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INDEPENDENT EVALUATION, MODIFICATION, AND USE OF THE NORTH MARINA GROUNDWATER MODEL TO ESTIMATE POTENTIAL AQUIFER IMPACTS

associated with the

PROPOSED MONTEREY PENINSULA WATER SUPPLY PROJECT

prepared for

California Marine Sanctuary Foundation
99 Pacific Street, Suite 455E
Monterey, California 93940

and

California Coastal Commission
45 Fremont Street, #2000
San Francisco, California 94105

July 10, 2020

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Job No. 466-2148.02

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Weiss Associates work at the California-American Water test slant well site and vicinity was conducted under my supervision. To the best of my knowledge, the data contained herein is true and accurate, based on what can be reasonably understood as a result of this project while satisfying the scope of work prescribed by the client for this project. The data, findings, recommendations, specifications, and/or professional opinions were prepared under contract with the California Marine Sanctuary Foundation solely for the use of the California Coastal Commission in accordance with generally accepted professional engineering and geologic practice. We make no other warranty, either expressed or implied, and are not responsible for the interpretation by others of the contents herein.

William A. McIlvride 07/10/2020
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Senior Project Hydrogeologist

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ACRONYMS AND ABBREVIATIONS

Cal-Am	California American Water
Commission	California Coastal Commission
CPUC	California Public Utilities Commission
EIR/EIS	Environmental Impact Report/Environmental Impact Statement
FO-SVA	Fort Ord/Salinas Valley Aquitard
FWP	fresh water percentage
GHB	general head boundary
gpm	gallons per minute
HWG	Hydrogeologic Working Group
K	hydraulic conductivity
KH	horizontal hydraulic conductivity
KV	vertical hydraulic conductivity
MGD	million gallons per day
MNW	multi-node well
MAW	multi-aquifer well
mg/L	milligrams per liter
MPWSP	Monterey Peninsula Water Supply Project
NAVD88	North American Vertical Datum of 1988
$NMGWM^{2016}$	North Marina Groundwater Model (2016 version)
OWP	ocean water percentage
Project	Monterey Peninsula Water Supply Project
RCH	recharge
RIV	river
SGMA	Sustainable Groundwater Management Act
SVIGSM	Salinas Valley Integrated Ground and Surface Water Model
TSW	Test Slant Well
TDS	total dissolved solids
USG	unstructured grid
USGS	U.S. Geological Survey
Weiss	Weiss Associates

1. INTRODUCTION

This report documents work performed by Weiss Associates (Weiss) to refine available estimates of the potential effects of California American Water's (Cal-Am's) proposed well field on aquifers in the vicinity of Cal-Am's proposed Monterey Peninsula Water Supply Project (MPWSP or Project) (Figure 1). The work employed a steady-state implementation of the 2016 North Marina Groundwater Model ($NMGWM^{2016}$) with uniform pre-pumping gradients to determine if key recommendations from Weiss's November 1, 2019 technical report (Weiss, 2019) can be addressed, or if it will be necessary to modify the transient implementation of $NMGWM^{2016}$ and possibly conduct a field investigation.

The objective of the work is to address the recommendations to the extent possible and improve upon the current modeling approach to better predict the percentage of ocean water ("ocean water percentage", or OWP) that will potentially be captured by the well field, and the percentage of fresh to brackish inland aquifer water (fresh water percentage, or FWP[1]) that will potentially be captured, and over what potential area the fresh water capture will occur. The predictions take into account potential ranges in groundwater gradient, recharge, well field pumping rates, extent of the Fort Ord/Salinas Valley Aquitard (FO-SVA), and Dune Sand Aquifer hydraulic conductivity (K). This provides an estimate of how the operating well field might affect the groundwater resource inland under current conditions, and under conditions of a seaward gradient in deeper aquifers that could potentially develop in response to proposed basin management changes being evaluated under the Sustainable Groundwater Management Act (SGMA).

Many of the figures included with this report are excerpted from documents developed for or associated with the MPWSP and have been renumbered for this document using red figure numbers. The numbering system from the document of origin has also been maintained so the reader can examine it from its original context, if desired. Some of the figures have been annotated for clarification in red but additional colors are used in annotation as noted on the figures and/or in text.

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[1] In this report, the term "fresh" water includes groundwater with total dissolved solids (TDS) less than or equal to 3,000 milligrams per liter (mg/L). Modeled OWP results discussed throughout this report and shown on Tables 2 and 3 assume that fresh water has a TDS of 0.0 mg/L. For comparison, Tables 2a and 3a show OWPs for fresh water with assumed TDS of 500 mg/L (OWP^{500}); Tables 2b and 3b show OWPs for fresh water with assumed TDS of 3,000 mg/L ($OWP^{3,000}$).

2. BACKGROUND

The final environmental impact report/environmental impact statement (EIR/EIS) for the MPWSP was published on March 29, 2018 (ESA, 2018), and included results of the NMGWM^{2016}. The EIR/EIS includes comments on the Draft EIR/EIS and responses to those comments, which were extensive regarding potential impacts of the MPWSP on local fresh groundwater resources. These impacts occur primarily in the two uppermost aquifers at the MPWSP: the Dune Sand Aquifer (which is contiguous with the Perched/Mounded Aquifer on its east side), and the 180-Foot/180-Foot Equivalent Aquifer (180-Foot Aquifer).

This report assumes the reader is familiar with the hydrogeology of the MPWSP as described in the EIR/EIS, in particular Appendix E3. If the reader is unfamiliar with the MPWSP, it is recommended to refer to this document for background and context.

After publication of the EIR/EIS, further comments were submitted and responses provided regarding the potential fresh groundwater impacts, with differing scientific opinions, leading to the California Coastal Commission's (Commission) request for an independent review in support of their decision process.

2.1 Test Slant Well

As documented in the EIR/EIS (ESA, 2018) and more recent monitoring reports, a Test Slant Well (TSW) was constructed from December 2014 to March 2015 at the MPWSP site (Figure 2) so that pumping tests could be conducted to gather chemical and physical data required to estimate potential freshwater capture by the full-scale project. Weiss reviewed reports and data from initial pumping of the TSW at 2,000 gallons per minute (gpm) (2.88 million gallons per day [MGD]), and produced an independent hydrogeological review report dated September 23, 2015 (Weiss, 2015). This resolved an operating permit issue regarding the hydraulic influence of the TSW and led to permit modifications and long-term testing of the TSW at 2,000 gpm for 22 months, from May 2, 2016 through February 28, 2018.

2.2 Hydraulic Gradient in Dune Sand Aquifer

In the winter of 2016/2017, during the long-term TSW pumping test, heavier than average rainfall resulted in a seaward steepening of the groundwater gradient in the Dune Sand-Perched/ Mounded Aquifer (Dune Sand Aquifer) in an area approximately 2,000 to 6,000 feet inland from the pumping well, based on data from key MPWSP monitoring well MW-7S (Geoscience, 2019). Accompanying this change was a decrease in TDS at the pumping well, indicating an increase in fresh water entering the well. These trends led to stakeholder comments that the EIR/EIS may not have accounted for these changes and potential additional post-2017 changes due to increased rainfall, and technical opinions differed on what those changes might represent. Weiss reviewed the EIR/EIS comments and documentation of the differing technical opinions and produced a technical report (Weiss, 2019) that addressed the Commission's study questions pertaining to the gradient changes.

The findings in that technical report included:

1. The steepening of the hydraulic gradient seaward in the Dune Sand Aquifer in 2017 will likely result in a limited to negligible effect on seawater intrusion, and will likely result in a decrease in OWP in water pumped, due to increased capture of fresh water from the aquifers tapped by the well field. The gradient change appears to result from local and regional aquifer recharge due to increased rainfall in 2016-2017 and 2018-2019. This is significant to the evaluation of the OWP resulting from the MPWSP since there are substantial data gaps with respect to groundwater flow paths in the Dune Sand Aquifer and the transfer of fresh water (TDS <3,000 mg/L) from the Dune Sand Aquifer to the 180-Foot Aquifer. Therefore, to be able to rely on NMGWM^{2016} results to accurately predict OWP, Weiss recommended additional data collection to address these data gaps, development of a consensus conceptual site model and modifications to the NMGWM^{2016} based on the revised conceptual model, and then calibration of the revised NMGWM^{2016} to match the effects of these recent rainfall events.
2. The well field capture analysis presented in the EIR/EIS appeared to be flawed as it did not account for potential freshwater capture beyond the identified capture zone of the well field. This is because it relied on an assumed landward groundwater gradient and did not account for the seaward gradient in the Dune Sand Aquifer. If such capture is greater than what is already accounted for, it will decrease the OWP in water extracted by the well field. The uncertainty in the range of OWP depends on how the hydrogeology of the Dune Sand Aquifer and underlying FO-SVA is interpreted and modeled. The uncertainty could be reduced through adjustments to the NMGWM^{2016} and applying it in a non-superposition mode to more accurately reflect the site hydrogeology and implications of the TSW pumping results.

2.3 Westward Extent of the Fort Ord-Salinas Valley Aquitard (FO-SVA)

A leading technical issue identified was the continuity and westward extent of the FO-SVA, the position of which would likely have a significant effect on predicted OWP and capture of fresh groundwater under different assumed groundwater gradient conditions. Comments and responses to the technical report were provided by the Hydrogeologic Working Group (HWG), the NMGWM^{2016} modeling team, the City of Marina, and the Marina Coast Water District and their consultants in a series of written questions and responses and two teleconference calls. The EIR/EIS contained different interpretations of the continuity and extent of the FO-SVA (Weiss, 2019):

1. Appendix E3 of the EIR/EIS showed the western boundary of the FO-SVA to be approximately 6,000 feet inland of the Project well field and east of monitoring well MW-7S (Figure 3); and three of six geologic cross-sections in Appendix E3 (Figures 4, 5, and 6) showed the FO-SVA to be discontinuous north, south, and east of well MW-7S.
2. In contrast, Appendix E2 of the EIR/EIS showed the western boundary of the FO-SVA, depicted as the western extent of Layer 3 of the NMGWM^{2016}, to be approximately 2,000 feet inland of the Project well field and west of monitoring well MW-7S (Figure 7), with the FO-SVA modeled as being continuous (Layer 3) north, south, east, and west of well MW-7S.

The latter interpretation, which has the FO-SVA margin closer to the Project well field and assumes continuity of the FO-SVA, is potentially conservative from the standpoint of Project impacts; as stated by the HWG (February 20, 2020), *"If the FO-SVA is assumed to be continuous… then all the westward flowing groundwater within the Perched/Mounded* [Dune Sand] *Aquifer spills over the western edge of the FO-SVA (such as near MW-7) closer to the areas of potential influence from proposed MPWSP pumping."* By conservative, it is meant that the project impact will err on the side of low OWP in the groundwater captured by the Project well field, assuming all other factors are equal. The HWG has clarified this interpretation using geologic cross-sections (Figures 4, 5, and 6) by connecting what are shown as fragmented clay layers where the FO-SVA occurs in the vicinity of monitoring well MW-7S (HWG, 2020).

While this helped to resolve the recommended action in Weiss finding (1) above, there was still a need to account for potential fresh water capture under seaward gradient conditions in the Dune Sand Aquifer and reduce the uncertainty in the range of OWP estimates. It was proposed to accomplish this through adjustments to the $NMGWM^{2016}$, in conjunction with additional field data collection, and applying the $NMGWM^{2016}$ in a non-superposition mode to more accurately reflect the site hydrogeology and implications of the TSW pumping results. It was decided to implement modeling first, as described in Section 3.

As of the writing of this report, a pumping rate of 15.5 MGD has been approved for the MPWSP by the California Public Utilities Commission (CPUC). This pumping rate is used as the base rate for the different scenarios modeled in this report.

2.4 Ocean Water Percentage (OWP)

Predicting OWP in groundwater extracted from the MPWSP well field has been a key concern throughout the Project planning, design, and approval process, and is the primary goal of the work documented in this report. Preliminary review of the $NMGWM^{2016}$ (Weiss, 2019) indicated that the long-term (after the first few months of pumping) OWP should be in the range of 85 to 96 percent within the range of likely pumping rates from the Project well field. This OWP range is consistent with the TSW pumping results.

Weiss also reviewed the range of OWP estimates included in the EIR/EIS (ESA, 2018). The results of the different methods of determining OWP were summarized in a memorandum addressing comments on the analyses (HWG, 2017), as shown in Table 1 from that memorandum. The HWG also plotted TSW OWP field data versus time and compared the data to some different modeling approaches (Figure 8). Both of these depictions of the TSW data show a partial record, including both the 1- and 2-year OWP; these are in the range of 90 to 95 percent. However, the full record of TSW pumping (Figure 9) shows the OWP in the range of 84 to 90 percent during April through August 2017, which followed the very wet period from November 2016 through April 2017.

The HWG described the OWP trends (HWG, 2018, page 4), and their presumed causes, from the full record of TSW pumping. In their description (below), Weiss's statements describing accompanying gradient changes are inserted in bold text:

> *"An analysis of the actual field data shows that there are four distinct periods of time represented in the data. The first time period is the ramp up in TDS after start of pumping on April 22, 2015 until November 30, 2015 (with non-pumping period from June 5 to October 27). TDS concentrations started at 26,000 mg/L (OWP = 77) and ended at*

29,800 mg/L (OWP = 89) on November 30, 2015. The second time period from December 1, 2015 to February 1, 2017 (a 14 month period) represents a steady TDS mostly within a range from 30,000 to 32,000 mg/L (OWP = 90 to 95) **[before the seaward gradient steepened]**. *The third time period starts in February 2017 and extends to August 2017 (6 months)* **[seaward gradient steepened during this period]**, *and represents a decline in TDS from an average of about 31,000 mg/L (OWP = 92) to about 29,000 mg/L (OWP = 86). The fourth time period starts in August 2017 and represents an increase in TDS from an average of about 29,000 mg/L (OWP = 86) to an average of about 30,500 mg/L (OWP = 91) as of end of October 2017* **[seaward gradient became slightly less steep during this period]**.

"The six month period from February to August 2017 reflects infiltration of rainfall (i.e., fresh water) during a record wet year from November 2016 to April 2017 **[It also represents a steepening of the seaward gradient]**. *The recharge from the record rainfall mixes with the ambient highly saline water in the TSW capture zone and is reflected in the observed TDS reduction (February to August 2017) – typically, rainfall recharge requires several days to a few months to be manifested as water level and quality changes in a given shallow aquifer. We understand that similar variations in intake water salinity related to differing rainfall amounts has been observed at the Sand City desalination plant intake wells.*

"Overall, the period of record for TSW TDS data provides an excellent long-term record that shows expected TDS concentrations following a below average (93% of normal) rainfall year (2014-2015) **[OWP 90-95%]**, *an above average (141% of normal) rainfall year (2015-2016)* **[OWP 90-95%]**, *and a record wet rainfall (174% of normal) year (2016-2017)* **[OWP 85-90%; and from Oct 2017 to Feb 2018, OWP was 87-93%]**. *The overall average rainfall is above average for the entire TSW pumping time period (126 percent of normal) and therefore can be considered conservative in terms of likely representing TSW TDS concentrations when freshwater recharge from rainfall is more abundant than normal (i.e., TSW TDS concentrations lower than normal)."*

To illustrate these trends, the OWP trend line is annotated and placed in corresponding position relative to the water level trends from 2015 through 2019 in monitoring wells MW-3S, MW-3M, MW-4S, MW-4M, MW-7S, and MW-7M (Figure 9). In performing the scope of work for this report, this data was compared to the model output values to inform making adjustments to model parameters to reflect conditions that were present during the Slant Well test.

As described in Weiss (2019), for wells pumping at the shoreline, the inland area can be considered for practical purposes to be the area where the cone of depression expands and at any given point water levels decrease over time, whereas in the seaward area a constant water level is maintained. Therefore, increasing pumping at the coast will create additive effects inland, expanding the cone of depression. Because the water level decrease associated with additional expansion of the cone of depression inland occurs over an area with already decreased water levels, the groundwater gradients from inland towards the pumping wells will increase at a slower rate in response to increased pumping relative to the gradients on the ocean side, which increase to a greater extent because sea level is not affected by pumping. This greater increase in the gradients on the ocean side in response to greater pumping will act to increase the OWP as pumping rates increase.

Thus, all else being equal, the OWP values shown in Table 1, and the OWP values shown on Figures 8 and 9, can be considered as minimums for any project that produces more than the TSW flow at the TSW location, under the rainfall/recharge conditions that occurred during TSW pumping. This principle was employed to do a "reality check" on the model outputs.

3. SCOPE OF WORK

To obtain more accurate and definitive OWP and groundwater capture zone estimates due to proposed pumping from the MPWSP well field, Weiss (2019) recommended the following:

1. Obtain additional hydrogeologic data from the 2 square-mile area east of monitoring well MW-7S to define the continuity of the FO-SVA;
2. Investigate the area west of monitoring well cluster MW-7 (between MW-4 and MW-7) to determine the potential extent of the FO-SVA westward from well cluster MW-7, and vertical groundwater gradients between the Dune Sand Aquifer and 180-Foot Aquifer; and
3. Incorporate the new data into $NMGWM^{2016}$ (Figures 10 through 13), which should be revised to reflect realistic values of horizontal and vertical hydraulic conductivity (KH and KV) (Figures 14 and 15) in the aquifers and aquitards proximal to the Project well field, and a FO-SVA configuration consistent with geological data east, north, and south of the Project well field area. The $NMGWM^{2016}$ is currently configured to allow most of the Dune Sand Aquifer (Perched/Mounded portion) water to flow vertically downward to the 180-Foot Aquifer well inland of the western margin of the FO-SVA, in the vicinity of monitoring well cluster MW-7 (Figure 16), which is not a conservative configuration.

To address the recommendations contained in the technical report in potentially less time than would be needed if the field work was included, it was decided that the $NMGWM^{2016}$ would be revised and implemented prior to the field work to see if a range of OWP and capture estimates could be calculated that would account for any reasonable variation in the range of possible aquitard configurations and discontinuities.

3.1 Tasks

For this work, Weiss employed the version of $NMGWM^{2016}$ used for the EIS/EIR to calculate ocean capture zones with variable regional groundwater gradients (ESA, 2018; Appendix E2, Figure E7) (Figure 17). This version of $NMGWM^{2016}$ was developed by assigning external water levels to the eastern-most general-head boundaries to approximately simulate the seasonal range in landward gradients observed in the Project area. It is a steady-state model; the modeling approach is described in Section 3.2.

This approach was judged to be potentially insensitive to the configuration of the FO-SVA and its westward extent, because it can include scenarios with pumping from both aquifers at similar and varying gradients. And these scenarios could be run with different simulated westward extent of the FO-SVA. Compared to using the transient version of the $NMGWM^{2016}$, the approach offered a relatively straightforward way to address certain model deficiencies, and to quickly estimate OWP and groundwater capture zones under a wide range of potential conditions and different pumping scenarios from the MPWSP well field.

Accordingly, the tasks performed for this project were as follows:

1. The model files to support the capture version of the NMGWM^{2016} were not available on the CPUC web site,[2] but were provided by Steve Deverel of HydroFocus on May 8, 2020. The model was run to reproduce the 0.0004, 0.0007, and 0.0011 capture scenarios from the EIS/EIR (ESA, 2018) to verify that the correct version of the model was being used and being used correctly, and to become familiar with the model itself. Scenarios for both non-pumping and pumping at 15.5 MGD were evaluated. For each of the gradient scenarios, the OWP of the simulated combined well discharge was calculated, and the size of the respective capture areas in the Dune Sand Aquifer and 180-foot Aquifer estimated using particle tracking, and compared with the modeled capture zones in the EIR/EIS (Figure 17).

2. The NMGWM^{2016} was modified to have a seaward gradient in the Dune Sand Aquifer, while keeping the same array of 0.0004, 0.0007, and 0.0011 landward gradients in the 180-Foot Aquifer. The KH east of monitoring well cluster MW-7 was maintained at the same values in the Dune Sand Aquifer as were employed in the original model.

3. The scenarios as described in task 2 above were repeated, but with a change for the 180-Foot Aquifer and deeper aquifer gradients to be flat to gently seaward, as could potentially occur under full implementation of SGMA by 2040. Differences in OWP were calculated for the different scenarios.

4. To create a seaward gradient in the Dune Sand Aquifer, recharge was added and varied to simulate the historical range of rainfall conditions. The original capture version of NMGWM^{2016} did not include a recharge component. The OWPs resulting from these runs were calculated and tabulated.

5. With recent revisions to water demand estimates, the project potentially may only need half of the approved 15.5 MGD desalinization facility capacity (CPUC, 2019). Therefore, model runs were included with half the pumping rate of runs described in tasks 2, 3, and 4 above; pumping rates in the six wells were reduced by half to achieve a total flow of 7.75 MGD.

6. Particle tracking was used to map out the capture areas in the Dune Sand Aquifer and 180-Foot Aquifer in key scenarios from tasks 1, 2, and 9.

7. A sensitivity analysis was performed for a range of conditions, including increasing KH east of MW-7 in zones KH16 and KH20 (Figure 14) from their current values of 2 and 4 feet per day to five times those values, and recalculating the OWP. This was a decision point for further modeling. The results to this point were reviewed and it was determined that the range of values was acceptable, and thus to continue with the subsequent modeling steps outlined below.

8. The results of the "wet" and "dry" season scenarios for 7.75 and 15.5 MGD pumping rates were used to estimate potential groundwater level changes in the vernal ponds under natural and pumping conditions. These are only relative changes since pond level data was not available to compare with the model results.

[2] See https://www.cpuc.ca.gov/Environment/info/esa/mpwsp/comms_n_docs.html,

9. The water levels specified at the southern boundary in Layer 2 were modified to constant, but much more realistic values. The southern boundary in the $NMGWM^{2016}$ had groundwater elevation values in Layer 2 close to sea level; these differed from actual values by as much as 90 feet (Figure 18). Some of the stakeholders cautioned that this modification would create perched conditions that would likely crash the model. This might have been the case if the capture version of $NMGWM^{2016}$ had been a transient model. However, the change did not cause stability problems for the steady-state model and the result was a much better agreement between the modeled and actual groundwater elevation contours in the southern portion of the model.
10. This report was prepared, describing the modeling implementation, results, and potential ranges in OWP and fresh groundwater capture by the Project.

3.2 Groundwater Modeling

The groundwater modeling was carried out with the assistance and collaboration of Eric Nichols of Substrata, LLC. The approach to $NMGWM^{2016}$ modifications and model runs themselves were developed and performed by Vivek Bedekar of S.S. Papadopulos & Associates, Inc., with input from Mr. Nichols, and Mr. William McIlvride of Weiss. Mr. Bedekar also performed the post-processing and created the graphical results.

This work built on the work of those who developed the $NMGWM^{2016}$ and its predecessors, as described in the Final EIR/EIS (ESA, 2018; Appendix E2); the methodology is briefly summarized here. The reader is referred to Appendix E2 of the EIR/EIS for a detailed description of the $NMGWM^{2016}$ and how it has been used to support the MPWSP Final EIR/EIS.

The $NMGWM^{2016}$ is composed of a uniform 200-by-200 foot grid with eight layers, 300 rows, and 345 columns at a rotation of 16 degrees (clockwise). Distance units are in feet and time units are in days. Three implementations of the model have been used to support the EIR/EIS:

1. ***Transient "calibration" version with 384 stress periods***, and calibrated to wells within the model domain. Its development resulted in the array of horizontal and vertical hydraulic conductivity zones within each model layer, and it serves as the basis for the following versions;
2. ***Transient, "superposition" version with 384 stress periods***, with all boundary conditions and initial heads set to zero. This was used to predict drawdown impacts from the Project over time; and
3. ***Steady-state "capture" version***, with landward gradients set by specifying heads at the eastern general head boundary. This was used to predict ocean water capture for different landward gradients and pumping rates. This version was adopted for the current work.

Of the model files supplied by HydroFocus, the "DD4" file with the 15.5 MGD pumping rate was used to implement the scenarios modeled for this work. This file was the version used to generate the estimated groundwater capture zones due to pumping at the proposed Project well field.

3.2.1 Groundwater Flow Simulation

As was done for the EIR/EIS (ESA, 2018), modeling to complete Tasks 1 through 9 for this study used input files run with the MODFLOW-2000 software that was developed by the U.S. Geological Survey (USGS) (Harbaugh et. al., 2000). The only modifications to the MODFLOW input files for NMGWM^{2016} that were made prior to performing Task 1 were:

- The parameter HCLOSE was adjusted from 10^{-4} to 10^{-5}, and RCLOSE was adjusted from 864 to 10^{-4} to achieve tighter solver convergence; and
- An LMT file was added to write to an FTL file, and create the inputs for MT3D.

The use of MODFLOW for running NMGWM^{2016} is well documented in Appendix E2 of the EIR/EIS (ESA, 2018) and is not repeated here; the reader is referred to that document for more information. Model outputs, including OWP visualizations, groundwater elevation contours, and groundwater flow pathlines were processed using the graphic user interface Groundwater Vistas version 7 (ESI, 2017).

3.2.2 Ocean Water Percentage Estimation and Visualization

MT3D-USGS (Bedekar, et al, 2016) is a finite-difference solute transport simulator that works in conjunction with the flow simulator MODFLOW. MT3D-USGS, developed by the USGS, is an updated version of MT3DMS. It simulates advection, dispersion, and reactions of solutes in the groundwater system, and was applied in this study as a ‘tracer’ to track the movement of ocean water within the modeling domain.

A unit plume approach[3] was used that: (1) ‘tagged’ ocean water entering the groundwater system from the constant head boundary that represents the ocean; (2) quantifies the OWP in water withdrawn by the pumping wells; and (3) provides a visual representation of the flow of ocean water within the groundwater system. The use of MT3D-USGS in this application was limited to advective transport, similar to how particle tracking is used to illustrate flow patterns within a groundwater system, and does not consider reactive transport processes, dispersion, diffusion, or the coupling of density-dependent flow and solute transport.

To implement the unit plume approach, a value of 1.0 (concentration of 100 percent ocean water) was assigned to water entering the groundwater system from the constant head (ocean) boundaries to represent ocean water. All other water entering the model and not originating from the ocean was assumed to be fresh water, and was assigned a value of 0.0 (concentration of zero percent, or fresh water). This applied to all other boundary conditions, including river (RIV), general head boundary (GHB), and recharge (RCH). Therefore, a concentration of 100 percent in water discharged from a pumping well signifies that 100 percent of the water in the well originated from the ocean, the same as OWP equals 100; and water with a concentration of 0.0 percent (OWP equals 0.0) discharged from the well is fresh water. A concentration between zero and 100 percent signifies a contribution of both fresh and ocean water, and OWP will be at a value intermediate between 0 and 100.

[3] In the “unit-plume” concept, a value of 1.0 is assigned at the unit source – in this case the ocean – denoting that the water at that location comprises 100% of the quantity of interest (i.e., it has not yet undergone any mixing with other water sources).

The OWP was calculated for the combined discharge from all slant wells pumped using a volume-weighted averaging approach as shown below:

$$OWP = \frac{\sum_{i=1}^{n}(Q_i C_i)}{\sum_{i=1}^{n}(Q_i)}$$

where:

n = the total number of model cells representing pumping wells;

Q_i = the flow rate at each model cell represented as a pumping well (ft^3/day); and

C_i = the concentration associated with respective model cells representing pumping wells (dimensionless unit plume).

For the 7.75 and 15.5 MGD pumping scenarios, the full slant well array (Figure 19) was used, with n = 42. For the 2.88 MGD TSW scenarios, only the original slant well used for testing was simulated, with n = 5.

To facilitate implementation of MT3D-USGS to calculate the OWP throughout the model, the model vertical datum was adjusted to an arbitrarily large negative value, in this case -1,000 feet, thereby avoiding any potential desaturation artifacts from the MODFLOW inputs to the MT3D model.

3.2.3 Flow Path Simulation

A subset of the scenarios generated using MODFLOW was processed with MODPATH version 6.0.01 (August 24, 2012) to illustrate groundwater flow paths. MODPATH works by delineating the flow path of "particles" of water moving through the modeled groundwater system, and computes the travel time for the simulated particles to reach their ending locations. For the scenarios processed with MODPATH, particles were "released" at every 10th cell in the center of the model, for an initial particle spacing of 2,000 feet. Each particle was released at the center of the model grid block corresponding to the particle release location, or at 0.5x the depth within the model cell. Points to consider when viewing and interpreting the figures that illustrate the MODPATH results include:

- A travel time of 63 years was specified for each particle, so the lines traced by the particles ("path lines") stop either at a groundwater sink or after 63 years of travel time[4];
- The rate of flow of the particles is indicated by the length of the path lines, and is dependent on what effective porosity is specified. A value of 0.1 was used, which is the same value used for the capture scenarios in the EIR/EIS (ESA, 2018). Short path lines indicate relatively slow flow and long path lines indicate relatively rapid flow;
- Path lines lengthen and extend further downgradient as flow velocity increases in response to steepening groundwater gradient;

[4] The 63-year period was used because 63-year pumping and 63-year recovery scenarios were simulated using NMGWM[2016] in the EIR/EIS (ESA, 2018), and this time period generates flow lines of an appropriate length to illustrate flow patterns while avoiding the output from becoming too cluttered.

- Path lines reside longer in Layer 2 due to horizontal gradients created by the RIV boundary; and
- A path line that is vertical will essentially be invisible on the model output, or show simply as a "dot".

The MODPATH results were converted to GIS shapefiles before plotting so that the path lines could be represented by a different color for each layer that a given particle travels through, to help illustrate the vertical component of flow. In the output presented in the figures with this report, the path lines are blue in Layer 2, green in Layer 4, and red in Layer 6 of the model; thus a path line that starts as blue, becomes green, and then red is tracing and illustrating not just horizontal flow, but also a vertical downward flow.

4. MODEL IMPLEMENTATION AND RESULTS

Input parameters and the results of each model run are described in this section. The OWPs in water from the pumping wells for each run are shown in Table 2. These OWP results are based on the assumption that fresh water has TDS of 0.0 mg/L, and for consistency the OWP results discussed in remainder of this report are based on this assumption. To provide comparison for different assumed fresh water TDS, Table 2a shows the OWPs based on the assumption that fresh water has TDS of 500 mg/L (OWP^{500}), and Table 2b shows the OWPs based on the assumption that fresh water has TDS of 3,000 mg/L ($OWP^{3,000}$).[5]

Some of the parameters in the original version of the $NMGWM^{2016}$ were adjusted to create the scenarios described below. Caution was used in selecting model parameters for adjustment, and in how they were adjusted, in keeping with the concept stated by HydroFocus (Appendix E2, page 19): *"the model-calculated water levels and groundwater volumetric budget terms should reasonably agree with the conceptual understanding of the groundwater system."* Therefore, whenever any aquifer zone KH or KV was adjusted for the MODFLOW runs, it was done so "in the direction of reasonableness", to bring the model more in alignment with physical reality. For example, the existing KH20 in Layer 2 set in $NMGWM^{2016}$ is 4 feet per day (Figure 14), which is at the bottom end of the 2 to 400 feet per day range in values reported from other sources. So, increasing the value from 4 to 40 feet per day is making it closer to its average value of 200 feet per day, thus changing it "in the direction of reasonableness".

4.1 Baseline – Replicate $NMGWM^{2016}$ Capture Results

After download of the capture version of the $NMGWM^{2016}$, it was reviewed and run as originally configured with landward gradients at 0.0004, 0.0007, and 0.0011 (Figures 20, 21, and 22) but initially with no pumping, to assess how the model was set up and allow for comparison with output from subsequent runs. There is also no rainfall recharge in the original configuration. Fresh water does enter the model from infiltration from rivers[6] and at the eastern GHB in Layer 2. All ocean water enters the model from the constant head boundary implemented on the western side of the model.

The results illustrate some key attributes of the original model configuration:

- The eastern GHB in Layer 2 was set at 0 feet in each of the three gradient scenarios;
- The eastern GHB in Layers 4 and 5 is set to -25, -50, and -75 feet, and in Layers 6, 7, and 8 is set to -15, -30, and -45 feet, to create the respective 0.0004, 0.0007, and 0.0011 inland gradients;
- The no-flow boundary in the northeastern corner of the model was removed from Layers 4 through 8, presumably to facilitate creation of a smooth landward gradient throughout the model. While this a departure from actual conditions in the north-eastern part of the model, it creates a more uniform and therefore realistic inland

[5] The effect on OWP of increasing the assumed TDS for fresh water is explained in detail on page 16 in Weiss (2019).
[6] Because of the presence of river boundaries in the original model, the original model is nonlinear and thus is not truly a "superposition model"(i.e., the capture extents will not be proportional to pumping rate or regional gradient).

gradient in the vicinity of the Project well field, which is the area of interest in evaluating groundwater capture due to pumping;

- Despite the eastern GHB setting of 0 feet in Layer 2, inland gradients were created in this layer for several miles inland of the Projects well field in response to the influence of heads in underlying Layer 4; and
- Fresh water enters the model at the river boundaries, and also in locations along the eastern boundary where heads are higher in the GHB for Layer 2 relative to the GHBs for Layers 4, 6, and 8.

The groundwater flow pattern that results from these conditions is depicted in the MODPATH outputs shown on Figures 23, 24, and 25.

All three gradient scenarios show inflow of fresh water from the rivers north of the Project well field. In an unpumped state, flow is to the east towards the GHB set to control the eastward gradients. As the gradient steepens from 0.0004 to 0.0011 (Figures 20, 21, and 22), the groundwater flow path lines lengthen, indicating increasing velocity of groundwater flow in response to the steeper gradients (Figures 23, 24, and 25).

Pumping at 15.5 MGD was then added, with flows allocated 44/56 percent between model Layers 2 and 4 to reproduce groundwater capture scenarios for comparison with those from the EIR/EIS (ESA, 2018; Figure 17). With increasing gradient, OWP in water captured by the slant wells increases (Figures 26, 27, and 28), and the capture area decreases (Figures 29, 30, and 31), as would be expected. The capture scenarios show good agreement with those from the EIR/EIS. The OWP exceeds 99 percent in all cases, reflecting that only landward gradients are present, even in Layer 2. Some aspects of the capture analysis include:

- Layer 4 particle tracks match the capture in the EIR/EIS (Figure 17).
- Captured particles in Layer 4 originate, travel, and are captured in Layer 4.
- The Layer 2 capture depicted in the EIR/EIS (Figure 17) is based on an ensemble of particles released at various depths within the model cell (0.1, 0.5, 0.9, and 1.0; 1.0 being at the water table).
- Particles in this analysis were released only at the midpoint of the model cells which show a more limited set of travel paths than the original model results.
- Most of the particles that originate south of the wells in Layer 2 travel downward into Layer 4, where they travel within Layer 4 for a majority of the time before getting captured in Layer 2 or 4.

In all of the scenarios, red path lines are crossing the shoreline south of the slant well field, and appear to defy/cross-over the capture zone boundaries. The red color of these path lines indicates particle travel through Layer 6, which is beneath the capture zones, thus passing below the capture area. After their initial release in Layers 2 or 4, these particles moved vertically downward to Layer 6 before moving laterally inland. The vertical flow segment of the particle flow path is not visible in the map view; the particles only become visible when they reach Layer 6 and begin to move horizontally; hence, they appear to originate in Layer 6.

4.2 Add Recharge to Create Layer 2 Seaward Gradient

As described in Section 2.2, the flat to very slight seaward groundwater gradient that was present in 2015 between wells MW-7S and MW-4S increased substantially, to approximately 0.001 beginning in 2016, and has remained elevated. A seaward gradient in Layer 2 was generated by adding recharge to the model, specifically, the annual average recharge of 5 inches per year referenced in the EIR/EIS (ESA, 2018). Recharge was applied to the model only on the land areas (Figure 32) and does not affect the Layer 1 ocean boundary. For the recharge scenario, the Layer 4 gradient was set at the intermediate value of 0.0007; slant well pumping was set at 15.5 MGD (Figure 33). This resulted in expected formation of a groundwater mound in the Dune Sand-Perched/Mounded Aquifer (Layer 2) inland of the slant wells, and a seaward gradient toward those wells. Due to more fresh water flowing toward the wells and capture of some of this water, the OWP dropped to 97.2 percent from the 99.97 percent baseline value. This is still higher that what was observed during TSW pumping (Figure 9). This is addressed by further modifications to the model described in Sections 4.7 and 4.8.

The sensitivity of OWP to variations in gradient was checked for the recharge scenario by running the model with 5 inches/year of recharge under the 0.0004, 0.0011, and 0.00 gradients. The results indicate that OWP becomes increasingly sensitive to recharge as the gradient flattens (Table 2). At a gradient of 0.0011, the OWP is 98.6 percent. Decreasing the gradient to 0.0007 decreases OWP by 1.4 percent, bringing it to a value of 97.2 percent. A further decrease in gradient to 0.0004 produces a much larger decrease in OWP of 5.7 percent, bringing it to a value of 91.5 percent. A further still gradient decrease to 0.00 produces the largest change of all in OWP: 12.1 percent, bringing it to a value of 74.9 percent.

It was noted that saline water upwells from Layer 4 to Layer 2 in the southeastern corner of the model (Figure 34), at the location of KV17 in Layer 2 and KV19 in Layer 3 (Figure 15). This is not likely to affect the OWP for this baseline scenario since it is far from the Project slant wells, and is on the other side of the groundwater divide created by recharge in Layer 2. However, it becomes important in further modifications to the model as described in Section 4.7.

4.3 Change 180-Foot Aquifer Gradient from Landward to Zero (SGMA Goal)

The baseline case developed with 5 inches of recharge, a hydraulic gradient of 0.0007, and well field pumping rate of 15.5 MGD described in Section 4.2 was used as the starting point to assess the effect of a zero groundwater gradient on OWP in water captured by the Project well field. The eastern GHB cells for Layers 4, 6, and 8 were set to +3 feet NAVD88 (same as the ocean boundary), the model was rerun, and OWP calculated. The resulting OWP of 74.9 percent is significantly lower than the baseline value of 92.7 percent (Table 2).

However, the 74.9 value generated by the steady-state model would not be seen for many decades or even centuries in real-world conditions. The steady-state model does not consider the large volume of saline water in storage in the 180-Foot Aquifer (Layer 4) that would have to be replaced by fresh water before the OWP at the Pumping well field would begin to decrease, and approach the 74.9 OWP calculated by the model.

Assuming that SGMA could create a flat gradient or even a pronounced seaward gradient,[7] for the initial decades after this condition is achieved the Project pumping wells would capture the existing saline water in the 180-Foot Aquifer (Layer 4) and OWP would likely be at or close to the 92.7 baseline value. After many decades or a few centuries when the 180-Foot Aquifer becomes filled with fresh water, this water would flow out to sea under non-pumping conditions, or would be captured by the Pumping well field if operating. Only under these conditions would the 74.9 OWP occur.

For comparison, it was decided to also check OWP for gradients of 0.0004 and 0.0011 in Layers 4, 6, and 8; these OWPs are 91.5 and 98.6 percent, respectively. This illustrates that when recharge is added to Layer 2, the OWP in water from the production wells becomes increasing sensitive to changes in the groundwater gradient in the deeper layers of the model (Layers 4, 6, and 8) as the gradient becomes gentler. A change in gradient by 0.0004, from 0.0011 to 0.0007, produces a decrease in OWP of 1.4 percent. But a reduction in gradient of the same magnitude starting with a shallower gradient, from 0.0004 to 0.00, produces a decrease in OWP of 12.1 percent. Presumably this is due to the increasing availability of fresh water for capture as the Layer 4 gradient flattens. Flattening the gradient decreases the flow of fresh water away from the pumping wells in Layer 4, until at zero gradient, there is no flow of fresh water away from the pumping wells.

4.4 Sensitivity to Variations in Recharge

The recharge amount of 5 inches per year in the baseline case was varied to determine the sensitivity of the model to variations in recharge. Values of 2.5, 10, and 15 inches per year were modeled.

The change in respective OWP calculated from these recharge values (Table 2) varies by about 7 to 23 percent, depending on the gradient specified in Layer 4. This indicates that OWP is quite sensitive to variations in recharge.

It should be pointed out that this steady-state model does not account for water storage variations in the aquifer, hence the OWPs calculated will not reflect the buffering effects of storage. In a transient situation as is the case in the real world, the actual OWP in a dry year will likely be lower than the calculated OWP due to residual water being present in storage from previous wetter years. In a like manner, the actual OWP in an abnormally wet year will likely be higher than the calculated OWP, as much of the extra water goes into storage and is not immediately available to the well. Therefore, the OWP represented by the sensitivity analysis from this steady-state model shows a narrower range in the OWP values than what would be expected in real-world conditions. To better identify the expected range in OWP, it is recommended to use the transient version of NMGWM^{2016} as discussed in Section 5.2.

4.5 Sensitivity to Variations in Pumping Rate

To determine the effect of changes in pumping rate on the OWP, the baseline scenario for all gradients was run with a pumping rate of half the baseline rate of 15.5 MGD, or 7.75 MGD (Table 1).

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[7] The landward gradient due to inland pumping that has caused seawater intrusion into the 180-Foot Aquifer is quite steep and has been for more than 60 to 80 years. It is highly unlikely that a similarly steep seaward gradient could be achieved under SGMA. If it could, it would take a similar period of 60 to 80 years to reverse seawater intrusion impacts and bring fresh water from the 180-Foot Aquifer to the Project well field. Under a more realistic flat or gentle seaward gradient, it would take far longer than 60 to 80 years to reverse the seawater intrusion impacts.

This resulted in a relatively small change in OWP, on the order of approximately 1 percent or less for the non-zero percent gradient scenarios. Doubling the pumping rate to 31 MGD also had a relatively small effect on these scenarios. Under the 0 percent gradient scenario in Layer 4, OWP variations from baseline OWP were about -6 percent at 7.75 MGD and +5 percent at 31 MGD.

4.6 Sensitivity to Variations in Aquifer Zone Hydraulic Conductivities

Several aquifer zones in the vicinity of the pumping wells and western edge of the FO-SVA were selected for modification of KH and KV to determine the potential effects of the position and magnitude of these uncertain soil properties on the OWP. In particular, the values of Layer 2 Zones KH20/KV20 (Figures 14 and 16) and Layer 3 Zones KH21/KV21 (Figures 15 and 16) determine the effective modeled position of the western extent of the FO-SVA. In the unmodified $NMGWM^{2016}$, the FO-SVA, modeled by Layer 3 and represented by Zones KV18 and KV21 (Figure 15), is present between monitoring well clusters MW-7 and MW-4, with the western edge of KV21 closer to MW-4 (Figure 7). The combination of KH20 of 4 feet per day and KV21 of 0.0005 feet per day favors vertical groundwater flow downward from Layer 2 to Layer 4 through Zone KV21 (Figure 16), effectively negating KV21 as representative of the FO-SVA and therefore positioning the edge of the FO-SVA at the western edge of Layer 3 Zones KH18/KV18. This position is inland of MW-7 and corresponds to the red-dashed line shown on Figure 7 (purple-dashed line on Figure 3).

The KH and KV zones modified, degree of modification, and resulting OWPs are shown in Table 2. The OWP was relatively insensitive to most of the changes, varying less than 1 percent from baseline values. The exceptions involved decreasing KV21 from 0.0005 to 0.0000005 feet per day, which yielded a 1.5 percent decrease in OWP in the 0.0007 gradient scenario, and increasing KH20 from 4 to 625 feet per day, which yielded decreases in OWP ranging from 1.9 percent in the zero gradient scenario to 3.7 percent in the 0.0007 gradient scenario.

Awareness of the relative sensitivity of the OWP to changes in KV21 and KH20 informed the adjustment of model parameters to recreate water level conditions at well MW-7S during pumping of the TSW, as described in Section 4.8.

4.7 Southern Boundary Condition Revision in Layer 2

One of the key technical discrepancies in $NMGWM^{2016}$ identified by stakeholders during Weiss's independent review (Weiss, 2019) is that the southern GHB groundwater elevation values for Layer 2 in the transient "calibration" version of the model were based on groundwater elevations from the Salinas Valley Integrated Ground and Surface Water Model (SVIGSM). These differ from the observed "perched" groundwater elevations by as much as 90 feet (Figures 18 and 34). Therefore, this condition was addressed before proceeding with further analysis of OWP and groundwater capture associated with the Project. A new GHB was created for Layer 2 with the configuration and head values shown on Figure 35. Heads for the GHB were set equal to projected groundwater elevation contours from measurements at Fort Ord, provided by EKI Environment and Water, Inc. Values between the contours were interpolated linearly. The GHB was only applied for cells with head greater than 50 feet to avoid generating artificial flows in and out of the model at lower elevations observed during initial model runs to evaluate the new GHB. Below 50 feet flow was mainly parallel to the southern edge of the model, so these portions of the Layer 2 southern boundary were assigned a no-flow condition.

Layers 3 through 8 were retained as no-flow boundaries, the same as in the unmodified capture version of NMGWM^{2016}.

During earlier model runs for the sensitivity analysis, another element of the unmodified model was discovered that exerted significant control of groundwater elevations along the southern margin. As mentioned in Section 4.2, there is an upwelling of saline water from Layer 4 to Layer 2 in the southeastern corner of the model (Figures 34 and 36) in the scenario with Layer 4 gradient at 0.0007. This location coincides with the location of KV17 in Layer 2 and KV19 in Layer 3 (Figure 15). The upwelling can be identified by an eastward bend, forming a point, in the -20 foot contour in Layer 4 at that location (Figure 33). Also, just west of that location, fresh water was entering Layer 4 from Layer 2, as indicated by the plume of lighter color moving downgradient from that spot. Essentially, KV19 was acting as a sink for fresh water from Layer 2 to flow vertically downward to Layer 4 (Figure 37).

The downward flow from Layer 2 to Layer 4 was much greater in the 0.0004 landward and 0.00 flat gradient scenarios, creating a groundwater mound in Layer 4 and warping the contours in Layer 2 (Figures 33 and 34). This truncated the groundwater mound formed in the Dune Sand Aquifer in the Fort Ord area. This had little effect on the unmodified model, as is shown in Figures 26, 27, and 28, mainly because there was no recharge, and the southern model boundary was a "no flow" boundary that was not putting any fresh water into the model. The problem at KV19 emerged due to its proximity to the newly-created Layer 2 GHB, which provides large quantities of fresh water in the adjacent model cells, creating a steep gradient between the Layer 2 GHB and Layer 3 at that location. The Layer 4 0.0011 and 0.0007 gradients are steep enough to drain this extra water away, in a landward direction away from the coast. But the 0.0004 gradient is not sufficient to drain away the water, hence the entire 180-foot Aquifer becomes unrealistically filled with fresh water, and under the 0.0004 and 0.00 gradients, an unrealistically large groundwater mound forms at the KV19 area. And, under all gradients, the Layer 2 groundwater elevation contours at Fort Ord were unrealistically truncated by the downward flow of groundwater from Layer 2 to Layer 4, as shown in Figures 33, 34, and 36.

The value of KV19 in the original NMGWM^{2016} was set at 8.7 feet per day (Figure 38), indicating the complete absence of the FO-SVA in that area. Note that KV in the adjoining zones is set orders of magnitude lower, where the FO-SVA is present. In Appendix E2 (page 17) of the EIR/EIS (ESA, 2018), it is stated,

> *"South of the Salinas River, the NMGWM^{2015} parameter zones were modified to represent reported hydrogeologic conditions in the Fort Ord Area. We modified the western extent of the FO-SVA delineated by Harding ESE (2001) based on the clay identified between the A-Aquifer and 180-FTE Aquifer in reported cross-sections (GSI, 2016). The **eastern boundary of the FO-SVA*** [emphasis added] *was delineated at the elevation difference between the upper dune sand and terrace deposits and the lower valley deposits."*

This statement seems to indicate that the FO-SVA should be present in the KV19 zone, as it lies beneath the dune sand and terrace deposits, and its northeastern border coincides with the abovementioned elevation difference between the upper dune sand and terrace deposits and the lower valley deposits (Figure 38). And the FO-SVA is interpreted as being present in cross section 4-4' (Figure 6) approximately 1 to 3 miles east of KV19. Cross-section 1-1' (Figure 2a; Appendix E2; ESA, 2015) shows several aquitards in the subsurface near the "elevation difference" between the terrace deposits and lower valley deposits north of KV19, indicating the nature of the FO-SVA in that area.

In Appendix E2 of the EIR/EIS (page 18), it is stated:

> "*In **Figure 3.3a**, most (76%) of the NMGWM^{2016} horizontal conductivity values are within the range of previous studies with the exception of two zones representing the older dune sand deposits where the modeled values are noticeably greater (KH13+KH15 and KH17+KH19). The model-specified values for these older dune sand parameter zones reflect new information developed from analysis of the slant well pumping test data **collected from an observation well located in the older dune sand deposits** (HLA, 1995)* [emphasis added].

It is unknown from which observation well located in the older dune sand deposits this information originated. It does not appear from the MW-1 through MW-9 hydrographs that the TSW had any effect on water levels in wells screened in the older dune sands – or any well further than well MW-4 from the TSW. Zone KH19 is more than 4 miles away from the TSW, so it is not clear how its KH or KV were determined on the basis of TSW pumping test data.

Based on the likely presence of the FO-SVA in the KV19 area and the anomalously low water levels it was creating by allowing water from Layer 2 to move downward to Layer 4, the value of KV19 was changed from 8.7 to 0.0000005, to be in accord with the adjoining KV18 (Figure 38). The effects of this change can be seen in the southeastern corner of the model by comparing the groundwater contours in Layer 2 before the revision (Figure 33) to the contours after the revision (Figures 39 and 40). Groundwater elevations became some 20 to 40 feet higher in much of the southeast corner. To ensure this did not result in groundwater rising above the land surface, in particular the relatively low elevation Salinas Valley, the revised model groundwater elevations (Figures 39 and 40) were compared with land surface elevations in the Valley (Figure 41). The comparison showed the modeled groundwater elevations of 10 to 30 feet in this area remained below actual surface elevations in the range of 30 to 40 feet.

All subsequent model runs described below were performed with the revised southern boundary conditions. The initial run (Figure 39) employed these elements:

- KV19 was adjusted to be the same as KV18 at 0.0000005 feet per day;
- KH16 and KH18 were adjusted from 2 to 3.5 feet per day. This change was necessary because adding the new boundary brings more water into the model; this water needs to flow away from the boundary to maintain a match between the modeled and measured groundwater elevations (Figure 40);
- Recharge was set at 5 inches/year;
- Layer 4 inland gradient was set to 0.0007;
- Pumping from the slant wells at 15.5 MGD; and
- The reference heads at all model boundaries were raised by 3 feet so that heads are consistently expressed relative to the North American Vertical Datum of 1988 (NAVD88) for sea level:
  - Initial heads so that drawdown is still the same;
  - The constant head boundary representing ocean water;
  - GHB heads;
  - RIV heads; and
  - RIV bottom elevations adjusted to match results.

The results show a good match to the groundwater contours in Layer 2 in the south end of the model (Figure 40). The OWP from this initial run was 96.8 percent, 0.4 percent lower than without the adjustments to the south model boundary (Table 3)[8].

4.8 Adjust Model Parameters to Replicate Test Slant Well Conditions at MW-7S

Although not included in the list of tasks for this modeling implementation, to check results of the sensitivity analysis and southern boundary adjustments, the model was applied to see if it could replicate a limited set of conditions from the TSW testing period (Figure 9). These conditions were the OWP values for the dry period prior to the summer of 2016, the wet period following, corresponding groundwater elevations in well MW-7S, and pumping at 2,000 gpm (2.88 MGD). The remaining parameters were set as specified in Section 4.7, with the exception of the following:

- Only the northernmost slant well was used, corresponding to the TSW;
- Pumping was proportionally distributed over the model cells representing that well, based on the distribution of pumping rates assigned to the well for the 15.5 MGD simulations; and
- KH20 was changed from 4 to 40 feet per day, and KV21 was changed from 0.0005 to 0.0000005 feet per day, simulating an extension of the FO-SVA westward by 2,600 to 4,800 feet, bringing it west of well MW-7S and close to well MW-4S.

Two seasonal conditions were assessed: (1) “Wet” conditions represented by recharge of 6 inches per year and gradient of 0.0004; and (2) “Dry” conditions represented by recharge of 4 inches per year and gradient of 0.0011. In both scenarios, the OWP was calculated for the TSW and groundwater elevation was noted at well MW-7S; results are shown on Figures 42 and 43.

The “wet” scenario predicts an OWP of 85.8 percent and a water level in well MW-7S of 8.9 feet, very similar to the early- to mid-2017 values obtained in the TSW test (Figure 9). The “dry” scenario predicts an OWP of 99.6 percent, much higher than any of the “dry” periods during the TSW test, and a water level in well MW-7S of 0.7 feet, much lower than at any time during the TSW test (Figure 9). The latter is likely an artifact of steady state modeling, which is unable to draw on prior storage of fresh water in Layer 2 – essentially assuming that it has always been “dry” and always will remain dry. In the real world, the OWP and water levels in well MW-7S in the 2015 and early 2016 “dry” period likely reflect the influence of a large volume of storage of fresh water from previous wet years. The range in the OWP values from 85.8 to 99.6 percent derived from modeling TSW pumping conditions is similar to the range in the OWPs derived from modeling the full Project well flow, as discussed in Section 4.9.

In evaluating different combinations of recharge, KH, KV, and gradient to get the model to reproduce the “wet” season OWP and well MW-7S water levels from the TSW test, no combination was successful without extending the edge of the FO-SVA seaward as was done. As previously mentioned, this was accomplished through a combination of decreasing vertical K in Layer 3 Zone KV21 to the same value as KV18 (0.0000005 feet per day), and increasing horizontal K in Layer 2 Zone KH20 from 4 to 20 feet per day. This is good evidence that the FO-SVA is continuous,

[8] To provide comparison for different assumed “fresh” water TDS, Table 3a shows the OWPs based on the assumption that “fresh” water has TDS of 500 mg/L (OWP^{500}), and Table 3b shows the OWPs based on the assumption that “fresh” water has TDS of 3,000 mg/L ($OWP^{3,000}$).

and indeed does extend west of well MW-7S. It is therefore unnecessary to conduct field work to establish the configuration and continuity of the FO-SVA; assuming it is continuous and extends west of well MW-7S produces conservatively low OWP estimates that match the TSW results.

4.9 Estimated Groundwater Capture in a Range of Scenarios

Building on the “wet” and “dry” scenarios described in Sections 4.7 and 4.8, both were run at slant well pumping rates of 7.75 and 15.5 MGD to obtain OWP estimates, and generate MODPATH plots to estimate the groundwater capture areas for these scenarios and pumping rates in Layers 2 and 4 (Figure 44 through 47).

Estimated fresh groundwater capture is greater in the “wet” scenarios due to the greater volume of fresh water coming into the system as recharge, and the reduced outflow from a gentler gradient in Layer 4 (Figures 44 and 45). For the 7.75 MGD Project pumping rate, the estimated capture areas are approximately 4 square miles in Layer 2, and 1.5 square miles in Layer 4. For the 15.5 MGD Project pumping rate, the capture areas are approximately 8 square miles in Layer 2, and 4 square miles in Layer 4.

Estimated fresh groundwater capture is less in the “dry” scenarios due to less availability of fresh water, and the steeper landward dry-season groundwater gradient in Layer 4. The steeper gradient induces greater fresh water flow inland, away from the Project well field. For the 7.75 MGD Project pumping rate, the estimated capture areas are approximately 0.75-square mile in Layer 2 and 0.5-square mile in Layer 4. For the 15.5 MGD Project pumping rate, the capture areas are approximately 2.5 square miles in Layer 2, and 0.75-square mile in Layer 4.

In addition, zero pumping and 7.75 and 15.5 MGD scenarios were run for a zero groundwater gradient set for Layers 4, 6, and 8 in the model (Table 3). The GHB for the eastern side of the model was set at +3 feet NAVD88 for all layers, creating a zero gradient from the eastern model boundary to the ocean. Recharge was set at 5 inches per year; this recharge and vertical downward flow from Layer 2 creates a gentle seaward gradient from several miles inland to the coast in these layers, in the region of the Pumping well field. MODPATH plots were generated for Layers 2 and 4 for each of these scenarios (Figures 48, 49, and 50).

The zero to slightly seaward groundwater gradient scenarios represent what may potentially occur following full implementation of the SGMA by 2040. In the no-pumping scenario (Figure 48), fresh groundwater flows from inland out to sea. Because the head differential between Layers 2 and 4 is eliminated in the zero to slightly seaward gradient scenarios, there is no spillover of fresh water from Layer 2 to Layer 4 at the edge of the FO-SVA – instead, all of the fresh water in both layers flows to the sea. In the pumping scenarios (Figures 49 and 50), much of the fresh water flowing toward the sea is captured by the Project well field. However, as discussed in Section 4.3, it would take many decades or even a few centuries before all of the sea water was flushed from the 180-foot aquifer and the OWPs of 66.6 for the 7.75 MGD pumping rate and 73.4 for the 15.5 MGD pumping rate were achieved.

4.10 Potential Impacts on Vernal Ponds

It is not known if the vernal ponds owe their existence to temporary perched water table conditions or are associated with temporary high overall groundwater elevations. Only in the latter case could the MPWSP pumping potentially impact the vernal ponds.

The potential impact of pumping on the vernal ponds located within the area of influence of the Project well field (Figure 51) was evaluated for both the "wet" and "dry" seasons. To serve as a baseline, the modeled groundwater elevations were compiled for the "wet" and "dry" season non-pumping model conditions for each pond (Table 4). Water level decreases (drawdown) at each pond due to pumping at rates of 7.75 and 15.5 MGD was also compiled and tabulated. The drawdowns for the "wet" and "dry" seasons are the same as a result of the principal of superposition; both seasons are tabulated to illustrate this principal.

As would be expected, baseline groundwater elevations are modeled to be lowest in the "dry" season and highest in the "wet" season, ranging from calculated lows of -2.8 to 0.29 feet NAVD88, to calculated highs of 2.7 to 6.9 feet NAVD88. These values are modeled estimates for comparison only, and are not a substitute for surveyed and measured groundwater elevations.

Model-predicted drawdowns are greatest in the ponds closest to the Project well field. Drawdowns range from 0.39 and 0.79 feet at the Lake Drive Pond for 7.75 and 15.5 MGD pumping rates, to 2.02 and 4.05 feet at the Armstrong Ranch Ponds for 7.75 and 15.5 MGD pumping rates, respectively.

4.11 Limitations of this Study

The numerical model used to simulate groundwater flow in this study is an approximate and non-unique representation of actual groundwater flow in the study area. As such, the study results are intended to be used strictly as a decision support tool. Due to a variety of known and unknown limitations, the results should not be considered as definitive representations of past, current, or future groundwater flow. The most important limitations that apply to the modeling conducted for this study are described below.

The subsurface hydrogeologic conditions within the study are not precisely defined and therefore hydrogeological features which are mathematically depicted in the numerical model are often based on extrapolation and assumptions by experienced professionals. While best practices have been used to establish valid model input parameters, the resulting solutions are not unique and the uncertainties in the model results cannot be quantified.

The model results are best applied to the area of the slant wells and vicinity, and become progressively less representative of actual conditions with increasing distance inland from the coast. The model should not be used to predict water levels or salinity in any area more than a few thousand feet from the Project well field. Such predictions would be approximations only, and should be augmented with information from other sources.

As described in Section 4.8, the steady-state model used in this study cannot reproduce "dry" season water levels accurately due to a lack of prior storage. The groundwater capture estimates discussed in Section 4.9 are based on steady-state modeling and do not account for groundwater storage, therefore the high and low ends of the range of estimates are not likely to occur and can be considered as "best-case" and "worst-case" estimates. Transient modeling is required to produce more realistic estimates of the capture areas likely to occur within this range.

Recharge is averaged over a year, when it actually takes place over a 4- to 6-month interval each year. This is good for determining general patterns and for comparing different scenarios, however it cannot be applied directly to predict specific circumstances, especially those with many variations.

Density differences between ocean water and fresh water are not accounted for. Compared with the single-density modeling performed for this study, the greater density of ocean water would have the effect that it would flow inland to a greater extent than what was modeled. This means that all else being equal, the OWP estimates from this single-density model will be in lower than actual values. An assessment of this issue in the EIR/EIS (ESA, 2018) indicated that the error in the OWP resulting from the single-density assumption is on the order of a few percent. However, this error appears to be largely offset by the specified inland gradients of 0.0004, 0.0007, and 0.0011 employed in the model (Figures 20, 21, 22, and 36) which create saline conditions in Layer 4. These gradients will partially account for saltwater intrusion in addition to the gradients induced by inland pumping alone.

The OWP and water level data obtained from the TSW (Figure 9) were used in this study and compared with model results. These data may have been impacted by adjacent CEMEX pond dredging sand washing with fresh water. The CEMEX operation moves large volumes of salt water and fresh water in dredging sand quarries (salt water) and washing sand (fresh water). These operations were active during the slant well testing, and the degree to which operations affected the results is unknown; opinions differ as to its significance (Hopkins, 2017). To the degree fresh water was discharged to the surface in the TSW vicinity from the sand washing operation, the OWP would be depressed. Discharges of saline dredge water would have the opposite effect.

It is important when interpreting the results of the steady-state version of the $NMGWM^{2016}$ implemented for this study, to understand that the results represent equilibrium conditions not experienced in the real world where variables such as recharge and pumping rates are constantly changing. Each model implementation scenario assumes values for the hydrogeologic variables that do not change, in effect assuming that conditions have always been the way the parameters are set, and will never change in the future. Whereas in the real world there are seasonal changes, long-term weather trends, and variable anthropogenic effects such as land use changes, groundwater pumping and surface water diversions. The steady-state model therefore can represent an average condition, long-term average condition, or "worst case" end member condition, and the OWP calculated from each scenario must be interpreted accordingly. Especially important to the real-world value of the OWP is the flow of groundwater in and out of aquifer storage, which is not accounted for in the steady-state model, and provides a buffering effect.

Therefore, the OWP results are best understood as long-term averages, and differences between OWP values calculated indicate the relative effects of changing a particular variable, and will not necessarily be representative of, or predict, short-term OWP changes. For example, the annual average recharge value of 5 inches per year is distributed evenly over the entire year in the steady-state model; a transient model would assign the recharge proportionately to the 4- to 6-month period when it actually occurs. This should make seasonal changes in the OWP evident, whereas the steady-state model results will depict only the average tendencies of the system.

Also important is the effect of travel time. In calculating the OWP for the zero-gradient scenario, the length of time for existing salt water in the aquifers to be pushed back to the sea is likely to be decades to centuries. The OWP calculated for the Project well field output under the 0.00 gradient in Layers 4, 6, and 8 will only gradually be approached as that existing salt water flows seaward; it will not "instantaneously" reach the 65 to 75 percent range calculated by the model – that requires equilibrium to be reached.

The steady-state version of NMGWM^{2016} does not account for the difference in density between fresh water and ocean water. The higher density of ocean water will induce flow inland, beneath the fresh water, in the absence of sufficient head in the inland fresh water aquifer(s). All else being equal, this would increase the OWP in the inland areas so impacted. Because this phenomenon is not modeled, the estimates of the OWP from the model err on the low side.

In both the original model and in the implementation for this study, the Dune Sand Aquifer (Layer 2) is modeled as confined. This results in zero change in transmissivity as water levels change, likely underestimating freshwater flow to the slant wells in wet conditions, and overestimating freshwater flow to the wells in dry conditions. And, the slant wells are modeled such that they withdraw a fixed proportion of water from each pumped layer, regardless of the actual layer transmissivity and gradient. The use of the multi-node well package (MNW) and/or multi-aquifer well package (MAW) in MODFLOW would rectify the latter.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The key conclusions from this study of OWP and fresh water capture under different conditions and assumed subsurface configurations are as follows:

1. OWP in water from the production wells becomes increasingly sensitive to changes in groundwater gradient in the deeper layers of the model (Layers 4, 6, and 8) as the gradient becomes gentler. A change in gradient by 0.0004, from 0.0011 to 0.0007 produces a decrease in the OWP of 1.4 percent. However, a reduction in gradient of the same magnitude starting with a shallower gradient, from 0.0004 to 0.00, produces a decrease in the OWP of 12.1 percent.
2. The OWP is relatively sensitive to changes in recharge and corresponding groundwater elevation differences inland from the Project well field.
3. The OWP is sensitive to the configuration/location of the western edge of the FO-SVA aquitard and the hydraulic conductivity of the overlying Dune Sand Aquifer under moderate inland gradient conditions (0.0004 to 0.0007). Moving the western edge of the FO-SVA 2,600 to 4,800 feet seaward from the original location assumed by the $NMGWM^{2016}$ reduces the OWP by 3.5 to 5 percent, depending on the gradient. There is little change in the OWP from moving the western edge of the FO-SVA under 0.00 gradient conditions, presumably because all the water in both Layers 2 and 4 inland from the coast is fresh.
4. The OWP and groundwater capture are not very sensitive to changes in aquifer zone KH and KV other than the changes mentioned above.
5. Potential fresh water capture by the MPWSP was estimated from particle tracking for "dry" and "wet" conditions, representing minimum and maximum likely capture areas. Under "dry" conditions, the MPWSP is calculated to potentially capture fresh groundwater from the Dune Sand Aquifer (Model Layer 2) over an area ranging from 0.75-square mile with pumping at 7.75 MGD to 2.5 square miles at 15.5 MGD. The range in the 180-Foot Aquifer (Model Layer 4) under these pumping conditions is 0.5- to 0.75-square mile. Under "wet" conditions, the corresponding capture areas increase in Layer 2 to range from 4 square miles with pumping at 7.75 MGD to 8 square miles at 15.5 MGD. In Layer 4, the "wet" conditions capture range is from 1.5 square miles with pumping at 7.75 MGD to 4 square miles at 15.5 MGD. These estimates are based on steady-state modeling and do not account for groundwater storage, therefore the high and low ends of the range are not likely to occur and can be considered "best-case" and "worst-case" estimates. Transient modeling would be required to produce more realistic estimates of the capture areas likely to occur within this range.
6. For zero gradient conditions in the 180-Foot Aquifer, potentially achievable by 2040 under SGMA, an OWP range of 66.6 to 73.4 was estimated for 7.75 MGD and 15.5 MGD pumping rates, respectively. However, as discussed in Section 4.3, it would

take many decades or even a few centuries for all of the sea water to be flushed from the 180-foot aquifer and for these OWPs to be achieved. Until that time, the Pumping well field would be capturing all of the saline water currently in storage in the 180-Foot Aquifer, resulting in average OWPs greater than 91.5.

7. If the vernal ponds do not owe their existence to perched groundwater conditions, they may be in hydraulic communication with shallow groundwater and subject to impact by the MPWSP pumping. In the latter case, model-predicted reductions in groundwater levels at the ponds range from 0.39 to 4.05 feet, depending on the location and the MPWSP pumping rate.

5.2 Recommendations

If more precise estimates of the OWP and groundwater capture and vernal pond impacts are necessary to support project decisions, it is recommended to employ the transient version of the $NMGWM^{2016}$ ("calibrated model"). This will overcome the limitations of the steady-state implementation of $NMGWM^{2016}$, which does not account for groundwater storage and short-term difference on a scale of a few years or less. It is recommended that the transient version of $NMGWM^{2016}$ be implemented as follows:

- Revise the starting heads file, possibly by importing the head file from one of the later or last stress periods, rather than relying on the SVIGSM starting heads.
- Revise the eastern model boundary conditions that are currently based on the SVIGSM, while retaining the adjustment to the Layer 2 GHB on the southern boundary and revision of KV19 made for this investigation. This will produce better model calibration with the calibration wells used in the $NMGWM^{2016}$; if this creates a perched condition for Layer 2 that MODFLOW-2000 will not work with, thicken Layer 3 from the bottom of Layer 2 to below sea level, with KV of Layer 3 set sufficiently low to keep it saturated, and provide hydraulic continuity between the bottom of Layer 2 and the top of Layer 4. Or, instead of MODFLOW-2000, use a Newton-Raphson formulation of MODFLOW such as MODFLOW-NWT (Niswonger et. al., 2011) or MODFLOW-USG (Panday et. al., 2013) that improves the solution of unconfined groundwater-flow problems.
- Keep sea level elevation at +3 feet relative to the NAVD-88 as was done for this investigation.
- Revise KH and KV in certain model zones as appropriate, using the values and results of the sensitivity analysis from this investigation as a guide.
- Specify that the Dune Sand Aquifer (Layer 2) is unconfined.
- Use the MNW or MAW packages in MODFLOW to model the slant wells so that they withdraw water from each pumped layer (Layers 2 and 4) in proportion to the actual layer transmissivity and gradient.
- Extend the model calibration period from 1980-2011 to 1980-2019; update recharge, evapotranspiration, boundary heads, and other model inputs accordingly.

- In addition to the existing group of wells used to calibrate the NMGWM[2016] to the 1980-2011 period, extend the calibration period to include 2015-2020 data from the MW-series of monitoring wells and the TSW, which includes periods of below-average rainfall, much higher than average rainfall, and slightly above average rainfall. Also add key Fort Ord monitoring wells screened in Layer 2 that have a long period of record. Adjust model parameters to accurately predict the draw-downs in the MW-series of monitoring wells in response to the TSW pumping that occurred between April 15, 2015 and February 28, 2018, and the recovery period that followed.
- Estimate the potential impact of CEMEX operations that discharged water related to sand quarry dredging (salt water) and sand washing (fresh water) on slant well testing results. The degree to which these operations affected the TSW results is unknown. A sensitivity analysis covering the potential range of reasonable assumptions of salt water and fresh water discharge should be performed to determine the potential effect of these inputs on OWP calculations.
- Vernal pond bottom elevations should be surveyed and water levels monitored, both in the ponds themselves and adjacent shallow groundwater to determine if they exist because of perched water conditions or as a result of hydraulic communication with shallow groundwater.

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b. Chapter 8.2 (*Master Responses 5-12*)
c. Chapters 8.5.1, 8.5.2 (*Comment letters of City of Marina and MCWD and Responses to Comments*)
d. Appendix E1, *Lawrence Berkeley National Laboratories Peer Review*
e. Appendix E2, *North Marina Groundwater Model Review, Revision, and Implementation for Slant Well Pumping Scenarios*
f. Appendix E3, *HWG Hydrogeologic Investigation Technical Report*
g. Appendix J, *Memorandum regarding Responses to Comments Received after Publication of MPWSP Final EIR/EIS*, File No. A. 12-04-019 Cal-Am MPWSP FEIR/EIS (September 12, 2018).

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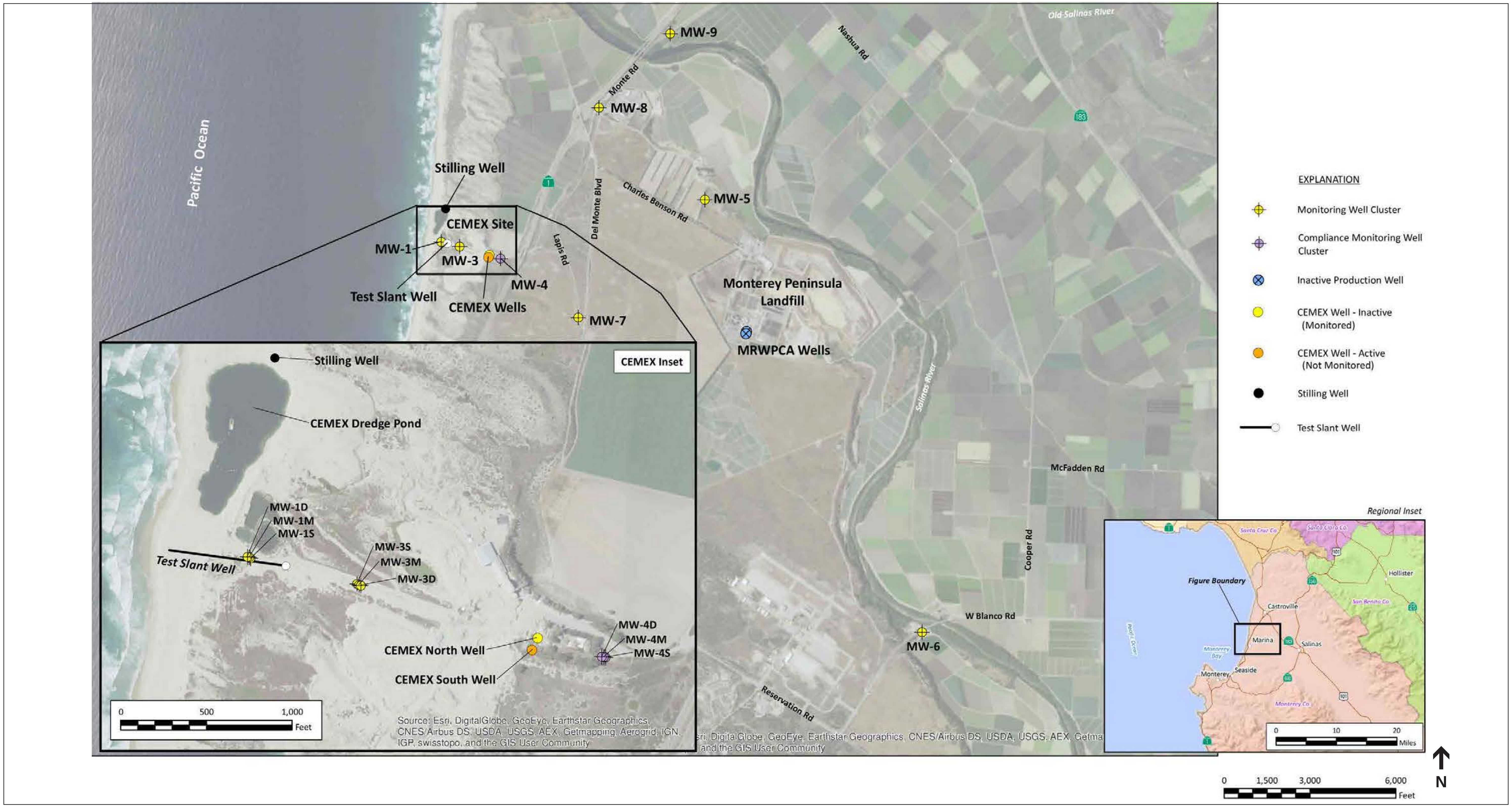
FIGURES

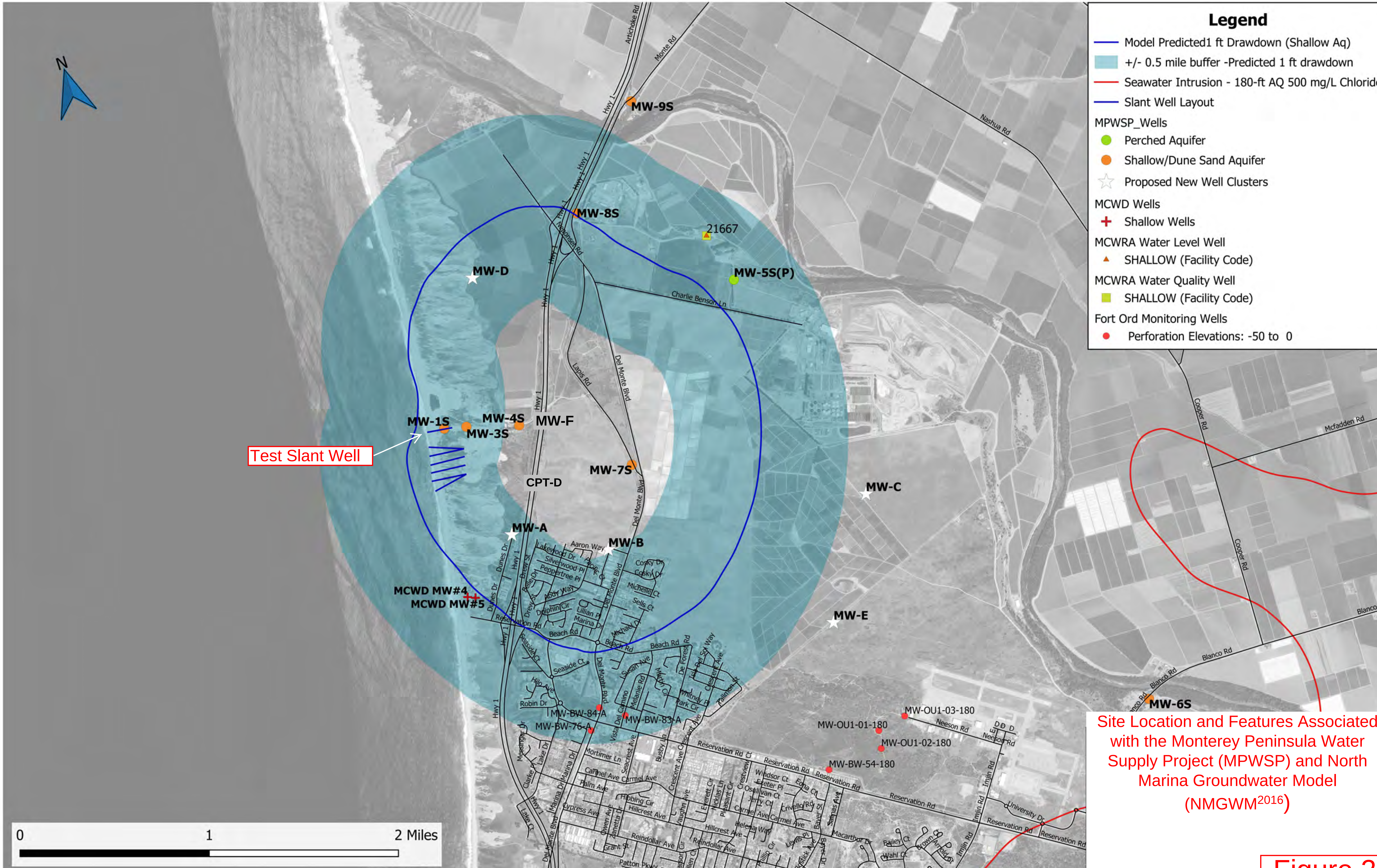


SOURCE: GeoScience, 2016

Monterey Peninsula Water Supply Project . 205335.01

Figure 4.4-9
Slant Well and Monitoring Well Locations

Figure 1

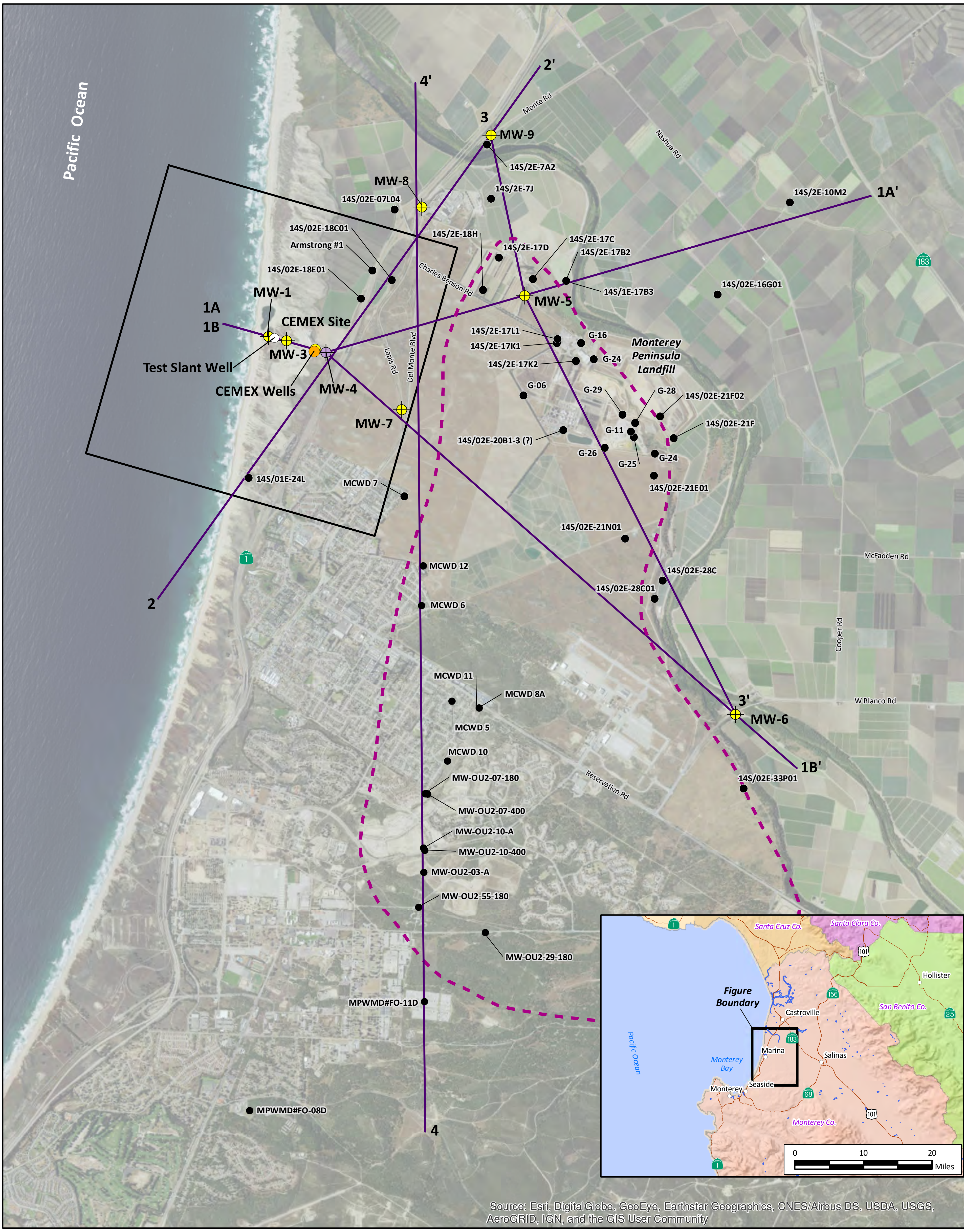


Site Location and Features Associated with the Monterey Peninsula Water Supply Project (MPWSP) and North Marina Groundwater Model (NMGWM^{2016})

Figure 2

CALIFORNIA AMERICAN WATER

MONTEREY PENINSULA WATER SUPPLY PROJECT
MONITORING WELL COMPLETION REPORT AND CEMEX MODEL UPDATE



EXPLANATION

- CEMEX Model Boundary
- 1 — 1' Cross-Section Location
- Fort Ord Salinas Valley Aquitard (FO-SVA) (GEOSCIENCE, 2016)
- Monitoring Well Cluster
- Compliance Monitoring Well Cluster
- CEMEX Well - Inactive (Monitored)
- CEMEX Well - Active (Not Monitored)
- Test Slant Well
- Other Well Used in Cross-Sections

NORTH

0 3,500 7,000 Feet

REGIONAL LOCATION MAP SHOWING WELL AND CROSS-SECTION LOCATIONS

8-Feb-17

Prepared by: DB. Map Projection: State Plane 1983, Zone IV.

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Figure 2

Figure 3

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Figure 3

X:\Projects\MONTEREY AREA DESAL STUDIES\01a) Test Slant Well Project\01) Monitoring Wells\4) TM Monitoring Well Completion\03) Final TM Feb_17\Figures

Figure 4

CALIFORNIA AMERICAN WATER
MONTEREY PENINSULA WATER SUPPLY PROJECT - MONITORING WELL COMPLETION REORT AND CEMEX MODEL UPDATE
GEOLOGIC CROSS-SECTION 1B-1B'
1B W-NW
1B' E-SE
CEMEX Site
Dune Complex - Highland Area
Salinas Valley
Gap in FO-SVA East of MW-7?
Elevation, ft NAVD88
Pacific Ocean
Deltaic Deposits (Qf?)
Older Dune Sand (Qod)
Terrace Deposits (Qt)
Qd
180-Foot Equivalent Aquifer
180/400-Foot Aquitard
FO-SVA
Terrace Deposits (Qt)
Aromas Sand (?) (Qar)
CEMEX North Well Screen Interval
CEMEX South Well Screen Interval
Paso Robles Formation (QT)
Salinas River
Flood Plain Deposits (Qfl)
Perched "A" Aquifer
SVA
Valley Fill (Qo)
180-Foot Aquifer
400-Foot Aquifer
MW-1
Test Slant Well
MW-3
CEMEX Well South
CEMEX Well North
MW-4
Cross-Section 2-2'
Highway 1
MW-7
Del Monte Blvd.
MCWD 7
14S/2E-21N1
14S/2E-28C1
W. Blanco Rd.
MW-6
Cross-Section 3-3'
14S/2E-33P1
Explanation
Holocene
Qfl
Qd
Pleistocene
Qo
Qt
Qod
Qf
Qar
Pliocene
QT
SVA Clay Layer
Clay Layer
Geologic Contact (approximate)
Wells
MPWSP Monitoring Well Screened Interval
Screened Interval from DWR Well Log
Well Lithology
Conductivity Induction Log Deep (CILD) [mmho/m]
Groundwater Elevation, ft NAVD88 10-Sep-2015)
5.1 Shallow Completion
4.0 Middle Completion
-9.0 Deep Completion
34,500 Water Quality (TDS) Measurement, mg/L (February, March, April, and August 2015)
Horizontal Approximate Scale Feet
Vertical Approximate Scale Feet
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Figure 4

Figure 5


CALIFORNIA AMERICAN WATER
MONTEREY PENINSULA WATER SUPPLY PROJECT - MONITORING WELL COMPLETION REPORT AND CEMEX MODEL UPDATE
GEOLOGIC CROSS-SECTION 4-4'
4 S
4' N
Salinas Valley
Elevation, ft NAVD88
Older Dune Sand (?) (Qod)
"A" Aquifer
Terrace Deposits (?) (Qt)
Paso Robles Formation (?) (Tpr)
FO-SVA
Older Dune Sand (Qod)
Terrace Deposits (Qt)
Upper 180-Foot Aquifer (HLA7)
Lower 180-Foot Aquifer (HLA7)
180/400-Foot Aquitard
Aroma Sand (?) (Qar)
180-Foot Equivalent Aquifer
180/400-Foot Aquitard
400-Foot Equivalent Aquifer
Aroma Sand (?) (Qar)
Flood Plain Deposits (Qfl)
SVA
Perched "A" Aquifer?
Terrace Deposits (Qt)
180-Foot Aquifer
Gaps in FO-SVA North and South of MW-7?
Explanation
Holocene
Qfl
Qb
Qd
Pleistocene
Qo
Qt
Qod
Qf
Qar
Pliocene
QT
SVA Clay Layer
Clay Layer
Silt Layer
Geologic Contact (approximate)
Well Lithology
Conductivity Induction Log Deep (CILD) [mmho/m]
Wells
MPWSP Monitoring Well Screened Interval
Screened Interval from DWR Well Log
Groundwater Elevation, ft NAVD88
5.1 Shallow Completion (Fall-2015)
4.0 Middle Completion (Fall-2015)
-9.0 Deep Completion (Fall-2015)
3.0 Infered Fall 2015 Water Levels from Contour Maps and Well Data.
34,500 Water Quality (TDS) Measurement, mg/L (May, June, and August 2015)
Horizontal Approximate Scale Feet
Vertical Approximate Scale Feet
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Figure 7
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Figure 6

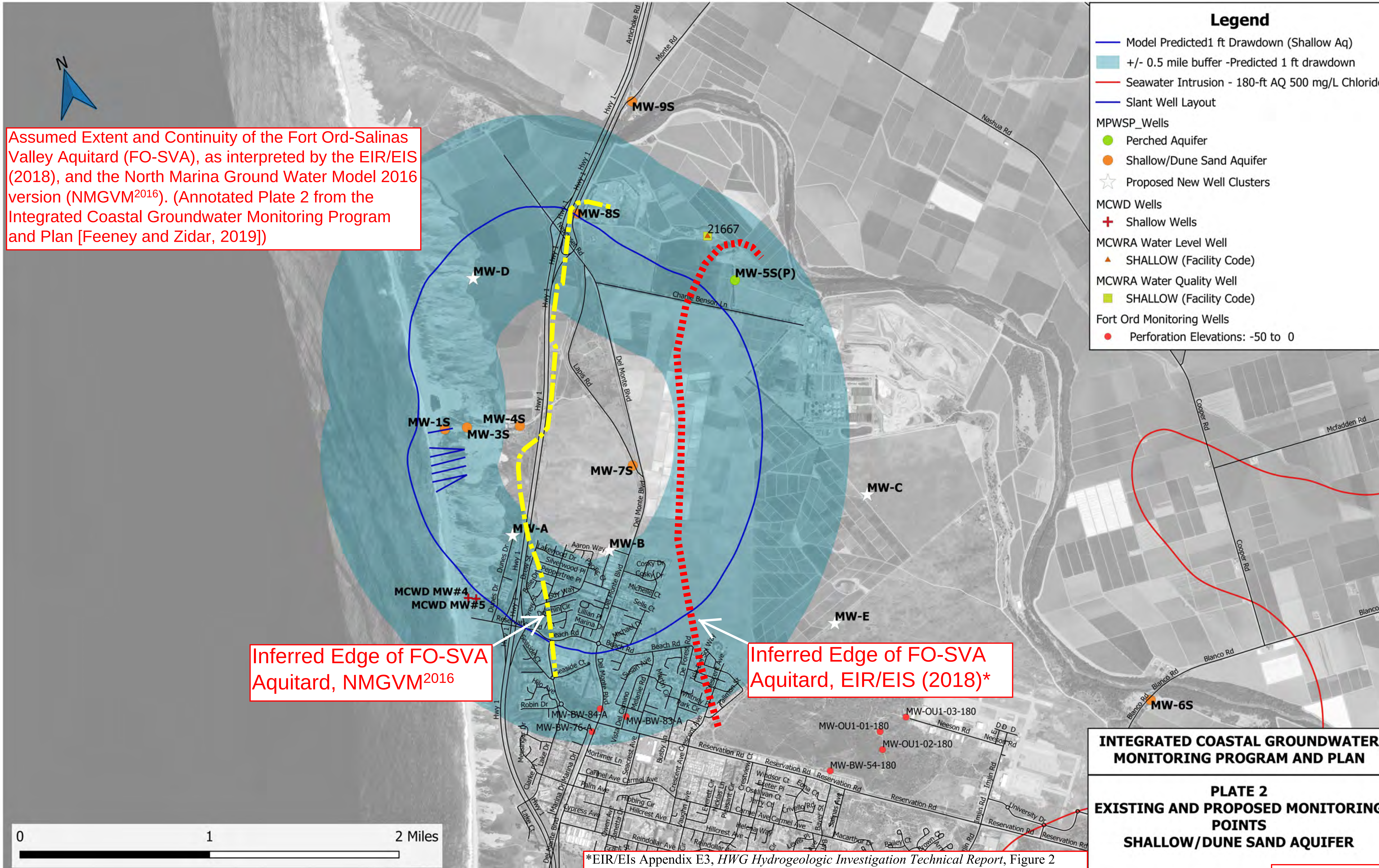

Assumed Extent and Continuity of the Fort Ord-Salinas Valley Aquitard (FO-SVA), as interpreted by the EIR/EIS (2018), and the North Marina Ground Water Model 2016 version (NMGVM2016). (Annotated Plate 2 from the Integrated Coastal Groundwater Monitoring Program and Plan [Feeney and Zidar, 2019])
Legend
Model Predicted1 ft Drawdown (Shallow Aq)
+/- 0.5 mile buffer -Predicted 1 ft drawdown
Seawater Intrusion - 180-ft AQ 500 mg/L Chloride
Slant Well Layout
MPWSP_Wells
Perched Aquifer
Shallow/Dune Sand Aquifer
Proposed New Well Clusters
MCWD Wells
Shallow Wells
MCWRA Water Level Well
SHALLOW (Facility Code)
MCWRA Water Quality Well
SHALLOW (Facility Code)
Fort Ord Monitoring Wells
Perforation Elevations: -50 to 0
MW-9S
MW-8S
21667
MW-5S(P)
MW-D
MW-1S
MW-4S
MW-3S
MW-7S
MW-C
MW-A
MW-B
MCWD MW#4
MCWD MW#5
MW-E
MW-6S
MW-BW-84-A
MW-BW-83-A
MW-BW-76-A
MW-OU1-03-180
MW-OU1-01-180
MW-OU1-02-180
MW-BW-54-180
Inferred Edge of FO-SVA Aquitard, NMGVM2016
Inferred Edge of FO-SVA Aquitard, EIR/EIS (2018)*
0 1 2 Miles
*EIR/EIs Appendix E3, HWG Hydrogeologic Investigation Technical Report, Figure 2
INTEGRATED COASTAL GROUNDWATER MONITORING PROGRAM AND PLAN
PLATE 2
EXISTING AND PROPOSED MONITORING POINTS
SHALLOW/DUNE SAND AQUIFER

Figure 7

A

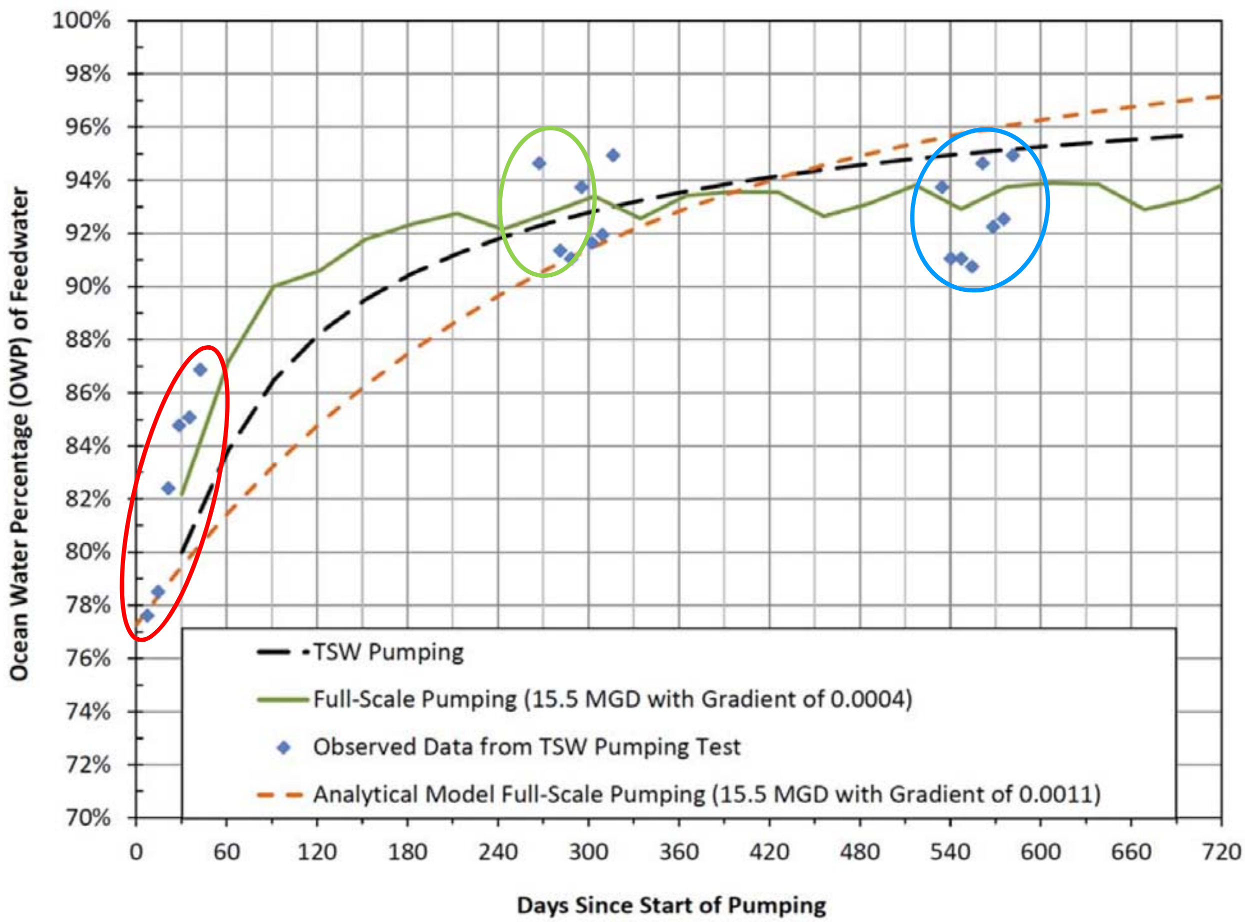
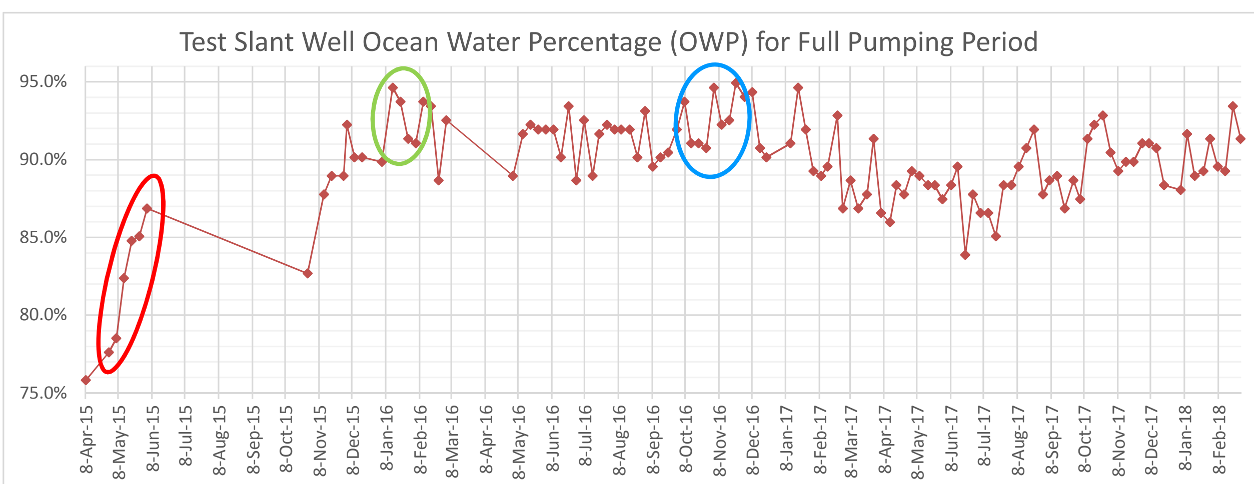


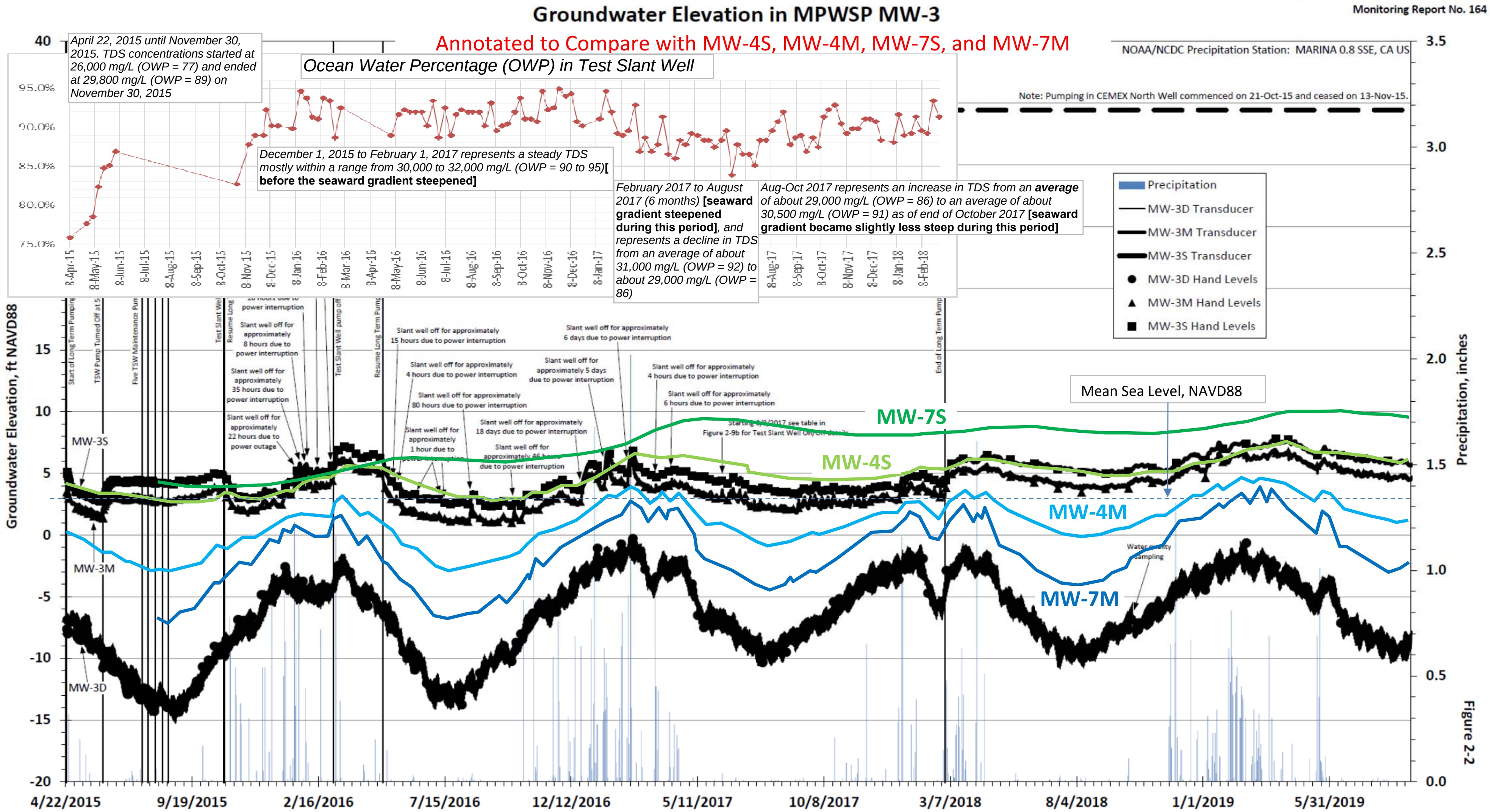
Figure 3.15 from the *MPWSP – HWG Hydrogeologic Investigation Technical Report* by the Hydrogeologic Working Group (November 6, 2017), EIR/EIS Appendix E3, Part 1

B



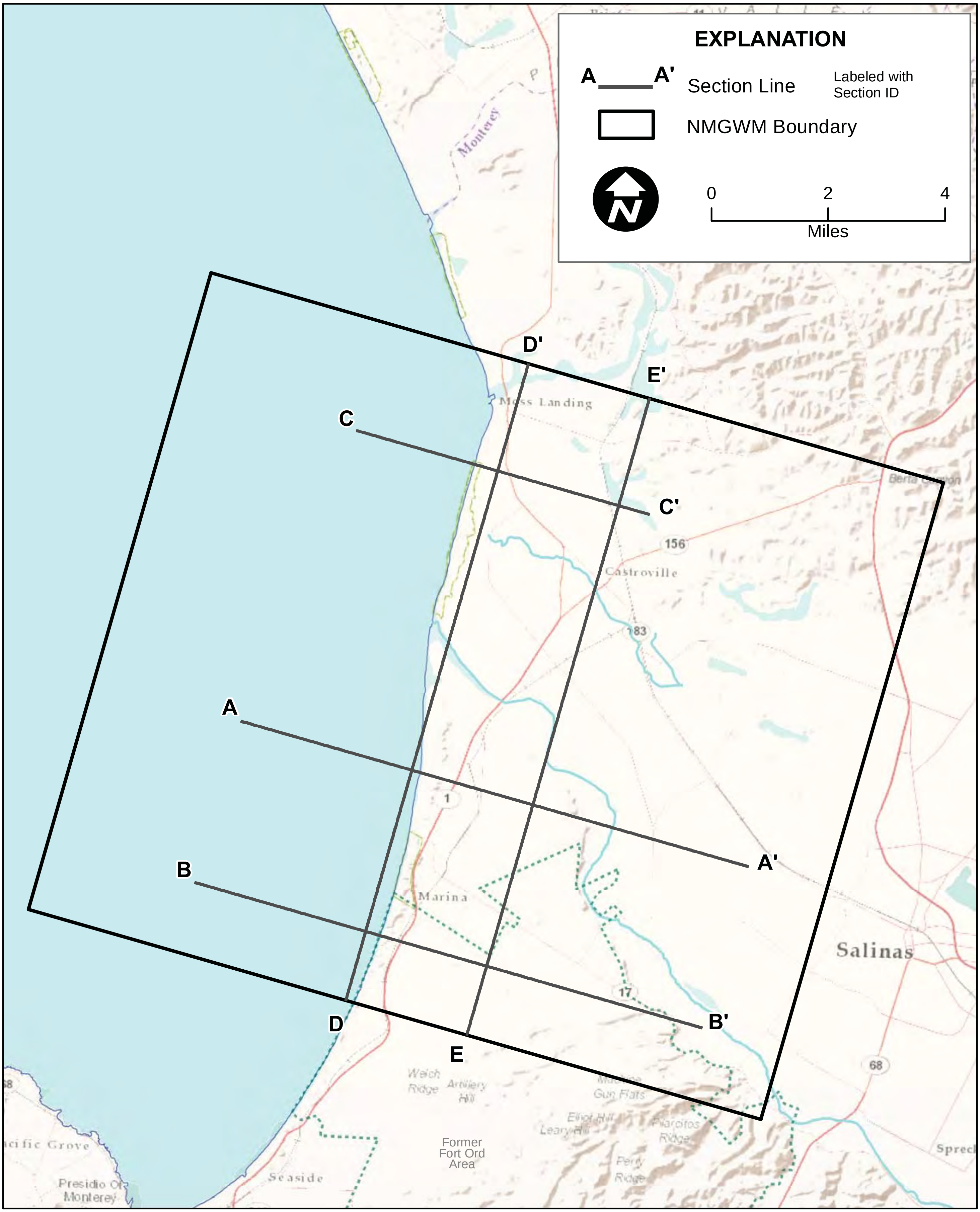
Comparison of Portions of the Test Slant Well OWP Record as Depicted in the EIR/EIS With OWP for the Full Pumping Record (Red, Green, and Blue Ovals Show Comparable Time Periods)

Figure 8



Test Slant Well Pumping - Comparison of OWP and Water Levels in MW-3, MW-4, and MW-7

Figure 9



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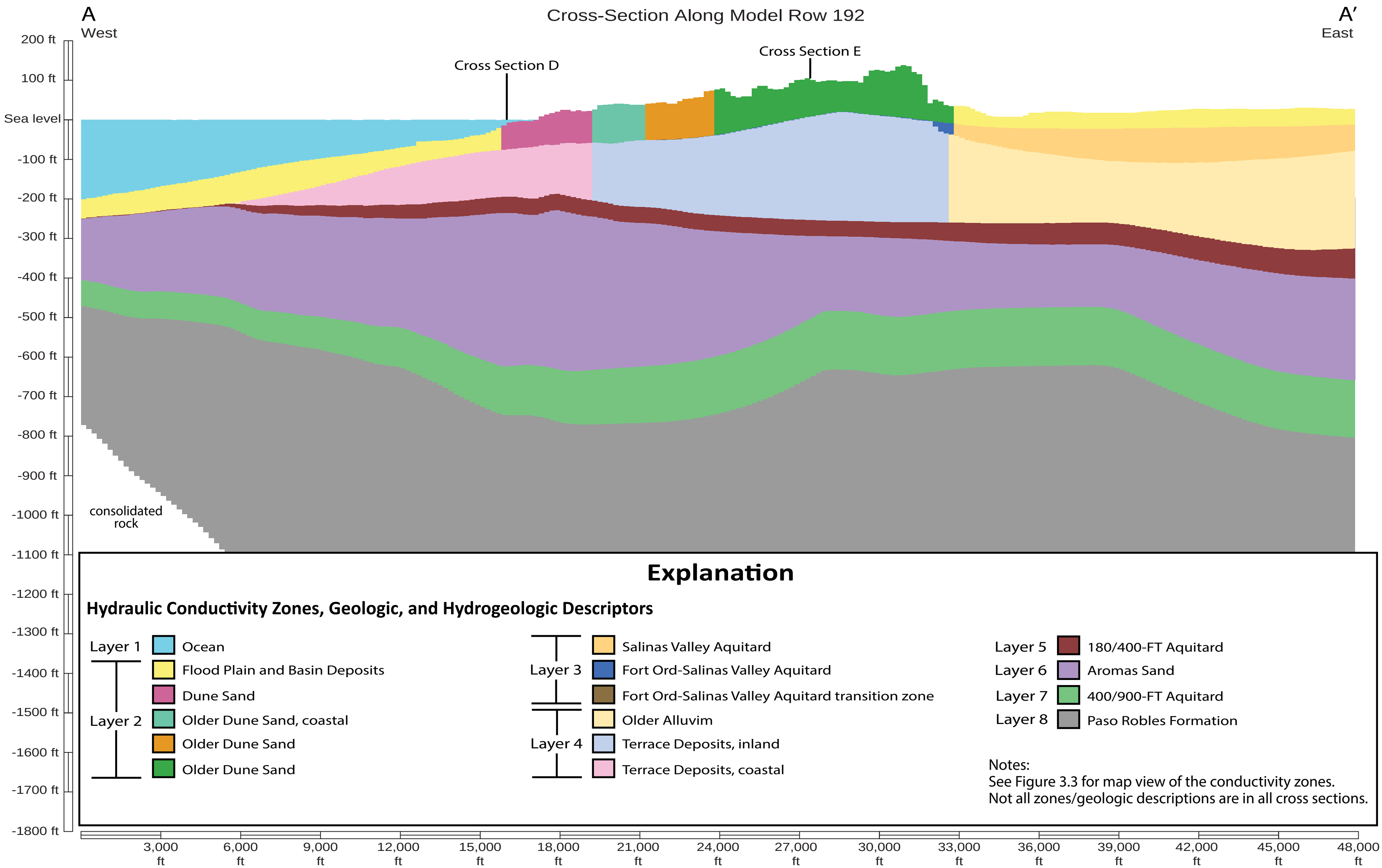
NMGWM[2016] section lines.

Figure 3.2a

PROJECT: 5073

DATE: 8/12/2016

Figure 10



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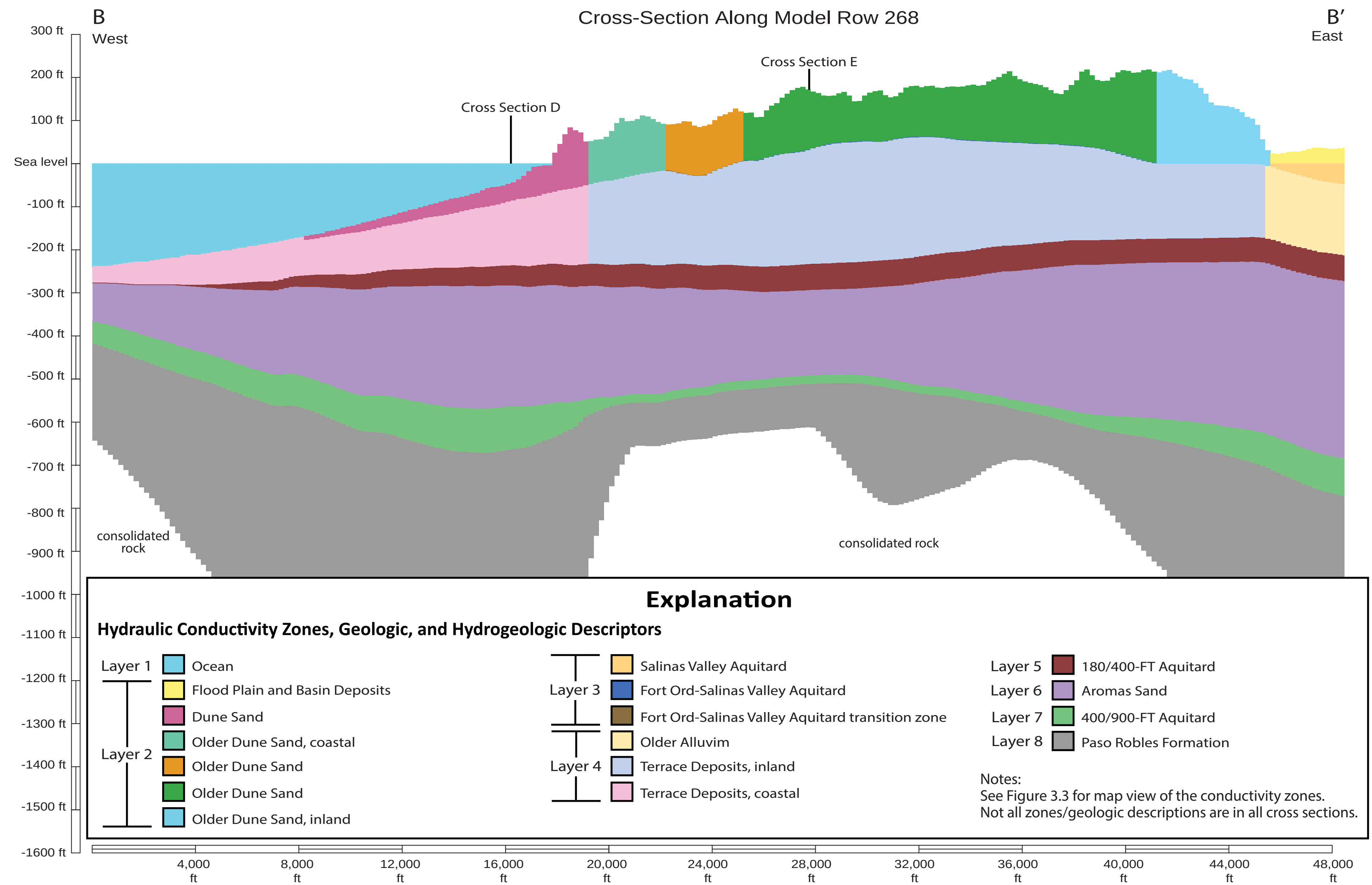
Section A-A′, NMGWM[2016].

Figure 3.2b

PROJECT: 5073

DATE: 11/8/2016

Figure 11



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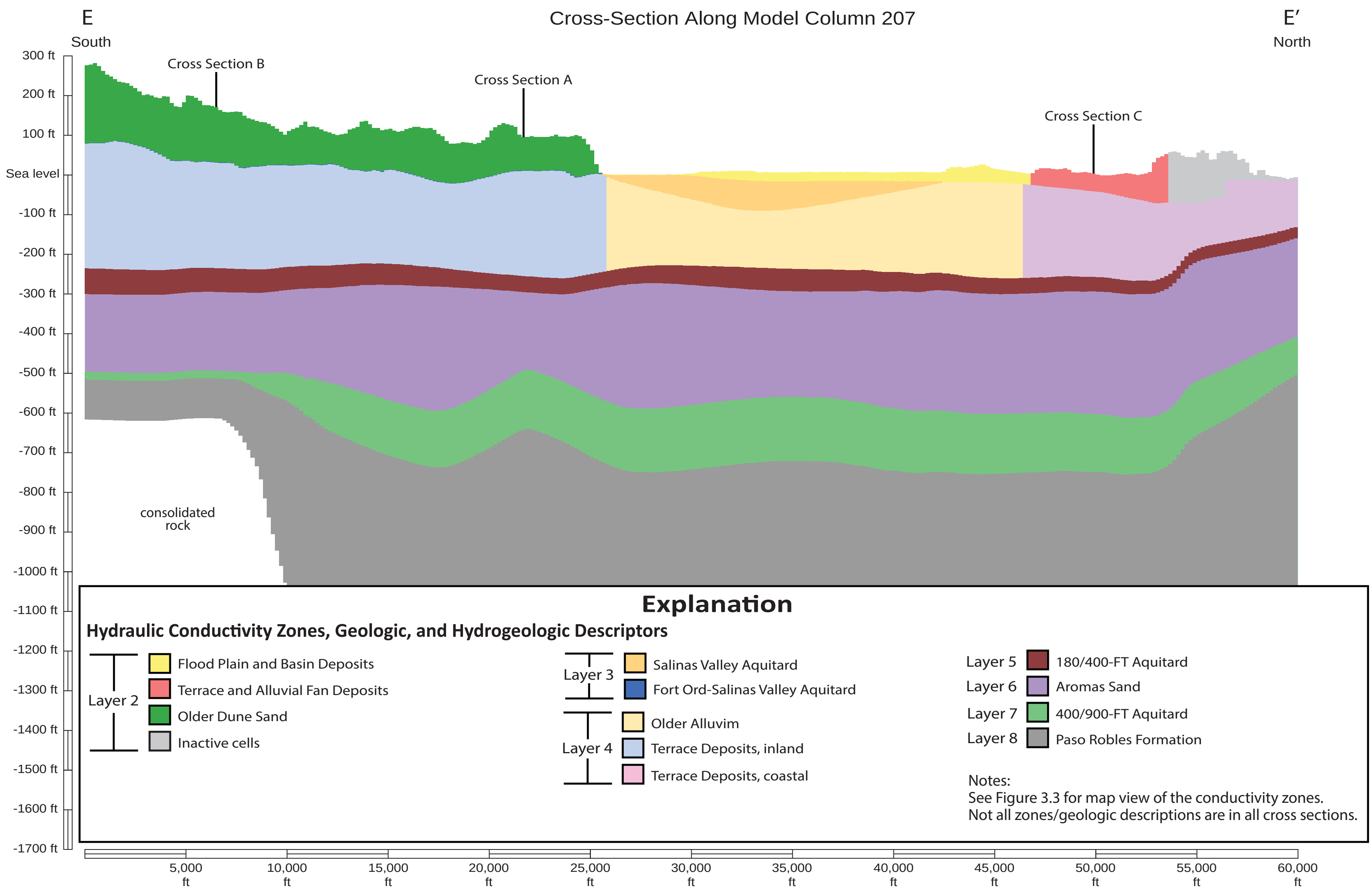
Section B-B', NMGWM[2016].

Figure 3.2c

PROJECT: 5073

DATE: 11/21/2016

Figure 12



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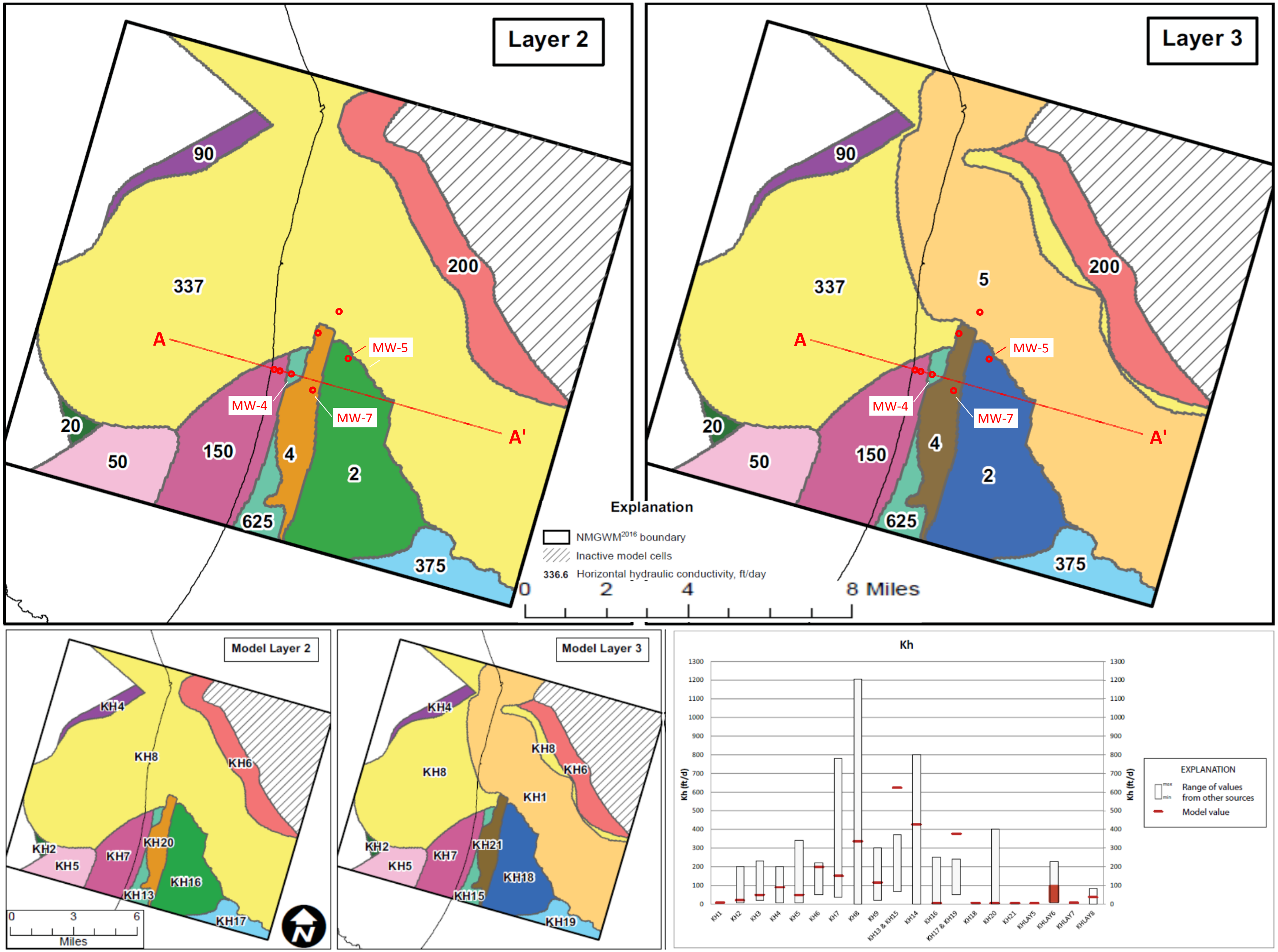
Section E-E', NMGWM2016.

Figure 3.2f

PROJECT: 5073

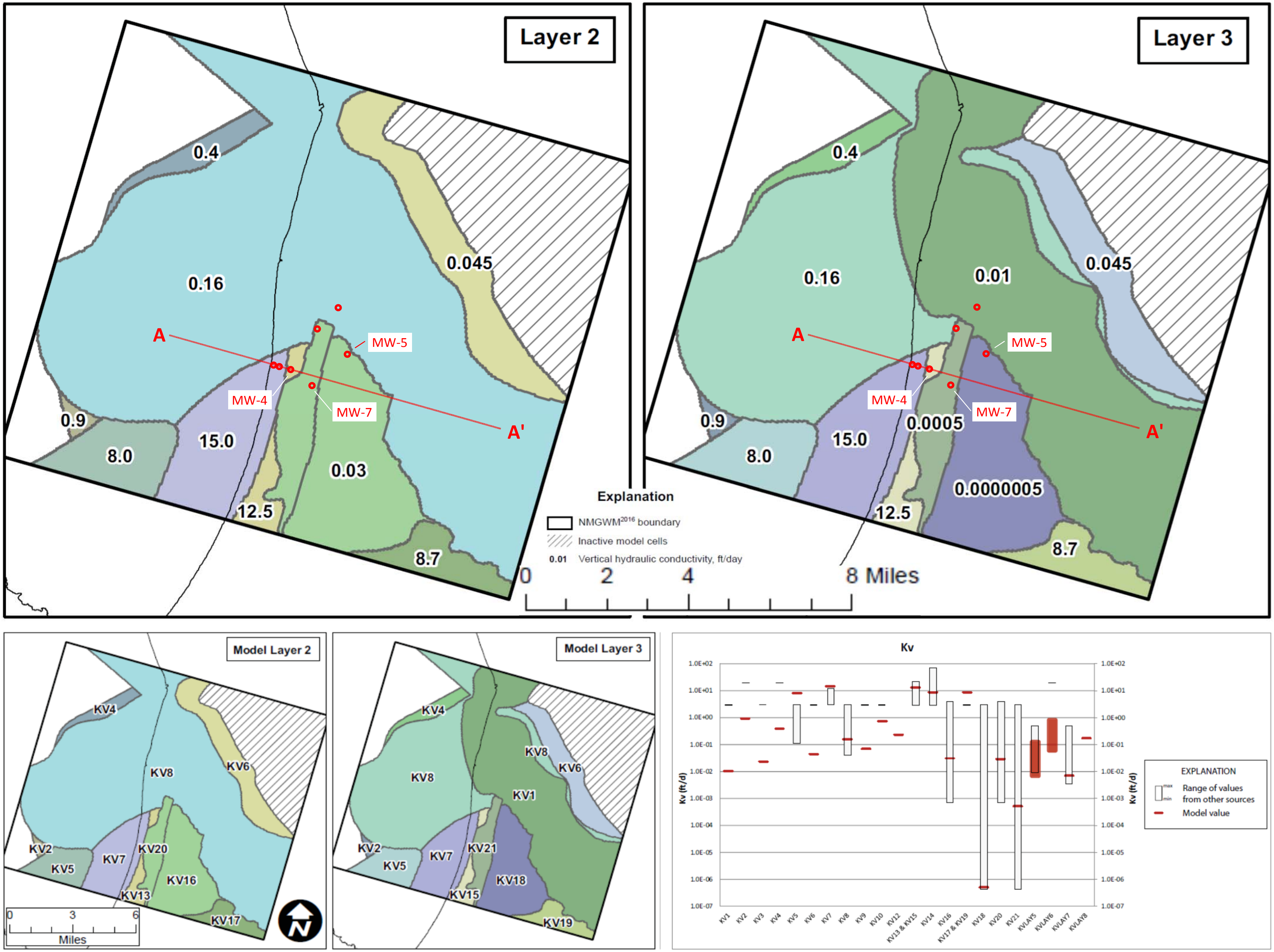
DATE: 11/21/2016

Figure 13



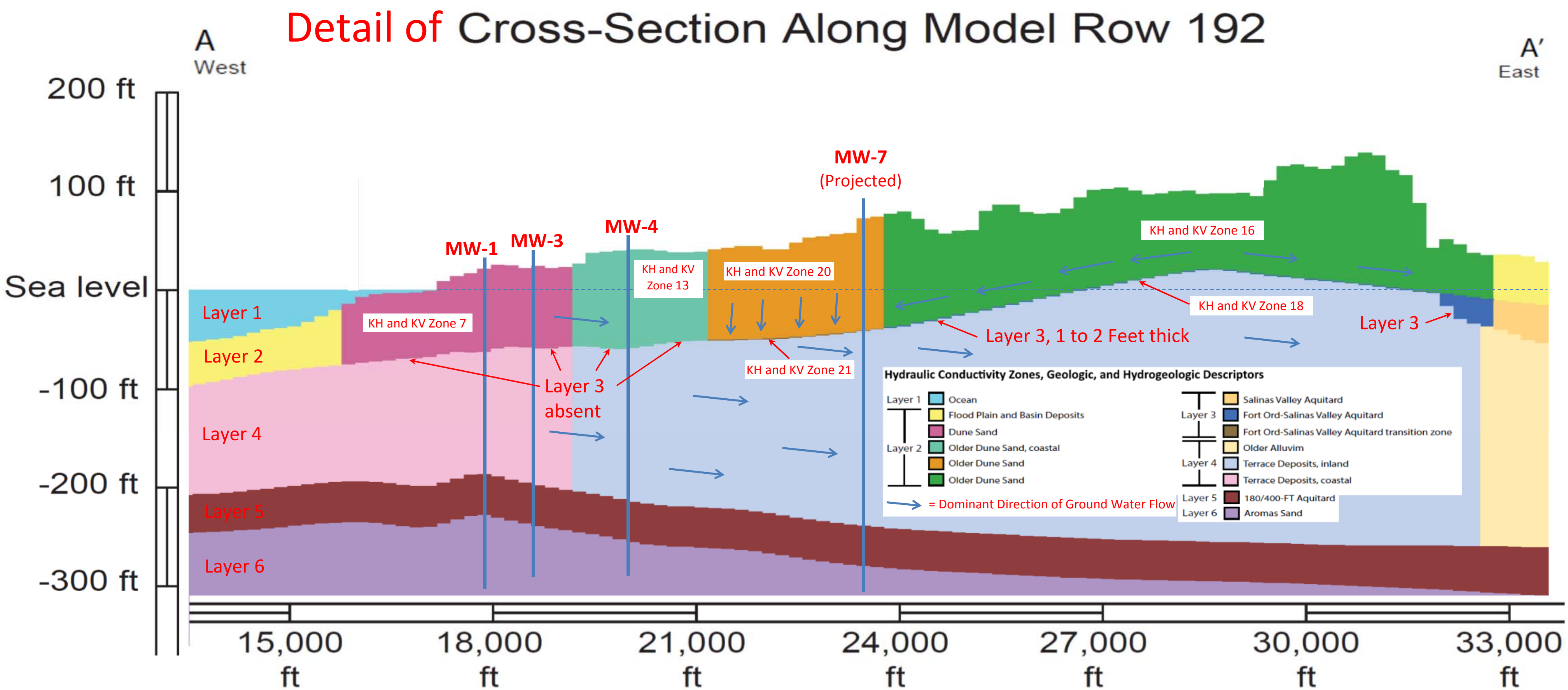
Horizontal Hydraulic Conductivity (KH) Parameter Zones and Values, Model Layers 2 and 3, NMGWM[2016], Excerpted from Figures 3.3a and 3.4a, *Final Environmental Impact Report/Environmental Impact Statement Appendix E2*, March 28, 2018. Red lines and text are added based on other figures in Appendix E2

Figure 14



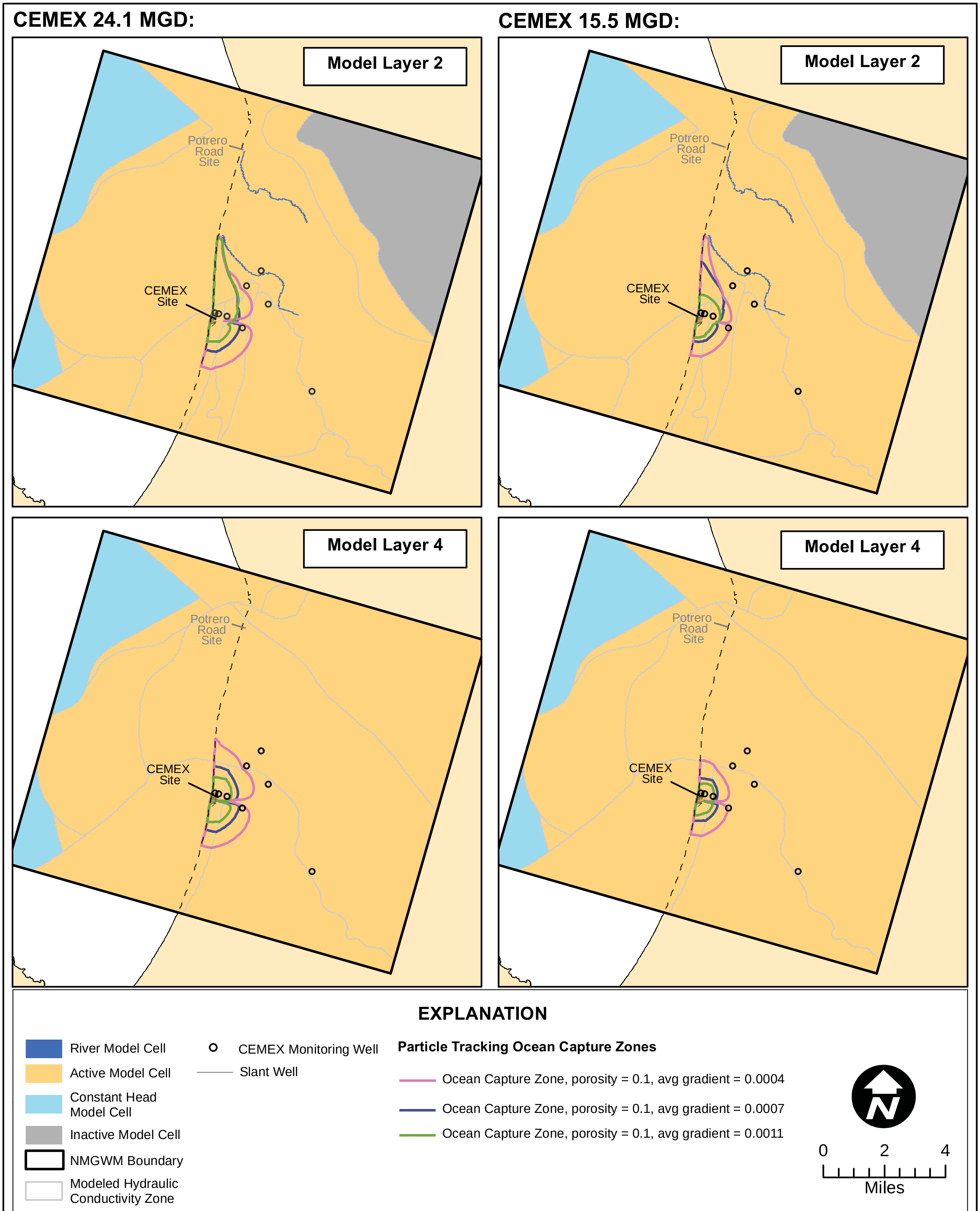
Vertical Hydraulic Conductivity (KV) Parameter Zones and Values, Model Layers 2 and 3, NMGWM[2016], Excerpted from Figures 3.3b and 3.4b, *Final Environmental Impact Report/Environmental Impact Statement Appendix E2*, March 28, 2018. Red lines and text are added based on other figures in Appendix E2

Figure 15



Hydraulic Conductivity Zones, Model Cross Section A-A', NMGWM[2016], excerpted from Figure 3.2b, *Final Environmental Impact Report/Environmental Impact Statement Appendix E2*, March 28, 2018. Well and Layer notations are added based on other figures in Appendix E2

Figure 16



HYDROFOCUS INC.
Solutions for Land and Water Resources

NMGWM[2016] calculated ocean capture zone with variable regional gradients, 63 years of slant well pumping (24.1 and 15.5 MGD), 44/56 Layer 2/Layer 4 distribution, 2012 sea level, CEMEX site.

Figure E-7

PROJECT: 5073

DATE: 11/15/2016

Figure 17

Legend

- MCWD's Service Area
- DWR Groundwater Basin
- Armstrong Ranch
- Groundwater Divide
- Edge of Fort Ord-Salinas Valley Aquitard
- Groundwater Elevation Contour (2' Interval)
- Groundwater Elevation Contour (10' Interval)
- Cal Am Monitoring Well
- Fort Ord Monitoring Well

Well Labeling

MW-5S — Well ID
35 — Groundwater Elevation (ft MSL)

Path: X:\B60094\Maps\2017\02\Fig5_GWE_DuneSandAquifer.mxd

Abbreviations

Cal Am = California American Water
DWR = Department of Water Resources
ft MSL = feet mean sea level
MCWD = Marina Coast Water District
mg/L = milligram per liter
TDS = total dissolved solids

Notes

1. All locations are approximate.
2. Groundwater levels obtained from Reference 2 are measured in May 2016. Groundwater levels at Fort Ord are measured during June 2016 (Ahta, 2016. Final Operable Unit Carbon Tetrachloride Plume Second Quarter 2016 Groundwater Monitoring Report, Former Fort Ord, California, dated 29 August 2016). All groundwater levels are approximate.
3. Groundwater levels have been correlated for density, where TDS > 10,000 mg/L (see Reference 3).
4. Groundwater elevation contour dashed where approximate.

Sources

1. Aerial photograph provided by ESRI's ArcGIS Online, obtained 21 February 2017.
2. Cal Am Monterey Peninsula Water Supply Project Test Slant Well Long Term Pumping—Monitoring Report No. 55, released 24-May-2016.
3. Guo & Langevin, 2002. User's Guide to SEAWAT, U.S. Geological Survey Techniques of Water Resources Investigations 6-A7, released 2002.

Erler & Kalinowski, Inc.

Groundwater Elevations
Dune Sand Aquifer

Marina Coast Water District
Marina, CA
February 2017
EKI B60094.01
Figure 5

Figure 18

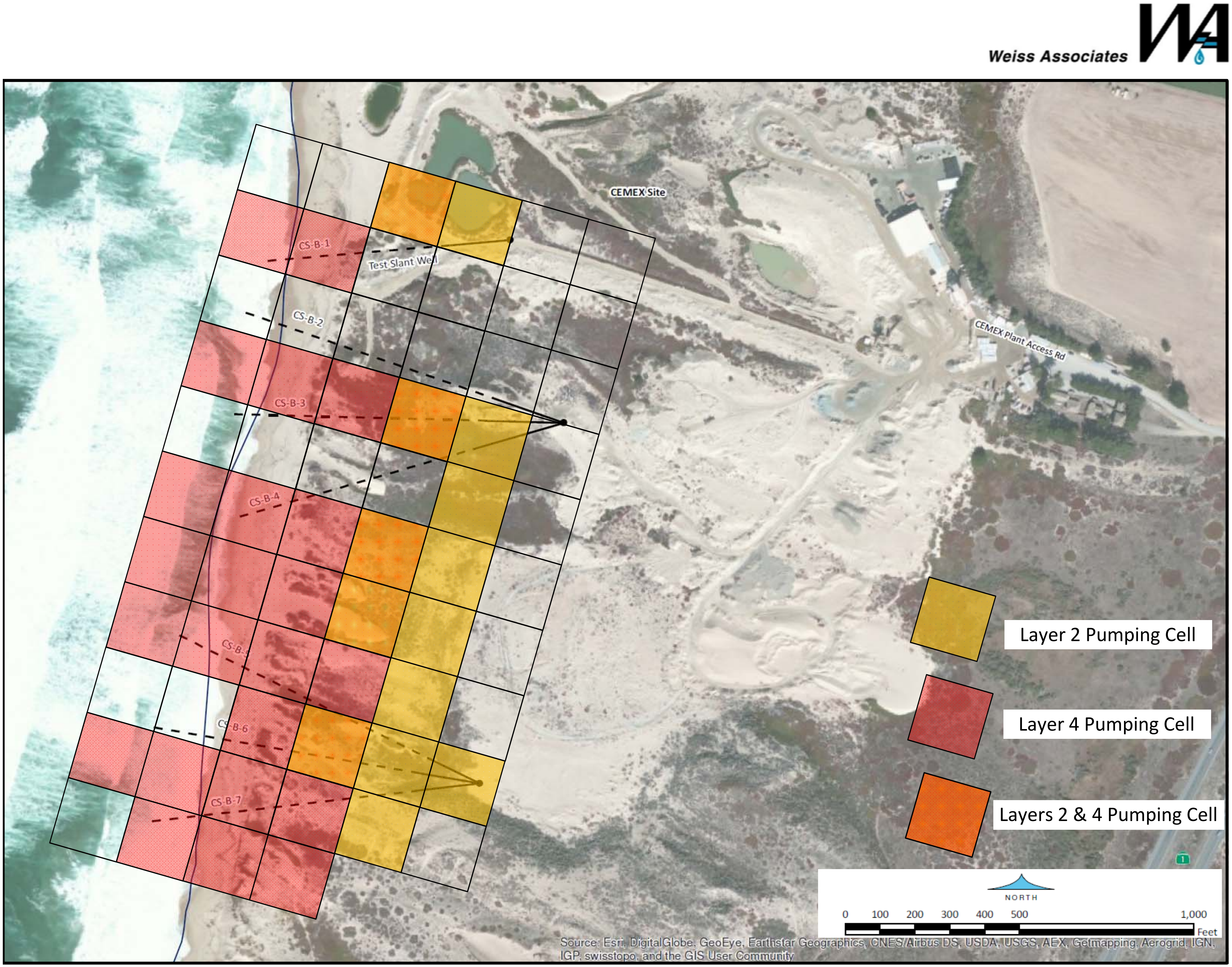
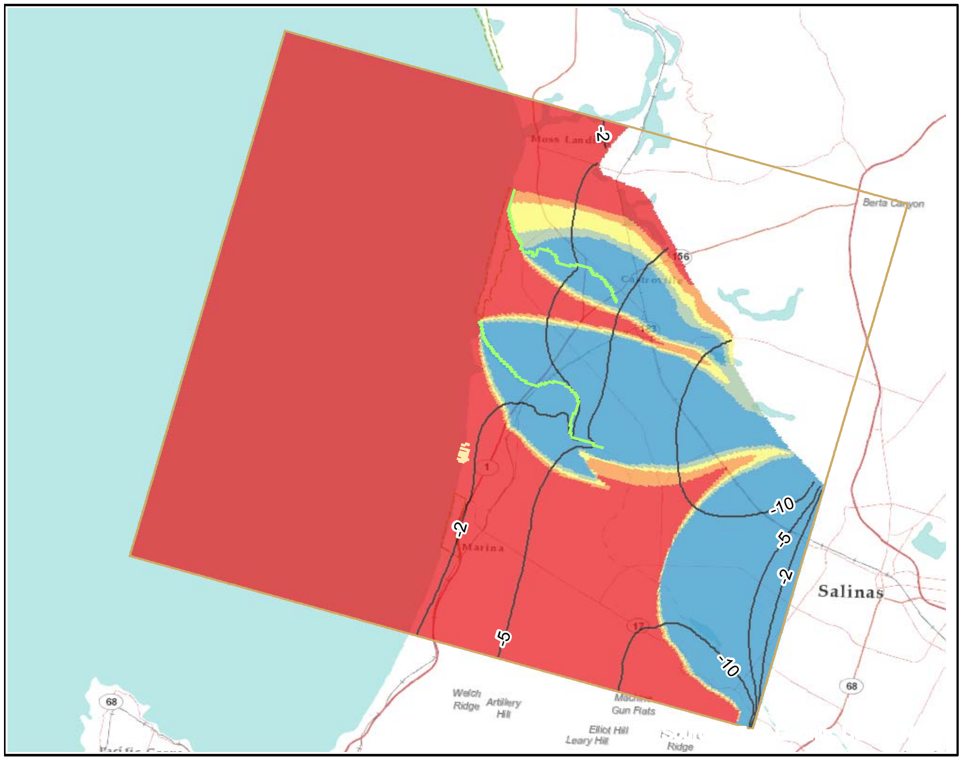
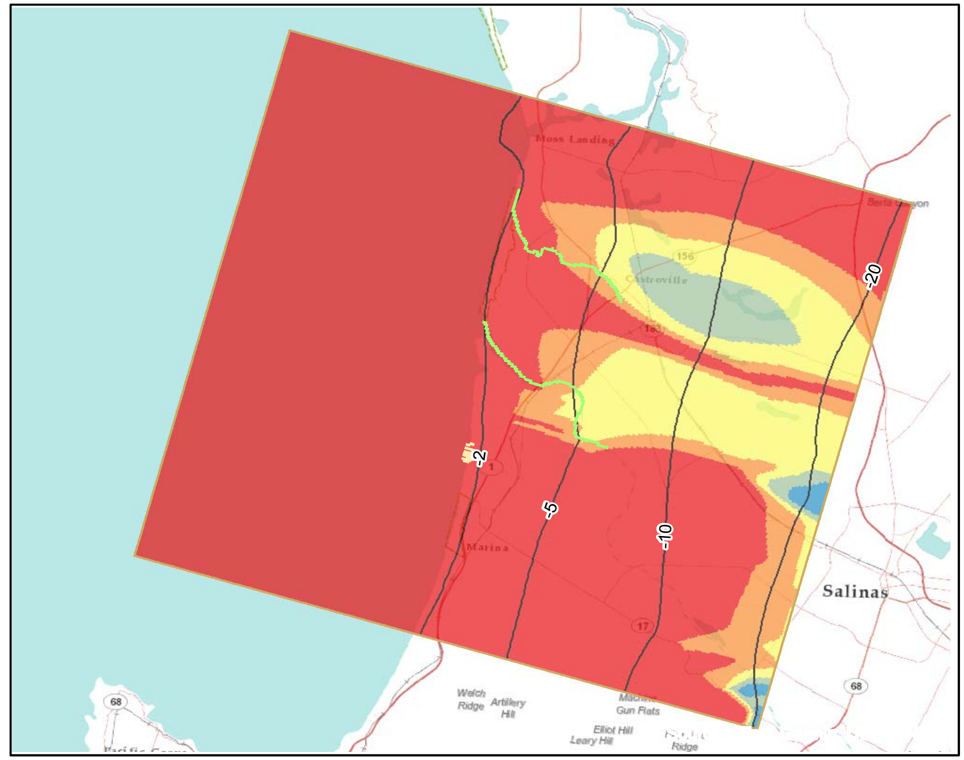


Figure 19. Slant Well Array and Model Cells Assigned to Pumping Wells

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

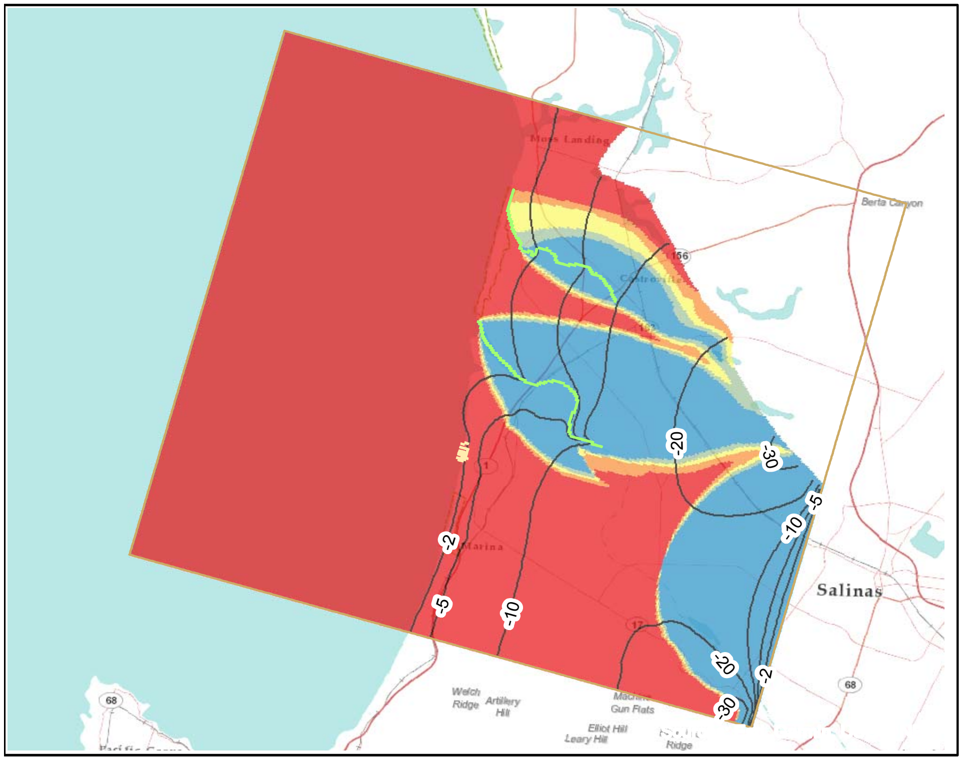
Salinity
Ocean Water Percent (OWP)

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

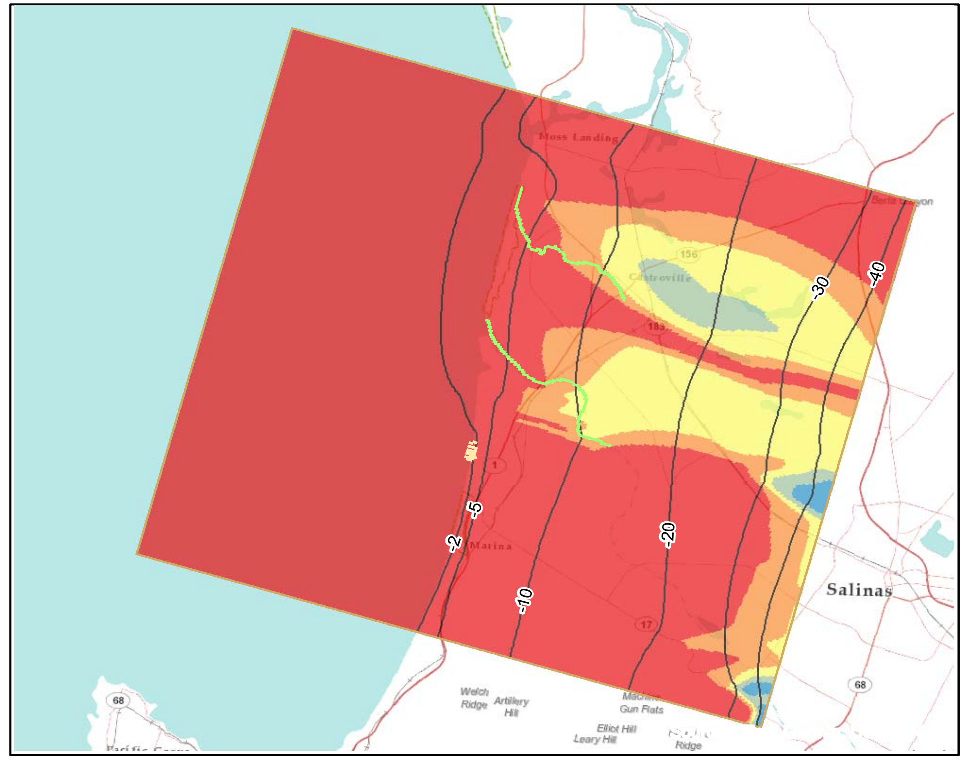
Model Parameter	Value	Comments
Layer 4 Gradient:	0.0004	Landward

Figure 20. Baseline - NMGWM^{2016} With Inland Gradient = 0.0004; no Pumping

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

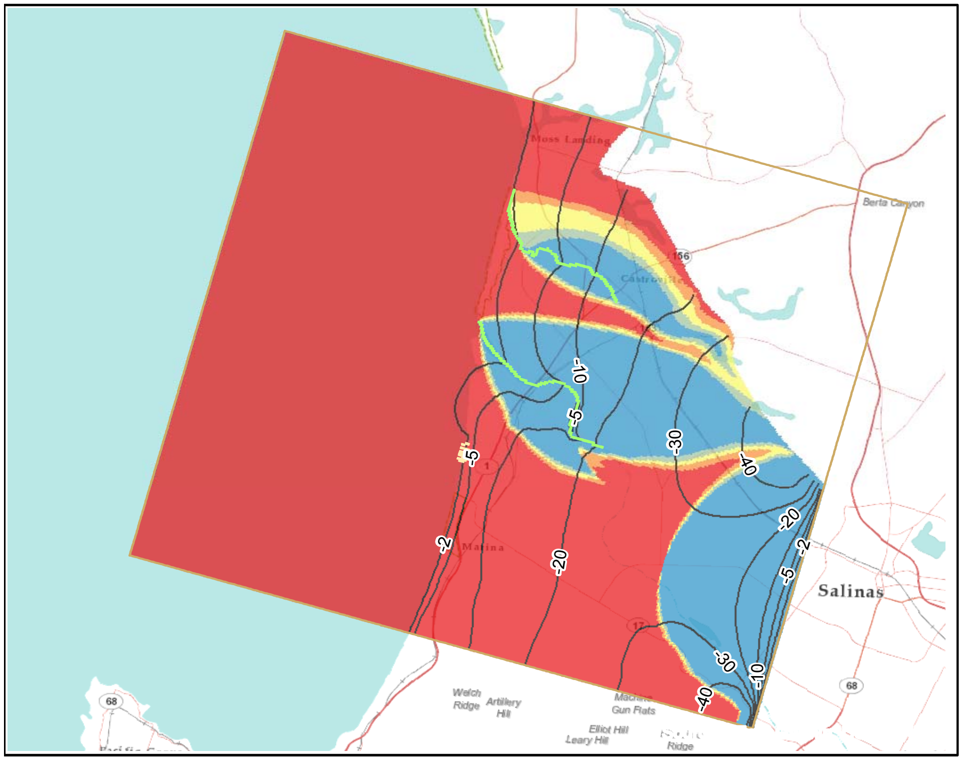
Salinity
Ocean Water Percent (OWP)

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

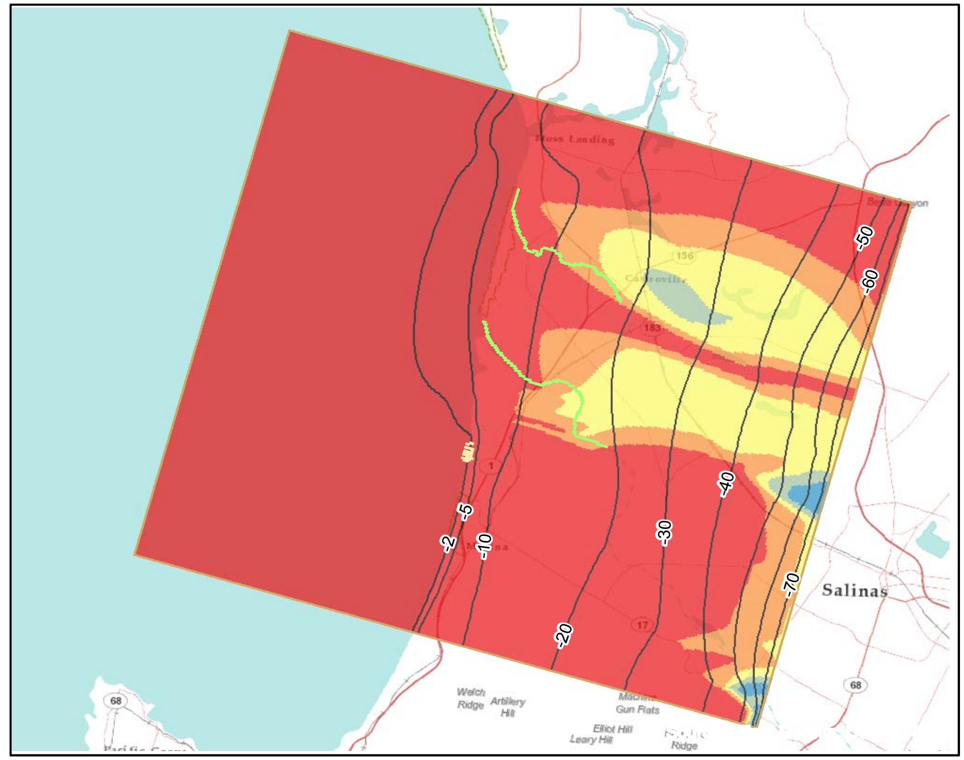
Model Parameter	Value	Comments
Layer 4 Gradient:	0.0007	Landward

Figure 21. Baseline - NMGWM^{2016} With Inland Gradient = 0.0007; no Pumping

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

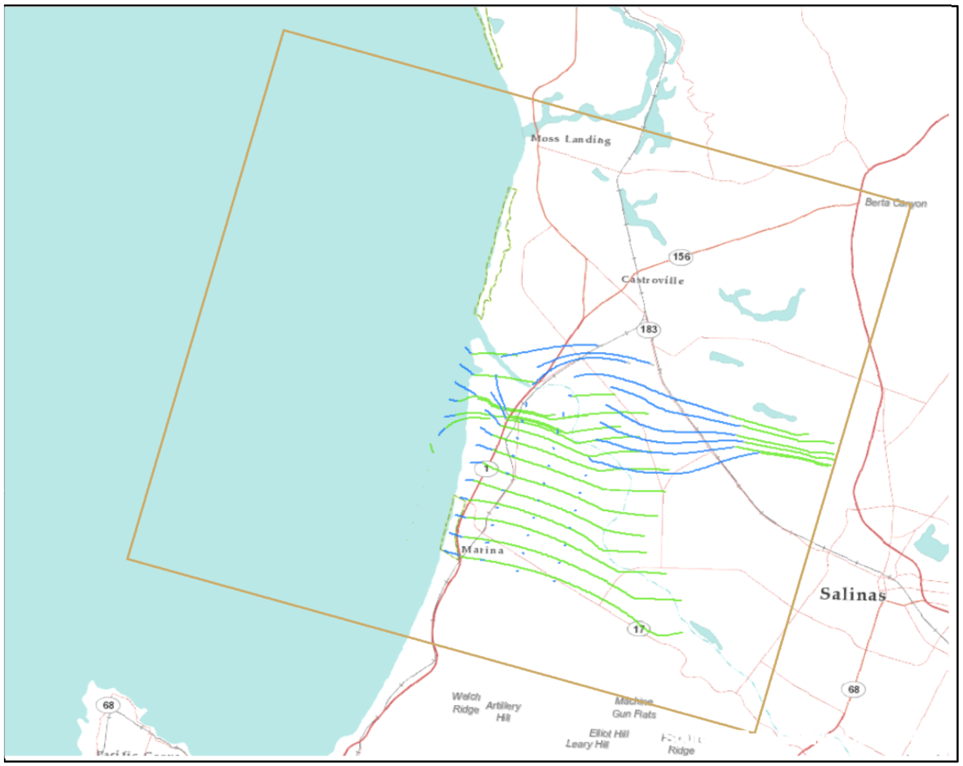
Salinity
Ocean Water Percent (OWP)

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

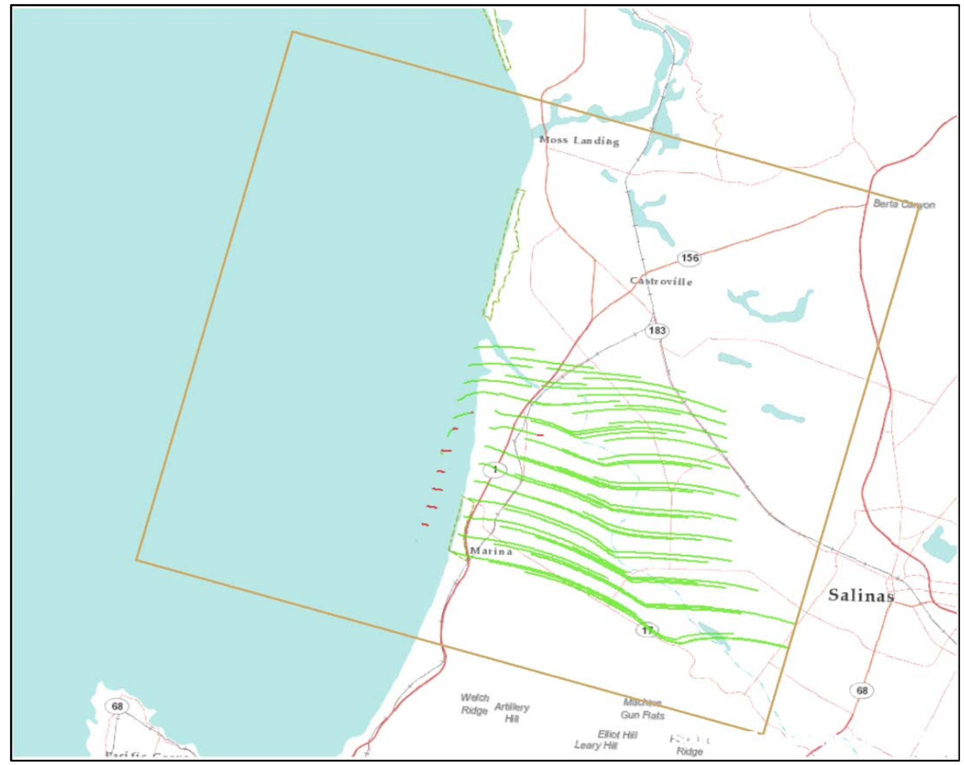
Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0011	Landward

Figure 22. Baseline - NMGWM^{2016} With Inland Gradient = 0.0011; no Pumping

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

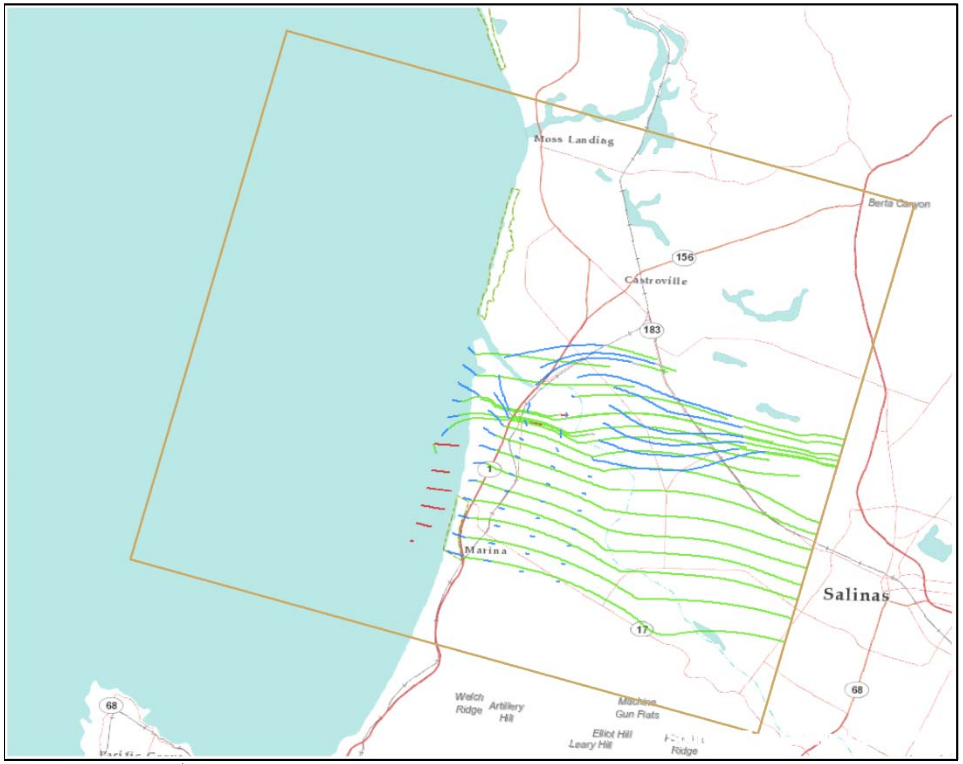
Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

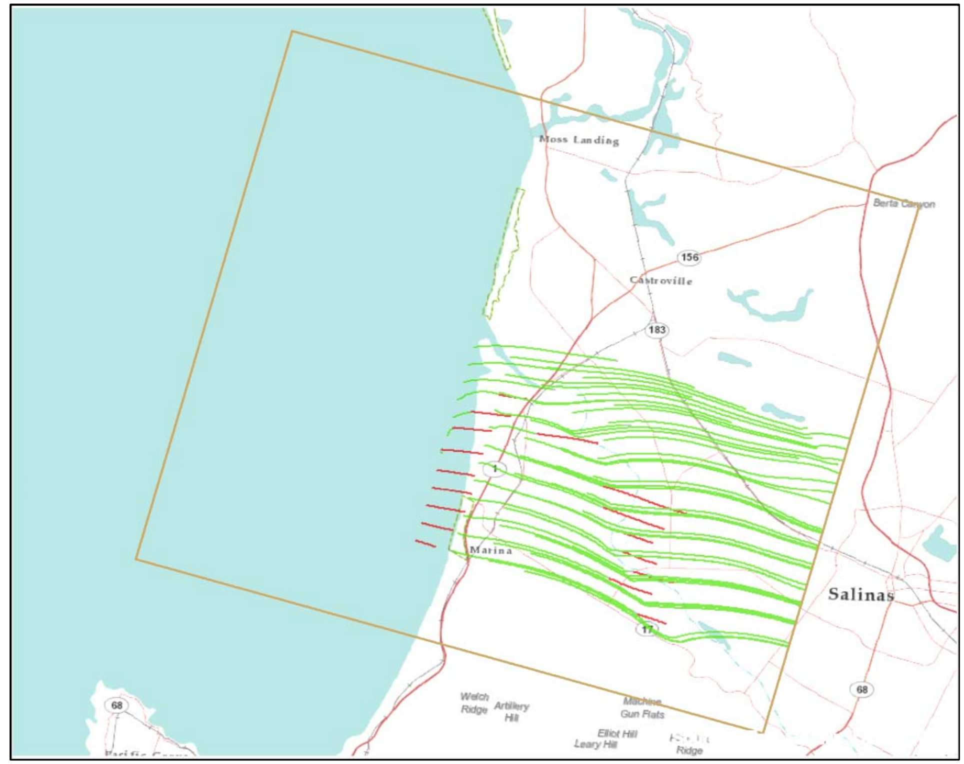
Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0004	Landward

Figure 23. Baseline Groundwater Flow Paths - NMGWM^{2016} With Inland Gradient = 0.0004; no Pumping

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

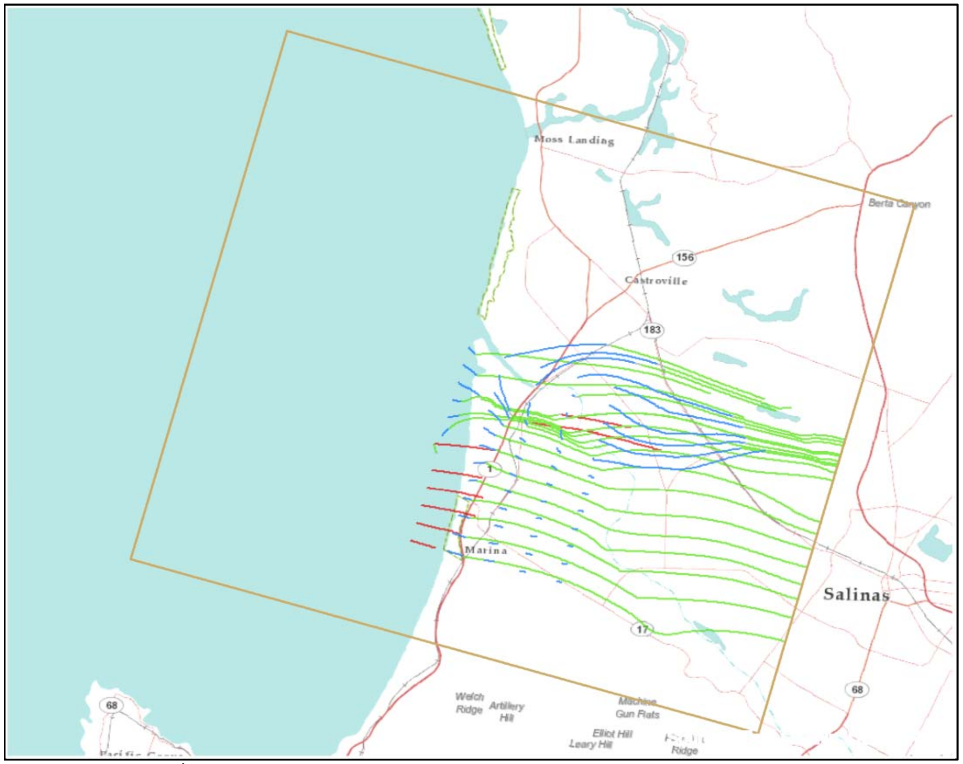
Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

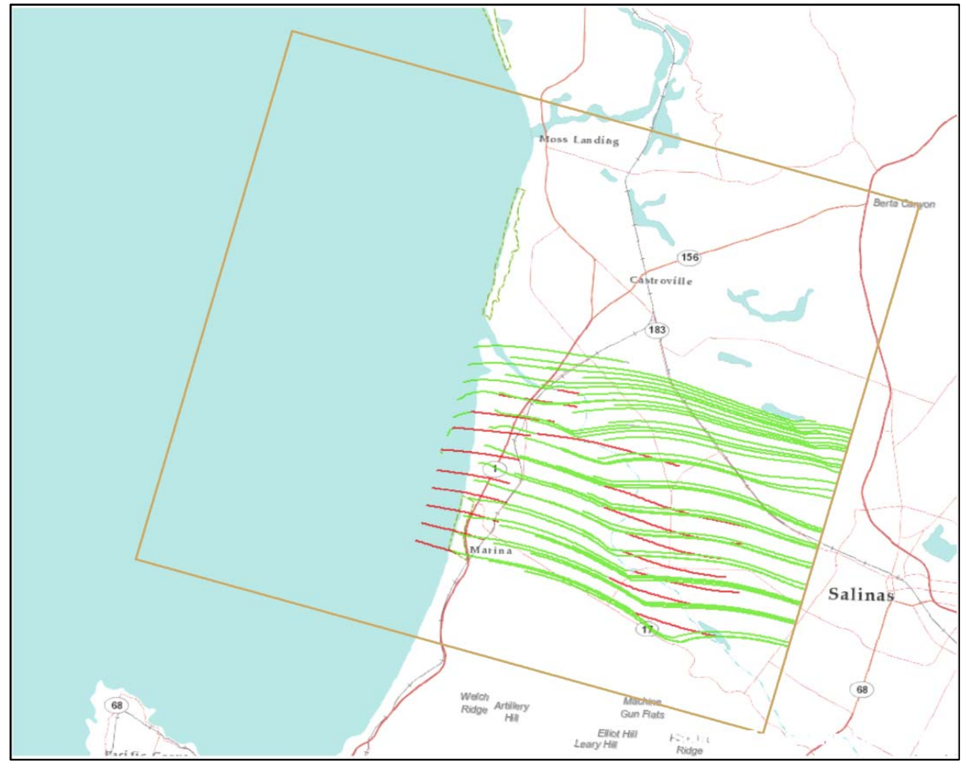
Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0007	Landward

Figure 24. Baseline Groundwater Flow Paths - NMGWM^{2016} With Inland Gradient = 0.0007; no Pumping

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

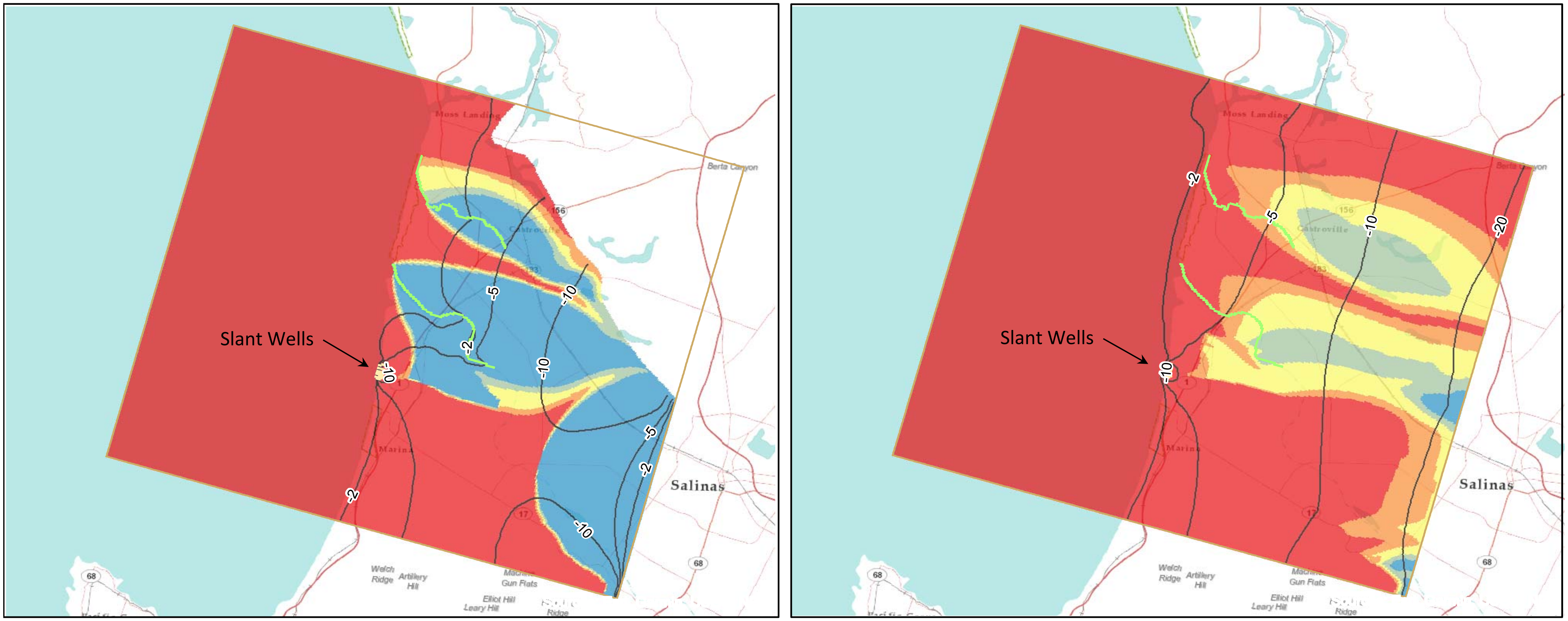
Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0011	Landward

Figure 25. Baseline Groundwater Flow Paths - NMGWM^{2016} With Inland Gradient = 0.0011; no Pumping

Layer 2 (Dune Sand Aquifer) | Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

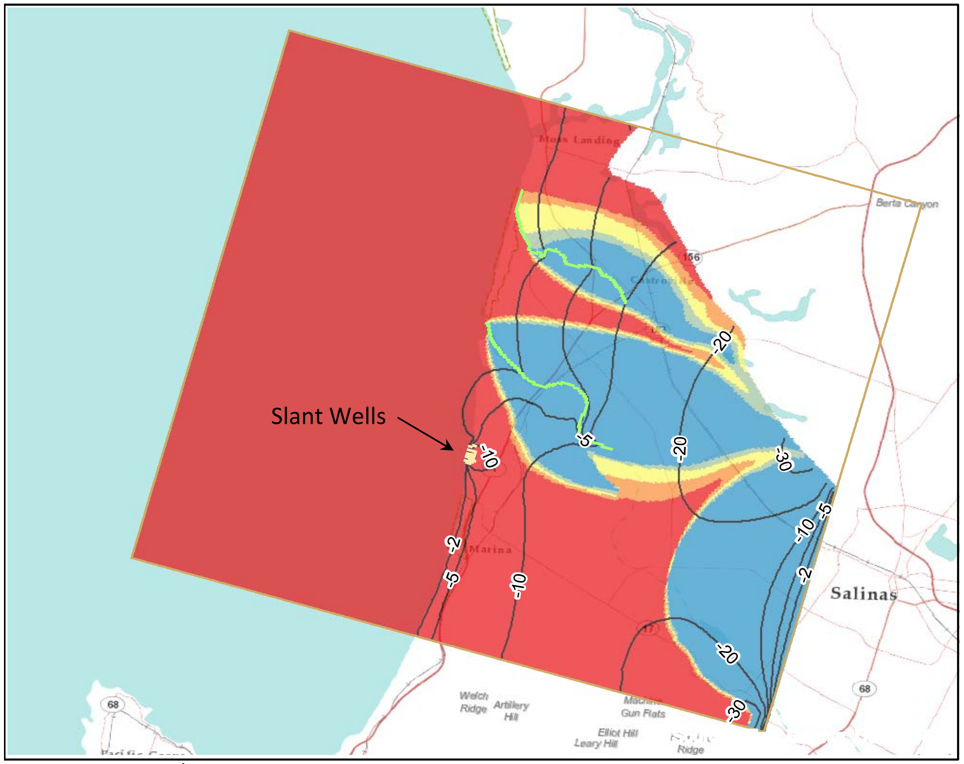
Salinity
Ocean Water Percent
(OWP)

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

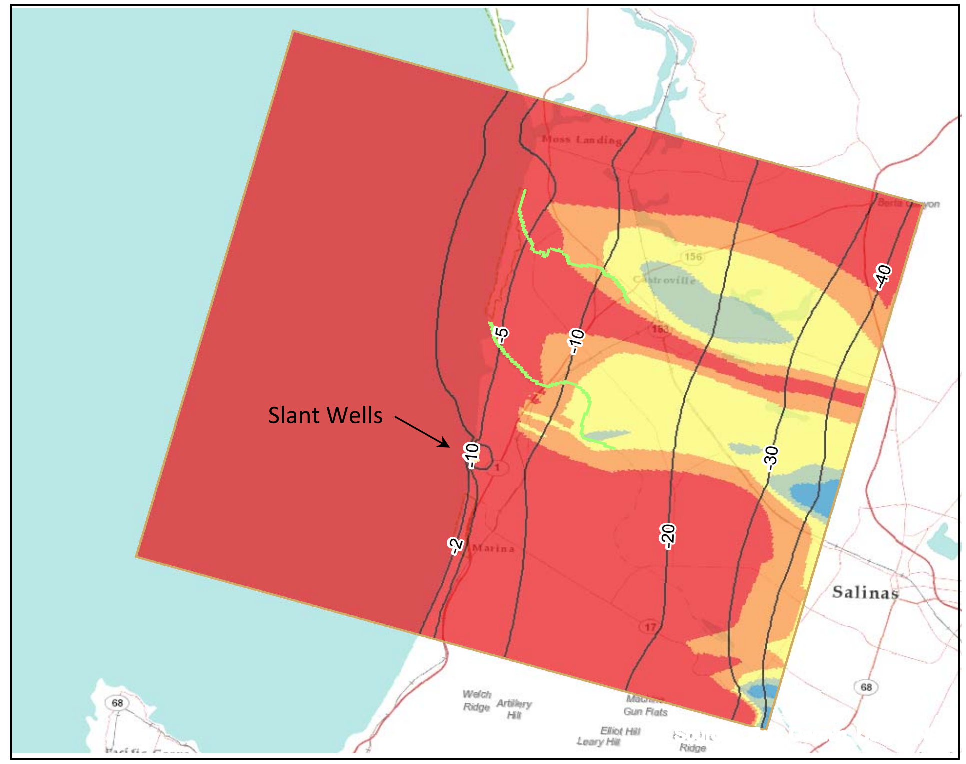
Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0004	Landward
Slant Wells Pumping Rate:	15.5	MGD
Well Discharge OWP:	99.3%	(Ocean Water Percentage)

Figure 26. Baseline - NMGWM^{2016} With Inland Gradient = 0.0004; Slant Wells Pumping 15.5 MGD

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Salinity
Ocean Water Percent
(OWP)

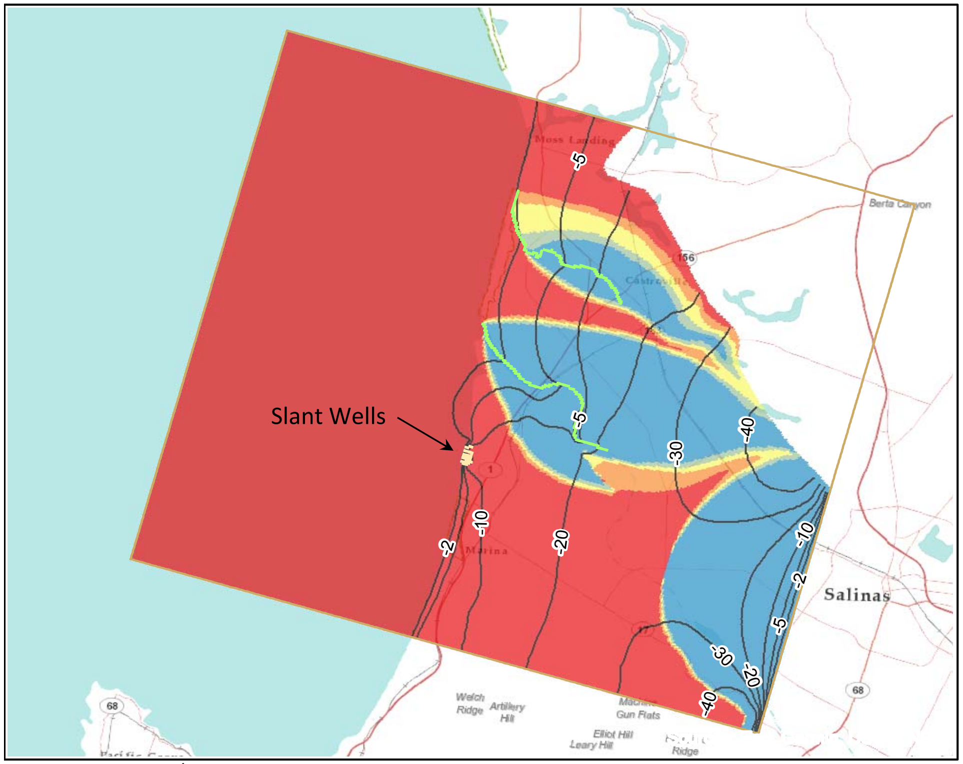
- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0007	Landward
Slant Wells Pumping Rate:	15.5	MGD

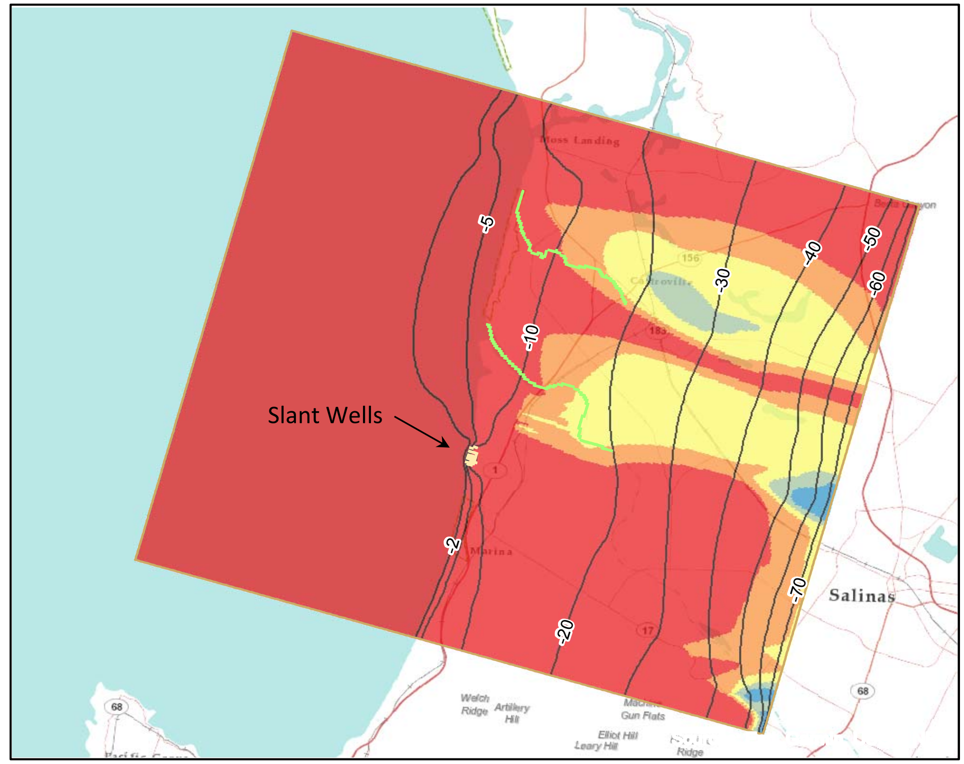
Well Discharge OWP: 99.97% (Ocean Water Percentage)

Figure 27. Baseline - NMGWM^{2016} With Inland Gradient = 0.0007; Slant Wells Pumping 15.5 MGD

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Salinity
Ocean Water Percent (OWP)

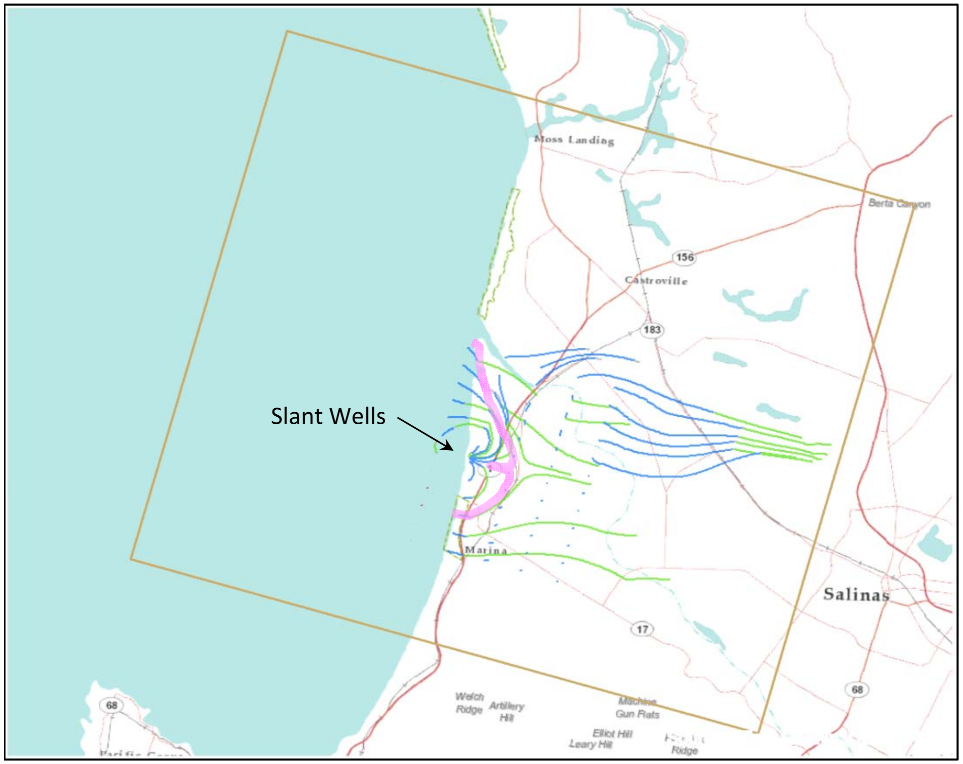
- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0011	Landward
Slant Wells Pumping Rate:	15.5	MGD

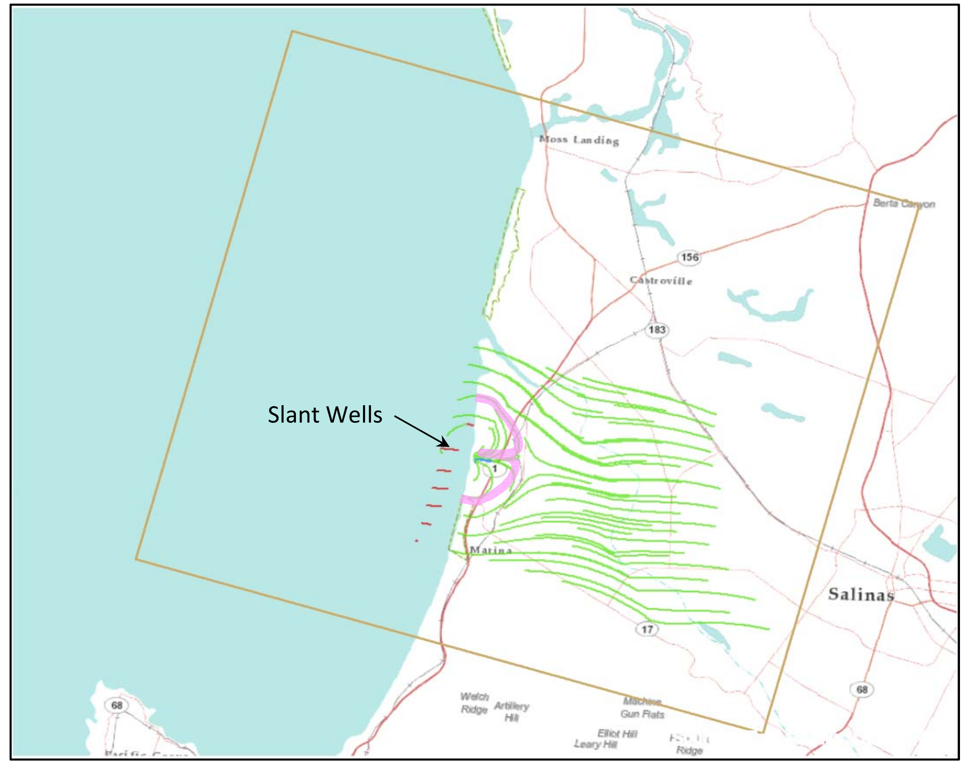
Well Discharge OWP: 99.99% (Ocean Water Percentage)

Figure 28. Baseline - NMGWM^{2016} With Inland Gradient = 0.0011; Slant Wells Pumping 15.5 MGD

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

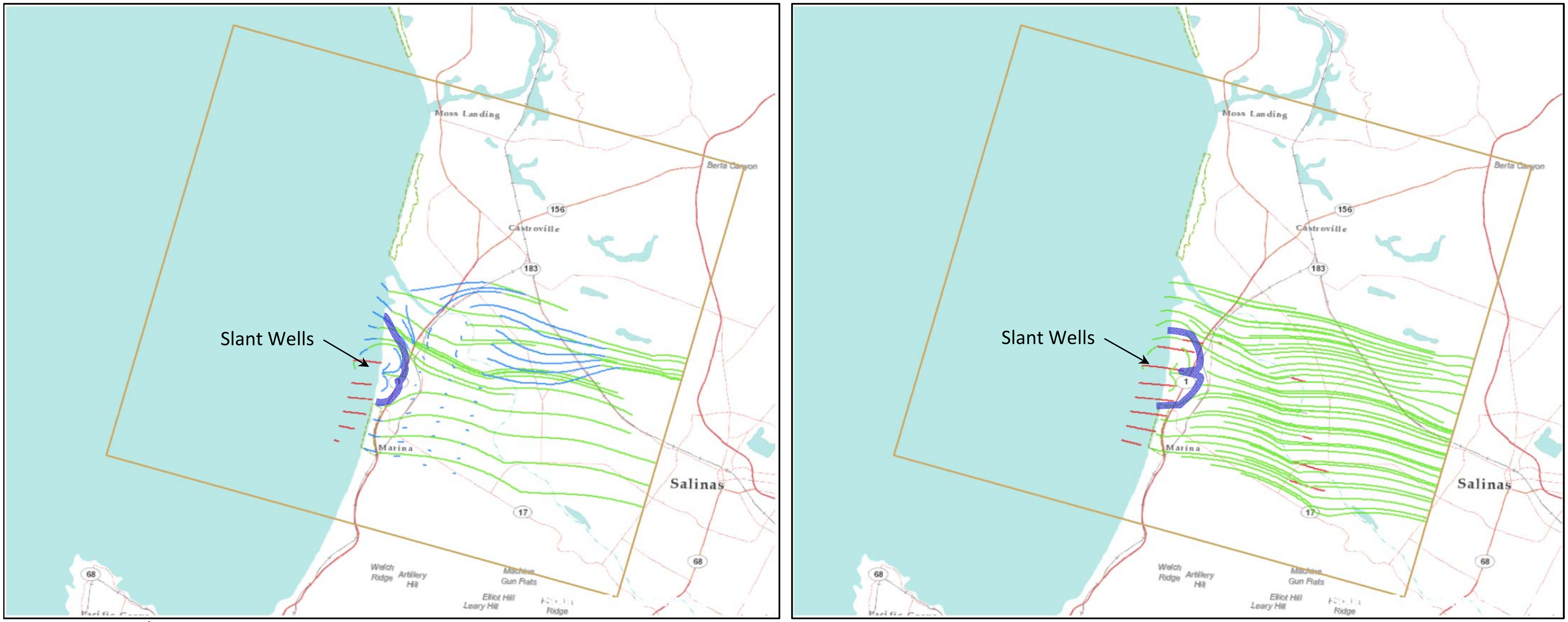
Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0004	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge:	0.0	Inches/year

Well Discharge OWP: 99.3% (Ocean Water Percentage)

Ocean Capture Zone
(EIR/EIS, Appendix E2, Figure E7)

Figure 29. Baseline Groundwater Flow Paths - NMGWM2016 With Inland Gradient = 0.0004; Slant Wells Pumping 15.5 MGD

Layer 2 (Dune Sand Aquifer) | Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Flow Path within Model Layer

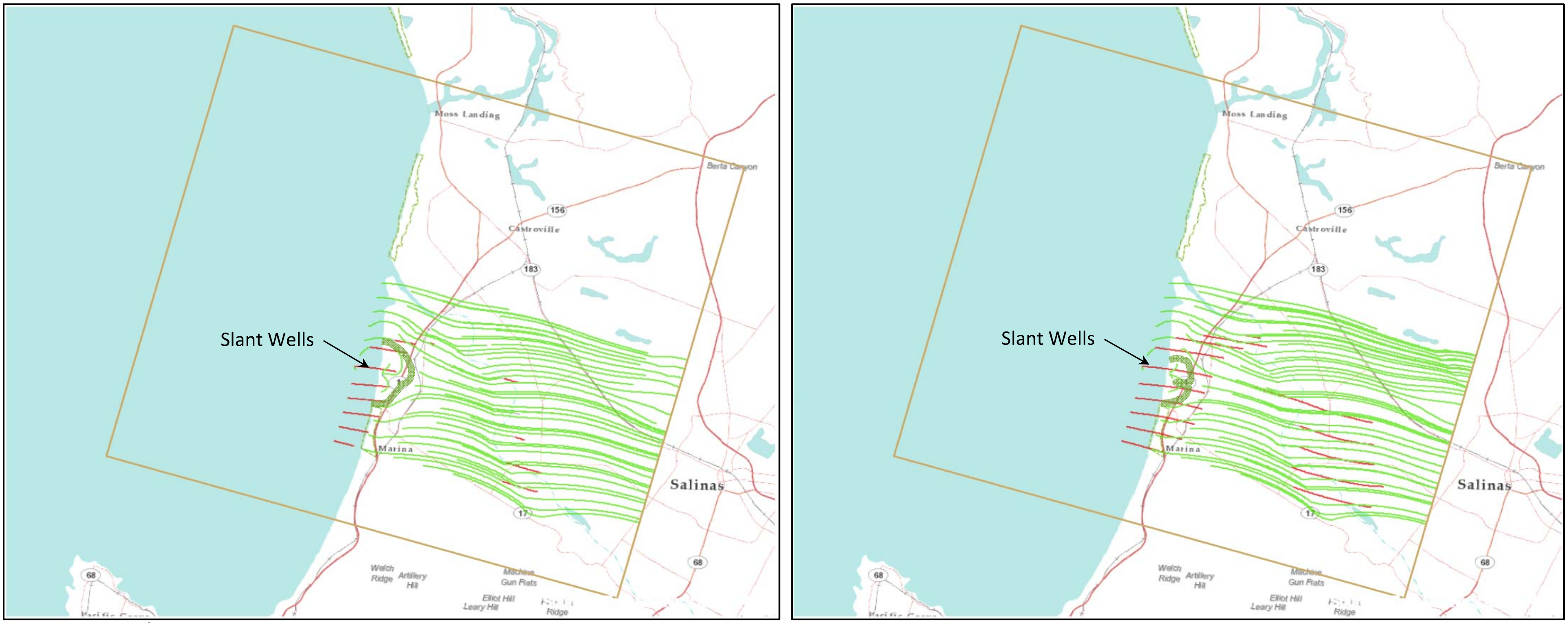
- 2
- 3
- 4
- 5
- 6

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0004	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge:	0.0	Inches/year
Well Discharge OWP:	99.97%	(Ocean Water Percentage)

Ocean Capture Zone
(EIR/EIS, Appendix E2, Figure E7)

Figure 30. Baseline Groundwater Flow Paths - NMGWM^{2016} With Inland Gradient = 0.0007; Slant Wells Pumping 15.5 MGD

Layer 2 (Dune Sand Aquifer) Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0004	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge:	0.0	Inches/year

Well Discharge OWP: 99.99% (Ocean Water Percentage)

Ocean Capture Zone
(EIR/EIS, Appendix E2, Figure E7)

Figure 31. Baseline Groundwater Flow Paths - NMGWM^{2016} With Inland Gradient = 0.0011; Slant Wells Pumping 15.5 MGD

Weiss Associates

Layer 2 (Dune Sand Aquifer)

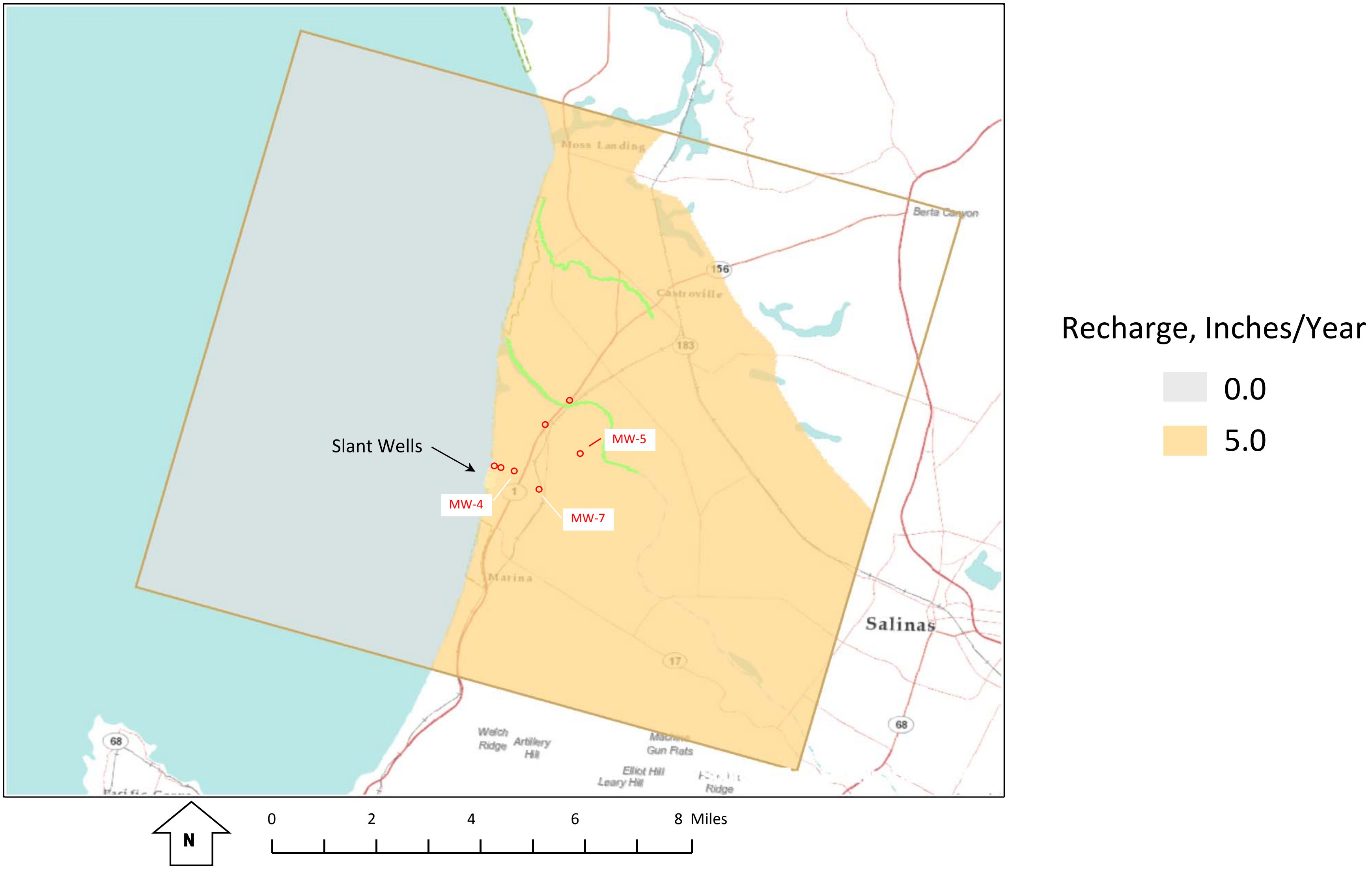
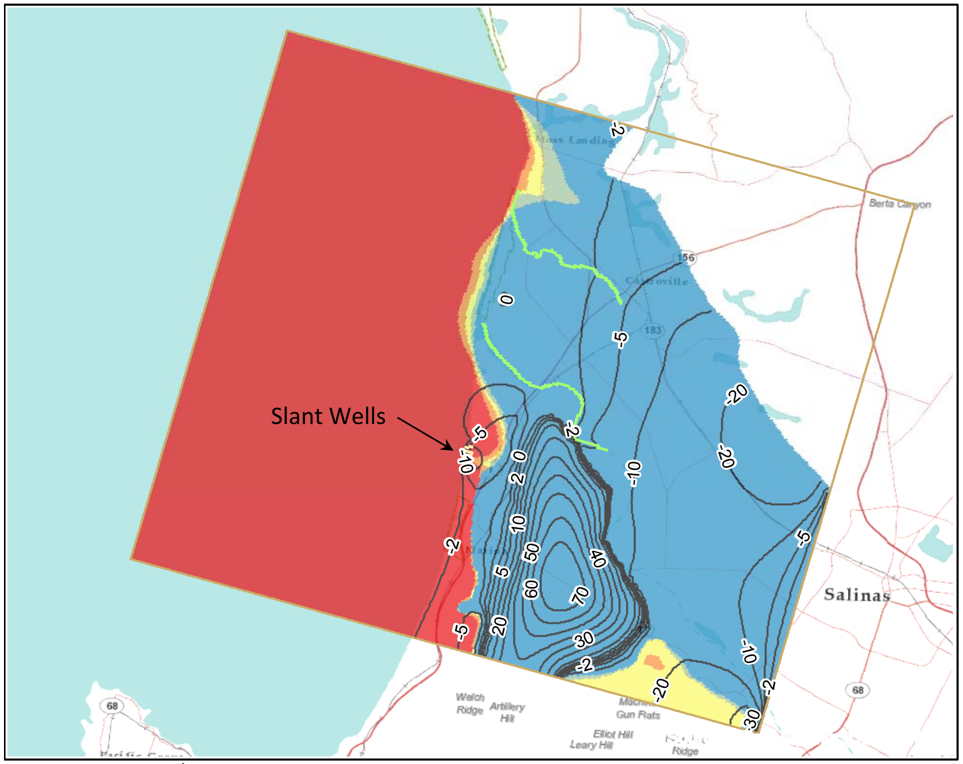
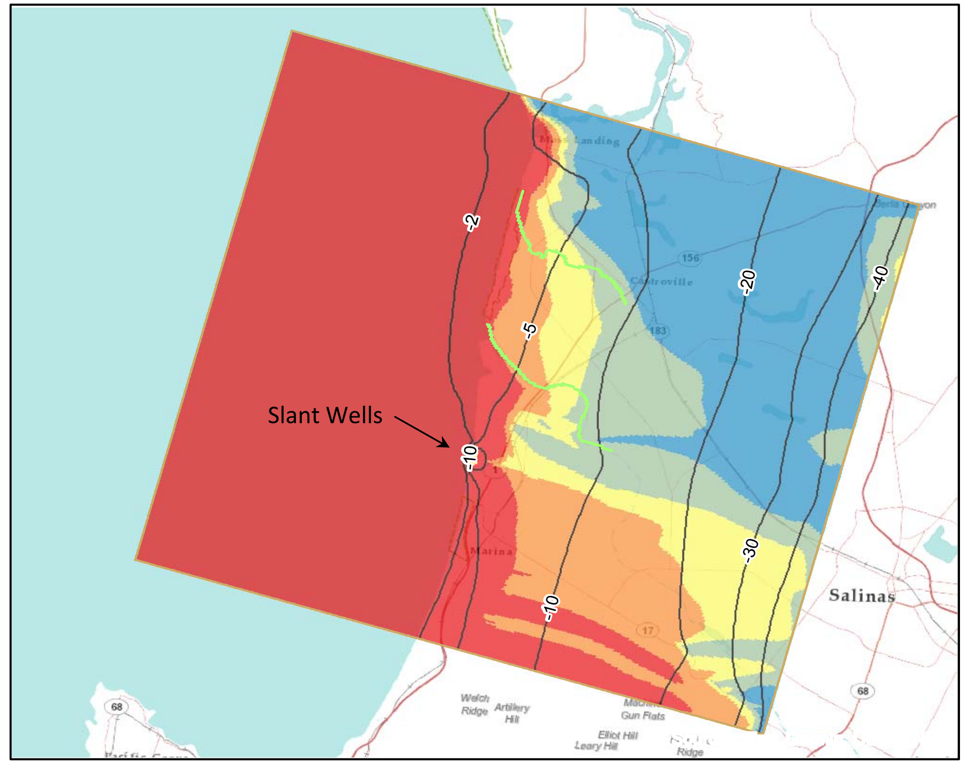


Figure 32. Area Where Recharge was Added to Layer 2 of NMGWM2016

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

-5 Groundwater Elevation Contour

Salinity
Ocean Water Percent (OWP)

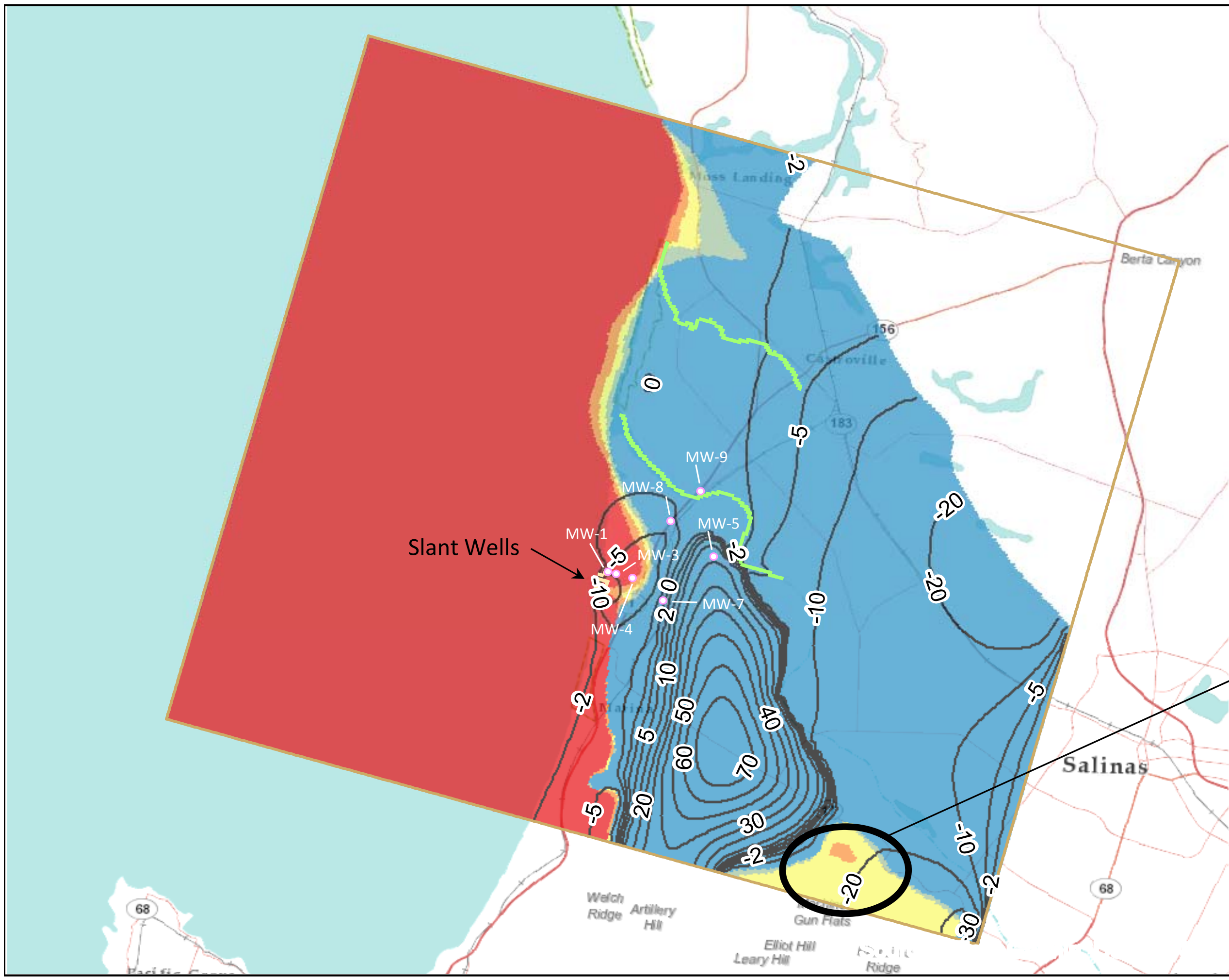
- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0007	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge:	5.0	Inches/year
KH16 and KH18:	4 and 2	Feet/day
Well Discharge OWP:	97.2%	(Ocean Water Percentage)

Figure 33. Recharge Added - NMGWM[2016] With Layer 4 Inland Gradient = 0.0007; Slant Wells Pumping 15.5 MGD

Weiss Associates

Layer 2 (Dune Sand Aquifer)



-5 Groundwater Elevation Contour

Salinity
Ocean Water Percent (OWP)

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

Salinity in Layer 2 caused by upwelling of saline water from Layer 4, through Aquifer Zone KV19

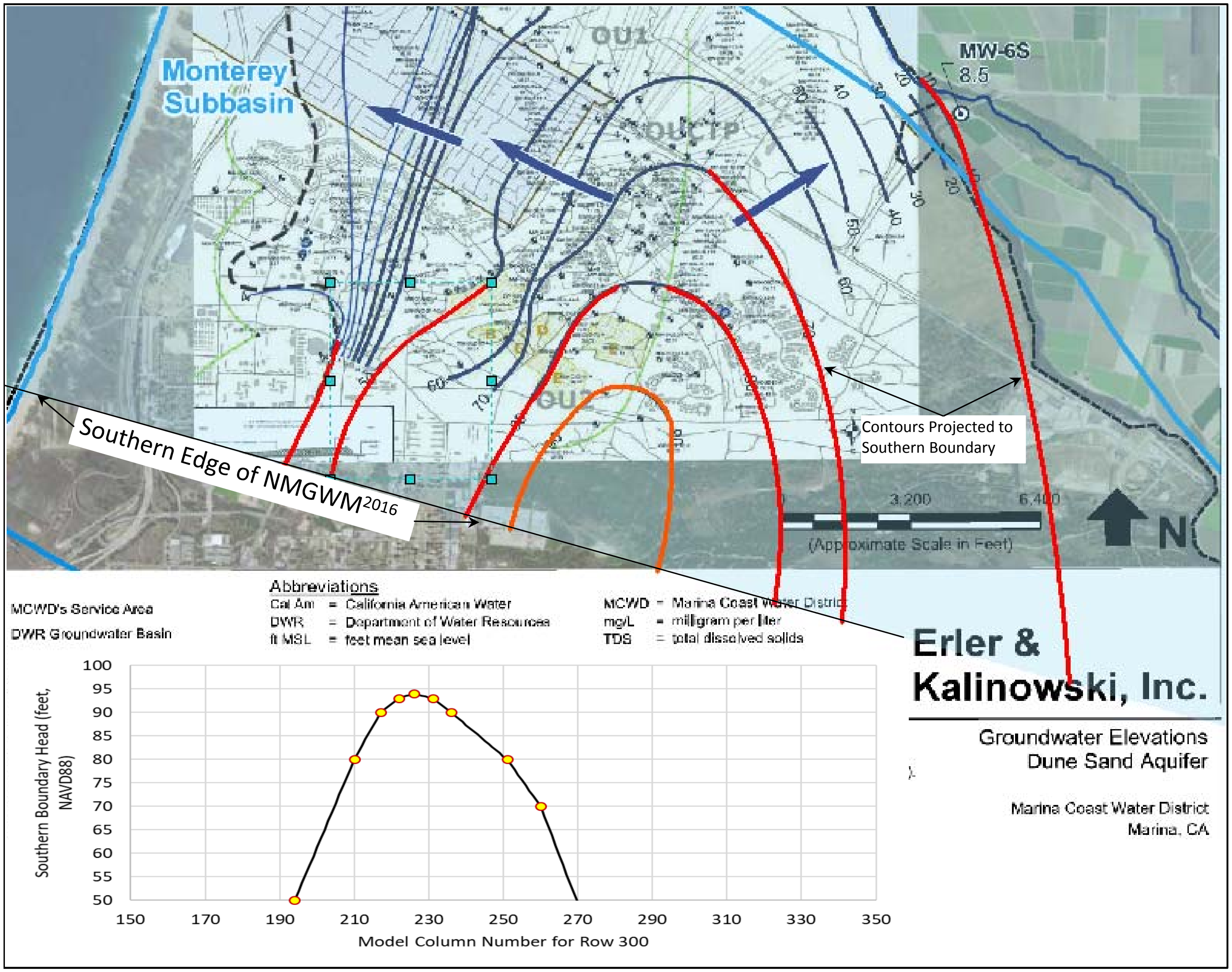
N

0 2 4 6 8 Miles

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0007	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge, Inches/Year:	5.0	Inches/year
Well Discharge OWP:	97.2%	(Ocean Water Percentage)

Figure 34. Saline Water Upwelling from Layer 4 to Layer 2

Layer 2 (Dune Sand Aquifer) Groundwater Elevations



Southern boundary imposed as a general head boundary with heads equal to projected groundwater elevation contours

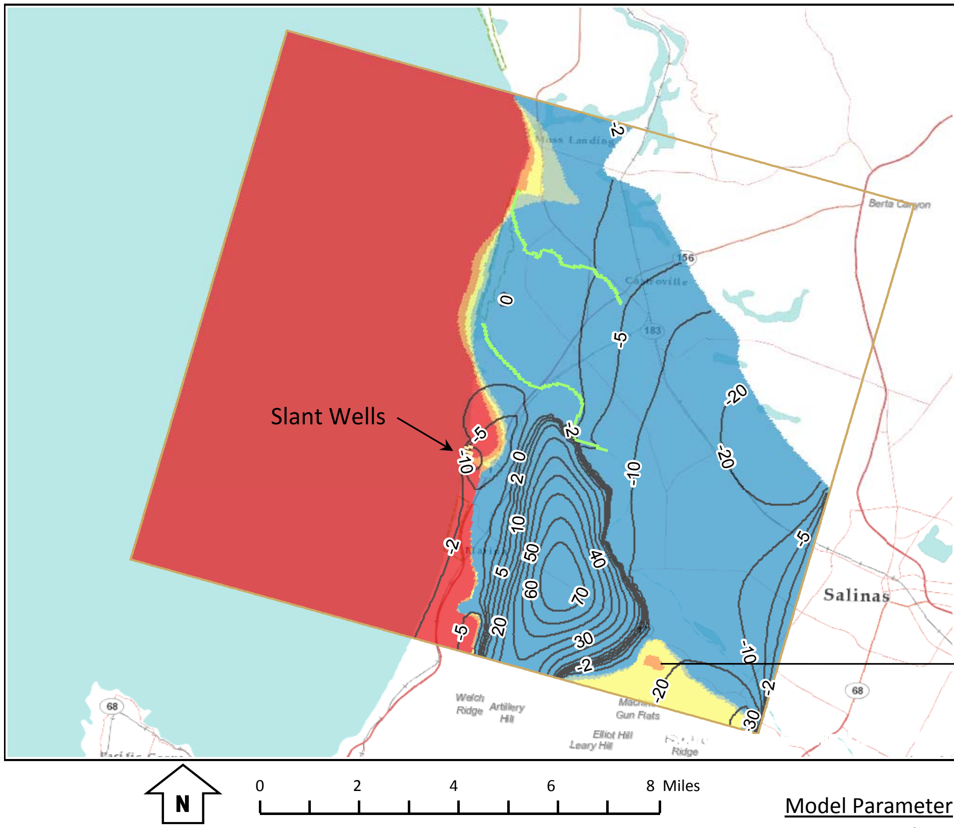
Piecewise linear interpolation between contours

The general head boundary is only applied for cells with head greater than 50 feet

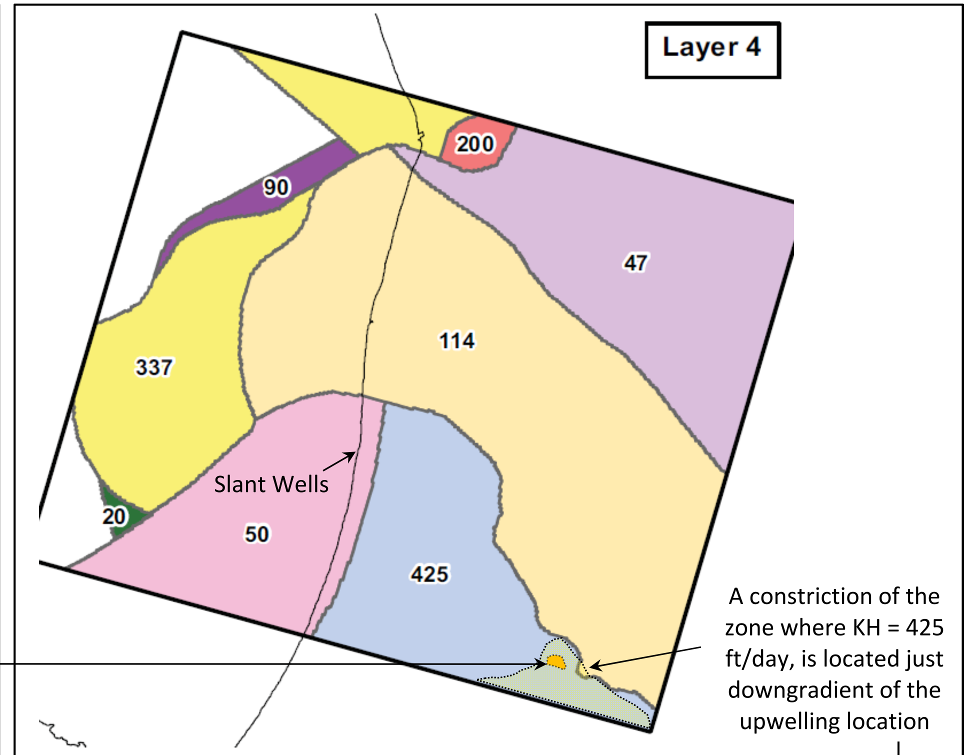
Figure 35. Modification of Southern Boundary of NMGWM[2016] in Layer 2

Weiss Associates

Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer) KH Zone Values (Feet/Day)



Salinity
Ocean Water Percent (OWP)

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

-5 Groundwater Elevation Contour

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0007	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge:	5.0	Inches/year
Well Discharge OWP:	97.2%	(Ocean Water Percentage)

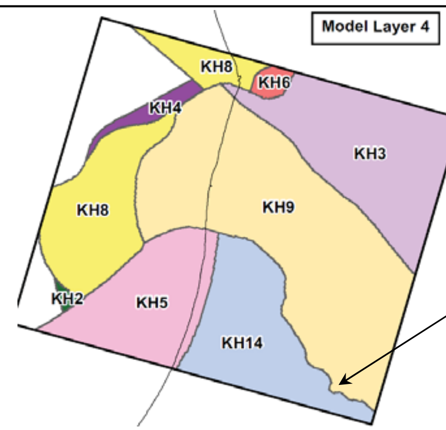


Figure 36. Comparison of Upwelling Location With Layer 4 KH Zone Configuration and Values (Feet/Day)

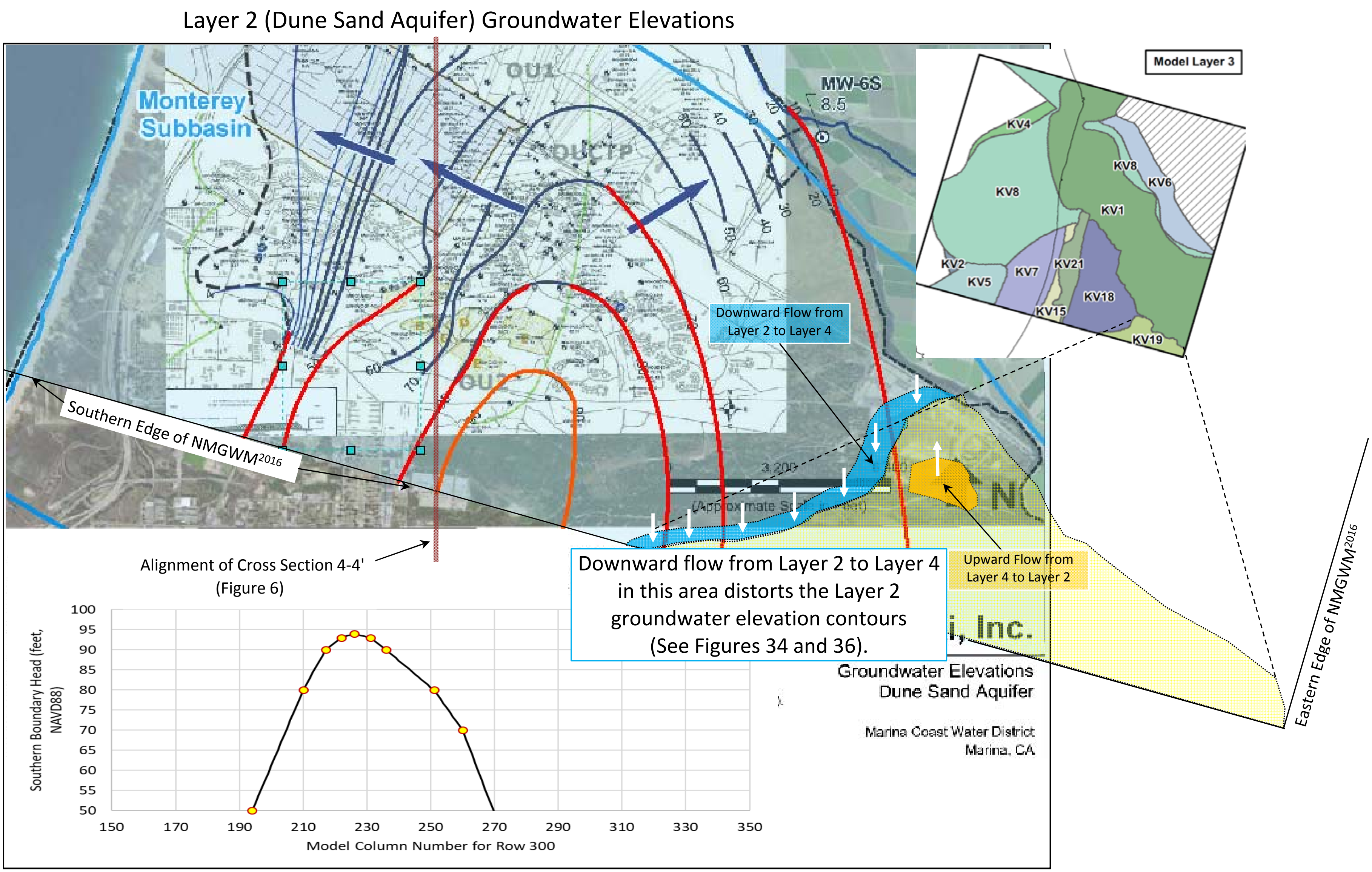
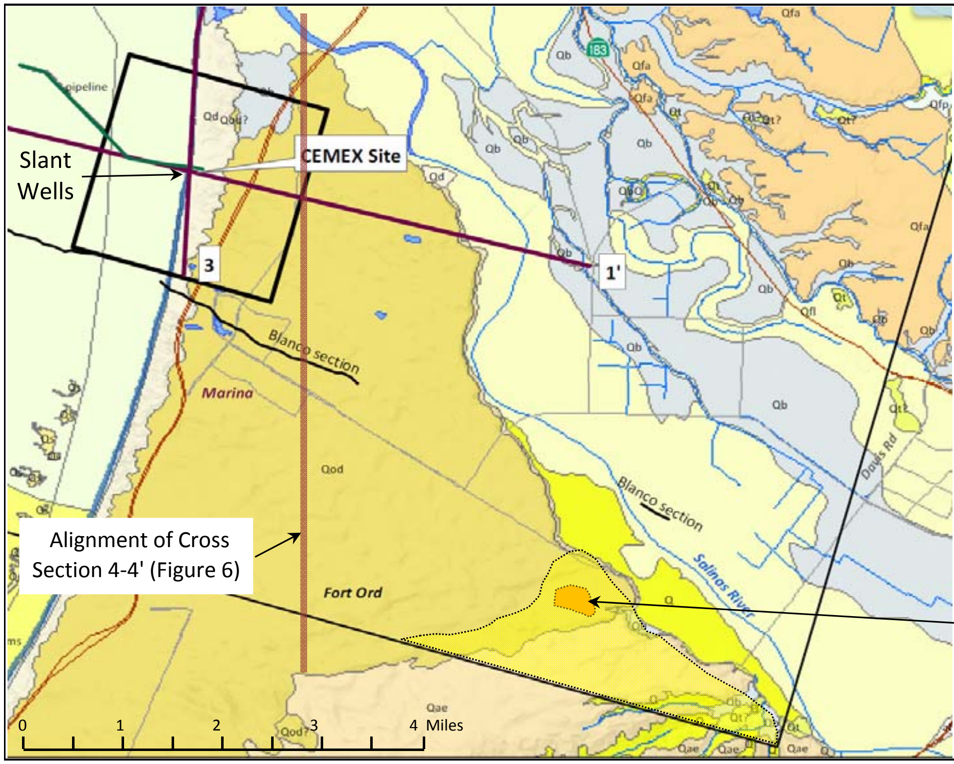
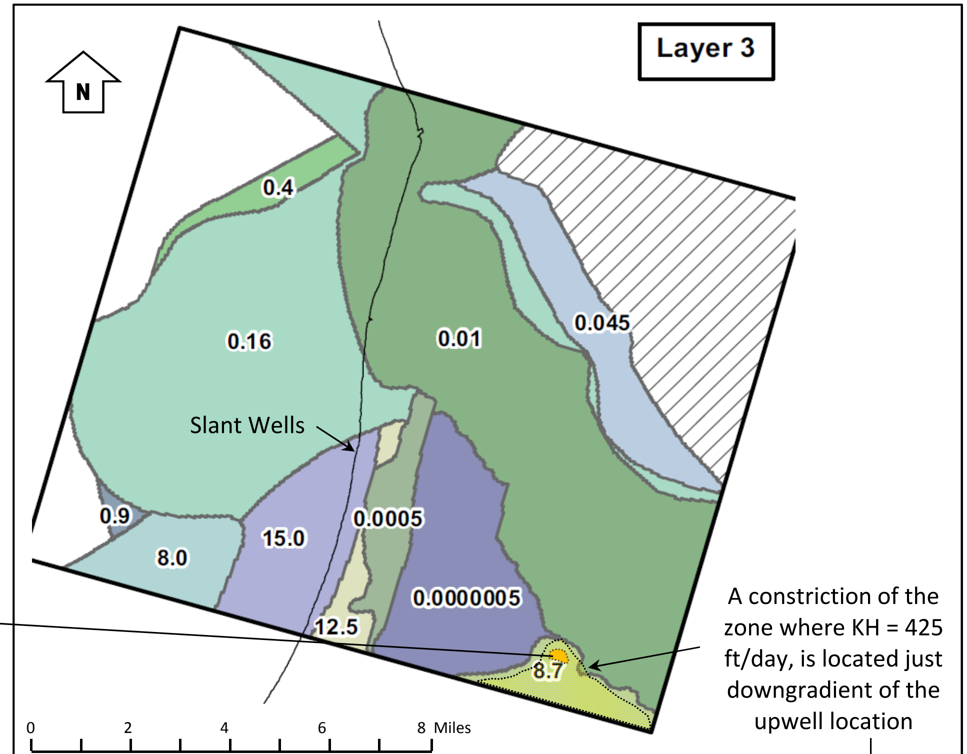


Figure 37. Vertical Groundwater Flow Through Layer 3, KV19

Geologic Map (Dune Sand Aquifer)

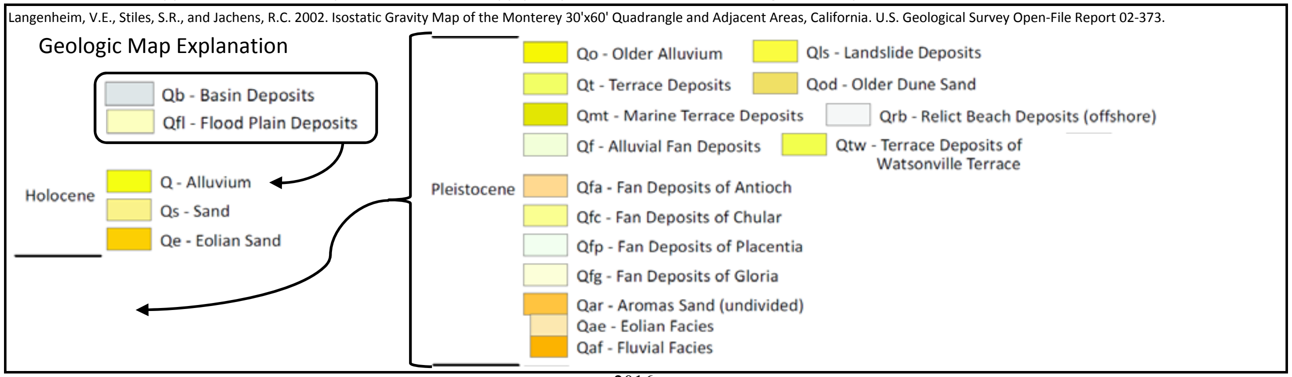


Layer 3 (FO-SVA Aquitard) KV Zone Values (Feet/Day)



Sources: 2015 EIR Appendix E2 - Monterey Peninsula Water Supply Project Groundwater Modeling and Analysis, contains the reference below:

Langenheim, V.E., Stiles, S.R., and Jachens, R.C. 2002. Isostatic Gravity Map of the Monterey 30'x60' Quadrangle and Adjacent Areas, California. U.S. Geological Survey Open-File Report 02-373.



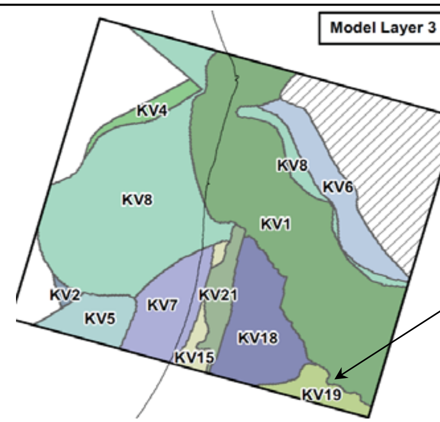
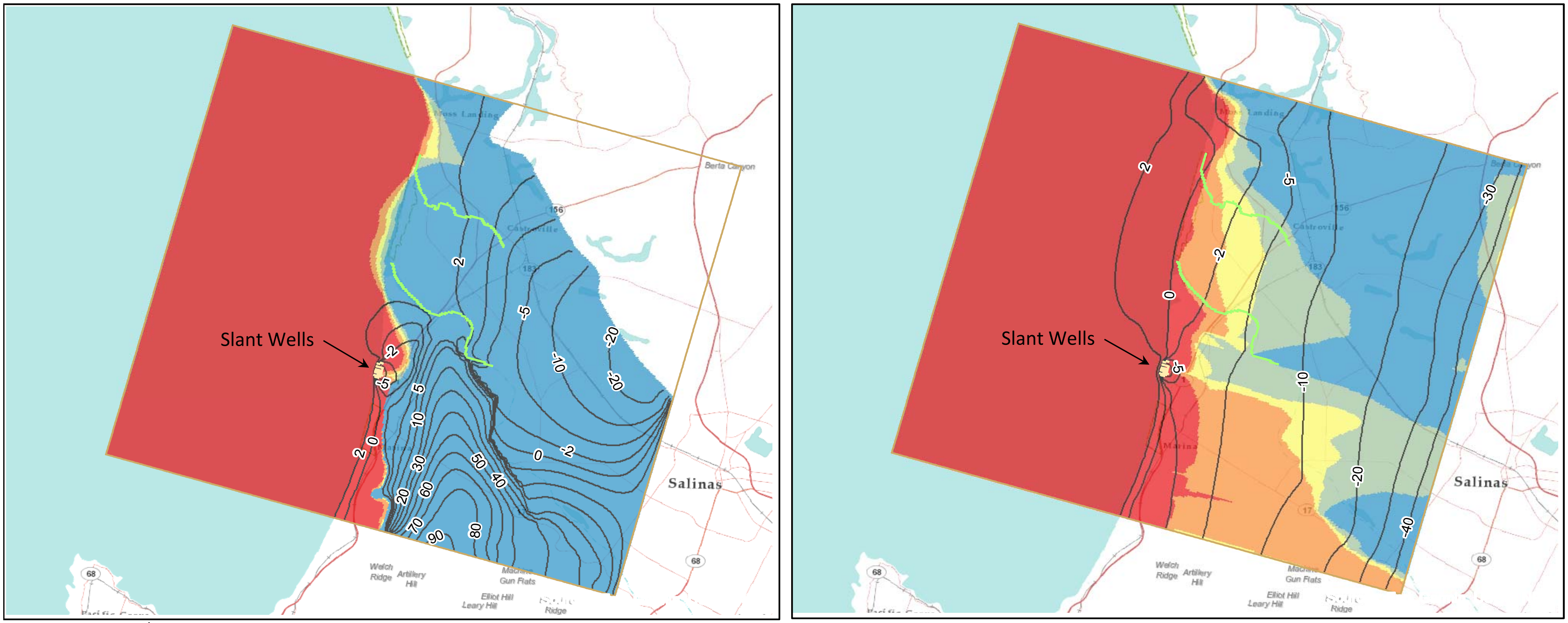


Figure 38. Comparison of Geology and NMGWM[2016] Layer 3 KV Zone Values (Feet/Day)

Layer 2 (Dune Sand Aquifer) | Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

-5

Groundwater Elevation Contour

Salinity

Ocean Water Percent (OWP)

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0007	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge:	5.0	Inches/year
KH16 and KH18:	4 and 2	Feet/day

Well Discharge OWP: 96.8% (Ocean Water Percentage)

Figure 39. Southern Boundary Revised - NMGWM^{2016} With Layer 4 Inland Gradient = 0.0007; Slant Wells Pumping 15.5 MGD

Groundwater Elevation Contours Based on Field Measurements are Shown in Blue.

Model-Generated Contours are Shown in Orange.

Layer 2 (Dune Sand Aquifer)

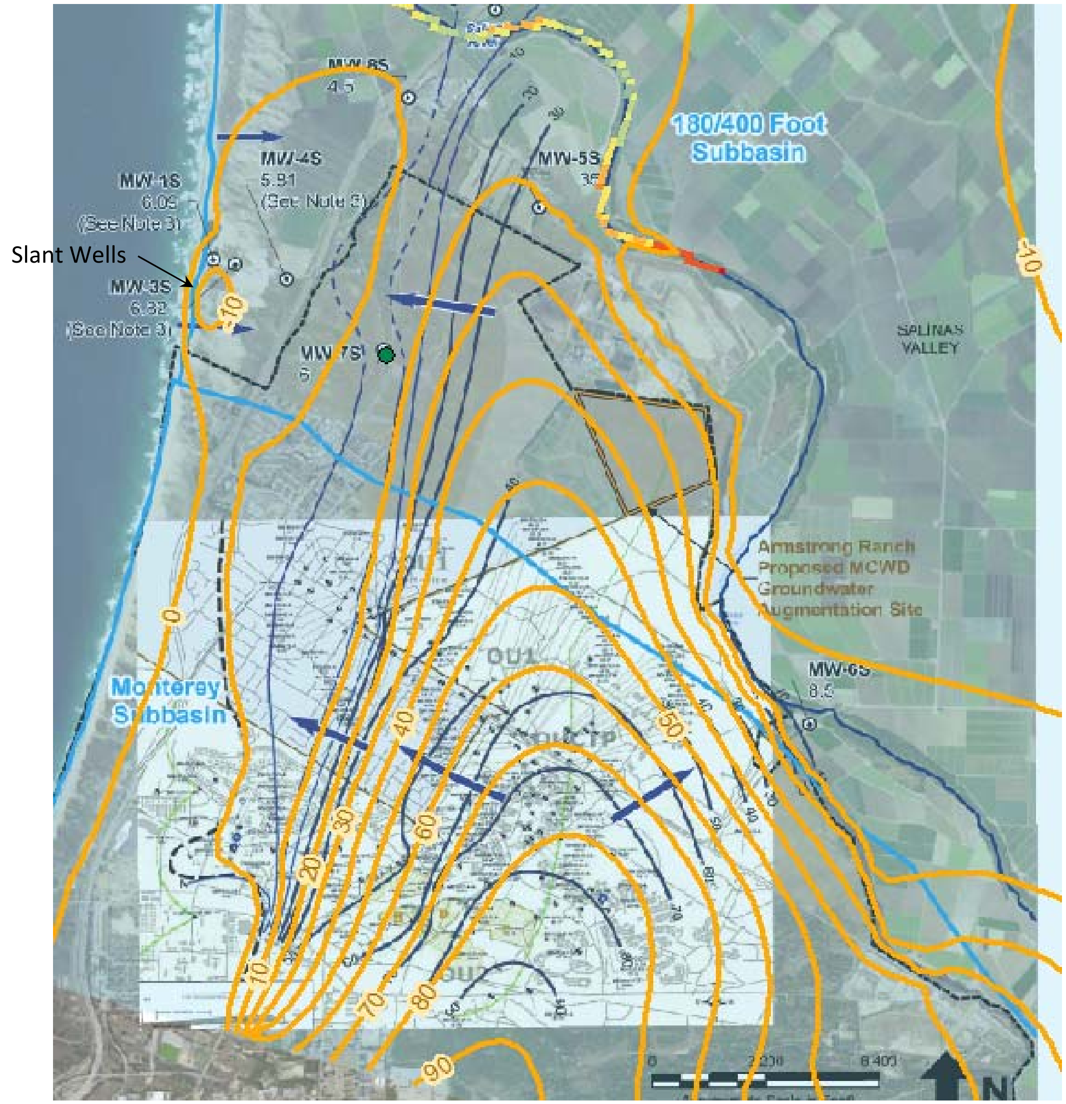


Figure 40. Revised Southern Boundary - Comparison of Modeled and Measured Groundwater Elevation Contours

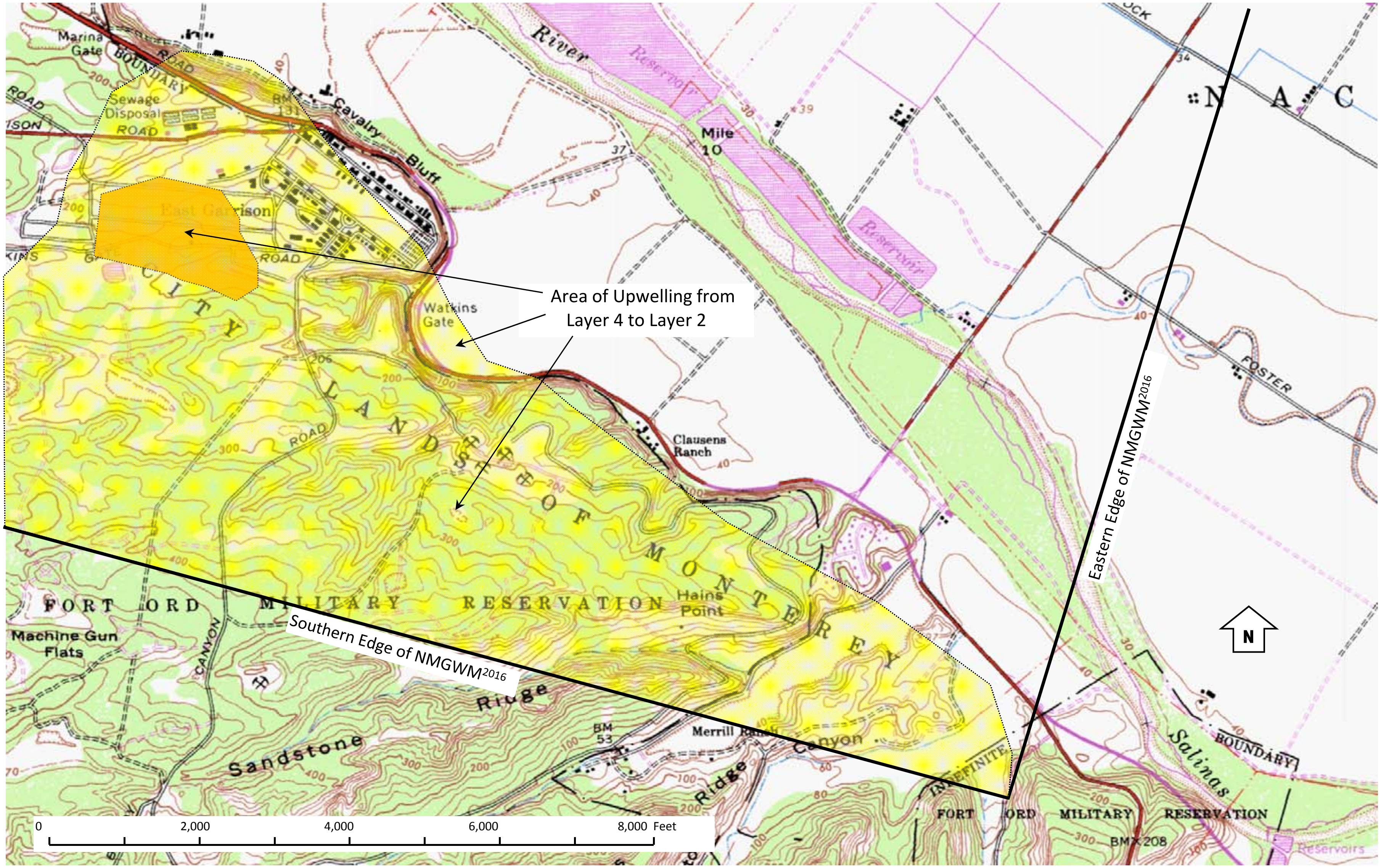


Figure 41. Revised Southern Boundary - Topography in the Southeast Corner of NMGWM2016

NMGWM2016 Results - "Wet" Season TSW Comparison

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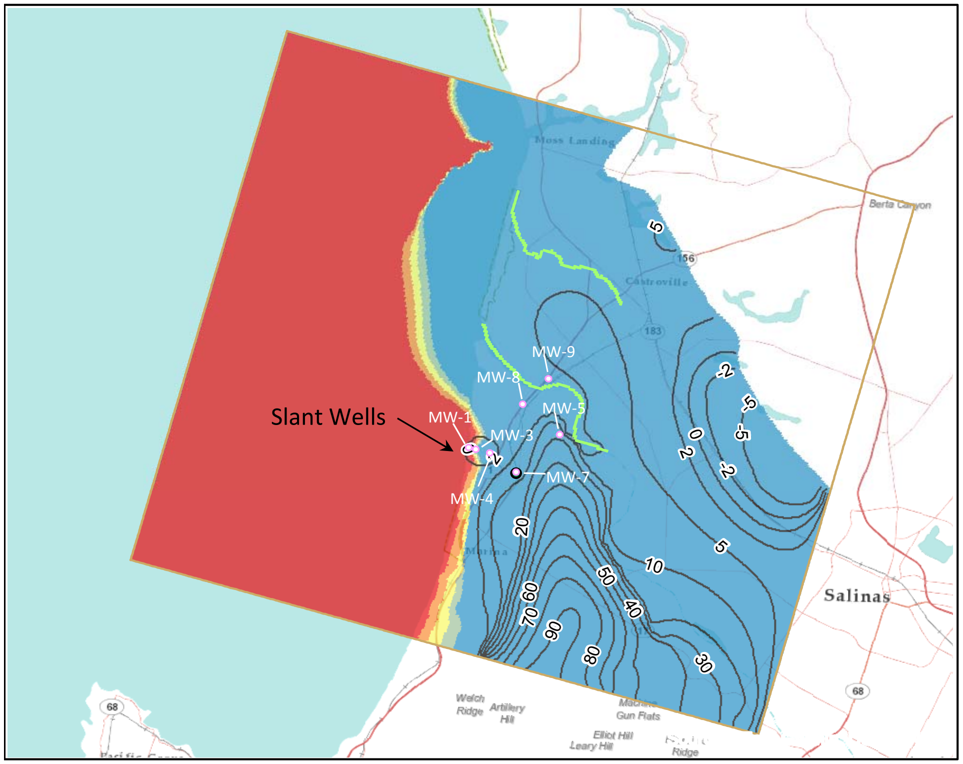
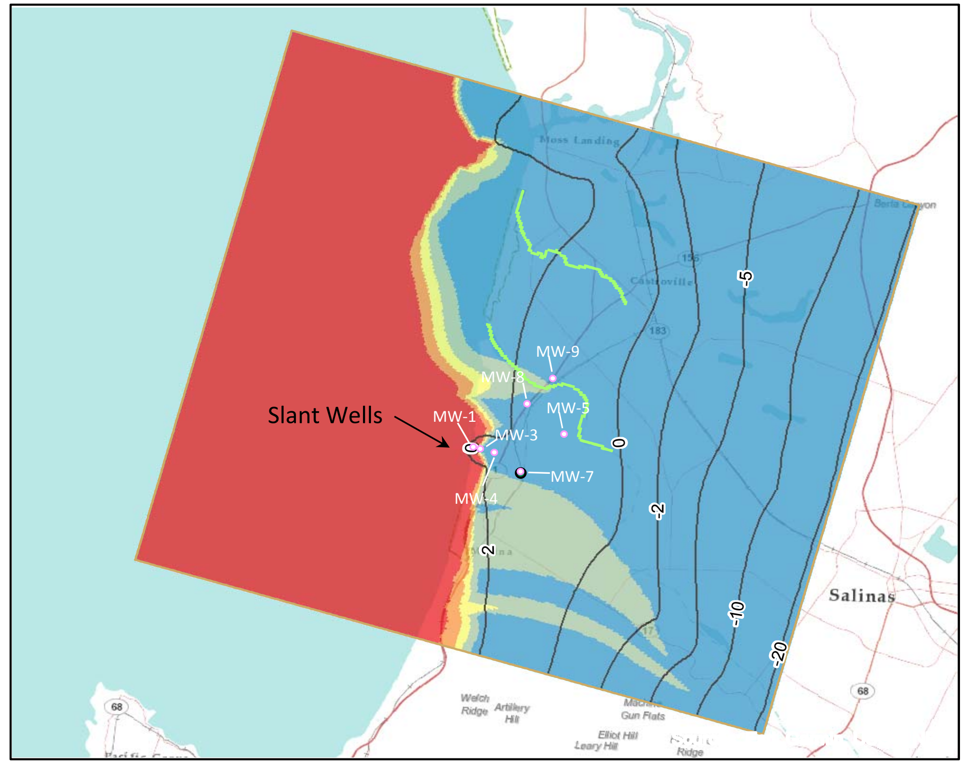
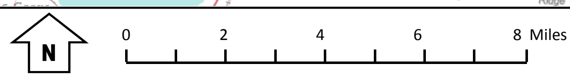
Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)





Salinity
Ocean Water Percent
(OWP)

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0004	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge:	6.0	Inches/year
KH16 and KH18:	3.5	Feet/day
Well Discharge OWP:	85.8%	(Ocean Water Percentage)
Groundwater Elevation in MW-7S:	8.9	Feet

Figure 42. "Wet" Season TSW Results Comparison - NMGWM2016, Layer 4 Gradient = 0.0004; Slant Wells Pumping 2.88 MGD, Recharge = 6 inches/year

NMGWM2016 Results - "Dry" Season TSW Comparison

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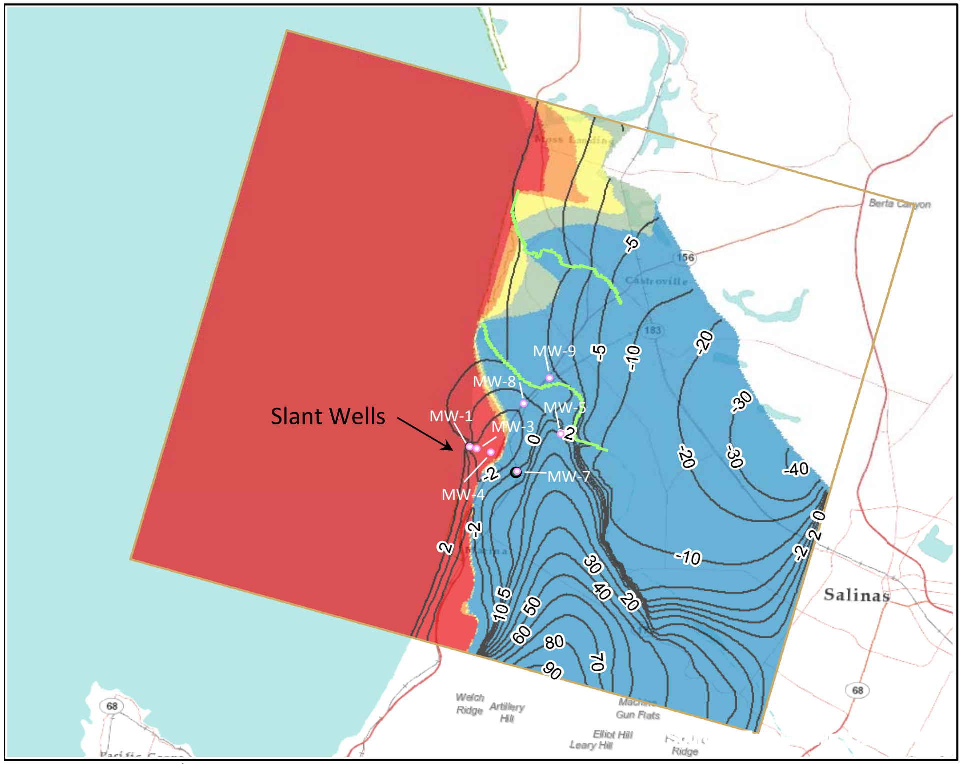
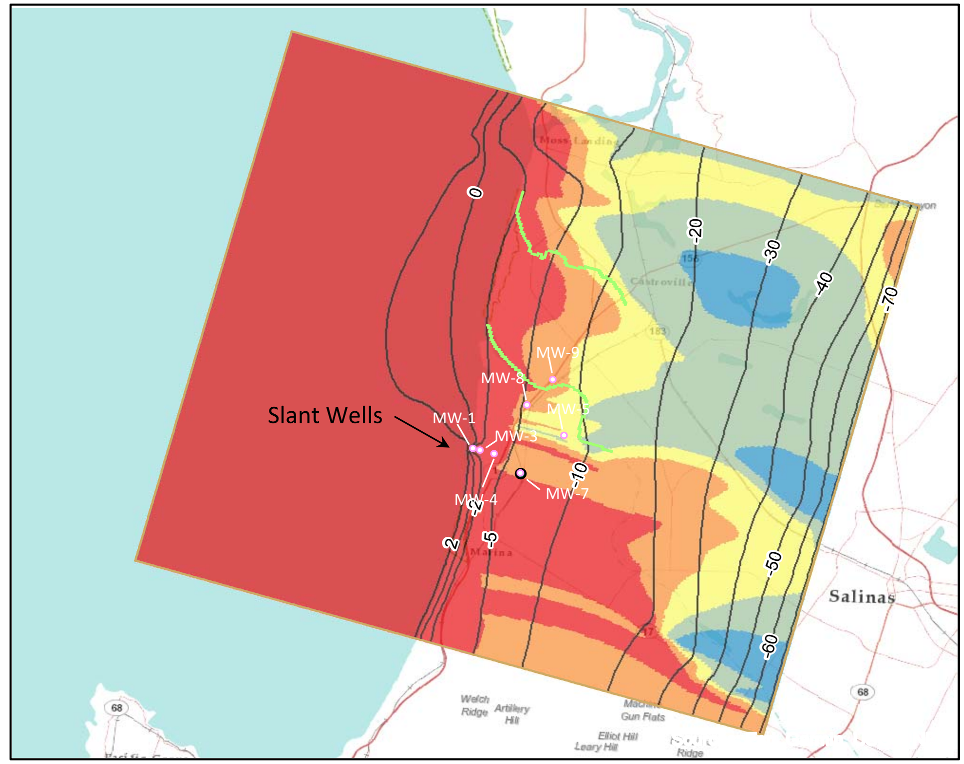
Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Salinity
Ocean Water Percent (OWP)

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0011	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge:	4.0	Inches/year
KH16 and KH18:	3.5	Feet/day
Well Discharge OWP:	99.6%	(Ocean Water Percentage)
Groundwater Elevation in MW-7S:	0.7	Feet

Figure 43. "Dry" Season TSW Results Comparison - NMGWM2016, Layer 4 Gradient = 0.0011; Slant Wells Pumping 2.88 MGD, Recharge = 4 inches/year

NMGWM^{2016} Results - "Wet" Season, 7.75 MGD

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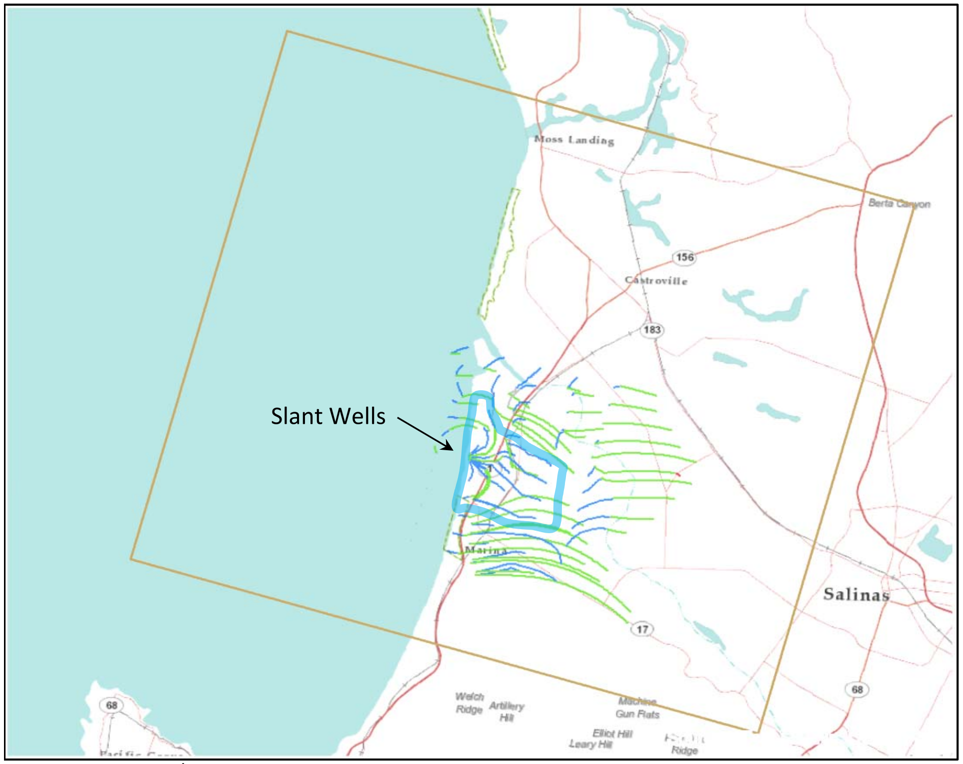
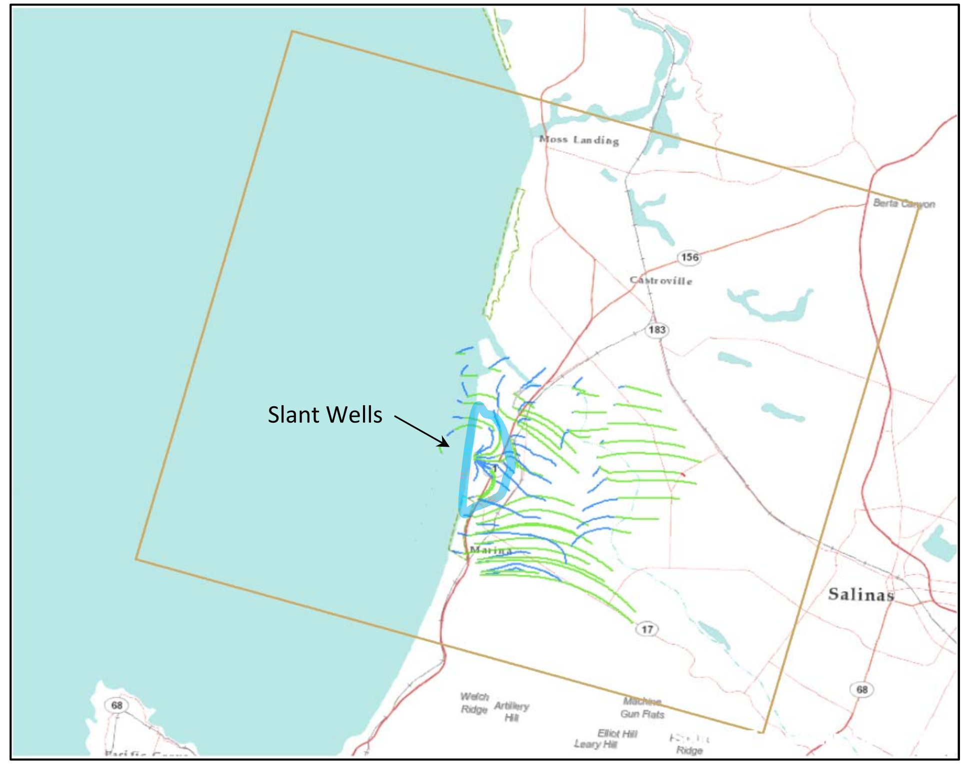
Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0004	Landward
Slant Wells Pumping Rate:	7.75	MGD
Recharge:	6.0	Inches/year
Well Discharge OWP:	84.7%	(Ocean Water Percentage)

"Fresh" Water Capture Zone

Figure 44. "Wet" Season Groundwater Capture - NMGWM$^{2016;}$ Slant Wells Pumping 7.75 MGD

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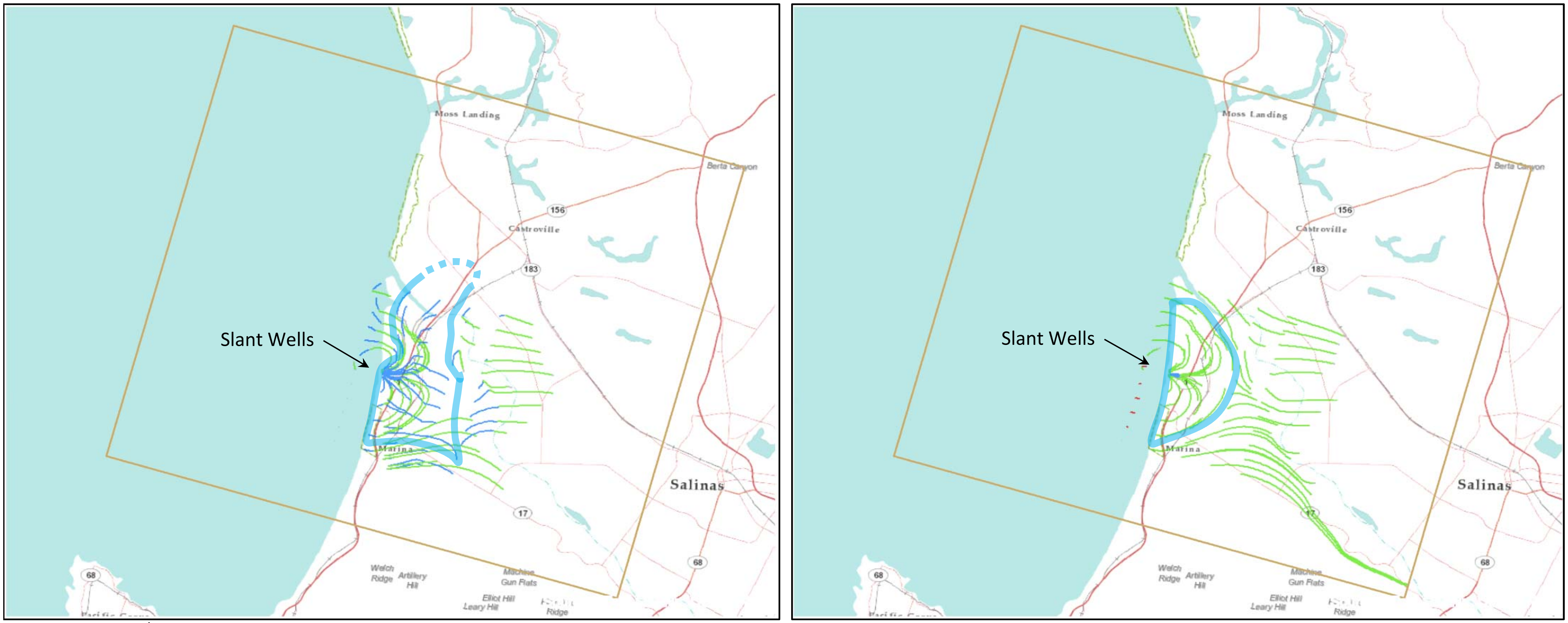
Layer 2 (Dune Sand Aquifer) — Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0004	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge:	6.0	Inches/year
Well Discharge OWP:	87.3%	(Ocean Water Percentage)

"Fresh" Water Capture Zone

Figure 45. "Wet" Season Groundwater Capture - NMGWM2016; Slant Wells Pumping 15.5 MGD

NMGWM^{2016} Results - "Dry" Season, 7.75 MGD

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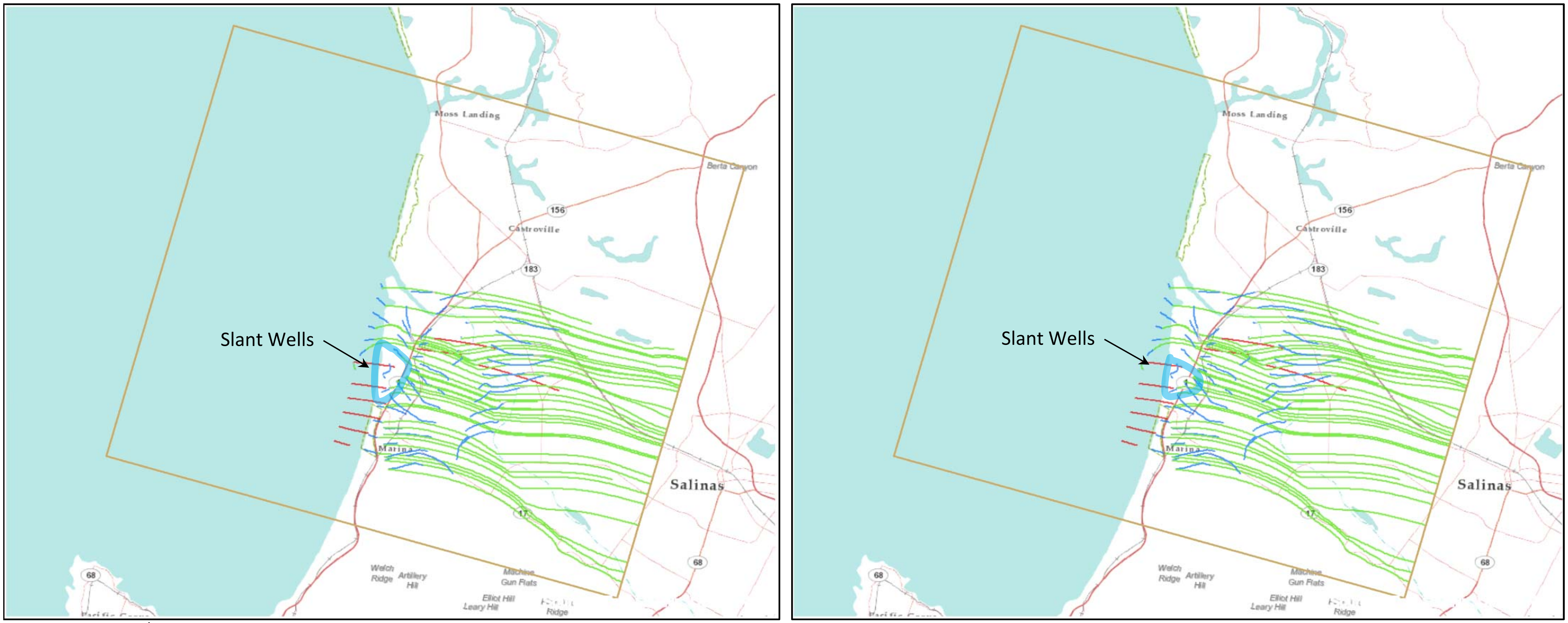
Layer 2 (Dune Sand Aquifer) | Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

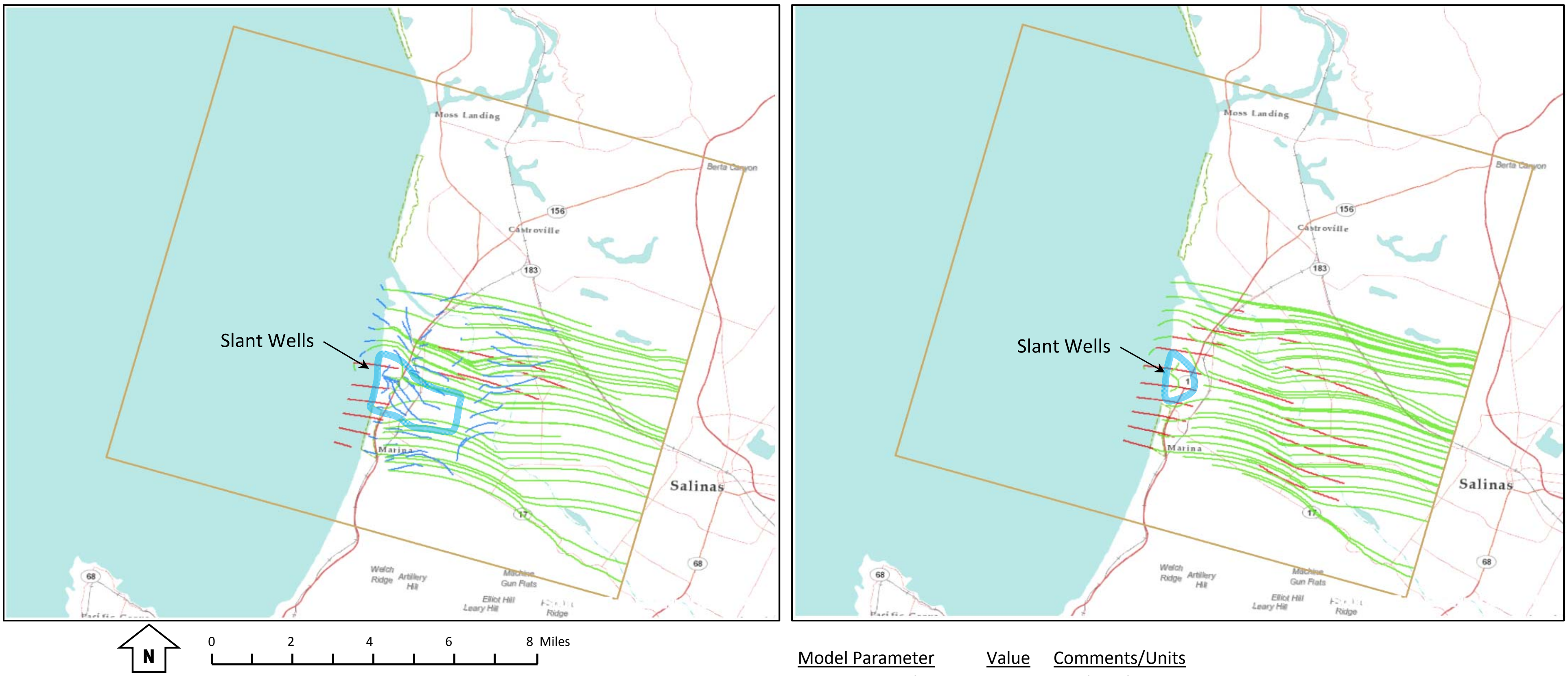
Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0011	Landward
Slant Wells Pumping Rate:	7.75	MGD
Recharge:	4.0	Inches/year
Well Discharge OWP:	98.9%	(Ocean Water Percentage)
		"Fresh" Water Capture Zone

Figure 46. "Dry" Season Groundwater Capture - NMGWM$^{2016;}$ Slant Wells Pumping 7.75 MGD

Layer 2 (Dune Sand Aquifer) | Layer 4 (180-Foot Aquifer)



Flow Path within Model Layer

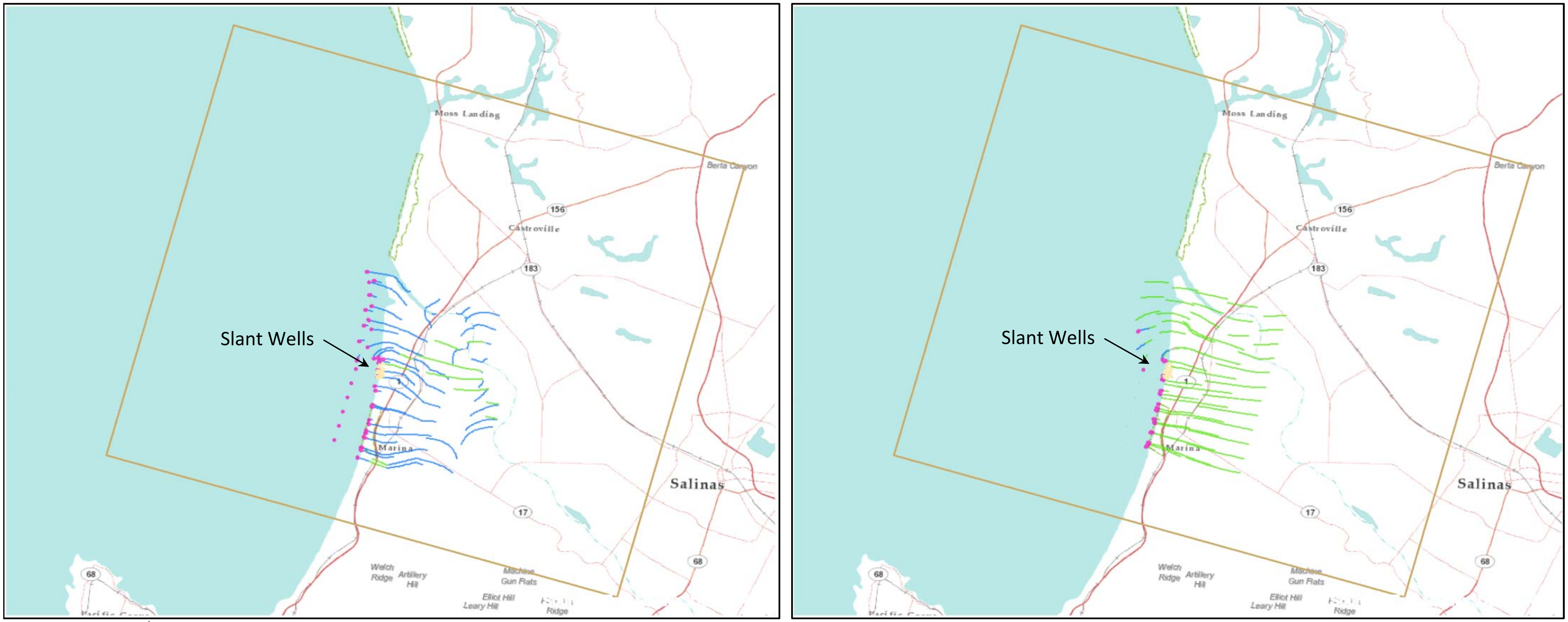
- 2
- 3
- 4
- 5
- 6

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.0011	Landward
Slant Wells Pumping Rate:	15.5	MGD
Recharge:	4.0	Inches/year
Well Discharge OWP:	97.6%	(Ocean Water Percentage)

"Fresh" Water Capture Zone

Figure 47. "Dry" Season Groundwater Capture - NMGWM$^{2016;}$ Slant Wells Pumping 15.5 MGD

Layer 2 (Dune Sand Aquifer) | Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.00	Landward
Slant Wells Pumping Rate:	0.00	MGD
Recharge:	5.0	Inches/year

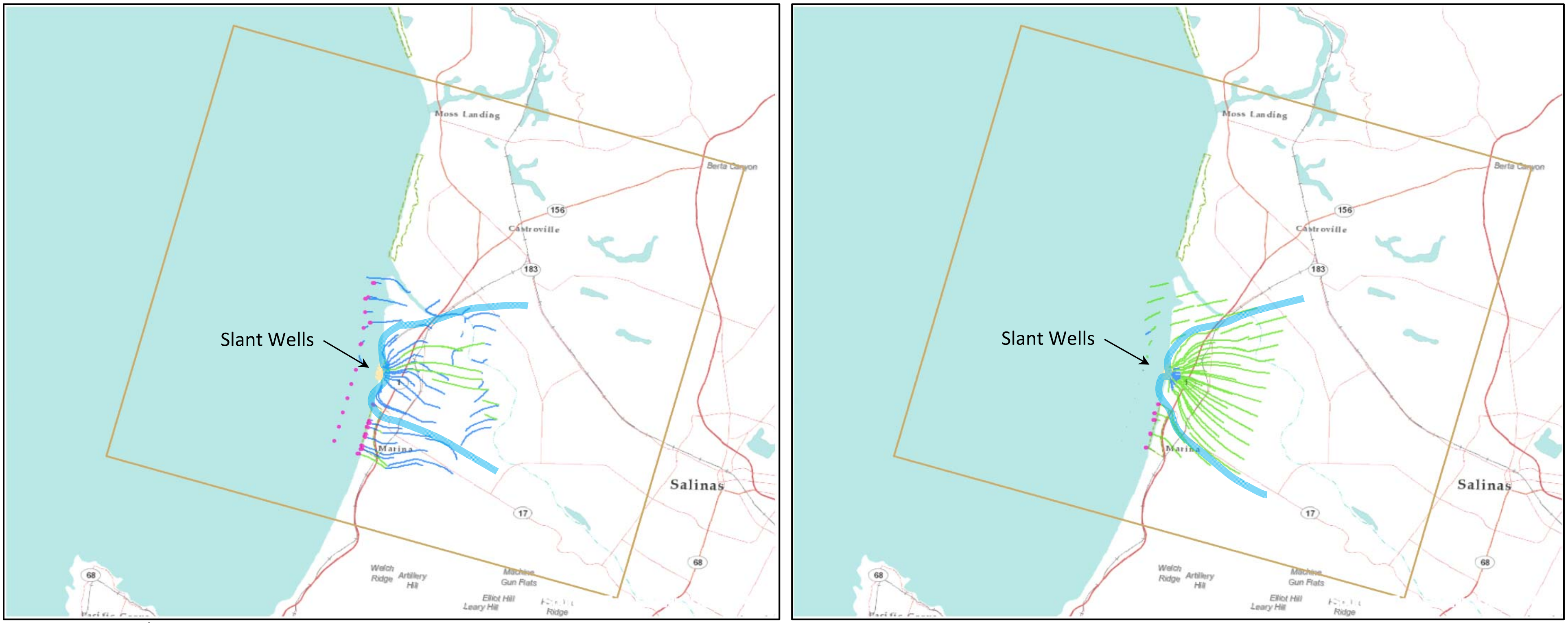
*Although the eastern general head boundary in Layers 2, 4, 6, and 8 is set to +3 NAVD88, creating a zero gradient from the eastern model boundary to the ocean, recharge and vertical downward flow from Layer 2 creates a gentle seaward gradient from several miles inland to the coast in these layers.

Well Discharge OWP: 0.0% (Ocean Water Percentage)

"Fresh" Water Capture Zone

Figure 48. Zero Gradient Groundwater Flow - NMGWM2016; No Pumping, No Capture

Layer 2 (Dune Sand Aquifer) — Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.00	Landward
Slant Wells Pumping Rate:	7.75	MGD
Recharge:	5.0	Inches/year

*Although the eastern general head boundary in Layers 2, 4, 6, and 8 is set to +3 NAVD88, creating a zero gradient from the eastern model boundary to the ocean, recharge and vertical downward flow from Layer 2 creates a gentle seaward gradient from several miles inland to the coast in these layers.

Well Discharge OWP: 66.6% (Ocean Water Percentage)

"Fresh" Water Capture Zone

Figure 49. Zero Gradient Groundwater Capture - NMGWM2016; Slant Wells Pumping 7.75 MGD

NMGWM^{2016} Results - Zero* Gradient

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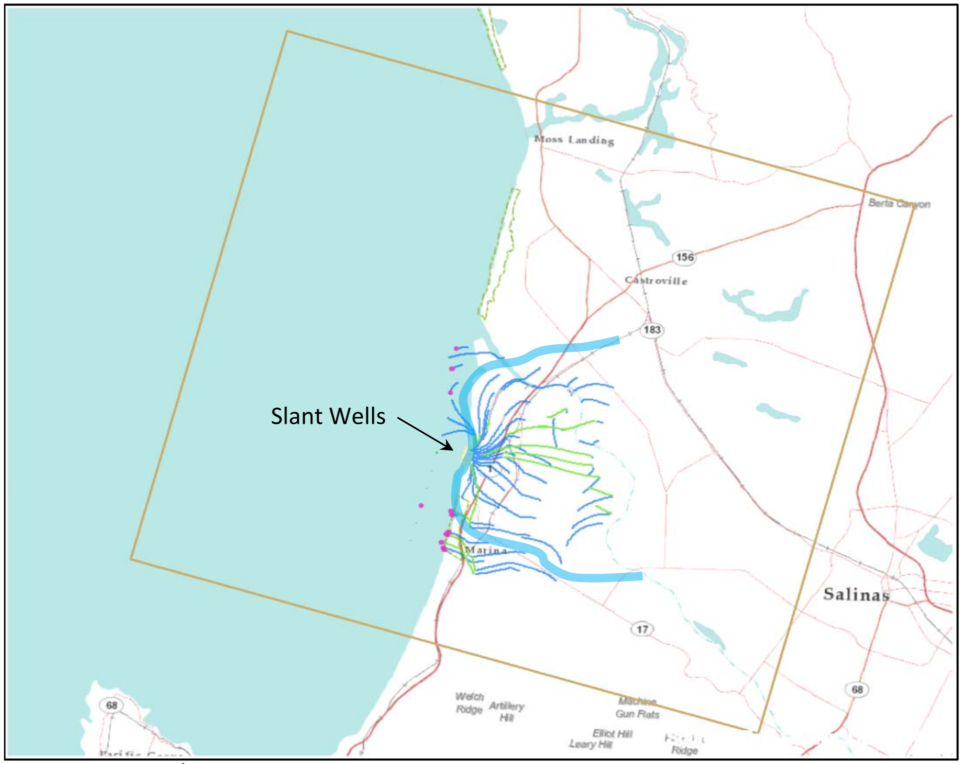
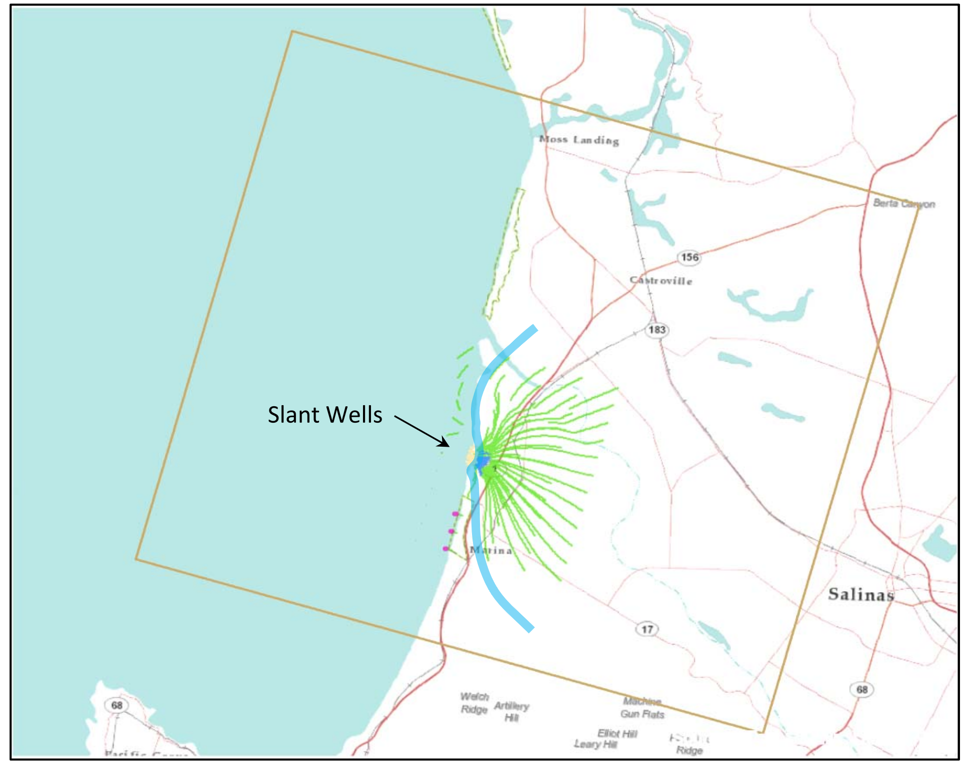
Layer 2 (Dune Sand Aquifer)



Layer 4 (180-Foot Aquifer)



N

0 2 4 6 8 Miles

Flow Path within Model Layer

- 2
- 3
- 4
- 5
- 6

Model Parameter	Value	Comments/Units
Layer 4 Gradient:	0.00	Landward
Slant Wells Pumping Rate:	15.50	MGD
Recharge:	5.0	Inches/year

*Although the eastern general head boundary in Layers 2, 4, 6, and 8 is set to +3 NAVD88, creating a zero gradient from the eastern model boundary to the ocean, recharge and vertical downward flow from Layer 2 creates a gentle seaward gradient from several miles inland to the coast in these layers.

Well Discharge OWP: 73.4% (Ocean Water Percentage)

"Fresh" Water Capture Zone

Figure 50. Zero Gradient Groundwater Capture - NMGWM^{2016}; Slant Wells Pumping 15.5 MGD

NMGWM^{2016} Results - "Wet" Season, 15.5 MGD

- Two seasonal conditions ('wet' and 'dry') were assessed for
  - No pumping
  - Total pumping rate of 7.75 MGD
  - Total pumping rate of 15.5 MGD
- Average drawdown calculated (pumping minus no pumping) over the cells (blue model cells in figure) representing vernal pond locations
- Drawdowns at model cells associated with each vernal pond are calculated and the values for averaged for each pond

Figure 51. Location of Vernal Ponds Relative to Slant Wells

TABLES

Table 1. Summary of Ocean Water Percentage (OWP) Analyses

Source	1-month OWP	1-year OWP	2-years OWP	Long-term OWP	Method
2015 Draft EIR	--	89 – 92	93 – 96	93 – 96	Variable Density Solute Transport Model
MCWD/GeoHydros	69	89	90	90	Model Water Balance
TSW Field Data	85	92 – 95	90 – 92	--	Field Data
HWG Analytical	78 – 79	88 – 93	93 – 97	96+	Analytical Mixing Model
HWG Numerical	82	93	93 – 94	94	Variable Density Solute Transport Model
Overall Range	69 – 85	89 – 95	90 – 96	90 – 96+	Various

Abbreviations:
EIR – Environmental Impact Report
HWG – Hydrogeological Working Group
MCWD – Marina Coast Water District
OWP – Ocean Water Percentage
TSW – Test Slant Well

Table 2. Ocean Water Percentages (OWP) From Slant Well Pumping Simulations, With Fresh Water TDS = 0.0 mg/L

Scenario	OWP Results by Layer 4 Gradient			
	0.0004	0.0007	0.0011	0.00
Original (No recharge with 15.5 MGD Pumping)	99.30%	99.97%	99.99%	---
Base Case for Sensitivity Analysis (Point of Comparison)				
Recharge (5 in/yr); Wells Pumping 15.5 MGD	**91.5%**	**97.2%**	**98.6%**	**74.9%**
Sensitivity Analysis				
Recharge Sensitivity (15 in/yr)	72.5%	84.6%	92.5%	63.8%
Recharge Sensitivity (10 in/yr)	81.0%	91.9%	96.4%	68.7%
Recharge Sensitivity (2.5 in/yr)	95.8%	98.8%	99.4%	79.9%
Recharge (5 in/yr); Well Pumping Sensitivity (7.75 MGD)	91.9%	97.9%	99.1%	68.7%
Recharge (5 in/yr); Well Pumping Sensitivity (31 MGD)	92.2%	95.8%	97.9%	79.9%
Layer 2 Sensitivity at Pumping Wells KH7 x 0.2 (150 changed to 30 ft/day)	89.6%	95.7%	97.8%	72.8%
Layer 2 Sensitivity at Pumping Wells KH7 x 5 (150 changed to 750 ft/day)	95.0%	99.0%	99.6%	78.7%
Variations in Hydraulic Conductivity, Margin of FO-SVA				
Increase Dune Sand KH (KH20 and KH16) x 5 (4 and 2 changed to 20 and 10 ft/day)	91.1%	96.6%	---	74.7%
Expand Moderate-K FO-SVA margin (KV15 = KV21 = 0.0005 and KV13 = KV20 = 0.03 ft/day)	91.9%	96.4%	97.3%	76.0%
Reduce Effectiveness (KV) of FO-SVA (KV21 = KV15 = 12.5 and KV20 = KV13 = 12.5 ft/day)	91.8%	97.5%	---	74.8%
Extend Low-K margin of FO-SVA west of Well 7 (KV21 = KV18 = 0.0000005 and KV20 = KV16 = 0.03 ft/day)	91.0%	96.0%	---	74.8%
Expand Area of Low-K Dune Sand Aquifer Westward (KH15 = KH21 = 4 and KH13 = KH20 = 4 ft/day)	92.3%	97.8%	---	76.5%
Expand Area of High-K Dune Sand Aquifer Eastward (KH21 = KH15 = 625 and KH20 = KH13 = 625 ft/day)	88.3%	93.5%	---	73.0%

Notes
FO-SVA = Fort Ord-Salinas Valley Aquitard
MGD = million gallons per day
KH = horizontal hydraulic conductivity
KV = vertical hydraulic conductivity
--- = value not determined

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Table 2a. Ocean Water Percentages (OWP) From Slant Well Pumping Simulations, With Fresh Water TDS = 500 mg/L

Scenario	OWP^{500} Results by Layer 4 Gradient			
	0.0004	0.0007	0.0011	0.00
Original (No recharge with 15.5 MGD Pumping)	99.29%	99.97%	99.99%	---
Base Case for Sensitivity Analysis (Point of Comparison)				
Recharge (5 in/yr); Wells Pumping 15.5 MGD	**91.4%**	**97.2%**	**98.6%**	**74.5%**
Sensitivity Analysis				
Recharge Sensitivity (15 in/yr)	72.1%	84.4%	92.4%	63.3%
Recharge Sensitivity (10 in/yr)	80.7%	91.8%	96.3%	68.2%
Recharge Sensitivity (2.5 in/yr)	95.7%	98.8%	99.4%	79.6%
Recharge (5 in/yr); Well Pumping Sensitivity (7.75 MGD)	91.8%	97.9%	99.1%	68.2%
Recharge (5 in/yr); Well Pumping Sensitivity (31 MGD)	92.1%	95.7%	97.9%	79.6%
Layer 2 Sensitivity at Pumping Wells KH7 x 0.2 (150 changed to 30 ft/day)	89.4%	95.6%	97.8%	72.4%
Layer 2 Sensitivity at Pumping Wells KH7 x 5 (150 changed to 750 ft/day)	94.9%	99.0%	99.6%	78.4%
Variations in Hydraulic Conductivity, Margin of FO-SVA				
Increase Dune Sand KH (KH20 and KH16) x 5 (4 and 2 changed to 20 and 10 ft/day)	91.0%	96.5%	---	74.3%
Expand Moderate-K FO-SVA margin (KV15 = KV21 = 0.0005 and KV13 = KV20 = 0.03 ft/day)	91.8%	96.3%	97.3%	75.6%
Reduce Effectiveness (KV) of FO-SVA (KV21 = KV15 = 12.5 and KV20 = KV13 = 12.5 ft/day)	91.7%	97.5%	---	74.4%
Extend Low-K margin of FO-SVA west of Well 7 (KV21 = KV18 = 0.0000005 and KV20 = KV16 = 0.03 ft/day)	90.9%	95.9%	---	74.4%
Expand Area of Low-K Dune Sand Aquifer Westward (KH15 = KH21 = 4 and KH13 = KH20 = 4 ft/day)	92.2%	97.8%	---	76.1%
Expand Area of High-K Dune Sand Aquifer Eastward (KH21 = KH15 = 625 and KH20 = KH13 = 625 ft/day)	88.1%	93.4%	---	72.6%

Notes

FO-SVA = Fort Ord-Salinas Valley Aquitard
MGD = million gallons per day
KH = horizontal hydraulic conductivity
KV = vertical hydraulic conductivity
mg/L = milligrams per liter
TDS = total dissolved solids
--- = value not determined

Weiss Associates

Table 2b. Ocean Water Percentages (OWP) From Slant Well Pumping Simulations, With Fresh Water TDS = 3,000 mg/L

Scenario	$OWP^{3,000}$ Results by Layer 4 Gradient			
	0.0004	0.0007	0.0011	0.00
Original (No recharge with 15.5 MGD Pumping)	99.23%	99.97%	99.99%	---
Base Case for Sensitivity Analysis (Point of Comparison)				
Recharge (5 in/yr); Wells Pumping 15.5 MGD	**90.7%**	**96.9%**	**98.5%**	**72.4%**
Sensitivity Analysis				
Recharge Sensitivity (15 in/yr)	69.8%	83.1%	91.8%	60.2%
Recharge Sensitivity (10 in/yr)	79.1%	91.1%	96.0%	65.6%
Recharge Sensitivity (2.5 in/yr)	95.4%	98.7%	99.3%	77.9%
Recharge (5 in/yr); Well Pumping Sensitivity (7.75 MGD)	91.1%	97.7%	99.0%	65.6%
Recharge (5 in/yr); Well Pumping Sensitivity (31 MGD)	91.4%	95.4%	97.7%	77.9%
Layer 2 Sensitivity at Pumping Wells KH7 x 0.2 (150 changed to 30 ft/day)	88.6%	95.3%	97.6%	70.1%
Layer 2 Sensitivity at Pumping Wells KH7 x 5 (150 changed to 750 ft/day)	94.5%	98.9%	99.6%	76.6%
Variations in Hydraulic Conductivity, Margin of FO-SVA				
Increase Dune Sand KH (KH20 and KH16) x 5 (4 and 2 changed to 20 and 10 ft/day)	90.2%	96.3%	---	72.2%
Expand Moderate-K FO-SVA margin (KV15 = KV21 = 0.0005 and KV13 = KV20 = 0.03 ft/day)	91.1%	96.0%	97.0%	73.6%
Reduce Effectiveness (KV) of FO-SVA (KV21 = KV15 = 12.5 and KV20 = KV13 = 12.5 ft/day)	91.0%	97.3%	---	72.3%
Extend Low-K margin of FO-SVA west of Well 7 (KV21 = KV18 = 0.0000005 and KV20 = KV16 = 0.03 ft/day)	90.1%	95.6%	---	72.3%
Expand Area of Low-K Dune Sand Aquifer Westward (KH15 = KH21 = 4 and KH13 = KH20 = 4 ft/day)	91.5%	97.6%	---	74.2%
Expand Area of High-K Dune Sand Aquifer Eastward (KH21 = KH15 = 625 and KH20 = KH13 = 625 ft/day)	87.1%	92.9%	---	70.3%

Notes

FO-SVA = Fort Ord-Salinas Valley Aquitard
MGD = million gallons per day
KH = horizontal hydraulic conductivity
KV = vertical hydraulic conductivity
mg/L = milligrams per liter
TDS = total dissolved solids
--- = value not determined

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Table 3. Ocean Water Percentages (OWP) From Slant Well Pumping Simulations - South Model Boundary Adjusted, With Fresh Water TDS = 0.0 mg/L

Scenario	OWP Results by Layer 4 Gradient			
	0.0004	0.0007	0.0011	0.00
Base Case - No South Model Boundary Adjustment (Point of Comparison)				
Recharge (5 in/yr); Wells Pumping 15.5 MGD; KH20 = 4; KH16 = 2 ft/day	**91.5%**	**97.2%**	**98.6%**	**74.9%**
South Model Boundary Adjusted				
Recharge (5 in/yr); Wells Pumping 15.5 MGD; KH20 = KH16 = 3.5 ft/day	---	96.8%	---	---
Seasonal Differences				
Test Slant Well Comparison - "Wet": Recharge (6 in/yr); Well Pumping 2.88 MGD	85.8%	---	---	---
Test Slant Well Comparison - "Dry": Recharge (4 in/yr); Well Pumping 2.88 MGD	---	---	99.6%	---
1/2 Project Well Flow - "Wet": Recharge (6 in/yr); Wells Pumping 7.75 MGD	84.7%	---	---	---
Full Project Well Flow - "Wet": Recharge (6 in/yr); Wells Pumping 15.5 MGD	87.3%	---	---	---
1/2 Project Well Flow - "Dry": Recharge (4 in/yr); Wells Pumping 7.75 MGD	---	---	98.9%	---
Full Project Well Flow - "Dry": Recharge (4 in/yr); Wells Pumping 15.5 MGD	---	---	97.6%	---
Zero Gradient Simulations				
No Pumping, Recharge (5 in/yr)	---	---	---	n/a
Wells Pumping 7.75 MGD, Recharge (5 in/yr)	---	---	---	66.6%
Wells Pumping 15.5 MGD, Recharge (5 in/yr)	---	---	---	73.4%

Notes
FO-SVA = Fort Ord-Salinas Valley Aquitard
MGD = million gallons per day
KH = horizontal hydraulic conductivity
KV = vertical hydraulic conductivity
n/a = not applicable
--- = value not determined

Weiss Associates

Table 3a. Ocean Water Percentages (OWP) From Slant Well Pumping Simulations - South Model Boundary Adjusted, With Fresh Water TDS = 500 mg/L

Scenario	OWP^{500} Results by Layer 4 Gradient			
	0.0004	0.0007	0.0011	0.00
Base Case - No South Model Boundary Adjustment (Point of Comparison)				
Recharge (5 in/yr); Wells Pumping 15.5 MGD; KH20 = 4; KH16 = 2 ft/day	**91.4%**	**97.2%**	**98.6%**	**74.5%**
South Model Boundary Adjusted				
Recharge (5 in/yr); Wells Pumping 15.5 MGD; KH20 = KH16 = 3.5 ft/day	---	96.8%	---	---
Seasonal Differences				
Test Slant Well Comparison - "Wet": Recharge (6 in/yr); Well Pumping 2.88 MGD	85.6%	---	---	---
Test Slant Well Comparison - "Dry": Recharge (4 in/yr); Well Pumping 2.88 MGD	---	---	99.6%	---
1/2 Project Well Flow - "Wet": Recharge (6 in/yr); Wells Pumping 7.75 MGD	84.5%	---	---	---
Full Project Well Flow - "Wet": Recharge (6 in/yr); Wells Pumping 15.5 MGD	87.1%	---	---	---
1/2 Project Well Flow - "Dry": Recharge (4 in/yr); Wells Pumping 7.75 MGD	---	---	98.9%	---
Full Project Well Flow - "Dry": Recharge (4 in/yr); Wells Pumping 15.5 MGD	---	---	97.6%	---
Zero Gradient Simulations				
No Pumping, Recharge (5 in/yr)	---	---	---	n/a
Wells Pumping 7.75 MGD, Recharge (5 in/yr)	---	---	---	66.1%
Wells Pumping 15.5 MGD, Recharge (5 in/yr)	---	---	---	73.0%

Notes

FO-SVA = Fort Ord-Salinas Valley Aquitard
MGD = million gallons per day
KH = horizontal hydraulic conductivity
KV = vertical hydraulic conductivity
mg/L = milligrams per liter
TDS = total dissolved solids
n/a = not applicable
--- = value not determined

Table 3b. Ocean Water Percentages (OWP) From Slant Well Pumping Simulations - South Model Boundary Adjusted, With Fresh Water TDS = 3,000 mg/L

Scenario	$OWP^{3,000}$ Results by Layer 4 Gradient			
	0.0004	0.0007	0.0011	0.00
Base Case - No South Model Boundary Adjustment (Point of Comparison)				
Recharge (5 in/yr); Wells Pumping 15.5 MGD; KH20 = 4; KH16 = 2 ft/day	**90.7%**	**96.9%**	**98.5%**	**72.4%**
South Model Boundary Adjusted				
Recharge (5 in/yr); Wells Pumping 15.5 MGD; KH20 = KH16 = 3.5 ft/day	---	96.5%	---	---
Seasonal Differences				
Test Slant Well Comparison - "Wet": Recharge (6 in/yr); Well Pumping 2.88 MGD	84.4%	---	---	---
Test Slant Well Comparison - "Dry": Recharge (4 in/yr); Well Pumping 2.88 MGD	---	---	99.6%	---
1/2 Project Well Flow - "Wet": Recharge (6 in/yr); Wells Pumping 7.75 MGD	83.2%	---	---	---
Full Project Well Flow - "Wet": Recharge (6 in/yr); Wells Pumping 15.5 MGD	86.1%	---	---	---
1/2 Project Well Flow - "Dry": Recharge (4 in/yr); Wells Pumping 7.75 MGD	---	---	98.8%	---
Full Project Well Flow - "Dry": Recharge (4 in/yr); Wells Pumping 15.5 MGD	---	---	97.4%	---
Zero Gradient Simulations				
No Pumping, Recharge (5 in/yr)	---	---	---	n/a
Wells Pumping 7.75 MGD, Recharge (5 in/yr)	---	---	---	63.3%
Wells Pumping 15.5 MGD, Recharge (5 in/yr)	---	---	---	70.8%

Notes
FO-SVA = Fort Ord-Salinas Valley Aquitard
MGD = million gallons per day
KH = horizontal hydraulic conductivity
KV = vertical hydraulic conductivity
mg/L = milligrams per liter
TDS = total dissolved solids
n/a = not applicable
--- = value not determined

Weiss Associates

Table 4. Simulated Water Level Changes at Vernal Ponds Due to Seasonal Effects and Proposed Slant Well Pumping

Pond Number	Pond Name	"Dry"			"Wet"		
		No-Pumping Groundwater Elevation	7.75 MGD Drawdown	15.5 MGD Drawdown	No-Pumping Groundwater Elevation	7.75 MGD Drawdown	15.5 MGD Drawdown
		<------- *Feet* ------->					
1	Robin Drive Pond	-2.08	0.40	0.80	2.70	0.40	0.80
2	Locke-Paddon Park	0.29	0.54	1.09	6.88	0.54	1.09
3	Marina Landing Pond	-0.01	0.75	1.50	5.93	0.75	1.49
4	Marina Coast Water District Pond	-0.08	0.57	1.15	2.89	0.57	1.15
5	Marina State Beach Pond	-0.48	0.42	0.84	2.84	0.42	0.84
6	Armstrong Ranch Ponds	-2.8	2.02	4.05	3.42	2.02	4.05
7	Lake Drive Pond	-2.47	0.39	0.79	2.72	0.39	0.79

Note
MGD = million gallons per day