agency Ordinance No. 3790

On November 8, 1994 the Board of Supervisors of the Monterey County Water Resources Agency approved Ordinance No. 3790:

> *An ordinance of the Monterey County Water Resources Agency establishing the regulations for the classification, operation, maintenance and destruction of groundwater wells in MCWRA Zone 2B, to protect the Salinas Valley Groundwater Basin against further seawater intrusion.*

The ordinance provides "…for the destruction of abandoned wells, contaminated wells, wells that allow cross-contamination of aquifers in intruded areas, and other wells." The ordinance also establishes a procedure for the destruction of wells in Zone 2B, which is the area served by the Castroville Seawater Intrusion Project (CSIP) (Figure 11). As described in §1.02.05 of Ordinance No. 3790:

> *After the start-up of the Castroville Seawater Intrusion Project, no person shall own, operate, or maintain a well in Zone 2B if such well is required to be destroyed, in violation of such destruction requirement, and no person shall interfere with actions taken by the MCWRA to accomplish the destruction of such a well in conformity with this ordinance.*

Ordinance No. 3790 includes provisions for wells that are exempt from destruction, if they have not been abandoned and are not contaminated or cross-contaminating wells, including: supplemental, aquifer storage and recovery (ASR), domestic, commercial or industrial, monitoring, test, cathodic protection, and standby wells.

Ordinance No. 3790 further instructs that any well not exempt from destruction shall be destroyed by the Agency once (a) the Castroville Seawater Intrusion Project has established a satisfactory record of water deliveries, as determined by the Board of Directors, or (b) until at least one year after the start-up of the Castroville Seawater Intrusion Project, whichever occurs later. The cost of said well destructions shall be borne by the Agency (§1.03.05).

4.2.2 Impetus for Recommendation

As described previously in this report, the presence of wells in poor condition with potentially corroded well casings; wells constructed in multiple aquifers; and improperly constructed or abandoned wells serve as conduits for movement of seawater intruded groundwater between aquifers when coupled with a downward hydraulic gradient. Maps of the 2015 seawater intrusion contours depict newly emerging islands of groundwater with chloride concentrations exceeding 500 mg/L (Figure 2). Evidence discussed in Section 3 suggests that the cause of these islands in the Pressure 400-Foot Aquifer is inter-aquifer seawater intrusion facilitated by the presence of multiple conduits in an area with overlying seawater intrusion in the Pressure 180-Foot Aquifer and aided by a downward hydraulic gradient.

By initiating the destruction of wells in Zone 2B, as specified in Ordinance No. 3790, the Agency will begin eliminating some of the anthropogenic[24] conduits facilitating inter-aquifer seawater intrusion.

4.3 Prioritization of Wells for Destruction

One hundred forty-two (142) wells within Zone 2B have been identified as being subject to destruction under Ordinance No. 3790. This total does not include supplemental wells for the CSIP program or monitoring wells. Given the large number of wells that require destruction per Ordinance No. 3790, staff used three weighted criteria to rank the wells, the goal of which was to identify those wells whose destruction would yield the highest benefit. The criteria used and resulting prioritization are described below.

4.3.1 Criteria

Each well in Zone 2B that is subject to Ordinance No. 3790 was evaluated for:

- Degree of hydraulic separation between aquifers at the well location (i.e. thin/absent Pressure 180/400 Foot Aquitard or unimpaired aquitard);
- Well location relative to the seawater intrusion front in the Pressure 400-Foot Aquifer as defined by contour line demarking 500 mg/L chloride concentration; and,
- Chloride concentration at the well during the 2015 sampling event.

Wells were first categorized by which aquifer the well was screened in: Pressure 180-Foot or Pressure 400-Foot Aquifer. Each well was then ranked on the basis of the three categories listed above (Figure 16). Assigned points from all three categories were summed to derive a total for each well.

A relative value was assigned to each variation of the criteria, providing a mechanism for weighting. Multi-aquifer wells - those with screened intervals in both the Pressure 180-Foot and Pressure 400-Foot Aquifers - were assigned a total of 30 points; this effectively ensured that such wells would receive the highest possible point total and, therefore, priority ranking.

[24] Anthropogenic means: originating in human activity. (oxforddictionaries.com)

For wells screened in the Pressure 180-Foot Aquifer, priority was placed on destroying wells that would prevent further vertical migration of seawater intrusion. For example, wells in areas with a discontinuous aquitard[25] were ranked highly for destruction. Priority was also given to destruction of wells in areas where the Pressure 180-Foot Aquifer is not yet intruded. Wells with low chloride concentrations (<100 mg/L) were ranked highly because the integrity of the water quality in these areas can still be preserved by destroying potential locations for pumping or conduits for transport of seawater intruded groundwater. Wells in areas that were already intruded (chloride concentration >250 mg/L) were given low priority for destruction, because water quality in these locations has already deteriorated.

Wells screened in parts of the Pressure 400-Foot Aquifer that are especially vulnerable were given high priority for destruction. For example, destroying wells in locations where the Pressure 180-Foot Aquifer is intruded, but the underlying Pressure 400-Foot Aquifer is not yet intruded, was prioritized in an effort to prevent migration from the overlying, intruded, aquifer. Pressure 400-Foot Aquifer wells in locations with an aquitard present were ranked higher because, at these locations, the aquitard serves as a natural barrier that will reinforce the action of destroying the well. With regard to water quality, priority was placed on eliminating wells at the active seawater intrusion front (i.e. chloride concentrations between 100 and 250 mg/L).

In 1994, Staal, Gardner & Dunne, Inc. developed a Well Destruction Priority List for wells in the CSIP area (Appendix C). Some of the same criteria were used in this review, with the primary difference being that the prioritization described herein gives consideration to chloride concentrations and location of the well relative to the seawater intrusion front.

4.3.2 Ranking

Each of the 142 wells subject to destruction per Ordinance No. 3790 was prioritized for destruction using the criteria described above. Five categories of prioritization were used (urgent, high, medium, low, and minimal) with the final rankings distributed among the categories as shown in Table 5 and Figure 17.

Table 5 - Prioritization Categories and Well Counts for Destructions in Zone 2B

Prioritization Category	Number of Wells in Category
Urgent	8
High	27
Medium	39
Low	45
Minimal	23
TOTAL	**142**

[25] A map of areas with discontinuities in the Pressure 180/400 Foot Aquitard, based on Kennedy/Jenks (2004), Todd (1989) and shown in Figure 12, was used to determine the degree of hydraulic separation at the well location.

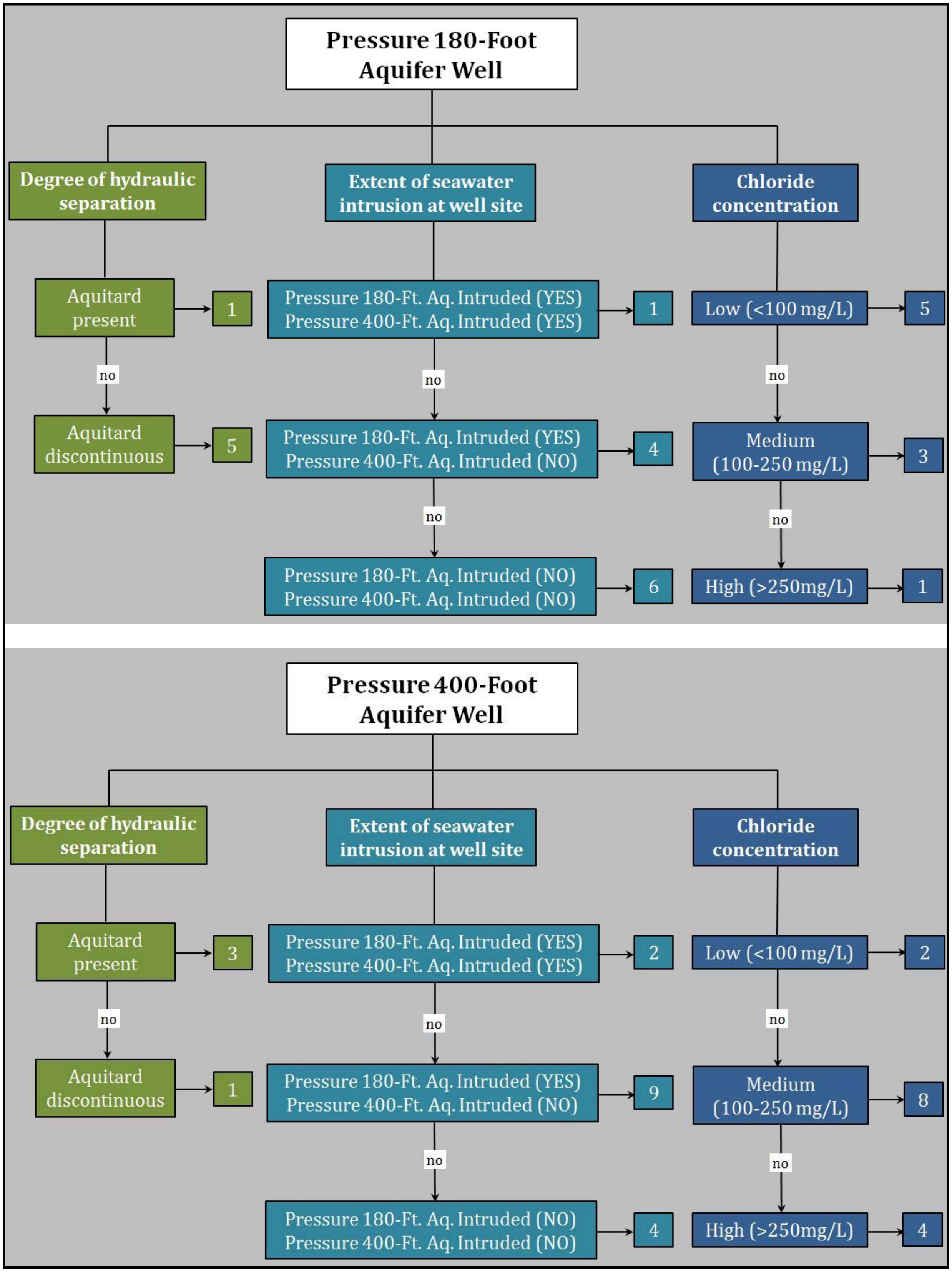

Figure 16 - Criteria and Weighting Approach for Well Destructions in Zone 2B

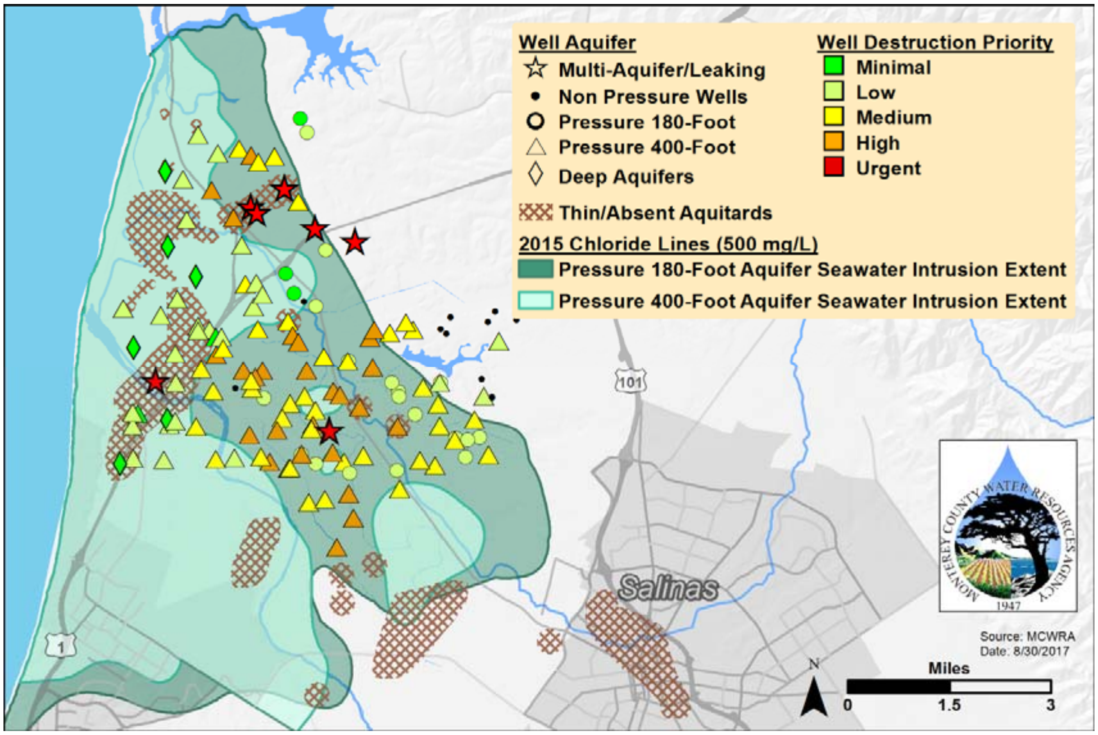

Figure 17 - Map of Wells Prioritized for Destruction in Zone 2B

4.4 Costs and Funding

Based on recent well destruction projects completed for the Agency, staff estimates that it will cost approximately $50,000 per well destruction. Using this as an average number, it would cost the Agency approximately $7,100,000 to destroy the 142 wells that have been identified in Zone 2B. If the Agency chooses to proceed with implementing this recommendation, staff suggests using a phased approach based on the well prioritization discussed previously. The cost to destroy wells under each prioritization category is shown in Table 6.

On August 4, 2016 the Agency submitted a pre-application to the State Water Resources Control Board for a grant from the Groundwater Quality Funding Program. Funds totaling $4,500,000 were requested for the purpose of destroying wells in Zone 2B. To date, grant funding to implement this project has not been secured.

Table 6 - Well Destruction Costs by Prioritization Category

Prioritization Category	Number of Wells	Cost to Destroy Wells
Urgent	8	$400,000
High	27	$1,350,000
Medium	39	$1,950,000
Low	45	$2,250,000
Minimal	23	$1,150,000
TOTAL	**142**	**$7,100,000**

Section 5 – Deep Aquifers of the 180/400 Foot Aquifer Subbasin

5.1 Recommendations

The following recommendations are intended to cease activities that have a strong likelihood of increasing vertical migration of seawater-intruded groundwater into the Deep Aquifers of the 180/400 Foot Aquifer and Monterey Subbasins:

5. An immediate moratorium on groundwater extractions from new wells within the entirety of the Deep Aquifers of the 180/400 Foot Aquifer and Monterey Subbasins until such time as an investigation of the Deep Aquifers is completed and data pertaining to the hydraulic properties and long-term viability of the Deep Aquifers are available for knowledge-based water resource planning and decision making.
    a. Monitoring wells, public agency wells, municipal water supply wells, wells for which a construction permit has already been issued, and well repairs should be considered for exemption from this recommendation.
    b. The moratorium should include a prohibition of:
        i. Replacement wells, unless it can be demonstrated that the installation of such a well will not result in further expansion of the seawater intrusion front; and,
        ii. Deepening of wells from overlying aquifers into the Deep Aquifers, deepening of wells within the Deep Aquifers, and other activities that would expand the length, depth, or capacity of an existing well.

6. Initiate and diligently proceed with an investigation to determine the long-term viability of the Deep Aquifers.

5.2 Background and Discussion

5.2.1 Nomenclature

As defined by the California Department of Water Resources, the Salinas Valley Groundwater Basin is comprised of eight subbasins, one of which is called the 180/400 Foot Aquifer. The extent of the 180/400 Foot Aquifer Subbasin approximately coincides with the area referred to by the Agency as the Pressure Subarea. The Monterey Subbasin, also defined by DWR, overlaps with the western edge of the Pressure Subarea.

Within the 180/400 Foot Aquifer and Monterey Subbasins, there are multiple water-bearing units (aquifers) interspersed with confining clay layers (aquitards) that, generally speaking, result in zones that are hydraulically separated from one another. The deepest of these aquifers underlies the Pressure 400-Foot Aquifer and has, historically, been referred to as the "800-Foot Aquifer," "900-Foot Aquifer," "1000-Foot Aquifer," "1500-Foot Aquifer," "Pressure Deep Aquifer", "deep zone," and "deep aquifer" (Feeney and Rosenberg, 2003 and Kennedy/Jenks, 2004). For the remainder of this report, the term "Deep Aquifers" will be used to refer to the water-bearing zones in the 180/400 Foot Aquifer Subbasin underlying the Pressure 400-Foot Aquifer.

Historically, a set of terms has been used to refer to aquifer units in the Salinas Valley, despite the fact that the terminology is not necessarily consistent with geologic depositional units. For example, the Paso Robles Formation, which is derived from sediments that were shed from the uplifting Santa Lucia and La Panza Ranges, is associated in the Pressure 180/400 Foot Aquifer Subbasin with both the lower portion of the Pressure 400-Foot Aquifer and the upper portion of the Deep Aquifers.

5.2.2 Geology and Hydrostratigraphy of the Deep Aquifers

The Deep Aquifers of the Pressure Subarea are confined by an aquitard that can be several hundred feet thick (Kennedy/Jenks, 2004).

Studies of the deepest hydrostratigraphic unit of the 180/400 Foot Aquifer Subbasin, historically referred to as the Pressure Deep Aquifer, indicate that it actually consists of two units which, at least near the coast, are hydraulically isolated from one another. The uppermost unit in the Deep Aquifers consists of continental deposits of the Paso Robles formation while the lower unit of the Deep Aquifers is associated with the marine Purisima Formation (Feeney and Rosenberg, 2003). The Purisima Formation has been mapped as being exposed on the southwestern side of the Monterey submarine canyon (Hanson et al., 2002).

Geologic cross sections created by Feeney and Rosenberg (2003) in the vicinity of Marina illustrate the relationship of these units and have been included as Appendix D. The formations comprising the Deep Aquifers are underlain by the minimally- to non-water bearing Monterey shale, an unnamed sandstone, and granitic basement.

5.2.3 Spatial Extent of the Deep Aquifers

Information on the Deep Aquifers is scant and what data exist are concentrated largely near the coast, where the most wells have been drilled into the Deep Aquifers (Figure 18). The Deep Aquifers have been mapped at locations as far inland as the south-southeast edge of the city of Salinas (Kennedy/Jenks, 2004). However, the geologic units that comprise the Deep Aquifers – the Paso Robles and Purisima formations – are present throughout the 180/400 Foot Aquifer Subarea. Formations comprising the Deep Aquifers occur closer to the surface with increasing distance toward the southern Salinas Valley, i.e. with the transition into the Forebay Subarea (Brown and Caldwell, 2015).

5.2.4 Wells in the Deep Aquifers

The use of the Deep Aquifers for groundwater production has been driven by the need to drill deeper in order to avoid seawater intrusion, with wells being installed to subsequently deeper elevations with fresh-water-bearing materials (Feeney and Rosenberg, 2003). Most available hydrogeologic data on the Deep Aquifers have been obtained through well drilling activities and related well or aquifer testing rather than through an intentional aquifer-wide study. Wells of all types have been installed in the Deep Aquifers, including production wells for agricultural purposes; domestic, industrial, and municipal water supply wells; and monitoring wells.

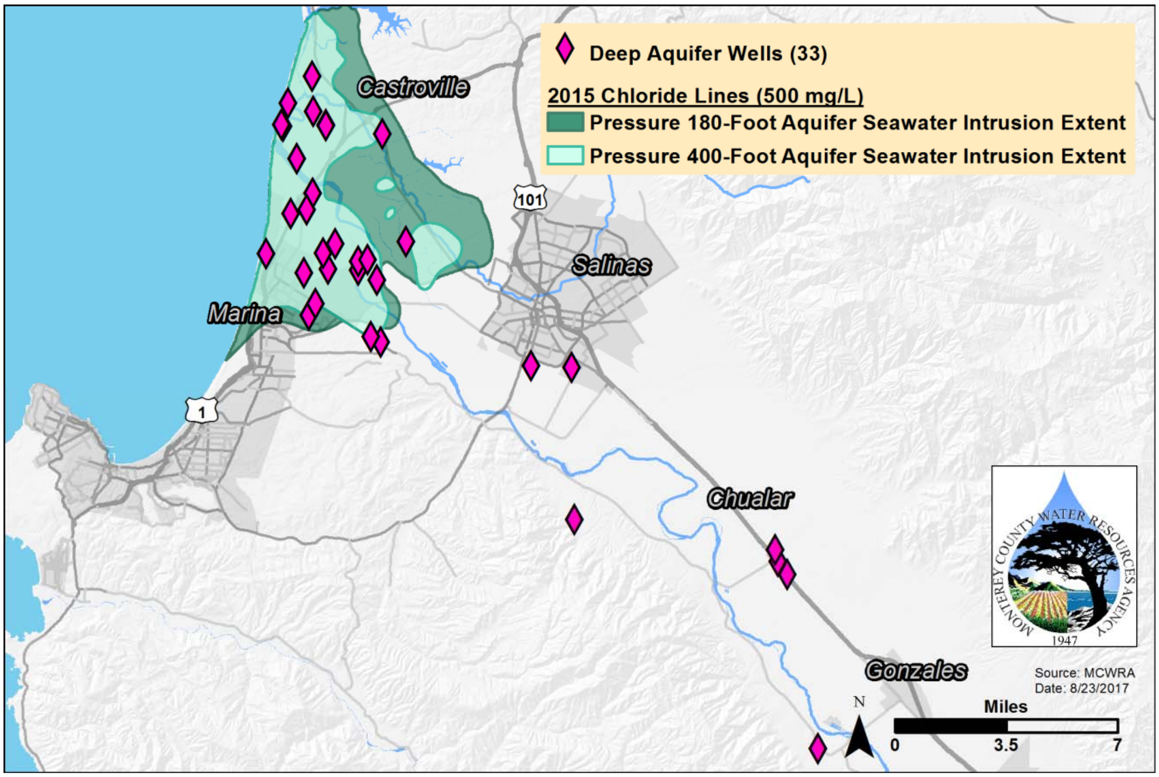

Figure 18- Wells in the Deep Aquifers

5.2.5 Well Installation History in the Deep Aquifers

The first production well in the Deep Aquifers was installed in 1974. As of August 1, 2017, a total of 41 wells have been installed in the Deep Aquifers: 33 production wells and 8 monitoring wells (Figure 19). One of the production wells was destroyed in 2004, so 40 wells remain in the Deep Aquifers at present. Of the 32 existing production wells, 18 are agricultural wells, 7 are municipal wells, 3 are residential wells, 3 are industrial wells, and one has an unknown usage.

Well Completion Reports for wells in the Deep Aquifers are provided in Appendix E and a table detailing installation dates, depths, and well types for the Deep Aquifers can be found in Appendix F.

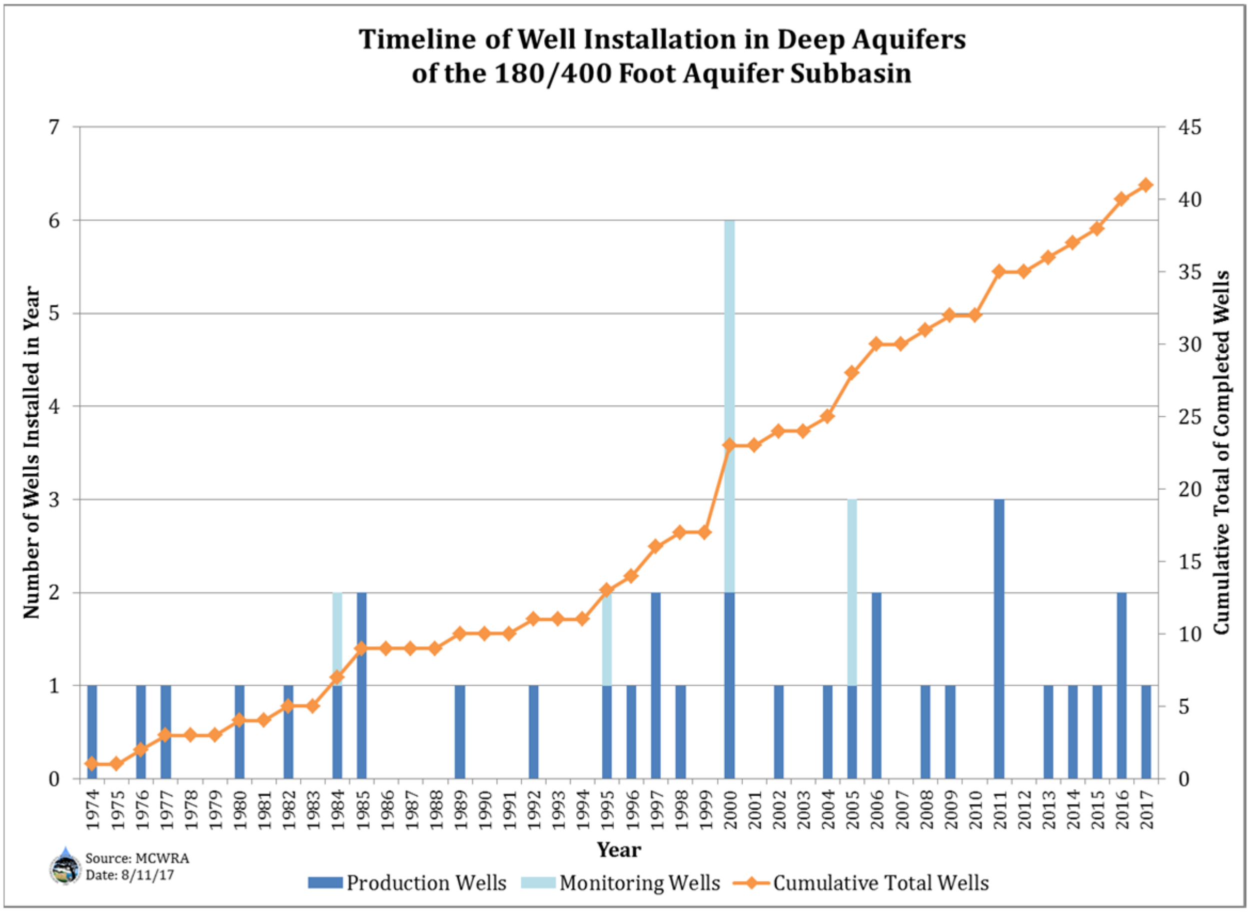

Figure 19 - Timeline of Well Installation in Deep Aquifers of the 180/400 Foot Aquifer Subbasin

5.2.6 Trends in Well Construction in the Deep Aquifers

Since 1995, wells have been installed in the Deep Aquifers with more regularity – approximately one well per year, as shown in Figure 19. Analysis of agricultural production well depths over time suggests that there is a strong correlation between the age of a well, particularly for the period from 1990 to present, and depth of the well (Figure 20). Specifically, for the period 1990 to 2017, newer agricultural production wells are likely to be deeper at a statistically significant level (P value = 0.02).

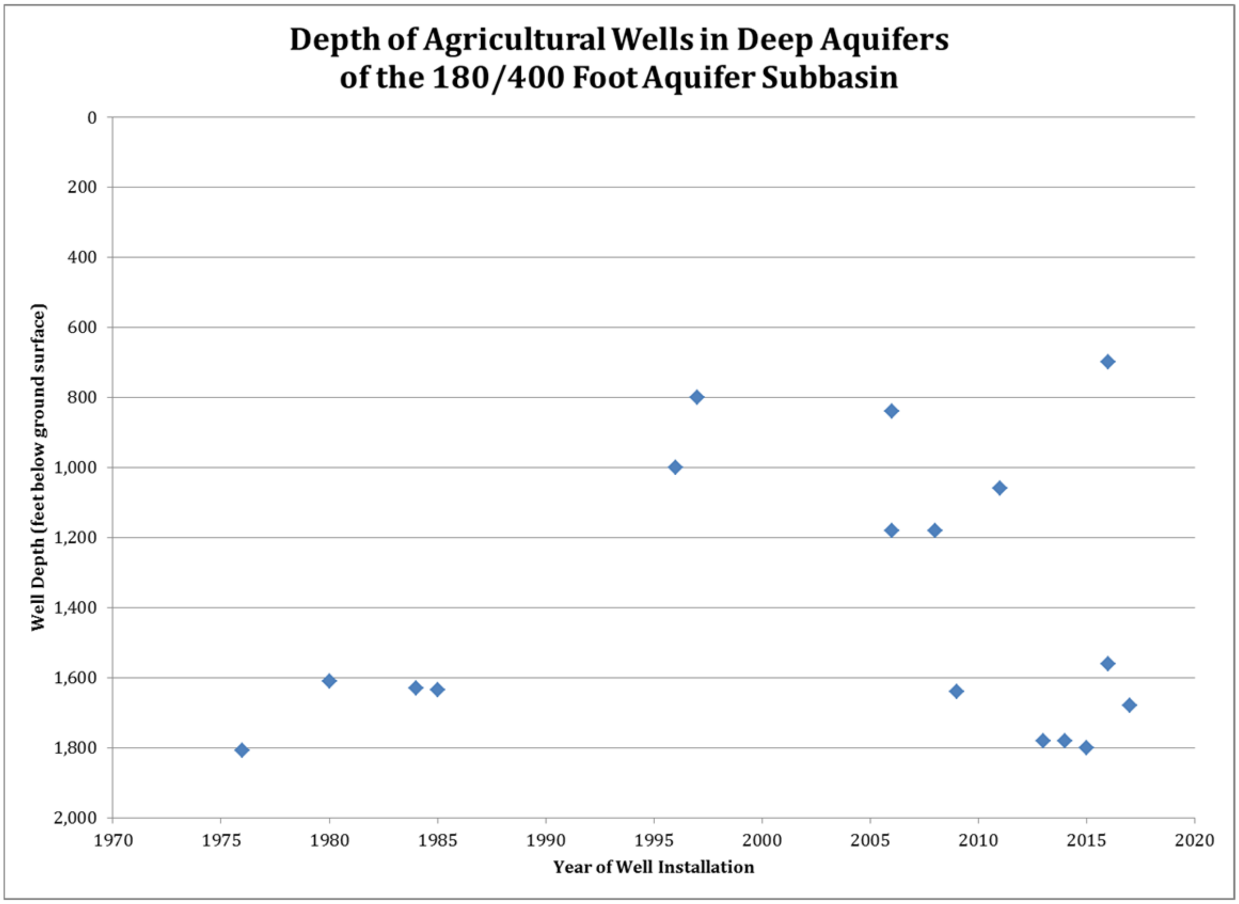

Figure 20 - Depth of Agricultural Wells in Deep Aquifers of the 180/400 Foot Aquifer Subbasin

5.2.7 Groundwater Levels in the Deep Aquifers

The Agency currently monitors groundwater levels at thirteen locations in the Deep Aquifers with varying frequency. Five of the groundwater level data collection points are monitoring wells which are equipped with continuously-recording pressure transducers, which log water levels on an hourly basis. The remaining eight groundwater level data collection points are production wells manually monitored on either a monthly (seven wells) or annual (one well) basis.

As is the case with the Pressure 180-Foot and Pressure 400-Foot aquifers, groundwater levels in the Deep Aquifers are generally below sea level and below the ground surface throughout the year. This contrasts sharply with some of the earliest groundwater level data from the Deep Aquifers, recorded shortly after construction of municipal and agricultural production wells, which document flowing artesian conditions near the coast between 1977 and 1980. The Agency began programmatic monitoring of groundwater levels in the Deep Aquifers in 1983, shortly before the last documented occurrence of flowing artesian conditions in February, 1984.

An analysis of average changes in groundwater levels from a subset of wells in the Deep Aquifers near the coast indicates that groundwater levels generally declined until the Castroville Seawater Intrusion Project (CSIP) began operations in 1998. Following startup of CSIP, groundwater levels in the Deep Aquifers rapidly increased and then leveled off until approximately 2006, when groundwater levels began to decline once again (Figure 21).

To date, seawater intrusion has not been documented in the Deep Aquifers, even though groundwater levels in the Deep Aquifers are consistently below sea level. This lack of seawater intrusion in the Deep Aquifers may be due, at least in part, to the geologic setting (Feeney and Rosenberg, 2003).

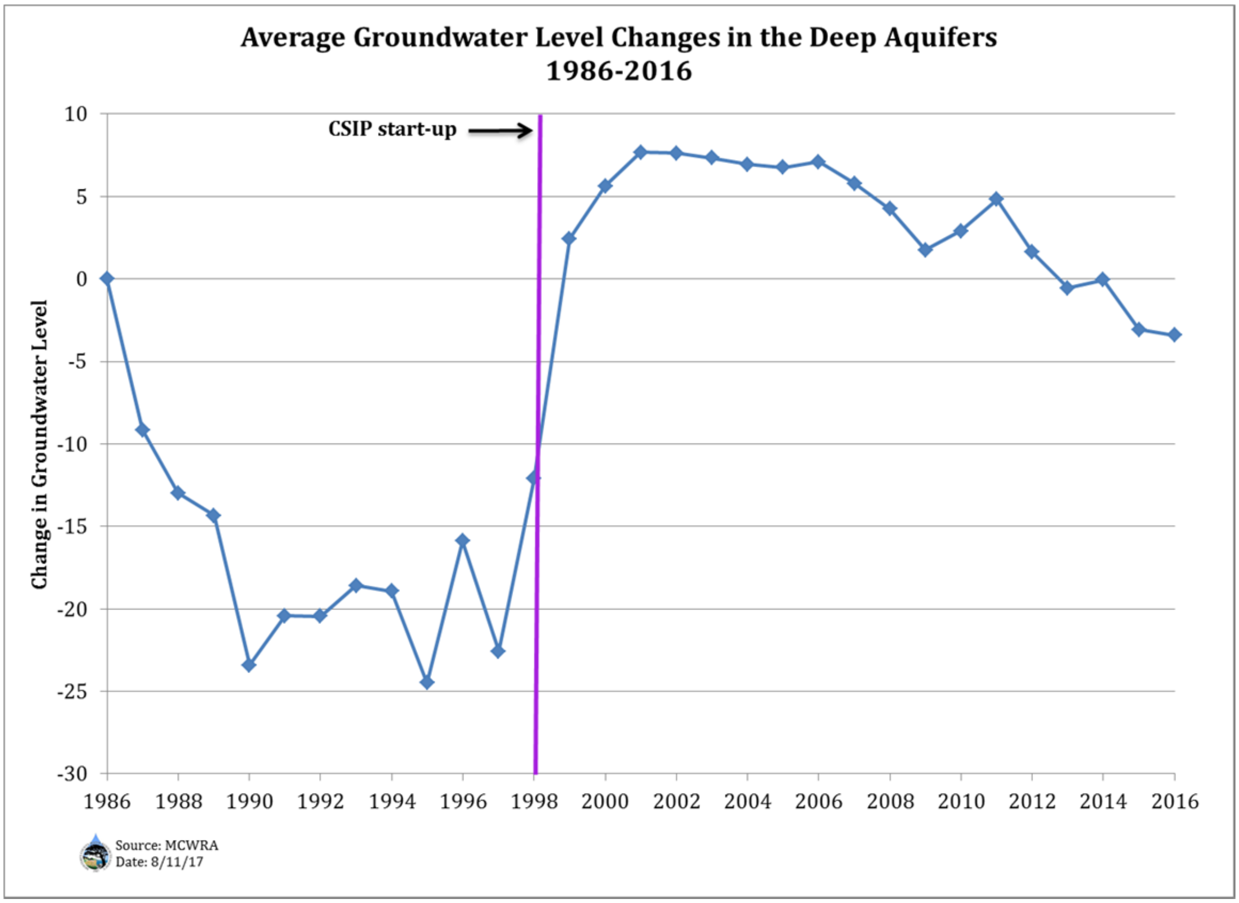

Figure 21 - Average Groundwater Level Changes in the Deep Aquifers (1986-2016)

5.2.8 Groundwater Quality in the Deep Aquifers

Water quality in the Deep Aquifers has been monitored by the Agency since 1976. Data are collected during two sampling events that occur annually in the summer. Samples are collected from seventeen wells in the Deep Aquifers and analyzed for major cations and anions.

Native groundwater in the Deep Aquifers has a distinct character, with a higher pH than groundwater in the overlying aquifers, relatively low calcium and high sodium concentrations, and an elevated temperature. The Piper diagram in Figure 22 illustrates the similarities in the chemical compositions of native groundwater in the Pressure 180-Foot and Pressure 400-Foot Aquifers (green and blue symbols), and how both are distinct from the chemistry of native groundwater in the Deep Aquifers (red symbols). All three have a chemical composition that is discernable from seawater (black symbols).

The low calcium levels in water from the Deep Aquifers are illustrated on the lower left-hand triangle, where water from the Deep Aquifers plots in the extreme lower right corner of the triangle (calcium levels are in the single-digits in these samples). The alkalinity of water in all of the aquifers is similar, as demonstrated by the lower right-hand triangle on the Piper diagram that displays anion data and shows a cluster of data points from wells in all of Pressure aquifers.

While no seawater intrusion has been detected during the forty-two years that the Agency has been monitoring water quality in the Deep Aquifers, existing water quality data provides a valuable baseline for ongoing comparisons and will allow the Agency to observe changes in water quality if they occur.

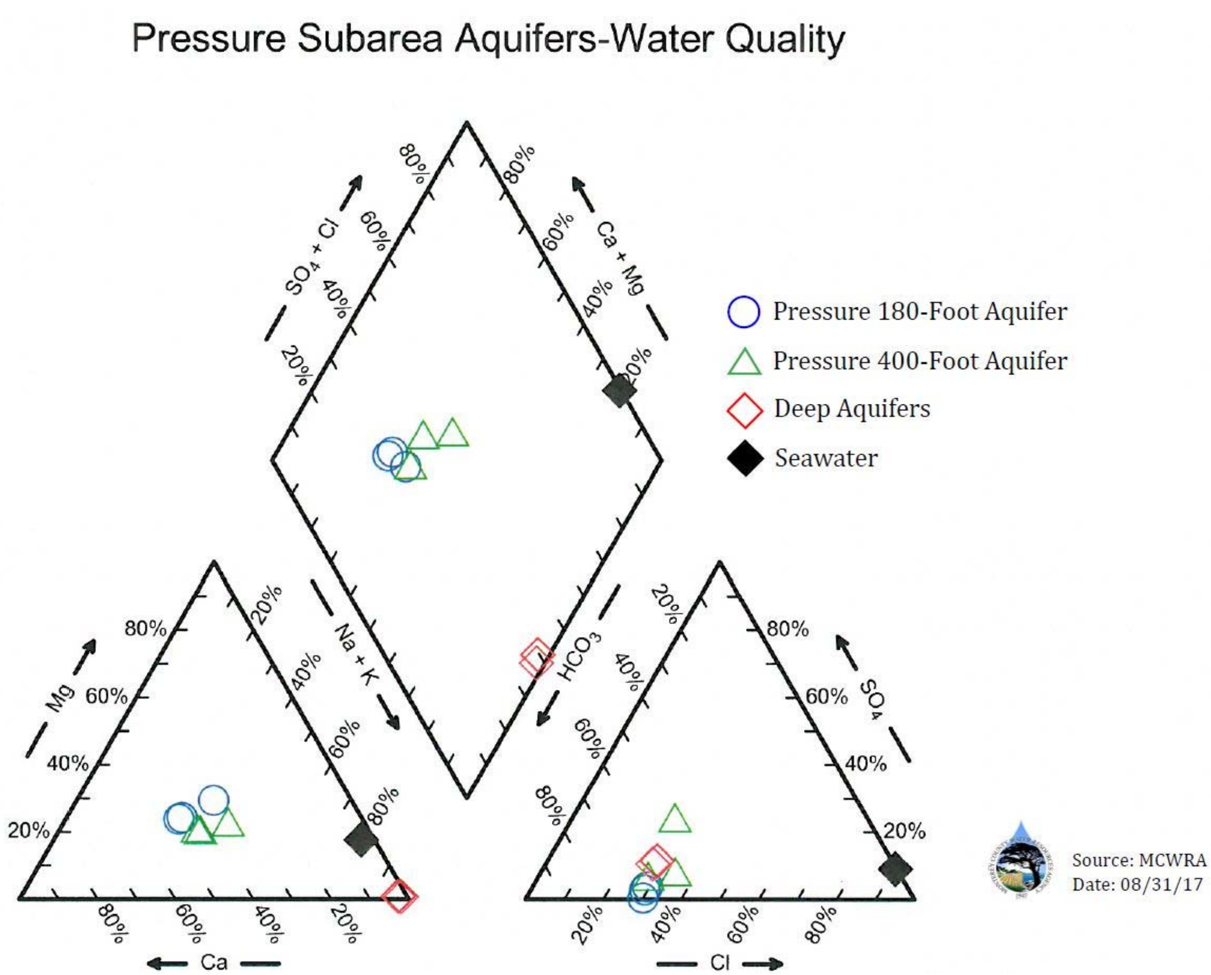

Figure 22 - Piper Diagram of Native Water Quality in Pressure Subarea Aquifers

5.2.9 Extraction from Wells in the Deep Aquifers

The Agency receives data on groundwater extractions from wells in the Deep Aquifers as part of its Groundwater Extraction Management System (GEMS) program. These data, which exist from 1993 to present, indicate that groundwater pumping in the Deep Aquifers decreased for a short period following startup of CSIP in 1998 (Figure 23). However, since 2002, total annual pumping from the Deep Aquifers has been generally increasing as more wells are installed. Total annual extractions from the Deep Aquifers, for the period 1995 through 2016, range from 2,151 acre-feet (in 1999) to 8,901 acre-feet (in 2016).

Groundwater pumping from wells in the Deep Aquifers is thought to be supported primarily by leakage from the overlying aquifer system, i.e. the Pressure 180-Foot Aquifer and Pressure 400-Foot Aquifer (Feeney and Rosenberg, 2003). Some groundwater pumping is derived from depletion of groundwater storage, but hydraulic properties of the Deep Aquifers (specifically storage coefficients) suggest that while some groundwater may come from storage immediately following the onset of pumping a well, very little groundwater can be removed from storage over time. Therefore, increases in groundwater pumping in the Deep Aquifers will likely be supported by increased leakage from the overlying aquifers (Feeney and Rosenberg, 2003).

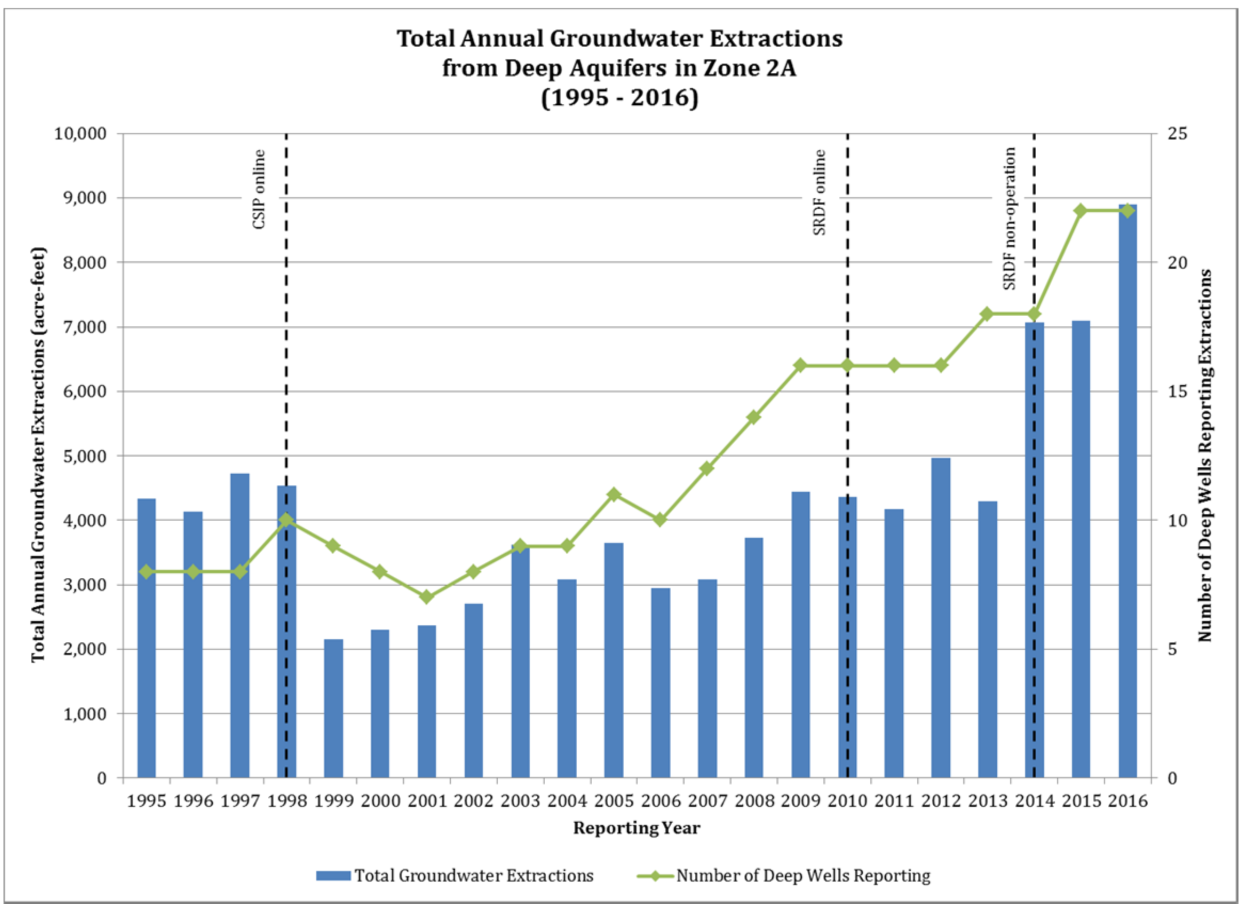

Figure 23 - Total Annual Groundwater Extractions from Deep Aquifers in Zone 2A (1995-2016)

5.2.10 Recharge and Storage in the Deep Aquifers

Groundwater recharge in the Deep Aquifers is theorized to occur through three primary sources: infiltration from overlying aquifers, surface exposure of the geologic formations (outcrops), and subterranean inflow from the Forebay Aquifer Subbasin.

The Purisima Formation does not outcrop on land in Monterey County, so recharge to that layer is primarily through leakage from overlying aquifers. The other stratigraphic unit comprising the Deep Aquifers, the Paso Robles Formation, is exposed on land in Monterey County. However, even in the locations where it is exposed at the surface, precipitation is minimal (WRIME, 2003). In most places, the Paso Robles is overlain by alluvium and the Aromas Sands, which correlate with the Pressure 180-Foot and Pressure 400-Foot Aquifers. Data from aquifer tests in the Marina area suggest that groundwater extractions from both the Paso Robles and Purisima are derived primarily from leakage through the overlying aquifers.

Groundwater modeling performed using the Salinas Valley Integrated Groundwater Surface Water Model (SVIGSM) suggests that increased pumping the Deep Aquifers will lead to increased vertical flow from the overlying aquifers (WRIME, 2003).

Recharge to the Deep Aquifers from subterranean flow from the adjacent Forebay Aquifer Subbasin is theorized on the basis of groundwater levels and connectivity of geologic formations but neither a rate nor route of recharge has been studied in detail.

A range of isotope analyses were performed on water samples collected from a series of wells in the Marina area as part of a 2002 study by the U.S. Geological Survey. Analysis of oxygen and deuterium in water from monitoring wells in the Deep Aquifers suggest that, unlike the upper aquifer system (Pressure 180-Foot and Pressure 400-Foot Aquifers), water in the Deep Aquifers was not recharged under current climatic conditions. Furthermore, tritium and carbon-14 analyses of water from the Deep Aquifers indicates that it is “old” water, recharged thousands of years before present (Hanson et al., 2002).

A 1983 report by Thorup estimated that the Pressure Deep Aquifer receives 65,500 acre-feet of recharge per year, but no other estimates of a volume of recharge have been published. The same 1983 report estimated that the Deep Aquifers contained approximately 4.6 million acre-feet of usable groundwater (Feeney and Rosenberg, 2003).

5.2.11 Data Gaps in Knowledge of the Deep Aquifers

In general, additional geologic and geochemical investigations are needed to determine whether, how, and to what extent the Deep Aquifers are being actively recharged (Hanson et al., 2002). As shown in Figure 18, wells in the Deep Aquifers are clustered fairly close to the coast. A more representative and areally extensive monitoring network is necessary to characterize inland portions of the Deep Aquifer. Further aquifer testing and resultant determination of hydraulic parameters of the Deep Aquifer are also needed.

5.3 Findings in Support of Recommendations

- WRIME (2003) and Feeney and Rosenberg (2003) suggest that the predominant source of recharge to the Deep Aquifers is leakage from the overlying Pressure 180-Foot and Pressure 400-Foot Aquifers. Both of these aquifers have extensive areas of documented seawater intrusion overlying the Deep Aquifers. Continued pumping, and especially increased pumping, in the Deep Aquifers has the potential to induce additional leakage from the impaired overlying aquifers.

- The recommendation to prohibit construction of new wells in the Area of Impact and, following the enhancement and expansion of CSIP, to cease groundwater pumping within the Pressure 400-Foot Aquifer in the Area of Impact, has the potential to result in increased pumping in the Deep Aquifers. History has shown that once well construction and/or pumping is prohibited in a given area, people are very likely to drill wells to the next deepest water-bearing zone which, in this case, would be the Deep Aquifers. The construction and pumping of more wells in the Deep Aquifers will induce further leakage from the impaired overlying aquifers (Pressure 180-Foot and Pressure 400-Foot Aquifers), potentially degrading the water quality of the Deep Aquifers.

- Isotope analysis of water from the Deep Aquifers indicates that it is not derived from recent recharge (Hanson et al., 2002). Though stored groundwater may not be the primary source of current extractions from the Deep Aquifers, continued pumping of this old water represents mining of a groundwater resource.

- Scant data exists on the hydraulic properties of the Deep Aquifers. The areal extent, quantified rates of recharge, and estimates of water available for extraction are all topics that are poorly understood when it comes to the Deep Aquifers. Investigation of these and related topics should be completed before pursuit of groundwater from the Deep Aquifers continues.

The recommendation to prohibit the construction of new wells in the Deep Aquifers is a preventative measure because, at present, seawater intrusion has not been observed in the Deep Aquifers. However, the potential for inducing additional leakage by increased groundwater pumping is a legitimate concern that has been documented by previous studies (WRIME and Feeney/Rosenberg).

Implementing the recommendation to commence an in-depth study of the Deep Aquifers represents an investment in the future of the Deep Aquifers and groundwater management of the Salinas Valley Groundwater Basin as a whole. Expanding the Agency's understanding of this groundwater resource will assist with both near-term decision making and long-term water resource planning, such as steps that could be taken to prevent groundwater mining in the Deep Aquifers. Such a study will also serve to address many questions that have been posed by the Agency's stakeholders.

Section 6 – Agency Authority and Regulations Applicable to Implementing Recommendations

This section discusses the ordinances, regulations, and statutes that impart authority to the Agency to implement the recommendations described in this report. Table 7 summarizes the documents and indicates which documents may be considered for implementation of each recommendation.

6.1 Monterey County Water Resources Agency Act

Section 8 of the Monterey County Water Resources Agency Act (Agency Act) describes the objects and purposes of the act, one of which is *"…to increase, and prevent the waste or diminution of the water supply in the Agency, including the control of groundwater extractions as required to prevent or deter the loss of usable groundwater through intrusion of seawater and the replacement of groundwater so controlled through the development and distribution of a substitute surface water supply […]."*

Section 9 of the Agency Act, which describes the powers of the Agency, including the power to *"prevent interference with, or diminution of, […] the natural flow of any stream or surface or subterranean supply of waters used or useful for any purpose of the Agency or of common benefit to the lands within the Agency or to its inhabitants."* Furthermore, Section 9 grants the Agency the power to *"prevent contamination, pollution, or otherwise rendering unfit for beneficial use the surface or subsurface water used or useful in the Agency, and commence, maintain, and defend actions and proceedings to prevent any interference with those waters which endangers or damages the inhabitants, lands, or use of water in, or flowing into, the Agency."*

Section 22 of the Agency Act allows the Board of the Agency to *"take appropriate steps to prevent or deter the further intrusion of underground seawater by establishing and defining an area and depth from which the further extraction of groundwater is prohibited"* if, following a study by the Agency, the Board determines that *"any portion of a groundwater basin underlying the Agency is threatened with the loss of a usable water supply as a result of seawater intrusion into that portion of the groundwater basin."*

Section 22 of the Agency Act further defines the process by which the Board shall make a determination regarding the nature and extent of the threat of seawater intrusion. Finally, Section 22 provides a mechanism by which the Board, following a public hearing, may *"adopt an ordinance prohibiting the further extraction of groundwater"* from a specified area and depth. Such an ordinance would *"be effective as to any existing groundwater well extracting water from the area and depth prohibited only if there is made available to the lands served from that well a substitute surface water supply adequate to replace the water supply previously available from that well."*

Applicable sections of the Agency Act are included in Appendix G.

6.2 Monterey County Code Chapter 15.08 Water Wells

Chapter 15.08 of the Monterey County Code provides for "the construction, repair, and reconstruction of all wells […] to the end that the groundwater of [Monterey] County will not be polluted or contaminated." Chapter 15.08 specifies that the Health Officer, meaning the Health Officer of the County of Monterey or his authorized representative, including the Director of Environmental Health, is responsible for the issuance of permits that shall comply with the standards of the chapter (Appendix H).

Per a Delineation of Responsibility between the Division of Environmental Health (now Environmental Health Bureau) and the Monterey Flood Control & Water Conservation District (now Monterey County Water Resources Agency), the Agency has a role in the well permit review process. The Agency provides technical expertise to the Environmental Health Bureau (EHB) on aspects of the permitting process that pertain to geology and hydrogeology, among other topics, and EHB typically enacts the Agency's recommendations in order to ensure that the standards of the Water Wells chapter are upheld.

Thus, while the Agency does not have direct authority specified in Chapter 15.08, the Agency's recommendations are typically upheld and put into effect via this relationship with EHB and, through them, the Health Officer of Monterey County. Implementation of any moratoria related to well construction activities would likely require collaboration between the Agency, County, and EHB.

6.3 2010 Monterey County General Plan

Policy PS-3.5 of the 2010 Monterey County General Plan prohibits the "construction of any new wells in known areas of saltwater intrusion as identified by Monterey County Water Resources Agency or other applicable water management agencies" until either a program is approved and funded to minimize or avoid expansion of seawater intrusion or the well construction is approved by the applicable water resources agency (Appendix I).

This policy has been implemented such that any area defined by the Agency as having groundwater quality where chloride levels meet or exceed the 500 mg/L threshold, i.e. where the published contour lines are drawn, is considered to be seawater intruded. As of release of the 2015 seawater intrusion contours in July 2017, the areas being defined as seawater intruded include not only the contiguous front but also the isolated areas in the Pressure 400-Foot Aquifer in advance of the contiguous seawater intrusion front.

6.4 Monterey County Water Resources Agency Ordinance No. 3709

Monterey County Water Resources Agency Ordinance No. 3709, adopted in 1993, prohibits groundwater extractions from and the construction of new wells in portions of the Pressure 180-Foot Aquifer after January 1, 1995 (Appendix J). The purpose of Ordinance No. 3709 is to "reduce the rate of seawater intrusion and allow recharge to raise groundwater levels" in portions of the Pressure 180-Foot Aquifer because of increasing demand, overdraft of the groundwater basin, and imminent threats posted by the location of the seawater intrusion front.

While Ordinance No. 3709 pertains only to the Pressure 180-Foot Aquifer, it sets a precedent for the Agency exercising the powers authorized by the Agency Act in order to prevent diminution of the water supply and to limit groundwater extractions that are determined to be harmful to the groundwater basin.

6.5 Monterey County Water Resources Agency Ordinance No. 3790

As described in Section 4 of this report, Agency Ordinance No. 3790 specifies that the Agency will destroy wells in the CSIP area once (a) the Castroville Seawater Intrusion Project has established a satisfactory record of water deliveries, as determined by the Board of Directors, or (b) until at least one year after the start-up of the Castroville Seawater Intrusion Project, whichever occurs later. The cost of said well destructions shall be borne by the Agency (§1.03.05). A copy of Agency Ordinance No. 3790 is included as Appendix K.

6.6 Specifications for Wells in Zone 6 of the Monterey County Flood Control & Water Conservation District

In 1988 the Monterey County Health Department, Division of Environmental Health, adopted the Specifications for Wells in Zone 6 of the Monterey County Flood Control & Water Conservation District, commonly referred to as the "Zone 6 Standards" (Appendix L). The purpose of the Zone 6 Standards is to "protect groundwater quality and prevent corrosion of the well casing caused by seawater intrusion."

The boundary of Zone 6 does not extend completely through the Area of Impact where the Pressure 400-Foot Aquifer is overlain by the seawater intruded Pressure 180-Foot Aquifer; however, it does cover a portion of that area. The Zone 6 Standards represent an example of how there is precedent for the Health Officer enacting additional technical standards and conditions in order to ensure aquifer protection.

6.7 Sustainable Groundwater Management Act (SGMA)

The Sustainable Groundwater Management Act (SGMA), which is comprised of three legislative bills, was signed on September 16, 2014 by Governor Brown. It establishes a definition of "sustainable groundwater management"; requires that a Groundwater Sustainability Plan be adopted for the most important groundwater basins in California; establishes a timetable for adoption of Groundwater Sustainability Plans; empowers local agencies to manage basins sustainably; establishes basic requirements for Groundwater Sustainability Plans; and provides for a limited state role (DWR, 2017).

The Agency is one of eight members of a joint powers authority that has filed with the California Department of Water Resources to form the Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA). As described in its Groundwater Sustainability Agency (GSA) formation notice, the SVBGSA would be responsible for implementing the policies of the Sustainable Groundwater Management Act (SGMA) in the majority of the Salinas Valley Groundwater Basin, with the exception of the adjudicated Seaside Basin and some portions of the 180/400 Foot Aquifer Subbasin, Monterey Subbasin, and Forebay Aquifer Subbasin.[26] Among others, responsibilities of the SVBGSA would include managing groundwater within the Salinas Valley Groundwater Basin to avoid undesirable results such as significant and unreasonable seawater intrusion, land subsidence, chronic lowering of groundwater levels, and reduction in groundwater storage (Appendix M).[27]

The implementation of SGMA by a GSA in the Salinas Valley Groundwater Basin does not relieve the Agency of its responsibility to manage the groundwater basin as described in the Agency Act. Rather, the Agency now has an opportunity to optimize management of water resources alongside the GSA.

Table 7 - Summary of Ordinances, Regulations, and Statutes Applicable to the Recommendations in this Report

Recommendations	Ordinances, Regulations, and Statutes						
	Agency Act	MCC 15.08 Water Wells	2010 General Plan	Ord. No. 3709	Ord. No. 3790	Zone 6 Specs.	SGMA
1. Moratorium on new well construction in Pressure 400-Foot Aquifer	✓	✓	✓			✓	✓
2. Enhancement and Expansion of CSIP	✓						✓
3. Termination of pumping in Area of Impact	✓			✓			✓
4. Destroy wells in Agency Zone 2B	✓	✓			✓	✓	✓
5. Moratorium on new well construction in Deep Aquifers	✓			✓		✓	✓
6. Investigation of Deep Aquifers	✓						✓

[26] The Marina Coast Water District has filed a GSA formation notice with DWR to form a Groundwater Sustainability Agency that would manage a portion of the 180/400 Foot Aquifer and Monterey Subbasins. The Arroyo Seco Groundwater Sustainability Agency has submitted a formation notice to DWR to manage portions of the Forebay Aquifer Subbasin.

[27] Sustainable Groundwater Management Act, Chapter 2, 10721.

Section 7 – Summary

Staff makes the following recommendations with the aim to slow or halt seawater intrusion, and impacts related thereto, in the Salinas Valley Groundwater Basin:

1. An immediate moratorium on groundwater extractions from new wells[28] in the Pressure 400-Foot Aquifer[29] within an identified Area of Impact[30], except for the following use categories:
   a. Wells operating under the auspices of the Castroville Seawater Intrusion Project; and,
   b. Monitoring wells owned and maintained by the Agency or other water management agencies.

2. Enhancement and expansion of the Castroville Seawater Intrusion Project (CSIP) Service Area. The expansion should include, at a minimum, lands served by wells currently extracting groundwater within the Area of Impact.

3. Following expansion of the CSIP Service Area, termination of all pumping from existing Pressure 180-Foot or Pressure 400-Foot Aquifer wells within the Area of Impact, except for the following use categories:
   a. Municipal water supply wells;
   b. Wells operating under the auspices of the Castroville Seawater Intrusion Project; and,
   c. Monitoring wells owned and maintained by the Agency or other water management agencies.

4. Initiate and diligently proceed with destruction of wells in Agency Zone 2B, in accordance with Agency Ordinance No. 3790, to protect the Salinas Valley Groundwater Basin against further seawater intrusion.

5. An immediate moratorium on groundwater extractions from new wells within the entirety of the Deep Aquifers of the 180/400 Foot Aquifer and Monterey Subbasins until such time as an investigation of the Deep Aquifers is completed and data pertaining to the hydraulic properties and long-term viability of the Deep Aquifers are available for knowledge-based water resource planning and decision making.

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[28] "New well" is not intended to include (a) any well for which a construction permit has been issued by the Monterey County Health Department or (b) any well for which drilling or construction activities have commenced in accordance with a well construction permit issued by the Monterey County Health Department.

[29] Aquifer means: a water-bearing or saturated formation that is capable of serving as a groundwater reservoir supplying enough water to satisfy a particular demand, as in a body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs (Poehls and Smith, 2009).

[30] See Section 1.5 for a description of the Area of Impact. The Area of Impact is also depicted in Figure 4.

a. Monitoring wells, public agency wells, municipal water supply wells, wells for which a construction permit has already been issued, and well repairs should be considered for exemption from this recommendation.
b. The moratorium should include a prohibition of:
    i. Replacement wells, unless it can be demonstrated that the installation of such a well will not result in further expansion of the seawater intrusion front; and,
    ii. Deepening of wells from overlying aquifers into the Deep Aquifers, deepening of wells within the Deep Aquifers, and other activities that would expand the length, depth, or capacity of an existing well.

6. Initiate and diligently proceed with an investigation to determine the hydraulic properties and long-term viability of the Deep Aquifers.

The timeline for implementing these recommendations is variable as is the degree of financial impact between each. Furthermore, implementation of these recommendations will require close consultation with the County Counsel and, depending on the actions pursued, additional work by Agency staff and cooperation with RMA-Planning staff to ensure compliance with CEQA and other applicable procedures and policies. Some of the recommendations, such as a moratorium[31] relating to the well ordinance, might require implementation under the Government Code and coordination between Agency and County staff, and the Board of Supervisors of the Monterey County Water Resources Agency and Board of Supervisors of Monterey County.

While these recommendations can be implemented individually or in any combination, there is a significant degree of inter-dependence between the six recommendations. As discussed in this report, implementing some of the recommendations without implementing others could lead to irreversible negative impacts to aquifers of the Salinas Valley Groundwater Basin. Current groundwater level and chloride concentration trends suggest that without proactive steps, the continued viability of the Pressure 400-Foot Aquifer in and near the Area of Impact is endangered.

[31] Certain moratoria may have consequences for a "taking" where the moratorium deprives an owner of all reasonable economic use of the owner's property. Whether there is a taking is an issue that would require further review and analysis on a case-by-case basis for each affected property.

Section 8 – References

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