APPENDIX E1

Lawrence Berkeley National Laboratories Peer Review

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LBNL-1006421

Peer Review of Groundwater Modeling for the

Monterey Peninsula Water Supply Project (MPWSP) April 2015 Draft EIR

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DISCLAIMER

Abstract

The proposed Monterey Peninsula Water Supply Project (MPWSP) involves desalinating water produced from slant wells completed in sand aquifers along the coast of Monterey Bay in Marina, California. Aquifers in the adjacent Salinas Valley are used heavily for groundwater for agricultural irrigation, and seawater intrusion has been a longstanding problem in the area. As part of the CEQA process, a team led by the CPUC carried out groundwater modeling to determine the impacts of the MPWSP on groundwater in the surrounding aquifers.

Following a change in leadership of the groundwater modeling effort, the CPUC requested LBNL hydrogeologists to carry out an independent and objective peer review of the original groundwater modeling that was used to support the Draft EIR published in April 2015.

In our review, we re-created the workflow used by the original modeling team, reviewed conceptual models of the shallow subsurface in the Marina area, re-ran models using data files and executable codes provided by the CPUC, and compared the outputs of our modeling results against those presented in Appendix E2 of the Draft EIR.

We found that the computer simulations carried out by the modeling team can be replicated using the input and executable codes provided to us. Agreement between the original output and our re-run results was mostly excellent (agreed exactly or differences were very small). Differences in simulation results can probably be attributed to machine round-off and cancellation errors.

We also found that the groundwater model results may not represent the detailed response of the actual system because the conceptual model used for groundwater modeling of the shallow sands at Marina neglected to include an aquitard present in the subsurface (the Fort Ord Salinas Valley Aquitard, or FO-SVA). We recommend that future groundwater modeling include the FO-SVA. Finally, we found the initial and calibrated hydraulic conductivities in the simulation were higher by one to two orders of magnitude and the Dune Sand aquifer storativity* was low compared to values derived from nearby field data. This may be because the lack of FO-SVA in the model resulted in higher horizontal to vertical conductivity ratios in the aquifers than is typical and indicated by the field data. We recommend using results from surrounding field data to initialize the model in those areas.

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*Storativity is a measure of the amount of water released by an aquifer for a given drop in hydraulic head.

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1. Introduction

The proposed Monterey Peninsula Water Supply Project (MPWSP) entails construction and operation of a desalination plant to produce potable water from saline groundwater extracted from beneath the sea floor near the shoreline. The resulting supply will compensate for reduced diversions from the Carmel River and reduced extraction from the Seaside Groundwater Basin, both of which are legally required. The proposed desalination plant would also produce potable water in excess of that needed to replace the aforementioned reductions. This additional water would provide a stable supply for existing customers, fire suppression, future development, and tourism.

The Project was determined to require full environmental analysis in accord with the California Environmental Quality Act. An analysis was prepared under the auspices of the California Public Utilities Commission (CPUC) and issued as a Draft Environmental Impact Report (DEIR) in April 2015. Among the potential environmental impacts considered, reduction of groundwater supplies, declines in groundwater levels resulting from extraction of saline groundwater from beneath the sea floor near the shoreline, and degradation of groundwater quality were assessed.

The approach to assessing these impacts involved development of conceptual models of the surface and groundwater hydrology in the area that could potentially be affected by the groundwater withdrawals associated with the project. This was followed by development of the quantitative inputs necessary to simulate the subsurface hydrology using groundwater models, such as description of the hydrostratigraphy and selection of hydraulic parameter values. Using these as inputs, groundwater modeling of subsurface hydrology without and with the proposed groundwater extraction was performed to assess the magnitudes of water level drawdown and the changes in water quality throughout the study area.

Following a change in the leadership of the groundwater modeling effort, the CPUC commissioned Lawrence Berkeley National Laboratory (LBNL) to review the numerical simulations of the proposed saline groundwater extraction at the CEMEX and Potrero Road sites. The scope did not include reviewing any of the other results in the DEIR, such as the effect of the project on groundwater in the Seaside Groundwater Basin.

This report conveys the results of LBNL's review of the proposed saline groundwater extraction modeling and its effects in a series of Appendices labeled LBNL-A, LBNL-B, LBNL-C, LBNL-D, and LBNL-E to distinguish them from other appendices in the work being reviewed. We present in Appendix LBNL-A the scope of work we carried out as defined by the CPUC. As shown, the primary focus of our review was the groundwater modeling with an emphasis on replicating the groundwater modeling results presented in Appendix E2 of the DEIR. In Appendix LBNL-B we summarize the modeling workflow, and do consistency checks on model input files. In Appendix LBNL-C we present the results of re-running the groundwater models and comparing input parameters with values in tables and figures in the DEIR. In Appendix LBNL-D, we summarize our review of the conceptual model of the local hydrostratigraphy, groundwater budget, and hydrologic parameters. In total, LBNL reviewed the following aspects of the overall groundwater modeling effort:

- Numerical simulations
- Hydrostratigraphy
- Groundwater budget
- Hydrologic parameters, such as hydraulic conductivity
- The impact assessments based upon all of the above

The DEIR discusses these analyses in Section 4.4 and Appendices E1 and E2. LBNL reviewed those parts of these sections that regarded the saline groundwater extraction and its impacts. Below we present first the results of our summary of the groundwater modeling work flow reported in Appendix E2, and the comparisons and analysis of the groundwater modeling that we carried out to confirm the results presented in the DEIR Appendices E1 and E2. The approach we took was to re-run all of the groundwater models using identical input and executable code (groundwater modeling software) and compare output files in various ways. This review of groundwater modeling is followed by our review of the hydrostratigraphy, groundwater budget, hydrologic parameters, and related impact assessment.

2. Conclusions

Based on this review, LBNL found its simulation results match those in Appendix E2 of the DEIR. Some of the groundwater modeling outputs are reproduced exactly, while others show small differences that can be attributed to computer round-off and cancellation errors.

As for our review of the foundation of the groundwater modeling, we find that there are shortcomings in the hydrostratigraphic model and simulation inputs that could potentially change the impact assessments. Chief among these was the absence of the Fort Ord-Salinas Valley Aquitard (FO-SVA), which hydraulically separates the Dune Sand and 180-foot equivalent (180-FTE) aquifers from greater than about 2 km east of the proposed extraction site.

The extent of the FO-SVA relative to the proposed slant extraction wells should be characterized. The numerical simulation of the proposed groundwater extraction should be performed including this unit. The accuracy with which the simulation results predict the capture zones, the drawdown distribution, and the percentage of the extracted water that flows from beneath onshore is particularly sensitive to the position of the western edge of the FO-SVA and initial water levels in the 180-FTE at this edge.

If there are insufficient data to constrain the position of water levels and the position of the FO-SVA, multiple simulations should be conducted to provide a suite of results that in sum bracket the likely changes resulting from the proposed extraction. This suite of results can be used to determine the maximum capture area, drawdowns, and extraction from beneath onshore, or to provide a probability distribution for those values if probability distributions for the inputs can be established. If the maximum output value approach is utilized, these will not all result from one simulation out of the suite, but rather from a combination of simulations.

The new simulation should be initialized with hydraulic conductivities measured from field data collected in the nearby former Fort Ord. In general these hydraulic conductivities are lower than

than those previously used to initialize the model and resulting from calibration by the model. The model should also be initialized with larger storativities in the Dune Sand aquifer based upon analysis of field data from the nearby former Fort Ord.

3. Acknowledgments

This work was funded by the California Public Utilities Commission through Earth Science Associates (ESA), San Francisco, CA, and by Lawrence Berkeley National Laboratory, University of California, under Department of Energy Contract No. DE-AC02-05CH11231.

4. References

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LaBolle, E.M., Ahmed, A.A., and Fogg, G.E., *Groundwater 41*(2), 238-246, March-April, 2003.

Appendix LBNL-A. Task list and schedule

Task 1. Workflow review Review the North Marina Groundwater Model (NMGWM)/CEMEX model files received from ESA. Develop a detailed simulation pathway schematic (i.e., workflow) which includes all pre- and post-processing steps and the specific software required to complete each step. Resolve questions and outstanding information needs and finalize the workflow schematic.	**Weeks 1-2**
Task 2. Consistency check Confirm the NMGWM/CEMEX model input files are consistent with the description in the documentation provided by the CPUC CEQA Team. For example, confirm grid extent, model cell dimensions, types, and location of boundary conditions, aquifer parameters, prescribed stresses (recharge, pumpage, and stream percolation), and water quality (for solute transport simulations).	**Weeks 2-4**
Task 3. Groundwater modeling Run NMGWM/CEMEX models and confirm output is consistent with results reported by the CPUC CEQA Team. Ensure the models run as described and that they produce reasonable results.	**Weeks 2-8**
Task 4. Reporting Prepare a Draft report documenting the peer-review process and its results to CPUC CEQA Team. Revise and issue a Final report, incorporating comments, as appropriate.	**Weeks 2-10**

Appendix LBNL-B. Workflow and Consistency Check

Task 1: Review the North Marina Groundwater Model (NMGWM)/CEMEX model files received from ESA. Develop a detailed simulation pathway schematic (i.e., workflow) which includes all pre- and post-processing steps and the specific software required to complete each step. Resolve questions and outstanding information needs and finalize the workflow schematic.

Workflow review

We were provided with a CD containing the DEIR and all of its appendices, along with a portable external hard disk containing 1,151 Gb of datafiles and executables of groundwater modeling files. We reviewed all of the files.

A workflow is presented below. The only specific software noted are the main simulation programs: IGSM, MODFLOW, MT3DMS, SEAWAT; and the pre/post-processing package Groundwater Vista, which is used to develop the NMGWM and Cemex models and to import initial conditions (IC) from the regional SVIGSM to the NMGWM model. Information on programs used to present simulation results graphically was not found.

Workflow

1. Review historical data.
2. Collect new borehole data (DEIR, Appendix C).
3. Run SVIGSM using finite element model IGSM (we do not have source or executable; there is a critical review of model correctness (LaBolle et al., 2003) but we did not examine that issue.
    a. Update and calibrate SVIGSM (Described in DEIR App. E2, App. A; we do not have files); old calibration period 1949-1994; new calibration period 1949-2011.
        i. Recharge and discharge data applied: precipitation, evapotranspiration, surface water in/out, groundwater pumping
        ii. Observations: groundwater levels
        iii. Parameters varied: horizontal and vertical permeability, effective porosity
    b. Run SVIGSM for all calibration and predictive scenarios to be simulated with NMGWM to determine boundary conditions (BC) for NMGWM: head at boundaries, pumping, deep percolation, stream inflow/outflow.
4. Run NMGWM using MODFLOW and MT3DMS (DEIR App. E2).
    a. Take parameters, IC, and BC from SVIGSM; assign to NMGWM.
    b. Calibrate NMGWM (1980-2011; we have files).
        i. Observations : groundwater levels and TDS
        ii. Parameters varied: horizontal and vertical permeability, effective porosity, dispersivity

   c. Run 17 predictive scenarios (15 cases cover MPWSP operation for years 2012-2074; 2 cases cover rebound after MPWSP ceases for years 2075-02137; we have files)
5. Run CEMEX Model (CM) using SEAWAT
   a. Take parameters, IC, and BC from NMGWM; assign to CEMEX model.
   b. Calibrate CM against long-term pump test from test slant well (DEIR App. E1)
   c. Run two CEMEX predictive scenarios (2012-2074; we have files)
6. Plot and present all results.

Consistency check

Task 2: Confirm the NMGWM/CEMEX model input files are consistent with the description in the documentation provided by the CPUC CEQA Team. For example, confirm grid extent, model cell dimensions, types, and location of boundary conditions, aquifer parameters, prescribed stresses (recharge, pumpage, and stream percolation), and water quality (for solute transport simulations).

In the notes below "Consistent with App. E2" means that every entry was checked – this was only possible for uniform parameter distributions or for control parameters. "Consistent with Figure * in App. E2" means that the values in the files were plotted and the plots compared visually with those in Appendix E2. "Taken from SVIGSM; not checked in detail" means that the SVIGSM results shown graphically in Figures 12-24 in Appendix A of Appendix E2 were found reasonable, but were not correlated to individual entries in the input files. Similarly, "Taken from NMGWM; not checked in detail" means that the NMGWM results shown graphically in Figures 12-24 in Appendix E2 were found reasonable, but were not correlated to individual entries in the input files. To verify all individual entries of these input files would require far more time than was allotted for this review.

MODFLOW input files

NAM – name file with file names of all other input files

BAS – basic input. For each of 8 model layers, identifies each cell in the 300 by 345 array as being variable head, no flow, or constant head. Provides initial head values for all cells. Cell identifiers are consistent with Figure 18 of App. E2. Initial head distributions were plotted and appear reasonable.

DIS – discretization information. Provides number of cells as 300 by 345, uniform lateral discretization: 200 ft by 200 ft; depth distributions of 8 model layers. Bottom elevation of each layer is consistent with Figure 19 of App. E2.

LPF – layer properties. Provides distributions of hydraulic conductivity, vertical hydraulic conductivity, and primary storage for 8 model layers. Horizontal hydraulic conductivity values are consistent with Figure 31 of App. E2. Vertical hydraulic conductivity values are consistent with Figure 32 of App. E2, except for one small region in the upper left corner of Layer 1 where Figure 32 claims vertical conductivity is between 0.21 and 0.40, but the file indicates it is 4. Storativity values are not consistent with Figure 33 of App. E2, but tend to be much lower, as shown in **Figure B1** in this report.

WEL – well package. Roughly 90,000 entries for each of 252 stress periods (number of entries varies by stress period); taken from SVIGSM; not checked in detail.

GHB – general head boundary package. 711 entries around the non-ocean perimeter of NMGWM for each of layers 2-8, for each of 252 stress periods; taken from SVIGSM. First stress period should match end of calibration (2011). See App. E2, App. A, Figure 6a: SVIGSM Layer 1 maps to NMGWM layer 4 – compares okay; Figure 6b: SVIGSM Layer 2 maps to NMGWM layer 6 – compares okay. Note that boundary for NMGWM layer 2 has a section in the NE with heads >200 ft, but this corresponds to a location where no-flow cells exist in layers 2 and 3 (See App. E2, Figure 31), so these high head values should have no effect. The time variation for boundary conditions appears reasonable: seasonal variations, plus long-term decrease for first 20-year period (prolonged dry), then long-term recovery for second 20-year period (prolonged wet).

RCH – recharge package. 103,500=300*345 entries (one for each cell in top layer of model) for each of 252 stress periods; taken from SVIGSM; not checked in detail.

OC – output specifications. Specify 252 one-month-long stress periods for each 20-year simulation. Consistent with App. E2.

PCG– preconditioned conjugate-gradient package – not mentioned in App. E2.

LMT – link to MT3DMS – not mentioned in App. E2.

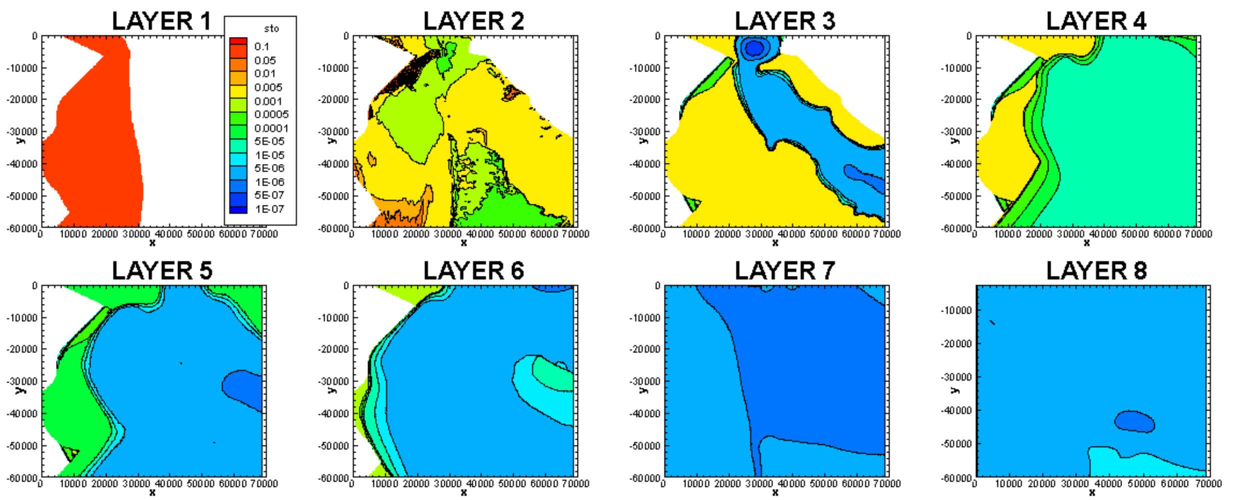


Figure B1. *Storativity distribution in each layer of the NMGWM, plotted from nm_sce3n_1.lpf. Compared to Figure 33 of App. E2, these storativity values tend to be lower.*

MT3DMS input files

NAM – name file with file names of all other input files

BTN – basic transport package. Includes spatial distributions of DELZ, porosity, flag ICUBUND, and initial concentration. DELZ values are consistent with Figures 20-26 of App. E2, except for layer 2, where the values show much more variability than the figure. However, this could be because the data were smoothed to create a more visually pleasing contour plot. Porosity values are consistent with Figure 34 of App. E2. Initial concentrations are consistent with Figure 35 of App. E2.

ADV- advection flags – not mentioned in App. E2.

DSP – dispersion information. Uniform dispersivity (20 ft); uniform horizontal dispersivity ratio (0.1), uniform vertical dispersivity ratio (0.01), zero molecular diffusion. Consistent with App. E2.

SSM – source, sink, mixing. Not checked.

GCG – conjugate gradient solver parameters – not mentioned in App. E2.

FTL –binary output file from MODFLOW – not examined.

SEAWAT input files

NAM – name file with file names of all other input files

Flow part

BAS – basic input. For each layer identifies each cell in the 540 by 540 array as being variable head, no flow, or constant head. Provides initial head values for all cells. Cell identifiers and initial heads plotted and found to be consistent with NMGWM.

DIS – discretization information. Provides number of cells as 540 by 540, uniform lateral discretization: 20 ft by 20 ft; depth distributions of 12 model layers. Bottom elevation of each layer plotted and found to be consistent with NMGWM elevations shown in Figure 19 of App. E2.

LPF – layer properties. Provides distributions of hydraulic conductivity, vertical hydraulic conductivity, and primary storage for 12 model layers. CEMEX property distributions of each layer plotted and found to be consistent with NMGWM property distributions plotted from nm_lpf files.

WEL – well package – Roughly 188,000 entries for each of 252 stress periods (number of entries varies by stress period); taken from NMGWM; not checked in detail.

GHB – general head boundary package – 23,716 entries for each of 252 stress periods; taken from NMGWM; not checked in detail.

RCH – recharge package – – 291,600=540*540 entries (one for each cell in top layer of model) for each of 252 stress periods; taken from NMGWM; not checked in detail.

OC – output specifications. Specify 252 one-month long stress periods for each 20-year simulation. Consistent with App. E2.

PCG – preconditioned conjugate-gradient package – not mentioned in App. E2.

ZONE – zone information – not mentioned in App. E2.

Transport part

BTN – basic transport package. Includes spatial distributions of DELZ, porosity, flag ICUBUND, and initial concentration. Porosity uniform in all layers except layer 5. DELZ, porosity, and initial concentration of each layer plotted and found to be consistent with NMGWM distributions.

ADV – advection flags – not mentioned in App. E2.

DSP – dispersion information. Uniform dispersivity (20 ft); uniform horizontal dispersivity ratio (0.1), uniform vertical dispersivity ratio (0.01), zero molecular diffusion. Consistent with App. E2.

SSM – source, sink, mixing – 155,597 entries for each of 252 stress periods, information not found in App. E2; not checked in detail.

GCG – conjugate gradient solver parameters – not mentioned in App. E2.

VDF – variable density flags – not mentioned in App. E2.

Appendix LBNL-C. Groundwater modeling

Task 3: Run NMGWM/CEMEX models and confirm output is consistent with results reported by the CPUC CEQA Team. Ensure the models run as described and that they produce reasonable results.

In file names below, NM stands for the North Marina Groundwater Model, which uses MODFLOW and MT3DMS. CEMEX stands for the Cemex Model, which uses SEAWAT.

Executables

MODFLOW: mf2k.exe - Flow model used for NMGWM simulations. Runs only on a 64-bit Windows computer.

MT3DMS: mt3dms4b.exe – Transport model used for NMGWM simulations. Runs on either a 32-bit or 64-bit Windows computer.

SEAWAT: sw_v4x64.exe – Combined flow and transport model used for CEMEX simulations. Runs only on a 64-bit Windows computer when the file "msvcr100.dll" is present (downloaded from https://www.dll-files.com/msvcr100.dll.html; a reputable site according to PC Advisor, an online magazine published by IDG).

Notes on standard executables available for download from official USGS sites.

MODFLOW: The current version of MODFLOW available from *water.usgs.gov/ogw/**modflow**/* is mf2005.exe. It will not read the input files used for mf2k.exe; apparently file naming and content structure has changed since the mf2k.exe version.

MT3DMS: The current version of MT3DMS available from *hydro.geo.ua.edu/**mt3d**/* is mt3dms5b.exe. It was used for the second calibration run (nm_cali_2), and produced no significant differences in the main output file: printout header format is different, and the convention for counting point sources and sinks is slightly different, but all simulation results are identical.

SEAWAT: The current version of SEAWAT available from *water.**usgs**.gov/ogw/**seawat**/* is sw_v4x64.exe. It is identical to the version provided on the hard drive.

Input files

The files received include input for the NMGWM/CEMEX models in two forms.

1. Huge self-contained files that contain all input required for the MODFLOW pre-processor Groundwater Vista for the NMGWM calibration run and one predictive scenario each for NMGWM and CEMEX. We do not have the Groundwater Vistas program, so we are not able to use these.
2. Folders that contain all the files for using MODFLOW, MT3DMS, and SEAWAT directly. These are the files we used.

In Folder "(0)MPWSP_Model_Files_for_TD" of the hard drive, there is one NMGWM calibration case that includes two simulation periods (1979 – 2000 and 2000 – 2011) and 17 NMGWM predictive cases, each of which includes three 20-year-long simulation periods (15 cases cover 2011-2032, 2032-2053, 2053-2074; two "rebound" cases cover 2075-2096, 2096-2117, 2117-2137). There are two CEMEX predictive cases, each of which includes three 20-year-long simulation periods (2011-2032, 2032-2053, 2053-2074).

Calibration Case

1. NM_CALI

Predictive Cases

North Marina Groundwater Model (NMGWM)

No project

1. NM_SCE1N
2. NM_SCE2F
3. NM_SCE2AF

Project at Cemex Site

4. NM_SCE3N
5. NM_SCE3NCB
6. NM_SCE3NC
7. NM_SCE4F
8. NM_SCE4RF
9. NM_SCE5N
10. NM_SCE5NCB
11. NM_SCE5NC
12. NM-SCE5F

Project at Potrero Rd Site

13. NM_SCE6SN
14. NM_SCE7SF
15. NM_SCE7SRF
16. NM_SCE8SN
17. NM_SCE8SF

Cemex Model

1. CEMEX_SCE4F
2. CEMEX_SCE3N

Running the Codes

On the hard drive, each NMGWM simulation period of each case is in a separate folder and includes 37 files, but these are both input and output files for MODFLOW and MT3DMS. For MODFLOW, there are 10 required input files and the code produces 2 user-readable output files: *.GLO and *.LST. MODFLOW also produces a binary file *.FTL that is read by MT3DMS, and binary files with heads (*.HDS), drawdowns (*.DDN), and cell-by-cell flows (*.CBB) in binary format, but the binary files were not examined in the present study. For MT3DMS, there are 7 required input files and the simulation produces 3 user-readable output files: MT3D.CNF, MT3D001.MAS, and *.OUT; and a binary file *.UCN. For each simulation period of the two CEMEX cases using SEAWAT, there are 16 required input files and the simulation produces 5 user-readable output files: MT3D.CNF, MT3D001.MAS, MT3D001.OBS, *.GLO and *.LST; and 4 binary files: *.HDS, *.DDN, and *.CBB.

Programs were run by copying the executable into a folder where only the input files for that executable were present (separate folders for MODFLOW and MT3DMS for each of the three time periods for each of the 17 NMGWM cases). The programs begin by prompting the user for the name of the file that lists all the input files and data files required to run the code. These files must be present in the folder.

The computer used has an Intel Xeon® CPU with 2.50 GHz speed. It has a 64-bit operating system running Windows 7 Professional, and 8 GB RAM. Each 20-year part of the predictive simulations required about 20 minutes of CPU time for MODFLOW about 35 minutes of CPU time for MT3DMS. The SEAWAT simulations were significantly slower, with each 20-year time period requiring about 4 days.

All the MT3DMS and SEAWAT simulations ran successfully. All but one of the MODFLOW simulations ran successfully. Predictive scenario NM_SCE5N, time period 1, failed to run, producing an error message when reading the LPF input file. Examination of the LPF file showed that it was corrupted. Since the LPF file contains layer information that does not vary between different time periods, the LPF file from NM_SCE5N, time period 2, was copied into the folder for the time period 1 simulation, which then ran successfully.

Comparison of New and Original Output Files

MODFLOW

The GLO (global) file identifies file names and unit number being assigned, and prints out basic input data for the simulation. It is small (604 lines) and could be examined directly, using the Windows DIFF command. Unit number assignments differed between the new simulations and the original simulations, but this should not affect the actual simulation results in any way. No other differences were found. All the basic input data for the simulations agree with that reported in Appendix E2, including number of model layers (8), rows (300), columns (345), and stress periods (252); lateral dimensions of cells (200 ft by 200 ft); stress period duration 30.4 days (1 month); layers are confined; hydraulic conductivity is horizontally isotropic.

The LST (list) file is the main MODFLOW simulation output. It is so big (about 1 GB, containing about 25 million lines) that it was inconvenient to work with it directly to compare the new simulation results to the original simulation results. Thus a utility program (readlst2.f) was created to read the LST file and write the water balance information for each of 252 stress periods to a summary file that is only 2 MB (about 18,000 lines). **Figure C1** shows the portion of a summary file, showing the volumetric water budget at the end of the first year.

Then a second utility program (comp2.f) read the new and original summary files, and calculated the difference of all the components of the water budget for each stress period (both "cumulative volumes" shown in the left hand column and "rates for this time step" shown in the right hand column). To facilitate comparison of different terms, a relative difference was used, defined as

$$(C_1 - C_2)/\max(C_1, C_2, \varepsilon)$$

where C_1 is a component of the water budget in the original LST file, C_2 is the corresponding component in the new LST file, and $\varepsilon = 10^{-5}$ is included to prevent dividing by zero in case C_1 and C_2 are both zero. The utility program output the maximum difference for each stress period (partial example shown in **Figure C2**) and the maximum difference for the entire simulation. The latter values are presented in **Table C1** for all the NMGWM calibration and predictive runs.

To get a better sense of the significance of the relative differences for the MODFLOW simulations, histograms of the relative differences for five selected cases are presented in **Figures C3a – C3e**. It is apparent that most of the relative differences are quite small, with the histogram peaks in the 10^{-5} to 10^{-4} range. Checking the individual MODFLOW water budgets shows that the larger relative differences only arise when the value of the term itself is quite small. Such terms are generally storage terms in the "rates for this time step" column. For example, for the largest relative difference (0.062), which occurs during stress period 126 in case nm_sce5f_2, "storage in" is 1.9155 for the original simulation and 1.7973 for the new simulation, whereas the "total in" terms (of which "storage in" is one component) are 26109390 and 26108476, respectively, with a relative difference of only 3.5E-5. Our conclusion is that differences in MODFLOW simulation results can probably be attributed to machine round-off and cancellation errors.

In addition to the components of the water balance, MODFLOW outputs the difference of total input and total output ("IN – OUT" line in **Figure C1**). This quantity is a measure of model error and is orders of magnitude smaller than the individual components making up the water balance, hence it is subject to numerical errors. Not surprisingly, values of this quantity, also shown in **Table C1** (DMAXM and DMAXMALL), can differ significantly between the original and new simulations.

NM_sce3n_1 new simulation

```
 OUTPUT CONTROL FOR STRESS PERIOD   12   TIME STEP   1

     CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T

           IN:                                    IN:
             STORAGE =   634788032.0000             STORAGE =      250851.6562
       CONSTANT HEAD =  2431358464.0000       CONSTANT HEAD =     5508881.0000
               WELLS =   658728832.0000               WELLS =     2562273.5000
     HEAD DEP BOUNDS =  4960042496.0000     HEAD DEP BOUNDS =    12399316.0000
            RECHARGE =  2540330496.0000            RECHARGE =     7270796.5000
            TOTAL IN = 11225247744.0000            TOTAL IN =    27992118.0000

          OUT:                                   OUT:
             STORAGE =  1837821440.0000             STORAGE =     1033678.8750
       CONSTANT HEAD =   540294400.0000       CONSTANT HEAD =     1504761.3750
               WELLS =  4650597376.0000               WELLS =    14654779.0000
     HEAD DEP BOUNDS =  4112643072.0000     HEAD DEP BOUNDS =    10538483.0000
            RECHARGE =    84051560.0000            RECHARGE =      240196.7969
           TOTAL OUT = 11225408512.0000           TOTAL OUT =    27971900.0000

            IN - OUT =     -160768.0000            IN - OUT =       20218.0000
```

NM_sce3n_1 original simulation

```
OUTPUT CONTROL FOR STRESS PERIOD     12   TIME STEP      1

     CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T

           IN:                                    IN:
             STORAGE =   634788096.0000             STORAGE =      250851.9375
       CONSTANT HEAD =  2431358464.0000       CONSTANT HEAD =     5508881.0000
               WELLS =   658728832.0000               WELLS =     2562273.5000
     HEAD DEP BOUNDS =  4960042496.0000     HEAD DEP BOUNDS =    12399316.0000
            RECHARGE =  2540330496.0000            RECHARGE =     7270796.5000

            TOTAL IN = 11225247744.0000            TOTAL IN =    27992118.0000

          OUT:                                   OUT:
             STORAGE =  1837821312.0000             STORAGE =     1033679.3125
       CONSTANT HEAD =   540294400.0000       CONSTANT HEAD =     1504761.3750
               WELLS =  4650597376.0000               WELLS =    14654779.0000
     HEAD DEP BOUNDS =  4112643072.0000     HEAD DEP BOUNDS =    10538483.0000
            RECHARGE =    84051560.0000            RECHARGE =      240196.7969

           TOTAL OUT = 11225407488.0000           TOTAL OUT =    27971900.0000

            IN - OUT =     -159744.0000            IN - OUT =       20218.000
```

Figure C1. *Portion of the summary file for the NMGWM predictive simulations. Each 20-year time period contains 252 such water budgets. Top: new simulation; bottom: original simulation.*

```
NM_sce3n_1
 icount=    1 dmax= .1092E-06 dmaxm= .1208E-03
 icount=    2 dmax= .2350E-06 dmaxm= .7098E-04
 icount=    3 dmax= .2350E-06 dmaxm= .1506E-03
 icount=    4 dmax= .2160E-05 dmaxm= .1012E-03
 icount=    5 dmax= .1091E-06 dmaxm= .1852E-03
 icount=    6 dmax= .8229E-07 dmaxm= .6720E-04
 icount=    7 dmax= .9328E-07 dmaxm= .1158E-03
 icount=    8 dmax= .2264E-06 dmaxm= .1249E-03
 icount=    9 dmax= .2692E-06 dmaxm= .2929E-04
 icount=   10 dmax= .8357E-06 dmaxm= .3965E-04
 icount=   11 dmax= .9849E-06 dmaxm= .1024E-03
…
 icount=  110 dmax= .4261E-05 dmaxm= .1000E+00
 icount=  111 dmax= .2037E-05 dmaxm= .1447E+00
 icount=  112 dmax= .2000E-05 dmaxm= .1942E+00
 icount=  113 dmax= .3517E-03 dmaxm= .2247E+00
 icount=  114 dmax= .9218E-03 dmaxm= .2571E+00
 icount=  115 dmax= .3192E-02 dmaxm= .3043E-01
 icount=  116 dmax= .5612E-04 dmaxm= .2581E-01
 icount=  117 dmax= .2645E-03 dmaxm= .1530E-01
 icount=  118 dmax= .6112E-04 dmaxm= .7946E-02
 icount=  119 dmax= .2079E-04 dmaxm= .5736E-02
 icount=  120 dmax= .1072E-04 dmaxm= .8318E-02
…
 icount=  241 dmax= .6976E-05 dmaxm= .1181E-02
 icount=  242 dmax= .5137E-05 dmaxm= .1800E-02
 icount=  243 dmax= .7680E-06 dmaxm= .1208E-02
 icount=  244 dmax= .7680E-06 dmaxm= .1232E-02
 icount=  245 dmax= .7613E-06 dmaxm= .1208E-02
 icount=  246 dmax= .7524E-06 dmaxm= .1174E-02
 icount=  247 dmax= .7475E-06 dmaxm= .1747E-02
 icount=  248 dmax= .7433E-06 dmaxm= .1704E-02
 icount=  249 dmax= .1245E-04 dmaxm= .3663E-02
 icount=  250 dmax= .7679E-05 dmaxm= .1094E-02
 icount=  251 dmax= .8461E-05 dmaxm= .1601E-02
 icount=  252 dmax= .9257E-06 dmaxm= .2052E-02

 DMAXALL= .3192E-02 DMAXMALL= .1692E+01
```

Figure C2. *Part of the output of utility program comp2.f, showing the maximum relative difference of each term in the water budget (dmax) and the maximum relative difference of model error "IN – OUT" (dmaxm) for each stress period. The overall maximum of all 252 stress periods is shown at the bottom (DMAXALL and DMAXMALL); these are the values that appear in* ***Table C1****.*

Table C1. *Maximum relative difference of components of water budget for calibration and predictive simulations of the NMGWM, shown separately for each 20-year time period.*

Case	**DMAXALL (water budget components)**			**DMAXMALL (model error)**		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
Calibration	8.8E-5	1.2E-4	-	0.32	0.13	-
Prediction - No Project						
NM_SCE1N	2.6E-3	9.3E-3	6.9E-3	0.65	0.15	0.55
NM_SCE2F	1.2E-3	5.5E-3	7.3E-4	1.1	2.0	0.20
NM_SCE2AF	1.3E-2	9.8E-3	5.0E-3	0.53	0.22	0.16
Prediction - Project at Cemex Site						
NM_SCE3N	3.2E-3	7.8E-3	1.4E-3	1.7	0.15	1.6
NM_SCE3NCB	3.2E-3	4.0E-3	6.5E-4	0.40	0.15	1.0
NM_SCE3NC	3.3E-3	8.1E-3	9.9E-4	0.15	0.15	1.0
NM_SCE4F	8.9e-3	2.5E-2	3.5E-3	1.2	2.0	0.15
NM_SCE4RF	7.9E-3	8.5E-3	3.1E-3	1.3	1.9	0.21
NM_SCE5N	5.7E-3	1.9E-2	5.6E-3	0.93	0.43	1.4
NM_SCE5NCB	3.0E-3	7.2E-3	7.6E-3	1.5	0.47	1.8
NM_SCE5NC	2.9E-3	5.6E-3	5.4E-3	1.0	0.59	1.8
NM-SCE5F	2.7E-3	6.2E-2	4.6E-3	0.85	1.8	1.0
Prediction - Project at Potrero Road Site						
NM_SCE6SN	1.4E-4	3.6E-3	6.8E-3	0.039	0.20	0.16
NM_SCE7SF	1.9E-3	4.4E-2	9.1E-3	0.78	1.3	0.16
NM_SCE7SRF	7.4E-3	1.4E-2	1.6E-3	1.7	1.2	0.19
NM_SCE8SN	3.8E-3	5.8E-3	1.2E-2	1.5	1.3	1.6
NM_SCE8SF	5.0E-3	1.3E-2	5.3E-3	0.70	1.8	0.82

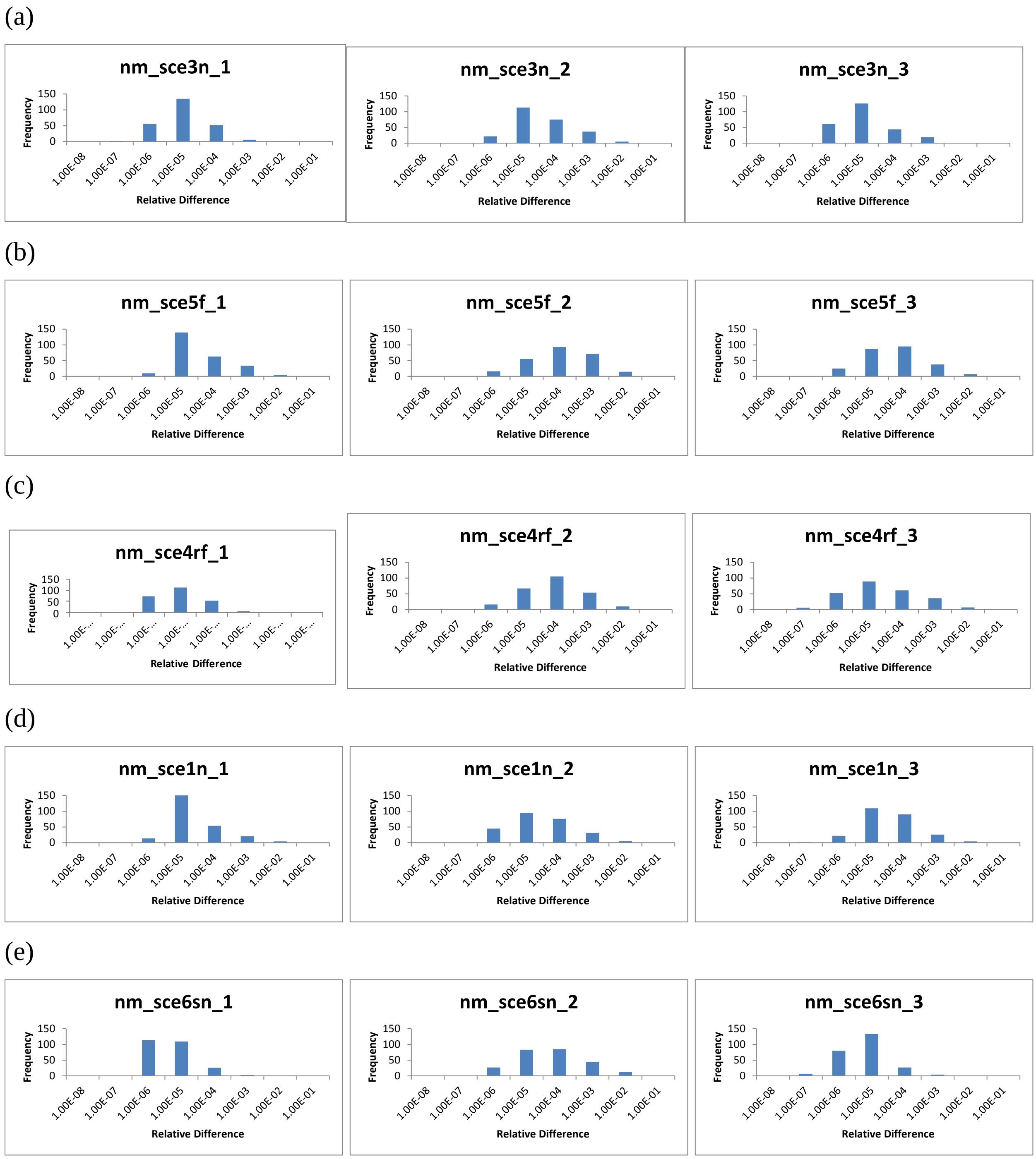


Figure C3. *Histograms of relative differences between new and original MODFLOW simulations for selected cases: (a) nm_sce3n: base case for CEMEX site, (b) nm_sce5f: case with biggest relative error, (c) nm_sce4rf: rebound case; (d) nm_sce1n: no project case; (e) nm_sce6sn: Potrero Road case. For each case, relative differences for the three 20-year time periods are shown separately*

MT3DMS

The sizes of the three user-readable output files produced by each MT3DMS simulation, *.CNF, *.MAS, and *.OUT, were identical to the size of the corresponding original output files. The Windows DIFF command was used to compare the files, and for every time period for every case for the NMGWM calibration and predictive runs, zero differences were found, indicating that the results of the new simulations were identical to the results of the original simulations. **Figure C4** shows a screen shot of using the DIFF command after a MT3DMS simulation.

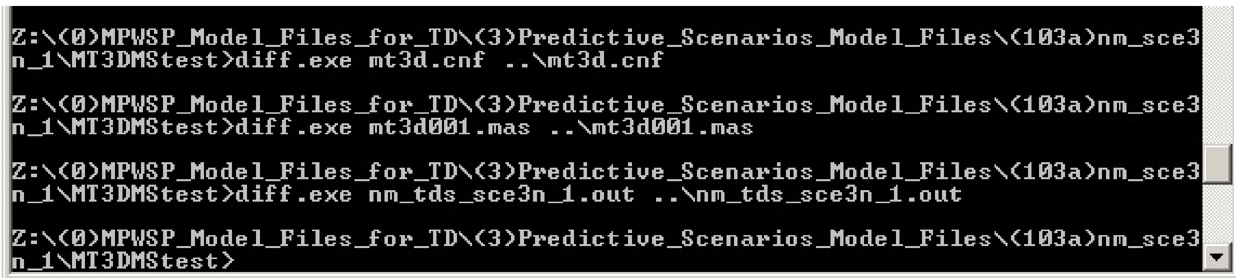


Figure C4. *Screen shot of using the DIFF command on the three main output files of MT3DMS. The new output is in the current directory and the original output is in the parent directory. The blank line after the command indicates that no differences were found between the files.*

MT3DMS also produces a binary file *.UCN, containing dissolved concentration in each cell. The DIFF command was also used to compare new and original versions of this file for selected cases, and they were always identical.

SEAWAT

The two SEAWAT simulations are complete. For all three time periods of both cases, cemex_sce4f and cemex_sce3n, the DIFF command indicated that four small output files were identical to original versions, as illustrated in **Figure C5** for the first time period. The binary files *.UCN were also identical. The main output files, *.LST, were 5.5 GB each, which is too big for the DIFF command. These files were broken into 500 MB parts, and each part produced zero differences when compared to the original files with the DIFF command.

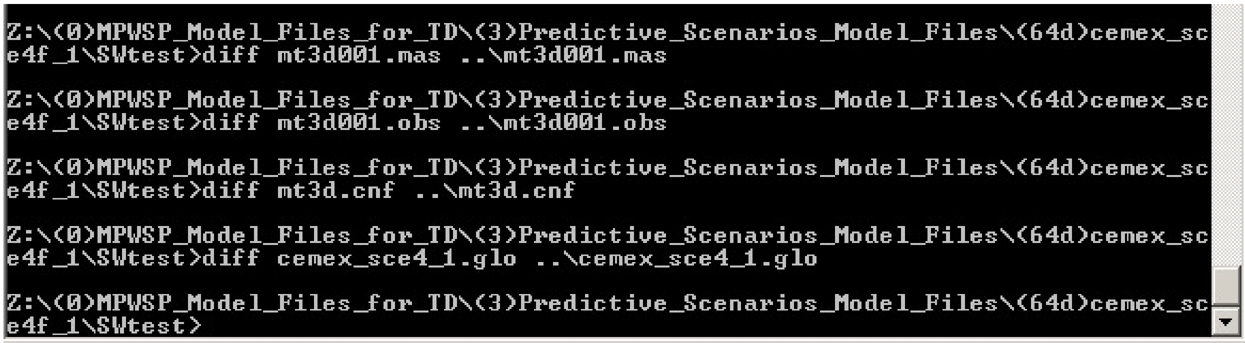


Figure C5. *Screen shot of using the DIFF command on 4 small output files of SEAWAT. The new output is in the current directory and the original output is in the parent directory. The blank line after the command indicates that no differences were found between the files.*

Comparison of Water Budget Components to App. E2

In Appendix E2, a series of attached tables show the annual water budgets for each case. To convert the model results, given as cumulative volumes once per month and illustrated in **Figure C1**, to the format of the tables, the following steps were taken.

1. Read only multiples of 12 water balances (12th month = 1st year, 24th month = 2nd year, 36th month = 3rd year, etc.).

2. Convert all quantities in cubic feet to acre-feet by dividing by 43,559.9.

3. Assume the following equivalences between quantities in the MODFLOW output (left hand side of equation) and Appendix E2 water budget table (right hand side of equation, with column number labeled)

    a. Head Dep Bounds In – Head Dep Bounds Out = [1] Northern, Eastern, and Southern, Model Boundary (Underflow)

    b. Recharge In + Wells In = [2]Stream Recharge and Deep Percolation from Precipitation and Applied Water (Irrigation) + [3] MPWSP with Injection Returning Basin Water

    c. Constant Head In = [4] Ocean Inflow

    d. Sum of a, b, c = [5] Total Inflow

    e. Wells Out = [6] Non-Project Groundwater Pumping + [7] Marina Coast Water District Desalination Pumping + [8] MPWSP Project Slant Well Pumping

    f. Recharge Out = [9] Aquifer Loss to Streams

g. Constant Head Out = [10] Ocean Outflow

h. Sum of e, f, g = [11] Total Outflow

i. Difference of d and h = [12] Change in Groundwater Storage (labeled In – Out)

j. Storage In – Storage Out = [12] Alternative means of calculating Change in Groundwater Storage (labeled Dstorage)

4. Calculate the difference between a through j for each year and the previous year (except for the first year of each 20-year time period, which is used directly).

The results of steps 1 – 4 are shown in Appendix LBNL-E for each predictive case. The table number of the relevant table from DEIR Appendix E2 is shown in parentheses in the table title, and the column numbers to compare to are shown above the column headers.

The comparisons of the new simulation results to the tables are all reasonable, but the numerical values are not all identical, which is expected based on the differences between new simulation results and original simulation results described in Section 4.4.1 above. As a consistency check, the original simulation results for case nm_sce3n were processed as above. The results are shown in Appendix LBNL-E just after the new simulation results for case nm_sce3n.

The original-simulation results are not identical, but are very similar, to the new-simulation results (generally, single digit differences in the final decimal place). The relative differences between the simulation results and entries in the Appendix E2 tables are generally in the 10^{-5} to 10^{-3} range for all entries except column [12]. This increase over the relative differences in the MODFLOW simulations themselves (most relative differences in the range 10^{-5} to 10^{-4}, as illustrated in **Figure C3**) is due to the fact that the quantities in the water budget tables are all derived from differences of simulation results (from one year to the next), so relative difference becomes larger.

An extreme version of this relative difference increase is apparent in column [12], which shows change in groundwater storage. This quantity is a difference of differences (Total Outflow – Total Inflow, from one year to the next). As the errors of individual terms are added and the value of the term itself gets smaller, relative difference can grow dramatically. This growth is illustrated in the tables shown in Appendix LBNL-E, where the change in groundwater storage is calculated in two different ways: column [12] is the difference of column [5] and column [11], whereas [alt 12] is calculated directly from "STORAGE" terms in the MODFLOW water budgets (**Figure C1**). The differences between these two columns are indicative of the cancellation and round-off error occurring within a single numerical simulation. These differences are comparable to the differences between the new simulation results and those shown in column [12] in the Appendix E2 tables, indicating that it would be unrealistic to expect any closer agreement between distinct numerical simulations. Although differences appear large for small entries, when viewed in the context of the dominant terms in the water budgets, they are actually quite small.

Appendix LBNL-D. Groundwater Conceptual Model

Hydrostratigraphy

Having reported on our groundwater modeling review above, we turn now to a review of the conceptual model of the hydrostratigraphic units in the vicinity of the CEMEX site. This hydrostratigraphy is discussed in the section “Pressure Area Aquifers and Aquitards” from pages 4.4-5 to 4.4-11. With increasing depth from the ground surface in the vicinity of the CEMEX site, this section describes the Dune Sand Aquifer, the 180-Foot Equivalent Aquifer (180-FTE), the 180/400-Foot Aquitard, the 400-Foot and 900-Foot Aquifers.

The hydrostratigraphy in the vicinity of the CEMEX site is represented on east-west cross section 1-1’ and north-south section A-A’ in Appendix E2. The portion of Section 1-1’ shown on **Figure D1** indicates there is an aquitard between the Dune Sand and 180-FTE aquifers approximately two miles east of the site. It is possible this aquitard extends to the CEMEX site as there are no logs plotted on the section between the interpreted western edge of this aquitard and the site. There is also a well log plotted at the eastern edge of the CEMEX site (14S/2E-18E1) that has a 25-foot thick clay at the approximate position of this aquitard.

The eastern edge of this aquitard is shown on Section 1-1’ as disconnected from the Salinas Valley Aquitard (SVA). However no log is plotted between the easternmost well with this aquitard (14S/2E-21E01) and the westernmost well with the SVA (14S/2E-21F02) to support this interpretation.

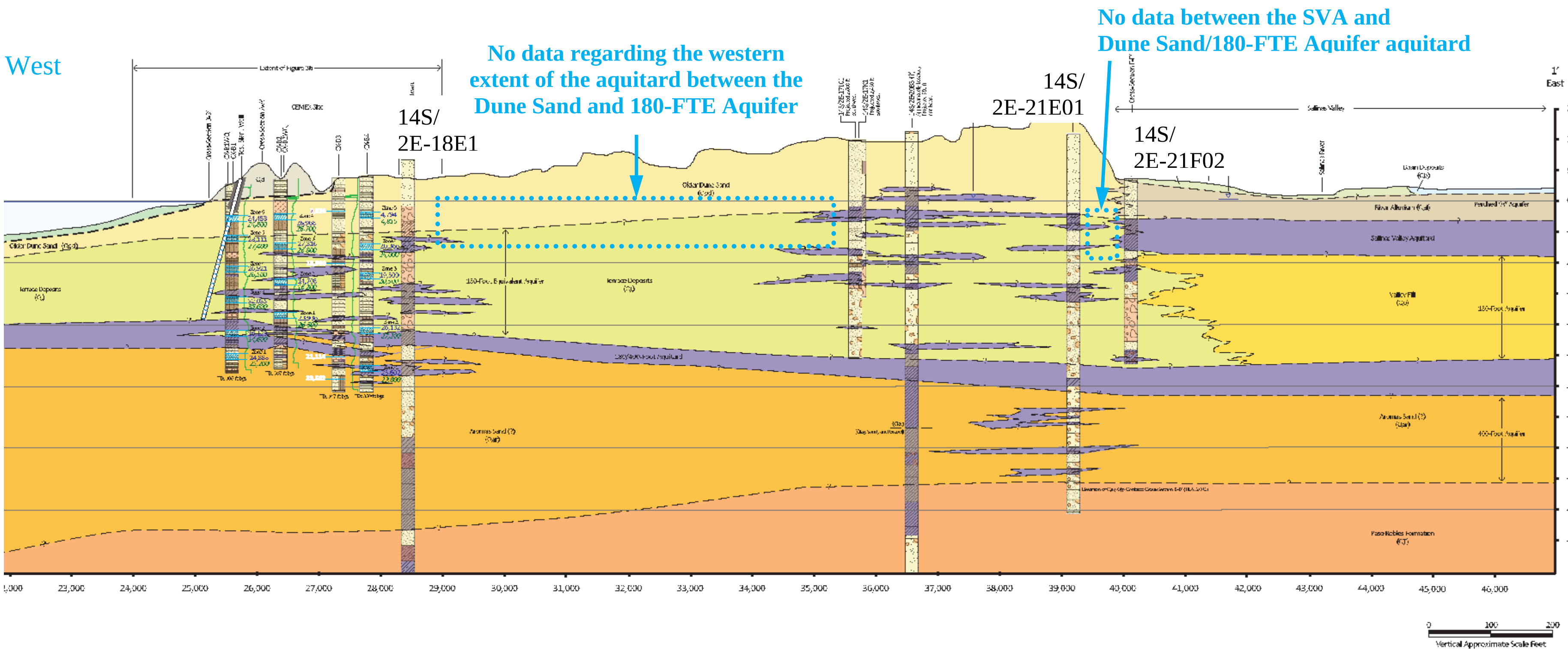
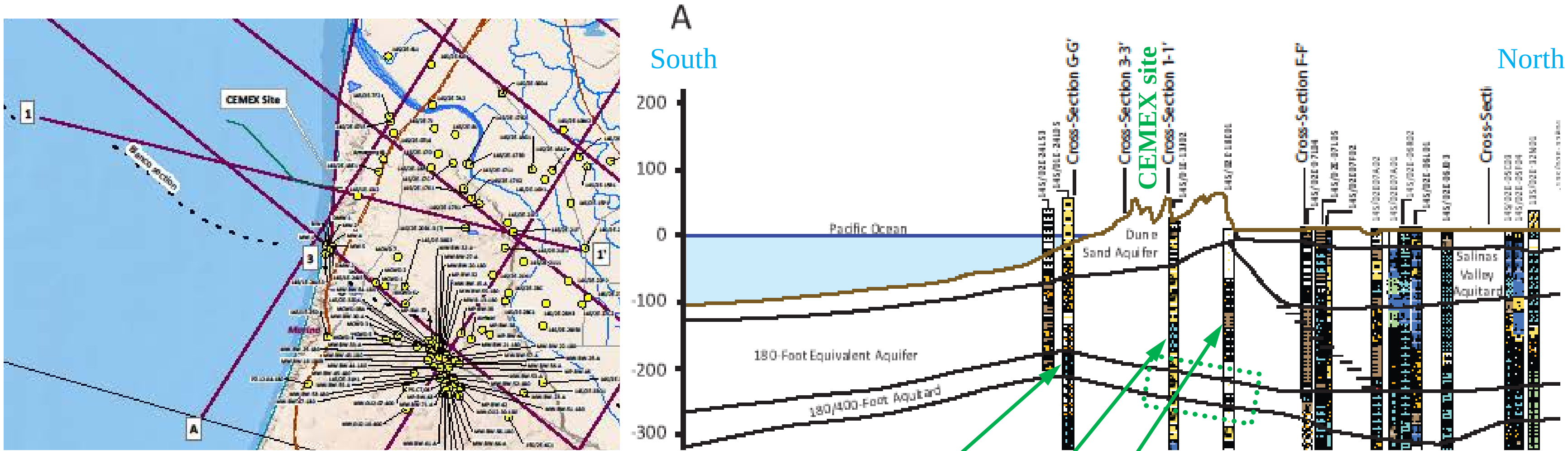


Figure D1. *The eastern half of Section 1-1' with data gaps regarding continuity of the aquitard between the Dune Sand and 180-FTE Aquifer indicated.*

The southern portion of Section A-A’ is in generally the same location as southern portion of Section B-B’ of Kennedy/Jenks Consultants (2004), which is referenced in the DEIR, as shown on **Figure D2**. Section A-A’ interprets no aquitard at the contact between the Dune Sand and 180-FTE aquifers. Section B-B’ does interpret an aquitard between these two aquifers, and interprets it as continuous with the SVA. The sections plot some of the same lithologic logs in their southern portions, including those indicated on **Figure D2**. The portion of these sections including these wells is shown in **Figure D2**.

Section B-B’ interprets ~50 ft of sandy clay and ~20 ft of clay at depths of about 150 ft encountered in each of these borings, respectively, as separating the Dune Sand from the 180’ Aquifer in the terminology of that report (Kennedy/Jenks Consultants, 2004). Section A-A’ interprets these materials as within the 180-FTE Aquifer, and the 180/400-Foot Aquitard as passing through gravel and sand in those borings. The interpretation of Kennedy/Jenks Consultants (2004) is considerably more credible given the data.



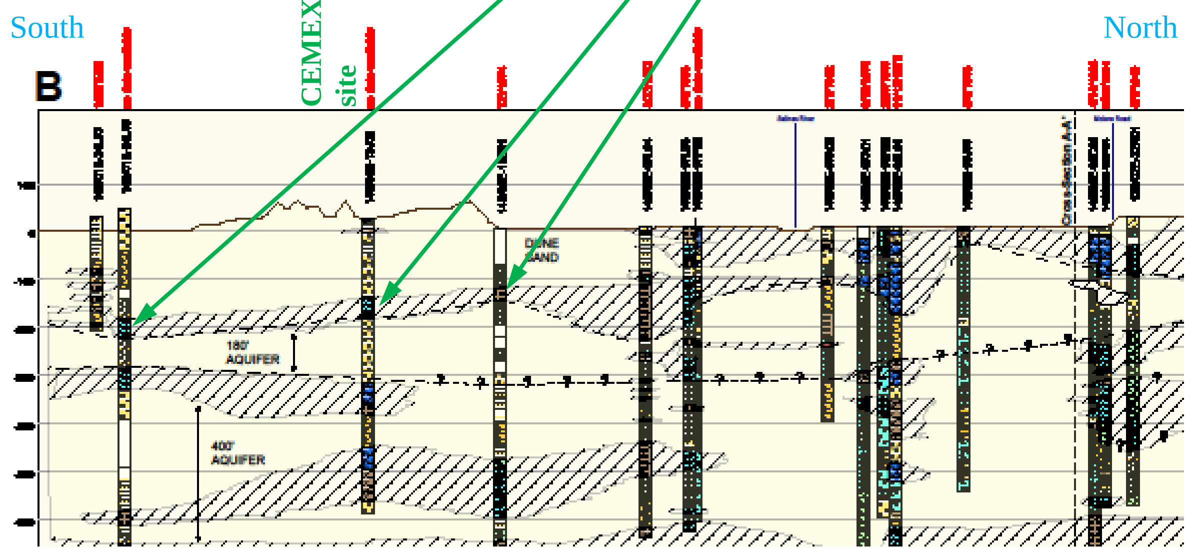


Figure D2. *Southwestern portion of Section A-A' from DEIR Appendix E2, located as shown on the map, and Section B-B' from Kennedy/Jenks Consultants (2004), which is along the same line. Arrows indicate fine-grained material in the same borings on both sections interpreted as part of the 180-FTE aquifer in the DEIR and part of the aquitard between the Dune Sand and 180' Aquifer in Kennedy/Jenks Consultants (2004). The dotted box indicates coarse-grained material interpreted as the 180/400 Aquitard in the DEIR section.*

Beyond the references cited regarding the hydrogeology in the vicinity of the CEMEX site, no reference is made to reports resulting from remedial investigation of the former Fort Ord Army Base ("the former Base"). In particular, Harding Lawson Associates (1995) characterizes the hydrogeology of the former base.

Harding Lawson Associates (1995) defines an unconfined A-aquifer comprising primarily older dune sand. This is separated from the underlying 180-foot aquifer by the FO-SVA over most of the base. Harding Lawson Associates (1995) suggests the western edge of the FO-SVA is approximately two km east of the proposed slant well site. To the east of this location, the 180-foot aquifer is confined. To the west it is in hydraulic connection with the overlying A-aquifer, and so unconfined. In contrast the western edge of an aquitard in this stratigraphic position is more than three km east on section 1-1' in **Figure D1**, and does not appear to be included at all in the NMGWM, and Kennedy/Jenks Consultants (2004) interpret this aquitard extending to the CEMEX site and beneath the sea bed beyond.

Harding Lawson Associates (1995) divides the 180-foot aquifer into an Upper and a Lower portion based upon water level data. It finds the two are hydraulically disconnected by the intervening Intermediate 180-foot aquitard, and the Lower 180-foot aquifer is hydraulically connected to the 400-foot aquifer.

The 180-FTE aquifer is confined by the FO-SVA within the area with greater than one foot of water level drawdown predicted by the numerical simulation, as shown on Figure 4.4-14 in the DEIR. The absence of the FO-SVA in the numerical model allows areal recharge to the 180-FTE aquifer by the portion of precipitation that infiltrates past the root zone. This would tend to decrease the area with at least one foot of drawdown in the 180-FTE aquifer predicted by the model as compared to reality. However the gradient in the Dune Sand aquifer within a portion of the predicted drawdown area is toward the west, so a portion of the areal recharge in this area will still flow toward the proposed extraction wells where the FO-SVA is present, albeit through the smaller transmissivity of the Dune Sand aquifer alone as compared to that of the combined Dune Sand and 180-FTE aquifers in the model.

Depending upon how much the gradient in the A-aquifer in the modeled capture area is toward the west, the location of the capture zone that develops may not be substantially different from that modeled. However the area with greater than one foot of drawdown in the Dune Sand aquifer, which is only a portion of the capture zone, may be greater if the 180-FTE aquifer is confined at the edge of the FO-SVA. In this case, gradients in the Dune Sand aquifer over the FO-SVA will be greater than modeled and so water levels decline more within the capture zone. However in the case that the 180-FTE aquifer is unconfined at the edge of the FO-SVA, there will be no decline in water levels in the overlying Dune Sand aquifer. In this case, the input of areal recharge to the 180-FTE at the edge of the FO-SVA will not increase in response to extraction, and so the area of the capture zone in the 180-FTE aquifer will increase.

Consequently the distribution of water level drawdowns due to the proposed extraction will be different than those predicted by the model. The portion of the total volume of water extracted that is from beneath onshore is also likely to be different.

Hydraulic Parameters

Appendix E2 to the DEIR provides the hydraulic conductivities used in the simulation and indicates they are the result of textural correlations. **Table D1** compares these to hydraulic conductivities measured in a variety of tests reported in Harding Lawson Associates (1995) and Jordan et al. (2005).

Table D1. *Comparison of hydraulic conductivities based on textural correlations used in the NMGWM compared to calibrated values in that model and measured values reported by Harding Lawson Associates (1995) and Jordan et al. (2005). All values in ft/day.*

Aquifer	Appendix E2[1]				Harding Lawson Associates (1995)					Jordan et al. (2005)	
	Horizontal		Vertical		Slug		Specific capacity		Constant Discharge	Hori-zontal	Ver-tical
	I[4]	C[5]	I[4]	C[5]	R[6]	M[7]	R[6]	M[7]	R[6]		
Dune Sand (A-)[2]	109-304 (207)	270	8.16-11.87 (10.02)	10.02	6.4-95.0 (13)	28.1			1.6-41.1 (3)	7-10[a]	1-4[b]
180-FTE (Upper 180-foot)[3]	71-216 (143)	160	0.11-0.21 (0.16)	0.21-0.40	0.04-311 (25)	12.7	30-366 (10)	106[8]	0.32-44.0 (3)		

[1]Calibrated values for the portion of the NMGWM under the former Fort Ord near the CEMEX site

[2]Calibrated hydraulic conductivities from NMGWM layer 2

[3]Calibrated hydraulic conductivities from NMGWM layer 4

[4]Initial hydraulic conductivity range (and mean) input to the NMGWM model

[5]Hydraulic conductivity range calibrated by the NMGWM model to match well hydrographs

[6]Range (number of tests in parentheses)

[7]Geometric mean

[8]Given as 300, but value shown recalculated from individual test results

[a]Given in executive summary based on four different data types ranging from near-well to plume (~1 km) scale

[b]From natural and engineered recharge transients, rounded to one significant figure

Based on the results in **Table 2**, the vertical and horizontal hydraulic conductivity values for the Dune Sand and 180-FTE aquifer used to initialize the NMGWM and the resulting hydraulic conductivities calibrated by the NMGWM to match the well hydrographs appear too large. Additionally, the greater than two orders of magnitude larger horizontal than vertical hydraulic conductivity values for the 180-FTE aquifer is more than typical for a single hydrostratigraphic unit. These large ratios may be needed to compensate for the lack of the FO-SVA in the model. It may be that the values produced by a model including the FO-SVA are closer to those measured, particularly using those measured values as a starting point for calibration.

Storativity was also calibrated by the NMGWM. **Table D2** compares these values to those from earlier studies.

Table D2. *Comparison of storativities calibrated by the NMGWM for the Dune Sand (A-) aquifer compared to those reported by Harding Lawson Associates (1995) and Jordan et al. (2005).*

Appendix E2[1]	Harding Lawson Associates (1995)[2]	Jordan et al. (2005)[3]
0.065-0.1	0.0082-0.24 (0.106)	0.20-0.27

[1]Calibrated values for the portion of the NMGWM layer 2 under the former Fort Ord near the CEMEX site

[2]Value in parentheses is the mean

[3]Specific yield, which is virtually the same as storativity for an unconfined aquifer

Table D2 suggests the storativity values used for the A-aquifer in the model are smaller than the values based on field data in the other references. Given that this value has a strong effect on the propagation rate of drawdown in the unconfined Dune Sand aquifer, the NMGWM should also be run with higher initial storativities to determine how sensitive drawdown is to the value of this parameter.

Appendix LBNL-E. Additional Appendix E2 Tables

(Separate Document)

Appendix LBNL-E.

Water budget for case NM_sce1n (App. E2 Table 2)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	20008.	72254.	36349.	128611.	80571.	2121.	15946.	98639.	29972.	30008.
2013	677.	53003.	21642.	75321.	49338.	2190.	19287.	70815.	4506.	4468.
2014	9629.	71092.	22874.	103594.	80662.	2211.	20694.	103568.	26.	21.
2015	1152.	51871.	21024.	74047.	49305.	2246.	20675.	72226.	1821.	1767.
2016	10785.	70432.	22498.	103715.	80720.	2273.	21453.	104446.	-730.	-715.
2017	2158.	51508.	20763.	74428.	49363.	2277.	21217.	72856.	1572.	1514.
2018	8152.	40008.	22753.	70913.	65886.	2222.	18475.	86583.	-15670.	-15655.
2019	13495.	27246.	30240.	70981.	78155.	1646.	11818.	91619.	-20637.	-20484.
2020	8277.	26321.	34919.	69517.	65753.	1454.	8675.	75883.	-6365.	-6331.
2021	4339.	22824.	37521.	64684.	64340.	1376.	7427.	73142.	-8458.	-8341.
2022	-1505.	39103.	39573.	77171.	65987.	1330.	6729.	74047.	3125.	3177.
2023	-2992.	35598.	39913.	72519.	68616.	1314.	6776.	76707.	-4188.	-4094.
2024	2958.	30518.	44729.	78205.	80184.	1270.	5592.	87047.	-8841.	-8809.
2025	888.	28611.	50257.	79757.	80009.	1222.	4280.	85510.	-5754.	-5612.
2026	-8391.	27018.	51704.	70331.	65753.	1215.	4085.	71053.	-722.	-666.
2027	-11573.	23207.	52646.	64279.	64348.	1216.	3953.	69517.	-5238.	-5140.
2028	-16103.	38693.	53620.	76210.	66261.	1208.	3785.	71255.	4955.	5014.
2029	-16108.	34696.	53084.	71671.	69710.	1205.	3948.	74862.	-3191.	-3058.
2030	-13926.	61499.	52746.	100319.	92178.	1192.	4222.	97593.	2726.	2969.
2031	-24391.	45841.	49524.	70974.	61083.	1189.	4427.	66698.	4275.	4411.
2032	-16664.	67395.	47115.	97846.	87634.	1209.	5246.	94089.	3757.	3941.
2033	-24827.	51331.	43619.	70123.	57857.	1205.	5666.	64728.	5395.	5456.
2034	-18156.	78812.	40211.	100866.	80850.	1272.	7097.	89220.	11646.	11637.
2035	-29056.	78671.	31143.	80757.	48080.	1519.	11424.	61023.	19734.	19730.
2036	-15128.	56974.	26400.	68247.	47275.	1721.	13815.	62811.	5436.	5398.
2037	-554.	77416.	26139.	103001.	80481.	1802.	15984.	98266.	4735.	4706.
2038	-9995.	75918.	20753.	86677.	43969.	2519.	24533.	71021.	15656.	15567.
2039	-458.	59183.	19325.	78050.	47020.	2477.	26041.	75538.	2512.	2491.
2040	5025.	43065.	19837.	67927.	47269.	2390.	23301.	72960.	-5033.	-5169.
2041	14628.	69025.	21810.	105463.	80894.	2369.	22811.	106073.	-610.	-594.
2042	2322.	69442.	18200.	89963.	45032.	3784.	30055.	78872.	11092.	11024.
2043	8670.	54841.	17638.	81148.	47846.	3239.	29914.	80999.	149.	97.
2044	11837.	39349.	18546.	69732.	47507.	2684.	26052.	76243.	-6511.	-6643.
2045	19739.	66601.	20761.	107101.	81190.	2716.	24825.	108731.	-1630.	-1588.
2046	6388.	67857.	17522.	91767.	45589.	4348.	31673.	81610.	10157.	10125.
2047	20901.	65883.	19666.	106450.	81868.	3117.	27943.	112928.	-6478.	-6425.
2048	10940.	46598.	18753.	76291.	49320.	2608.	25677.	77605.	-1314.	-1331.
2049	18321.	67022.	20772.	106115.	81111.	2681.	25010.	108802.	-2687.	-2649.
2050	8192.	48643.	19451.	76286.	49330.	2479.	24034.	75843.	443.	410.
2051	12656.	48916.	21052.	82624.	65674.	2332.	21210.	89216.	-6592.	-6517.
2052	11776.	51184.	22802.	85761.	68723.	2266.	18566.	89554.	-3793.	-3777.
2053	5158.	52707.	22646.	80511.	55994.	2021.	18188.	76203.	4307.	4295.
2054	7446.	47907.	23209.	78562.	65886.	2138.	17393.	85417.	-6855.	-6809.
2055	11292.	28312.	29253.	68857.	79195.	1674.	12426.	93295.	-24438.	-24343.
2056	8373.	26224.	34218.	68815.	65753.	1479.	8972.	76204.	-7389.	-7373.
2057	4828.	22781.	36983.	64592.	64340.	1392.	7620.	73351.	-8759.	-8659.

2058	-874.	39109.	39101.	77335.	66101.	1345.	6883.	74329.	3006.	3051.
2059	-2085.	35652.	39536.	73103.	69126.	1322.	6904.	77351.	-4249.	-4171.
2060	-16428.	71291.	34818.	89681.	58850.	1410.	8694.	68955.	20726.	20611.
2061	-2282.	35111.	34370.	67200.	69060.	1466.	9050.	79576.	-12376.	-12350.
2062	-15684.	74194.	29694.	88204.	48353.	1670.	12047.	62070.	26133.	26088.
2063	-7413.	53116.	24475.	70178.	47267.	1903.	15468.	64637.	5541.	5487.
2064	4185.	74781.	24751.	103717.	80547.	1967.	17554.	100069.	3649.	3579.
2065	-6414.	73362.	19952.	86899.	44223.	2925.	25913.	73061.	13839.	13772.
2066	2748.	43130.	19801.	65679.	44981.	2483.	22641.	70104.	-4425.	-4499.
2067	4489.	47716.	20272.	72477.	49342.	2410.	21549.	73301.	-824.	-825.
2068	4204.	46659.	19989.	70852.	44741.	2488.	22411.	69640.	1212.	1117.
2069	10401.	44621.	22558.	77581.	64799.	2166.	18032.	84998.	-7417.	-7421.
2070	7610.	46538.	23576.	77724.	64443.	2023.	16453.	82919.	-5195.	-5192.
2071	10054.	37216.	27889.	75159.	77359.	1732.	13227.	92317.	-17159.	-17126.
2072	-448.	49808.	27098.	76457.	56033.	1763.	12916.	70711.	5746.	5758.
2073	8577.	75281.	26057.	109915.	80921.	1863.	15605.	98390.	11526.	11474.
2074	-2017.	55162.	22391.	75536.	49304.	2092.	18136.	69531.	6005.	5926.
Average	949.	51050.	29723.	81722.	63641.	1982.	15594.	81216.	506.	519.

Water budget for case NM_sce2f (App. E2 Table 3)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	6492.	64774.	42327.	113593.	80093.	1792.	10456.	92342.	21252.	21234.
2013	-6340.	50096.	27732.	71488.	53253.	1900.	12470.	67623.	3865.	3839.
2014	1893.	65138.	28366.	95397.	80092.	1874.	13301.	95267.	130.	81.
2015	-5065.	48609.	26695.	70239.	53251.	1957.	13346.	68553.	1685.	1693.
2016	3312.	64314.	27727.	95353.	80114.	1914.	13856.	95885.	-531.	-562.
2017	-3833.	48315.	26185.	70667.	53321.	1986.	13768.	69075.	1592.	1565.
2018	1766.	29953.	29125.	60844.	67151.	1926.	11863.	80940.	-20096.	-20053.
2019	9341.	22375.	39216.	70931.	79363.	1459.	7254.	88076.	-17144.	-17003.
2020	3473.	21790.	44482.	69745.	68333.	1340.	5608.	75282.	-5536.	-5489.
2021	-851.	19315.	47246.	65710.	67014.	1295.	4980.	73289.	-7579.	-7463.
2022	-5780.	32533.	49767.	76520.	68420.	1253.	4477.	74150.	2371.	2468.
2023	-7594.	29382.	50300.	72087.	70747.	1251.	4474.	76472.	-4385.	-4269.
2024	-2585.	24537.	55502.	77455.	81094.	1224.	3788.	86105.	-8651.	-8535.
2025	-4195.	23418.	60858.	80081.	80855.	1213.	3085.	85153.	-5072.	-4844.
2026	-12539.	22361.	62132.	71955.	68333.	1211.	3006.	72550.	-595.	-440.
2027	-16026.	19642.	62827.	66443.	67021.	1211.	2954.	71186.	-4744.	-4539.
2028	-19639.	32060.	64158.	76579.	68694.	1205.	2795.	72694.	3885.	4023.
2029	-20172.	28972.	63853.	72653.	71839.	1201.	2859.	75900.	-3247.	-3063.
2030	-18261.	51774.	64008.	97521.	91672.	1183.	2874.	95729.	1792.	2060.
2031	-27445.	37758.	61395.	71709.	63961.	1188.	3023.	68172.	3537.	3679.
2032	-20999.	55263.	59321.	93585.	87131.	1190.	3298.	91619.	1966.	2195.
2033	-28701.	42325.	56501.	70125.	60759.	1185.	3519.	65464.	4662.	4800.
2034	-23998.	64634.	53118.	93753.	80349.	1199.	4022.	85570.	8183.	8293.
2035	-37016.	71713.	43531.	78228.	52416.	1303.	5915.	59634.	18595.	18639.
2036	-26009.	55537.	37536.	67063.	51501.	1454.	7336.	60291.	6773.	6804.
2037	-10310.	70591.	35546.	95827.	80120.	1525.	8758.	90403.	5425.	5434.
2038	-18132.	71558.	27852.	81279.	48085.	1820.	14155.	64060.	17219.	17197.
2039	-10490.	57296.	25330.	72136.	51336.	1968.	15766.	69070.	3066.	3023.
2040	-6039.	43958.	25718.	63636.	51493.	1981.	14311.	67785.	-4149.	-4249.
2041	4056.	64405.	27455.	95916.	80136.	1850.	14095.	96081.	-165.	-174.
2042	-6109.	63703.	23050.	80645.	48461.	2269.	19259.	69989.	10656.	10592.
2043	-907.	52344.	22332.	73769.	51429.	2221.	19631.	73280.	489.	437.
2044	1890.	40247.	23269.	65405.	51493.	2177.	17229.	70899.	-5494.	-5542.
2045	10017.	61542.	25532.	97090.	80179.	2020.	16309.	98508.	-1418.	-1440.
2046	-1149.	61627.	21796.	82275.	48669.	2571.	21262.	72503.	9772.	9702.
2047	11297.	59929.	24112.	95338.	80483.	2155.	18860.	101498.	-6159.	-6134.
2048	3256.	45070.	23392.	71718.	53251.	2180.	17101.	72532.	-814.	-833.
2049	10263.	61251.	25276.	96791.	80239.	2078.	16759.	99076.	-2285.	-2269.
2050	1723.	46125.	24106.	71954.	53252.	2121.	15963.	71335.	618.	599.
2051	5355.	46178.	25740.	77273.	66621.	2069.	14327.	83017.	-5744.	-5716.
2052	5382.	46476.	27917.	79775.	69599.	1996.	12550.	84145.	-4370.	-4356.
2053	152.	47673.	28540.	76366.	58762.	1790.	11844.	72395.	3970.	4006.
2054	1953.	43235.	28980.	74168.	67147.	1913.	11601.	80662.	-6493.	-6451.
2055	7005.	22772.	36382.	66159.	80042.	1540.	8294.	89875.	-23716.	-23534.
2056	4686.	21653.	42473.	68812.	68333.	1379.	6109.	75821.	-7009.	-6964.
2057	547.	19247.	45618.	65413.	67014.	1321.	5319.	73654.	-8241.	-8105.
2058	-4279.	32549.	48337.	76607.	68531.	1271.	4730.	74532.	2075.	2178.
2059	-6031.	29530.	49083.	72582.	71256.	1266.	4688.	77210.	-4628.	-4494.

2060	-20787.	64044.	44262.	87519.	61067.	1302.	5631.	68000.	19519.	19444.
2061	-6933.	30186.	43563.	66816.	71047.	1354.	5918.	78319.	-11503.	-11428.
2062	-21528.	67131.	38613.	84216.	52688.	1480.	7443.	61611.	22605.	22613.
2063	-14189.	51289.	32416.	69516.	51494.	1658.	9581.	62733.	6782.	6819.
2064	-3157.	68043.	31595.	96482.	80160.	1697.	10934.	92790.	3692.	3632.
2065	-12403.	67470.	25414.	80480.	48247.	2054.	16434.	66735.	13746.	13701.
2066	-5645.	42953.	25216.	62524.	49456.	2126.	14734.	66316.	-3793.	-3838.
2067	-3063.	45695.	25802.	68434.	53253.	2053.	13921.	69227.	-793.	-779.
2068	-2976.	45188.	25275.	67487.	49626.	2105.	14538.	66270.	1217.	1159.
2069	2384.	41547.	28522.	72453.	66620.	1885.	11720.	80225.	-7772.	-7730.
2070	464.	36912.	30602.	67977.	66329.	1751.	10359.	78439.	-10462.	-10363.
2071	6719.	30098.	36958.	73775.	78319.	1512.	7920.	87750.	-13975.	-13810.
2072	-6738.	43799.	36143.	73204.	58935.	1534.	7843.	68312.	4892.	4946.
2073	527.	67457.	34385.	102368.	80417.	1599.	9166.	91182.	11186.	11149.
2074	-7728.	52817.	29689.	74778.	53261.	1798.	11057.	66116.	8661.	8597.
Average	-5582.	45876.	37463.	77757.	65772.	1671.	10007.	77450.	307.	351.

Water budget for case NM_sce2af (App. E2 Table 4)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	-4302.	51354.	35719.	82771.	26126.	3052.	14932.	44111.	38660.	38540.
2013	-6348.	30306.	22131.	46088.	30454.	2749.	17860.	51063.	-4975.	-5004.
2014	-7038.	48028.	20997.	61986.	23172.	3765.	20179.	47115.	14871.	14742.
2015	-4793.	28700.	20443.	44350.	30491.	3199.	20371.	54061.	-9711.	-9732.
2016	-5376.	45995.	19941.	60560.	20700.	4444.	21874.	47018.	13542.	13398.
2017	-3270.	27593.	19504.	43827.	27491.	3792.	21879.	53163.	-9335.	-9352.
2018	9351.	22401.	25112.	56863.	65854.	2437.	15695.	83986.	-27123.	-27127.
2019	13903.	22123.	35428.	71454.	79209.	1640.	8992.	89841.	-18387.	-18221.
2020	6837.	21578.	40830.	69246.	67700.	1432.	6729.	75860.	-6615.	-6543.
2021	1896.	19141.	44137.	65174.	66733.	1350.	5755.	73839.	-8665.	-8520.
2022	-6397.	31874.	45954.	71430.	61670.	1323.	5293.	68287.	3144.	3274.
2023	-5318.	28209.	47109.	69999.	69322.	1294.	5140.	75756.	-5756.	-5619.
2024	-757.	24293.	52980.	76516.	80443.	1246.	4173.	85863.	-9347.	-9245.
2025	-2667.	23312.	58794.	79439.	80543.	1214.	3312.	85069.	-5629.	-5452.
2026	-11516.	22244.	60401.	71130.	67762.	1211.	3189.	72162.	-1033.	-899.
2027	-15135.	19563.	61436.	65865.	66741.	1211.	3097.	71050.	-5185.	-4994.
2028	-21795.	31609.	61621.	71434.	61938.	1216.	3046.	66200.	5235.	5402.
2029	-19593.	28481.	61744.	70632.	70415.	1202.	3064.	74681.	-4049.	-3863.
2030	-22331.	51243.	59742.	88654.	80108.	1193.	3324.	84625.	4029.	4263.
2031	-28045.	36128.	58054.	66137.	58831.	1197.	3398.	63426.	2711.	2898.
2032	-27701.	52372.	53818.	78489.	68618.	1224.	4030.	73872.	4617.	4797.
2033	-30274.	38371.	52101.	60198.	51488.	1218.	4155.	56862.	3336.	3515.
2034	-33758.	56891.	45863.	68995.	51294.	1339.	5453.	58086.	10909.	10948.
2035	-47482.	69799.	36565.	58883.	15050.	1642.	8599.	25291.	33592.	33473.
2036	-25329.	37031.	28560.	40263.	33358.	1986.	12115.	47460.	-7198.	-7160.
2037	-22347.	56315.	26815.	60783.	26667.	2368.	14035.	43070.	17713.	17642.
2038	-18132.	53725.	21362.	56954.	14791.	3461.	21247.	39499.	17456.	17320.
2039	-10844.	39805.	18557.	47518.	12805.	5090.	24732.	42628.	4890.	4754.
2040	-3952.	25279.	18349.	39676.	12718.	4837.	23785.	41340.	-1663.	-1786.
2041	-994.	42965.	17986.	59957.	21475.	7275.	25655.	54406.	5551.	5410.
2042	-760.	49391.	16060.	64691.	17698.	10495.	31185.	59377.	5314.	5152.
2043	5029.	38760.	15731.	59520.	18210.	10261.	31103.	59573.	-53.	-110.
2044	8372.	24554.	16275.	49200.	16462.	8562.	28300.	53323.	-4123.	-4212.
2045	8154.	42574.	16468.	67197.	24263.	10232.	29002.	63497.	3700.	3620.
2046	5994.	49117.	15099.	70209.	19857.	12619.	33755.	66231.	3978.	3856.
2047	9957.	43228.	15627.	68812.	26109.	11708.	31775.	69591.	-780.	-850.
2048	8684.	26261.	15909.	50854.	16009.	9783.	29382.	55174.	-4320.	-4451.
2049	9205.	42417.	16166.	67787.	24602.	10830.	29789.	65221.	2566.	2467.
2050	7120.	26158.	16210.	49488.	15195.	9172.	28423.	52790.	-3302.	-3423.
2051	15769.	28489.	18484.	62742.	48879.	5922.	24424.	79225.	-16482.	-16345.
2052	15933.	26272.	23421.	65627.	66769.	2752.	17637.	87158.	-21531.	-21448.
2053	-1255.	36905.	23032.	58683.	15584.	2849.	16760.	35193.	23490.	23315.
2054	8269.	22749.	23179.	54197.	57625.	2803.	17352.	77779.	-23582.	-23506.
2055	15126.	21920.	33572.	70618.	79730.	1722.	9850.	91302.	-20684.	-20517.
2056	8452.	21486.	39207.	69145.	67700.	1480.	7236.	76416.	-7271.	-7203.
2057	3408.	19096.	42702.	65206.	66733.	1378.	6121.	74233.	-9026.	-8871.
2058	-5027.	32060.	44516.	71549.	61464.	1356.	5620.	68441.	3108.	3227.
2059	-3733.	28267.	45963.	70498.	69831.	1310.	5394.	76534.	-6036.	-5909.

2060	-36863.	63196.	36892.	63224.	14212.	1641.	8136.	23988.	39236.	39083.
2061	-7335.	22763.	36125.	51553.	66435.	1716.	8852.	77002.	-25449.	-25242.
2062	-27196.	60062.	31364.	64230.	15322.	1937.	11108.	28366.	35864.	35735.
2063	-14214.	32146.	24410.	42342.	31800.	2336.	15480.	49617.	-7274.	-7245.
2064	-12025.	51719.	23333.	63027.	26115.	2936.	17335.	46386.	16641.	16556.
2065	-11034.	51385.	19278.	59630.	16527.	5229.	24401.	46157.	13473.	13309.
2066	-4794.	24043.	18314.	37563.	11334.	4910.	23567.	39812.	-2249.	-2446.
2067	-272.	26197.	18173.	44098.	15546.	5390.	23638.	44575.	-477.	-554.
2068	5974.	28041.	18998.	53014.	35675.	4348.	22765.	62788.	-9774.	-9759.
2069	12672.	20459.	25605.	58736.	66628.	2281.	14738.	83646.	-24910.	-24779.
2070	7250.	27486.	29364.	64100.	58280.	1963.	11414.	71658.	-7557.	-7449.
2071	9197.	27406.	35414.	72016.	71558.	1657.	8748.	81963.	-9947.	-9735.
2072	-9616.	37973.	33349.	61706.	44138.	1702.	9239.	55079.	6627.	6679.
2073	-14824.	56218.	27272.	68666.	30833.	2319.	13469.	46621.	22045.	21968.
2074	-11287.	34477.	24593.	47782.	31244.	2406.	15403.	49053.	-1271.	-1304.
Average	-5543.	35397.	31939.	61793.	42735.	3629.	15024.	61388.	405.	420.

Water budget for case NM_sce3n – new simulation (App. E2 Table 5)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	19454.	73440.	55816.	148711.	106763.	1930.	12403.	121096.	27614.	27618.
2013	1377.	53885.	41152.	96414.	75792.	2047.	14517.	92356.	4059.	4002.
2014	10448.	71806.	41960.	124215.	106841.	2008.	15505.	124354.	-139.	-68.
2015	2000.	53180.	40146.	95327.	75761.	2092.	15477.	93329.	1997.	1936.
2016	11512.	71381.	41367.	124259.	106885.	2060.	16114.	125059.	-800.	-805.
2017	3032.	52609.	39774.	95414.	75817.	2115.	15905.	93838.	1577.	1512.
2018	9107.	40312.	42669.	92088.	92109.	2072.	14041.	108222.	-16134.	-16116.
2019	14994.	27245.	52466.	94705.	104380.	1569.	9396.	115345.	-20640.	-20481.
2020	9701.	26327.	57986.	94014.	91859.	1408.	7143.	100411.	-6396.	-6357.
2021	5693.	22818.	60949.	89460.	90447.	1342.	6142.	97931.	-8471.	-8372.
2022	-194.	39119.	63167.	102092.	92093.	1291.	5567.	98952.	3140.	3188.
2023	-1684.	35611.	63442.	97369.	94727.	1284.	5583.	101594.	-4224.	-4127.
2024	4245.	30521.	68495.	103261.	106292.	1247.	4660.	112199.	-8938.	-8902.
2025	2189.	28631.	74376.	105196.	106116.	1217.	3647.	110980.	-5785.	-5628.
2026	-7082.	27031.	75889.	95838.	91859.	1215.	3509.	96583.	-745.	-680.
2027	-10297.	23208.	76912.	89823.	90455.	1216.	3406.	95077.	-5254.	-5134.
2028	-14852.	38672.	77915.	101735.	92367.	1207.	3253.	96827.	4908.	4980.
2029	-14844.	34708.	77336.	97199.	95820.	1203.	3371.	100394.	-3194.	-3064.
2030	-12650.	61458.	76855.	125663.	118287.	1185.	3515.	122987.	2676.	2921.
2031	-23162.	45887.	73664.	96389.	87190.	1187.	3733.	92111.	4278.	4392.
2032	-15462.	67455.	70988.	122982.	113742.	1195.	4261.	119198.	3784.	3962.
2033	-23594.	51283.	67462.	95151.	83974.	1194.	4641.	89809.	5342.	5404.
2034	-17043.	78843.	63645.	125445.	106958.	1240.	5625.	113824.	11621.	11613.
2035	-28651.	79138.	53294.	103781.	74543.	1427.	8571.	84541.	19240.	19253.
2036	-14363.	57787.	47999.	91423.	73859.	1600.	10286.	85745.	5678.	5658.
2037	252.	78277.	46741.	125270.	106711.	1667.	11788.	120166.	5104.	5048.
2038	-9252.	77131.	38745.	106624.	70259.	2146.	17922.	90327.	16297.	16206.
2039	301.	60481.	36861.	97643.	73549.	2209.	19301.	95059.	2584.	2540.
2040	5868.	44417.	38204.	88488.	73849.	2188.	17447.	93484.	-4996.	-5130.
2041	15260.	69981.	40412.	125652.	107046.	2122.	17221.	126389.	-737.	-716.
2042	3234.	70350.	34900.	108484.	71334.	3161.	22566.	97061.	11424.	11359.
2043	9564.	55747.	34445.	99756.	74216.	2627.	22639.	99481.	275.	232.
2044	12716.	40549.	36377.	89642.	74012.	2385.	19834.	96231.	-6589.	-6681.
2045	20317.	67674.	38955.	126946.	107349.	2369.	18992.	128710.	-1764.	-1704.
2046	7249.	68720.	33872.	109841.	71828.	3623.	23978.	99429.	10411.	10356.
2047	21705.	66639.	37160.	125503.	107964.	2658.	21467.	132089.	-6586.	-6557.
2048	11820.	47616.	36803.	96239.	75753.	2371.	19596.	97719.	-1481.	-1500.
2049	19078.	68216.	38952.	126246.	107283.	2352.	19139.	128774.	-2528.	-2474.
2050	9136.	49532.	37889.	96558.	75785.	2272.	18271.	96328.	230.	211.
2051	13431.	49983.	40289.	103703.	91780.	2182.	16316.	110278.	-6575.	-6472.
2052	12566.	51636.	42920.	107121.	94858.	2094.	14330.	111281.	-4160.	-4108.
2053	6022.	53578.	42720.	102321.	82231.	1910.	13851.	97992.	4329.	4316.
2054	8474.	48335.	43450.	100259.	92109.	2007.	13199.	107315.	-7056.	-7014.
2055	12731.	28219.	51162.	92111.	105302.	1597.	9772.	116672.	-24561.	-24463.
2056	9884.	26223.	57134.	93241.	91859.	1428.	7346.	100633.	-7392.	-7374.
2057	6220.	22773.	60288.	89282.	90447.	1357.	6288.	98092.	-8811.	-8710.
2058	472.	39126.	62598.	102196.	92207.	1305.	5687.	99199.	2996.	3040.
2059	-718.	35608.	63009.	97899.	95236.	1292.	5672.	102200.	-4301.	-4227.

2060	-15393.	71620.	57718.	113945.	84958.	1357.	6942.	93257.	20687.	20576.
2061	-941.	34915.	57316.	91289.	95166.	1406.	7221.	103793.	-12504.	-12468.
2062	-15073.	74599.	51646.	111172.	74816.	1567.	9117.	85499.	25673.	25634.
2063	-6479.	54110.	45382.	93013.	73851.	1757.	11452.	87060.	5953.	5897.
2064	5040.	75799.	44705.	125543.	106752.	1804.	12919.	121475.	4069.	4017.
2065	-5560.	74400.	37430.	106269.	70563.	2460.	19004.	92028.	14241.	14137.
2066	3531.	44412.	38378.	86321.	71458.	2277.	16943.	90678.	-4357.	-4439.
2067	5300.	48685.	39148.	93133.	75797.	2209.	16092.	94097.	-965.	-926.
2068	4898.	47934.	38597.	91429.	71317.	2264.	16686.	90266.	1163.	1105.
2069	11262.	45186.	42653.	99101.	91258.	2012.	13727.	106998.	-7897.	-7873.
2070	8631.	47326.	44136.	100093.	90668.	1898.	12537.	105103.	-5010.	-5014.
2071	11228.	37226.	49533.	97988.	103466.	1643.	10287.	115396.	-17409.	-17363.
2072	421.	49923.	48917.	99261.	82149.	1659.	10054.	93862.	5399.	5401.
2073	9435.	75944.	46893.	132273.	107028.	1731.	11772.	120531.	11742.	11701.
2074	-1005.	56180.	42386.	97561.	75749.	1956.	13522.	91227.	6333.	6227.
Average	1928.	51610.	50547.	104085.	89887.	1823.	11923.	103634.	451.	468.

Water budget for case NM_sce3n – original simulation (App. E2 Table 5)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	**NES Bdry**	**Rech&Wells**	**Ocean In**	**Total In**	**Wells Out**	**Stream Out**	**Ocean Out**	**Total Out**	**In - Out**	**Dstorage**
2012	19454.	73440.	55816.	148711.	106763.	1930.	12403.	121096.	27614.	27618.
2013	1377.	53885.	41152.	96414.	75792.	2047.	14517.	92356.	4059.	4002.
2014	10448.	71806.	41960.	124215.	106841.	2008.	15505.	124354.	-139.	-68.
2015	2003.	53180.	40147.	95330.	75761.	2092.	15476.	93329.	2001.	1936.
2016	11512.	71381.	41367.	124259.	106885.	2060.	16114.	125059.	-800.	-805.
2017	3032.	52609.	39774.	95415.	75817.	2115.	15905.	93838.	1577.	1512.
2018	9107.	40312.	42669.	92088.	92109.	2072.	14041.	108222.	-16134.	-16116.
2019	14994.	27245.	52466.	94705.	104380.	1569.	9396.	115345.	-20640.	-20481.
2020	9701.	26327.	57986.	94014.	91859.	1408.	7143.	100411.	-6397.	-6357.
2021	5690.	22818.	60949.	89458.	90447.	1342.	6142.	97932.	-8474.	-8372.
2022	-194.	39119.	63167.	102092.	92093.	1291.	5567.	98952.	3140.	3188.
2023	-1684.	35611.	63442.	97369.	94727.	1284.	5583.	101594.	-4224.	-4127.
2024	4245.	30521.	68495.	103261.	106292.	1247.	4660.	112199.	-8938.	-8903.
2025	2189.	28631.	74376.	105196.	106116.	1217.	3647.	110980.	-5785.	-5628.
2026	-7082.	27031.	75889.	95838.	91859.	1215.	3509.	96583.	-745.	-680.
2027	-10297.	23208.	76912.	89824.	90455.	1216.	3406.	95077.	-5254.	-5134.
2028	-14852.	38672.	77915.	101735.	92367.	1207.	3253.	96827.	4908.	4980.
2029	-14844.	34708.	77336.	97199.	95820.	1203.	3371.	100394.	-3195.	-3064.
2030	-12650.	61458.	76855.	125663.	118287.	1185.	3515.	122987.	2676.	2921.
2031	-23162.	45887.	73664.	96389.	87190.	1187.	3733.	92111.	4278.	4392.
2032	-15462.	67455.	70988.	122982.	113742.	1195.	4261.	119198.	3784.	3962.
2033	-23594.	51283.	67462.	95151.	83974.	1194.	4641.	89809.	5342.	5404.
2034	-17043.	78843.	63645.	125445.	106958.	1240.	5625.	113824.	11621.	11613.
2035	-28650.	79138.	53294.	103781.	74543.	1427.	8571.	84541.	19240.	19253.
2036	-14363.	57787.	47999.	91423.	73859.	1600.	10286.	85745.	5677.	5658.
2037	253.	78277.	46741.	125271.	106711.	1667.	11788.	120166.	5105.	5048.
2038	-9251.	77131.	38745.	106625.	70259.	2146.	17922.	90327.	16297.	16206.
2039	300.	60481.	36861.	97641.	73549.	2209.	19301.	95059.	2582.	2540.
2040	5868.	44417.	38204.	88488.	73849.	2188.	17447.	93484.	-4996.	-5131.
2041	15260.	69981.	40412.	125652.	107046.	2122.	17221.	126389.	-736.	-716.
2042	3234.	70350.	34900.	108484.	71334.	3161.	22566.	97061.	11423.	11360.
2043	9568.	55747.	34446.	99760.	74216.	2627.	22638.	99481.	279.	232.
2044	12716.	40549.	36377.	89642.	74012.	2385.	19834.	96231.	-6589.	-6680.
2045	20319.	67674.	38955.	126948.	107349.	2369.	18992.	128710.	-1762.	-1704.
2046	7248.	68720.	33872.	109840.	71828.	3623.	23978.	99429.	10410.	10357.
2047	21704.	66639.	37160.	125502.	107964.	2658.	21468.	132089.	-6587.	-6557.
2048	11822.	47616.	36803.	96240.	75753.	2371.	19596.	97719.	-1479.	-1500.
2049	19078.	68216.	38952.	126246.	107283.	2352.	19139.	128774.	-2528.	-2474.
2050	9136.	49532.	37889.	96558.	75785.	2272.	18271.	96328.	230.	211.
2051	13431.	49983.	40289.	103703.	91780.	2182.	16316.	110278.	-6575.	-6472.
2052	12566.	51636.	42920.	107121.	94858.	2094.	14330.	111281.	-4160.	-4108.
2053	6023.	53578.	42720.	102321.	82231.	1910.	13851.	97992.	4329.	4316.
2054	8474.	48335.	43450.	100259.	92109.	2007.	13199.	107315.	-7056.	-7014.
2055	12731.	28219.	51162.	92111.	105302.	1597.	9772.	116672.	-24561.	-24463.
2056	9884.	26223.	57134.	93241.	91859.	1428.	7346.	100633.	-7392.	-7374.
2057	6220.	22773.	60288.	89281.	90447.	1357.	6288.	98092.	-8811.	-8710.
2058	472.	39126.	62598.	102196.	92207.	1305.	5687.	99199.	2996.	3040.
2059	-718.	35608.	63009.	97899.	95236.	1292.	5672.	102200.	-4301.	-4227.

2060	-15393.	71620.	57718.	113944.	84958.	1357.	6942.	93257.	20687.	20576.
2061	-941.	34915.	57316.	91289.	95166.	1406.	7221.	103793.	-12504.	-12468.
2062	-15073.	74599.	51646.	111172.	74816.	1567.	9117.	85499.	25673.	25634.
2063	-6484.	54110.	45381.	93007.	73851.	1757.	11452.	87060.	5947.	5898.
2064	5039.	75799.	44705.	125542.	106752.	1804.	12919.	121475.	4068.	4017.
2065	-5561.	74400.	37430.	106269.	70563.	2460.	19004.	92028.	14241.	14137.
2066	3531.	44412.	38378.	86321.	71458.	2277.	16943.	90678.	-4357.	-4439.
2067	5300.	48685.	39148.	93133.	75797.	2209.	16092.	94097.	-964.	-926.
2068	4898.	47934.	38597.	91429.	71317.	2264.	16686.	90266.	1163.	1105.
2069	11263.	45186.	42654.	99102.	91258.	2012.	13727.	106997.	-7895.	-7873.
2070	8629.	47326.	44136.	100091.	90668.	1898.	12537.	105103.	-5012.	-5014.
2071	11228.	37226.	49533.	97987.	103466.	1643.	10287.	115396.	-17409.	-17363.
2072	421.	49923.	48917.	99261.	82149.	1659.	10054.	93862.	5399.	5401.
2073	9435.	75944.	46893.	132273.	107028.	1731.	11772.	120531.	11742.	11701.
2074	-1005.	56180.	42386.	97561.	75749.	1956.	13522.	91227.	6333.	6227.
Average	1928.	51610.	50547.	104085.	89887.	1823.	11923.	103634.	451.	468.

Water budget for case NM_sce3ncb (App. E2 Table 6)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	19169.	74520.	55507.	149196.	106763.	1930.	12488.	121181.	28015.	28019.
2013	923.	54965.	40754.	96643.	75792.	2047.	14664.	92503.	4140.	4083.
2014	9958.	72886.	41562.	124406.	106841.	2008.	15675.	124524.	-118.	-46.
2015	1498.	54260.	39744.	95503.	75761.	2092.	15649.	93502.	2001.	1943.
2016	11007.	72461.	40969.	124437.	106885.	2060.	16294.	125239.	-802.	-804.
2017	2528.	53689.	39374.	95591.	75817.	2115.	16083.	94015.	1576.	1513.
2018	8604.	41392.	42242.	92238.	92109.	2072.	14190.	108371.	-16134.	-16116.
2019	14491.	28325.	51993.	94809.	104380.	1569.	9500.	115449.	-20640.	-20481.
2020	9198.	27407.	57494.	94100.	91859.	1408.	7229.	100496.	-6396.	-6357.
2021	5190.	23898.	60445.	89533.	90447.	1342.	6215.	98005.	-8472.	-8372.
2022	-697.	40199.	62659.	102161.	92093.	1291.	5637.	99021.	3140.	3188.
2023	-2188.	36691.	62935.	97439.	94727.	1284.	5653.	101664.	-4225.	-4127.
2024	3742.	31601.	67973.	103316.	106292.	1247.	4715.	112254.	-8938.	-8903.
2025	1686.	29711.	73838.	105235.	106116.	1217.	3686.	111019.	-5785.	-5628.
2026	-7584.	28111.	75347.	95875.	91859.	1215.	3545.	96619.	-744.	-680.
2027	-10800.	24288.	76369.	89858.	90455.	1216.	3440.	95111.	-5254.	-5134.
2028	-15355.	39752.	77372.	101768.	92367.	1207.	3287.	96861.	4907.	4980.
2029	-15347.	35788.	76794.	97234.	95820.	1203.	3406.	100429.	-3195.	-3064.
2030	-13152.	62538.	76319.	125705.	118287.	1185.	3556.	123028.	2677.	2921.
2031	-23665.	46967.	73128.	96429.	87190.	1187.	3774.	92152.	4278.	4392.
2032	-15964.	68535.	70465.	123036.	113742.	1195.	4315.	119252.	3784.	3962.
2033	-24097.	52363.	66944.	95210.	83974.	1194.	4700.	89868.	5342.	5404.
2034	-17546.	79923.	63141.	125518.	106958.	1240.	5698.	113897.	11621.	11613.
2035	-29154.	80218.	52825.	103890.	74543.	1427.	8679.	84650.	19240.	19253.
2036	-14866.	58867.	47542.	91543.	73859.	1600.	10407.	85866.	5678.	5658.
2037	-251.	79357.	46303.	125410.	106711.	1667.	11928.	120306.	5104.	5048.
2038	-9754.	78211.	38374.	106831.	70259.	2146.	18128.	90534.	16297.	16206.
2039	-199.	61561.	36498.	97860.	73549.	2209.	19515.	95272.	2587.	2540.
2040	5360.	45497.	37817.	88673.	73849.	2188.	17637.	93674.	-5001.	-5129.
2041	14757.	71061.	40021.	125839.	107046.	2122.	17407.	126575.	-737.	-717.
2042	2731.	71430.	34555.	108717.	71334.	3161.	22799.	97293.	11424.	11359.
2043	9061.	56827.	34099.	99988.	74216.	2627.	22870.	99713.	275.	232.
2044	12213.	41629.	36006.	89848.	74012.	2385.	20040.	96437.	-6589.	-6681.
2045	19814.	68754.	38576.	127144.	107349.	2369.	19190.	128908.	-1764.	-1704.
2046	6746.	69800.	33533.	110078.	71828.	3623.	24216.	99667.	10411.	10356.
2047	21202.	67719.	36798.	125719.	107964.	2658.	21683.	132305.	-6586.	-6557.
2048	11317.	48696.	36429.	96441.	75753.	2371.	19799.	97922.	-1481.	-1500.
2049	18575.	69296.	38574.	126445.	107283.	2352.	19338.	128973.	-2528.	-2474.
2050	8633.	50612.	37506.	96751.	75785.	2272.	18465.	96521.	230.	211.
2051	12928.	51063.	39883.	103874.	91780.	2182.	16487.	110449.	-6575.	-6472.
2052	12062.	52716.	42491.	107269.	94858.	2094.	14478.	111430.	-4160.	-4108.
2053	5519.	54658.	42293.	102470.	82231.	1910.	14001.	98142.	4328.	4316.
2054	7971.	49415.	43015.	100400.	92109.	2007.	13341.	107456.	-7056.	-7014.
2055	12228.	29299.	50693.	92219.	105302.	1597.	9880.	116780.	-24561.	-24463.
2056	9381.	27303.	56645.	93329.	91859.	1428.	7434.	100721.	-7392.	-7374.
2057	5717.	23853.	59787.	89358.	90447.	1357.	6364.	98168.	-8810.	-8710.
2058	-31.	40206.	62092.	102267.	92207.	1305.	5758.	99270.	2996.	3040.
2059	-1221.	36688.	62503.	97971.	95236.	1292.	5744.	102272.	-4301.	-4227.

2060	-15895.	72700.	57230.	114035.	84958.	1357.	7032.	93347.	20688.	20576.
2061	-1445.	35995.	56829.	91378.	95166.	1406.	7311.	103883.	-12504.	-12468.
2062	-15577.	75679.	51179.	111282.	74816.	1567.	9227.	85609.	25672.	25634.
2063	-6988.	55190.	44935.	93137.	73851.	1757.	11583.	87191.	5946.	5898.
2064	4537.	76878.	44279.	125695.	106752.	1804.	13071.	121626.	4069.	4017.
2065	-6064.	75480.	37066.	106481.	70563.	2460.	19217.	92241.	14240.	14137.
2066	3028.	45492.	37991.	86511.	71458.	2277.	17133.	90867.	-4357.	-4439.
2067	4796.	49765.	38750.	93312.	75797.	2209.	16272.	94277.	-966.	-926.
2068	4395.	49014.	38206.	91615.	71317.	2264.	16871.	90452.	1163.	1105.
2069	10761.	46266.	42224.	99250.	91258.	2012.	13874.	107145.	-7894.	-7873.
2070	8124.	48406.	43695.	100226.	90668.	1898.	12673.	105239.	-5013.	-5014.
2071	10726.	38306.	49070.	98101.	103466.	1643.	10401.	115510.	-17409.	-17363.
2072	-83.	51003.	48456.	99376.	82149.	1659.	10170.	93978.	5398.	5401.
2073	8933.	77024.	46450.	132407.	107028.	1731.	11906.	120665.	11742.	11701.
2074	-1508.	57260.	41961.	97714.	75749.	1956.	13675.	91380.	6334.	6227.
Average	1430.	52690.	50104.	104224.	89887.	1823.	12054.	103765.	459.	476.

Water budget for case NM_sce3nc (App. E2 Table 7)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	19313.	74520.	55183.	149017.	106763.	1930.	12489.	121182.	27835.	27839.
2013	1156.	54965.	40458.	96579.	75792.	2047.	14645.	92483.	4095.	4039.
2014	10210.	72886.	41274.	124371.	106841.	2008.	15651.	124500.	-130.	-58.
2015	1756.	54260.	39457.	95473.	75761.	2092.	15623.	93476.	1998.	1940.
2016	11266.	72461.	40684.	124411.	106885.	2060.	16269.	125214.	-803.	-805.
2017	2788.	53689.	39088.	95564.	75817.	2115.	16056.	93988.	1576.	1513.
2018	8863.	41392.	41955.	92210.	92109.	2072.	14163.	108344.	-16134.	-16116.
2019	14750.	28325.	51708.	94783.	104380.	1569.	9475.	115424.	-20640.	-20481.
2020	9458.	27407.	57211.	94077.	91859.	1408.	7206.	100473.	-6396.	-6357.
2021	5449.	23898.	60165.	89513.	90447.	1342.	6195.	97984.	-8471.	-8372.
2022	-438.	40199.	62379.	102141.	92093.	1291.	5617.	99001.	3140.	3188.
2023	-1928.	36691.	62656.	97419.	94727.	1284.	5633.	101644.	-4224.	-4127.
2024	4002.	31601.	67698.	103301.	106292.	1247.	4700.	112238.	-8937.	-8902.
2025	1945.	29711.	73568.	105224.	106116.	1217.	3675.	111008.	-5784.	-5628.
2026	-7325.	28111.	75078.	95864.	91859.	1215.	3535.	96609.	-745.	-680.
2027	-10541.	24288.	76100.	89848.	90455.	1216.	3430.	95102.	-5254.	-5134.
2028	-15097.	39752.	77103.	101758.	92367.	1207.	3277.	96851.	4907.	4980.
2029	-15089.	35788.	76525.	97223.	95820.	1203.	3396.	100419.	-3196.	-3064.
2030	-12892.	62538.	76048.	125694.	118287.	1185.	3545.	123017.	2677.	2921.
2031	-23407.	46967.	72857.	96417.	87190.	1187.	3763.	92140.	4277.	4392.
2032	-15706.	68535.	70190.	123020.	113742.	1195.	4300.	119237.	3783.	3962.
2033	-23838.	52363.	66667.	95192.	83974.	1194.	4682.	89850.	5342.	5404.
2034	-17287.	79923.	62861.	125498.	106958.	1240.	5678.	113876.	11621.	11613.
2035	-28894.	80218.	52539.	103863.	74543.	1427.	8653.	84623.	19240.	19253.
2036	-14607.	58867.	47255.	91516.	73859.	1600.	10379.	85838.	5678.	5658.
2037	9.	79357.	46018.	125383.	106711.	1667.	11902.	120279.	5104.	5048.
2038	-9495.	78211.	38093.	106810.	70259.	2146.	18107.	90512.	16297.	16206.
2039	60.	61561.	36216.	97836.	73549.	2209.	19492.	95250.	2586.	2540.
2040	5618.	45497.	37531.	88646.	73849.	2188.	17611.	93648.	-5002.	-5130.
2041	15016.	71061.	39736.	125813.	107046.	2122.	17382.	126550.	-737.	-716.
2042	2990.	71430.	34278.	108699.	71334.	3161.	22781.	97275.	11424.	11359.
2043	9321.	56827.	33820.	99968.	74216.	2627.	22850.	99693.	275.	232.
2044	12472.	41629.	35721.	89822.	74012.	2385.	20015.	96411.	-6590.	-6681.
2045	20074.	68754.	38292.	127120.	107349.	2369.	19165.	128884.	-1764.	-1704.
2046	7005.	69800.	33256.	110062.	71828.	3623.	24199.	99650.	10412.	10356.
2047	21461.	67719.	36517.	125696.	107964.	2658.	21661.	132283.	-6586.	-6557.
2048	11576.	48696.	36143.	96415.	75753.	2371.	19772.	97896.	-1481.	-1500.
2049	18834.	69296.	38289.	126420.	107283.	2352.	19313.	128948.	-2528.	-2474.
2050	8893.	50612.	37219.	96724.	75785.	2272.	18437.	96494.	230.	211.
2051	13187.	51063.	39595.	103846.	91780.	2182.	16458.	110420.	-6575.	-6472.
2052	12322.	52716.	42203.	107241.	94858.	2094.	14449.	111401.	-4160.	-4108.
2053	5779.	54658.	42005.	102441.	82231.	1910.	13972.	98113.	4329.	4316.
2054	8230.	49415.	42728.	100373.	92109.	2007.	13314.	107429.	-7056.	-7014.
2055	12487.	29299.	50408.	92194.	105302.	1597.	9855.	116755.	-24561.	-24463.
2056	9640.	27303.	56363.	93306.	91859.	1428.	7411.	100698.	-7392.	-7374.
2057	5977.	23853.	59507.	89337.	90447.	1357.	6343.	98147.	-8811.	-8710.
2058	228.	40206.	61812.	102246.	92207.	1305.	5738.	99250.	2996.	3040.
2059	-961.	36688.	62223.	97951.	95236.	1292.	5723.	102252.	-4301.	-4227.

2060	-15636.	72700.	56947.	114010.	84958.	1357.	7008.	93323.	20687.	20576.
2061	-1185.	35995.	56546.	91356.	95166.	1406.	7288.	103860.	-12504.	-12468.
2062	-15317.	75679.	50893.	111255.	74816.	1567.	9200.	85583.	25673.	25634.
2063	-6729.	55190.	44648.	93109.	73851.	1757.	11556.	87164.	5946.	5898.
2064	4796.	76878.	43994.	125669.	106752.	1804.	13045.	121601.	4068.	4017.
2065	-5805.	75480.	36785.	106461.	70563.	2460.	19196.	92220.	14241.	14137.
2066	3288.	45492.	37704.	86483.	71458.	2277.	17105.	90840.	-4357.	-4439.
2067	5056.	49765.	38463.	93285.	75797.	2209.	16244.	94249.	-964.	-926.
2068	4654.	49014.	37919.	91587.	71317.	2264.	16844.	90425.	1163.	1105.
2069	11018.	46266.	41937.	99221.	91258.	2012.	13847.	107118.	-7897.	-7873.
2070	8387.	48406.	43408.	100201.	90668.	1898.	12645.	105211.	-5010.	-5014.
2071	10985.	38306.	48784.	98075.	103466.	1643.	10375.	115484.	-17409.	-17363.
2072	177.	51003.	48169.	99349.	82149.	1659.	10143.	93951.	5399.	5401.
2073	9192.	77024.	46164.	132380.	107028.	1731.	11879.	120638.	11742.	11701.
2074	-1248.	57260.	41674.	97686.	75749.	1956.	13647.	91352.	6334.	6227.
Average	1687.	52690.	49821.	104198.	89887.	1823.	12032.	103742.	455.	472.

Water budget for case NM_sce4f (App. E2 Table 8)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	5648.	65506.	63868.	135022.	106324.	1662.	8761.	116747.	18275.	18260.
2013	-5530.	51074.	50057.	95601.	80082.	1767.	10161.	92010.	3591.	3598.
2014	2665.	66063.	50226.	118954.	106323.	1729.	10679.	118731.	222.	181.
2015	-4084.	49538.	48712.	94167.	80082.	1825.	10764.	92671.	1495.	1484.
2016	4118.	65434.	49393.	118945.	106322.	1763.	11100.	119185.	-240.	-307.
2017	-2866.	49182.	48079.	94396.	80151.	1854.	11088.	93093.	1302.	1298.
2018	3001.	30009.	51662.	84672.	93382.	1807.	9746.	104935.	-20263.	-20237.
2019	10861.	22379.	62911.	96151.	105594.	1399.	6243.	113237.	-17086.	-16936.
2020	4846.	21792.	68479.	95117.	94460.	1308.	4903.	100671.	-5554.	-5498.
2021	450.	19316.	71432.	91197.	93122.	1267.	4386.	98776.	-7578.	-7457.
2022	-4487.	32470.	74071.	102054.	94528.	1231.	3962.	99721.	2333.	2429.
2023	-6387.	29419.	74589.	97621.	96855.	1228.	3948.	102030.	-4409.	-4283.
2024	-1281.	24546.	79808.	103073.	107200.	1215.	3365.	111781.	-8708.	-8566.
2025	-2935.	23433.	85337.	105834.	106963.	1213.	2757.	110933.	-5098.	-4870.
2026	-11266.	22371.	86622.	97727.	94460.	1211.	2694.	98365.	-638.	-465.
2027	-14763.	19641.	87397.	92275.	93130.	1211.	2646.	96988.	-4713.	-4529.
2028	-18414.	32044.	88737.	102368.	94802.	1205.	2502.	98509.	3859.	4003.
2029	-18959.	28986.	88403.	98430.	97947.	1201.	2556.	101705.	-3274.	-3074.
2030	-17027.	51757.	88540.	123270.	117780.	1177.	2545.	121502.	1768.	2026.
2031	-26244.	37748.	85939.	97443.	90067.	1188.	2697.	93951.	3492.	3634.
2032	-19848.	55279.	83841.	119272.	113236.	1184.	2907.	117326.	1945.	2175.
2033	-27457.	42357.	81091.	95992.	87092.	1185.	3113.	91390.	4602.	4744.
2034	-22908.	64673.	77577.	119341.	106457.	1184.	3513.	111154.	8188.	8299.
2035	-36002.	71963.	67673.	103634.	78880.	1261.	5020.	85161.	18472.	18516.
2036	-25578.	56190.	61498.	92111.	78088.	1384.	6134.	85607.	6504.	6544.
2037	-9712.	71281.	59003.	120573.	106351.	1437.	7153.	114941.	5632.	5665.
2038	-17336.	72984.	49512.	105159.	74506.	1666.	11012.	87184.	17975.	17945.
2039	-9811.	58873.	46274.	95335.	77924.	1830.	12307.	92061.	3274.	3230.
2040	-5301.	45148.	47240.	87088.	78079.	1848.	11390.	91317.	-4229.	-4317.
2041	4658.	65546.	49028.	119232.	106341.	1707.	11281.	119329.	-97.	-121.
2042	-5330.	65097.	43205.	102973.	74873.	2034.	15073.	91980.	10993.	10913.
2043	-278.	53622.	42411.	95755.	77892.	2010.	15439.	95340.	415.	366.
2044	2688.	41456.	44067.	88210.	78079.	2024.	13717.	93820.	-5610.	-5664.
2045	10901.	62527.	46573.	120001.	106423.	1856.	13106.	121385.	-1384.	-1434.
2046	-339.	62762.	41504.	103926.	75073.	2230.	16745.	94049.	9878.	9813.
2047	11981.	61096.	44475.	117553.	106680.	1959.	15114.	123753.	-6200.	-6184.
2048	4194.	46155.	44440.	94789.	80082.	2038.	13735.	95855.	-1066.	-1094.
2049	10932.	62443.	46260.	119635.	106426.	1896.	13485.	121807.	-2172.	-2139.
2050	2711.	47114.	45445.	95271.	80081.	1986.	12848.	94915.	356.	340.
2051	6287.	46865.	47563.	100715.	92729.	1939.	11667.	106335.	-5620.	-5568.
2052	6064.	46680.	50329.	103073.	95811.	1865.	10384.	108060.	-4988.	-4951.
2053	1364.	48278.	51188.	100830.	84999.	1681.	9812.	96492.	4338.	4373.
2054	2804.	43573.	51581.	97957.	93375.	1785.	9597.	104758.	-6801.	-6743.
2055	8548.	22790.	59806.	91144.	106149.	1470.	7060.	114679.	-23535.	-23353.
2056	6127.	21653.	66300.	94080.	94460.	1344.	5328.	101132.	-7052.	-7002.
2057	1905.	19243.	69673.	90821.	93122.	1293.	4674.	99089.	-8269.	-8135.
2058	-2951.	32526.	72525.	102101.	94640.	1245.	4178.	100062.	2038.	2141.
2059	-4712.	29513.	73282.	98082.	97364.	1240.	4127.	102731.	-4649.	-4527.

2060	-19584.	64274.	68281.	112971.	87385.	1264.	4886.	93536.	19435.	19346.
2061	-5512.	30134.	67576.	92198.	97262.	1318.	5095.	103676.	-11478.	-11410.
2062	-20618.	67520.	62285.	109187.	79152.	1399.	6288.	86839.	22348.	22356.
2063	-13356.	52094.	55684.	94422.	78080.	1548.	7895.	87523.	6899.	6893.
2064	-2324.	68770.	54200.	120646.	106391.	1585.	8838.	116814.	3832.	3759.
2065	-11596.	68949.	46264.	103618.	74663.	1860.	12741.	89264.	14354.	14314.
2066	-4963.	44223.	46703.	85962.	75943.	1994.	11750.	89686.	-3724.	-3794.
2067	-2249.	46759.	47670.	92180.	80082.	1917.	11181.	93179.	-999.	-972.
2068	-2153.	46247.	46913.	91007.	76239.	1961.	11593.	89792.	1215.	1134.
2069	3216.	41856.	51067.	96139.	93225.	1766.	9658.	104648.	-8509.	-8454.
2070	1579.	37267.	53693.	92539.	92554.	1638.	8615.	102807.	-10268.	-10162.
2071	8265.	30249.	60473.	98986.	104425.	1446.	6748.	112619.	-13633.	-13464.
2072	-5371.	43854.	59747.	98230.	85270.	1464.	6718.	93452.	4778.	4828.
2073	1149.	67766.	57637.	126552.	106524.	1510.	7661.	115695.	10858.	10847.
2074	-6863.	53657.	52670.	99464.	80084.	1667.	9070.	90821.	8643.	8627.
Average	-4594.	46413.	60293.	102112.	92096.	1577.	8193.	101867.	246.	292.

Water budget for case NM_sce4rf (App. E2 Table 9)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2075	-145.	65275.	30921.	96052.	80093.	1763.	11336.	93192.	2860.	2847.
2076	-6734.	50234.	27818.	71318.	53253.	1891.	12413.	67557.	3761.	3743.
2077	1631.	65227.	28439.	95297.	80094.	1866.	13242.	95202.	95.	37.
2078	-5128.	48699.	26736.	70307.	53251.	1954.	13311.	68516.	1791.	1799.
2079	3177.	64365.	27765.	95307.	80107.	1912.	13822.	95840.	-533.	-570.
2080	-3837.	48217.	26208.	70588.	53321.	1984.	13748.	69053.	1535.	1521.
2081	1726.	30125.	29143.	60994.	67151.	1925.	11842.	80918.	-19925.	-19889.
2082	9331.	22369.	39204.	70904.	79363.	1459.	7257.	88079.	-17175.	-17035.
2083	3470.	21788.	44476.	69734.	68333.	1340.	5609.	75283.	-5549.	-5501.
2084	-858.	19315.	47243.	65700.	67014.	1295.	4980.	73289.	-7589.	-7470.
2085	-5755.	32484.	49772.	76501.	68420.	1253.	4477.	74149.	2353.	2448.
2086	-7628.	29395.	50304.	72071.	70747.	1251.	4473.	76471.	-4400.	-4280.
2087	-2580.	24537.	55503.	77460.	81094.	1224.	3788.	86105.	-8645.	-8514.
2088	-4208.	23418.	60868.	80078.	80855.	1213.	3084.	85152.	-5074.	-4847.
2089	-12544.	22361.	62140.	71957.	68333.	1211.	3006.	72550.	-593.	-442.
2090	-16028.	19642.	62833.	66447.	67021.	1211.	2953.	71186.	-4739.	-4538.
2091	-19641.	32058.	64163.	76580.	68694.	1205.	2795.	72694.	3886.	4022.
2092	-20175.	28972.	63858.	72655.	71839.	1201.	2858.	75899.	-3244.	-3063.
2093	-18273.	51771.	64014.	97512.	91672.	1183.	2874.	95728.	1784.	2053.
2094	-27455.	37757.	61404.	71706.	63961.	1188.	3022.	68171.	3535.	3676.
2095	-21005.	55249.	59331.	93574.	87131.	1190.	3297.	91618.	1956.	2191.
2096	-28715.	42329.	56513.	70127.	60759.	1185.	3518.	65462.	4665.	4803.
2097	-23987.	64600.	53130.	93744.	80349.	1199.	4021.	85568.	8175.	8276.
2098	-37055.	71725.	43548.	78219.	52416.	1302.	5910.	59629.	18590.	18635.
2099	-26004.	55529.	37548.	67073.	51501.	1453.	7331.	60286.	6787.	6818.
2100	-10320.	70514.	35568.	95762.	80120.	1525.	8749.	90394.	5368.	5380.
2101	-18065.	71460.	27873.	81268.	48058.	1819.	14136.	64013.	17256.	17234.
2102	-10534.	57265.	25338.	72068.	51336.	1966.	15759.	69060.	3008.	2969.
2103	-5924.	43959.	25718.	63752.	51493.	1981.	14312.	67786.	-4033.	-4129.
2104	3974.	64406.	27467.	95847.	80103.	1846.	14088.	96038.	-190.	-208.
2105	-6110.	63659.	23061.	80610.	48472.	2270.	19246.	69988.	10621.	10554.
2106	-967.	52410.	22336.	73779.	51421.	2219.	19627.	73267.	512.	471.
2107	1859.	40360.	23265.	65484.	51493.	2181.	17237.	70911.	-5427.	-5490.
2108	10141.	61487.	25525.	97153.	80230.	2029.	16322.	98580.	-1426.	-1416.
2109	-1224.	61520.	21814.	82109.	48682.	2571.	21235.	72488.	9622.	9545.
2110	11214.	60005.	24115.	95335.	80507.	2159.	18855.	101522.	-6187.	-6139.
2111	3273.	45130.	23394.	71796.	53251.	2181.	17100.	72532.	-736.	-737.
2112	10267.	61279.	25291.	96838.	80241.	2080.	16738.	99058.	-2220.	-2241.
2113	1648.	46075.	24111.	71834.	53252.	2117.	15959.	71328.	505.	512.
2114	5478.	46057.	25758.	77293.	66619.	2068.	14314.	83001.	-5708.	-5668.
2115	5216.	46460.	27924.	79600.	69592.	1993.	12544.	84129.	-4529.	-4497.
2116	333.	47596.	28578.	76507.	58762.	1788.	11818.	72368.	4139.	4187.
2117	2036.	43009.	29019.	74065.	67147.	1910.	11574.	80631.	-6566.	-6533.
2118	7068.	22688.	36413.	66169.	80042.	1539.	8280.	89861.	-23692.	-23519.
2119	4685.	21654.	42488.	68827.	68333.	1378.	6105.	75816.	-6989.	-6944.
2120	541.	19248.	45631.	65419.	67014.	1321.	5316.	73651.	-8231.	-8100.
2121	-4289.	32550.	48343.	76605.	68531.	1271.	4729.	74531.	2074.	2182.
2122	-6026.	29547.	49082.	72604.	71256.	1265.	4687.	77209.	-4605.	-4466.

2123	-20747.	64040.	44250.	87542.	61067.	1302.	5633.	68003.	19540.	19463.
2124	-6902.	30253.	43524.	66875.	71047.	1354.	5927.	78328.	-11454.	-11388.
2125	-21448.	67080.	38583.	84215.	52688.	1481.	7453.	61622.	22593.	22601.
2126	-14125.	51093.	32419.	69387.	51494.	1659.	9579.	62732.	6656.	6690.
2127	-3070.	68058.	31597.	96586.	80160.	1696.	10928.	92785.	3801.	3733.
2128	-12537.	67510.	25415.	80388.	48235.	2054.	16430.	66719.	13669.	13628.
2129	-5615.	43098.	25197.	62680.	49456.	2127.	14758.	66342.	-3661.	-3700.
2130	-3132.	45764.	25776.	68408.	53253.	2054.	13945.	69252.	-844.	-828.
2131	-2868.	45109.	25269.	67510.	49626.	2105.	14545.	66276.	1234.	1155.
2132	2529.	41470.	28536.	72535.	66620.	1885.	11711.	80216.	-7681.	-7654.
2133	366.	37054.	30583.	68003.	66329.	1751.	10367.	78447.	-10444.	-10351.
2134	6685.	30103.	36923.	73711.	78319.	1512.	7934.	87765.	-14054.	-13888.
2135	-6704.	43800.	36121.	73216.	58935.	1536.	7850.	68321.	4895.	4944.
2136	592.	67405.	34359.	102356.	80417.	1600.	9178.	91195.	11161.	11125.
2137	-7842.	52769.	29678.	74606.	53259.	1798.	11064.	66121.	8485.	8434.
Average	-5698.	45879.	37289.	77471.	65772.	1671.	10016.	77458.	12.	58.

Water budget for case NM_sce5n (App. E2 Table 10)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	20538.	71776.	47101.	139415.	93287.	2182.	13632.	109102.	30314.	30303.
2013	1006.	52358.	32170.	85534.	63043.	2259.	16201.	81503.	4031.	4018.
2014	9824.	70622.	33001.	113448.	93404.	2275.	17261.	112939.	509.	488.
2015	1404.	51346.	31283.	84033.	63043.	2308.	17315.	82666.	1367.	1329.
2016	10750.	70077.	32512.	113339.	93442.	2331.	17917.	113689.	-350.	-313.
2017	2367.	50964.	30944.	84275.	63043.	2338.	17766.	83146.	1129.	1095.
2018	7774.	40680.	33300.	81754.	77352.	2308.	15725.	95385.	-13631.	-13608.
2019	12723.	27169.	41964.	81857.	90605.	1720.	10858.	103183.	-21326.	-21182.
2020	7723.	26296.	47309.	81328.	78102.	1515.	8272.	87889.	-6561.	-6526.
2021	3996.	22841.	50078.	76916.	76688.	1429.	7145.	85262.	-8346.	-8236.
2022	-1894.	39134.	52164.	89404.	78335.	1389.	6529.	86254.	3150.	3197.
2023	-3308.	35612.	52426.	84730.	80968.	1363.	6536.	88867.	-4137.	-4053.
2024	2637.	30525.	57302.	90464.	92533.	1292.	5443.	99268.	-8804.	-8769.
2025	535.	28573.	62892.	92000.	92358.	1228.	4250.	97836.	-5837.	-5678.
2026	-8751.	26990.	64355.	82595.	78102.	1219.	4055.	83376.	-781.	-743.
2027	-11826.	23207.	65334.	76714.	76696.	1218.	3917.	81831.	-5116.	-5004.
2028	-16426.	38726.	66257.	88557.	78610.	1213.	3773.	83595.	4962.	5054.
2029	-16406.	34690.	65695.	83979.	82062.	1208.	3904.	87174.	-3195.	-3048.
2030	-14163.	61462.	65384.	112684.	104777.	1199.	4118.	110093.	2590.	2841.
2031	-24539.	45801.	62281.	83543.	73679.	1192.	4356.	79226.	4316.	4451.
2032	-16825.	67386.	59661.	110222.	100229.	1218.	5054.	106501.	3722.	3907.
2033	-24961.	51313.	56221.	82573.	70453.	1238.	5512.	77203.	5370.	5434.
2034	-18199.	78819.	52495.	113115.	93447.	1322.	6666.	101436.	11679.	11669.
2035	-28537.	78264.	42632.	92360.	60910.	1602.	10116.	72628.	19732.	19742.
2036	-14795.	56588.	37548.	79341.	60075.	1814.	12040.	73929.	5412.	5366.
2037	-333.	77013.	36802.	113481.	93182.	1888.	13664.	108734.	4747.	4690.
2038	-9823.	74965.	29682.	94824.	56795.	2642.	20364.	79801.	15023.	14960.
2039	-293.	58654.	28270.	86631.	59822.	2523.	21641.	83986.	2645.	2575.
2040	5035.	42360.	29414.	76809.	60080.	2453.	19550.	82084.	-5275.	-5365.
2041	14663.	68418.	31584.	114665.	93616.	2446.	19257.	115319.	-654.	-635.
2042	2408.	68969.	26498.	97875.	58023.	3914.	24975.	86912.	10963.	10904.
2043	8717.	54340.	26123.	89180.	60725.	3347.	24894.	88966.	215.	169.
2044	11933.	38836.	27788.	78557.	60380.	2739.	21878.	84997.	-6440.	-6594.
2045	19733.	66294.	30272.	116299.	93992.	2793.	20979.	117765.	-1465.	-1430.
2046	6367.	67279.	25651.	99296.	58542.	4467.	26378.	89388.	9909.	9864.
2047	20973.	65397.	28690.	115059.	94616.	3178.	23552.	121346.	-6286.	-6251.
2048	11074.	45946.	28320.	85340.	63075.	2606.	21549.	87230.	-1890.	-1909.
2049	18354.	66658.	30363.	115376.	93832.	2723.	21009.	117564.	-2188.	-2190.
2050	8355.	47896.	29307.	85558.	63043.	2498.	20148.	85688.	-131.	-153.
2051	12668.	48465.	31482.	92614.	78268.	2398.	17992.	98658.	-6043.	-5955.
2052	11601.	50758.	33668.	96028.	81335.	2317.	15964.	99617.	-3589.	-3583.
2053	4997.	52434.	33340.	90771.	68692.	2115.	15640.	86447.	4324.	4301.
2054	7069.	47612.	33836.	88518.	77351.	2240.	14939.	94530.	-6012.	-5991.
2055	10574.	28383.	40817.	79774.	91544.	1751.	11251.	104547.	-24773.	-24683.
2056	7770.	26206.	46593.	80569.	78102.	1539.	8453.	88095.	-7526.	-7496.
2057	4434.	22804.	49557.	76795.	76688.	1447.	7280.	85414.	-8620.	-8519.
2058	-1299.	39159.	51703.	89563.	78449.	1404.	6643.	86496.	3067.	3102.
2059	-2420.	35615.	52062.	85256.	81477.	1374.	6624.	89475.	-4219.	-4148.

2060	-16622.	71214.	47092.	101684.	71443.	1491.	8124.	81058.	20625.	20517.
2061	-2429.	34972.	46663.	79206.	81656.	1528.	8401.	91585.	-12380.	-12346.
2062	-15410.	73886.	41248.	99725.	61182.	1761.	10642.	73586.	26139.	26084.
2063	-7205.	52481.	35381.	80658.	60068.	1997.	13260.	75325.	5333.	5270.
2064	4117.	74282.	35203.	113602.	93283.	2043.	14827.	110153.	3449.	3394.
2065	-6250.	72568.	28737.	95056.	57103.	3003.	21378.	81484.	13572.	13508.
2066	3064.	42759.	29731.	75554.	59164.	2507.	18779.	80449.	-4895.	-4954.
2067	4728.	47114.	30423.	82265.	63043.	2433.	17858.	83334.	-1069.	-1038.
2068	4158.	46349.	29757.	80264.	57763.	2526.	18574.	78863.	1401.	1333.
2069	10504.	43929.	33413.	87845.	77686.	2231.	15359.	95276.	-7430.	-7408.
2070	7734.	46403.	34722.	88859.	77138.	2095.	14095.	93328.	-4469.	-4474.
2071	9701.	37246.	39485.	86432.	89951.	1809.	11713.	103472.	-17039.	-17019.
2072	-519.	49598.	38894.	87973.	68631.	1853.	11499.	81982.	5991.	6002.
2073	8534.	74798.	37063.	120395.	93517.	1952.	13533.	109002.	11393.	11365.
2074	-1813.	54473.	33133.	85793.	63043.	2163.	15358.	80564.	5229.	5165.
Average	881.	50758.	40716.	92354.	76374.	2041.	13435.	91849.	505.	521.

Water budget for case NM_sce5ncb (App. E2 Table 11)

Model Year	[1] NES Bdry	[2]+[3] Rech&Wells	[4] Ocean In	[5] Total In	[6]+[7]+[8] Wells Out	[9] Stream Out	[10] Ocean Out	[11] Total Out	[12] In - Out	[alt 12] Dstorage
2012	20354.	72476.	46914.	139744.	93287.	2182.	13701.	109171.	30574.	30563.
2013	712.	53058.	31940.	85711.	63043.	2259.	16325.	81627.	4084.	4070.
2014	9504.	71322.	32772.	113598.	93404.	2275.	17400.	113079.	520.	502.
2015	1078.	52046.	31054.	84178.	63043.	2308.	17457.	82808.	1369.	1333.
2016	10424.	70777.	32283.	113485.	93442.	2331.	18062.	113834.	-349.	-312.
2017	2041.	51664.	30715.	84420.	63043.	2338.	17911.	83292.	1128.	1095.
2018	7444.	41380.	33052.	81876.	77352.	2308.	15851.	95512.	-13635.	-13607.
2019	12397.	27869.	41675.	81942.	90605.	1720.	10943.	103268.	-21327.	-21182.
2020	7397.	26996.	47001.	81394.	78102.	1515.	8338.	87955.	-6561.	-6526.
2021	3670.	23541.	49764.	76975.	76688.	1429.	7204.	85321.	-8346.	-8236.
2022	-2220.	39834.	51846.	89460.	78335.	1389.	6585.	86310.	3150.	3197.
2023	-3634.	36312.	52109.	84787.	80968.	1363.	6593.	88924.	-4137.	-4053.
2024	2311.	31225.	56974.	90510.	92533.	1292.	5490.	99315.	-8805.	-8769.
2025	208.	29273.	62551.	92032.	92358.	1228.	4283.	97869.	-5837.	-5679.
2026	-9077.	27690.	64011.	82625.	78102.	1219.	4085.	83406.	-781.	-743.
2027	-12152.	23907.	64988.	76742.	76696.	1218.	3945.	81858.	-5116.	-5004.
2028	-16752.	39426.	65911.	88586.	78610.	1213.	3801.	83623.	4963.	5054.
2029	-16732.	35390.	65351.	84008.	82062.	1208.	3933.	87203.	-3195.	-3048.
2030	-14488.	62162.	65046.	112719.	104777.	1199.	4154.	110129.	2590.	2841.
2031	-24866.	46501.	61944.	83578.	73679.	1192.	4392.	79263.	4315.	4451.
2032	-17151.	68086.	59333.	110268.	100229.	1218.	5099.	106546.	3722.	3907.
2033	-25287.	52013.	55897.	82623.	70453.	1238.	5562.	77253.	5370.	5434.
2034	-18525.	79519.	52180.	113175.	93447.	1322.	6726.	101496.	11679.	11669.
2035	-28862.	78964.	42353.	92455.	60910.	1602.	10210.	72722.	19732.	19742.
2036	-15121.	57288.	37276.	79443.	60075.	1814.	12142.	74031.	5412.	5366.
2037	-659.	77713.	36546.	113600.	93182.	1888.	13783.	108853.	4747.	4690.
2038	-10148.	75665.	29470.	94987.	56795.	2642.	20526.	79963.	15023.	14960.
2039	-619.	59354.	28066.	86800.	59822.	2523.	21811.	84156.	2644.	2575.
2040	4703.	43060.	29197.	76959.	60080.	2453.	19708.	82241.	-5282.	-5365.
2041	14336.	69118.	31362.	114816.	93616.	2446.	19409.	115471.	-655.	-636.
2042	2081.	69669.	26304.	98054.	58023.	3914.	25155.	87092.	10962.	10904.
2043	8394.	55040.	25928.	89362.	60725.	3347.	25072.	89144.	218.	169.
2044	11609.	39536.	27576.	78721.	60380.	2739.	22041.	85159.	-6438.	-6594.
2045	19408.	66994.	30054.	116456.	93992.	2793.	21136.	117921.	-1465.	-1430.
2046	6040.	67979.	25462.	99481.	58542.	4467.	26563.	89573.	9909.	9864.
2047	20651.	66097.	28483.	115231.	94616.	3178.	23718.	121512.	-6281.	-6250.
2048	10744.	46646.	28105.	85495.	63075.	2606.	21709.	87390.	-1894.	-1909.
2049	18024.	67358.	30145.	115527.	93832.	2723.	21165.	117720.	-2193.	-2190.
2050	8030.	48596.	29087.	85712.	63043.	2498.	20302.	85842.	-130.	-153.
2051	12341.	49165.	31250.	92756.	78268.	2398.	18134.	98800.	-6044.	-5955.
2052	11274.	51458.	33420.	96153.	81335.	2317.	16090.	99743.	-3590.	-3583.
2053	4671.	53134.	33097.	90902.	68692.	2115.	15771.	86578.	4324.	4301.
2054	6743.	48312.	33582.	88638.	77351.	2240.	15059.	94650.	-6012.	-5990.
2055	10248.	29083.	40532.	79863.	91544.	1751.	11340.	104635.	-24773.	-24683.
2056	7444.	26906.	46286.	80636.	78102.	1539.	8521.	88162.	-7526.	-7496.
2057	4108.	23504.	49244.	76855.	76688.	1447.	7340.	85475.	-8620.	-8519.
2058	-1625.	39859.	51386.	89620.	78449.	1404.	6700.	86553.	3067.	3102.
2059	-2746.	36315.	51745.	85314.	81477.	1374.	6682.	89532.	-4219.	-4148.

2060	-16949.	71914.	46788.	101753.	71443.	1491.	8194.	81128.	20625.	20517.
2061	-2755.	35672.	46359.	79276.	81656.	1528.	8471.	91655.	-12380.	-12346.
2062	-15736.	74586.	40970.	99820.	61182.	1761.	10738.	73681.	26139.	26084.
2063	-7538.	53181.	35120.	80763.	60068.	1997.	13374.	75438.	5325.	5270.
2064	3793.	74982.	34958.	113733.	93283.	2043.	14955.	110281.	3452.	3394.
2065	-6576.	73268.	28532.	95224.	57103.	3003.	21546.	81652.	13572.	13508.
2066	2741.	43460.	29508.	75709.	59164.	2507.	18930.	80600.	-4892.	-4954.
2067	4399.	47814.	30195.	82408.	63043.	2433.	18004.	83480.	-1072.	-1037.
2068	3835.	47049.	29533.	80417.	57763.	2526.	18725.	79013.	1404.	1332.
2069	10182.	44629.	33160.	87971.	77686.	2231.	15480.	95397.	-7425.	-7409.
2070	7410.	47103.	34460.	88973.	77138.	2095.	14208.	93441.	-4467.	-4474.
2071	9376.	37946.	39203.	86525.	89951.	1809.	11805.	103564.	-17039.	-17019.
2072	-845.	50298.	38613.	88066.	68631.	1853.	11592.	82076.	5991.	6002.
2073	8207.	75498.	36805.	120510.	93517.	1952.	13649.	109118.	11393.	11365.
2074	-2139.	55173.	32892.	85927.	63043.	2163.	15492.	80697.	5229.	5165.
Average	558.	51458.	40450.	92466.	76374.	2041.	13541.	91956.	510.	526.

Water budget for case NM_sce5nc (App. E2 Table 12)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	20447.	72476.	46712.	139635.	93287.	2182.	13709.	109179.	30457.	30446.
2013	862.	53058.	31756.	85677.	63043.	2259.	16320.	81622.	4055.	4041.
2014	9668.	71322.	32593.	113583.	93404.	2275.	17393.	113071.	512.	495.
2015	1245.	52046.	30875.	84166.	63043.	2308.	17448.	82799.	1367.	1331.
2016	10596.	70777.	32107.	113480.	93442.	2331.	18053.	113825.	-345.	-312.
2017	2209.	51664.	30537.	84410.	63043.	2338.	17902.	83282.	1128.	1095.
2018	7617.	41380.	32873.	81870.	77352.	2308.	15839.	95499.	-13629.	-13608.
2019	12565.	27869.	41492.	81927.	90605.	1720.	10928.	103254.	-21326.	-21182.
2020	7565.	26996.	46818.	81379.	78102.	1515.	8322.	87940.	-6561.	-6526.
2021	3838.	23541.	49581.	76961.	76688.	1429.	7190.	85307.	-8346.	-8236.
2022	-2052.	39834.	51663.	89446.	78335.	1389.	6571.	86296.	3150.	3197.
2023	-3466.	36312.	51927.	84773.	80968.	1363.	6579.	88910.	-4137.	-4053.
2024	2479.	31225.	56794.	90498.	92533.	1292.	5478.	99303.	-8804.	-8769.
2025	376.	29273.	62374.	92023.	92358.	1228.	4274.	97860.	-5837.	-5678.
2026	-8909.	27690.	63835.	82617.	78102.	1219.	4077.	83398.	-781.	-743.
2027	-11984.	23907.	64812.	76734.	76696.	1218.	3937.	81851.	-5117.	-5004.
2028	-16584.	39426.	65736.	88578.	78610.	1213.	3793.	83616.	4962.	5054.
2029	-16563.	35390.	65175.	84002.	82062.	1208.	3926.	87195.	-3194.	-3048.
2030	-14319.	62162.	64868.	112711.	104777.	1199.	4144.	110119.	2591.	2841.
2031	-24698.	46501.	61765.	83568.	73679.	1192.	4382.	79252.	4316.	4451.
2032	-16982.	68086.	59153.	110256.	100229.	1218.	5087.	106534.	3723.	3907.
2033	-25119.	52013.	55716.	82610.	70453.	1238.	5549.	77240.	5370.	5434.
2034	-18357.	79519.	51999.	113161.	93447.	1322.	6713.	101482.	11679.	11669.
2035	-28695.	78964.	42171.	92441.	60910.	1602.	10196.	72708.	19732.	19742.
2036	-14953.	57288.	37095.	79431.	60075.	1814.	12130.	74018.	5413.	5366.
2037	-491.	77713.	36367.	113589.	93182.	1888.	13772.	108842.	4747.	4690.
2038	-9980.	75665.	29300.	94984.	56795.	2642.	20523.	79961.	15023.	14960.
2039	-452.	59354.	27895.	86797.	59822.	2523.	21809.	84154.	2642.	2575.
2040	4872.	43060.	29022.	76953.	60080.	2453.	19701.	82234.	-5281.	-5365.
2041	14505.	69118.	31186.	114809.	93616.	2446.	19402.	115464.	-655.	-635.
2042	2250.	69669.	26138.	98057.	58023.	3914.	25158.	87095.	10963.	10904.
2043	8562.	55040.	25759.	89362.	60725.	3347.	25072.	89144.	218.	169.
2044	11776.	39536.	27402.	78714.	60380.	2739.	22034.	85153.	-6439.	-6593.
2045	19578.	66994.	29880.	116452.	93992.	2793.	21129.	117914.	-1462.	-1430.
2046	6209.	67979.	25299.	99486.	58542.	4467.	26568.	89577.	9909.	9864.
2047	20814.	66097.	28311.	115223.	94616.	3178.	23716.	121509.	-6287.	-6250.
2048	10914.	46646.	27931.	85491.	63075.	2606.	21702.	87383.	-1892.	-1910.
2049	18190.	67358.	29970.	115518.	93832.	2723.	21159.	117714.	-2196.	-2190.
2050	8197.	48596.	28910.	85703.	63043.	2498.	20294.	85834.	-131.	-153.
2051	12508.	49165.	31071.	92744.	78268.	2398.	18124.	98790.	-6046.	-5954.
2052	11443.	51458.	33240.	96141.	81335.	2317.	16078.	99731.	-3590.	-3583.
2053	4838.	53134.	32916.	90888.	68692.	2115.	15758.	86566.	4323.	4301.
2054	6911.	48312.	33402.	88625.	77351.	2240.	15046.	94637.	-6012.	-5991.
2055	10416.	29083.	40350.	79849.	91544.	1751.	11326.	104621.	-24773.	-24683.
2056	7612.	26906.	46103.	80621.	78102.	1539.	8505.	88147.	-7526.	-7496.
2057	4276.	23504.	49061.	76841.	76688.	1447.	7326.	85461.	-8620.	-8519.
2058	-1457.	39859.	51204.	89606.	78449.	1404.	6686.	86539.	3067.	3102.
2059	-2578.	36315.	51563.	85299.	81477.	1374.	6668.	89518.	-4219.	-4148.

2060	-16781.	71914.	46604.	101737.	71443.	1491.	8178.	81112.	20625.	20517.
2061	-2587.	35672.	46176.	79260.	81656.	1528.	8456.	91640.	-12380.	-12346.
2062	-15568.	74586.	40788.	99806.	61182.	1761.	10724.	73667.	26139.	26084.
2063	-7363.	53181.	34940.	80759.	60068.	1997.	13361.	75426.	5333.	5270.
2064	3964.	74982.	34780.	113725.	93283.	2043.	14945.	110271.	3454.	3394.
2065	-6408.	73268.	28363.	95222.	57103.	3003.	21546.	81651.	13571.	13508.
2066	2909.	43460.	29332.	75700.	59164.	2507.	18921.	80592.	-4892.	-4954.
2067	4566.	47814.	30017.	82397.	63043.	2433.	17995.	83471.	-1073.	-1037.
2068	3997.	47049.	29357.	80402.	57763.	2526.	18716.	79005.	1397.	1333.
2069	10350.	44629.	32980.	87959.	77686.	2231.	15467.	95384.	-7426.	-7410.
2070	7576.	47103.	34279.	88959.	77138.	2095.	14195.	93428.	-4469.	-4474.
2071	9544.	37946.	39021.	86512.	89951.	1809.	11791.	103550.	-17039.	-17019.
2072	-677.	50298.	38430.	88052.	68631.	1853.	11577.	82061.	5991.	6002.
2073	8376.	75498.	36624.	120498.	93517.	1952.	13636.	109106.	11393.	11365.
2074	-1971.	55173.	32712.	85915.	63043.	2163.	15480.	80686.	5229.	5165.
Average	724.	51458.	40272.	92454.	76374.	2041.	13531.	91946.	508.	523.

Water budget for case NM_sce5f (App. E2 Table 13)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	6086.	64922.	54597.	125604.	92449.	1827.	9605.	103881.	21723.	21666.
2013	-6357.	49890.	40620.	84152.	68264.	1909.	11201.	81374.	2778.	2772.
2014	1370.	65063.	40640.	107073.	92449.	1890.	11819.	106158.	915.	851.
2015	-5048.	48598.	39407.	82958.	68264.	1960.	11854.	82078.	880.	894.
2016	2657.	64444.	39873.	106973.	92477.	1927.	12285.	106689.	284.	269.
2017	-3943.	48136.	38801.	82994.	68264.	1988.	12201.	82453.	541.	587.
2018	853.	30040.	41799.	72691.	78276.	1968.	10830.	91075.	-18383.	-18365.
2019	8266.	22329.	52251.	82846.	91473.	1502.	7172.	100147.	-17301.	-17163.
2020	2382.	21774.	57552.	81708.	80338.	1372.	5632.	87341.	-5634.	-5589.
2021	-1755.	19321.	60377.	77943.	79000.	1316.	5001.	85317.	-7374.	-7263.
2022	-6751.	32538.	62840.	88627.	80403.	1278.	4539.	86220.	2407.	2505.
2023	-8518.	29410.	63334.	84226.	82733.	1265.	4514.	88513.	-4288.	-4150.
2024	-3451.	24555.	68433.	89536.	93075.	1232.	3821.	98128.	-8592.	-8508.
2025	-5224.	23408.	73802.	91985.	92839.	1213.	3129.	97181.	-5196.	-4985.
2026	-13589.	22357.	75089.	83858.	80338.	1211.	3048.	84597.	-739.	-628.
2027	-16946.	19656.	75923.	78632.	79008.	1211.	2983.	83202.	-4570.	-4399.
2028	-20734.	32100.	77205.	88572.	80677.	1208.	2829.	84714.	3858.	4006.
2029	-21180.	28966.	76925.	84711.	83826.	1201.	2878.	87905.	-3194.	-3002.
2030	-19211.	51711.	77116.	109616.	103905.	1185.	2888.	107978.	1637.	1906.
2031	-28350.	37617.	74644.	83912.	76187.	1188.	3042.	80416.	3495.	3651.
2032	-21948.	55315.	72474.	105841.	99362.	1192.	3305.	103860.	1982.	2213.
2033	-29449.	42366.	69706.	82623.	73217.	1188.	3533.	77938.	4684.	4805.
2034	-24855.	64752.	66156.	106053.	92582.	1216.	4046.	97845.	8208.	8325.
2035	-37537.	71589.	56668.	90721.	65329.	1342.	5856.	72527.	18194.	18240.
2036	-26316.	55304.	50730.	79717.	64249.	1495.	7092.	72836.	6881.	6913.
2037	-10886.	70590.	48311.	108015.	92476.	1568.	8268.	102312.	5703.	5704.
2038	-18254.	71210.	39835.	92791.	62236.	1832.	12391.	76459.	16332.	16321.
2039	-10630.	57517.	37180.	84066.	65329.	1960.	13644.	80933.	3133.	3107.
2040	-6300.	43901.	37693.	75294.	64244.	2022.	12722.	78988.	-3694.	-3750.
2041	3306.	64107.	39414.	106827.	92500.	1889.	12649.	107039.	-212.	-198.
2042	-6218.	63583.	34281.	91646.	62741.	2244.	16573.	81557.	10088.	10039.
2043	-1083.	52349.	33603.	84869.	65413.	2178.	16840.	84432.	437.	412.
2044	1320.	40301.	34816.	76437.	64244.	2192.	15095.	81531.	-5094.	-5158.
2045	9412.	61414.	37157.	107983.	92611.	2061.	14514.	109186.	-1203.	-1206.
2046	-1391.	61461.	32768.	92838.	62949.	2494.	18300.	83743.	9095.	9029.
2047	10553.	60067.	35352.	105973.	92858.	2168.	16568.	111594.	-5622.	-5572.
2048	3257.	44935.	35445.	83638.	68264.	2169.	14990.	85424.	-1786.	-1816.
2049	9596.	61390.	37039.	108025.	92592.	2089.	14756.	109436.	-1412.	-1416.
2050	1584.	46140.	36381.	84106.	68264.	2118.	14036.	84419.	-313.	-333.
2051	4887.	45944.	38174.	89004.	78859.	2098.	12841.	93798.	-4793.	-4748.
2052	4514.	46738.	40472.	91724.	81941.	2051.	11597.	95589.	-3865.	-3838.
2053	-812.	47394.	41165.	87747.	71124.	1865.	11099.	84088.	3659.	3694.
2054	753.	43226.	41429.	85408.	78270.	1990.	10826.	91087.	-5678.	-5621.
2055	5897.	22659.	49089.	77646.	92026.	1598.	8132.	101756.	-24110.	-23946.
2056	3640.	21636.	55422.	80699.	80338.	1416.	6119.	87873.	-7175.	-7122.
2057	-305.	19253.	58693.	77640.	79000.	1348.	5339.	85687.	-8047.	-7929.
2058	-5204.	32599.	61353.	88749.	80515.	1308.	4799.	86622.	2127.	2226.
2059	-6841.	29537.	62057.	84752.	83243.	1284.	4732.	89258.	-4506.	-4378.

2060	-21447.	64019.	57283.	99855.	73510.	1355.	5718.	80582.	19273.	19216.
2061	-7563.	30208.	56650.	79296.	83386.	1390.	5869.	90645.	-11349.	-11276.
2062	-21916.	66870.	51558.	96512.	65492.	1532.	7312.	74335.	22177.	22200.
2063	-14489.	51122.	45325.	81957.	64245.	1706.	9080.	75032.	6926.	6915.
2064	-3829.	68044.	43998.	108212.	92516.	1754.	10089.	104359.	3853.	3791.
2065	-12634.	67339.	36995.	91700.	62495.	2060.	14218.	78774.	12927.	12883.
2066	-5474.	43225.	37639.	75391.	64766.	2107.	12790.	79662.	-4272.	-4355.
2067	-2916.	45726.	38556.	81366.	68264.	2032.	12153.	82449.	-1082.	-1042.
2068	-3288.	45179.	37526.	79417.	62939.	2107.	12731.	77777.	1640.	1560.
2069	2119.	41718.	41260.	85098.	79354.	1922.	10797.	92073.	-6975.	-6943.
2070	-554.	37137.	43557.	80140.	78680.	1798.	9762.	90240.	-10100.	-9994.
2071	5800.	30108.	49898.	85806.	90552.	1556.	7736.	99843.	-14037.	-13872.
2072	-7413.	43751.	49383.	85721.	71398.	1585.	7720.	80703.	5018.	5074.
2073	-111.	67453.	47154.	114497.	92651.	1661.	8843.	103155.	11342.	11306.
2074	-7735.	52393.	42864.	87522.	68269.	1816.	10225.	80310.	7212.	7193.
Average	-6194.	45848.	50059.	89713.	78564.	1692.	9158.	89415.	299.	345.

Water budget for case NM_sce6sn (App. E2 Table 15)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	24239.	71814.	52243.	148296.	106832.	2173.	13013.	122019.	26277.	26261.
2013	5740.	52434.	38507.	96681.	75798.	2233.	14834.	92865.	3816.	3765.
2014	14830.	70570.	39680.	125080.	106932.	2273.	15937.	125141.	-61.	-44.
2015	6417.	51501.	37771.	95688.	75767.	2294.	15828.	93890.	1799.	1747.
2016	15947.	69936.	39220.	125103.	106996.	2343.	16541.	125880.	-777.	-750.
2017	7445.	50983.	37453.	95882.	75823.	2324.	16257.	94404.	1477.	1423.
2018	13396.	40368.	39890.	93654.	92118.	2266.	14184.	108568.	-14914.	-14868.
2019	18279.	27220.	48495.	93994.	104389.	1663.	8867.	114920.	-20925.	-20780.
2020	13139.	26320.	53952.	93411.	91870.	1468.	6467.	99804.	-6393.	-6366.
2021	9261.	22826.	56961.	89048.	90458.	1383.	5642.	97483.	-8435.	-8313.
2022	3422.	39115.	59133.	101670.	92104.	1342.	5090.	98536.	3134.	3180.
2023	1982.	35584.	59428.	96994.	94737.	1320.	5113.	101170.	-4176.	-4081.
2024	7902.	30516.	64683.	103101.	106302.	1272.	4349.	111924.	-8823.	-8784.
2025	5855.	28599.	70645.	105099.	106127.	1222.	3485.	110834.	-5735.	-5608.
2026	-3435.	27010.	72104.	95678.	91870.	1216.	3312.	96397.	-719.	-669.
2027	-6681.	23206.	73110.	89635.	90466.	1216.	3226.	94908.	-5273.	-5162.
2028	-11191.	38711.	74131.	101651.	92378.	1208.	3097.	96683.	4968.	5030.
2029	-11154.	34692.	73525.	97063.	95831.	1205.	3207.	100243.	-3180.	-3053.
2030	-8986.	61473.	73089.	125576.	118297.	1195.	3349.	122841.	2735.	2977.
2031	-19455.	45826.	69851.	96222.	87201.	1189.	3541.	91930.	4291.	4419.
2032	-11686.	67338.	67142.	122794.	113752.	1212.	4077.	119041.	3753.	3930.
2033	-19856.	51289.	63499.	94933.	83984.	1207.	4383.	89574.	5358.	5432.
2034	-13141.	78801.	59600.	125260.	106969.	1284.	5326.	113578.	11681.	11673.
2035	-23461.	78334.	49128.	104001.	74550.	1542.	8177.	84269.	19732.	19734.
2036	-9621.	56791.	44331.	91501.	73863.	1748.	10447.	86058.	5442.	5397.
2037	4790.	76959.	43746.	125496.	106720.	1839.	12248.	120807.	4689.	4643.
2038	-4581.	75287.	36869.	107576.	70502.	2657.	19188.	92348.	15228.	15160.
2039	4986.	58774.	35352.	99111.	73702.	2575.	20402.	96680.	2432.	2389.
2040	10321.	42561.	36424.	89306.	73863.	2432.	18170.	94466.	-5160.	-5271.
2041	19856.	68616.	38417.	126889.	107160.	2455.	17797.	127412.	-522.	-475.
2042	7698.	69003.	33673.	110373.	71632.	4021.	23861.	99515.	10858.	10807.
2043	14077.	54479.	33178.	101734.	74531.	3460.	23628.	101619.	116.	71.
2044	17169.	39005.	34764.	90938.	74181.	2786.	20433.	97401.	-6463.	-6558.
2045	24953.	66405.	37128.	128485.	107492.	2835.	19468.	129796.	-1311.	-1293.
2046	11612.	67566.	32834.	112012.	72172.	4603.	25266.	102040.	9971.	9914.
2047	26067.	65526.	35548.	127141.	108144.	3266.	22087.	133497.	-6356.	-6306.
2048	16175.	46102.	34875.	97152.	75846.	2700.	20093.	98640.	-1488.	-1495.
2049	23388.	66806.	37025.	127218.	107420.	2792.	19600.	129812.	-2593.	-2534.
2050	13643.	47989.	35794.	97426.	75791.	2538.	18691.	97020.	406.	358.
2051	17817.	48334.	37777.	103929.	91801.	2380.	16305.	110487.	-6558.	-6487.
2052	16884.	50943.	39881.	107709.	94867.	2283.	14165.	111316.	-3607.	-3572.
2053	10334.	52305.	39644.	102284.	82240.	2054.	13760.	98054.	4229.	4210.
2054	12687.	47689.	40599.	100975.	92118.	2176.	13307.	107600.	-6625.	-6572.
2055	16190.	28302.	47607.	92100.	105313.	1692.	9472.	116477.	-24377.	-24305.
2056	13198.	26227.	53256.	92680.	91870.	1492.	6694.	100056.	-7376.	-7360.
2057	9650.	22786.	56444.	88880.	90457.	1399.	5771.	97628.	-8748.	-8640.
2058	3959.	39132.	58705.	101796.	92217.	1356.	5187.	98760.	3036.	3074.
2059	2821.	35599.	59112.	97532.	95246.	1329.	5200.	101775.	-4243.	-4176.

2060	-11438.	71156.	53738.	113456.	84969.	1429.	6291.	92689.	20767.	20647.
2061	2639.	35149.	53316.	91105.	95174.	1485.	6770.	103429.	-12324.	-12297.
2062	-10209.	73874.	47658.	111323.	74822.	1694.	8673.	85189.	26134.	26092.
2063	-1963.	52672.	42139.	92848.	73855.	1925.	11705.	87485.	5362.	5294.
2064	9485.	74189.	42082.	125755.	106799.	2007.	13429.	122234.	3521.	3445.
2065	-996.	72953.	35886.	107842.	70764.	3099.	20278.	94141.	13701.	13605.
2066	8013.	42492.	36325.	86830.	71446.	2517.	17467.	91430.	-4600.	-4664.
2067	9821.	47044.	36998.	93862.	75803.	2458.	16542.	94804.	-941.	-929.
2068	9562.	46357.	36658.	92577.	71371.	2548.	17365.	91285.	1292.	1196.
2069	15744.	44124.	40036.	99905.	91264.	2192.	13775.	107230.	-7326.	-7318.
2070	12979.	46196.	41109.	100284.	90677.	2048.	12442.	105167.	-4883.	-4893.
2071	15088.	37233.	45991.	98312.	103476.	1758.	10032.	115267.	-16954.	-16935.
2072	4730.	49686.	44958.	99374.	82159.	1793.	9495.	93447.	5927.	5935.
2073	13761.	74923.	43489.	132174.	107038.	1906.	11745.	120689.	11485.	11435.
2074	3251.	54466.	39431.	97148.	75755.	2129.	13717.	91601.	5547.	5469.
Average	6085.	50796.	47556.	104437.	89938.	2030.	12036.	104004.	433.	447.

Water budget for case NM_sce7sf (App. E2 Table 16)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2012	9760.	64722.	58937.	133420.	106333.	1781.	8027.	116142.	17278.	17265.
2013	-1815.	49980.	45885.	94050.	80083.	1879.	8983.	90944.	3106.	3077.
2014	6452.	65130.	46460.	118042.	106344.	1864.	9647.	117855.	187.	127.
2015	-262.	48691.	44807.	93237.	80083.	1935.	9573.	91591.	1646.	1635.
2016	7900.	64175.	45726.	117801.	106350.	1904.	10042.	118297.	-496.	-507.
2017	1027.	48055.	44230.	93312.	80153.	1960.	9854.	91967.	1345.	1336.
2018	6469.	29770.	47711.	83949.	93391.	1911.	8646.	103947.	-19998.	-19968.
2019	13878.	22384.	59058.	95320.	105603.	1448.	5316.	112368.	-17048.	-16911.
2020	7967.	21794.	64850.	94611.	94470.	1333.	4288.	100091.	-5480.	-5429.
2021	3669.	19319.	67806.	90794.	93133.	1290.	3894.	98316.	-7523.	-7411.
2022	-1248.	32524.	70443.	101718.	94539.	1246.	3538.	99323.	2396.	2492.
2023	-3112.	29443.	70941.	97272.	96865.	1245.	3520.	101631.	-4358.	-4233.
2024	1952.	24539.	76387.	102878.	107211.	1219.	3077.	111508.	-8629.	-8518.
2025	352.	23418.	81965.	105735.	106974.	1213.	2594.	110780.	-5045.	-4837.
2026	-7991.	22358.	83229.	97597.	94470.	1211.	2513.	98195.	-597.	-455.
2027	-11547.	19642.	83961.	92056.	93141.	1211.	2470.	96823.	-4767.	-4562.
2028	-15143.	32069.	85337.	102263.	94813.	1205.	2349.	98367.	3896.	4035.
2029	-15682.	28978.	85000.	98297.	97958.	1201.	2392.	101551.	-3254.	-3059.
2030	-13755.	51771.	85147.	123162.	117790.	1182.	2384.	121356.	1806.	2084.
2031	-22918.	37704.	82535.	97320.	90077.	1188.	2528.	93793.	3527.	3667.
2032	-16501.	55311.	80355.	119165.	113248.	1189.	2718.	117154.	2011.	2238.
2033	-24072.	42320.	77525.	95773.	87100.	1185.	2906.	91191.	4582.	4718.
2034	-19429.	64619.	73930.	119120.	106467.	1197.	3254.	110918.	8202.	8322.
2035	-32318.	71691.	63680.	103053.	78886.	1295.	4397.	84579.	18475.	18519.
2036	-21166.	55447.	57584.	91865.	78093.	1442.	5616.	85150.	6715.	6751.
2037	-5668.	70578.	55161.	120070.	106360.	1518.	6664.	114543.	5527.	5539.
2038	-13338.	71275.	45634.	103572.	74549.	1809.	10214.	86572.	17000.	16945.
2039	-5727.	57210.	42871.	94354.	77929.	1952.	11482.	91363.	2991.	2946.
2040	-1197.	44078.	43781.	86663.	78084.	1965.	10580.	90629.	-3967.	-4055.
2041	8728.	64316.	45520.	118564.	106369.	1838.	10400.	118606.	-42.	-41.
2042	-1484.	63610.	39788.	101914.	74949.	2268.	14239.	91456.	10458.	10410.
2043	3743.	52352.	39127.	95222.	78011.	2204.	14542.	94758.	464.	414.
2044	6562.	40238.	40710.	87510.	78084.	2161.	12785.	93029.	-5519.	-5570.
2045	14733.	61457.	43105.	119296.	106483.	2020.	12059.	120563.	-1267.	-1246.
2046	3473.	61466.	38240.	103179.	75175.	2571.	15846.	93592.	9587.	9534.
2047	15775.	60043.	41118.	116936.	106756.	2152.	14037.	122945.	-6010.	-6000.
2048	8100.	44856.	40743.	93699.	80083.	2160.	12527.	94770.	-1071.	-1073.
2049	14883.	61217.	42678.	118778.	106491.	2065.	12326.	120882.	-2104.	-2086.
2050	6535.	46033.	41665.	94234.	80083.	2101.	11602.	93786.	448.	429.
2051	10050.	45944.	43661.	99656.	92744.	2055.	10444.	105243.	-5587.	-5539.
2052	9972.	46676.	46251.	102899.	95843.	1986.	9158.	106987.	-4088.	-4080.
2053	4667.	47449.	46842.	98958.	85007.	1782.	8478.	95267.	3691.	3733.
2054	6607.	43218.	47633.	97459.	93385.	1898.	8509.	103792.	-6333.	-6287.
2055	11554.	22767.	55941.	90262.	106160.	1535.	6246.	113941.	-23679.	-23510.
2056	9225.	21652.	62604.	93482.	94470.	1372.	4654.	100496.	-7015.	-6970.
2057	5043.	19248.	66039.	90330.	93133.	1316.	4126.	98574.	-8244.	-8115.
2058	207.	32582.	68931.	101721.	94651.	1266.	3711.	99627.	2094.	2196.
2059	-1506.	29532.	69670.	97695.	97375.	1261.	3668.	102303.	-4608.	-4465.

2060	-16201.	63985.	64532.	112316.	87393.	1297.	4214.	92905.	19411.	19327.
2061	-2354.	30101.	63910.	91657.	97272.	1347.	4526.	103145.	-11488.	-11401.
2062	-16903.	67110.	58220.	108426.	79158.	1473.	5283.	85914.	22512.	22520.
2063	-9412.	51217.	51675.	93480.	78085.	1645.	7033.	86763.	6717.	6765.
2064	1465.	68069.	50466.	119999.	106400.	1690.	8052.	116142.	3856.	3762.
2065	-7779.	67260.	42618.	102099.	74693.	2038.	11875.	88605.	13494.	13448.
2066	-977.	43170.	42996.	85189.	75949.	2112.	10751.	88812.	-3623.	-3643.
2067	1659.	45693.	43884.	91236.	80083.	2030.	10108.	92221.	-985.	-962.
2068	1744.	45119.	43245.	90108.	76243.	2087.	10654.	88984.	1124.	1050.
2069	7195.	41531.	47345.	96070.	93229.	1868.	8700.	103796.	-7727.	-7686.
2070	5094.	37063.	49626.	91783.	92564.	1739.	7600.	101903.	-10120.	-10026.
2071	11233.	30140.	56550.	97923.	104436.	1506.	5907.	111849.	-13926.	-13767.
2072	-2164.	43771.	55666.	97273.	85278.	1527.	5667.	92472.	4801.	4859.
2073	5150.	67367.	53430.	125946.	106535.	1598.	6551.	114685.	11262.	11217.
2074	-2924.	52601.	48381.	98058.	80091.	1781.	7871.	89743.	8315.	8265.
Average	-980.	45839.	56567.	101426.	92114.	1662.	7422.	101198.	227.	273.

Water budget for case NM_sce7srf (App. E2 Table 17)

	[1]	[2]+[3]	[4]	[5]	[6]+[7]+[8]	[9]	[10]	[11]	[12]	[alt 12]
Model Year	NES Bdry	Rech&Wells	Ocean In	Total In	Wells Out	Stream Out	Ocean Out	Total Out	In - Out	Dstorage
2075	794.	64685.	31218.	96696.	80093.	1795.	10690.	92577.	4119.	4098.
2076	-6462.	50073.	27732.	71342.	53253.	1901.	12411.	67565.	3777.	3763.
2077	1927.	65023.	28391.	95340.	80097.	1872.	13267.	95236.	104.	41.
2078	-5048.	48853.	26665.	70470.	53251.	1958.	13367.	68576.	1894.	1873.
2079	3293.	64271.	27717.	95281.	80106.	1915.	13867.	95888.	-607.	-644.
2080	-3846.	48190.	26179.	70523.	53321.	1987.	13774.	69081.	1441.	1412.
2081	1869.	29786.	29143.	60798.	67153.	1927.	11850.	80929.	-20131.	-20103.
2082	9344.	22383.	39262.	70989.	79363.	1457.	7238.	88059.	-17069.	-16929.
2083	3472.	21792.	44509.	69773.	68333.	1340.	5602.	75275.	-5502.	-5454.
2084	-855.	19317.	47260.	65722.	67014.	1295.	4977.	73285.	-7563.	-7447.
2085	-5774.	32520.	49776.	76523.	68420.	1253.	4476.	74148.	2375.	2471.
2086	-7638.	29422.	50301.	72085.	70747.	1251.	4474.	76471.	-4386.	-4265.
2087	-2577.	24538.	55497.	77458.	81094.	1224.	3789.	86106.	-8648.	-8518.
2088	-4195.	23418.	60864.	80088.	80855.	1213.	3085.	85153.	-5065.	-4844.
2089	-12531.	22361.	62127.	71957.	68333.	1211.	3007.	72551.	-594.	-440.
2090	-16021.	19642.	62824.	66445.	67021.	1211.	2954.	71187.	-4742.	-4537.
2091	-19632.	32062.	64151.	76581.	68694.	1205.	2796.	72695.	3886.	4023.
2092	-20166.	28972.	63845.	72651.	71839.	1201.	2860.	75900.	-3249.	-3065.
2093	-18250.	51763.	64004.	97517.	91671.	1183.	2875.	95728.	1789.	2053.
2094	-27448.	37770.	61393.	71715.	63961.	1188.	3023.	68172.	3543.	3683.
2095	-21009.	55311.	59311.	93613.	87131.	1190.	3299.	91620.	1993.	2219.
2096	-28717.	42331.	56493.	70107.	60759.	1185.	3520.	65464.	4643.	4780.
2097	-23974.	64575.	53111.	93712.	80349.	1199.	4023.	85571.	8141.	8254.
2098	-37018.	71662.	43534.	78177.	52416.	1302.	5914.	59633.	18544.	18586.
2099	-26021.	55560.	37553.	67091.	51501.	1454.	7330.	60285.	6807.	6857.
2100	-10389.	70672.	35547.	95830.	80120.	1524.	8758.	90403.	5428.	5441.
2101	-18106.	71478.	27853.	81224.	48070.	1820.	14156.	64046.	17178.	17157.
2102	-10492.	57227.	25334.	72069.	51336.	1966.	15765.	69067.	3002.	2965.
2103	-5893.	43985.	25714.	63806.	51493.	1979.	14314.	67786.	-3980.	-4038.
2104	4031.	64311.	27466.	95808.	80110.	1846.	14087.	96043.	-235.	-252.
2105	-6106.	63716.	23050.	80660.	48466.	2269.	19258.	69994.	10667.	10600.
2106	-933.	52459.	22325.	73851.	51423.	2220.	19649.	73292.	559.	523.
2107	1855.	40323.	23257.	65435.	51493.	2182.	17247.	70921.	-5486.	-5546.
2108	10065.	61426.	25542.	97034.	80232.	2029.	16303.	98564.	-1530.	-1561.
2109	-1205.	61651.	21806.	82252.	48684.	2575.	21243.	72503.	9750.	9691.
2110	11317.	59904.	24123.	95344.	80505.	2159.	18843.	101507.	-6163.	-6148.
2111	3323.	45062.	23402.	71786.	53251.	2179.	17090.	72519.	-733.	-766.
2112	10231.	61330.	25279.	96840.	80227.	2078.	16751.	99055.	-2215.	-2224.
2113	1551.	46159.	24108.	71818.	53252.	2121.	15965.	71337.	480.	441.
2114	5471.	46096.	25749.	77315.	66619.	2068.	14319.	83006.	-5690.	-5646.
2115	5292.	46490.	27928.	79710.	69561.	1986.	12542.	84089.	-4380.	-4357.
2116	144.	47631.	28561.	76337.	58762.	1789.	11829.	72379.	3958.	3998.
2117	1957.	43192.	28997.	74146.	67147.	1912.	11591.	80650.	-6505.	-6478.
2118	7086.	22695.	36405.	66186.	80042.	1539.	8284.	89865.	-23679.	-23507.
2119	4691.	21654.	42483.	68828.	68333.	1379.	6106.	75818.	-6990.	-6946.
2120	545.	19247.	45624.	65416.	67014.	1321.	5318.	73652.	-8236.	-8100.
2121	-4299.	32576.	48336.	76613.	68531.	1271.	4730.	74532.	2081.	2190.
2122	-6036.	29530.	49081.	72575.	71256.	1266.	4688.	77210.	-4635.	-4496.

2123	-20771.	64014.	44265.	87508.	61067.	1302.	5630.	67999.	19509.	19431.
2124	-6920.	30175.	43568.	66824.	71047.	1353.	5917.	78317.	-11493.	-11421.
2125	-21513.	67132.	38611.	84230.	52688.	1480.	7443.	61611.	22618.	22634.
2126	-14141.	51273.	32409.	69541.	51494.	1659.	9585.	62737.	6803.	6846.
2127	-3218.	68059.	31604.	96445.	80160.	1696.	10925.	92781.	3664.	3603.
2128	-12507.	67514.	25405.	80411.	48203.	2043.	16444.	66691.	13720.	13691.
2129	-5715.	43120.	25201.	62605.	49456.	2126.	14760.	66343.	-3737.	-3791.
2130	-3130.	45866.	25774.	68509.	53253.	2052.	13950.	69255.	-746.	-735.
2131	-3045.	45219.	25252.	67426.	49626.	2106.	14573.	66305.	1120.	1047.
2132	2304.	41323.	28529.	72156.	66620.	1885.	11719.	80224.	-8068.	-8035.
2133	510.	37060.	30652.	68222.	66329.	1749.	10331.	78409.	-10187.	-10094.
2134	6720.	30162.	36961.	73843.	78319.	1511.	7917.	87748.	-13905.	-13743.
2135	-6756.	43794.	36145.	73183.	58935.	1535.	7841.	68311.	4871.	4923.
2136	539.	67411.	34399.	102348.	80417.	1599.	9159.	91176.	11172.	11124.
2137	-7801.	52773.	29707.	74679.	53262.	1798.	11045.	66105.	8574.	8542.
Average	-5680.	45873.	37291.	77484.	65771.	1671.	10009.	77451.	33.	77.

Water budget for case NM_sce8sn (App. E2 Table 18)

Model Year	[1] NES Bdry	[2]+[3] Rech&Wells	[4] Ocean In	[5] Total In	[6]+[7]+[8] Wells Out	[9] Stream Out	[10] Ocean Out	[11] Total Out	[12] In - Out	[alt 12] Dstorage
2012	22919.	71251.	44893.	139063.	93392.	2352.	13877.	109621.	29442.	29422.
2013	3425.	51477.	30591.	85493.	63083.	2399.	16278.	81760.	3733.	3704.
2014	12280.	70084.	31590.	113955.	93487.	2468.	17370.	113325.	629.	623.
2015	3770.	50605.	29829.	84205.	63083.	2455.	17410.	82948.	1257.	1224.
2016	13274.	69490.	31124.	113888.	93560.	2549.	18043.	114151.	-263.	-249.
2017	4844.	50079.	29533.	84456.	63084.	2487.	17868.	83439.	1017.	987.
2018	10302.	40545.	31476.	82323.	77422.	2447.	15585.	95455.	-13131.	-13114.
2019	14715.	27182.	39146.	81043.	90665.	1778.	9947.	102389.	-21346.	-21227.
2020	9729.	26293.	44315.	80337.	78164.	1563.	7170.	86897.	-6560.	-6525.
2021	5997.	22842.	47310.	76149.	76751.	1462.	6253.	84466.	-8317.	-8191.
2022	124.	39157.	49337.	88619.	78399.	1422.	5624.	85445.	3173.	3219.
2023	-1222.	35521.	49640.	83940.	81030.	1394.	5663.	88088.	-4148.	-4069.
2024	4706.	30545.	54701.	89952.	92596.	1310.	4799.	98705.	-8753.	-8719.
2025	2605.	28558.	60501.	91665.	92418.	1236.	3831.	97485.	-5821.	-5667.
2026	-6650.	26982.	61961.	82293.	78164.	1225.	3648.	83037.	-744.	-714.
2027	-9749.	23198.	62948.	76398.	76759.	1219.	3554.	81532.	-5134.	-5006.
2028	-14314.	38742.	63863.	88291.	78673.	1215.	3414.	83302.	4989.	5076.
2029	-14256.	34681.	63264.	83688.	82124.	1211.	3533.	86868.	-3180.	-3039.
2030	-11972.	61420.	62828.	112277.	104830.	1208.	3683.	109720.	2556.	2784.
2031	-22327.	45753.	59725.	83152.	73738.	1194.	3899.	78831.	4321.	4458.
2032	-14625.	67487.	56971.	109833.	100284.	1232.	4499.	106015.	3818.	3993.
2033	-22791.	51270.	53518.	81997.	70510.	1259.	4857.	76625.	5371.	5454.
2034	-16047.	78778.	49670.	112401.	93502.	1358.	5908.	100767.	11634.	11671.
2035	-25658.	77873.	39832.	92047.	60965.	1676.	9383.	72023.	20024.	20034.
2036	-12188.	55903.	35327.	79042.	60130.	1911.	11855.	73897.	5145.	5101.
2037	2272.	76208.	34991.	113471.	93242.	2004.	13674.	108921.	4550.	4515.
2038	-7244.	74087.	28833.	95676.	56943.	2997.	21206.	81146.	14531.	14462.
2039	2346.	57802.	27473.	87621.	60038.	2865.	22369.	85272.	2349.	2315.
2040	7736.	41430.	28376.	77542.	60144.	2643.	19937.	82724.	-5183.	-5298.
2041	17325.	67617.	30319.	115261.	93741.	2697.	19425.	115862.	-601.	-562.
2042	5021.	68353.	26013.	99388.	58210.	4456.	25890.	88556.	10832.	10750.
2043	11210.	53884.	25537.	90630.	60934.	3984.	25611.	90529.	101.	64.
2044	14439.	38139.	26890.	79468.	60533.	3074.	22226.	85834.	-6366.	-6521.
2045	22319.	65667.	29095.	117082.	94128.	3133.	21161.	118422.	-1341.	-1295.
2046	8835.	66930.	25225.	100990.	58794.	5106.	27337.	91236.	9754.	9685.
2047	23430.	64629.	27717.	115776.	94781.	3588.	23843.	122212.	-6435.	-6379.
2048	13687.	45289.	27207.	86182.	63133.	2894.	21786.	87813.	-1631.	-1651.
2049	20785.	66141.	29136.	116063.	93997.	3036.	21191.	118224.	-2161.	-2110.
2050	10925.	47070.	28047.	86042.	63085.	2705.	20359.	86149.	-107.	-100.
2051	15004.	47787.	29804.	92595.	78332.	2559.	17794.	98685.	-6090.	-6019.
2052	14184.	50217.	31617.	96018.	81381.	2447.	15572.	99399.	-3381.	-3362.
2053	7456.	51707.	31359.	90522.	68751.	2223.	15341.	86316.	4206.	4178.
2054	9460.	47150.	32054.	88664.	77423.	2364.	14720.	94507.	-5843.	-5813.
2055	12610.	28338.	38403.	79350.	91604.	1811.	10535.	103950.	-24600.	-24520.
2056	9672.	26207.	43782.	79661.	78164.	1588.	7391.	87142.	-7482.	-7455.
2057	6404.	22806.	46850.	76060.	76751.	1481.	6381.	84612.	-8553.	-8443.
2058	716.	39150.	48909.	88776.	78512.	1435.	5724.	85671.	3105.	3132.
2059	-374.	35575.	49305.	84506.	81539.	1405.	5752.	88696.	-4191.	-4120.

2060	-14278.	70877.	44122.	100720.	71501.	1546.	7077.	80124.	20596.	20488.
2061	-276.	35083.	43780.	78588.	81714.	1583.	7547.	90844.	-12256.	-12226.
2062	-12639.	73359.	38490.	99210.	61237.	1838.	9890.	72965.	26245.	26191.
2063	-4774.	51784.	33436.	80447.	60123.	2096.	13175.	75395.	5051.	4971.
2064	6747.	73502.	33584.	113832.	93366.	2179.	14895.	110439.	3393.	3315.
2065	-3792.	71959.	28004.	96171.	57278.	3455.	22237.	82969.	13202.	13112.
2066	5595.	41607.	28580.	75782.	59236.	2690.	18993.	80919.	-5137.	-5203.
2067	7361.	46453.	29189.	83003.	63083.	2607.	18034.	83724.	-721.	-687.
2068	6793.	45423.	28702.	80918.	57838.	2753.	18975.	79567.	1351.	1252.
2069	12963.	43403.	31681.	88047.	77738.	2359.	15153.	95249.	-7203.	-7194.
2070	10231.	45742.	32734.	88707.	77194.	2199.	13737.	93129.	-4422.	-4431.
2071	12015.	37195.	37023.	86234.	90014.	1891.	11079.	102983.	-16749.	-16739.
2072	2021.	49368.	36099.	87488.	68689.	1935.	10685.	81310.	6179.	6182.
2073	10889.	74178.	34763.	119831.	93572.	2069.	13161.	108803.	11028.	11037.
2074	710.	53385.	31302.	85396.	63083.	2284.	15254.	80621.	4775.	4736.
Average	3249.	50337.	38767.	92353.	76455.	2191.	13223.	91868.	484.	500.

Water budget for case NM_sce8sf (App. E2 Table 19)

Model Year	[1] NES Bdry	[2]+[3] Rech&Wells	[4] Ocean In	[5] Total In	[6]+[7]+[8] Wells Out	[9] Stream Out	[10] Ocean Out	[11] Total Out	[12] In - Out	[alt 12] Dstorage
2012	8487.	64576.	51091.	124155.	92513.	1916.	8694.	103123.	21032.	20967.
2013	-3921.	49164.	37531.	82774.	68290.	1983.	9946.	80220.	2554.	2570.
2014	3743.	64421.	37784.	105948.	92529.	1995.	10631.	105156.	792.	760.
2015	-2590.	47995.	36443.	81849.	68290.	2036.	10606.	80932.	916.	945.
2016	5194.	63544.	37069.	105806.	92535.	2032.	11077.	105644.	162.	118.
2017	-1528.	47590.	35879.	81940.	68291.	2064.	10943.	81299.	641.	687.
2018	3066.	29799.	38684.	71549.	78353.	2045.	9499.	89897.	-18348.	-18318.
2019	10168.	22329.	49199.	81697.	91539.	1540.	5890.	98969.	-17273.	-17135.
2020	4369.	21772.	54811.	80952.	80405.	1390.	4724.	86518.	-5567.	-5523.
2021	200.	19323.	57829.	77352.	79067.	1331.	4283.	84681.	-7329.	-7218.
2022	-4772.	32546.	60323.	88097.	80471.	1299.	3888.	85657.	2440.	2537.
2023	-6523.	29415.	60805.	83697.	82801.	1281.	3870.	87952.	-4255.	-4112.
2024	-1455.	24555.	66077.	89176.	93143.	1242.	3375.	97760.	-8584.	-8495.
2025	-3098.	23375.	71603.	91881.	92907.	1214.	2849.	96969.	-5089.	-4909.
2026	-11431.	22326.	72811.	83706.	80405.	1211.	2770.	84385.	-679.	-554.
2027	-14759.	19645.	73593.	78479.	79075.	1211.	2722.	83009.	-4529.	-4343.
2028	-18406.	32097.	74823.	88514.	80745.	1207.	2595.	84547.	3966.	4093.
2029	-18907.	28974.	74484.	84551.	83893.	1201.	2637.	87731.	-3180.	-2992.
2030	-16843.	51785.	74533.	109475.	103970.	1188.	2621.	107778.	1697.	1973.
2031	-25863.	37611.	72036.	83784.	76252.	1188.	2791.	80231.	3553.	3704.
2032	-19475.	55378.	69763.	105666.	99427.	1197.	2987.	103612.	2054.	2283.
2033	-27016.	42301.	67089.	82374.	73278.	1192.	3213.	77684.	4690.	4819.
2034	-22384.	64650.	63396.	105662.	92647.	1234.	3592.	97473.	8189.	8307.
2035	-34945.	71298.	53466.	89819.	65383.	1379.	4899.	71661.	18158.	18210.
2036	-23361.	54974.	47644.	79257.	64305.	1554.	6274.	72133.	7124.	7163.
2037	-8207.	70076.	45248.	107118.	92540.	1645.	7432.	101616.	5501.	5504.
2038	-15518.	70181.	36931.	91594.	62307.	1945.	11509.	75761.	15833.	15797.
2039	-7913.	56350.	34539.	82976.	65374.	2063.	12772.	80210.	2766.	2747.
2040	-3469.	43000.	35061.	74592.	64300.	2107.	11813.	78220.	-3628.	-3686.
2041	6146.	63137.	36685.	105968.	92567.	1996.	11563.	106126.	-159.	-170.
2042	-3615.	62647.	31819.	90852.	62842.	2455.	15674.	80971.	9881.	9808.
2043	1479.	51481.	31230.	84191.	65539.	2358.	15950.	83846.	344.	327.
2044	3897.	39443.	32415.	75755.	64300.	2324.	14116.	80740.	-4984.	-5063.
2045	11924.	60565.	34546.	107035.	92707.	2188.	13356.	108251.	-1216.	-1234.
2046	1046.	60751.	30382.	92179.	63045.	2799.	17367.	83212.	8968.	8925.
2047	13022.	59369.	32837.	105229.	92963.	2323.	15442.	110728.	-5499.	-5496.
2048	5655.	44119.	32750.	82525.	68290.	2280.	13799.	84370.	-1845.	-1873.
2049	12117.	60739.	34341.	107197.	92664.	2215.	13539.	108417.	-1220.	-1242.
2050	4078.	45292.	33591.	82961.	68290.	2210.	12800.	83301.	-340.	-324.
2051	7202.	45341.	35210.	87753.	78918.	2184.	11530.	92633.	-4880.	-4835.
2052	7086.	46504.	37324.	90914.	82013.	2135.	10166.	94314.	-3400.	-3388.
2053	1617.	46707.	37829.	86152.	71184.	1930.	9578.	82693.	3460.	3473.
2054	3185.	42876.	38404.	84466.	78347.	2067.	9476.	89890.	-5424.	-5388.
2055	7705.	22663.	46136.	76503.	92093.	1642.	6953.	100689.	-24186.	-24023.
2056	5543.	21633.	52654.	79830.	80405.	1441.	5129.	86975.	-7145.	-7095.
2057	1681.	19259.	56061.	77001.	79067.	1367.	4546.	84980.	-7979.	-7864.
2058	-3210.	32604.	58758.	88152.	80583.	1332.	4085.	86000.	2151.	2254.
2059	-4825.	29503.	59470.	84148.	83310.	1300.	4040.	88650.	-4502.	-4370.

2060	-19240.	63880.	54311.	98951.	73571.	1385.	4688.	79644.	19307.	19238.
2061	-5498.	30207.	53831.	78540.	83449.	1417.	5001.	89867.	-11327.	-11263.
2062	-19412.	66760.	48230.	95578.	65548.	1591.	5971.	73110.	22468.	22480.
2063	-11923.	50690.	42179.	80946.	64301.	1782.	7946.	74029.	6917.	6896.
2064	-1386.	67386.	41063.	107062.	92579.	1838.	9011.	103429.	3633.	3570.
2065	-10232.	66194.	34345.	90307.	62537.	2205.	13253.	77995.	12312.	12292.
2066	-3048.	42431.	35007.	74390.	64788.	2191.	11738.	78717.	-4327.	-4367.
2067	-444.	45091.	35807.	80454.	68290.	2112.	11007.	81409.	-955.	-937.
2068	-875.	44505.	34897.	78526.	62985.	2204.	11713.	76902.	1624.	1543.
2069	4783.	41187.	38402.	84371.	79409.	1992.	9586.	90988.	-6617.	-6581.
2070	1718.	36905.	40431.	79054.	78741.	1868.	8469.	89078.	-10024.	-9926.
2071	7662.	30113.	46828.	84603.	90616.	1603.	6530.	98749.	-14146.	-13979.
2072	-5249.	43687.	46070.	84508.	71457.	1639.	6328.	79424.	5084.	5144.
2073	2414.	67227.	43709.	113349.	92716.	1737.	7368.	101821.	11529.	11491.
2074	-5353.	51669.	39521.	85836.	68303.	1892.	8835.	79030.	6806.	6784.
Average	-3833.	45454.	47264.	88885.	78626.	1760.	8214.	88600.	284.	329.

APPENDIX E2

North Marina Groundwater Model Review, Revision, and Implementation for Slant Well Pumping Scenarios

North Marina Groundwater Model Review,
Revision, and Implementation for
Slant Well Pumping Scenarios

August 31, 2017

Report and Appendices
(Revised)

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Executive Summary

California American Water (CalAm) is proposing construction of extraction wells for the Monterey Peninsula Water Supply Project (MPWSP). Two sites are being considered for a subsurface ocean water intake system, the CEMEX and Potrero Road sites (**Figure E-1**). This Technical Memorandum describes our review and revision of the North Marina Groundwater Model.[1] We used the revised model (NMGWM^{2016}) to calculate changes in groundwater levels (drawdown) and delineate the area where drawdown (cone of depression) is 1-foot or greater in response to proposed pumping.

The NMGWM^{2016} is an application of the U.S. Geological Survey Finite Difference Groundwater Flow Model (MODFLOW).[2] The NMGWM^{2016} is bounded on the west by the Pacific Ocean, and the inland model boundaries are bounded by adjacent portions of the Salinas Valley Groundwater Basin (**Figure E-1**). Four model layers represent the primary water-bearing zones.

NMGWM^{2016} revisions included additional water level calibration points in the CEMEX and Fort Ord areas, layer elevation modifications based on new geologic information, and aquifer properties estimated from test slant well[3] pumping monitoring data. Additionally, aquifer parameter zones were added and refined to include the former Fort Ord area A-Aquifer and Fort Ord Salinas Valley Aquitard (FO-SVA) to better represent groundwater conditions south of the Salinas River and improve model performance in that part of the model.

We evaluated NMGWM^{2016} performance by comparing model-calculated and measured water level data from the period October 1979 through September 2011. In general, the patterns of the water levels are similar, and the model generally captures measured trends. The relative error calculated from the standard deviation of the model errors and range of measured water levels in the model meets calibration criteria and ensures that model errors are only a small part of the overall model response. Model calibration was also assessed by comparing the magnitude, timing and longer term trends in observed and model-calculated water levels, a scatter plot of measured and model-calculated water levels, and analysis of model residuals (the difference between model-calculated and measured water levels). The results provide confidence that the model calculations are reliable estimates of the groundwater response to pumping, which was confirmed by simulating measured drawdown during test slant well pumping.

The residual analysis indicated a general lack of model bias, however model performance was less favorable in some model layers, and a bias between model-calculated water levels and model errors was identified for wells in Model Layer 4. The model discrepancies are attributed to (1) MODFLOW limitations for simulating steep vertical gradients and perched conditions in localized areas of

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[1] Geoscience Support Services, Inc., 2015, "*Monterey Peninsula Water Supply Project Groundwater Modeling and Analysis – DRAFT,"* prepared for California American Water and Environmental Science Associates, April 17, 2015.

[2] U.S. Geological Survey, 2000, "*MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*," Open-File Report 00-92.

[3] Slant wells are proposed for the CEMEX and Potrero Road sites. A conceptual diagram of an example slant well which is installed at a low angle relative to the horizontal is shown in **Figure 1.1**.

Model Layer 2 in the Fort Ord Area, (2) errors in the specified initial water levels for Model Layer 2 in the Fort Ord Area, (3) errors in the specified boundary condition water levels along the southern head-dependent flux boundaries, and (4) errors in the timing and magnitude of specified recharge and pumping. Most of these deficiencies were removed from the modeling analysis by utilizing the superposition approach.

The reliability of the NMGWM^{2016} for simulating drawdown from slant well pumping was confirmed using test slant well pumping data reported by Geoscience.[4] There is generally good agreement between the timing of drawdown and recovery, and at all locations model performance improved after the revision (**Figure E-2**). These improvements resulted from adjustments to the water transmitting and storage properties in the coastal parameter zones and modifying the conceptual geologic framework represented by the model in the Fort Ord Area.

Model scenarios were developed to estimate future groundwater level changes (drawdown) due to slant well pumping and assess the uncertainty in calculated drawdown in relation to model assumptions and input. Pumping and recovery scenarios were defined for the CEMEX and Potrero Road sites, and the 63-year pumping and 63-year recovery scenarios were simulated using monthly stress periods. Due to the complex nature of simulating recharge and discharge processes in the Salinas Valley Groundwater Basin, and the identified problems with specified initial water levels, boundary conditions, and background recharge and pumping, we applied the theory of superposition[5] to remove these deficiencies and isolate the calculated groundwater level changes (drawdown) resulting solely from proposed slant well pumping. The principal advantage of superposition is that it isolates the effect of the one stress (slant well pumping) from all other stresses operating in a basin (background recharge and pumping). The NMGWM^{2016} was thus utilized to calculate drawdown by employing the superposition approach under the following assumed conditions.

- Two well configurations and pumping rates (8 wells pumping and 2 wells on rotating standby collectively pumping at 24.1 MGD; and, 5 wells pumping and 2 wells on rotating standby collectively pumping at 15.5 MGD).[6]
- Two sea levels (2012 and projected 2073 sea levels).
- Some portion of the pumped water could be returned to the Basin. Four return water percentages were assumed (0%, 3%, 6%, and 12% of total pumping). The return water is used to replace Castroville Community Services District (CCSD) Well No. 3 pumping from Model Layer 6, and pumping from Model Layer 6 by irrigators within the Castroville Seawater Intrusion Project (CSIP) area (Model Layer 6 represents the 400-FT Aquifer). For the lower

[4] Geoscience Support Services Inc., 2016, "*DRAFT Monterey Peninsula Water Supply Project Monitoring Hydrogeologic Investigation Technical Memorandum (TM2) Well Completion Report and CEMEX Model Update*," prepared for California American Water, July 15, 2016.
[5] The "theory of superposition" states that solutions to the parts of a complex problem can be added to solve the composite problem. Superposition can therefore be utilized to isolate the effect of one stress from all other stresses operating in a basin.
[6] Future operations schedule provided by Brian Villalobos, Geoscience Support Services, Inc., written communication, May 3, 2016.

production rate (15.5 MGD), 4,260 acre-feet per year of additional water is assumed delivered to the CSIP area from the Pure Water Monterey Groundwater Replenishment Project (GWR).

Thirty four scenarios were developed to calculate drawdown and assess its sensitivity to model input and model assumptions. Model results are reported in maps that show the area where calculated drawdown (the cone of depression) is 1-foot or greater.

Based on an analysis of variations in model outputs with varying model inputs (sensitivity analysis), the most likely sources of uncertainty in the NMGWM^{2016} are associated with modeled sea level rise, specified hydraulic conductivity values, and assumed project operations including pumping rates and the relative contributions of groundwater from Model Layer 2 and Model Layer 4 to total slant well pumping. We therefore included two sea levels (2012 and 2073), variable hydraulic conductivity values, and different assumed model layer contributions to total slant well production to characterize the sensitivity of the model-calculated cone of depression. Model-calculated drawdown at the CEMEX site (24.1 MGD) is mapped in **Figure E-3**, and the model-calculated drawdown for 15.5 MGD is mapped in **Figure E-4**; the shaded areas in these figures represent the uncertainty in the model-calculated cone of depression due to simulated variations in the above factors. For 2012 sea level conditions, the maximum distance from the well field to the 1-foot drawdown contour was about 15,000 feet in Model Layer 2, and about 20,000 feet in Model Layer 4. Due to uncertainty in sea level rise, hydraulic conductivity, and pumping layer allocation distribution, the estimated distances ranged from less than 10,000 feet to 24,000 feet in Model Layer 2, and 12,000 to 24,000 feet in Model Layer 4. At the lower pumping rate (15.5 MGD), these distances range from about 6,000 feet to more than 17,000 feet in Model Layer 2, and almost 6,000 feet to 19,000 feet in Model Layer 4.

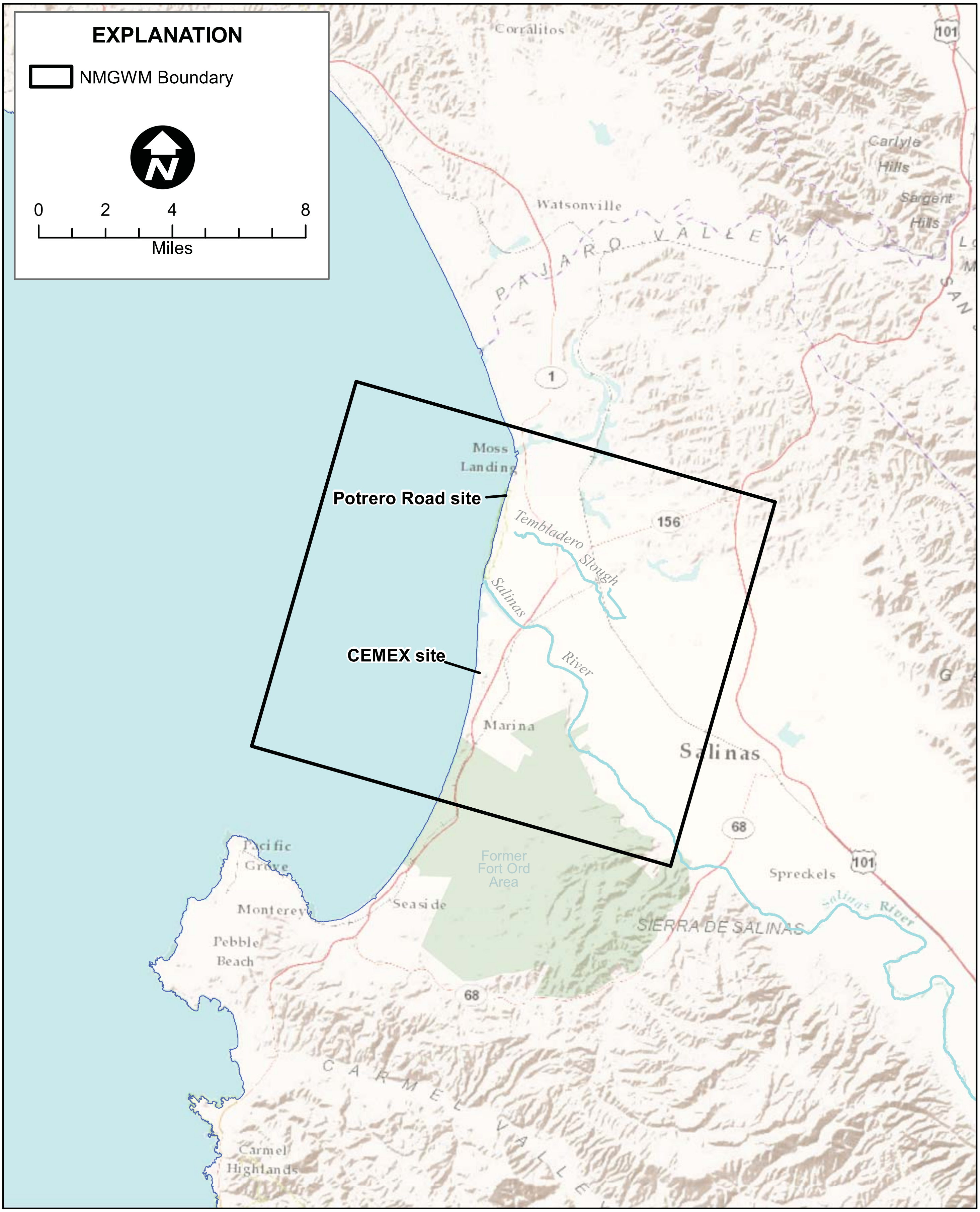
Similar drawdown maps for 24.1 MGD and 15.5 MGD pumping at the Potrero Road site are provided in **Figure E-5** and **Figure E-6**, respectively. The maximum estimated distances from the well field to the 1-foot drawdown contour ranged from about 19,000 to 27,000 feet, and 16,000 to almost 25,000 feet in Model Layer 2 as a result of uncertainty in sea level rise, hydraulic conductivity, and pumping layer allocation distribution for the 24.1 and 15.5 MGD pumping rates, respectively.

Groundwater "capture zone" boundaries were delineated using NMGWM^{2016} steady-state flow condition results and particle tracking using the MODFLOW computer code post-processer MODPATH.[7] For slant well pumping at the CEMEX site, the general size of the capture zone is greater in Model Layer 2 than Model Layer 4, and decreases with increasing simulated inland gradient (**Figure E-7**). Results are similar at the Potrero Road site, but there is no ocean water capture zone in Model Layer 4 because the slant wells would be screened only in Model Layer 2 (**Figure E-8**). These model results are consistent with the primary source of recharge to the wells being ocean water.

[7] Pollock DW, 2012, "*User Guide for MODPATH Version 6 – A Particle-Tracking Model for MODFLOW*," U.S. Geological Survey Techniques and Methods 6-A41.

Slant well pumping effects on the inland movement of saltwater were assessed using the NMGWM^{2016} and particle tracking with the MODPATH code. Particles were placed along the edge of the inferred 2013 seawater intrusion front in Model Layer 4 and Model Layer 6 (the 180-FT Aquifer and 400-FT Aquifer reported by MCWRA).[8] Results show that slant well pumping at the CEMEX site slows continued saltwater intrusion in the southern portion of Model Layer 4; slant well pumping at the CEMEX site has little to no effect on continued saltwater intrusion in the Model Layer 6. At the Potrero Road site, slant well pumping slows continued saltwater intrusion in the northern portion of Model Layers 4 and 6.

[8] Monterey County Water Resources Agency, 2014, "Historic Seawater Intrusion Map. Pressure 180-Foot Aquifer – 500 mg/L Chloride Areas." ; Monterey County Water Resources Agency, 2014, "Historic Seawater Intrusion Map. Pressure 400-Foot Aquifer – 500 mg/L Chloride Areas."



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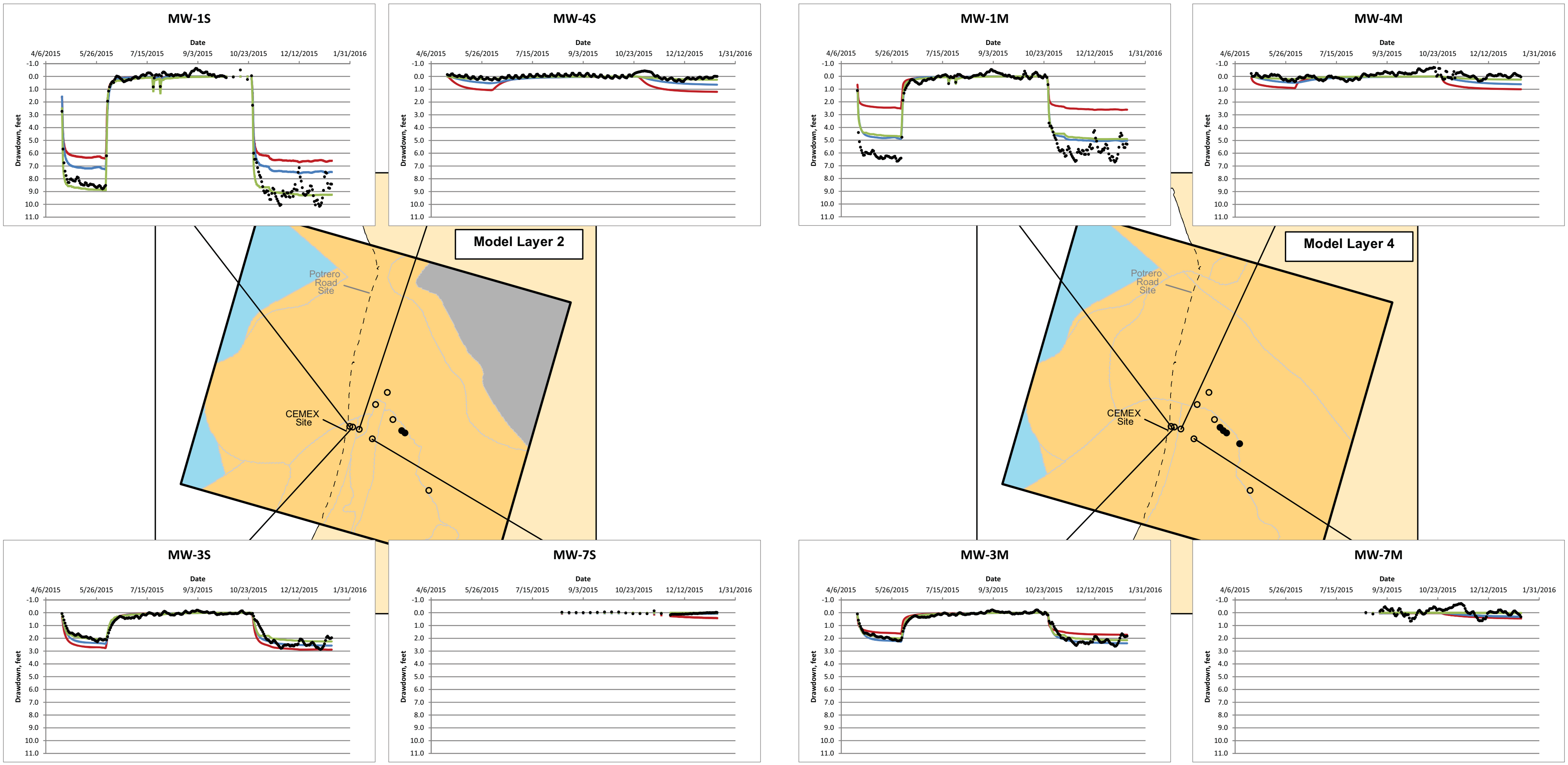
North Marina Groundwater Model (NMGWM) boundaries and relevant features.

Figure E-1

PROJECT: 5073

DATE: 11/15/2016



EXPLANATION

Wells

- ○ CEMEX Monitoring
- ● Other

- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell

Hydrograph:

- NMGWM[2015]
- NMGWM[2016]
- CEMEX
- Measured *

NMGWM[2015], NMGWM[2016] and CEMEX: Geoscience (2016)

Notes:
* measured values are detrended

Source:
Geoscience Support Services Inc., 2016, “DRAFT Monterey Penisula Water Supply Project Monitoring Well Completion Report and CEMEX Model Update,” prepared for California American Water, July 15, 2016.

0 2 4 8
Miles

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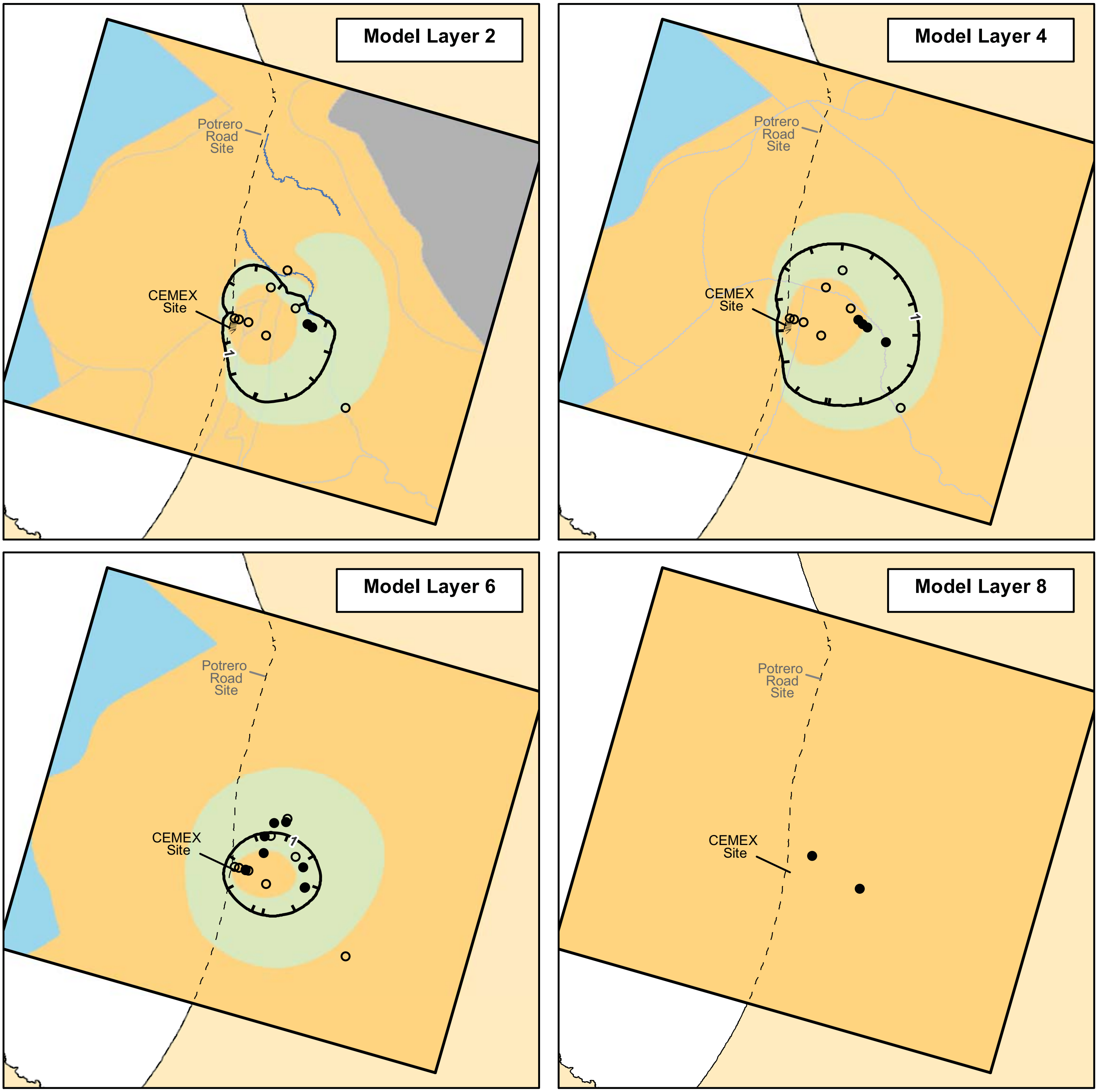
Measured vs. model-calculated drawdown in CEMEX monitoring wells during test slant well pumping.

Figure E-2

PROJECT: 5073

DATE: 11/15/2016



EXPLANATION

- River Model Cell
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell
- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone

Groundwater Level Decrease (Drawdown) Contour (ft) for CEMEX Site 24.1 MGD, 44/56 Layer 2/Layer 4 distribution, 2012 sea level, no return water

Only +/- 1 foot drawdown contours are shown. Contours not shown where groundwater level change is less than 1 foot.

Possible extent of 1 ft drawdown based on sensitivity tests

Slant Well

Wells

- CEMEX Monitoring
- Other

N

0 2 4

Miles

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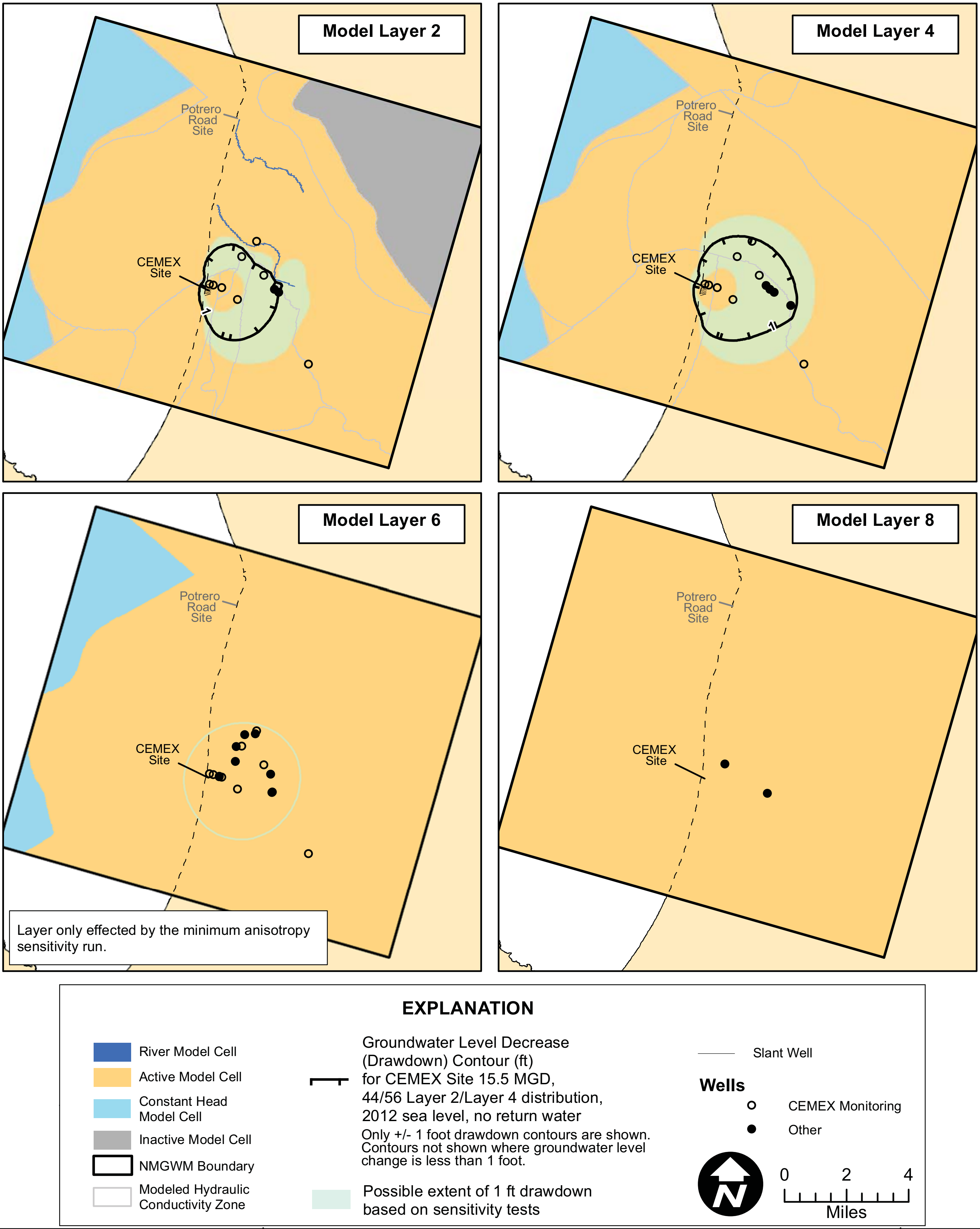
Uncertainty in calculated drawdown from slant well pumping at CEMEX site due to projected sea level rise, layer distribution, and hydraulic conductivity; 24.1 MGD.

Figure E-3

PROJECT: 5073

DATE: 8/19/2016



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Uncertainty in calculated drawdown from slant well pumping at CEMEX site due to projected sea level rise, layer distribution, and hydraulic conductivity; 15.5 MGD.

Figure E-4

PROJECT: 5073

DATE: 8/19/2016

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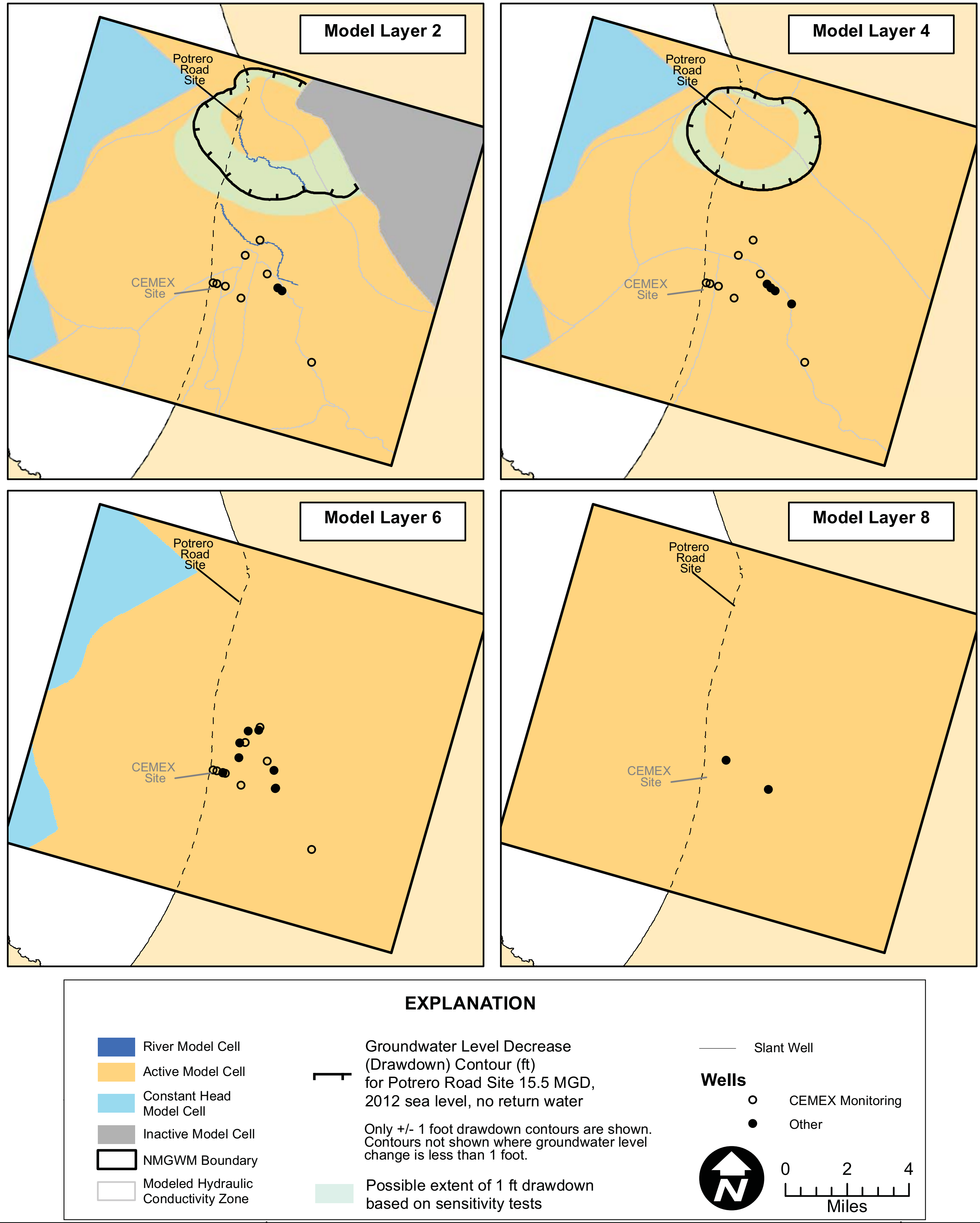
Uncertainty in calculated drawdown from slant well pumping at Potrero Road site due to projected sea level rise and hydraulic conductivity; 24.1 MGD.

Figure E-5

PROJECT: 5073

DATE: 8/12/2016



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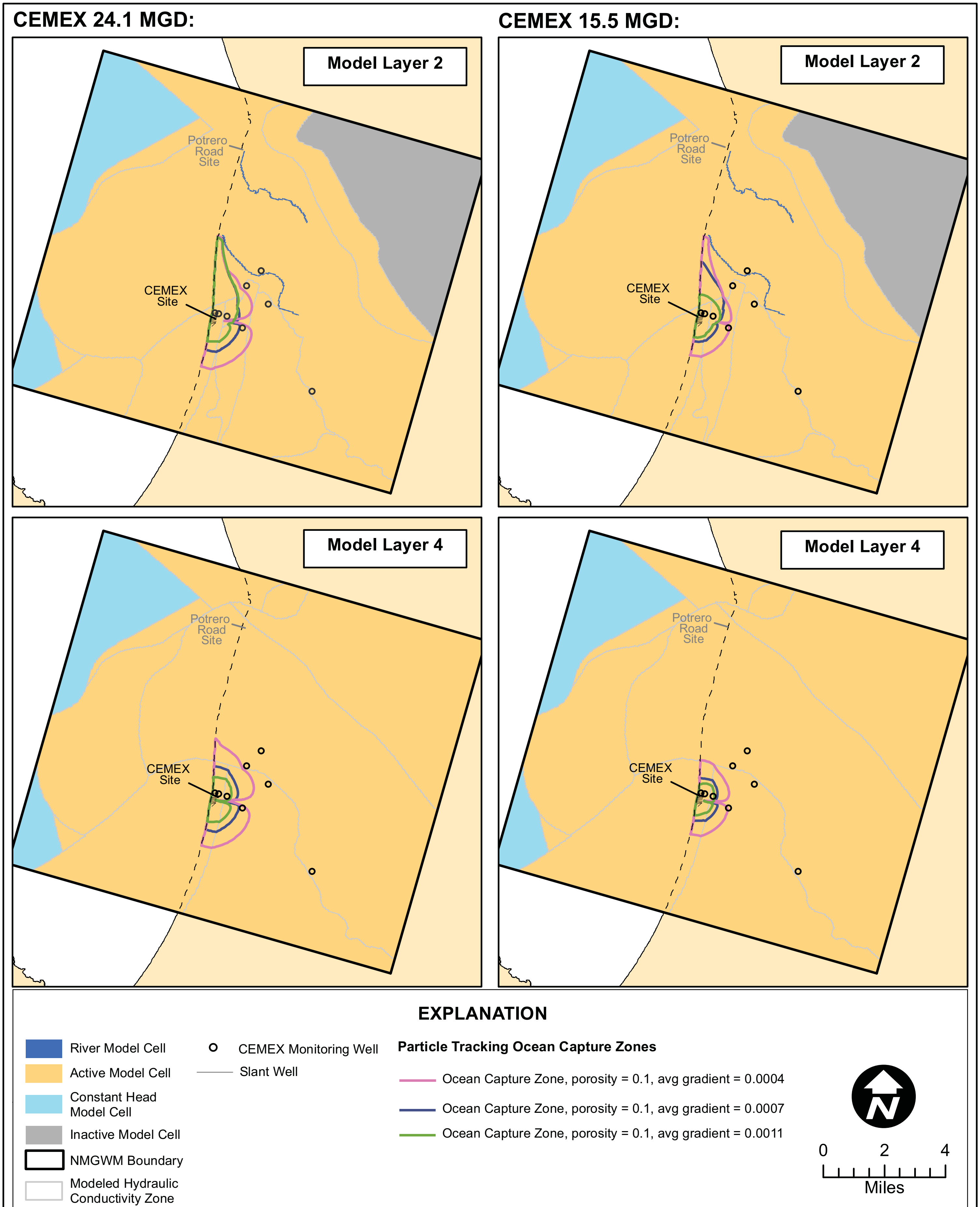
Uncertainty in calculated drawdown from slant well pumping at Potrero Road site due to projected sea level rise and hydraulic conductivity; 15.5 MGD.

Figure E-6

PROJECT: 5073

DATE: 8/19/2016



HYDROFOCUS INC. Solutions for Land and Water Resources

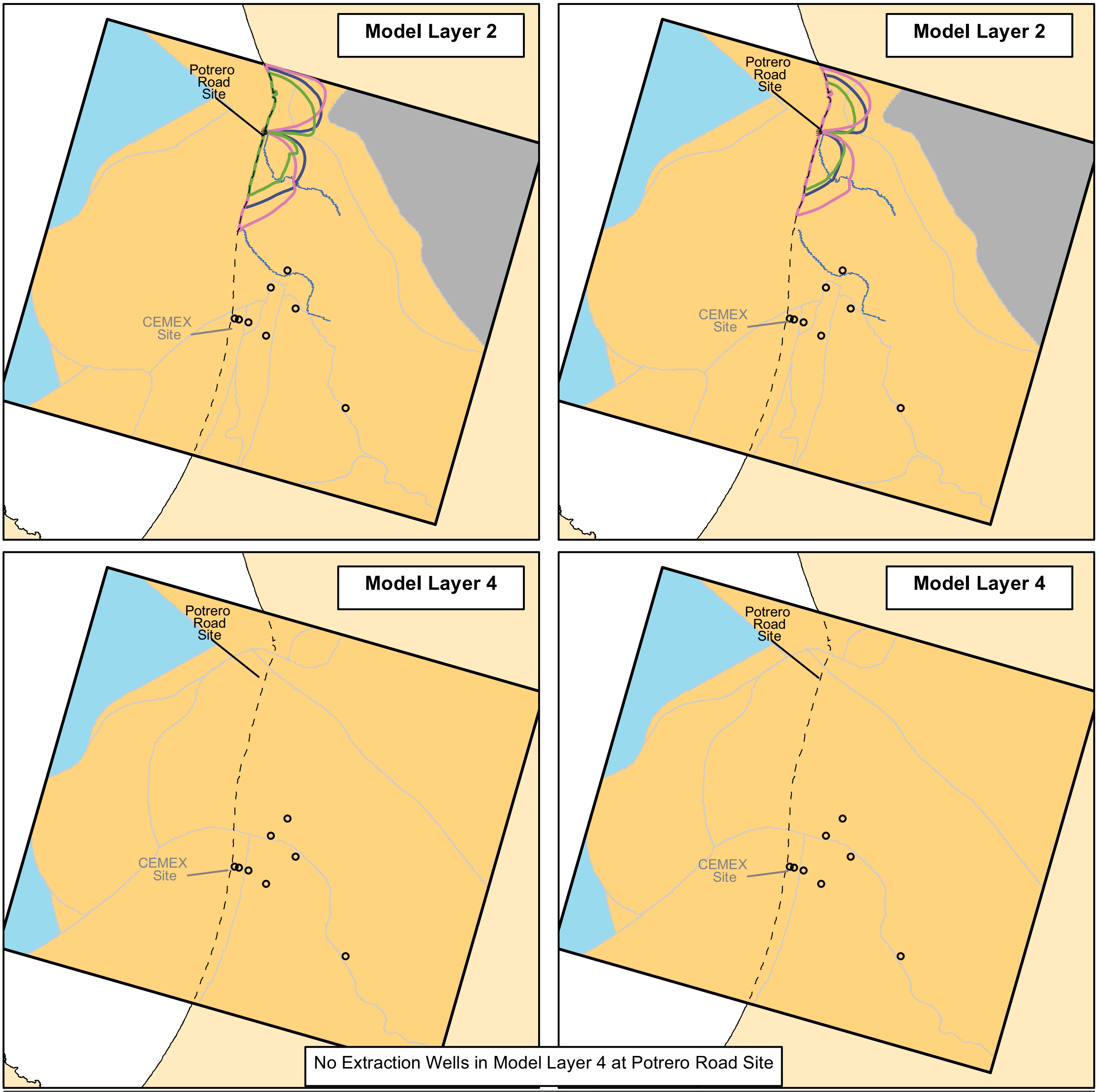
NMGWM[2016] calculated ocean capture zone with variable regional gradients, 63 years of slant well pumping (24.1 and 15.5 MGD), 44/56 Layer 2/Layer 4 distribution, 2012 sea level, CEMEX site.

Figure E-7

PROJECT: 5073

DATE: 11/15/2016

Potrero Road 24.1 MGD: | Potrero Road 15.5 MGD:



EXPLANATION

- River Model Cell
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell
- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone
- CEMEX Monitoring Well
- Slant Well

Particle Tracking Ocean Capture Zones

- Ocean Capture Zone, porosity = 0.1, avg gradient = 0.0004
- Ocean Capture Zone, porosity = 0.1, avg gradient = 0.0007
- Ocean Capture Zone, porosity = 0.1, avg gradient = 0.0011

0 2 4
Miles

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), 2012 sea level, Potrero Road site.

Figure E-8

PROJECT: 5073

DATE: 8/30/2016

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1.0 Introduction

California American Water (CalAm) proposes the Monterey Peninsula Water Supply Project (MPWSP). The MPWSP would employ low angle horizontal extraction wells, herein referred to as "slant wells" (**Figure 1.1**) to construct a subsurface ocean water intake system at one of two sites – the CEMEX or Potrero Road sites. **Figure 1.2** shows the locations of the CEMEX and Potrero Road sites within the general area encompassed by the North Marina Groundwater Model (NMGWM) discussed below.

The NMGWM was developed in 2008 to evaluate proposed groundwater extraction projects for the Monterey Peninsula area.[9] The NMGWM was updated in 2015 (herein referred to as "NMGWM^{2015}").[10] This Technical Memorandum describes our review and refinement of the NMGWM^{2015}. The refinements were based on new information and improved the reliability of model-calculated water-level changes (drawdown) in response to slant well pumping. Specifically, this Technical Memorandum reports results on the following tasks.

- Review NMGWM^{2015} to confirm reported hydraulic properties (horizontal and vertical hydraulic conductivity and specific storage), specified stresses (recharge and pumping), boundary conditions, and model-calculated groundwater levels and fluxes. (**Section 2.0**)
- Update NMGWM^{2015} using new information from borehole, monitoring well, and slant well pumping test data[11] (herein referred to as "NMGWM^{2016}"). (**Section 3.0**)
- Evaluate the NMGWM^{2016} by assessing history matching results (October 1979 through September 2011) and slant well pumping test results (April 2015 through January 2016). (**Section 4.0**)
- Employ NMGWM^{2016} to calculate drawdown from proposed slant well pumping at two sites (CEMEX and Potrero Road), two pumping rates (24.1 and 15.5 million gallons per day [MGD]), and a range of assumed return flows (0% to 12% of total slant well pumping). (**Section 5.0**)
- Characterize sensitivity of NMGWM^{2016} results to model assumptions and parameter values. (**Section 6.0**)

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[9] Geoscience Support Services, Inc., 2008, "*North Marina Groundwater Model Evaluation of Proposed Projects*," prepared for California American Water.

[10] Geoscience Support Services, Inc., 2015, "*Monterey Peninsula Water Supply Project Groundwater Modeling and Analysis – DRAFT,*" prepared for California American Water and Environmental Science Associates, April 17, 2015.

[11] Geoscience Support Services Inc., 2016, "*DRAFT Monterey Peninsula Water Supply Project Hydrogeologic Investigation Technical Memorandum (TM2) Monitoring Well Completion Report and CEMEX Model Update*," prepared for California American Water, July 15, 2016.

2.0 NMGWM[2015] Review

2.1 Conceptual Hydrogeology

Geologic Framework

The northern Salinas Valley and adjacent areas are underlain by groundwater bearing zones (herein referred to as "aquifers") that are classified as unconfined ("water table" aquifer), semi-confined, and confined.[12] Confining layers (herein referred to as "aquitards") are sufficiently permeable to transmit water vertically to or from the confined aquifer, but not permeable enough to laterally transmit water like an aquifer. Researchers however have concluded that subsurface three-dimensional heterogeneity and inter-fingering of fine- and coarse-grained deposits within Salinas Valley aquitards influence subsurface flow,[13] and therefore the aquitards in the northern Salinas Valley are an important component for modeling hydrogeologic conditions.[14]

Figure 2.1 presents a conceptual hydrogeologic representation of the depth distribution of aquifers and aquitards in the NMGWM area and the corresponding model layering (the "hydrogeologic framework"). **Table 2.1** summarizes the various aquifers and aquitards which have been represented in the layering of the NMGWM and discussed further below.

[12] The terms confined and semi-confined refer to the depth distribution of water levels in wells screened in different aquifers. In a confined aquifer, groundwater is under sufficient pressure such that the water level in a well screened solely in the confined aquifer rises above the elevation of the top of the aquifer. Semi-confined aquifers are intermediate between confined and unconfined aquifers. The extent of confinement is due to the heterogeneous nature of the subsurface fine-grained layers which causes spatially varying degrees of confinement.

[13] Fogg GE, LaBolle EM, Weissman GS, 1999, "Groundwater Vulnerability Assessment: Hydrogeologic Perspective and Example from Salinas Valley" *in* Assessment of Non-Point Source Pollution in the Vadose Zone (eds Corwin DL, Loague K, Ellswork TR), American Geophysical Union, Geophysical Monograph 108.

[14] Montgomery Watson, 1994, "Salinas River Basin Water Resources Management Plan Task 1.09 Salinas Valley Groundwater Flow and Quality Model Report".

Table 2.1 NMGWM and associated hydro-geologic descriptors		
NMGWM Layer	**Water-Bearing Zone**	**Hydro-geologic Descriptor**
1	--	Ocean
2	First	Dune Sand Aquifer A-Aquifer Perched Aquifer Perched "A" Aquifer 35-ft Aquifer -2 ft Aquifer
3		Salinas Valley Aquitard (SVA) Fort Ord Salinas Valley Aquitard (FO-SVA) Aquitard Transition Zone
4	Second	180-FT Aquifer 180-FT Equivalent Aquifer (180-FTE) Upper & Lower 180-FT Aquifer Pressure 180-Foot Aquifer
5		180/400-FT Aquitard Pressure 180/400-FT Aquitard
6	Third	400-FT Aquifer Pressure 400-Foot Aquifer
7		400/900-FT Aquitard Pressure 400-Foot/Deep Aquitard
8	Fourth	900-FT Aquifer Deep Aquifer Pressure Deep Aquifer

In the NMGWM area, the uppermost stratum represented by Model Layer 2 is the shallow aquifer. The names and characteristics of this upper water-bearing zone are variable throughout the NMGWM. For example, the Dune Sand Aquifer is present beneath the CEMEX site and consists of younger and older dune sand geologic units.[15] The A-Aquifer located beneath the former Fort Ord Area contains older dune sand deposits and overlies the Fort Ord-Salinas Valley Aquitard (FO-SVA).[16] The Perched "A" Aquifer located in the Salinas Valley floor area is composed of flood plain and valley basin deposits and overlies the Salinas Valley Aquitard (SVA).[17] These and other shallow aquifers are collectively represented by Model Layer 2.

The SVA and FO-SVA are composed of clay layers that, where present, reportedly confine underlying aquifers (for example, the 180-FT Aquifer).[18] The SVA underlies most of the northern Salinas Valley floor deposits and the FO-SVA is present beneath most of the former Fort Ord Area. The available information indicates that the FO-SVA thins towards the coast and is absent beneath

[15] *Ibid.* [10]
[16] Harding Lawson Associates, 1994, "Draft Final Basewide Hydrogeologic Characterization Fort Ord, California Volume I – Text and Plates," A Report Prepared for U.S. Department of the Army Corps of Engineers Sacramento District, June 10, 1994.
[17] *Ibid.* [11]
[18] Kennedy/Jenks Consultants, 2004, "Final Report Hydrostratigraphic Analysis of the Northern Salinas Valley," prepared for Monterey County Water Resources Agency, May 14, 2004.

the younger dune sand deposits;[19] at the CEMEX site, borehole logs for the younger dune sand deposits confirm this clay layer is absent, however thin clay layers are reported in borehole logs further inland indicating transition zones can exist between the aquitards and where they are absent near the coast.[20] The transition zones provide variable hydraulic connections between the overlying shallow aquifers and deeper aquifers[21] (see **Figure 2.1**). These aquitards and transition zones are collectively represented by Model Layer 3, and their water transmitting properties are variable throughout the NMGWM area.

Model Layer 4 represents aquifers underlying Model Layer 3 which includes the 180-FT Aquifer. The 180-FT Aquifer is composed of valley fill material including older alluvium and alluvial fan deposits[22] and is confined by the overlying SVA.[23] In the former Fort Ord Area, the 180-FT Aquifer is characterized as having "Upper" and "Lower" zones where gravels and sands corresponding to lower valley terrace deposits are separated by a thin intermediate confining clay unit, and the Upper 180-FT aquifer is confined by the overlying FO-SVA, where present.[24] The terrace deposits underlying the CEMEX site have been referenced as the "180-FT Equivalent (180-FTE)" Aquifer.[25]

The 180/400-FT Aquitard, represented by Model Layer 5, underlies the 180-FT aquifers (Model Layer 4) and overlies the "400-FT Aquifer."[26] The 400-FT Aquifer is composed of the Aromas Sands, which are eolian (wind-blown) and fluvial sands.[27] The 400/900-FT Aquitard separates the 400-FT Aquifer from deeper aquifers (the "900-FT Aquifer")[28]; the 400/900-FT Aquitard is represented by Model Layer 7 and the 900-FT Aquifer is represented by Model Layer 8. The 900-FT Aquifer is composed of Paso Robles Formation deposits, and is part of a deep aquifer system.[29]

Recharge and Discharge

Recharge to the Salinas Valley is primarily from deep percolation of rainfall and applied irrigation, surface water infiltration, and subsurface boundary inflows.[30] Water quality in the shallow aquifer

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[19] *Ibid.* [16]

[20] Borehole logs from MW-1, MW-3, and MW-4 do not contain clay, however the borehole log from MW-7 does contain a thin clay layer, as shown in **Figure 4** *Ibid.* [11]

[21] *Ibid.* [16] and *ibid.* [20]

[22] Greene HG, 1970, "Geology of the Southern Monterey Bay and its Relationship to the Ground Water Basin and Salt Water Intrusion," U.S. Geological Survey Open-File Report 70-141.

[23] *Ibid.* [18]

[24] Harding ESE, 2001, "*Final Report Hydrogeologic Investigation of the Salinas Valley Basin in the Vicinity of Fort Ord and Marina Salinas Valley, California*", prepared for Monterey County Water Resources Agency, April 12, 2001

[25] *Ibid.* [10]

[26] Hall P, 1992, "Selected Geological Cross Sections in the Salinas Valley Using GEOBASE," Earthware of California. Prepared for Monterey County Water Resources Agency Basin Management Plan, May 1992.

[27] Johnson MJ, 1983, "Ground Water in North Monterey County, California, 1980," U.S. Geological Survey Water-Resources Investigations Report 83-4023.

[28] *Ibid.* [18]

[29] Hanson RT, Everett RR, Newhouse MW, Crawford SM, Pimentel MI, Smith GA, "Geohydrology of a Deep-Aquifer System Monitoring-Well Site at Marina, Monterey County, California," U.S. Geological Survey Water-Resources Investigations Report 02-4003.

[30] Brown and Caldwell, 2015, "State of the Salinas River Groundwater Basin," Prepared for Monterey County Resource Management Agency Salinas, CA, January 16, 2015.

is poor and therefore groundwater pumped from the shallow aquifer is not typically used for irrigation or drinking.[31] Groundwater is pumped primarily from the 180-FT and 400-FT Aquifers,[32] and pumping currently exceeds recharge. The groundwater pumping has caused ocean water to flow inland. Monterey County Water Resources Agency (MCWRA) has mapped the inland movement of the seawater intrusion interface since 1944[33] and has estimated that 374,000 acre-feet of seawater intrusion occurred from 1970 to 1992 (average annual intrusion rate of 17,000 AF/yr).[34]

2.2 Model Construction

The NMGWM was first constructed in 2008 to simulate monthly groundwater conditions in the area shown in **Figure 1.2**. The NMGWM incorporated horizontal and vertical hydraulic conductivity, specific storage, monthly pumping, and monthly recharge from the Monterey County Water Resource Agency's Salinas Valley Integrated Ground and Surface Water Model (SVIGSM).[35] The SVIGSM represents the entire Salinas Valley Groundwater Basin; whereas, the NMGWM represents only a 149 square mile portion of the over 650 square mile SVIGSM area. The NMGWM includes part of the Pacific Ocean and about seven miles of the inland area southeast of the coastline (**Figure 2.2**).

The NMGWM employs the U.S. Geological Survey Finite Difference Groundwater Flow Model (MODFLOW),[36] and its rectangular finite-difference grid is comprised of square 200-ft by 200-ft model cells oriented along 300 rows and 345 columns. The grid is rotated 16 degrees clockwise from horizontal and approximately parallels the coastline. In the vertical direction, the NMGWM is comprised of eight-layers of variable thicknesses that are intended to represent aquifers and aquitards as summarized above and shown in **Table 2.1**. Four of the eight model layers (Layers 2, 4, 6, and 8) represent the primary water-bearing zones, Model Layer 1 is used exclusively to represent the ocean, and Model Layers 3, 5, and 7 represent the primary aquitards.

The NMGWM is bounded on the west by the Pacific Ocean, and inland the model is bounded by adjacent portions of the Salinas Valley Groundwater Basin (**Figure 2.3**). The ocean boundary is represented using specified water levels equal to sea level.[37] The specified water levels are referred to as "*constant head boundaries*" because they allow the model to simulate unlimited water flow in

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[31] *Ibid.* [18] and *ibid.* [24]
[32] *Ibid* [30].
[33] Monterey County Water Resources Agency, 2014, "Historic Seawater Intrusion Map. Pressure 180-Foot Aquifer – 500 mg/L Chloride Areas." ; Monterey County Water Resources Agency, 2014, "Historic Seawater Intrusion Map. Pressure 400-Foot Aquifer – 500 mg/L Chloride Areas."
[34] *Ibid* [30].
[35] Montgomery Watson, 1997, "*Salinas Valley Integrated Ground Water and Surface Model Update, Final Report*," May 1997.
[36] U.S. Geological Survey, 2000, "*MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*," Open-File Report 00-92.
[37] The water levels represent hydraulic potential, or hydraulic head, and are corrected for density differences between the high saline, denser ocean water relative to the less saline, less dense inland groundwater. These corrected water levels are referred to as "equivalent freshwater heads."

or out of these cells to maintain constant water levels throughout the simulation. The movement of groundwater across the inland NMGWM boundaries is represented by "*head-dependent flow boundaries*" (denoted as general-head boundaries in **Figure 2.3**). Head-dependent flow boundaries allow for water flow in or out of the model in proportion to the model-calculated water level at the boundary, a specified monthly water level external to the model boundary, and the specified subsurface water-transmitting properties. The specified external water levels at the NMGWM head-dependent flow boundaries were extrapolated from the distribution of monthly model-calculated water levels from the SVIGSM.

The spatial distribution of model inputs for monthly pumping, recharge, and stream losses and gains (Salinas River and Tembladero Slough) were extracted from the SVIGSM and applied to the NMGWM. Groundwater pumping is spatially distributed within the SVIGSM by individual model elements based on total pumping for model subregions. The total pumping for agricultural and urban portions of the model subregions was based on records collected, maintained, and reported annually by MCWRA,[38] and then distributed between SVIGSM elements.[39] Groundwater recharge for the SVIGSM was estimated from climate, land-use, and surface water supply data and also distributed by model element.[40] The timing and magnitude of the adjusted pumping, recharge, and simulated stream losses and gains were extracted from the SVIGSM and then distributed among NMGWM cells representing the corresponding elements and surface water features.[41]

2.3 Assessment of Model Inputs and Outputs

In September 2015, we received the most recent version of the NMGWM (herein referred to as NMGWM^{2015}). Additionally, in November 2015 we requested and received Microsoft Excel spreadsheets utilized to prepare head-dependent flow boundary water levels, pumping rates, recharge rates, and stream losses and gains from SVIGSM output for input to the NMGWM^{2015}. We compared modeled pumping, recharge, and stream infiltration with the corresponding SVIGSM output and found that the values agreed.

We ran the model (NMGWM^{2015}) and confirmed the model results were the same as reported. The model-calculated water levels at observation well locations were extracted, compared to the information reported for model-calculated and measured water levels, and found to agree with two exceptions.[42] The two exceptions were data associated with wells 14S/3E-6R1 and 14S/2E-14L01. In the NMGWM^{2015} data set, the water level measurement dates reported for well 14S/3E-6R1 were 11-days off, and well 14S/2E-14L01 was designated as representing Model Layer 6 in the NMGWM^{2015} but was identified by MCWRA as representing the 180-FT Aquifer (Model Layer 4). We

[38] Monterey County Water Resources Agency, 2014, Annual Groundwater Summary Reports, http://www.mcwra.co.monterey.ca.us/.
[39] Luhdorff and Scalmanini Consulting Engineers (LSCE), 2015, "*Hydrologic Modeling of the Monterey Peninsula Water Supply Project Using the Salinas Valley Integrated Ground and Surface Water Model*."
[40] *Ibid.* [39]
[41] *Ibid.* [10]
[42] Figure 37, Comparison of Measured Versus Model-Calculated Groundwater Elevations – Transient Model Calibration (Water Years 1980-2011), "*Appendix E2, Monterey Peninsula Water Supply Project Groundwater Modeling and Analysis*," Geoscience Support Services, April 17, 2015.

corrected the measurement dates for 14S/3E-6R1, and learned that the water levels in 14S/2E-14L01 are similar to Model Layer 6 wells and were therefore assigned to Layer 6 to be consistent with SVIGSM.[43] We therefore did not change the layer designation of 14S/2E-14L01.

We extracted, mapped, and reviewed model input values for horizontal and vertical hydraulic conductivity and storativity[44] from NMGWM^{2015} input files for comparison with values reported on maps.[45] The horizontal hydraulic conductivity values in the NMGWM^{2015} agreed with the reported maps,[46] and the mapped vertical hydraulic conductivity values also agreed with reported maps[47] with two exceptions. In Model Layer 1, there was a zone in the northwest part of the model where the reported map showed vertical hydraulic conductivity ranging from 0.21-0.40 feet per day (ft/d), but the model value was 4.0 ft/d. Because all active Model Layer 1 cells are constant-head cells that represent the ocean, the effect of the difference in conductivity values was insignificant. The second exception is related to mapped areas which show a range in vertical hydraulic conductivity values whereas the actual model input were constant values. The difference represents a mapping discrepancy, and had no influence on reported model results. The modeled storativity values are within the reported map ranges[48] with the following exceptions. In Model Layers 3, 4, and 5 the minimum modeled storativity values (0.000003, 0.000002, and 0.000002, respectively) are below the minimum reported values (0.000010, 0.000100, and 0.000010, respectively). In Model Layer 5, the maximum modeled storativity value (0.000800) is above the maximum reported value (0.000100). These differences also represent reporting discrepancies and had no influence on model results.

3.0 NMGWM^{2015} Revisions (NMGWM^{2016})

Table 3.1 summarizes modifications to the NMGWM^{2015} to improve overall model functionality and its correspondence with the conceptual model described in Section 2.1 above (herein referred to as the NMGWM^{2016}). Details on key modifications are summarized in the sections that follow **Table 3.1**. These include additional data from wells located south of the Salinas River, incorporating results from analysis of test slant well monitoring data, and refinements to model parameter zones utilized to represent the spatial distribution of water-transmitting and storage properties in the model.

[43] Johnson Yeh, Geoscience Support Services Inc., written communication, January 14, 2016.
[44] MODFLOW utilizes specific storage, and for this comparison storativity was calculated from modeled specific storage (Ss) multiplied by layer thickness.
[45] *Ibid* [10].
[46] Figure 31, Horizontal Hydraulic Conductivity of the NMGWM, in "*Appendix E2, Monterey Peninsula Water Supply Project Groundwater Modeling and Analysis*," Geoscience Support Services, April 17, 2015.
[47] Figure 32, Vertical Hydraulic Conductivity of the NMGWM, in "Appendix E2, Monterey Peninsula Water Supply Project Groundwater Modeling and Analysis," Geoscience Support Services, April 17, 2015.
[48] Figure 33, Storativity of the NMGWM, in "*Appendix E2, Monterey Peninsula Water Supply Project Groundwater Modeling and Analysis*," Geoscience Support Services, April 17, 2015.

Table 3.1
Modifications implemented in $NMGWM^{2016}$

$NMGWM^{2015}$	$NMGWM^{2016}$	Objective
General model file structure and program		
Simulation period split into parts to reduce file size, and model run using Groundwater Vistas project files. Groundwater Vistas is a proprietary graphical user interface.	Model files combined into a single simulation period, and input files modified to run with MODFLOW 2000 executable freely available from the USGS.	Simplified post-processing and eliminated the need for proprietary software; this increases accessibility to interested parties.
Layer Type		
Layer 1 layer type set to confined.	Layer 1 layer type set to convertible (can be confined or unconfined).	Layer 1 is effectively a boundary condition, and represents the ocean as a free-surface water body (See **Figure 3.2b**).
Layer Elevations		
Layer 1 specified with a uniform 1-ft thickness.	In model areas that represent the Pacific Ocean, Layer 1 has variable thickness and the top elevation set equal to mean sea level (0 feet).	Improved physical representation of the ocean by specifying the top of Layer 1 equivalent to the upper-most surface at mean sea level, and the bottom of the layer equivalent to the ocean bottom, thereby representing the entire water column above the ocean bottom.
In 72 Layer 1 ocean model cells located along the coast, the bottom of Layer 1 was above the specified constant head.	Layer 1 bottom elevations were modified to a value of 1.0 feet below mean sea level.	Prevented model cells with convertible layer type (confined or unconfined) from starting out dry causing the model simulation to abort.
In 26 inland cells along the coast, the Layer 1 bottom elevation (corresponding with land surface elevation) was below sea level.	Layer 1 bottom elevation set to the average bottom elevation of adjacent inland cells and sea level.	Improved representation of land surface for implementation of effects of sea level rise.
Aquifer bottom elevations were not updated with revised cross sections.	Modified aquifer bottom elevations based on updated cross sections and point elevation data.[49]	Represent most up-to-date geologic sections based on new borehole data.
Layer 2 bottom elevations in Fort Ord area equal to mean sea level (0 feet).	Layer 2 bottom elevation in Fort Ord area modified to correspond with top elevation of FO-SVA.	Represent A-Aquifer and underlying FO-SVA, which was missing from the $NMGWM^{2015}$.

[49] Johnson Yeh, Geoscience Support Services, Inc., written communication, March 4, 2016, shapefile of bottom elevation control points.

Table 3.1
Modifications implemented in NMGWM2016

NMGWM2015		NMGWM2016	Objective
Active Model Cells (IBOUND array)			
CEMEX dredge pond not represented.		Represented dredge pond identified on aerial photograph[50] as constant head cells in Layer 1.	Represent effect of dredge pond.
Model cells representing ocean were inactive in parts of Layers 1-6.		Activated all cells where ocean exists and specified as constant head cells.	Represent ocean water column overlying Layers 7 and 8.
Initial Heads			
CEMEX dredge pond not represented.		Specified initial heads equal to mean sea level in activated cells representing the dredge pond.	Specify initial heads in newly activated cells.
Model cells representing ocean were inactive in parts of Layers 1-6.		Specified initial heads in newly activated constant head cells in Layers 1-6 to equal equivalent freshwater heads.	
Head-Dependent (GHB) Flow Boundaries			
GHB and constant head cells overlapped at ocean/land interface causing discrepancies in model-calculated water budget terms.		Removed two (2) overlapping GHB and constant head cells.	Correct for overlapping boundary conditions and resolve problems with water budget terms.
Aquifer Properties			
Aquifer property arrays specified in MODFLOW's layer properties file (LPF file).		Modified LPF file to use MODFLOW parameter feature, and moved the calibrated aquifer property arrays to the multiplier array (MULT file). The parameter values are specified in the LPF and SEN files according to MODFLOW 2000 conventions.	Utilize MODFLOW 2000 to efficiently quantify model sensitivity to aquifer properties.
Layer 1	Aquifer properties specified the same as Layer 2.	Specified high values of horizontal and vertical conductivity and a specific yield of 1.0.	Minimize resistance to flow to mimic surface water body and simulate presence of ocean water.
Layer 1-6	Inactive cells in parts of ocean.		
Layer 2	Only one parameter zone representing Model Layer 2 near CEMEX site.	Split Model Layer 2 into multiple zones: dune sand (coastal); dune sand (inland); transition zone; and older dune sand. Updated horizontal and vertical conductivity values based on reported analysis of test slant well pumping.	Represent updated conceptual model and revised aquifer parameters; improve agreement between measured and model-calculated water level drawdown.

[50] Aerial photograph from: World Imagery - Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Table 3.1 Modifications implemented in NMGWM2016			
	NMGWM2015	NMGWM2016	Objective
Layer 3	No aquitard in Fort Ord area south of Salinas River.	Added Fort Ord Salinas Valley Aquitard and transition zone. Adjusted horizontal and vertical conductivity values based on reported aquifer tests and modeling studies to improve comparisons between measured and model-calculated water levels.	
Layer 4	One parameter zone to represent Model Layer 4 near CEMEX site.	Split Model Layer 4 into two zones and updated horizontal and vertical conductivity values based on test slant well pumping analysis.	
Calibration data			
	Calibration targets implemented within Groundwater Vistas.	Implemented in MODFLOW Head Observation (HOB) file.	Extract model-calculated water levels at specified model locations (for example, monitoring wells) without need for proprietary software; HOB file used by MODFLOW to calculate model sensitivity to input values.
		Added measured water level data from 6 well cluster sites located in the Fort Ord area.	Add data to model areas where data was lacking and improve overall model assessment.

3.1 Monitoring Wells Added South of Salinas River

We assessed model-calculated water levels south of the Salinas River using measured data from six well cluster sites in the Ford Ord Area (**Figure 3.1**). The well cluster sites have monitoring wells screened in different model layers. Five sites have monitoring wells screened within Model Layer 2 and Model Layer 4, and one site has monitoring wells screened within Model Layer 2, Model Layer 4, and Model Layer 6. We included the historical water level data reported for these wells[51] in our comparisons between model-calculated and measured water levels.

3.2 Test Slant Well Pumping

As part of another study, monitoring data collected during test slant well pumping was analyzed to re-calibrate a local model of the CEMEX area (the CEMEX groundwater model).[52,53] The CEMEX

[51] Historical water level elevation data extracted from yearly Annual Report of Quarterly Monitoring, Groundwater Monitoring Program Sites 2 and 12, OU2, OUCTP, and OU1 Off-Site Former Fort Ord, California. Available online at: http://fortordcleanup.com/

[52] *Ibid.* [11]

model has more model layers than the NMGWM, where CEMEX model layers 2 through 5 and model layers 6 through 8 correspond to NMGWM Model Layers 2 and 4, respectively. As part of that re-calibration effort, CEMEX model layers 2 through 5 were split into two subareas which generally correspond to mapped deposits of dune sand and older dune sand deposits. The horizontal and vertical hydraulic conductivity values in these two new subareas were increased during re-calibration relative to the values specified in the NMGWM2015. The same general area of CEMEX model layers 6 through 8 were also split into approximately inland and offshore subareas. Relative to the NMGWM2015, the horizontal hydraulic conductivity was decreased in the offshore subarea, but was increased in the inland subarea; the vertical conductivity was increased in both offshore and inland subareas. Specific storage values were generally increased in CEMEX model layers 2 through 8. These aquifer parameter changes in the CEMEX groundwater model were incorporated into the equivalent areas and model layers of the NMGWM2016.

3.3 Aquifer Parameter Zones

The spatial distribution of hydraulic conductivity (horizontal and vertical) and storage properties is represented in the NMGWM by parameter zones. Select NMGWM2015 parameter zones were modified and their parameter values updated to reflect information from the Fort Ord Area studies, updated geologic sections from new borehole and monitoring well data, and the slant well pumping test results described above.

South of the Salinas River, the NMGWM2015 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[54] based on the clay identified between the A-Aquifer and 180-FTE Aquifer in reported cross-sections.[55] The eastern boundary of the FO-SVA was delineated at the elevation difference between the upper dune sand and terrace deposits and the lower valley deposits. We noted that clay deposits corresponding to the FO-SVA transition and thin towards the coast, and published water level elevation maps show the horizontal water level gradients increase in this transition zone.[56] We therefore added a parameter zone west of the FO-SVA to represent the transition zone.

NMGWM layers were adjusted using information from reported geologic sections to re-contour the bottom of Model Layers 2, 4 and 6. In the CEMEX area, the average thickness of Model Layer 2 decreased by about 14 feet, Model Layer 4 increased in average thickness by almost 16 feet, Model

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[53] Measured water level data collected from CEMEX monitoring wells during test slant well pumping were de-trended. This removed the effect of background recharge and pumping which result in the measured regional hydraulic gradient and temporal water level trends. To remove these trends (de-trend the measured water-level data), Geoscience Support Services, Inc. subtracted the measured water levels in wells near the test slant well from measured regional trends in more distant wells to isolate the water-level changes (drawdown) due solely to slant well pumping. The drawdown was then analyzed using the local CEMEX model.
[54] *Ibid.* [24]
[55] *Ibid.* [11]
[56] Figure 4-1 in Ahtna Engineering Services, 2013, "Final Annual Report of Quarterly Monitoring October 2011 through September 2012 Groundwater Monitoring Program Sites 2 and 12, OU2, OUCTP and OU1 Off-Site Former Fort Ord, California." Prepared for Department of the Army U.S. Army Corps of Engineers, June 21, 2013.

Layer 6 increased in average thickness by almost 22 feet, and Model Layer 8 decreased in average thickness by about 23 feet. There was no change in the thicknesses of Model Layer 3, Model Layer 5, and Model Layer 7. Additionally, the bottom of Model Layer 2 was modified to better correspond with the reported top elevation of the FO-SVA.[57] **Figure 3.2** shows model section lines approximately aligned with the previously reported section lines[58] (**Figure 3.2a**), and the corresponding layering and parameter zones utilized in the NMGWM^{2016} (**Figures 3.2b-f**).

Figure 3.3 shows the NMGWM^{2016} parameter zones utilized to represent spatial variations in geologic materials and water-bearing properties, and compares the values specified for each zone to values from other hydrogeological and modeling studies (see **Figure 3.3d** for a listing of other data sources). **Figure 3.4** shows the NMGWM^{2016} specified values for horizontal hydraulic conductivity (**Figure 3.4a**), vertical hydraulic conductivity (**Figure 3.4b**), and specific storage (**Figure 3.4c**). 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.[59] Fewer (45%) vertical NMGWM^{2016} hydraulic conductivity parameter zones agree with previous studies (**Figure 3.3b**), but the number of previous studies are typically limited to only one study (the SVIGSM values) leaving considerable uncertainty in the likely range of values. In **Figure 3.3c**, most of the specific storage values agree with values from previous studies.

4.0 NMGWM^{2016} Evaluation

We conducted a performance assessment of the NMGWM^{2016} to support its use for calculating water level changes in response to slant well pumping. We considered an acceptable model as one constructed using an accepted computer code[60] and reasonable parameter values relative to our understanding of the hydrogeology and groundwater flow system. Moreover, the model-calculated water levels and groundwater volumetric budget terms should reasonably agree with the conceptual understanding of the groundwater system. For example, the model-calculated groundwater-flow direction should be inland where documented saltwater intrusion is occurring. Model-calculated water levels should also show the expected seasonal variability and longer-term

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[57] Based on FO-SVA top elevations reported in Harding Lawson Associates, 1994, "Draft Final Basewide HydroGeologic Characterization Fort Ord, California. Volume I - Text and Plates." A Report Prepared for U.S. Department of the Army Corps of Engineers, June 10, 1994; Harding Lawson Associates, 1999, "Draft Final OU 2 Plume Delineation Investigation Report Fort Ord, California." Prepared for United States Department of the Army Corps of Engineers, February 11, 1999. ; HydroGeoLogic, Inc., 2006, "Final 100% Engineering Design Report Volume 2 of 3 Groundwater Modeling and Design Analysis Operable Unit 1 Fritzsche Army Airfield Fire Drill Area Former Fort Ord, California." Prepared for U.S. Army Corps of Engineers Sacramento District, June 15, 2006. ; and *Ibid.* [10]
[58] Figures 4, 5, and 6 in *Ibid.* [10]
[59] *Ibid.* [11]
[60] The NMGWM^{2016} employs the numerical mathematical model MODFLOW, which is widely accepted and used and has been verified to produce numerically stable solutions.

trends identified by measured water levels. Finally, the volumetric water budget should be consistent with flux terms determined independently of the model (for example, water consumption and recharge based on climate data, water use, and so forth).

When models are utilized to project the outcome from altered hydrologic conditions, for example projecting the decline in water levels due to a planned pumping increase, a valid analysis will meet acceptable measures of numerical accuracy[61] and will consider how inaccurate the resulting projection might be due to uncertainty in model assumptions and model input. A valid analysis therefore considers the sensitivity of model-calculated water levels to model uncertainty, and includes information for planners to assess how the uncertainty may affect their decisions based on model results.

4.1 History Matching Assessment

"History matching" refers to the process of comparing model-calculated water levels with their corresponding measured values. The NMGWM2016 history matching assessment was conducted using measured water level data reported from October 1979 through September 2011. The difference between model-calculated and measured water levels is model error (referred to as "residuals"), and ideally residuals are small and randomly distributed both spatially and with time.

The relative error (RE) is defined as the standard deviation of the residuals (referred to as the root-mean-square error, or "RMSE")[62] divided by the range in measured water levels (the total change in measured water levels across the model domain). When the RE is small, model-calculated water levels are primarily influenced by modeled hydraulic conductivity, storage properties, and stresses (for example, recharge and pumping) and much less influenced by model error.[63] ESI Environmental, Inc. recommends a RE of less than 10% to 15% as sufficiently "small" model error and indicative of a reliable calibration.[64]

Anderson and Woessner[65] recommend additional tests to assess model performance and reliability:

1. Time-series plots of measured and model-calculated water levels (hydrographs) are compared to assess agreement between the magnitude, timing, and longer term trends in water level changes.

2. A scatterplot of measured water levels against model-calculated water levels to assess the correspondence between measured and modeled water levels. The points should plot along a

[61] Numerical accuracy refers to acceptable mass balance errors and water level closure criterion. All the slant well simulations we report had mass balance errors of 0.01% or less, and all converged for the pre-specified water level closure criterion of 0.0001 feet.
[62] The Root Mean Square Error (RMSE), which is the square root of the average of the squared residuals (the standard deviation), represents the "average" error or uncertainty in modeled water levels. The RMSE can be calculated globally for calibration points in the model domain, or individually for each observation point.
[63] Anderson M.P. and W.W. Woessner, 1992, "*Applied Groundwater Modeling*".
[64] ESI Environmental, Inc., 2004. Guide to Using Groundwater Vistas.
[65] *Ibid.* [63].

straight line with a slope of one, thus indicating that measured and model-calculated water levels agree.

3. A histogram of residuals to assess whether model errors are approximately randomly distributed.

4. Maps of residuals to reveal potentially poorly performing portions of the model.

The above tests can be applied to the entire model or selected parts of a model (for example, individual model layers). Variability in model performance is not unusual or unexpected, but their analysis can reveal model bias. Bias occurs when model errors tend to be mostly positive or mostly negative, and as a result model objectivity is limited because the model is inclined to over- or under-calculate water levels. Ultimately the decision of model acceptability is based on the weight of one or more of the above test results and their relevance for meeting modeling objectives (in this situation, concluding that the model acceptably projects the magnitude and distribution of the water level change due to coastal slant well pumping).[66]

Seasonal Water-Levels and Long-Term Variations

Time-series graphs can be used to assess whether the magnitude in model-calculated water levels is reasonable, and whether seasonal and longer term hydrologic variability is reproduced by the model. Time-series graphs of measured and model-calculated water levels are plotted in **Figure 4.1**. In general, model-calculated water levels mostly agree with measured water levels, and the model generally captures the measured trends presented in the hydrographs. The greatest discrepancies are in several Model Layer 2 wells in the Fort Ord Area, two Model Layer 4 wells in the Fort Ord Area, and late periods of the Model Layer 8 wells.

Shallow groundwater in the Fort Ord Area is influenced by the relatively low transmissivity of the aquifer and low vertical conductivity of the FO-SVA. Water levels in wells screened above the FO-SVA (MW-OU2-07-A, MW-OU2-29-A, MW-BW-31-A, and MW-BW-01-A) are noticeably higher than wells where the FO-SVA is less continuous or becomes absent (MW-BW-11-A and MW-2-15-180U). The modeled water levels clearly start too low, but as the simulation proceeds the agreement improves between model-calculated and measured water levels. We attribute these discrepancies to deficiencies in the prescribed initial water levels which originated from the SVIGSM.

The poorest performance in the Fort Ord Area occurs at MW-OU2-29-A where model-calculated water levels are consistently about 60-feet lower than measured. Measured water levels indicate that the vertical gradient between Model Layer 2 and Model Layer 4 at this location is near or greater than one (1.0). These large vertical gradients are indicative of limited vertical hydraulic

[66] Anderson and Woessner (1992) also recommend comparisons between contour maps of measured and model-calculated water levels. However, the available field data was insufficient to prepare reliable historical contour maps for the NMGWM area. Furthermore, contoured data can contain its own errors as a result of data uncertainty and contouring errors. The comparison of measured and model-calculated water levels was therefore not conducted as part of this model assessment.

connectivity between the two aquifers represented by the model layers, and the likely presence of an unsaturated interval between them that is not reproduced by the groundwater-flow model (groundwater in the uppermost water-bearing zone is likely perched).[67] Perched groundwater conditions are also inferred from the measured water levels in Fort Ord Area monitoring well MW-BW-01-A. Errors at these model locations are attributed in part to limitations in MODFLOW and its inability to simulate steep vertical gradients and perched conditions. This limitation appears to be localized, and model performance is relatively acceptable in other portions of the Fort Ord Area where the vertical gradients are less steep.

The agreement between seasonal and long-term water levels in Model Layer 4, Model Layer 6, and Model Layer 8 is generally superior to the comparisons to Model Layer 2 wells, but there are exceptions. The model-calculated water levels at two Model Layer 4 wells are noticeably greater than measured (wells MW-OU2-29-180 and MW-BW-02-180), and likely represent deficiencies in specified water levels for the southern head-dependent flux boundary. In Model Layer 8, the model-calculated water levels show greater seasonal variability than measured water levels. In 1998, the Castroville Seawater Intrusion Project (CSIP) reduced irrigation-related pumping by replacing groundwater use with recycled water. The model-calculated water levels after 1998 are generally lower and the seasonal highs and lows more pronounced than measured, indicating that modeled pumping may be greater than actually occurs in this portion of the $NMGWM^{2016}$ area. The discrepancies in Model Layer 8 well water levels therefore may indicate deficiencies in the prescribed stresses (recharge and pumping) which originated from the SVIGSM.

As a final test of long-term trends, we compared September 2011 model-calculated water levels from the $NMGWM^{2015}$ and $NMGWM^{2016}$ with measured water levels from recently constructed monitoring wells near the CEMEX site (measured water levels from June through October, 2015).[68] This comparison is limited because monitoring well construction occurred during December 2014 through July 2015, several years after the end of the history matching data set (September 2011). Model-calculated water levels therefore do not reflect recharge and pumping changes that occurred after September 2011. **Figure 4.2** shows generally good agreement between September 2011 model-calculated water levels and measured 2015 water levels. This suggests that model results are reasonable in areas where measured data were lacking for model construction and calibration, and that in this portion of the model domain annual hydrologic conditions have not likely changed substantially. The exceptions are monitoring wells MW-5S and MW-6M. Monitoring well MW-5S is perforated in the shallowest water-bearing zone, and including the FO-SVA as part of the update to $NMGWM^{2016}$ substantially improved model performance at the location of this monitoring well. The model-calculated water levels at monitoring well MW-6M are almost identical for both the $NMGWM^{2015}$ and $NMGWM^{2016}$, and are almost 20-feet greater than the corresponding measured value. The measured water level from monitoring well MW-6M is similar to measured and model-calculated water levels for Model Layer 6 which represents the 400-FT Aquifer, and may indicate

[67] When the vertical gradient between two aquifers exceeds one (e.g., a vertical gradient between aquifers represented by Model Layer 2 and Model Layer 4) the gradient exceeds natural drainage by gravity. Vertical gradients that exceed the limit of natural drainage can indicate the condition where the two aquifers are separated by an unsaturated zone (perched groundwater conditions).
[68] *Ibid.* [11]

the well is erroneously assigned to Model Layer 4.[69] These errors therefore are probably not indicative of a model deficiency.

Scatterplots and Histograms

Figure 4.3 shows the relationship between model-calculated and measured water levels. Ideally, points should fall on the 45-degree line (slope equal to 1.0) indicating model-calculated and measured values are identical. Plots were constructed for the entire model ("All Model Layers" in **Figure 4.3a**) and the relationships were quantified using linear regression. The strength of the linear relationships was determined by calculating the correlation coefficient (*r*).[70] In general, most model-calculated and measured water levels approach a diagonal line and linear regression indicates a slope approaching 1.0 (0.7). The RMSE reported in **Figure 4.3a** (10.2 feet) divided by the range in measured water levels over the entire model domain (161.6 feet) is about 6%, and substantially less than 10% to 15%, indicating that the relative error (RE) acceptably meets that calibration criteria. The low RE indicates that the residuals (model errors) are only a small part of the overall model response to the prescribed changes in recharge and pumping.

Figure 4.3b provides individual plots for Model Layers 2, 4, 6, and 8. In general, most model-calculated and measured water levels approach diagonal lines and linear regression indicates slopes approaching 1.0 (0.5 to 0.7). The strongest relationship (greatest correlation coefficient) is in Model Layer 6 and Model Layer 8 ($r = 0.8$), and weakest relationship is in Model Layer 2 ($r = 0.6$). The RE is 14% or less in Model Layers 4, 6 and 8, indicating that the calibration criterion is met in these layers. However, large residuals are calculated at two Model Layer 2 wells (MW-OU2-29-A and MW-BW-01-A), and as a result the RE is 30% (calculation not provided n **Figure 4.3b**). The large residuals are attributed to perched groundwater above the underlying layers. If the two perched wells are removed from the calculation, the RE in Model Layer 2 decreases from 30% to 16%. Large residuals also occur in Model Layer 2 during early portions of the historical run owing to errors in the specified initial conditions derived from the SVIGSM (**Figure 4.1a**). The limited geographic distribution of observation sites (all Model Layer 2 observation sites are located south of the Salinas River), the modeling limitations for reliably simulating localized perched conditions in the Fort Ord Area, and errors in the initial water levels specified for Model Layer 2 reduce model performance in Model Layer 2.

Histograms of the residuals are also plotted in **Figure 4.3**. Ideally, there should be both positive and negative residuals, random in sign and magnitude across the model grid, and normally distributed with a mean value of zero. For all layers combined, most of the residuals visually conform to the expected pattern and fall within a fairly narrow range that is close to zero, and the number of positive and negative residuals appear to be about the same (**Figure 4.3a**). Quantitatively, the calculated average of the residuals is 1.5 feet. The distributions of residuals are plotted by model layer in **Figure 4.3b**, and indicate they are likely not random in Model Layer 2 and Model Layer 8. In Model Layer 2, negative residuals are primarily due to the errors in prescribed initial water

[69] *Ibid* [11].

[70] The correlation coefficient (*r*) is a statistical measure of the strength of the relationship between the total variations in the model-calculated water levels and the measured water levels (or with the residuals).

levels derived from the SVIGSM, and as a result large residuals occur at the beginning of the simulation. In Model Layer 8, the reduction in pumping owing to CSIP project start-up is not adequately represented, and suggests that the modeled pumping from the SVIGSM may be too great.

In Model Layer 4, the histogram of residuals appear approximately random but there is a correlation between residuals and model-calculated water levels (r = 0.4). The positive correlation indicates that residuals tend to become more positive as the model-calculated water levels increase, which is evidence of simulation bias. There is no correlation between residuals and model-calculated water levels in Layers 2, 6 and 8 (r = 0), indicating the lack of bias in those layers. We obtained SVIGSM-calculated water levels[71] to investigate possible causes for the bias identified in **Figure 4.3b**.[72]

The NMGWM^{2016}-calculated water levels for Model Layer 4 and the SVIGSM-calculated water levels for the 180-FT Aquifer represented by the SVIGSM are compared in **Figure 4.3c** and show both models exhibit bias. Linear regression indicates generally good agreement between model-calculated and measured water levels (results from both models plot near diagonal lines and have slopes equal to 0.8), but the residuals in both models tend to become more positive as the model-calculated water levels increase (r values of 0.3 and 0.4). Hence, the bias identified in the NMGWM^{2016} is likely inherited from the SVIGSM.

Figure 4.3d provides a close inspection of the timing of water level changes and magnitude of the residuals in an example well represented by Model Layer 4 (02J01). Model-calculated and measured water levels show seasonal highs and lows, however during the beginning years of the simulation the modeled seasonal decline occurs about one- to two-months earlier than the measured decline and as a result their differences produce relatively large residuals. Later in the simulation period, the agreement in the timing of seasonal highs and lows improves and results in smaller residuals. **Figure 4.3d** reveals that the declining residuals with increasing time in Model Layer 4 are therefore likely the consequence of errors in the timing and magnitude of specified recharge and pumping (in other words, the bias in Model Layer 4 is attributed to deficiencies in the prescribed stresses). The timing and magnitude of recharge and pumping in the SVIGSM and NMGWM^{2016} are identical, and therefore both exhibit the same bias.

Residual Maps

The spatial distribution of residuals can identify potential geographic areas where the model may be a relatively poor representation of measured conditions. Ideally, their spatial distribution would be random (the signs of the median residuals are positive and negative and distributed randomly across the model), the absolute value of the medians variable (some residuals are relatively high and others are relatively low), and no clustering exists (the sign and magnitude of residuals do not group within particular model subareas).

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[71] Nick Watterson, LSCE, written communication, January 19, 2016.

[72] LSCE, "*Hydrologic Modeling of the Monterey Peninsula Water Supply Project Using the Salinas Valley Integrated Ground and Surface Water Model*," March 2015.

The spatial distribution of residuals is mapped in **Figure 4.4** and show that they are fairly random, and all model layers have positive and negative values. The observation well locations appear most limited in Model Layer 2 and Model Layer 8. In Model Layer 2, the measured water levels are limited to monitoring wells located in the Fort Ord Area, and the residual at one location is substantially greater than the other locations (median residual of -67 feet). This Model Layer 2 well was identified previously as problematic and likely representative of deficiencies in prescribed initial conditions and localized perched groundwater conditions (see Section "Seasonal Water-Levels and Long-Term Variations" above). In Model Layer 8, the observation wells are limted to locations near the coastline, and while the median residuals are fairly small (median residuals that range from 2 to -5 feet) the standard deviations are uniformly large at all wells. The large standard deviations are indicative of deficiencies in the magnitude and timing of pumping prescribed for Model Layer 8.

Volumetric Budget

The computer code ZONEBUDGET[73] was used to extract model simulated volumetric fluxes. Monthly fluxes are summarized and reported in **Figure 4.5** as average annual water budget components for 1979-2011. The water budget components represent the net inflow and outflow of water within the boundaries and at the edges of the NMGWM^{2016}. Groundwater pumping averaged over 66,000 acre-feet per year (AF/yr), and exceeded water table recharge by almost 27,000 AF/yr. An almost equal amount of recharge (22,600 AF/yr) flows into the model from the ocean, which is consistent with observed sea water intrusion that has been degrading groundwater quality in the basin for decades.

4.2 Test Slant Well Pumping

Model reliability for simulating drawdown from slant well pumping was assessed using test slant well pumping data.[74] The drawdown and drawdown recovery determined from measured water levels during and after cessation of test slant well pumping are plotted with the corresponding model-calculated drawdown in **Figure 4.6**. Additionally, the model-calculated drawdown from the NMGWM^{2015} and from a smaller focus area model developed by others (the CEMEX model)[75] is plotted in **Figure 4.6**. Comparison of the NMGWM^{2016} and NMGWM^{2015} results provide insight into performance changes as a result of our revisions, and comparisons with the CEMEX model results provide insight into the effects of model grid size on NMGWM performance (both the NMGWM^{2016} and NMGWM^{2015} employ a uniform 200-ft by 200-ft model cell grid, whereas the CEMEX model employs a uniform 20-ft by 20-ft model cell grid).

There is generally good agreement between the model-calculated and measured timing of drawdown and recovery, and at all locations the performance of the NMGWM^{2016} shows

[73] Harbaugh AW, 1990, "A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular three-dimensional ground-water flow model," U.S. Geological Survey Open-File Report 90-392, 46 p.
[74] *Ibid.* [11]
[75] *Ibid.* [11]

improvement relative to the NMGWM^{2015}. The improvement is the result of adjustments to the water transmitting and storage properties in the coastal parameter zones, as evident by comparisons at monitoring wells MW-1, MW-3, and MW-4, and modifying the model parameter zones in the Fort Ord Area, as evident by comparisons at monitoring well MW-7S. Specifically, **Figure 4.6** shows that drawdown was not observed in MW-7S, but the NMGWM^{2015} calculated declining water levels. The NMGWM^{2016}-calculated water levels are consistent with the measured water levels and showed no effects of drawdown after revising the conceptual framework in the southern part of the model.[76]

The measured drawdown is greater than NMGWM^{2016}-calculated water levels at monitoring wells located nearest the pumping well screens (MW-1S and MW-1M), and the comparison generally improves for monitoring wells located at increasing distances inland from the pumping well. The differences are due in part to the size of the square finite-difference model cells relative to the lengths and locations of the modeled monitoring and extraction wells. For example, the measured water level in a well represents a composite value for the variable aquifer materials adjacent to the well screen, whereas the modeled water level represents a point value at the center of the model cell. Similarly, aquifer properties and stresses can exhibit substantial spatial variability within the volume defined by a model cell, whereas the model is limited to constant values that represent "average" conditions within each model cell. As a result, the model cell size sacrifices detailed variations near the pumping wells, which limit model accuracy near the wells, but further from the well model performance improves.

4.3 Factors that Influence Model Calculations

A reliable groundwater-flow model is one that can produce field-measured water levels and groundwater flow within an acceptable range of error. Error exists because information on the real world system is always incomplete, and the field information that is available has associated errors (for example, measurement error or the assignment of monitoring wells to incorrect aquifers). The most likely sources of error in the NMGWM^{2016} could arise from neglecting potential processes (for example, density effects on groundwater flow and the hydraulic effect of future sea level changes) and uncertainty associated with modeled boundary conditions, specified hydraulic conductivity values, and assumed project operations. Background on these potentially important processes is provided below, and the sensitivity of model-calculated drawdown to the most relevant factors is discussed in Section 6.0 "Uncertainty."

[76] The drawdown in MW-7S calculated by NMGWM^{2015} declines over time, and is contrary to the measured drawdown which is essentially constant and zero. The CEMEX model and NMGWM^{2016} both calculate a constant drawdown of zero in MW-7S, which agrees with measured conditions. However, MW-7S is located near the boundary of the CEMEX model, and the specified conditions at the model boundary maintain constant water levels near the boundary regardless of the magnitude and timing of slant well pumping. Hence, the lack of model-calculated drawdown in MW-7S located at the CEMEX model boundary is a consequence of specified boundary conditions, and therefore comparisons between CEMEX model-calculated drawdown and measured drawdown in MW-7S are not reliable.

Variable Density

Spatial variations in water density due to salinity differences influence groundwater flow. The NMGWM^{2016} was developed using the MODFLOW computer code, which does not consider variable density effects. Comparisons between MODFLOW calculated water level changes and calculations using a variable density flow model (SEAWAT[77]) indicated slight differences in calculated water levels (approximately one foot).[78] These differences exist nearest the coast, where there is a measured difference in groundwater salinity ranging from seawater to freshwater. However, as the salinity concentration decreases with increasing distance inland from the coast, the differences in model-calculated water levels diminish and become insignificant. Near the coast, and where density effects are greatest, slant well pumping will have a much greater influence on water level changes and flow than the spatial differences in salinity and water density. The effects of variable density flow on the NMGWM^{2016}-calculated drawdown were therefore considered negligible.

Sea Level

Sea level rise can influence the volume of ocean water extracted by slant wells and the resulting drawdown distribution. An increase in sea level increases the inland encroachment of ocean water toward the subsurface well screens, and as a result increases the potential for ocean water to flow into the wells. We therefore considered the sensitivity of model-calculated drawdown to potential changes in sea level (2012 through 2073). The effects of sea level rise are described below in Section 5.3.

Boundary Conditions

Model-calculated water levels are variably affected by the type and scope of specified boundary conditions. Head-dependent flow boundaries (general-head boundaries) are specified around the perimeter of the inland portions of the NMGWM^{2016} (**Figure 2.3**), but no general-head boundaries are specified along the edges of the submarine aquifer units beneath the ocean. Further, model-calculated flow across those general-head boundaries can be sensitive to the external boundary water levels and boundary conductance values specified in the model.

To simulate the effect of submarine flow on model-calculated water levels, general-head boundaries were added along the entire model extent beneath the ocean. We compared the NMGWM^{2016} results with and without these added boundaries and found no discernable difference in model-calculated drawdown. With the submarine boundaries included, almost 2% more water enters the model domain through general-head boundaries, and the added inflow is compensated by a 0.2% decrease in ocean inflow simulated by the constant head boundaries. We therefore concluded model sensitivity to submarine boundary conditions was negligible. We also tested model sensitivity to the specified general-head boundary conductance values. We calculated alternative boundary conductance values based on the adjacent hydraulic conductivity of the parameter zone values in

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[77] Langevin CD, Thorne Jr. DT, Dausman AM, Sukop MC, Guo W, 2008, "SEAWAT Version 4: A Computer Program for Simulation of Multi-Species Solute and Heat Transport," U.S. Geological Survey Techniques and Methods Book 6, Chapter A22.

[78] *Ibid.* [10]

the model domain, and the resulting conductance values decreased on average by a factor of almost 200. However, there was no discernable difference in model-calculated drawdown as a result of decreasing boundary conductance. The model-calculated ocean inflow increased 0.03%, and was compensated by a 0.3% decrease in model-calculated inland flow from the general-head boundaries. We therefore concluded model sensitivity to general-head boundary conductance was also negligible. Because the model is fairly insensitive to submarine general-head boundaries and general-head boundary conductance values, the model-calculated drawdown is likely most sensitive to the specified external water levels derived from the SVIGSM.

Hydraulic Conductivity

Hydraulic conductivity values are spatially variable due to non-uniformly distributed soil and geologic units. Comparisons between modeled conductivity values and the values from other sources (**Figures 3.3a** and **3.3b**) indicate that each parameter zone has a wide range of possible hydraulic conductivity values. Sensitivity tests are therefore required to assess the uncertainty in model-calculated drawdown to uncertainty in hydraulic conductivity.

Project Operations

Model Layer 2 and Model Layer 4 have different water-transmitting and storage properties, and their contribution to the total well extraction rate can be variable. The quantity of water extracted from the aquifers represented by these model layers influences the magnitude and extent of drawdown. Sensitivity tests are therefore required to assess drawdown to uncertainty in the proportional contribution of groundwater from Model Layer 2 and Model Layer 4 to slant well pumping.

Returning water to the groundwater basin can reduce drawdown. The volume of return water and its method of return to the basin influence the magnitude and scope of the reduction in drawdown. Return water from the MPWSP would be delivered to either the Castroville Community Services District (CCSD) or the CSIP to replace simulated municipal and agricultural pumping from Model Layer 6 (Model Layer 6 represents the 400-FT Aquifer). The sensitivity of model-calculated drawdown to variations in replacement water volume was therefore assessed, and the return water volumes analyzed ranged from 0% to 12% of total slant well pumping.

5.0 Projected Drawdown from Slant Well Pumpage

Model scenarios were developed to estimate future project groundwater level changes (drawdown) due to slant well pumping and assess the uncertainty in drawdown due to model assumptions and input. Pumping and recovery scenarios were defined for the CEMEX and Potrero Road sites, and the 63-year pumping and 63-year recovery scenarios simulated using monthly stress periods.

5.1 Well Configuration and Pumping Rates

At the CEMEX site, the slant wells will be screened in both the Dune Sand Aquifer and 180-FT Aquifer. The fraction of well screen intersecting each aquifer influences the magnitude of groundwater extracted and the corresponding extent of drawdown within each aquifer. The configuration of the proposed slant wells was determined from cross sections, diagrams, and maps.[79] The designed screen position and length was then utilized to assign the proportional distribution of planned pumping to appropriate model cells and model layers (Model Layer 2 and Model Layer 4, respectively). We intersected the slant well configurations with the NMGWM[2016] model cells to determine well screen length in each cell, and then employed one of three methods to allocate the fraction of the total pumping to the well screen in each model layer.

Three methods were considered to allocate total slant well pumping in the model (**Table 5.1**). The first approach allocates pumping based on total screen length within each model layer, and indicates 21% of the extracted groundwater would come from Model Layer 2 and 79% from Model Layer 4. This approach is limited because the volume of water extracted is also likely influenced by the water transmitting properties of the aquifers represented by Model Layer 2 and Model Layer 4. Therefore the second approach allocated pumping by both screen length and modeled horizontal conductivity, and the approach indicates 44% of the extracted groundwater would come from Model Layer 2 and 56% from Model Layer 4. The third approach uses reported results that determined the pumping allocation based on well screen configuration and model calibration to the test slant well pumping results (66% from Model Layer 2 and 34% from Model Layer 4).[80] These percentages are most similar to the approach that weighted screen length and modeled horizontal hydraulic conductivity (the second approach described above). All three allocations were simulated by the model, and thus considered as part of our uncertainty analysis described in Section 6.0, however for reporting purposes we relied primarily on the second approach that weighted screen length and modeled horizontal hydraulic conductivity. At the Potrero Road Site, the slant wells are screened entirely in the Dune Sand Aquifer (100% of the pumping is from the Dune Sand Aquifer which is represented by Model Layer 2).

[79] CEMEX site: Brian Villalobos, Geoscience Support Services, Inc., written communication, February 24, 2016, PDF full-scale slant well cross sections and PDF of slant well layout and Brian Villalobos, Geoscience Support Services, Inc., written communication, May 5, 2016, shapefile of slant well layout; Potrero Road site: *Ibid* [10] Figures 49, 50, 68 to 84.

[80] *Ibid.* [11].

Table 5.1
Allocation of Pumping between Model Layer 2 and Model Layer 4

		CEMEX Site			
		Total Screen Length, feet	**% Total Screen Length**		
Model Layer 2	150 (Kh_2)	1,339 (L_2)	21%[a]	44%[c]	66%
Model Layer 4	50 (Kh_4)	5,186 (L_4)	79%[b]	56%[d]	34%

a: $\{[L_2]/([L_2]+[L_4])\}$ x 100
b: $\{[L_4]/([L_2]+[L_4])\}$ x 100
c: $\{[Kh_2]x[L_2]/([Kh_2]x[L_2]+[Kh_4]x[L_4])\}$ x 100
d: $\{[Kh_4]x[L_4]/([Kh_2]x[L_2]+[Kh_4]x[L_4])\}$ x 100
e: CEMEX model analysis of test slant well pumping indicated 64% from Layer 2 and 36% from Layer 4. These results were utilized to estimate the distribution of pumping as follows (Johnson Yeh, written communication, May 27, 2016):
(1) $Rat_{ts} = 64\%/36\% = 1.78$
(2) $Rat_{sl\text{-}i} = F_{adj} * 1.78$
(3) $F_{adj} = (b_{L2\text{-}sl\text{-}i}/b_{L4\text{-}sl\text{-}i})/(b_{L2\text{-}ts}/b_{L4\text{-}ts})$
(4) $p_{L2\text{-}sl\text{-}i} = Rat_{sl\text{-}i}/(1+Rat_{sl\text{-}i}) * 100$
(5) $p_{L4\text{-}sl\text{-}i} = 100 - p_{L2\text{-}sl\text{-}i}$
where,
Rat_{ts} is the ratio of pumping percentage from Model Layer 2 to pumping percentage from Model Layer 4 for the test slant well
$Rat_{sl\text{-}i}$ is the ratio of pumping percentage from Model Layer 2 to pumping percentage from Model Layer 4 for the project slant well i
$B_{L2\text{-}sl\text{-}I}$ is the screen length in Model Layer 2 for the project slant well i
$B_{L4\text{-}sl\text{-}I}$ is the screen length in Model Layer 4 for the project slant well i
$B_{L2\text{-}ts}$ is the screen length in Model Layer 2 for the test slant well
$B_{L4\text{-}ts}$ is the screen length in Model Layer 4 for the test slant well
$P_{L2\text{-}sl\text{-}i}$ is the pumping percentage from Model Layer 2 for the project slant well i
$P_{L4\text{-}sl\text{-}i}$ is the pumping percentage from Model Layer 4 for the project slant well i

The NMGWM2016 was employed to calculate drawdown using the pumping distributions in **Table 5.1** under the following assumed conditions.

- Two well configurations and pumping rates (8 wells pumping and 2 wells on rotating standby collectively pumping at 24.1 MGD; and, 5 wells pumping and 2 wells on rotating standby collectively pumping at 15.5 MGD).[81]
- Two sea levels (2012 and projected 2073 sea levels).
- Four assumed return water percentages (0%, 3%, 6%, and 12% of total pumping). The return water is used to replace CCSD Well No. 3 pumping from Model Layer 6, and pumping from Model Layer 6 by irrigators within the CSIP area (Model Layer 6 represents the 400-FT Aquifer). For the lower production rate (15.5 MGD), 4,260 acre-feet per year of additional water is assumed delivered to the CSIP area from the Pure Water Monterey Groundwater Replenishment Project (GWR).

A total of 34 model run scenarios were developed to calculate drawdown and assess its sensitivity to model input and model assumptions (**Table 5.2**). Model results are reported in maps that show the area where calculated drawdown is 1-foot or greater (the cone of depression). The comparison of contour maps provides visual means to compare the drawdown for each model scenario.

[81] Future operations schedule provided by Brian Villalobos, Geoscience Support Services, Inc., written communication, May 3, 2016.

Table 5.2
MPWSP matrix of modeling runs and assumptions

Project Site	Model Run Description	Sea Level	MPWSP Pumping (MGD)		Return Water to CSIP (AF/YR)			
					CCSD		CSIP Potrero Road Site	(AF/YR)
Drawdown Without Return Water	CEMEX Without Return Water	2012	24.1	---	---	0	---	---
	CEMEX Without Return Water	2073	24.1	---	---	0	---	---
	CEMEX Without Return Water	2012	15.5	---	---	0	---	---
	CEMEX Without Return Water	2073	15.5	---	---	0	---	---
	Potrero Without Return Water	2012	---	24.1	---	---	0	---
	Potrero Without Return Water	2073	---	24.1	---	---	0	---
	Potrero Without Return Water	2012	---	15.5	---	---	0	---
	Potrero Without Return Water	2073	---	15.5	---	---	0	---
CEMEX Site	Project - 3% Rtn Water as In-Lieu GW pumping	2012	24.1	---	800	10	---	---
	Project - 3% Rtn Water as In-Lieu GW pumping	2073	24.1	---	800	10	---	---
	Project - 6% Rtn Water as In-Lieu GW pumping	2012	24.1	---	800	821	---	---
	Project - 6% Rtn Water as In-Lieu GW pumping	2073	24.1	---	800	821	---	---
	Project - 12% Rtn Water as In-Lieu GW pumping	2012	24.1	---	800	2,442	---	---
	Project - 12% Rtn Water as In-Lieu GW pumping	2073	24.1	---	800	2,442	---	---
	Post-CEMEX	2073	0	---	0	0	---	No
	Variant - 3% Rtn Water as In-Lieu GW pumping	2012	15.5	---	521	0	---	4,260
	Variant - 3% Rtn Water as In-Lieu GW pumping	2073	15.5	---	521	0	---	4,260
	Variant - 6% Rtn Water as In-Lieu GW pumping	2012	15.5	---	690	352	---	4,260
	Variant - 6% Rtn Water as In-Lieu GW pumping	2073	15.5	---	690	352	---	4,260
	Variant - 12% Rtn Water as In-Lieu GW pumping	2012	15.5	---	690	1,395	---	4,260
	Variant - 12% Rtn Water as In-Lieu GW pumping	2073	15.5	---	690	1,395	---	4,260
Potrero Road Site	Potrero - 3% Rtn Water as In-Lieu GW pumping	2012	---	24.1	800	---	10	---
	Potrero - 3% Rtn Water as In-Lieu GW pumping	2073	---	24.1	800	---	10	---
	Potrero - 6% Rtn Water as In-Lieu GW pumping	2012	---	24.1	800	---	821	---
	Potrero - 6% Rtn Water as In-Lieu GW pumping	2073	---	24.1	800	---	821	---
	Potrero - 12% Rtn Water as In-Lieu GW pumping	2012	---	24.1	800	---	2,442	---
	Potrero - 12% Rtn Water as In-Lieu GW pumping	2073	---	24.1	800	---	2,442	---
	Post-Potrero	2073	---	0	0	---	0	No
	Potrero Variant - 3% Rtn Water as In-Lieu GW pumping	2012	---	15.5	521	---	0	4,260
	Potrero Variant - 3% Rtn Water as In-Lieu GW pumping	2073	---	15.5	521	---	0	4,260
	Potrero Variant - 6% Rtn Water as In-Lieu GW pumping	2012	---	15.5	690	---	352	4,260
	Potrero Variant - 6% Rtn Water as In-Lieu GW pumping	2073	---	15.5	690	---	352	4,260
	Potrero Variant - 12% Rtn Water as In-Lieu GW pumping	2012	---	15.5	690	---	1,395	4,260
	Potrero Variant - 12% Rtn Water as In-Lieu GW pumping	2073	---	15.5	690	---	1,395	4,260

5.2 Water Level Changes Calculated with Superposition

The question addressed by the model scenarios (**Table 5.2**) is "what drawdown is expected from operation of the proposed slant wells." Calculating these water level changes within the Salinas Valley Groundwater Basin is a complex problem because recharge and discharge processes vary geographically and temporally. A superposition approach was employed to calculate drawdown due solely to the proposed slant wells.[82] The "theory of superposition" states that solutions to the parts of a complex problem can be added to solve the composite problem.[83] Superposition can therefore be utilized to isolate the effect of one stress from all other stresses operating in a basin. The advantages of superposition for analyses using the NMGWM[2016] are summarized below.

- The NMGWM[2016] evaluation indicated deficiencies in specified recharge and pumping input from the SVIGSM. For example, modeled seasonal water level highs and lows in Model Layer 8 are more pronounced than measured due to specified pumping being too great. Additionally, deficiencies in the timing and magnitude of pumping from Model Layer 4 caused a bias in the model-calculated water levels. Because superposition calculates only the effect of the specified stress, which in this application is pumping from the slant wells, all other background stresses in the basin are removed, thereby eliminating the uncertainty introduced by the deficient recharge and pumping data set.

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[82] Examples of the use of superposition to solve groundwater problems:
- Durbin TJ, Delemos DW, and Rajagopal-Durbin A, 2008, "*Application of superposition to non-linear ground-water models*," Ground Water 46(2): 251-258.
- Durbin TJ, and K Loy, 2010, "*Development of a Groundwater Model Snake Valley Region Eastern Nevada and Western Utah,"* Report prepared for National Park Service, U. S. Bureau of Land Management, U. S. Fish and Wildlife Service, and U. S. Bureau of Indian Affairs.
- Halford KJ, and RW Plume, 2011, "*Potential effects of groundwater pumping on water levels, phreatophytes, and spring discharges in Spring and Snake Valleys, White Pine County, Nevada, and adjacent areas in Nevada and Utah*," U.S. Geological Survey Scientific Investigations Report 2011-5032.
- Hubbell JM, Bishop CW, Johnson GS, and Lucas JG, 1997, "*Numerical ground-water flow modeling of the Snake River Plain aquifer using the superposition technique*," Ground Water 35(1): 59–66.
- Leake SA, Greer W, Watt D, Weghorst P, 2008, "*Use of superposition models to simulate possible depletion of Colorado River water by ground-water withdrawal,"* U. S. Geological Survey Scientific Investigations Report 2008-5189.
- Reilly TE, Franke OL, Bennett GD, 1987, "*The principle of superposition and its application in ground-water hydraulics*," U. S. Geological Survey Techniques of Water-Resource Investigation 03-B6, 28 p.

[83] When applying superposition, both the equations describing groundwater conditions within the model domain and the boundary conditions must be linear. For example, doubling an input will double its response, halving the input will halve its response, and so forth. Some of the mathematical equations that describe groundwater flow are linear – others are not. The equations utilized to describe confined groundwater-flow, like groundwater conditions in most of the Salinas Valley Groundwater Basin, are linear. However, the equations utilized to describe unconfined groundwater-flow, like conditions that may exist beneath the beach and near the coast, are not linear. We tested the assumption of linearity when applying the NMGWM[2016] by calculating drawdown using unconfined and confined versions of the model, and the maximum difference between the two model runs was only 0.01 foot. The assumption of linearity is therefore reasonable, and application of superposition to calculate drawdown from slant well pumping is reliable.

- The NMGWM^{2016} evaluation indicated deficiencies in SVIGSM derived initial conditions and specified water levels for the general-head boundaries. For example, initial water levels for Model Layer 2 in the Fort Ord Area were clearly too low, causing large differences between measured and model-calculated water levels, and external water levels specified for the southern general-head boundary produced noticeably higher model-calculated water levels than measured values in Model Layer 4. Superposition eliminates the effects of specified initial water levels and specified external water levels for the general-head boundaries.

For additional background on the application of superposition, an example of its use to accurately isolate drawdown from a new pumping well introduced into a hypothetical groundwater basin is provided in **Attachment 1**.

5.3 Modifications to the NMGWM^{2016}

A superposition modeling approach solves for changes in water levels rather than their absolute values. Accordingly, we modified the NMGWM^{2016} to calculate the relative change in water levels due solely to slant well pumping.

Initial Heads, Boundary Conditions, and Stresses

In modeling practice, superposition is implemented by setting all initial water levels equal within the model domain (the initial water levels in the NMGWM^{2016} were specified with a value of zero so that simulated groundwater level changes correspond with drawdown). Constant (or fixed) water-level boundaries are all specified equal to the initial water levels so that the hydraulic gradient along the boundary is initially zero (in the NMGWM^{2016}, the boundaries representing the ocean and the head-dependent boundaries along the edges of the model domain were set to zero). The modeled stresses represent the incremental change relative to existing conditions, and therefore all background recharge and pumping is set equal to zero (in the NMGWM^{2016} the only stress simulated was pumping from the slant wells).

River Gains and Losses

Groundwater interaction with the Salinas River and the Tembladero Slough/Reclamation Ditch is simulated in the SVIGSM model. Previously, these water inflows and outflows were extracted from the SVIGSM model results and incorporated directly into the NMGWM^{2015} recharge and pumping input data. Because slant well pumping alters these flows, it was necessary to represent these channels in the superposition NMGWM^{2016}. The MODFLOW River Package was used to simulate changes in river gains (groundwater seepage) and losses (river leakage) in response to slant well pumping.

The MODFLOW River Package assumes that where groundwater levels are above the elevation of the channel bed bottom (RBOT), the water table is hydraulically connected to surface water in the river. Hence, drawdown alters the hydraulic gradient between the river and groundwater, causing greater river loss (or less river gain). In contrast, where groundwater levels are below RBOT, an unsaturated zone is assumed to separate the surface water in the river and the underlying water table. When an unsaturated interval exists between RBOT and the water table, the river loses water to the aquifer at a constant rate that is independent of further drawdown. A diagram of the relationships between RBOT, the surface water level elevation in the modeled river cell (HRIV), the water level elevation in the adjacent aquifer (GWE), and MODFLOW calculated river loss or gain (QRIV) is shown in **Figure 5.1**.

In MODFLOW, each model cell representing the river requires specification of the surface water level elevation (HRIV), the conductance of the river channel bed (CRIV), and the elevation of the river channel bed bottom (RBOT). As long as the model-calculated water level in the model cell (GWE) is greater than the value of RBOT, the water table is assumed hydraulically connected to the river and either surface water leaks to groundwater (model-calculated river loss) or groundwater seeps into the river (model-calculated river gain), depending on CRIV and the relative values of HRIV and GWE. The following equation represents the relationships shown in **Figure 5.1a** and calculates the quantity of flow between the modeled river and aquifer (QRIV):

$$QRIV = CRIV\ (HRIV - GWE).$$

River water leaks to the aquifer when HRIV is greater than GWE, and groundwater seeps into the river when HRIV is less than GWE. When GWE decreases and falls beneath RBOT, MODFLOW calculates a constant QRIV regardless of further GWE decreases using the following equation:

$$QRIV = CRIV\ (HRIV - RBOT).$$

Superposition calculates groundwater changes relative to background conditions. The values for HRIV and the GWE are initially set to zero, and the model calculates the change in the quantity of flow between the river and aquifer ($QRIV^*$) in response to the change in groundwater level as a result of slant well pumping (GWE^*):

$$QRIV^* = CRIV\ (0 - GWE^*).$$

A diagram of the relationships between RBOT, HRIV, the change in water level elevation in the adjacent aquifer (GWE^*), and change in river loss or gain ($QRIV^*$) calculated by superposition is shown in **Figure 5.1b**. Because GWE^* is initially set to zero, RBOT must also be changed to maintain the initial available drawdown to the channel bottom (the distance between RBOT and the GWE at the end of the $NMGWM^{2016}$ historical simulation). In other words, RBOT is adjusted so that the difference between the initial GWE^*, which is set to zero for superposition, and the adjusted RBOT ($RBOT^*$) is equal to the available drawdown at the end of the historical simulation. Under these conditions $QRIV^*$ resulting from slant well pumping is calculated as follows.

$$QRIV^* = CRIV\ (0 - GWE^*),\ GWE^* > RBOT^*$$

$$QRIV^* = CRIV\ (0 - RBOT^*);\ GWE^* \leq RBOT^*.$$

The $NMGWM^{2016}$ model cells for implementing the MODFLOW River Package were identified by overlaying the model grid, the Salinas River, and Tembladero Slough/Reclamation Ditch channel centers digitized from aerial photographs. The river cells were identified where GWE at the end of the NMGWM^{2016} historical simulation was above RBOT, The conductance of the river channel (CRIV) for each model cell was calculated as the product of channel length, width, and bed material conductivity divided by the assumed channel bed thickness. The channel lengths were determined for model cells intersecting more than 20 feet of river/ditch channel (more than 10% of the model cell dimensions); model cells intersecting less than 20 feet of river/ditch channel were not represented by the River Package. The channel width was also estimated from the aerial photos, which showed that the width increased from upstream to downstream (the widths ranged from 50 to 600 feet for the Salinas River, and from 12 to 75 feet for Tembladero Slough/Reclamation Ditch). The channel bed hydraulic conductivity was obtained from the SVIGSM, and values ranged from 0.1 to 1.5 ft/day for the Salinas River and 0.2 ft/day for the entire length of the Tembladero Slough/Reclamation Ditch. The river bed thicknesses were also obtained from the SVIGSM, which specified 5 feet for the Salinas River and 3 feet for the Tembladero Slough/Reclamation Ditch.

The elevation of the river channel bed bottom (RBOT) was calculated by subtracting 6 feet from the modeled land surface elevation of each cell representing the river (the 1-foot average depth from modeled land surface to the top of the channel bottom plus the assumed 5 feet of river bed thickness).[84] Similarly, the elevation of the slough channel bottom was calculated by subtracting 10 feet from the modeled land surface elevation (the 7-feet average depth from modeled land surface to the top of the channel bottom plus the assumed 3 feet of slough bed thickness). For superposition, RBOT* was the distance between RBOT and the GWE at the end of the NMGWM^{2016} historical simulation.

Projected Sea Level Rise

Sea level is projected to rise during the 63-year slant well pumping period,[85] and to represent this change in the NMGWM^{2016} requires conversion of inactive Layer 1 model cells along the coast into constant-head cells that represent the ocean. The cells are converted by either flooding in response to the higher sea level, or encroachment by erosion of the coastal bluffs. Ideally the NMGWM^{2016} would simulate the incremental sea level rise over the entire 63-year period, but MODFLOW cannot change inactive cells to active constant-head cells. The influence of potential sea level changes on model-calculated drawdown was therefore considered using two sets of constant head boundary conditions that represent the expected minimum (2012) and maximum (2073) sea levels.

Sea level is projected to rise 18.0 inches by 2073 relative to 2012,[86] and we used this projected rise to identify adjacent land areas that would be flooded by the higher water levels. In these areas, ocean water is projected to move inland inundating the relatively low elevation land areas adjacent

[84] The average depth to the top of the river channel bottom was calculated by subtracting the average channel bottom elevation estimated from a profile of the Salinas River (*Salinas River Stream Maintenance Program, Revised Final Environmental Impact Report, Appendix E: Flood Study, prepared by Cardno Entrix, January 9, 2013*) from the modeled land surface elevation. The average depth to the top of the slough bottom was calculated by subtracting the average channel bottom elevation estimated as the water depth at maximum flow (7 feet from SVIGSM rating tables) and modeled land surfaced elevation.

[85] ESA PWA, "*Monterey Peninsula Water Supply Project: Coastal Water Elevations and Sea Level Rise Scenarios,*" April 2013.

[86] *Ibid.* [85]

to the current coast line. Rising sea level also increases erosion along the coast, and is projected to increase inland flooding and encroachment of the coast.[87] To simulate future sea level rise, we activated cells in layer 1 based on land surface elevation and erosion. When sea level exceeded the elevation of a model cell, we assumed the ocean floods the entire model cell. When the interpolated erosion distance reached one-half of the model cell width (100 ft), we assumed the entire cell was flooded. The modified distribution of constant-head cells representing the ocean in 2073 are mapped in **Figure 5.2**.

Particle Tracking

The MODFLOW computer code post-processer MODPATH[88] was employed to simulate groundwater-flow paths. MODPATH utilizes the output from MODFLOW simulations to simulate paths for "particles" of water moving through the modeled groundwater system. In addition to delineating particle paths, MODPATH computes the time-of-travel for the simulated particles to reach their ending locations. Backward tracking shows the movement of groundwater to former points of recharge (for example, the movement of ocean water recharge to a pumping well), and forward tracking shows the movement of groundwater to future points of discharge (for example, the continued inland movement of the interface between intruded saltwater and native groundwater). We used MODPATH to track the backward and forward movement of particles in the groundwater system as described in greater detail below.

Well Capture Zone

Ocean water "capture zone" boundaries were delineated using $NMGWM^{2016}$ results and particle tracking. A capture zone refers to the three-dimensional volume of aquifer that contributes the water extracted by the wells. When the pumps are turned on, the wells initially extract the existing ambient mix of native groundwater in storage, but as pumping continues the wells extract increasing proportions of infiltrating recharge from the ocean. The ocean recharge gradually replaces the ambient water within the capture zone, and moves within the capture zone toward the well but does not spread beyond the capture zone. In map view, the capture zone is a 2-dimensional surface that delineates the underlying aquifer volume where ocean water replaces ambient groundwater and ultimately becomes the primary water source to the wells.

Using the $NMGWM^{2016}$, we delineated slant well ocean water capture zones under steady-state flow conditions. We summed the slant well pumping in each cell over the entire 63-year simulation and assigned that average rate in the model. We conducted particle-tracking with two different particle starting locations assuming a porosity of 0.1. Forward tracking particles placed in every cell along the coast in Model Layer 2, Model Layer 3, and Model Layer 4 provided path lines that delineate submarine groundwater flow paths to the extraction wells. Backwards tracking particles placed evenly within pumping cells provided path lines that delineate recharge that either originates at the

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[87] Johnson Yeh, Geoscience Support Services, Inc., written communication, March 30, 2016.
[88] Pollock DW, 2012, "*User Guide for MODPATH Version 6 – A Particle-Tracking Model for MODFLOW*," U.S. Geological Survey Techniques and Methods 6-A41.

ocean bottom or as submarine groundwater beneath the bay bottom. In both scenarios, submarine groundwater extracted by the wells is assumed recharged by ocean water.

The initial water levels in superposition are specified zero everywhere in the NMGWM2016, and therefore the model does not account for regional background gradients. These regional gradients significantly influence groundwater-flow paths from the ocean to the pumping slant wells, and therefore are important to consider when calculating capture zone boundaries. For the steady-state modeling analysis, we superimposed the measured regional background gradient calculated from Fall 2015 maps that show contours of equal groundwater elevations.[89] We first calculated the regional gradient across the CEMEX site from the contour maps, and then approximately reproduced the gradient in the NMGWM2016 by assigning external water levels to the eastern-most general-head boundaries. **Table 5.3** compares the observed and model-calculated gradients, and shows that the average measured gradient (0.0010) is reasonably close to the model-calculated gradient (0.0007).

Table 5.3
Comparison between calculated gradients at the CEMEX site

Model Layer	Measured Water Level Gradient	Model-Calculated Gradient
2	0.0004	0.0009
4	0.0020	0.0007
6	0.0009	0.0005
Average	**0.0010**	**0.0007**

Saltwater Intrusion

Slant well pumping effects on the inland movement of saltwater was assessed using the NMGWM2016 and MODPATH. Particles were placed along the edge of the inferred 2013 seawater intrusion front in the 180-FT Aquifer (Model Layer 4) and 400-FT Aquifer (Model Layer 6), as reported by MCWRA.[90] Forward particle-tracking was then employed to show the change in front location after 63-years of slant well pumping. Without slant well pumping, the particles representing saltwater would continue to migrate inland. With slant well pumping, the movement of saltwater is in response to the regional background gradient and drawdown created by slant well pumping. We therefore utilized the superposition NMGWM2016 without the regional gradient to isolate changes in saltwater movement due solely to slant well pumping. The change in particle locations initially placed at the seawater interface represent the change in saltwater location relative to its inland location due to continued background recharge and pumping (e.g., the acceleration or retardation of existing saltwater intrusion).

5.4 CEMEX Site Results

When water is extracted from an aquifer by a well it creates a cone of depression because water converges on the well from all directions and the gradient becomes steeper toward the well. The

89 *Ibid.* [11]
90 *Ibid.* [33]

radius of influence of the cone of depression was delineated by the 1-foot drawdown contour; the area inside the 1-foot drawdown contour delineates the area where drawdown is 1 foot or greater. **Figure 5.3** shows annual model calculated drawdown and the expansion of the cone of depression at the CEMEX site during the 63-year model simulation. Hydrographs of calculated drawdown show that the drawdown due solely to slant well pumping stabilizes near the wells within several years. In Model Layer 2, the expansion of the 1-foot contour away from the well slows substantially after about 20 years; whereas, in Model Layer 4 the maximum extent of the 1-foot contour is reached by the first year. We therefore compared the maximum drawdown between model scenarios by comparing the calculated cone of depression at the end of the 63-year simulations.

Drawdown

Figure 5.4 shows model calculated drawdown for 24.1 MGD at 2012 sea level (**Figure 5.4a**) and 2073 sea level (**Figure 5.4b**). Rising sea level clearly increases ocean inflow and reduces the area of the cone of depression. In Model Layer 2, the maximum distance from the well field to the 1-foot drawdown contour decreased from about 15,000 feet under 2012 sea level to less than 11,000 feet under 2073 sea level. Similarly, in Model Layer 4 the distance decreased from almost 20,000 feet to about 14,000 feet, respectively. At 2012 sea level, groundwater extraction from Model Layer 2 and Model Layer 4 influence water levels in Model Layer 6, but the effect decreases to less than 1 foot under 2073 sea level. Return water also reduces the area of the cone of depression, most noticeably in Model Layer 4. In Model Layer 2, the maximum distance from the well field to the 1-foot drawdown contour decreased from about 15,000 feet (0% return water) to 13,000 feet (12% return water) under 2012 sea level. Similarly, in Model Layer 4 the distance decreased from almost 20,000 feet to about 16,000 feet (0% and 12% return water, respectively). Negative drawdown occurs in some areas and depths, and indicates where water levels increase as a result of return water deliveries. The water-level increase (shown as negative numbers) occurs primarily in Model Layer 6 where return water replaces existing pumping.

Figure 5.5 shows model calculated drawdown for 15.5 MGD at 2012 sea level (**Figure 5.5a**) and 2073 sea level (**Figure 5.5b**). Reducing the extraction rate from 24.1 MGD to 15.5 MGD reduces the area of the cone of depression. In Model Layer 2, the maximum distance from the well field to the 1-foot drawdown contour decreased almost 3,000 feet, and the distance decreased more than 4,000 feet in Model Layer 4 (compared to 2012 sea level and without return water). Return water also decreases the drawdown in Model Layer 6 (and to a limited extent decreases drawdown in Model Layer 4). The area affected by the water-level increase is substantially greater than the 24.1 MGD scenario as a result of the 4,260 AFY of additional return water contributed by the GWR Project, and the reduced pumping from Model Layer 6 increases water levels also in overlying Model Layer 2 and Model Layer 4. Comparisons between **Figure 5.5a** and **Figure 5.5b** indicate that sea level rise substantially increases the areas with negative drawdown in Model Layer 6, and reduces drawdown in Model Layer 2 and Model Layer 4.

Model-calculated drawdown in Model Layer 6 in response to slant well pumping, and water level increases in Model Layer 2 and Model Layer 4 in response to return water deliveries is not unexpected. Groundwater in layered alluvial aquifer systems are typically hydraulically connected to variable extents. For example, the Salinas Valley Groundwater Basin Hydrology Conference described the interconnection between the 180-FT and 400-FT aquifers in the Pressure Area of the Salinas Valley.[91] A stress affecting water levels in one aquifer (for example, a water level decline in response to groundwater pumping or water level increases in response to recharge or reductions in groundwater pumping) may influence water levels in overlying and underlying aquifers,[92] and the observed response depends on the water transmitting and storage properties of the water-bearing and non-water bearing sediments (the aquifers and aquitards, respectively).

Recovery

Figure 5.6 shows the model-calculated recovery from drawdown due solely to 63-years of slant well pumping. Hydrographs at various locations show that drawdown decreases and water levels return to pre-pumped conditions within several years for all but two wells. The modeled water level recovery for monitoring wells MW-5S and MW-7S is completed within about 20 years. Considering that the recovery for surrounding wells is on the order of a few years, the longer recovery for just these two wells is the effect of the relatively low hydraulic conductivity associated with Model Layer 2 in those areas of the model.

Capture Zone and Saltwater Intrusion

The model-calculated, steady-state ocean water capture zone for slant wells are shown in **Figure 5.7**, and the figure includes the sensitivity of the capture zone to pumping rate (24.1 and 15.5 MGD) and superimposed regional gradient (0.0004, 0.0007, and 0.0011). The capture zone delineates the inland area through which particles placed beneath the coast line pass as they move to the slant wells. In general, the size of the capture zone is greater in Model Layer 2 than in Model Layer 4, and the capture zone area decreases with increasing regional gradient. These results are consistent with the primary source of recharge to the wells being ocean water.

The change in intrusion front location after 63-years of pumping is mapped in **Figure 5.8**, and results show that slant well pumping slows future saltwater intrusion in the southern portion of Model Layer 4; slant well pumping has little to no effect on future saltwater intrusion in Model Layer 6. The ending particle locations shown in **Figure 5.8** represent the change in the seawater interface location relative to its expected future location as a result of existing recharge and pumping. Particles that remain on the interface after 63-years delineate areas where the seawater interface continues to migrate inland under existing conditions. In contrast, particles that move from the interface toward the ocean indicate a change in the interface location relative to its expected future location. The direction of the flow paths are towards the coast, but this does not necessarily mean the interface moves back towards the ocean. Rather, the flow path directions indicate that existing intrusion at these interface locations will slow proportionally to the relative

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[91] Salinas Valley Ground Water Basin Hydrology Conference, 1995, "Hydrogeology and Water Supply of Salinas Valley," white Paper prepared for the Monterey County Water Resources Agency.
[92] For example in Hanson R, 2003, "Geohydrologic framework of recharge and seawater intrusion in the Pajaro Valley, Santa Cruz and Monterey Counties, CA," USGS Water-Resources Investigations Report 03-4096, hydrographs showed similar water level changes in wells completed at different depths.

lengths of the flow paths. Hence, slant well pumping retards the continued inland movement of the seawater interface in the southern portion of Model Layer 4.

5.5 Potrero Road Site Results

Figure 5.9 shows annual model calculated drawdown and the expansion of the cone of depression at the Potrero Road site during the 63-year model simulation. Hydrographs of calculated drawdown show that the water level changes near the well stabilize in less than three years. The expansion of the 1-foot contour with time is essentially completed within 5 years in both Model Layer 2 and Model Layer 4.

The drawdown results for the Potrero Road Site are limited because the extraction wells are located near the northern head-dependent flux boundary. This boundary provides an unlimited source of water in response to drawdown within the $NMGWM^{2016}$, and this water source could have the effect of reducing the model-calculated cone of depression. We therefore developed a simple test model based on the $NMGWM^{2016}$ and extended the boundaries north using information from the Pajaro Valley Hydrologic Model.[93] The simple model was designed to test the effect of boundary location on modeled drawdown within the $NMGWM^{2016}$ area. Results indicated that the general-head boundary flux has a modest effect on the cone of depression, but the effect is likely negligible for drawdown comparisons between the CEMEX and Potrero Road Sites. Details of test model construction and analyses are provided in **Attachment 2**.

Drawdown

Figure 5.10 shows model calculated drawdown for 24.1 MGD at 2012 sea level (**Figure 5.10a**) and 2073 sea level (**Figure 5.10b**). In contrast to sea level effects at the CEMEX site, the simulated location of the coast does not change relative to the Potrero Road site slant well screens, and the differences between drawdown contours simulated under 2012 and 2073 sea level conditions are negligible. In Model Layer 2, the maximum distance from the well field to the 1-foot drawdown contour under both 2012 and 2073 sea levels is approximately 25,000 feet. In Model Layer 4, this distance decreases to about 21,000 feet. Return water reduces the area of the cone of depression, most noticeably in Model Layer 4 and Model Layer 6. In Model Layer 2, the maximum distance from the well field to the 1-foot drawdown contour decreased from about 25,000 feet (0% return water) to about 23,000 feet (12% return water) under both 2012 and 2073 sea levels. Similarly, in Model Layer 4 the distance decreased from about 21,000 feet to almost 14,000 feet (0% and 12% return water, respectively). Water levels increased as a result of return water deliveries, and the response occurred primarily in Model Layer 6 where return water deliveries decrease background pumping.

Figure 5.11 shows model calculated drawdown for 15.5 MGD at 2012 sea level (**Figure 5.11a**) and 2073 sea level (**Figure 5.11b**). Reducing the extraction rate from 24.1 MGD to 15.5 MGD reduced the area of the cone of depression somewhat, primarily in Model Layer 4. In Model Layer 2, the

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[93] Hanson RT, Schmid W, Faunt CC, Lear J, Lockwood B, 2014, "Integrated Hydrologic Model of Pajaro Valley, Santa Cruz and Monterey Counties, California," U.S. Geological Survey Scientific Investigations Report 2014-5111. Prepared in cooperation with the Pajaro Valley Water Management Agency.

maximum distance from the well field to the 1-foot drawdown contour decreased about 2,000 feet, and the distance decreased almost 6,000 feet in Model Layer 4 (compared to 2012 sea level and without return water). Return water deliveries decrease drawdown in Model Layer 2, Model Layer 4, and Model Layer 6.

The water-level increase (shown as negative numbers) occurs primarily in Model Layer 6 where return water replaces background pumping. The area affected by the water-level increase is substantially greater than the 24.1 MGD scenario (**Figure 5.10**) as a result of the 4,260 AFY of additional return water contributed by the GWR Project, and the pumping reduction in Model Layer 6 produces water level increases in overlying Model Layer 2 and Model Layer 4.

Recovery

Figure 5.12 shows the model-calculated recovery from drawdown following the 63-years of slant well pumping at the Potrero Road Site. Hydrographs of the calculated recovery show that drawdown due solely to slant well pumping decreases and water levels return to pre-pumped conditions relatively rapidly (in less than three years).

Capture Zone and Saltwater Intrusion

The model-calculated, steady-state ocean water capture zone boundaries for slant wells at the Potrero Road site are shown in **Figure 5.13**, and include capture zone sensitivity to pumping rate (24.1 and 15.5 MGD) and regional gradient (0.0004, 0.0007, and 0.0011). The capture zone delineates the inland area through which particles placed beneath the coast line pass as they move to the slant wells. There is no ocean water capture zone in Model Layer 4 because the slant wells are screened only in Model Layer 2. In general, model results indicate that the size of the capture zone increases with increasing extraction rate, and decreases with increasing inland gradient. The model results are consistent with ocean water as the primary source of recharge to the wells.

The change in seawater intrusion front after 63-years of pumping is mapped in **Figure 5.14**, and results indicate that slant well pumping will slow future saltwater intrusion in the northern portion of Model Layer 4 and Model Layer 6. The ending particle locations shown in **Figure 5.14** represent the change in seawater interface location relative to its projected future location as a result of background recharge and pumping. Particles that remain on the interface after 63-years of slant well pumping delineate areas where the saltwater continues to migrate inland under existing conditions. In contrast, particles that move from the interface toward the ocean indicate a change in the interface location relative to its expected future location. The direction of the flow paths are towards the coast, but this does not necessarily mean the interface moves back towards the ocean. Rather, flow path directions indicate that existing intrusion at these interface locations will slow proportionally to the relative lengths of the flow paths. Hence, slant well pumping retards the continued inland movement of saltwater in the northern portions of Model Layer 4 and Model Layer 6.

6.0 Uncertainty

The sensitivity of model-calculated drawdown to uncertainty in pumping rates, return water volumes, and projected sea level was considered in Section 5.0 (see **Figure 5.4** and **Figure 5.5**). There is also uncertainty associated with modeled aquifer parameters and the relative contributions of groundwater in aquifers represented by Model Layer 2 and Model Layer 4 to total slant well pumping. In this section, we quantify the uncertainty in model-calculated drawdown to hydraulic conductivity and the assumed allocation of extracted groundwater from the two model layers, and then summarize drawdown results from all scenarios to characterize the uncertainty in model predictions. The objective of the sensitivity analysis is to address the question: "If the assumptions adopted in developing the model were changed, would the model predictions change so as to change the conclusions regarding proposed slant well operation?"

We utilized MODFLOW, the 1979-2011 water level data, and predicted water level changes to slant well pumping to calculate sensitivities for horizontal and vertical hydraulic conductivity values.[94] The results indicated that model-calculated water level changes in response to slant well pumping is associated mostly with select hydraulic conductivity parameter zones in Model Layer 2 (KH7 and KV7) and Model Layer 4 (KH5, KH14 and KH8). We conducted two model simulations to quantify the contribution of hydraulic conductivity uncertainty in these parameter zones on model-calculated drawdown. Our approach was conservative, and selected alternative parameters that maximized and minimized aquifer anisotropy (the ratio of horizontal and vertical conductivity). For maximum anisotropy we multiplied KH7, KH5, KH8, and KH14 by 5 and divided KV7 by 5; for minimum anisotropy we divided KH7, KH5, KH8, and KH14 by 5 and multiplied KV7 by 2.

The alternative conductivity values are plotted in **Figure 6.1** and show they are essentially extreme values relative to the calibrated values and values reported by other sources, and therefore using these values essentially brackets the range in possible drawdowns. **Figure 6.2** shows the sensitivity of model-calculated drawdown to hydraulic conductivity uncertainty. Increasing the anisotropy (increasing horizontal conductivity and decreasing vertical conductivity) minimizes the area of the cone of depression. Conversely, decreasing the anisotropy (decreasing horizontal conductivity and increasing vertical conductivity) maximizes the area of the cone of depression.

Model calculated drawdown at the CEMEX site (24.1 MGD) is mapped in **Figure 6.3a**, and the calculated drawdown for 15.5 MGD is mapped in **Figure 6.3b**; both drawdown contours are for 2012 sea level, no return water, and 44/56% allocation between Model Layer 2 and Model Layer 4. We overlaid these contours with the drawdown from sensitivity runs that tested sea level rise, the pumping layer allocation distribution, and hydraulic conductivity to delineate the potential range in the drawdown using all the model runs. The shaded areas in **Figure 6.3** represent the uncertainty in the model-calculated cone of depression due to the uncertainty in model input and assumptions. Under 2012 sea level conditions, the maximum distance from the well field to the 1-foot drawdown contour in Model Layer 2 is about 15,000 feet, and in Model Layer 4 the distance is about 20,000 feet. As a result of uncertainty in sea level rise, hydraulic conductivity, and the pumping layer

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[94] Hill MC and CR Tiedeman, 2007, "Effective Groundwater Model Calibration, With Analysis of Data, Sensitivities, Predictions, and Uncertainty," Wiley-Interscience.

allocation distribution, these distances ranged from less than 10,000 feet to 24,000 feet in Model Layer 2, and 12,000 feet to 24,000 feet in Model Layer 4. At the lower pumping rate (15.5 MGD), these distances range from about 6,000 feet to more than 17,000 feet in Model Layer 2, and almost 6,000 feet to 19,000 feet in Model Layer 4.

A similar analysis was completed for the Potrero Road Site. Model-calculated sensitivities indicated the most important hydraulic conductivity values for projecting drawdown are KH8, KH6, and KV8. For maximum anisotropy we multiplied KH8 and KH6 by 5, and divided KV8 by 5; for minimum anisotropy we divided KH8 and KH6 by 5, and multiplied KV8 by 5. We overlaid the drawdown from the sensitivity runs that tested sea level and hydraulic conductivity to delineate the range in potential drawdown due to uncertainty (**Figure 6.4**). The shaded areas in **Figure 6.4a** (24.1 MGD) and **Figure 6.4b** (15.5 MGD) represent the uncertainty in model-calculated drawdown to uncertainty in model input and assumptions. The maximum distances from the well field to the 1-foot drawdown contour can range from about 19,000 to 27,000 feet, and 16,000 to almost 22,000 feet in Model Layer 2 as a result of uncertainty in sea level rise, hydraulic conductivity, and the pumping layer allocation distribution for the 24.1 and 15.5 MGD pumping rates, respectively.

7.0 Summary

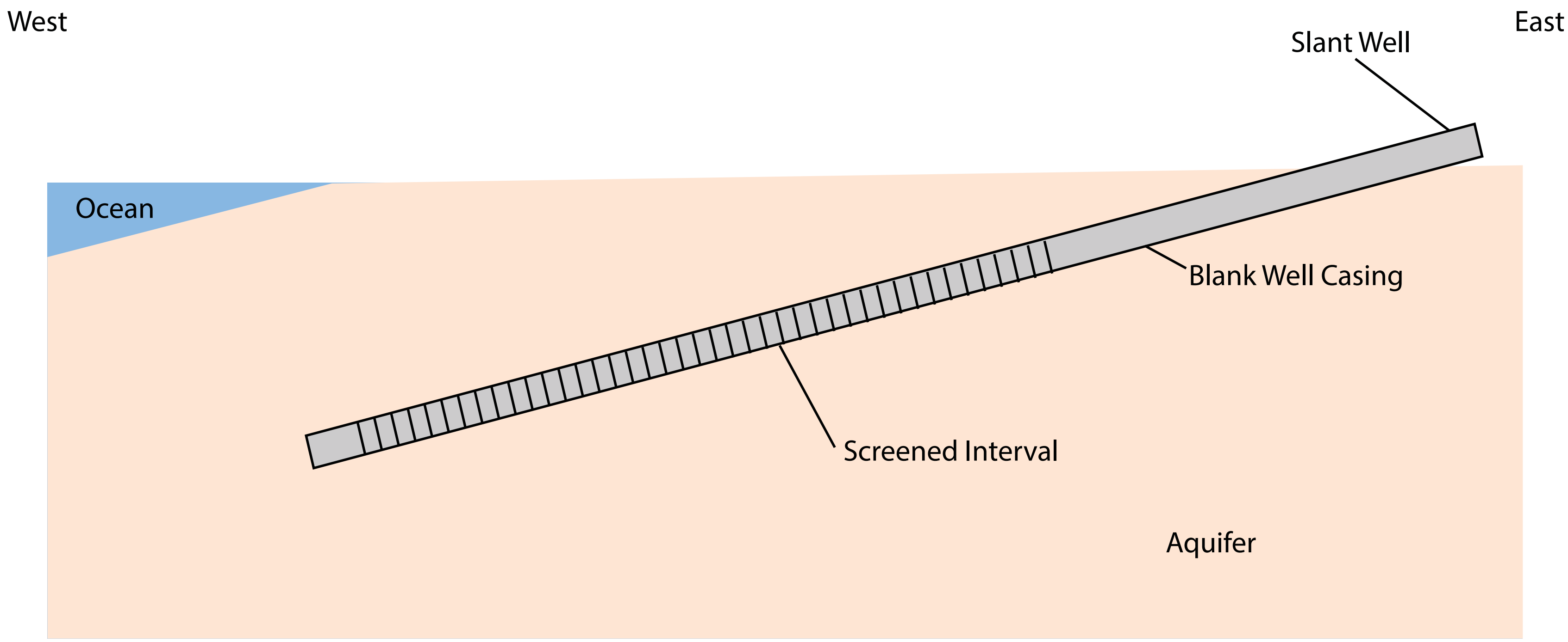
The North Marina Groundwater Model was revised using additional water level data, refined model layer bottom elevations from new geologic sections, and updated aquifer properties estimated from a slant well pumping test. Additionally, aquifer parameter zones were added to the model to include the former Fort Ord Area A-Aquifer and Fort Ord Salinas Valley Aquitard (FO-SVA) to better represent groundwater conditions south of the Salinas River. In this report, the updated model is referred to as the $NMGWM^{2016}$.

We evaluated the capability of $NMGWM^{2016}$ to match historical water levels (October 1979 through September 2011) and simulate drawdown in response to test slant well pumping. The $NMGWM^{2016}$ calculated water levels and trends generally match measured water levels and trends. The overall relative error is substantially less than 10% to 15%, which meets that calibration criteria, and indicates that model errors are only a small part of the overall model response. Model calibration was also assessed by comparing the magnitude, timing and longer term trends in observed and model-calculated water levels, a scatter plot of measured and model-calculated water levels, and analysis of model residuals (the difference between model-calculated and measured water levels). The results provide confidence that the model calculations are reliable estimates of the groundwater response to pumping, which was confirmed by simulating measured drawdown during test slant well pumping.

The residual analysis indicated that model errors fall within a fairly narrow range that is close to zero, and the number of positive and negative residuals appear about the same. The spatial distribution of model errors is fairly random, and all model layers have both positive and negative values. Relatively large differences between model-calculated and measured water levels were identified for wells in Model Layer 2, and simulation bias between model-calculated water levels and model errors was identified for some wells in Model layer 4. These errors are attributed to (1) limitations for simulating steep vertical gradients and localized perched conditions in areas of Model Layer 2, (2) specified initial water levels for Model Layer 2 in the Fort Ord Area, (3) specified water levels along the southern head-dependent flux boundaries, and (4) deficiencies in the timing and magnitude of specified recharge and pumping. Most of these deficiencies were introduced by the transfer of information from the SVIGSM to the NMGWM, and were removed from the modeling analysis by utilizing the superposition approach as described below.

Pumping and recovery model scenarios were defined for the CEMEX and Potrero Road sites, and the 63-year pumping and 63-year recovery scenarios simulated using monthly stress periods. Due to the complex nature of simulating recharge and discharge processes in the Salinas Valley Groundwater Basin, and identified problems with specified initial water levels and boundary condition water levels derived from SVIGSM results, we employed the theory of superposition to remove these deficiencies and determine water level changes (drawdown) resulting solely from proposed slant well pumping. We ran 34 future scenarios representing variable project operations and sea levels (2012 and 2073). Model results are presented in maps that show the area where calculated drawdown is 1 foot or greater under various future project scenarios for both the CEMEX and Potrero Road sites. Particle tracking was also employed to estimate the ocean capture zone for future slant well pumping and to simulate changes to the reported seawater intrusion front for different scenarios. Results show that slant well pumping at the CEMEX site slows future saltwater intrusion in the southern portion of Model Layer 4; however slant well pumping has little to no effect on future saltwater intrusion in Model Layer 6.

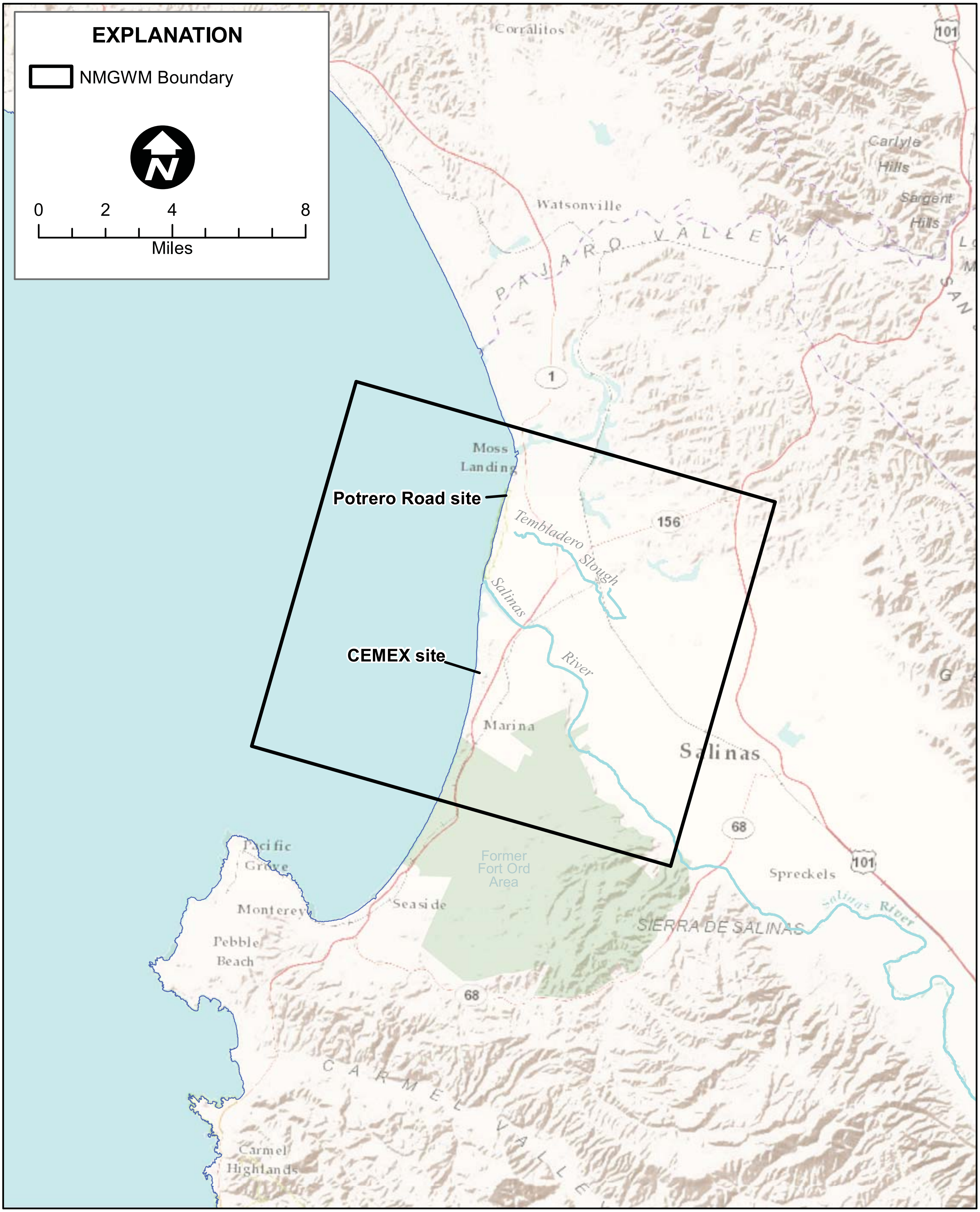
The most likely sources of error in the superposition analysis using the NMGWM^{2016} arise from uncertainty associated with modeled boundary conditions including sea level rise, specified hydraulic conductivity values, and assumed project operations including pumping rates and relative contributions of groundwater in aquifers represented by Model Layer 2 and Model Layer 4 to total slant well pumping. We used the results from sensitivity model runs to delineate the potential range in drawdown contours and thus bracket the possible drawdown due to uncertainty in model input and assumptions. At the CEMEX site (24.1 MGD), the maximum distance from the well field to the 1-foot drawdown contour was about 15,000 feet under 2012 sea level, and about 20,000 feet in Model Layer 4. As a result of uncertainty in sea level rise, hydraulic conductivity, and pumping layer allocation distribution, these distances ranged from less than 10,000 feet to 24,000 feet in Model Layer 2, and 12,000 to 24,000 feet in Model Layer 4. At the lower pumping rate (15.5 MGD), these distances range from about 6,000 feet to more than 17,000 feet in Model Layer 2, and almost 6,000 feet to 19,000 feet in Model Layer 4. Similarly at the Potrero Road site, the distances can range from about 19,000 to 27,000 feet, and 16,000 to almost 25,000 feet in Model Layer 2 as a result of uncertainty in sea level rise, hydraulic conductivity, and pumping layer allocation distribution for the 24.1 and 15.5 MGD pumping rates, respectively.



Modifed from: Geoscience Support Services, Inc., 2015, “Monterey Peninsula Water Supply Project Groundwater Modeling and Analysis – DRAFT,” prepared for California American Water and Environmental Science Associates, April 17, 2015.

Note: not to scale.

HYDROFOCUS INC. Solutions for Land and Water Resources	Example low-angle horizontal slant well diagram	Figure 1.1
PROJECT: 5073	DATE: 11/8/2016	



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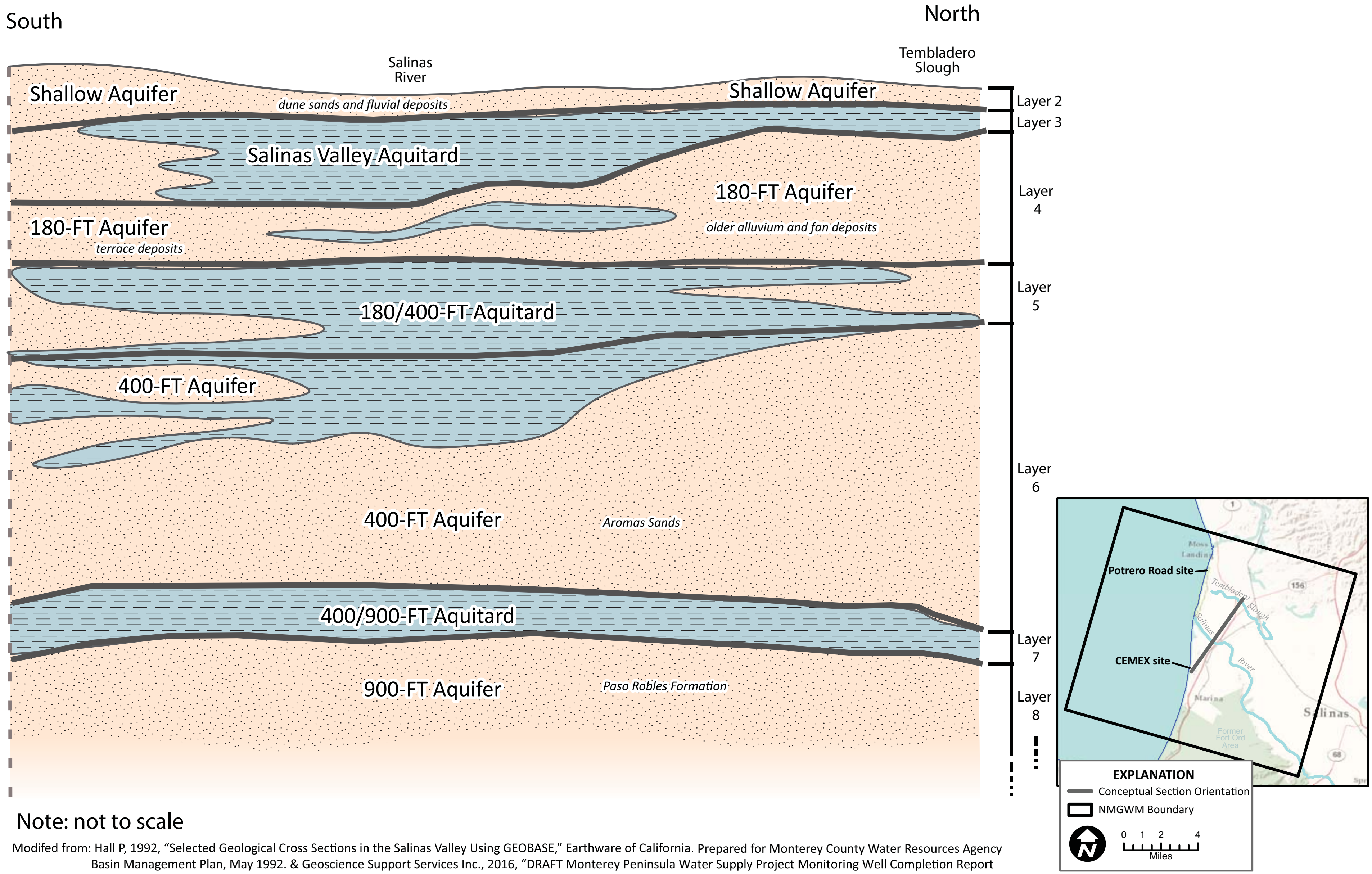
North Marina Groundwater Model (NMGWM) boundaries and relevant features.

Figure 1.2

PROJECT: 5073

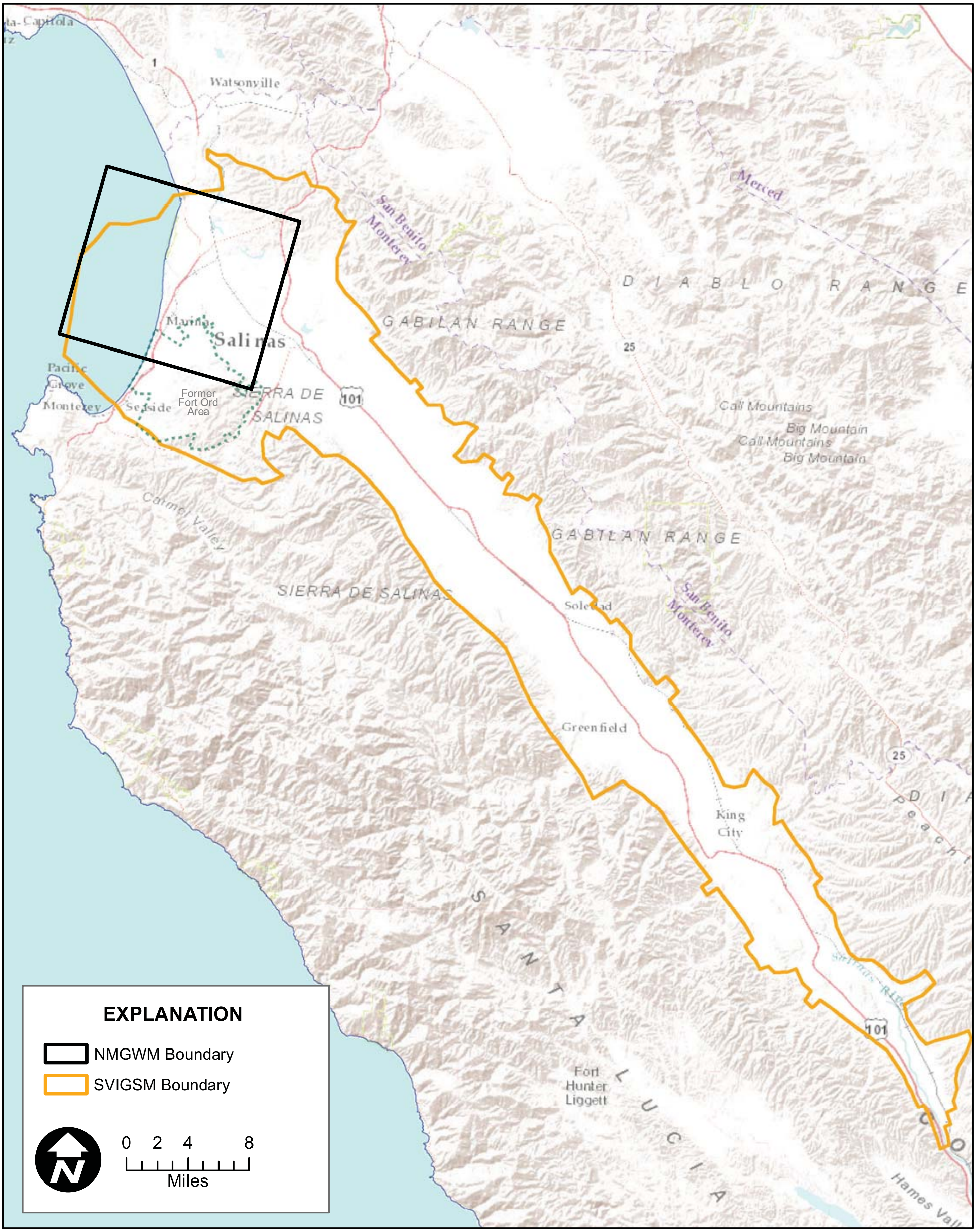
DATE: 11/15/2016



Note: not to scale

Modifed from: Hall P, 1992, "Selected Geological Cross Sections in the Salinas Valley Using GEOBASE," Earthware of California. Prepared for Monterey County Water Resources Agency Basin Management Plan, May 1992. & Geoscience Support Services Inc., 2016, "DRAFT Monterey Peninsula Water Supply Project Monitoring Well Completion Report and CEMEX Model Update," prepared for California American Water, July 15, 2016.

HYDROFOCUS INC. Solutions for Land and Water Resources	Conceptual hydrogeologic section in the NMGWM area.	Figure 2.1
PROJECT: 5073	DATE: 11/18/2016	



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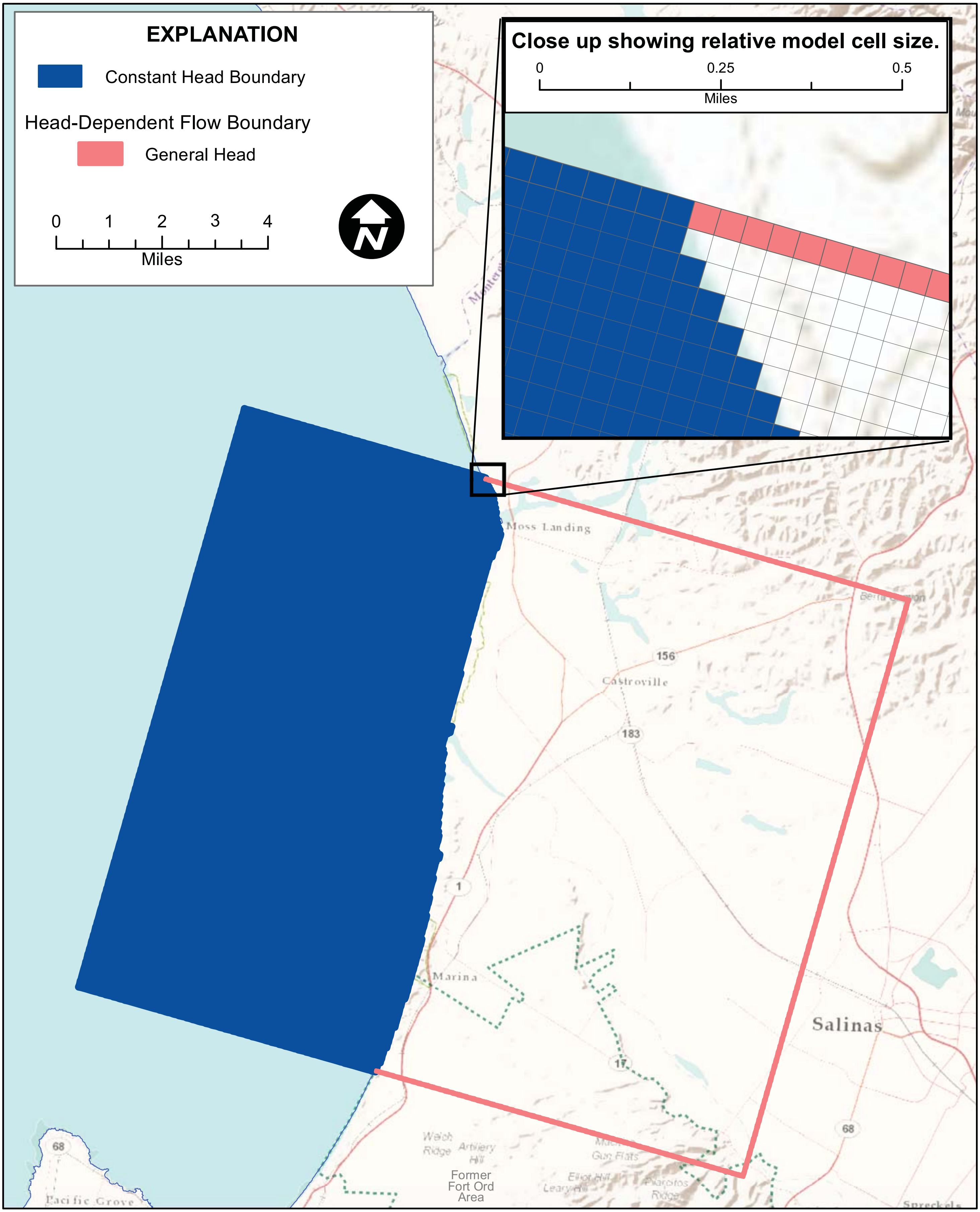
SVIGSM and NMGWM grid boundaries.

Figure 2.2

PROJECT: 5073

DATE: 11/15/2016



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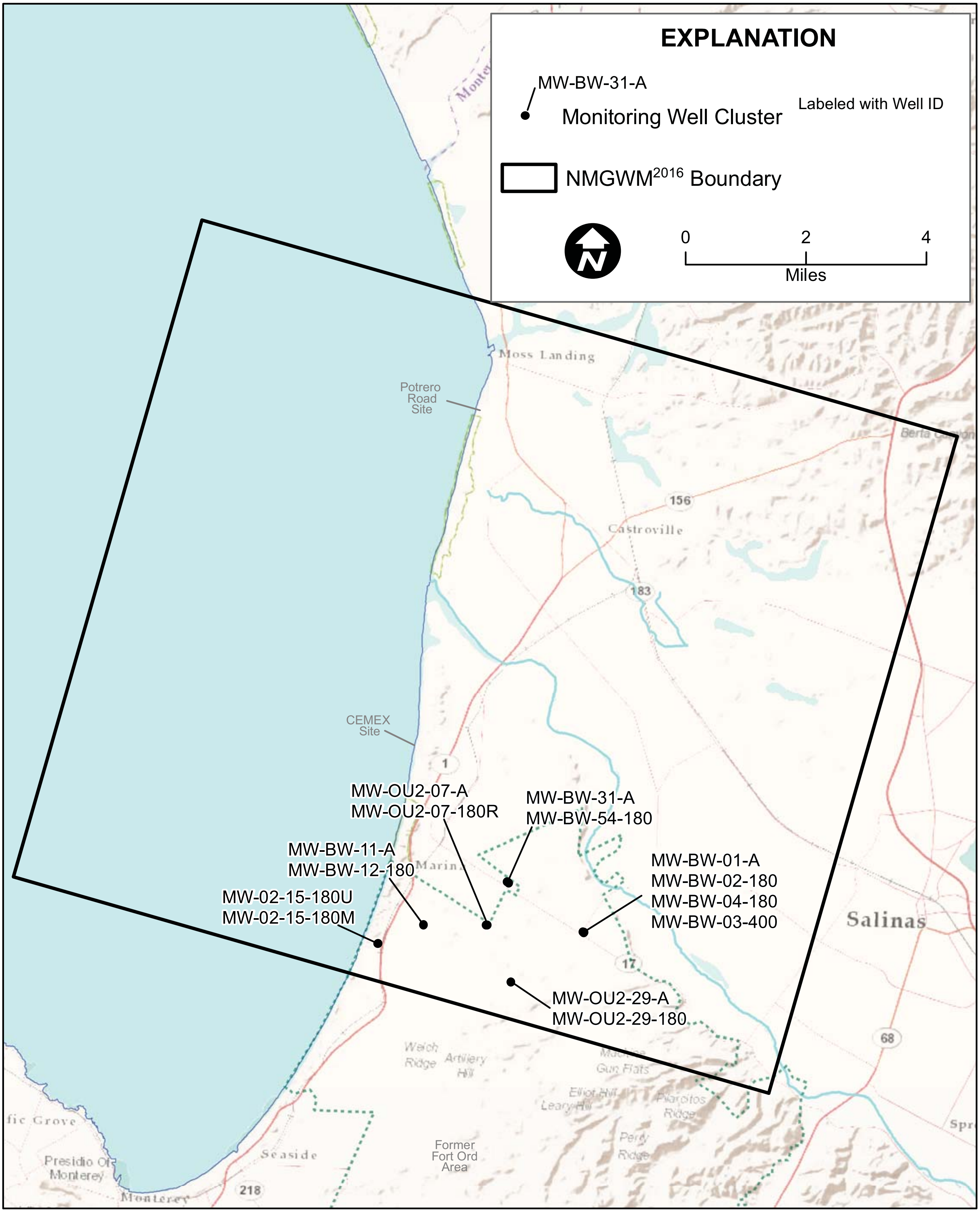
NMGWM^{2016} boundary conditions.

Figure 2.3

PROJECT: 5073

DATE: 8/25/2016



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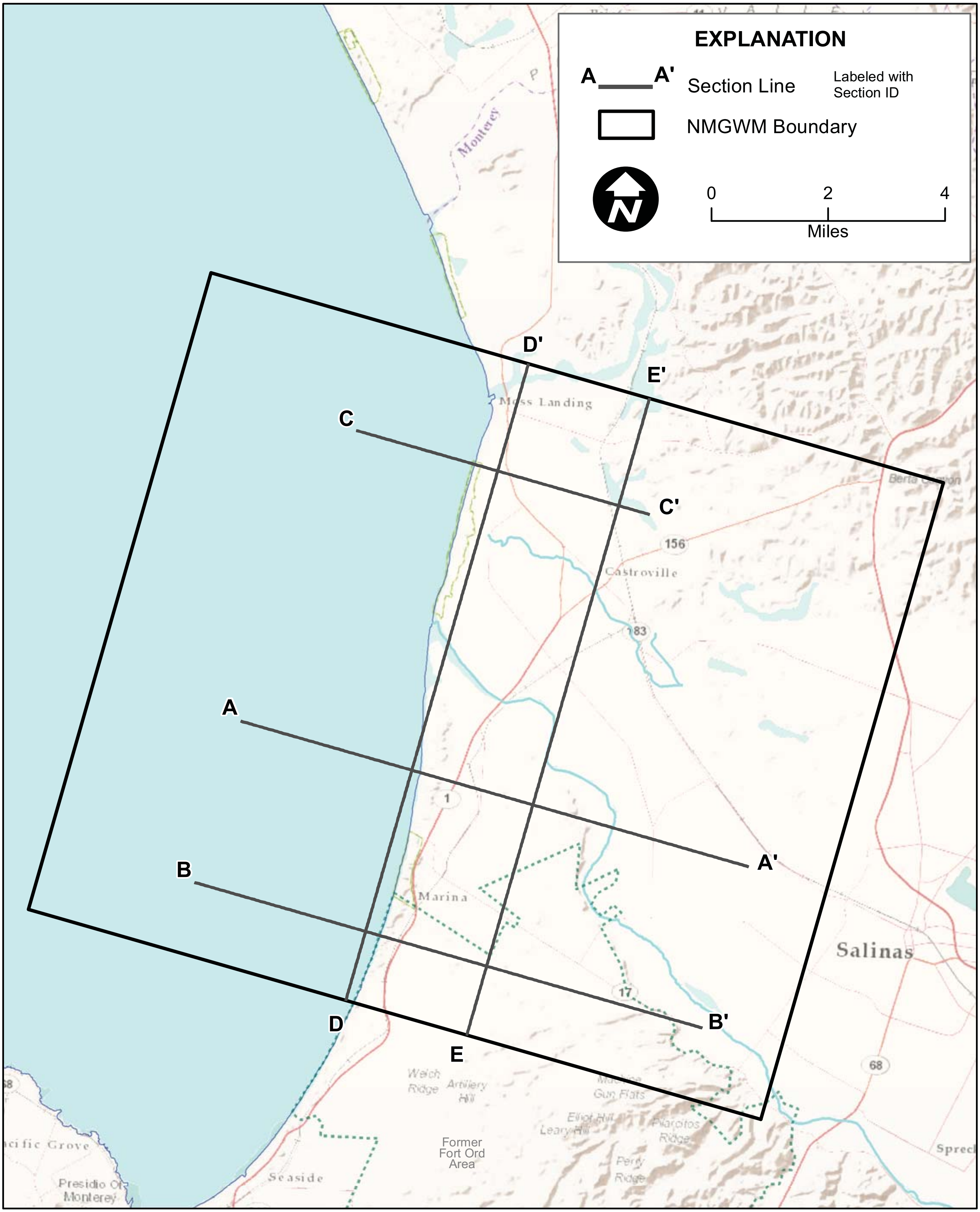
Monitoring well clusters added to model areas south of the Salinas River (former Fort Ord Area) for historical model run, 1979-2011.

Figure 3.1

PROJECT: 5073

DATE: 8/30/2016



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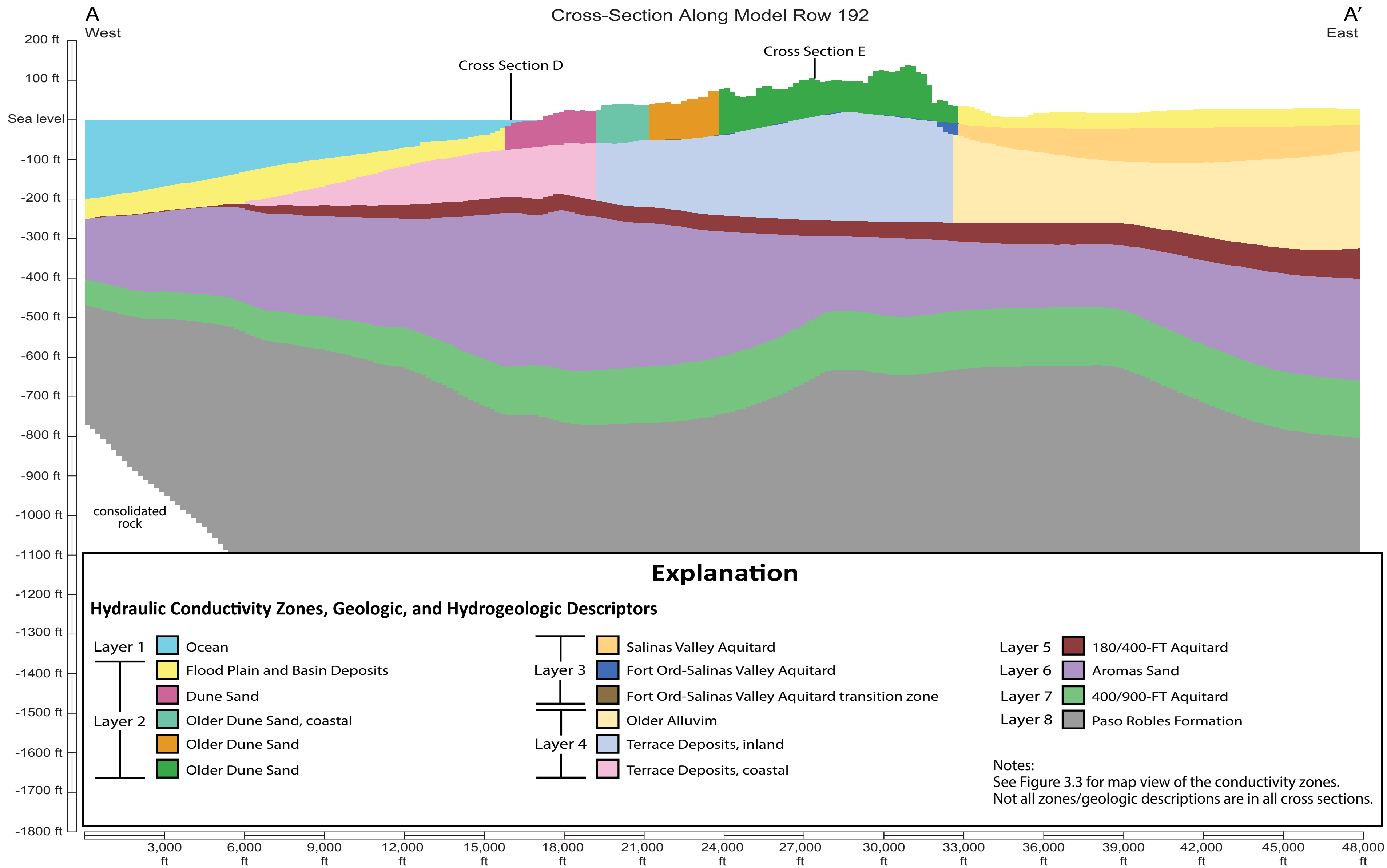
NMGWM[2016] section lines.

Figure 3.2a

PROJECT: 5073

DATE: 8/12/2016



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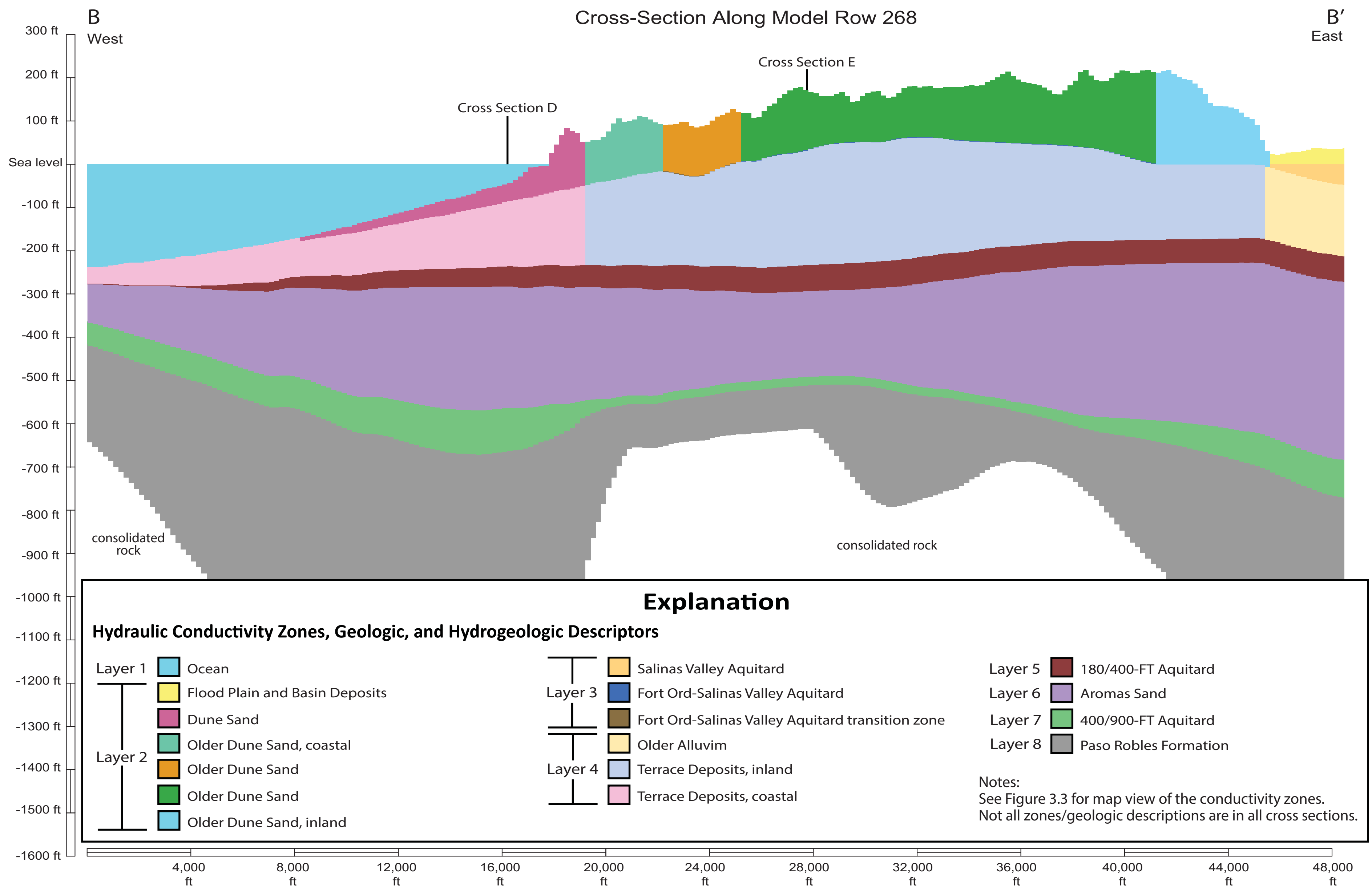
Section A-A', NMGWM[2016].

Figure 3.2b

PROJECT: 5073

DATE: 11/8/2016



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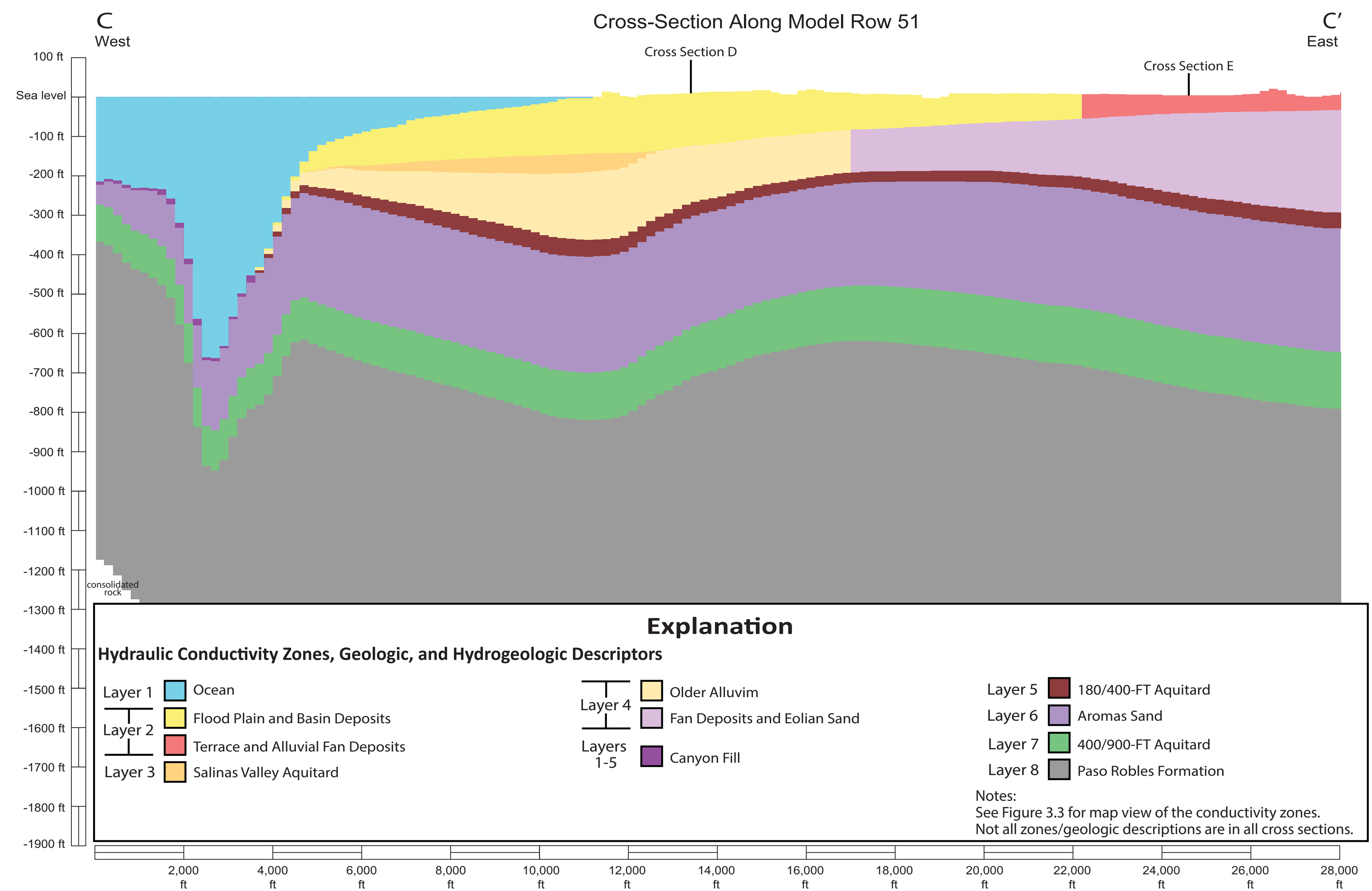
Section B-B', NMGWM[2016].

Figure 3.2c

PROJECT: 5073

DATE: 11/21/2016



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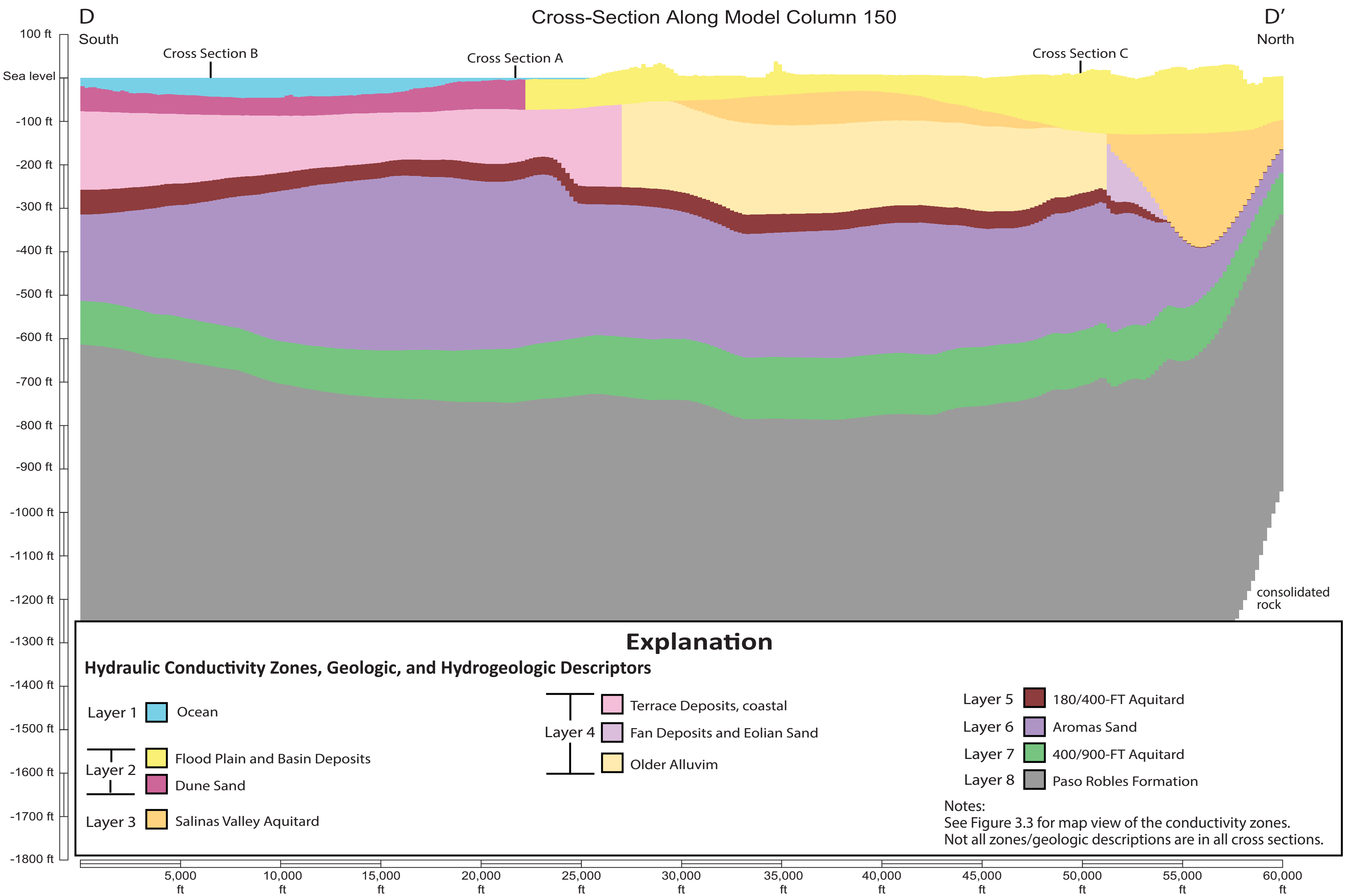
Section C-C', NMGWM[2016].

Figure 3.2d

PROJECT: 5073

DATE: 11/21/2016



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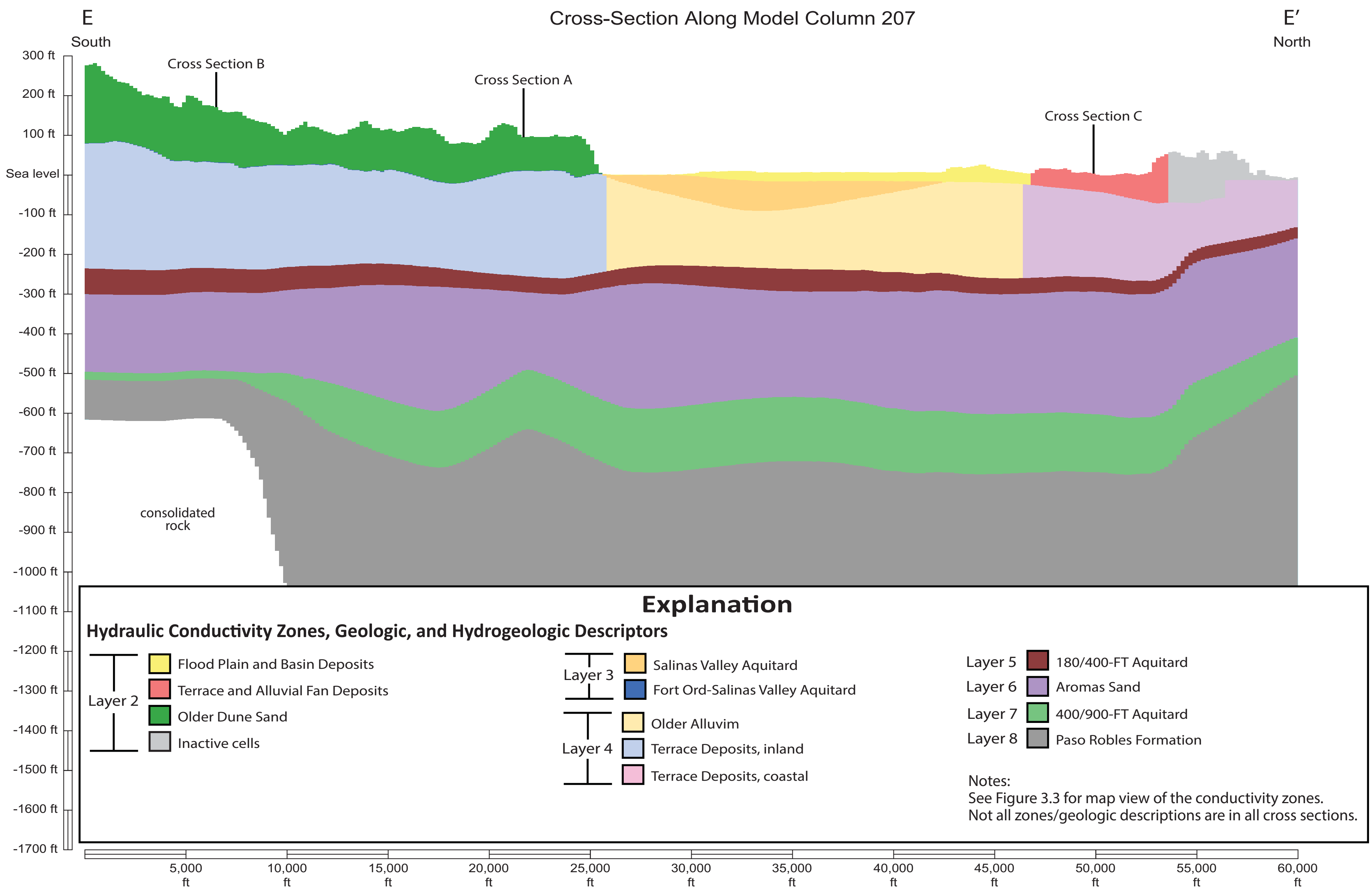
Section D-D', NMGWM[2016].

Figure 3.2e

PROJECT: 5073

DATE: 11/21/2016



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Section E-E', NMGWM2016.

Figure 3.2f

PROJECT: 5073

DATE: 11/21/2016

NMGWM2016 Boundary

Inactive Model Cells

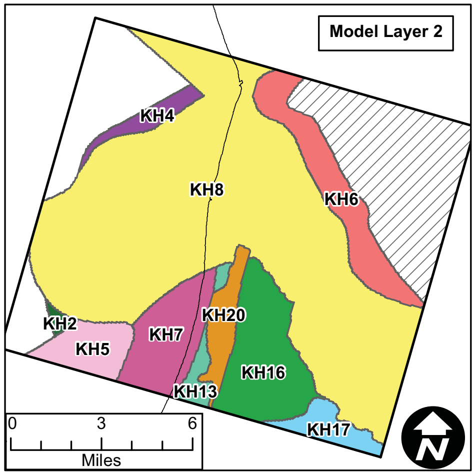
KH20 Horizontal Hydraulic Conductivity Zone

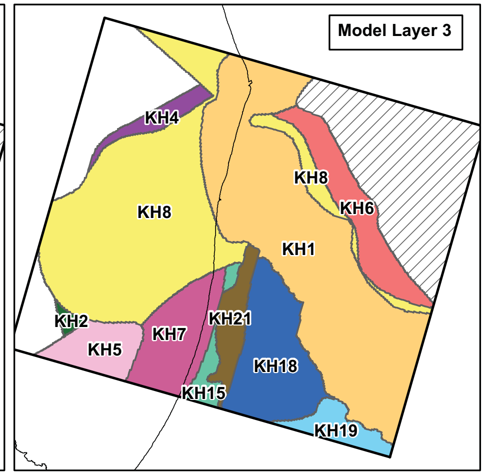
Zone	Sources
KH1	
KH2	1, 8, 9, 10, 11, 12
KH3	1, 7, 8
KH4	1, 8, 9, 10, 11, 12
KH5	1, 2, 3, 17
KH6	1, 8
KH7	1, 2, 3, 9, 16
KH8	1, 2, 3, 5, 8, 13, 14
KH9	1, 7, 8, 14
KH13 & KH15	1, 2, 4, 6, 8, 11, 12, 16, 17

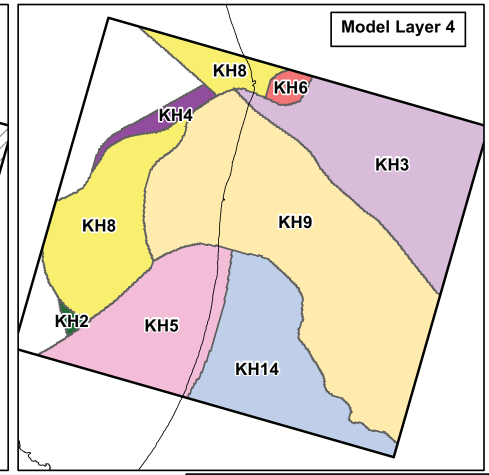
Zone	Sources
KH14	1, 2, 6, 7, 8, 9, 11, 12, 13, 14, 17
KH16	1, 4, 5, 6, 8, 9, 11, 12, 14, 16, 17
KH17 & KH19	1, 8
KH18	6, 11, 12
KH20	1, 4, 6, 8, 9, 11, 12, 13, 14, 16, 17
KH21	6, 11, 12
KHLAY5	
KHLAY6	1, 8, 9, 10, 11, 12, 17
KHLAY7	
KHLAY8	1, 8, 9, 10, 19, 20

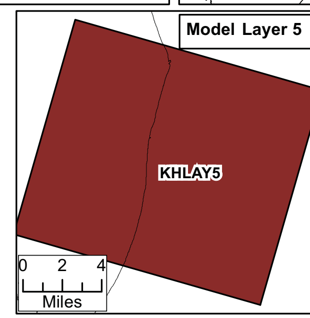
See Figure 3.3d for source information.

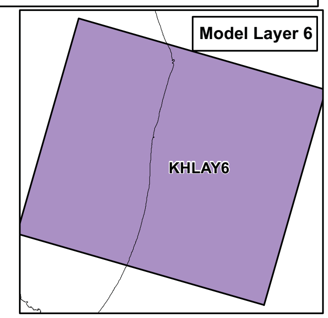
Layer 1 represents the ocean and therefore is not mapped.

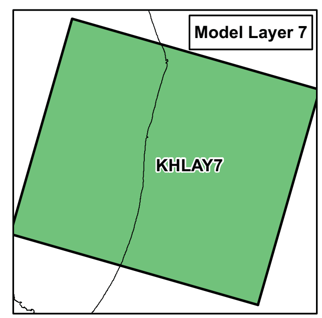


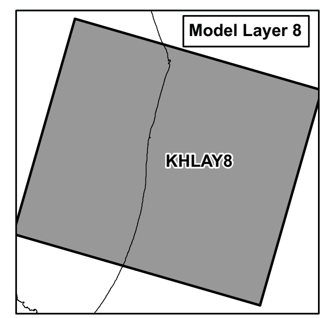


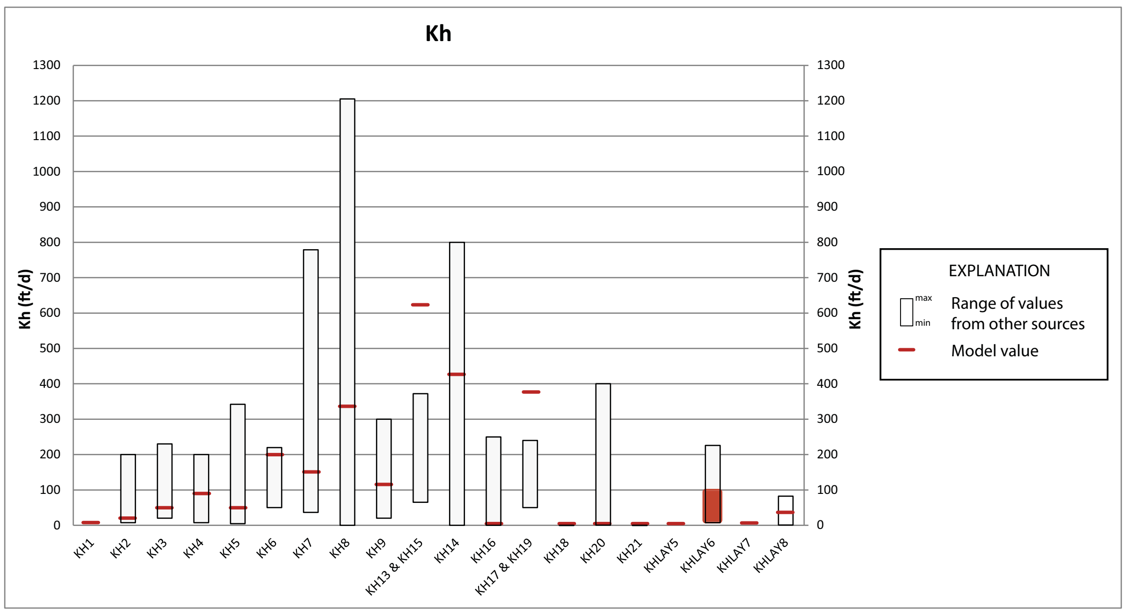












HYDROFOCUS Solutions for Land and Water Resources	Horizontal hydraulic conductivity parameter zones, NMGWM2016.	Figure 3.3a
PROJECT: 5073	DATE: 4/12/2017	

NMGWM2016 Boundary

Inactive Model Cells

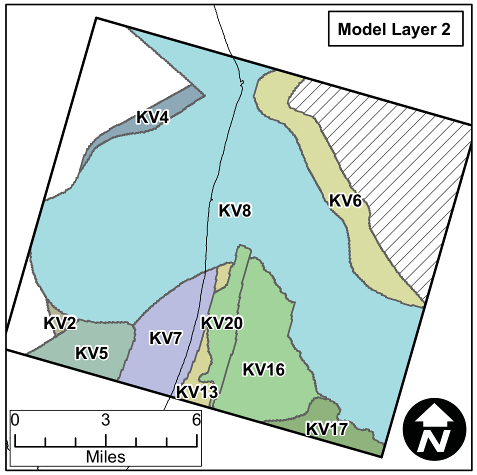
KV20 Vertical Hydraulic Conductivity Zone

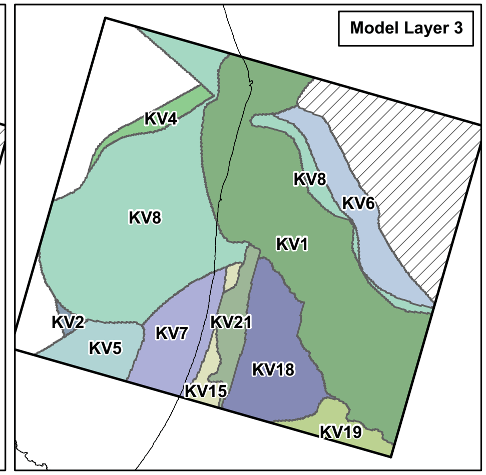
Zone	Sources
KV1	1
KV2	11
KV3	1
KV4	11
KV5	1, 3
KV6	1
KV7	1, 3
KV8	1, 3, 14
KV9	1, 14
KV10	1
KV12	

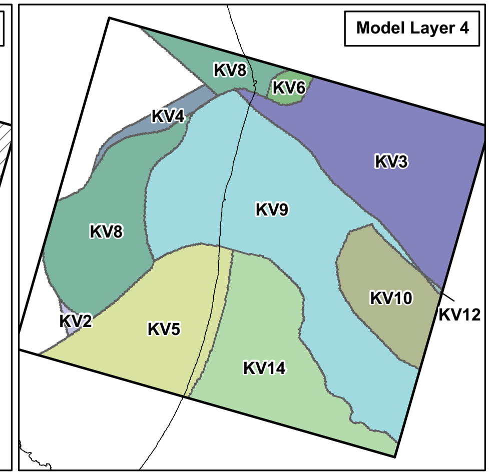
Zone	Sources
KV13 & KV15	1, 6, 11
KV14	1, 6, 11, 14
KV16	1, 6, 11, 14, 18
KV17 & KV19	1
KV18	1, 6, 11, 12, 15
KV20	1, 6, 11, 14
KV21	1, 6, 11, 12
KVLAY5	1, 7
KVLAY6	11
KVLAY7	1, 7
KVLAY8	

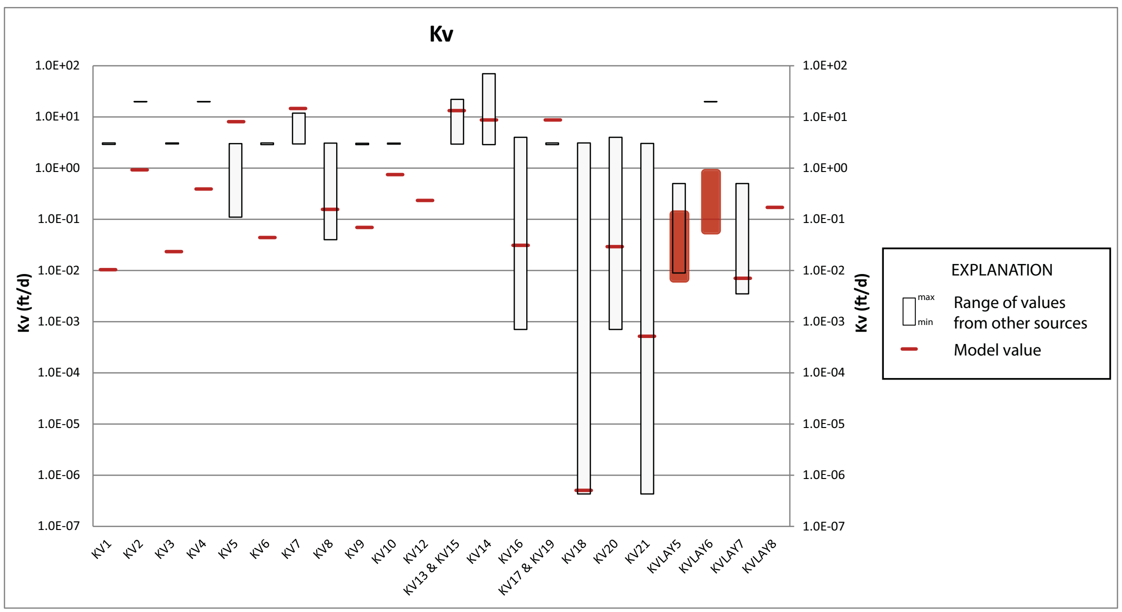
See Figure 3.3d for source information.

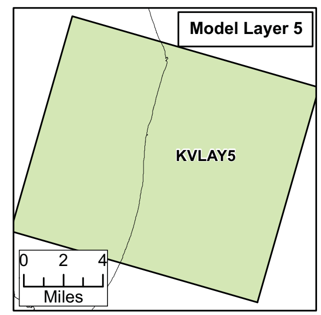
Layer 1 represents the ocean and therefore is not mapped.

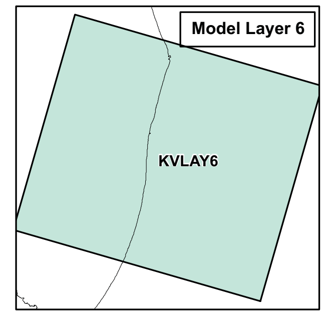


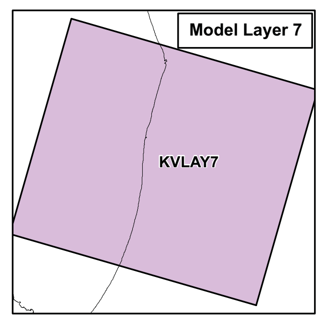


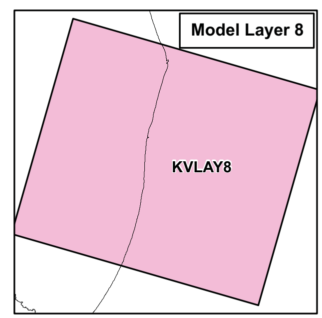












HYDROFOCUS INC. Solutions for Land and Water Resources

Vertical hydraulic conductivity parameter zones, NMGWM2016.

Figure 3.3b

PROJECT: 5073 | DATE: 11/21/2016

NMGWM2016 Boundary

Inactive Model Cells

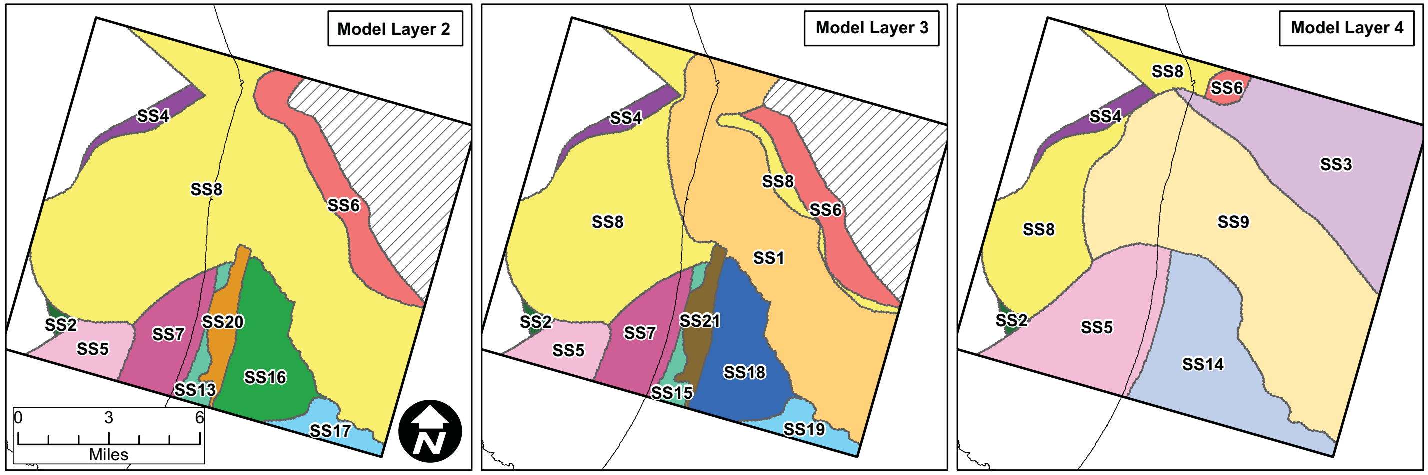
SS20 Specific Storage Zone

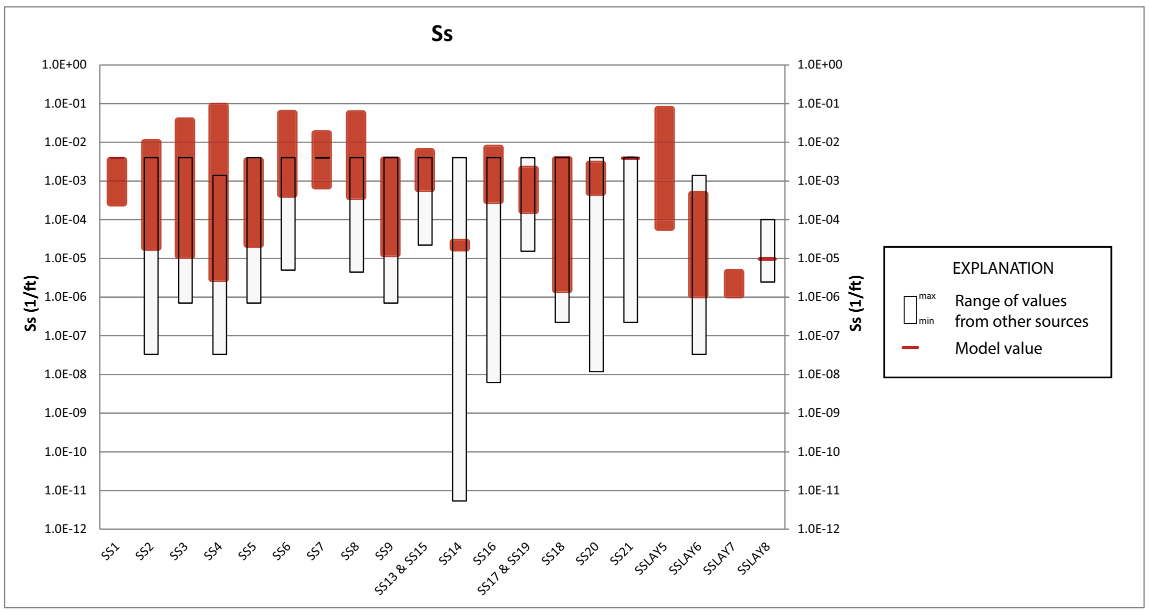
Zone	Sources
SS1	1
SS2	1
SS3	1, 7, 8
SS4	1
SS5	1, 7
SS6	1, 8
SS7	1
SS8	1, 8
SS9	1, 7, 8
SS13 & SS15	1, 8

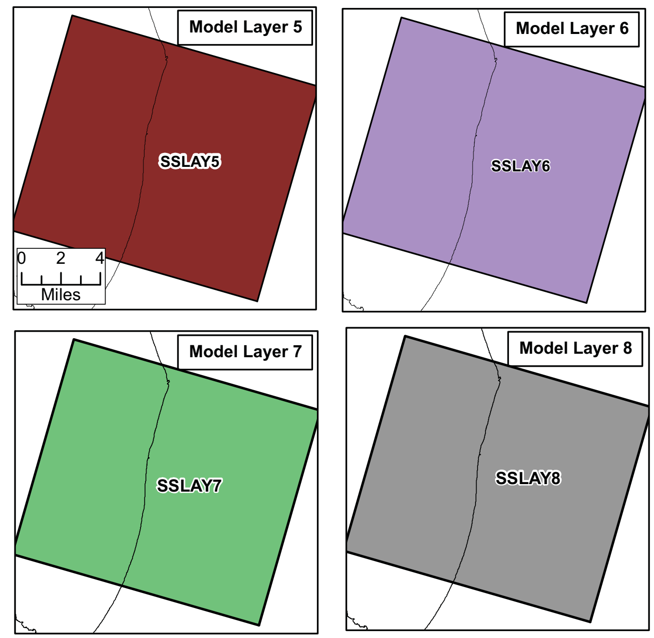
Zone	Sources
SS14	1, 7, 8, 9, 11
SS16	1, 8, 9, 10
SS17 & SS19	1, 8
SS18	1, 11
SS20	1, 8, 9
SS21	1, 11
SSLAY5	
SSLAY6	1, 8, 10, 11
SSLAY7	
SSLAY8	1, 8, 10

See Figure 3.3d for source information.

Layer 1 represents the ocean and therefore is not mapped.







HYDROFOCUS Solutions for Land and Water Resources

Specific storage parameter zones, NMGWM 2016.

Figure 3.3c

PROJECT: 5073

DATE: 11/21/2016

Source #	Source
1	Luhdorff and Scalmanini, Consulting Engineers, 2015, "Updated Draft Version 2 Hydrologic Modeling of the Monterey Peninsula Water Supply Project Using the Salinas Valley Integrated Ground and Surface Water Model." Prepared for Geoscience, March 2015 *in* GEOSCIENCE, 2015, "Monterey Peninsula Water Supply Project Groundwater Modeling and Analysis Draft." Prepared for California American Water and Environmental Science Associates, April 17, 2015.
2	GEOSCIENCE, 2014, "Monterey Peninsula Water Supply Project Hydrogeologic Investigation Technical Memorandum (TM1) Summary of Results - Exploratory Boreholes," Prepared for California American Water RBF Consulting, July 8, 2014. Tables 3-8.
3	GEOSCIENCE, 2014, "Monterey Peninsula Water Supply Project Hydrogeologic Investigation Technical Memorandum (TM1) Summary of Results - Exploratory Boreholes," Prepared for California American Water RBF Consulting, July 8, 2014. Figures 44-47.
4	GEOSCIENCE, 2014, "Monterey Peninsula Water Supply Project Hydrogeologic Investigation Technical Memorandum (TM1) Summary of Results - Exploratory Boreholes," Prepared for California American Water RBF Consulting, July 8, 2014. Pumping test (SGD, 1992).
5	California Regional Water Quality Control Board Central Coast Region, 2006, "Revised Waste Discharge Requirements Order No. R3-2006-0017 Waste Discharger Identification No. 3 270303001 For Monterey Regional Waste Management District Monterey Peninsula Calss III Landfill Monterey County"
6	HydroMetrics LLC, 2008, "Preliminary Modeling Results for the MCWD Desalination Intake," Draft Technical Memorandum to Martin Feeney, from Derrik Williams and Dave Van Brocklin, July 23, 2008.
7	Durbin TJ, Kapple GW, Freckleton JR, 1978, "Two-Dimensional and Three-Dimensional Digital Flow Models of the Salinas Valley Ground-Water Basin, California," U.S. Geological Survey Water-Resources Investigations 78-113. Prepared in cooperation with the U.S.
8	Yates EB, 1988, "Simulated Effects of Ground-Water Management Alternatives for the Salinas Valley, California," U.S. Geological Survey Water-Resources Investigations Report 87-4066. Prepared in cooperation with the Monterey County Flood Control and Water Conservation District
9	Various sources reporting Transmissivity, calculated K based on average model thickness in Fort Ord area. Transmissivity values from sources: 10(Tables 6 and 7), 13(page 7, Table 6), 15(App E), 16(Table 3.8)
10	Harding Lawson Associates, 1994, "Draft Final Basewide HydroGeologic Characterization Fort Ord, California. Volume I - Text and Plates." A Report Prepraed for U.S. Department of the Army Corps of Engineers, June 10, 1994. Tables 6-7.
11	Harding Lawson Associates, 1995, Appendix D Fort Ord Groundwater Model in "Basewide Remedial Investigation/Feasibility Study Fort Ord, California. Volume II - Remedial Investigation." Prepared for Department of the Army Corps of Engineers, October 19, 1995.
12	Harding Lawson Associates, 1995, "Draft Final Conceptual Design Analysis OU 2 Groundwater Remedy Operable Unit 2, Fort Ord Landfills Fort Ord, California." Prepared for Department of the Army Sacramento District Corp of Engineers, May 17, 1995
13	Harding Lawson Associates, 1999, "Draft Final OU 2 Plume Delineation Investigation Report Fort Ord, California." Prepared for United States Department of the Army Corps of Engineers, February 11, 1999.
14	MACTEC Engineering and Consulting, Inc., 2005, "Draft Final Report Groundwater Modeling Report Operable Unit Carbon Tetrachloride Plume Groundwater Remedial Investigation / Feasibility Study Former Fort Ord, California." Prepared for United States Army Corps of Engineers Sacramento District, October 28, 2005.
15	MACTEC Engineering and Consulting, Inc., 2006, "Final Operable Unit Carbon Tetrachloride Plume Groundwater Remedial Investigation / Feasibility Study Former Fort Ord, California Volume I - Remedial Investigation." Prepared for United States Army Corps of Engineers, May 19, 2006.
16	HydroGeoLogic, Inc., 2006, "Final 100% Engineering Design Report Volume 2 of 3 Groundwater Modeling and Design Analysis Operable Unit 1 Fritzsche Army Airfield Fire Drill Area Former Fort Ord, Califorina." Prepared for U.S. Army Corps of Engineers Sacramento District, June 15, 2006.
17	Various sources reporting K from aquifer and slug tests. Sources: 10(Table 5, Plate 19), 16(Table 3.8), 18(Table 10.9-1)
18	Jordan PD, Oldenburg CM, Su GW, 2005, "Analysis of Aquifer Response, Groundwater Flow, and Plume Evolution at Site OU 1, Former Fort Ord, California. Final Repot Part 1." February 21, 2005.
19	Hanson RT, Everett RR, Newhouse MW, Crawford SM, Pimentel MI, Smith GA, "Geohydrology of a Deep-Aquifer System Monitoring-Well Site at Marina, Monterey County, California," U.S. Geological Survey Water-Resources Investigations Report 02-4003.
20	Feeney MB and Rosenberg LI, 2003, "Deep Aquifer Investigation-Hydrogeologic Data Inventory, Review, Interpretation and Implications." Technical Memorandum to WRIME, Inc. March 31, 2003.

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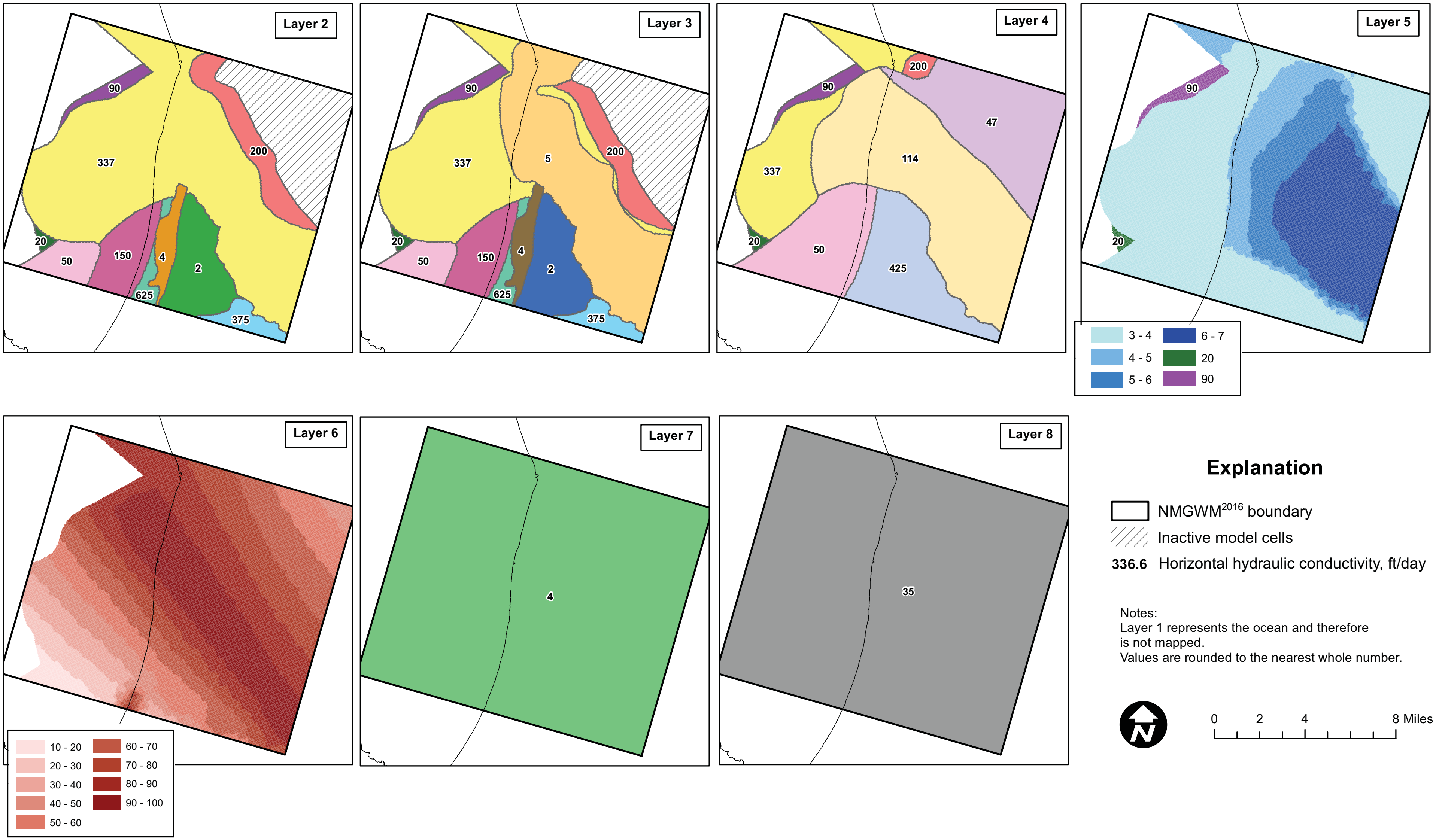
Sources for parameter values.

Figure 3.3d

PROJECT: 5073

DATE: 4/12/2017



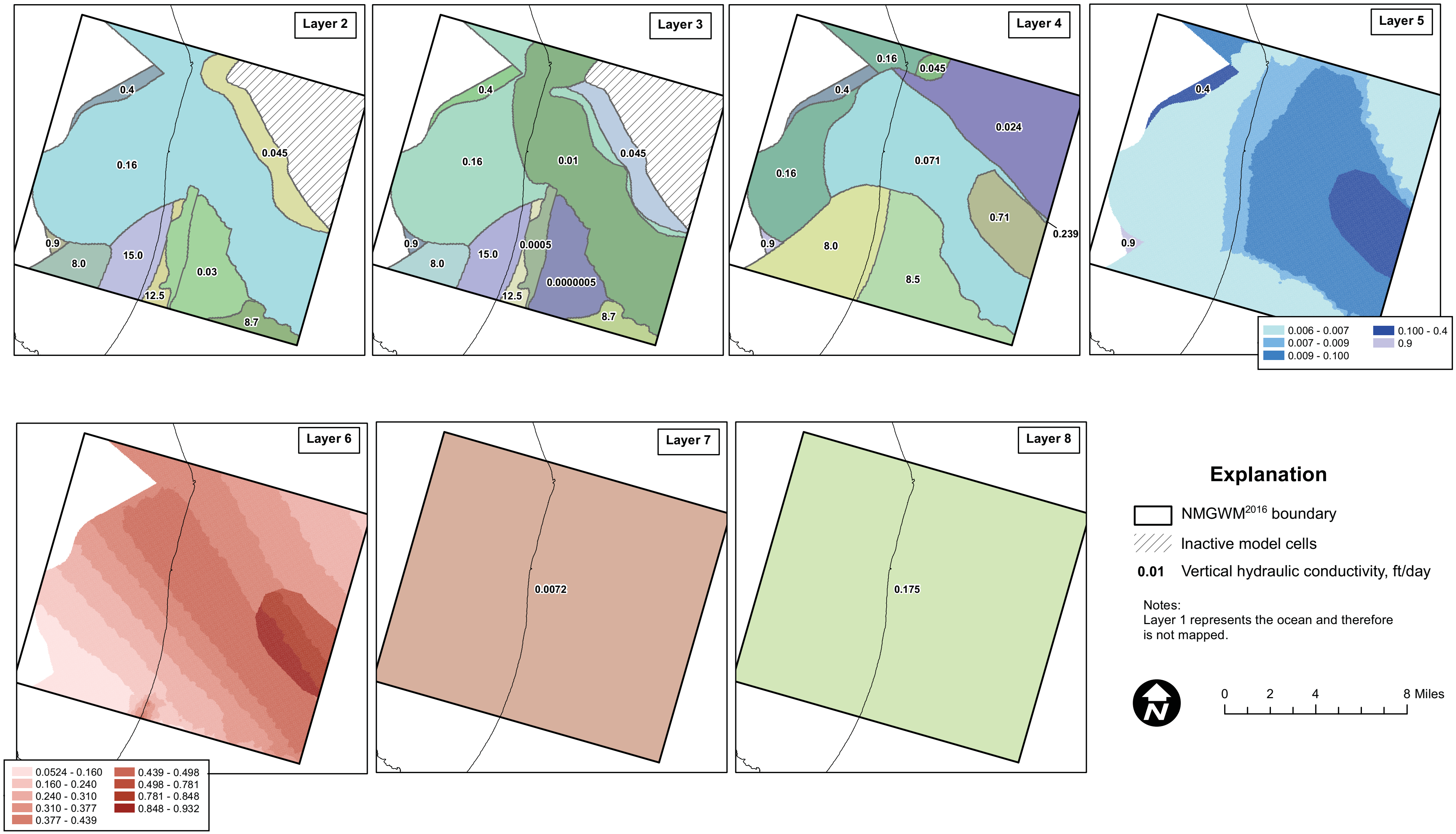
HYDROFOCUS INC. Solutions for Land and Water Resources

Horizontal hydraulic conductivity parameter zones and values, NMGWM^{2016}.

Figure 3.4a

PROJECT: 5073

DATE: 11/15/2016



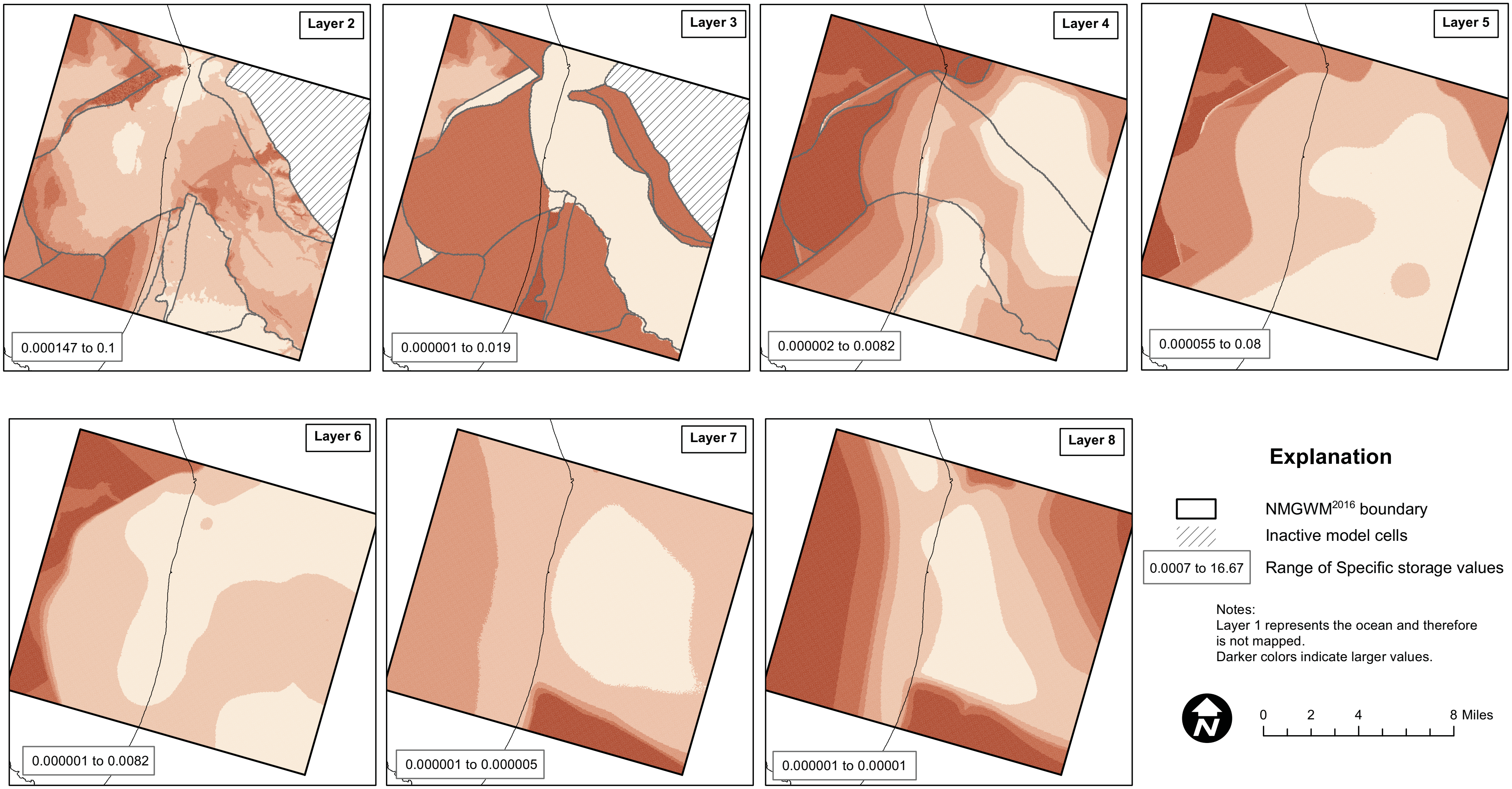
HYDROFOCUS INC. Solutions for Land and Water Resources

Vertical hydraulic conductivity parameter zones and values, NMGWM^{2016}.

Figure 3.4b

PROJECT: 5073

DATE: 11/15/2016



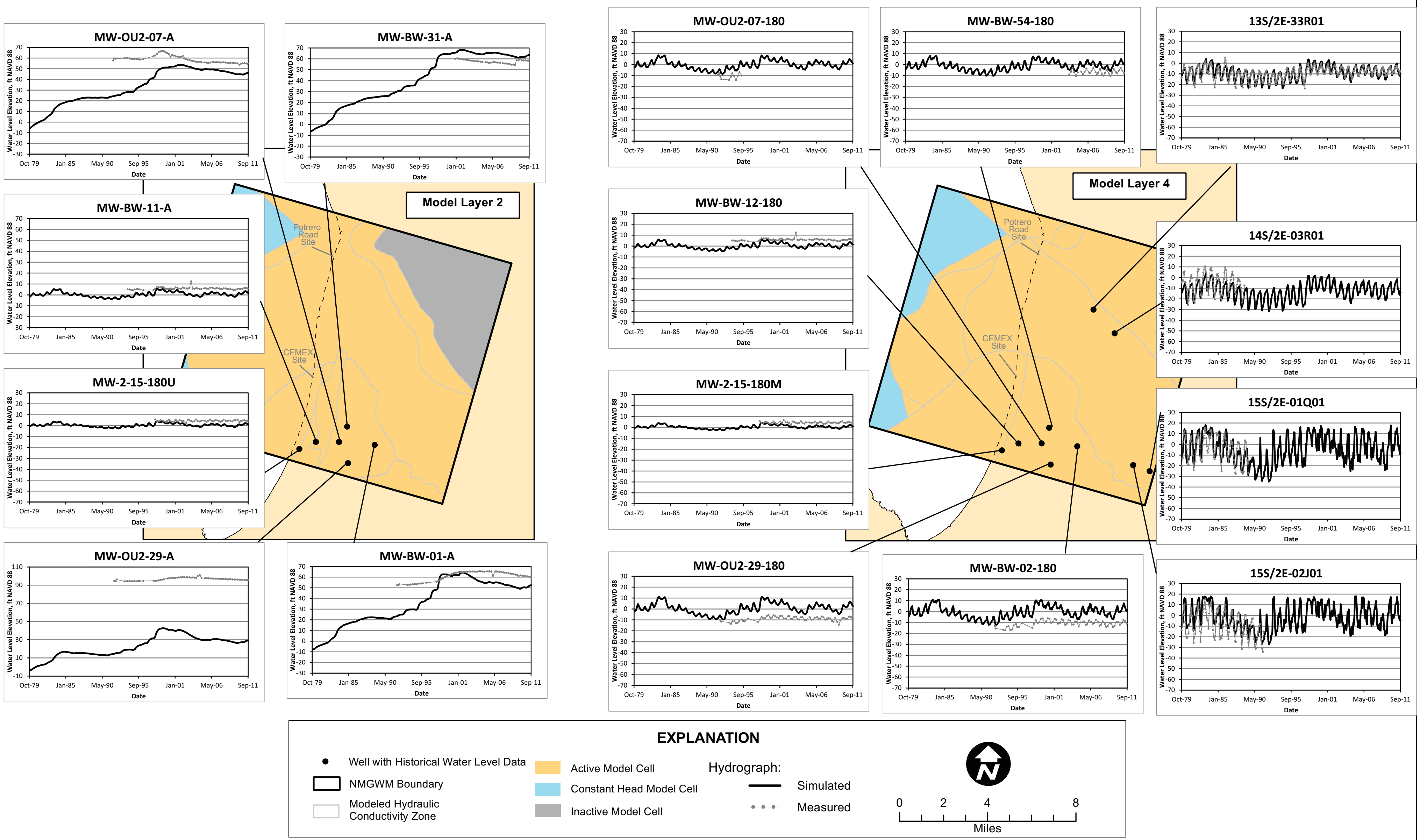
HYDROFOCUS INC. Solutions for Land and Water Resources

Specific storage parameter zones and values, NMGWM2016.

Figure 3.4c

PROJECT: 5073

DATE: 11/15/2016



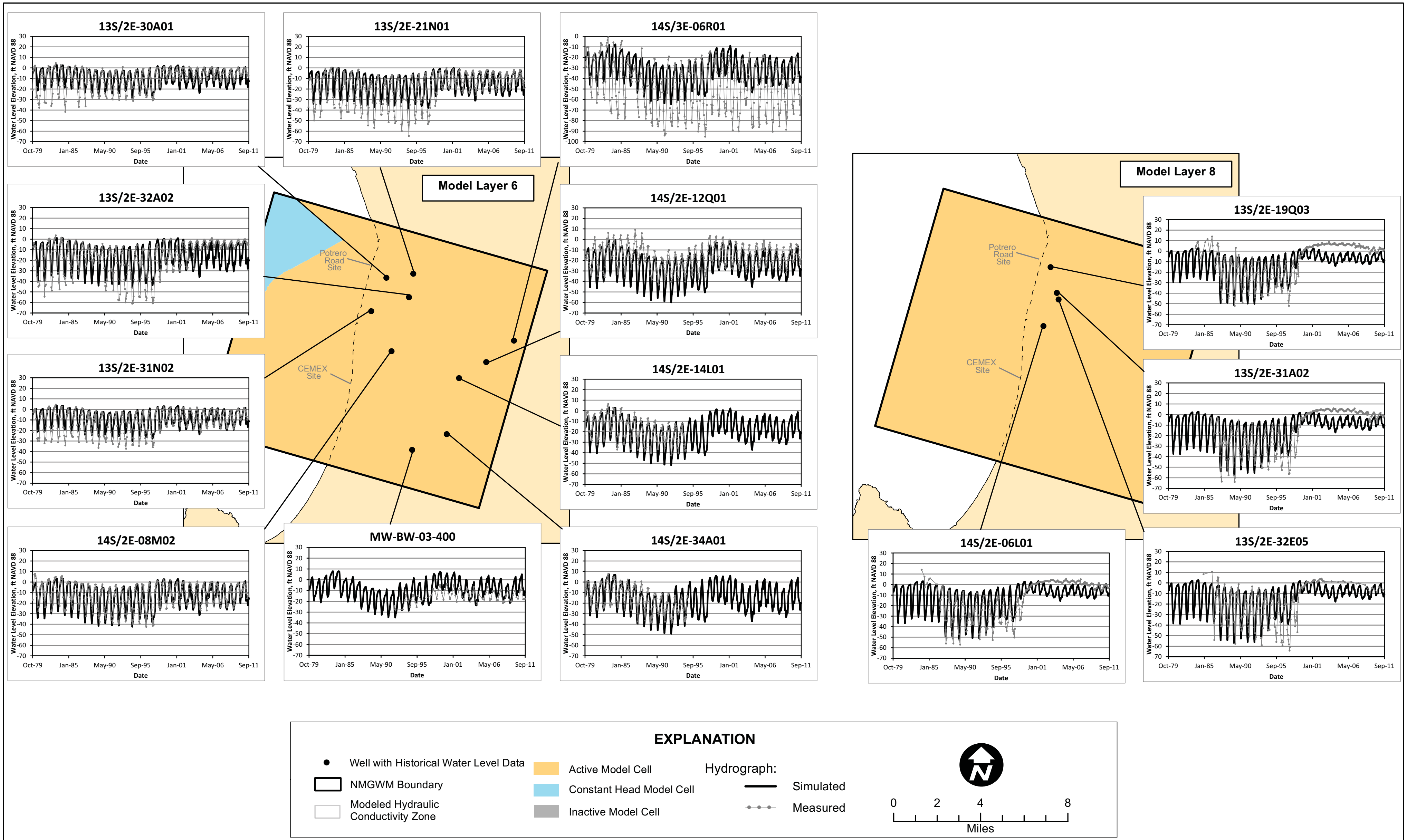
HYDROFOCUS INC. Solutions for Land and Water Resources

Measured and NMGWM[2016] calculated water levels, History Matching Run (1979-2011) for Model Layer 2 and Model Layer 4.

Figure 4.1a

PROJECT: 5073

DATE: 8/19/2016



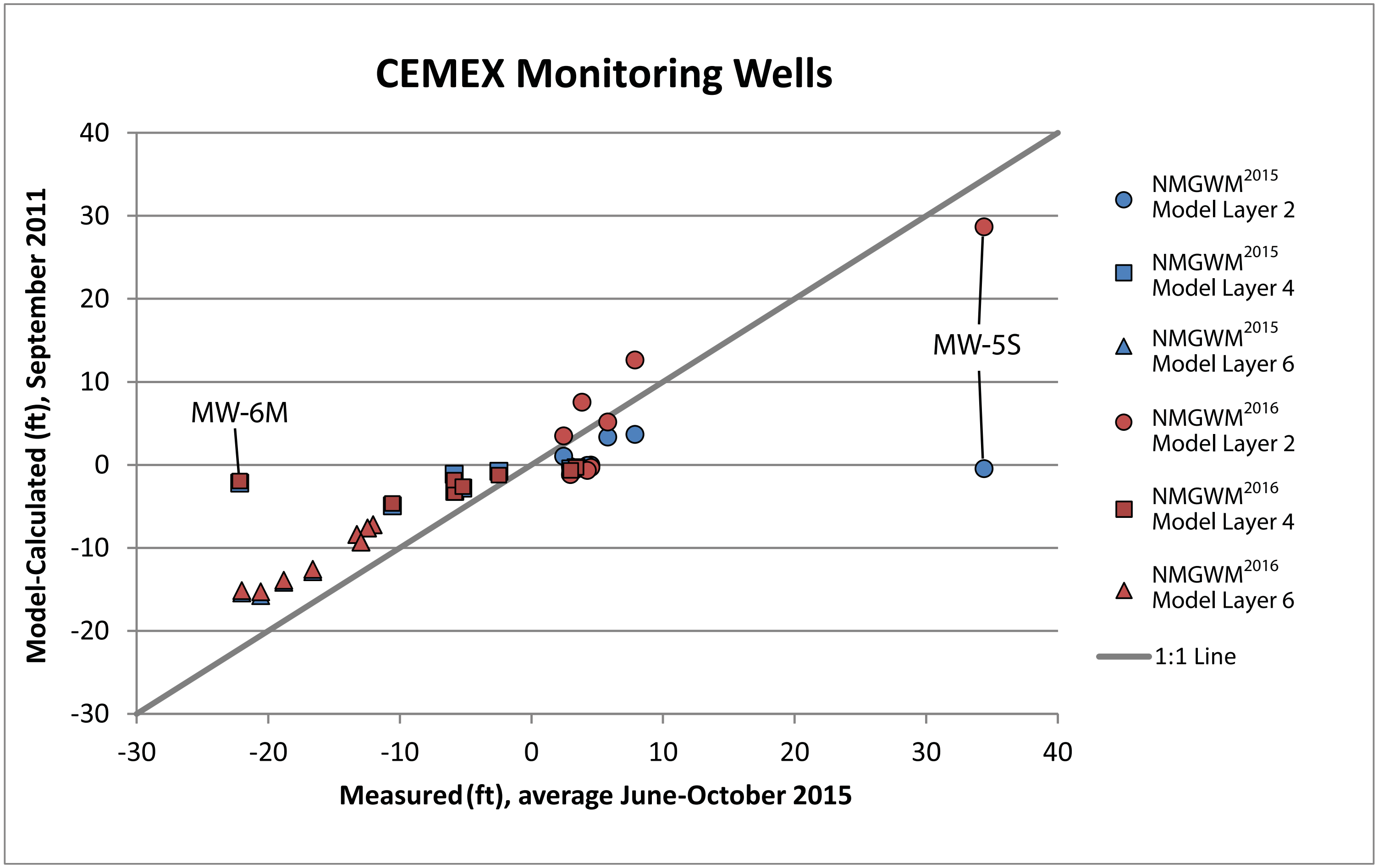
HYDROFOCUS INC. Solutions for Land and Water Resources

Measured and NMGWM2016 calculated water levels, History Matching Run (1979-2011) for Model Layer 6 and Model Layer 8.

Figure 4.1b

PROJECT: 5073

DATE: 8/12/2016



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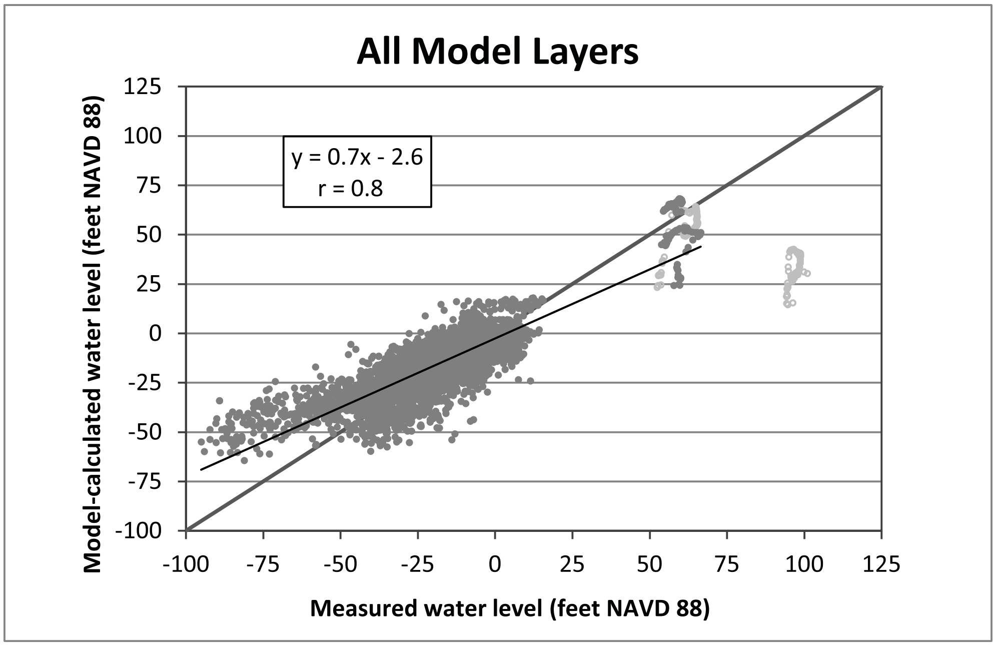
September 2011 model-calculated water levels (NMGWM^{2015} and NMGWM^{2016}) and 2015 water levels measured in CEMEX monitoring wells.

Figure 4.2

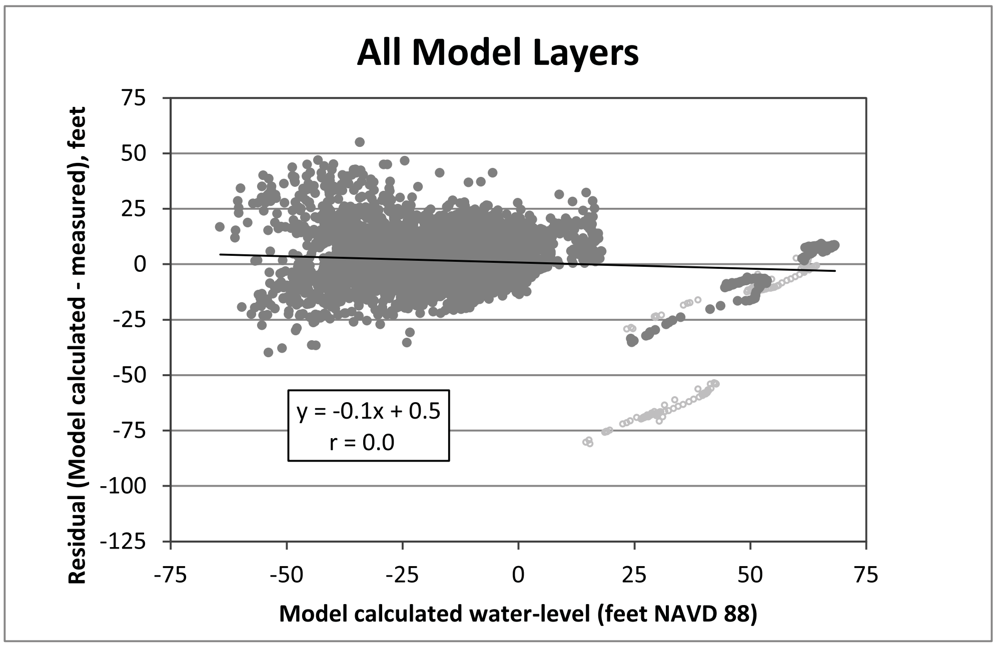
PROJECT: 5073

DATE: 8/19/2016



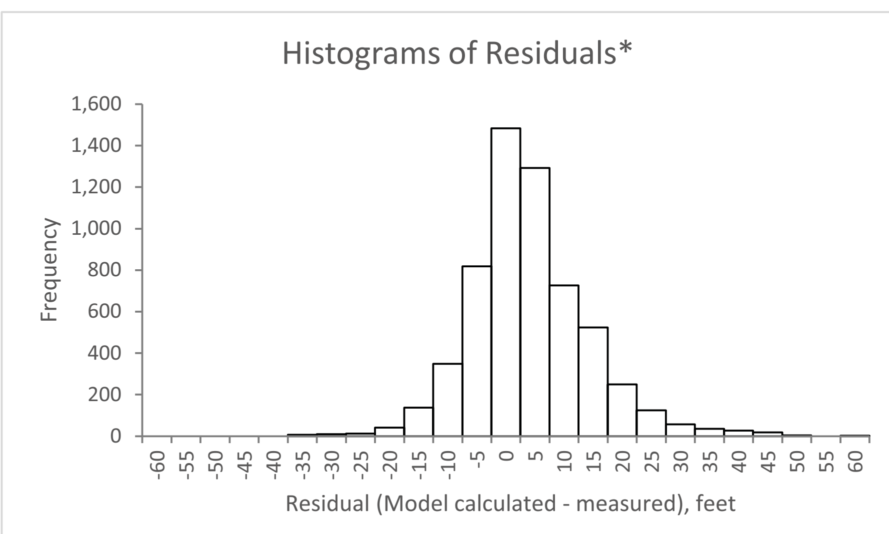
EXPLANATION

- Observation Well
- Perched Observation Well*
- Linear (Wells)
- 1 to 1



EXPLANATION

- Residual
- Perched Residual*
- Linear (Residual)



Error Statistics (in feet)*:
RMSE: 10.2
Min error: -39.9
Max error: 55.0
Mean error: 1.5

*perched wells MW-BW-01-A and MW-OU2-29-A are excluded from histogram plot and error statistics

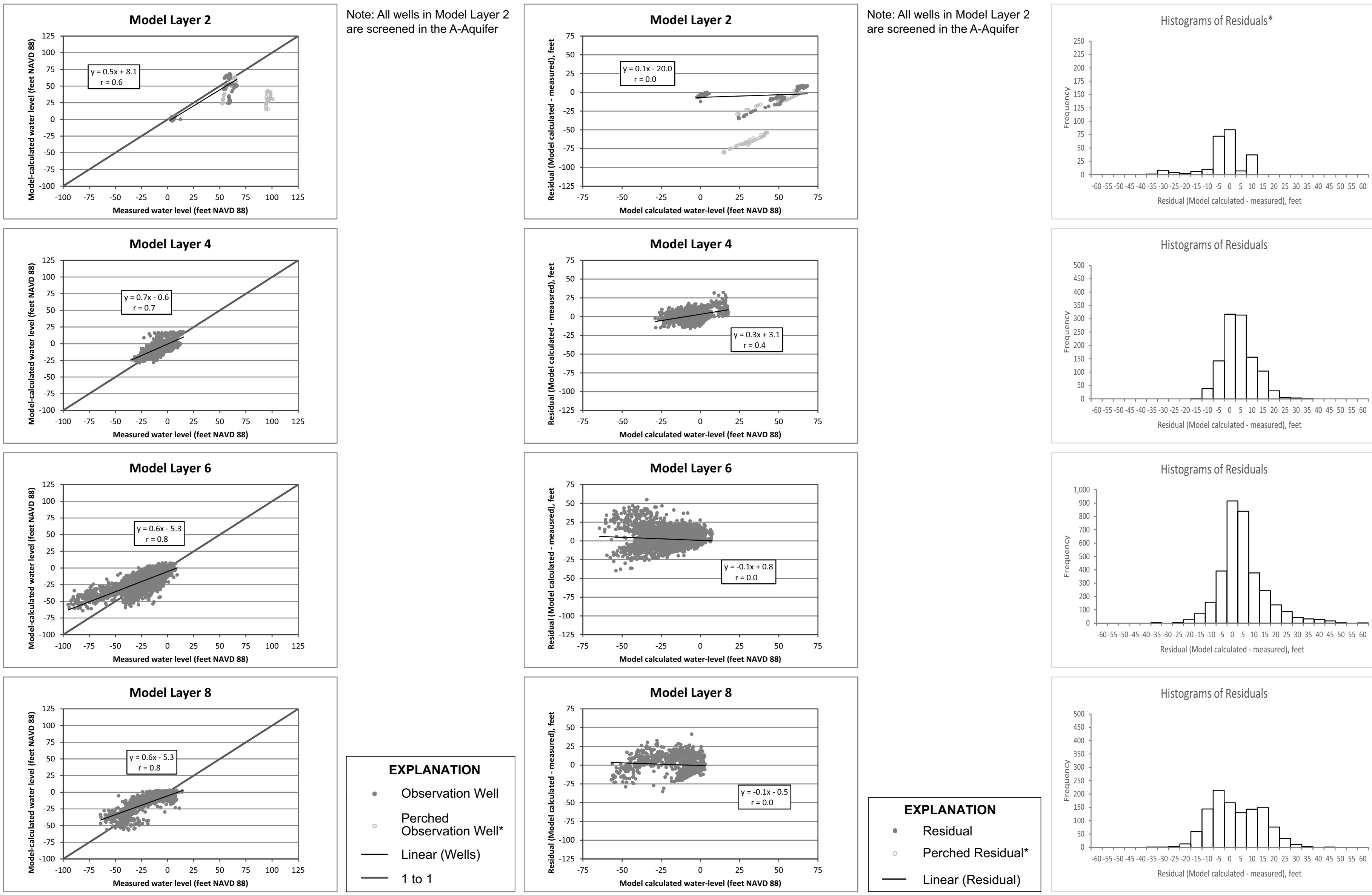
HYDROFOCUS INC. Solutions for Land and Water Resources

Measured vs. NMWGM2016 calculated water levels and residuals.

Figure 4.3a

PROJECT: 5073

DATE: 3/20/2017



Error Statistics (in feet)*

RMSE: 10.1
Min error: -35.2
Max error: 9.2
Mean error: -4.9

*perched wells MW-BW-01-A and MW-OU2-29-A are excluded from histogram plot and error statistics

RMSE: 7.2
Min error: -15.8
Max error: 32.2
Mean error: 1.4

RMSE: 10.7
Min error: -39.9
Max error: 55.0
Mean error: 2.1

RMSE: 11.3
Min error: -35.4
Max error: 41.2
Mean error: 0.4

HYDROFOCUS INC. Solutions for Land and Water Resources

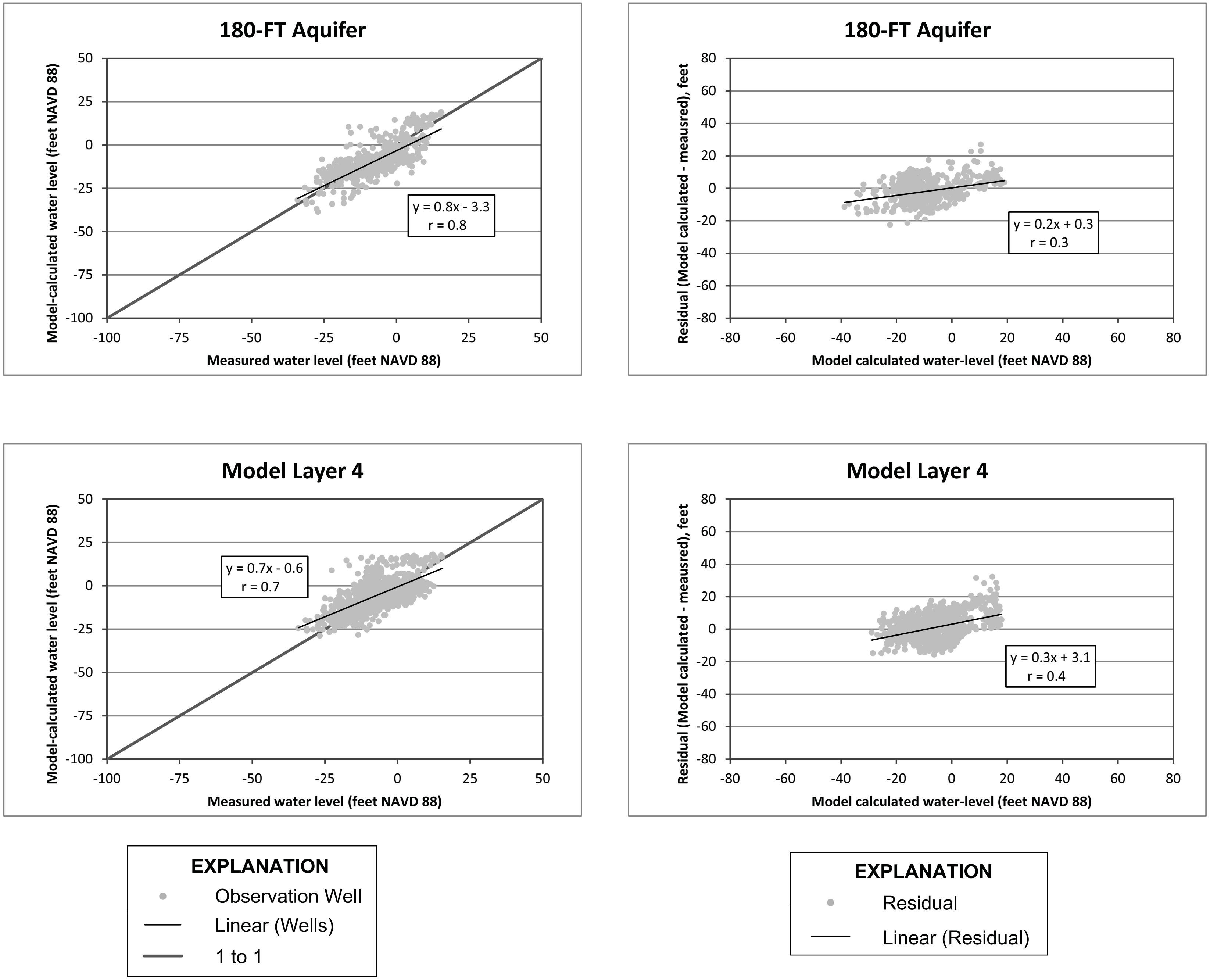
Measured vs. NMGWM[2016] calculated water levels and residuals, model layers 2-8.

Figure 4.3b

PROJECT: 5073 | DATE: 3/20/2017

SVIGSM:

NMGWM2016:



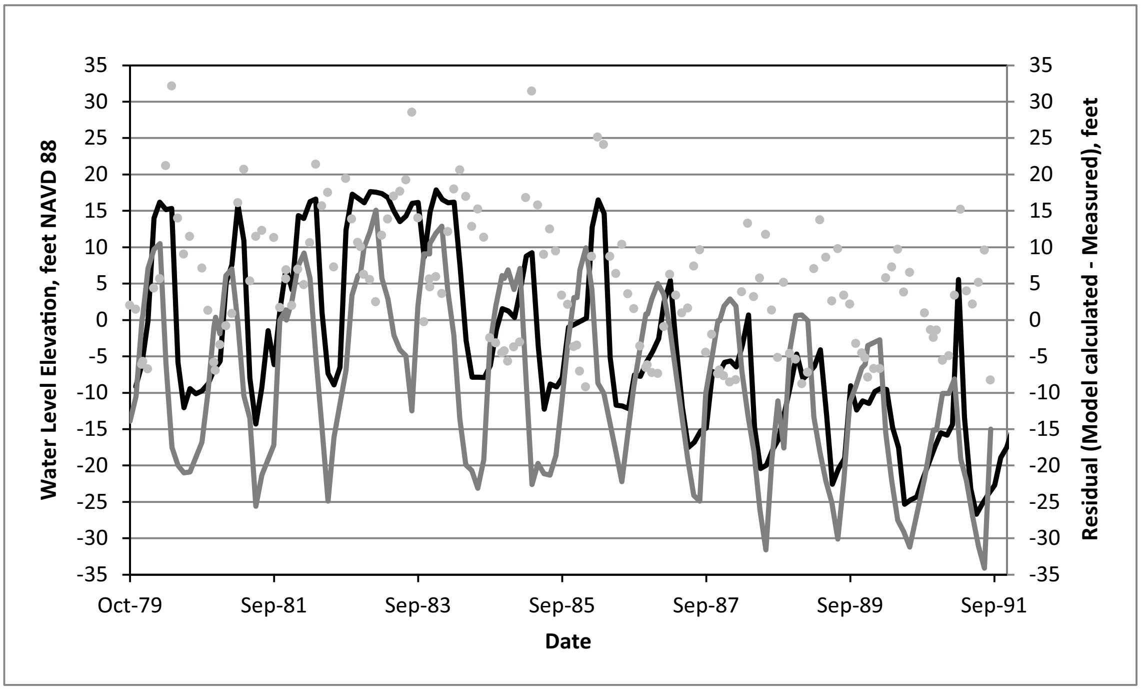
HYDROFOCUS INC. Solutions for Land and Water Resources

Comparison between SVIGSM and NMGWM2016 calculated water levels and residuals, Model Layer 4/180-FT Aquifer.

Figure 4.3c

PROJECT: 5073

DATE: 3/20/2017

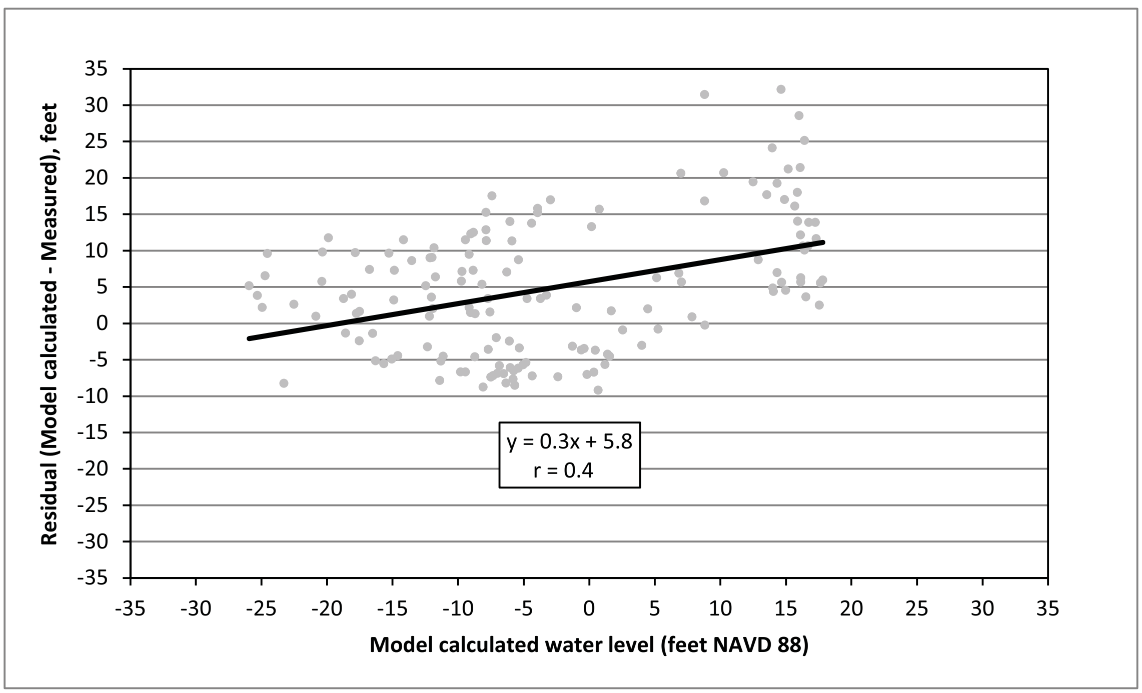


EXPLANATION

Residual

Model Calculated

Measured

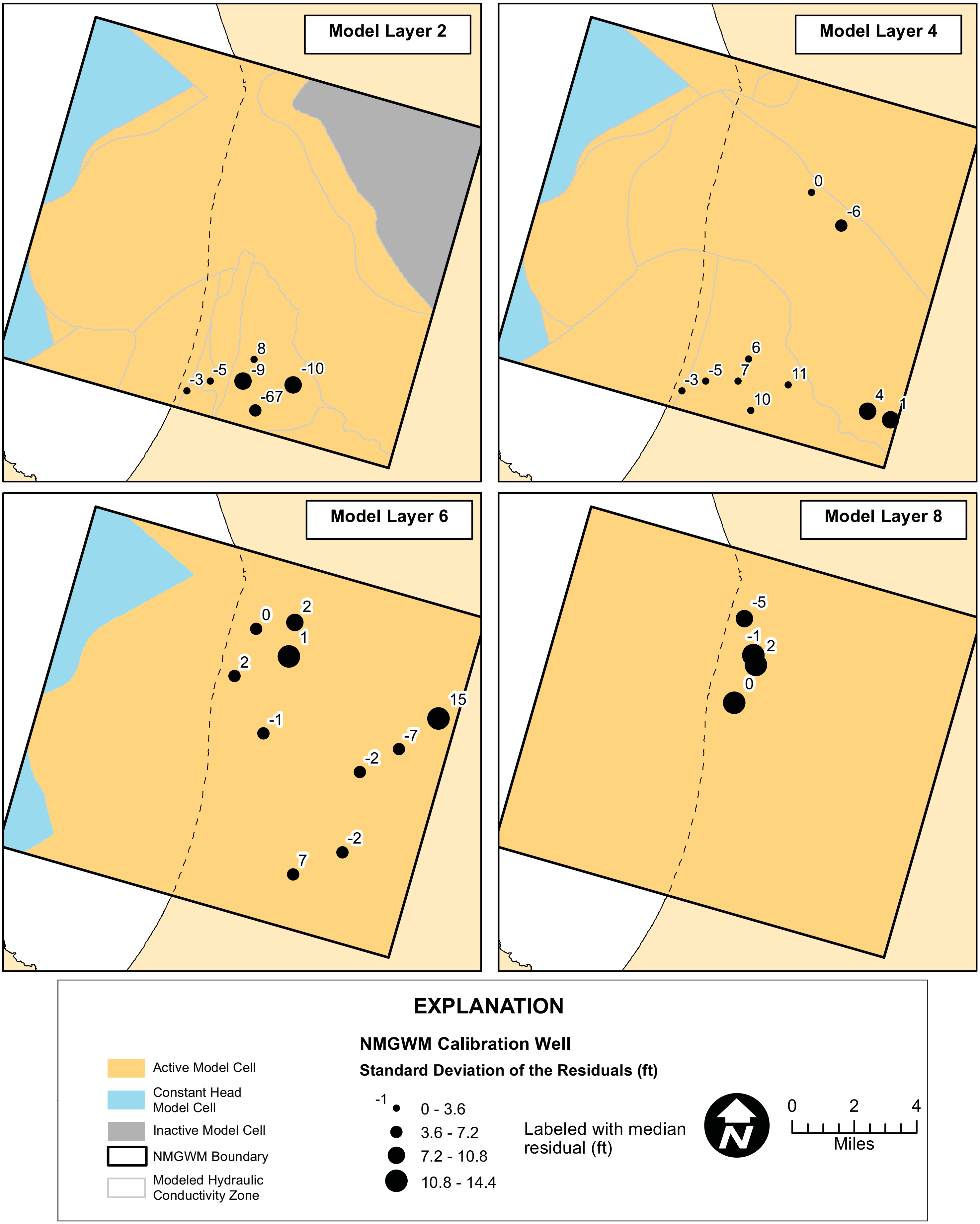


EXPLANATION

Residual

Linear (Residual)

HYDROFOCUS INC. Solutions for Land and Water Resources	Relationships between measured water levels, NMGWM[2016] calculated water levels, and residuals. Well 02J01, Model Layer 4.	Figure 4.3d
PROJECT: 5073	DATE: 3/20/2017	



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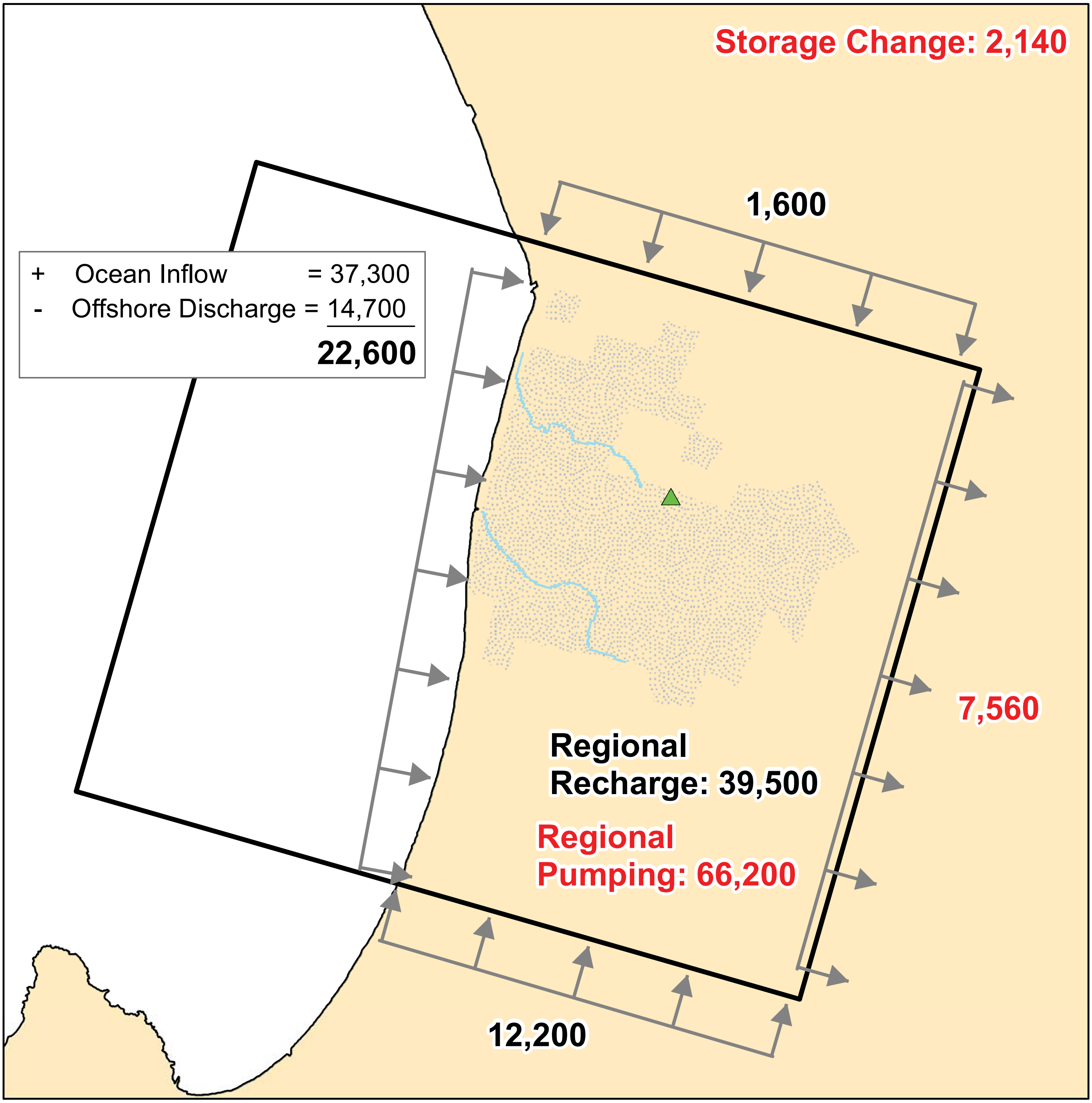
Geographic distribution of residuals by NMGWM[2016] model layer.

Figure 4.4

PROJECT: 5073

DATE: 8/18/2016



EXPLANATION

- Castroville Well #3
- 1,600 Net Groundwater Flow (AF/yr)
- CSIP Area
- River Model Cell
- NMGWM Boundary

Black numbers indicate an addition to the dynamic groundwater system, and red numbers indicate a subtraction from the dynamic groundwater system.

0 2 4
Miles

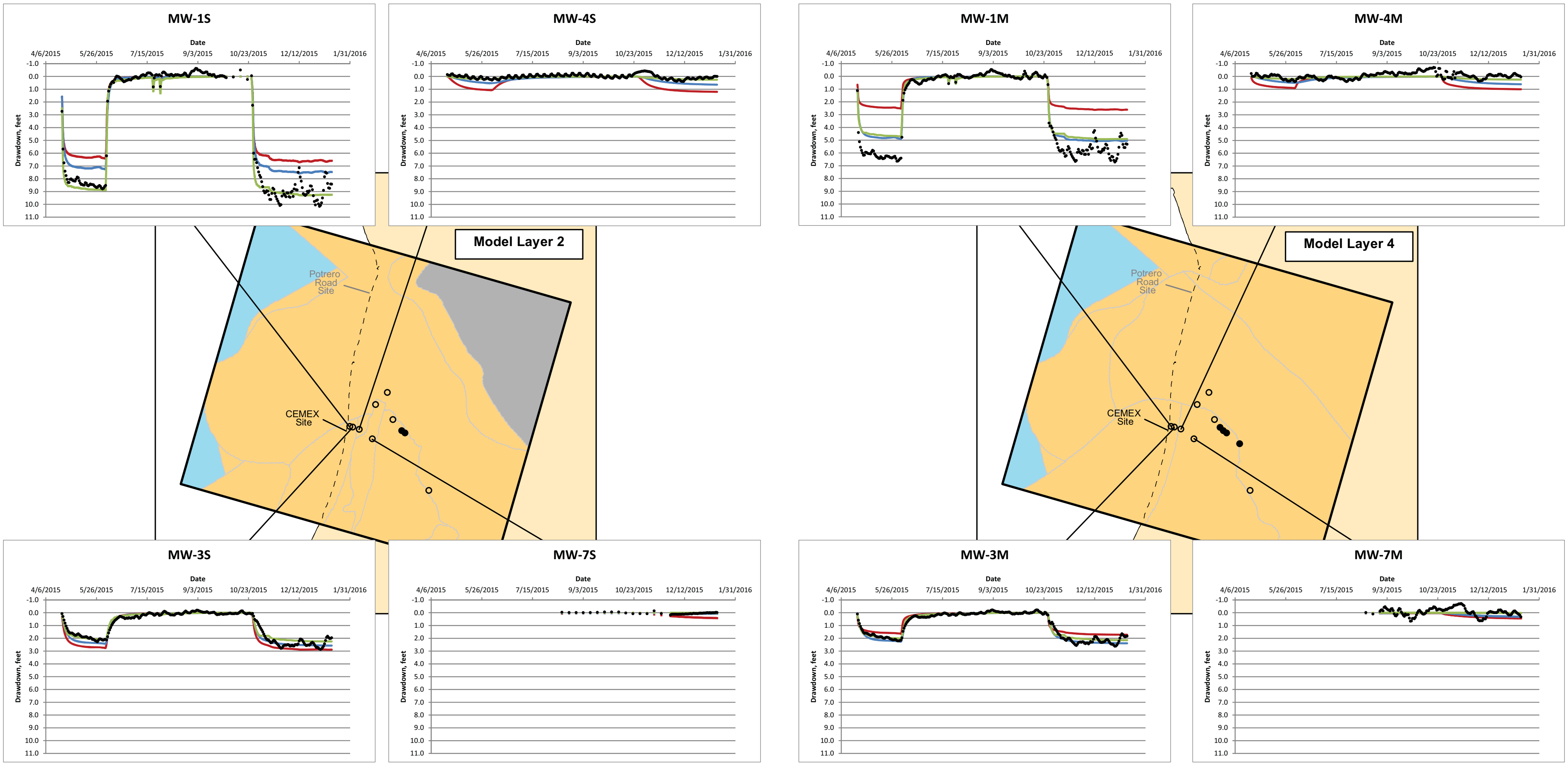
HYDROFOCUS INC. Solutions for Land and Water Resources

NMGWM^{2016} calculated average annual volumetric water budget, 1979-2011.

Figure 4.5

PROJECT: 5073

DATE: 11/21/2016



EXPLANATION

Wells

- ○ CEMEX Monitoring
- ● Other

- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell

Hydrograph:

- NMGWM[2015]
- NMGWM[2016]
- CEMEX
- Measured * (CEMEX and Measured: Geoscience (2016))

Notes:
* measured values are detrended

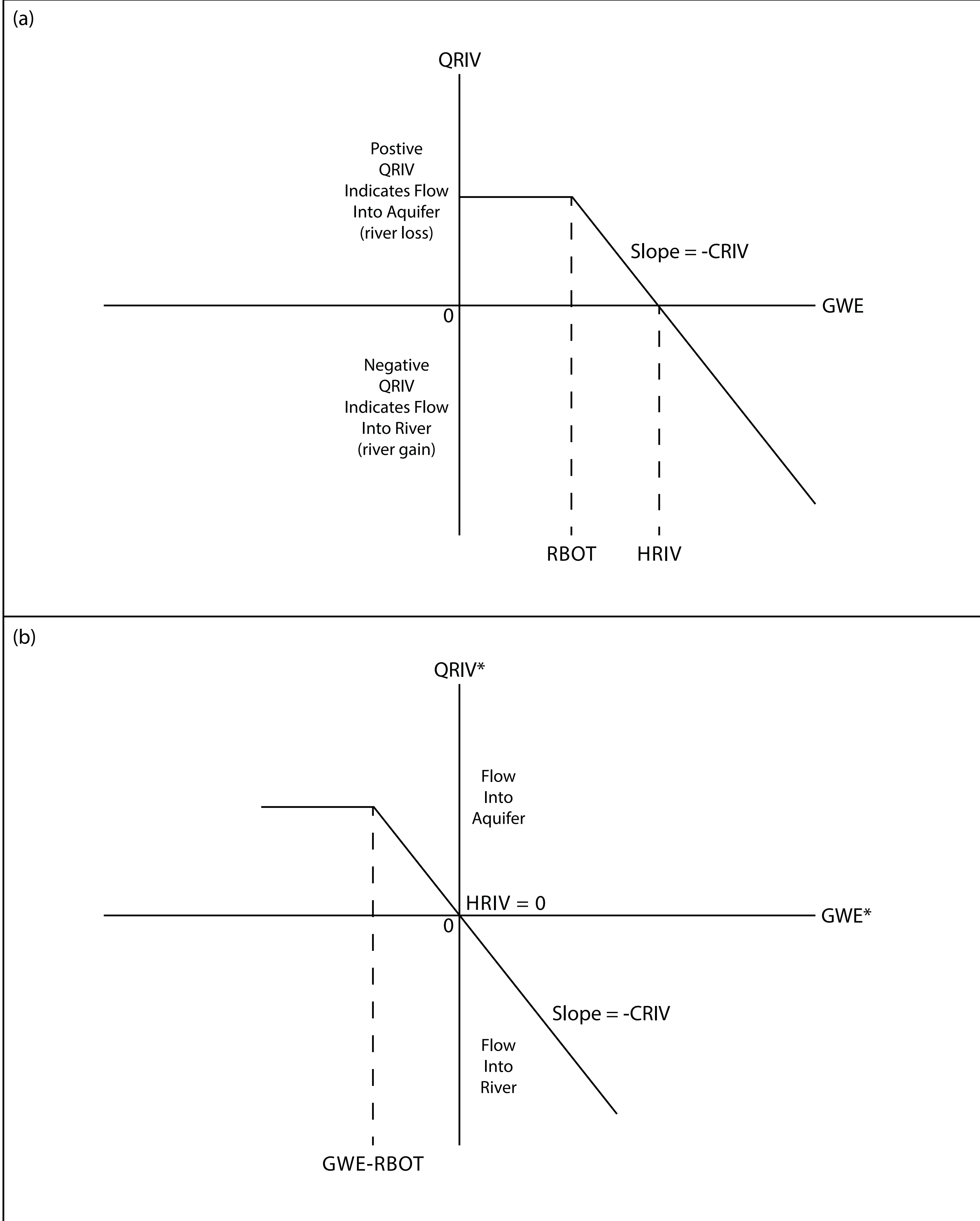
Source:
Geoscience Support Services Inc., 2016, "DRAFT Monterey Penisula Water Supply Project Monitoring Well Completion Report and CEMEX Model Update," prepared for California American Water, July 15, 2016.

HYDROFOCUS INC. Solutions for Land and Water Resources

Measured vs. model-calculated drawdown in CEMEX monitoring wells during test slant well pumping.

Figure 4.6

PROJECT: 5073 | DATE: 11/15/2016



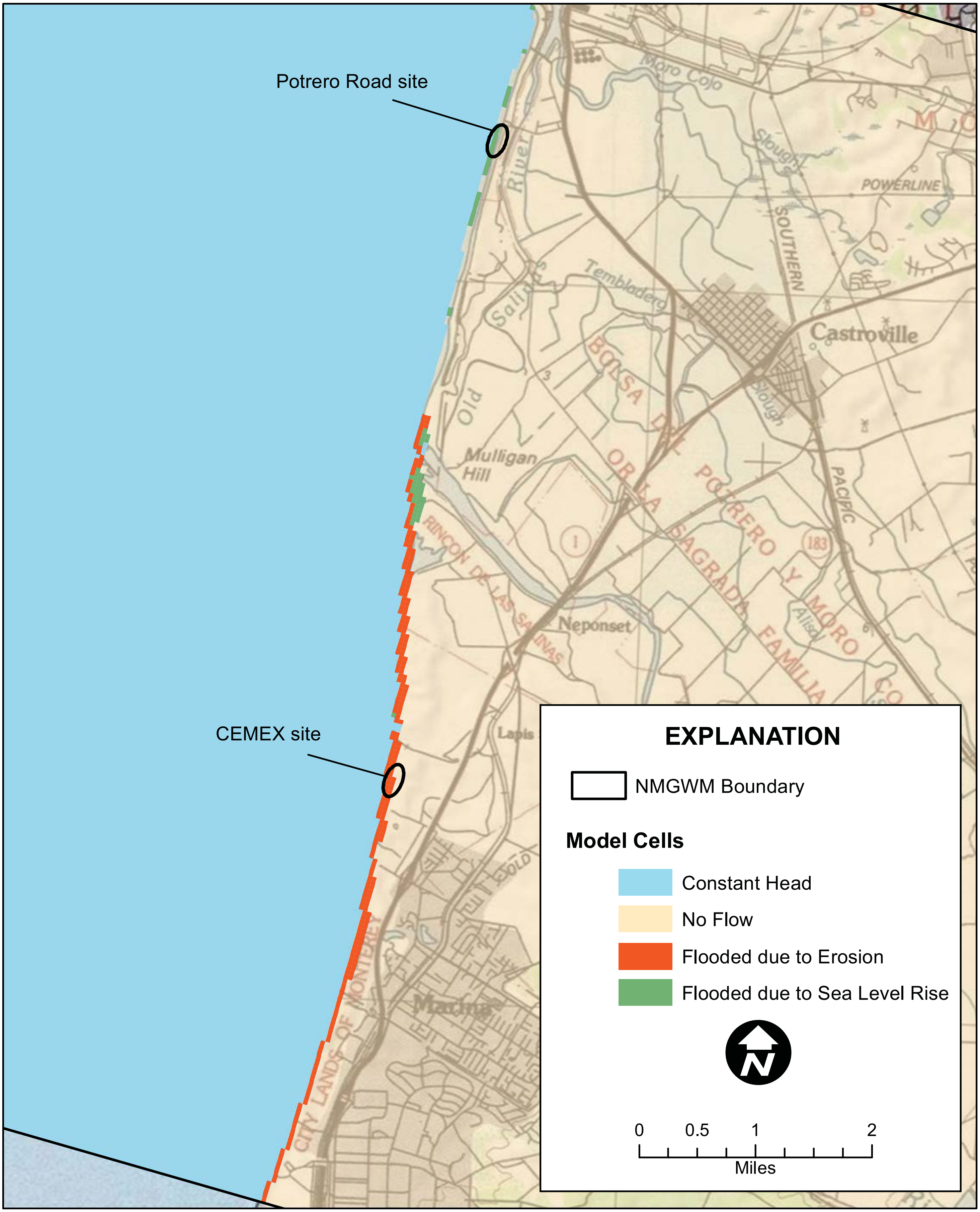
HYDROFOCUS INC. Solutions for Land and Water Resources

Plot of flow, QRIV, from a stream into a cell as a function of water level elevation (GWE) in the model cell where RBOT is the elevation of the bottom of the streambed and HRIV is the water level elevation in the stream.

Figure 5.1

PROJECT: 5073

DATE: 2/8/2017



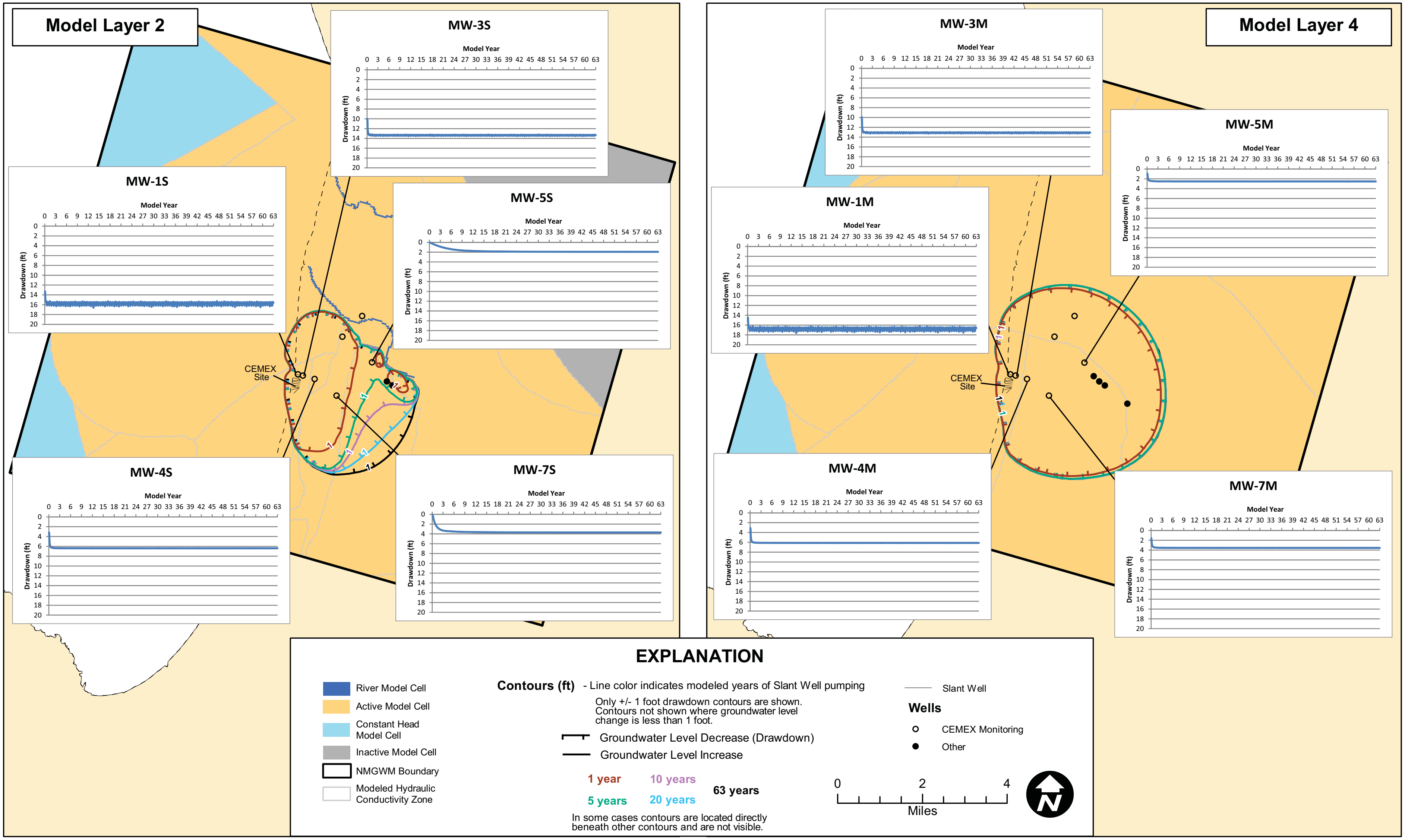
HYDROFOCUS INC. Solutions for Land and Water Resources

NMGWM2016 constant head cells activated for 2073 sea level rise.

Figure 5.2

PROJECT: 5073

DATE: 7/28/2016

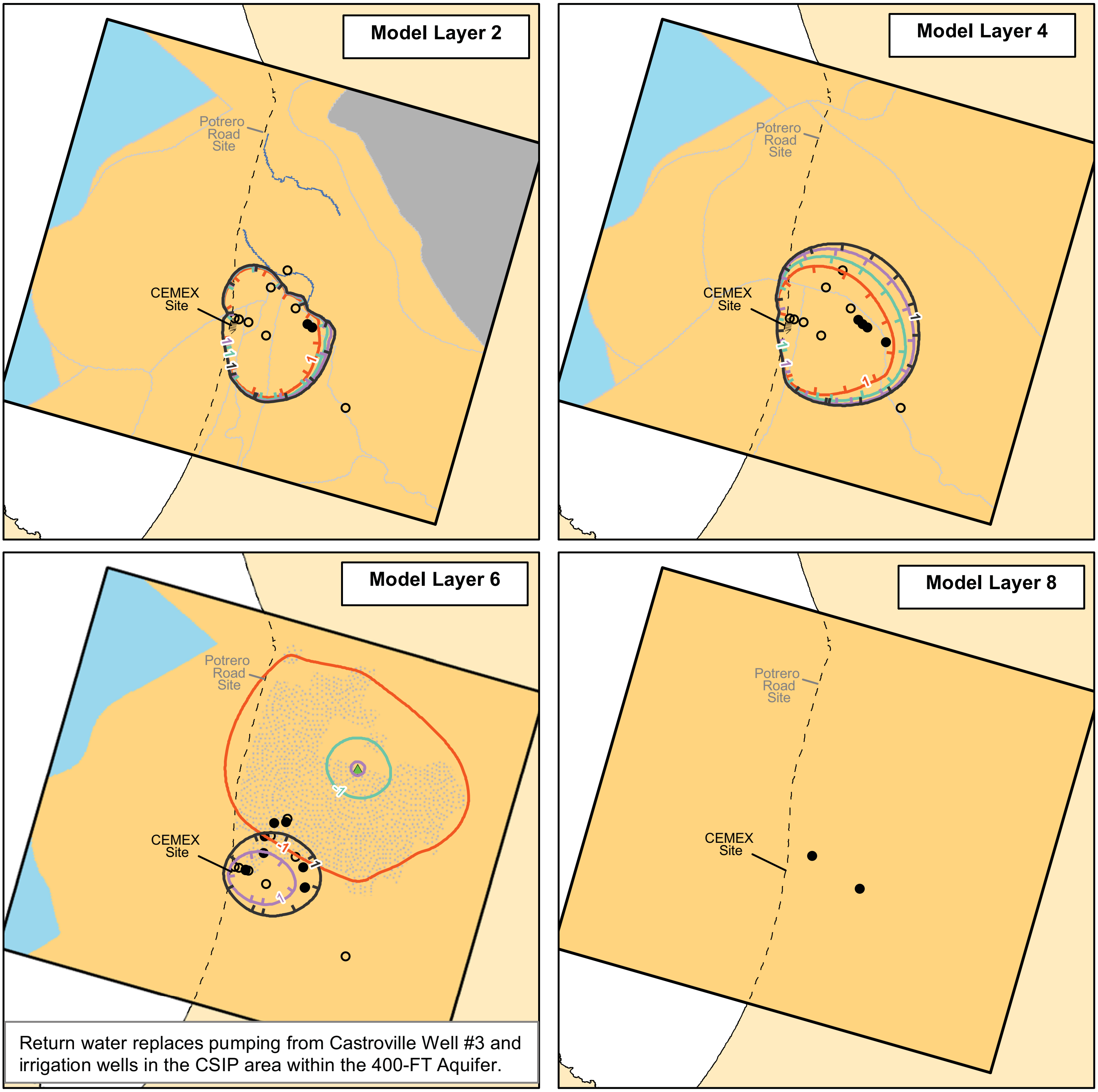


HYDROFOCUS INC. Solutions for Land and Water Resources

Annual NMGWM[2016] calculated drawdown from slant well pumping (24.1 MGD), 44/56 Layer 2/Layer 4 distribution, 2012 sea level, with no return water, CEMEX site.

Figure 5.3

PROJECT: 5073 | DATE: 7/11/2017



EXPLANATION

Model Layer 6 area underlying CSIP
River Model Cell
Active Model Cell
Constant Head Model Cell
Inactive Model Cell
NMGWM Boundary
Modeled Hydraulic Conductivity Zone

Contours (ft) - Line color indicates % return water

Only +/- 1 foot drawdown contours are shown. Contours not shown where groundwater level change is less than 1 foot.

Groundwater Level Decrease (Drawdown)
Groundwater Level Increase

0% Return Water **6% Return Water**
3% Return Water **12% Return Water**

In some cases contours are located directly beneath other contours and are not visible.

Wells

Slant Well
Castroville Well #3, 400-FT Aquifer
CEMEX Monitoring
Other

0 2 4
Miles

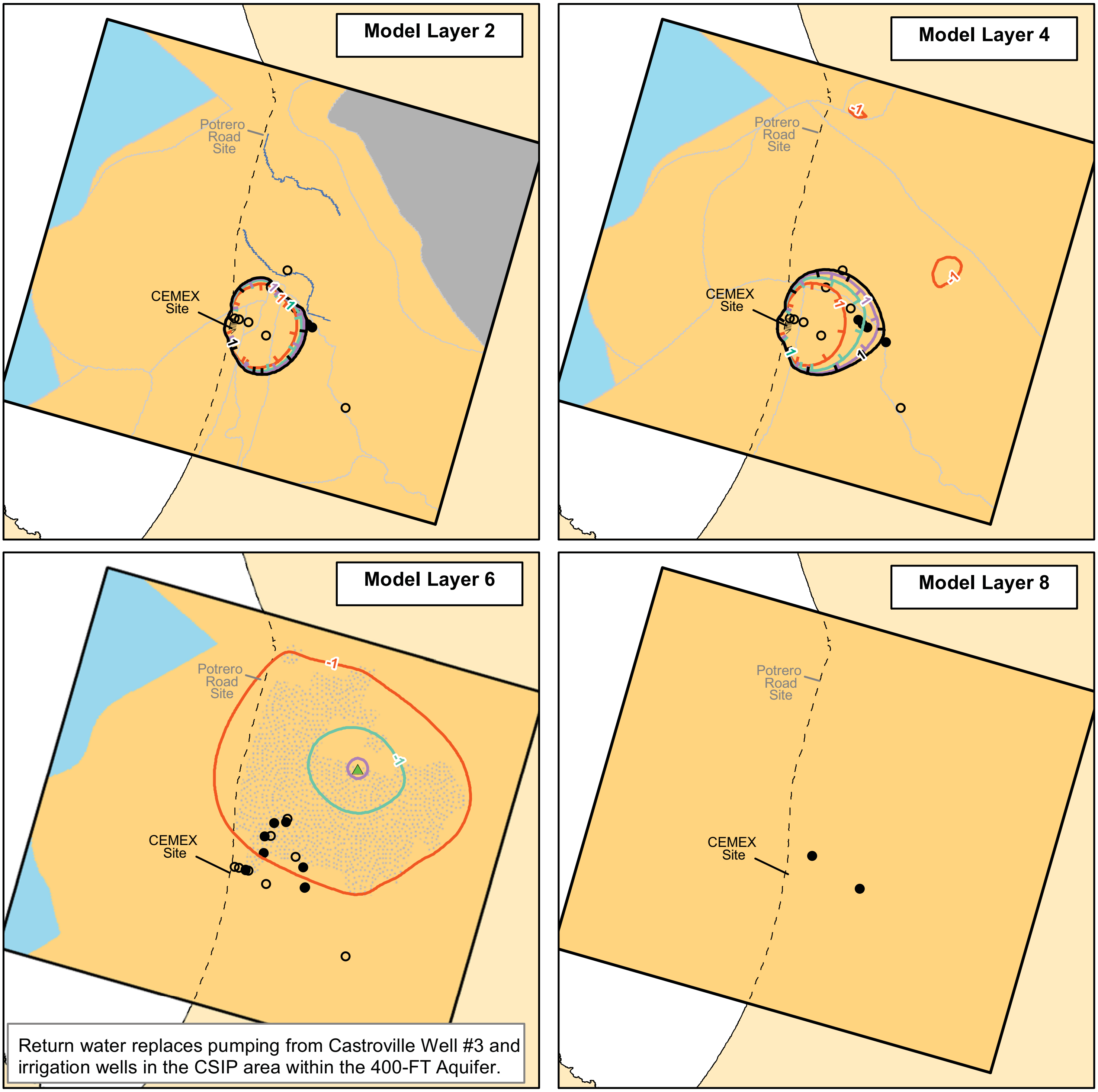
HYDROFOCUS INC.
Solutions for Land and Water Resources

NMGWM[2016] calculated drawdown
63 years of slant well pumping (24.1 MGD), 44/56 Layer 2/Layer 4 distribution, 2012 sea level, with variable return water, CEMEX site.

Figure 5.4a

PROJECT: 5073

DATE: 8/29/2016



EXPLANATION

- Model Layer 6 area underlying CSIP
- River Model Cell
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell
- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone

Contours (ft) - Line color indicates % return water

Only +/- 1 foot drawdown contours are shown. Contours not shown where groundwater level change is less than 1 foot.

- Groundwater Level Decrease (Drawdown)
- Groundwater Level Increase

0% Return Water **6% Return Water**
3% Return Water **12% Return Water**

In some cases contours are located directly beneath other contours and are not visible.

Wells

- Slant Well
- Castroville Well #3, 400-FT Aquifer
- CEMEX Monitoring
- Other

0 2 4
Miles

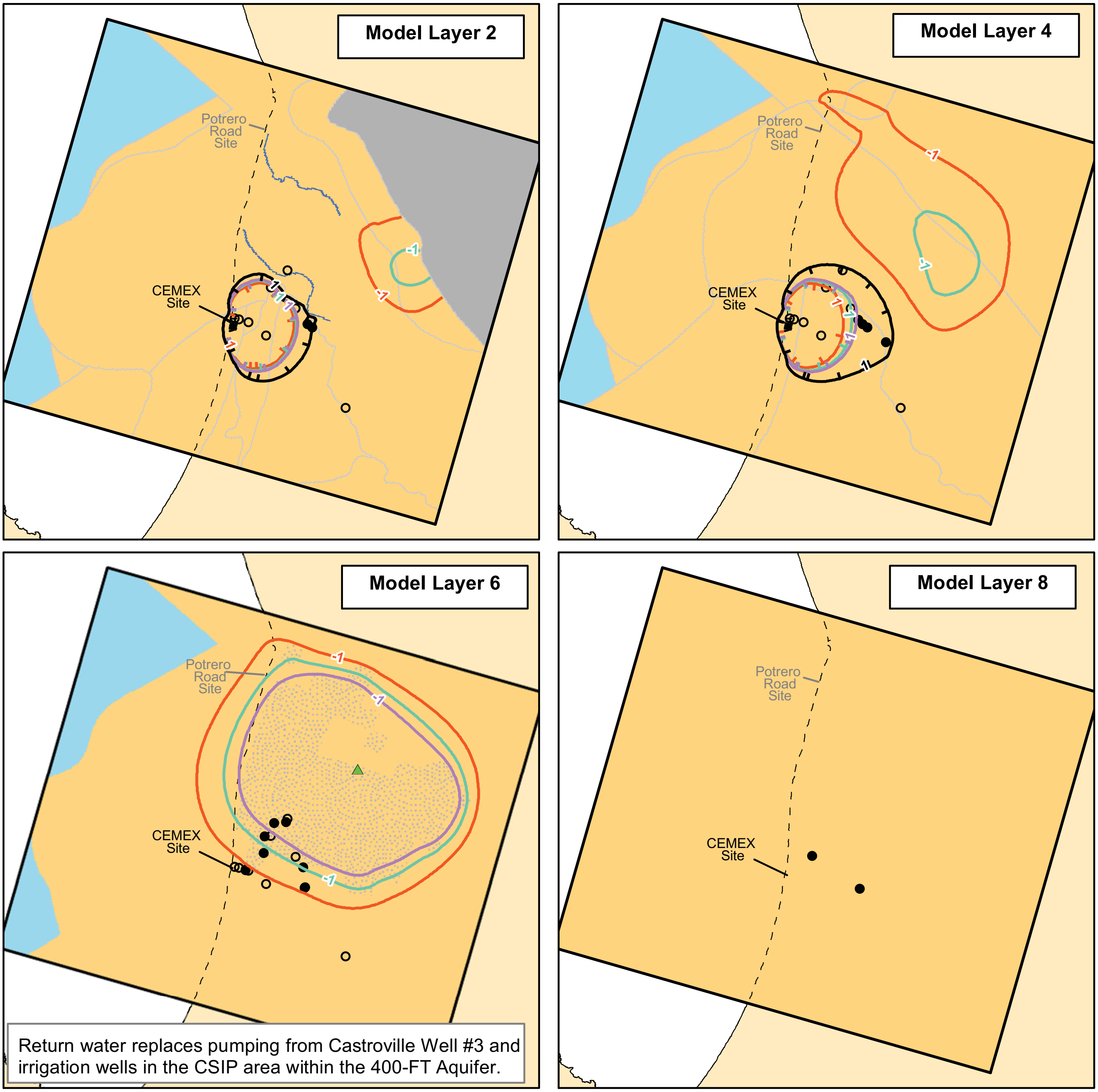
HYDROFOCUS INC. Solutions for Land and Water Resources

NMGWM2016 calculated drawdown
63 years of slant well pumping (24.1 MGD), 44/56 Layer 2/Layer 4 distribution, 2073 sea level, with variable return water, CEMEX site.

Figure 5.4b

PROJECT: 5073

DATE: 8/12/2016



EXPLANATION

- Model Layer 6 area underlying CSIP
- River Model Cell
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell
- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone

Contours (ft) - Line color indicates % return water

Only +/- 1 foot drawdown contours are shown. Contours not shown where groundwater level change is less than 1 foot.

- Groundwater Level Decrease (Drawdown)
- Groundwater Level Increase

0% Return Water **6% Return Water**
3% Return Water **12% Return Water**

In some cases contours are located directly beneath other contours and are not visible.

Wells

- Slant Well
- Castroville Well #3, 400-FT Aquifer
- CEMEX Monitoring
- Other

0 2 4
Miles

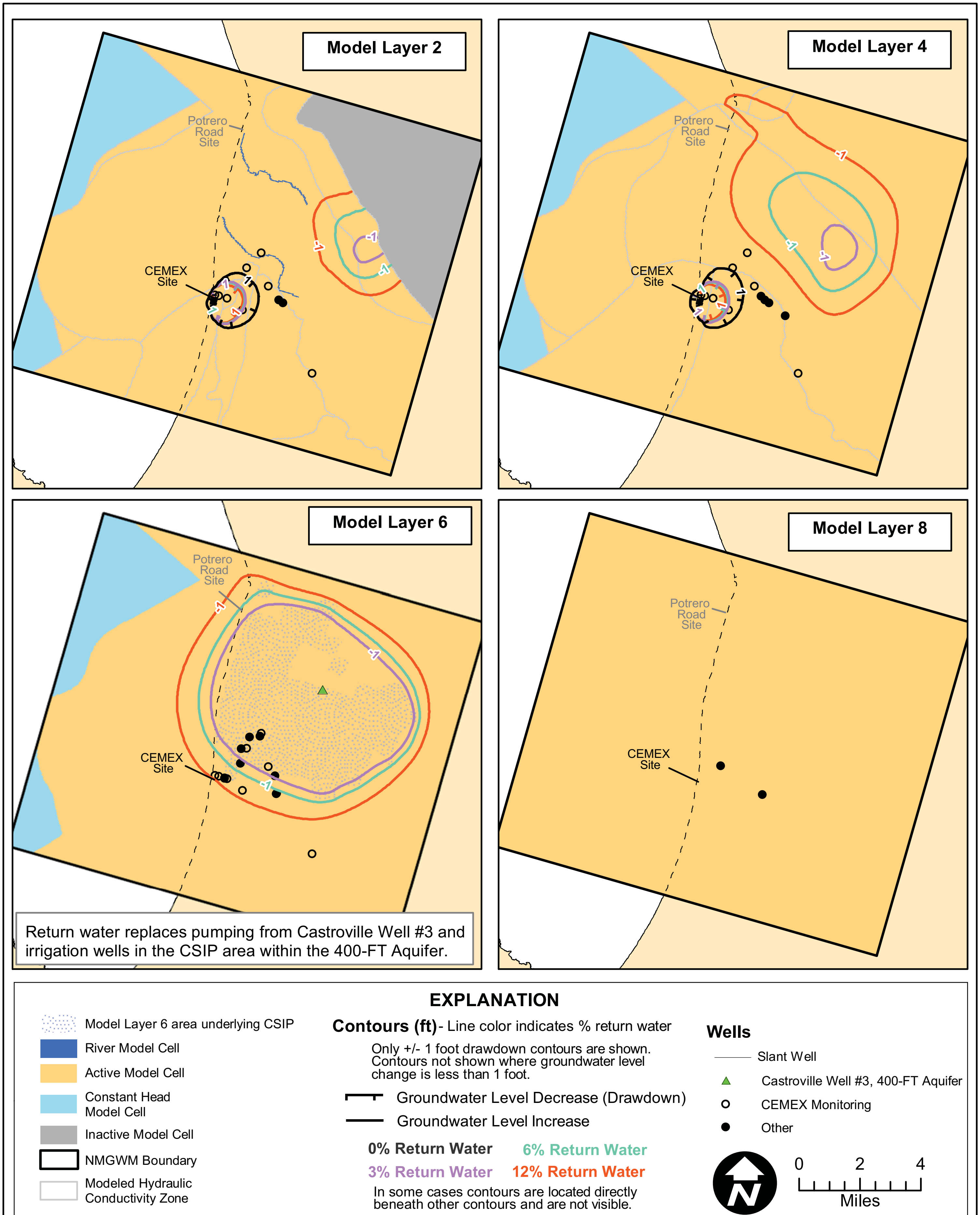
HYDROFOCUS INC.
Solutions for Land and Water Resources

NMGWM2016 calculated drawdown
63 years of slant well pumping (15.5 MGD), 44/56 Layer 2/Layer 4 distribution, 2012 sea level, with variable return water, CEMEX site.

Figure 5.5a

PROJECT: 5073

DATE: 8/19/2016



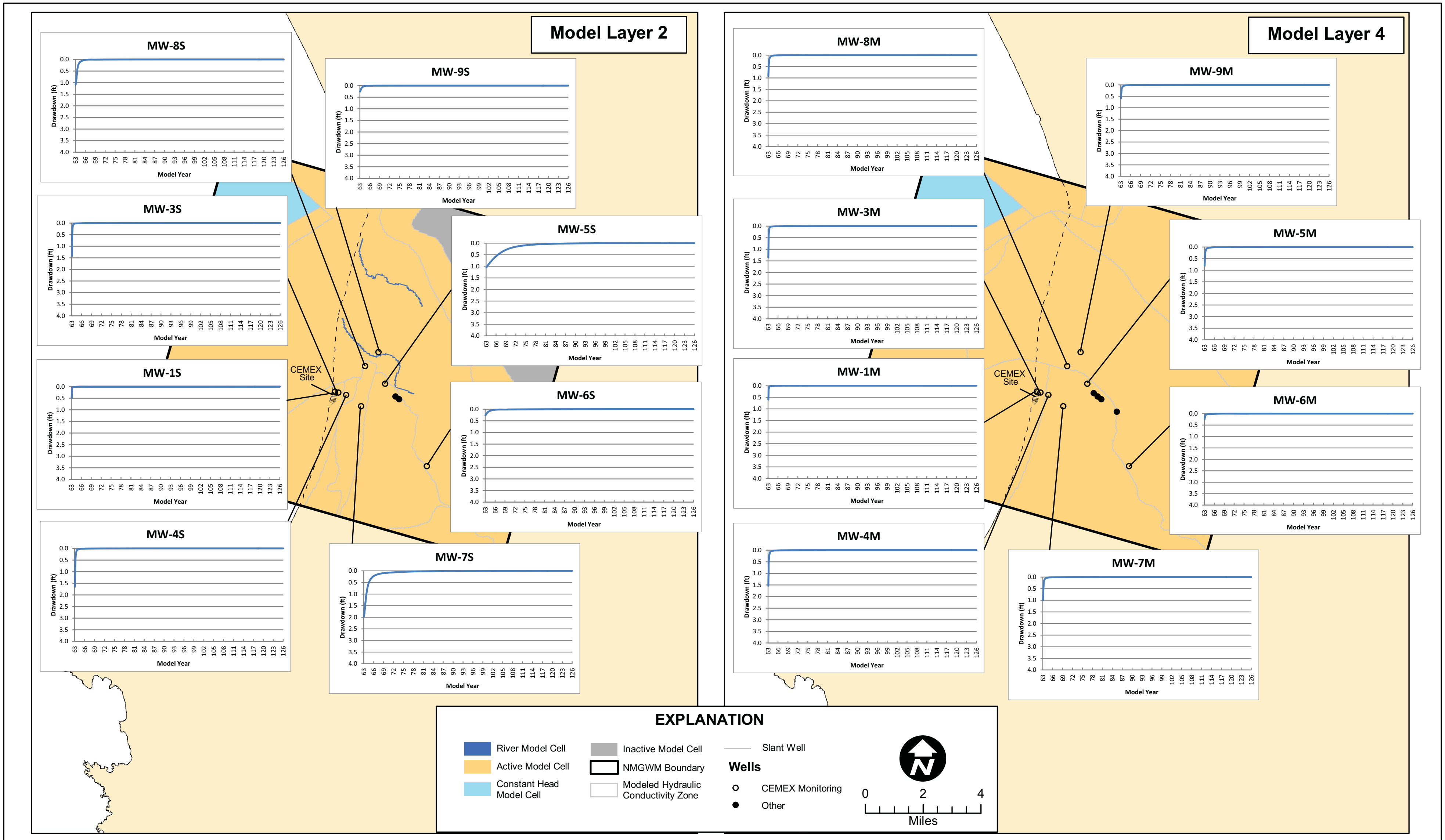
HYDROFOCUS INC. Solutions for Land and Water Resources

NMGWM^{2016} calculated drawdown
63 years of slant well pumping (15.5 MGD), 44/56 Layer 2/Layer 4 distribution, 2073 sea level, with variable return water, CEMEX site.

Figure 5.5b

PROJECT: 5073

DATE: 8/19/2016



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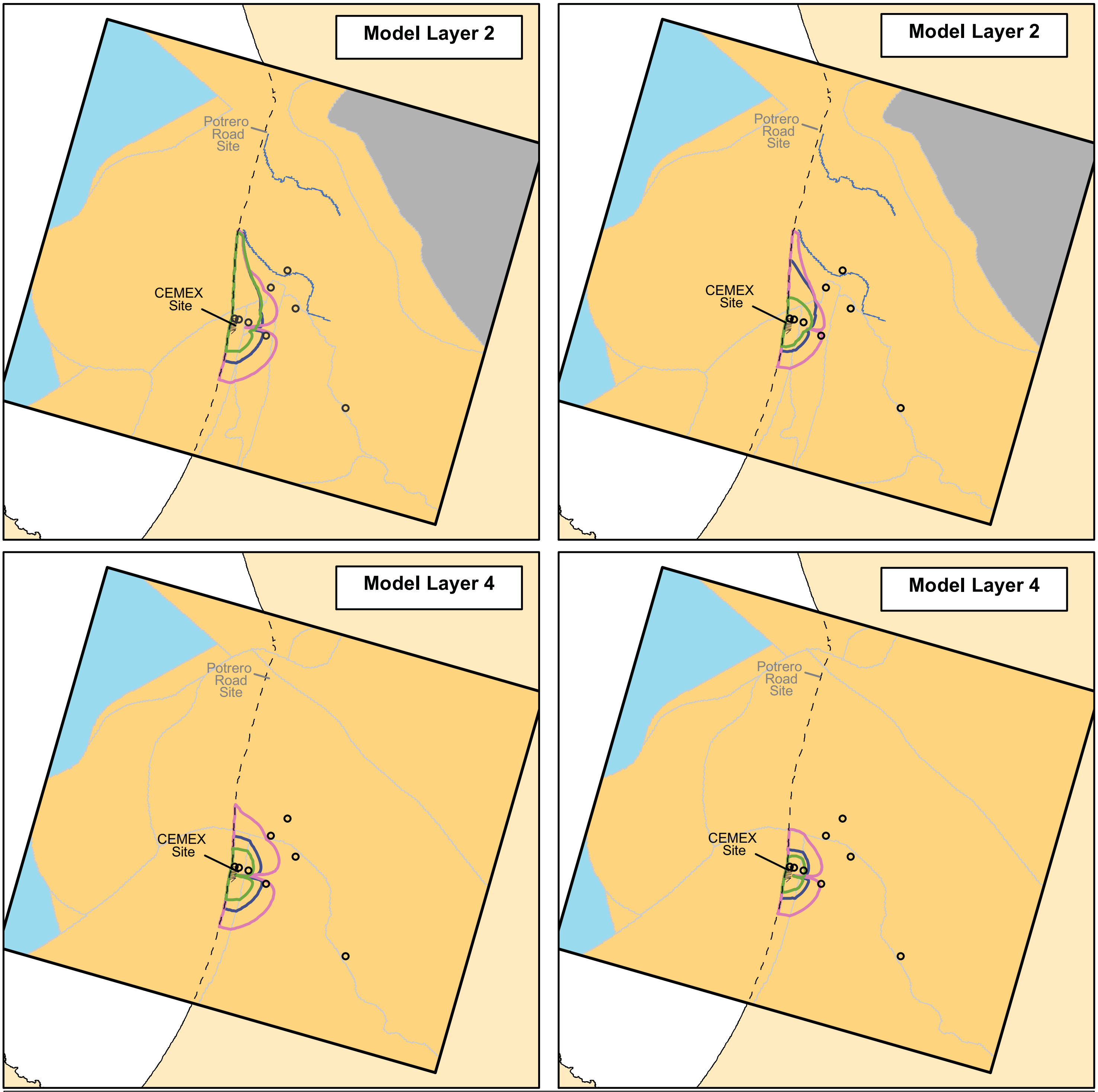
NMGWM[2016] calculated recovery hydrographs
post-CEMEX site, 2073 sea level.

Figure 5.6

PROJECT: 5073 | DATE: 7/11/2017

CEMEX 24.1 MGD: **CEMEX 15.5 MGD:**



EXPLANATION

- River Model Cell
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell
- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone
- CEMEX Monitoring Well
- Slant Well

Particle Tracking Ocean Capture Zones

- Ocean Capture Zone, porosity = 0.1, avg gradient = 0.0004
- Ocean Capture Zone, porosity = 0.1, avg gradient = 0.0007
- Ocean Capture Zone, porosity = 0.1, avg gradient = 0.0011

N

0 2 4

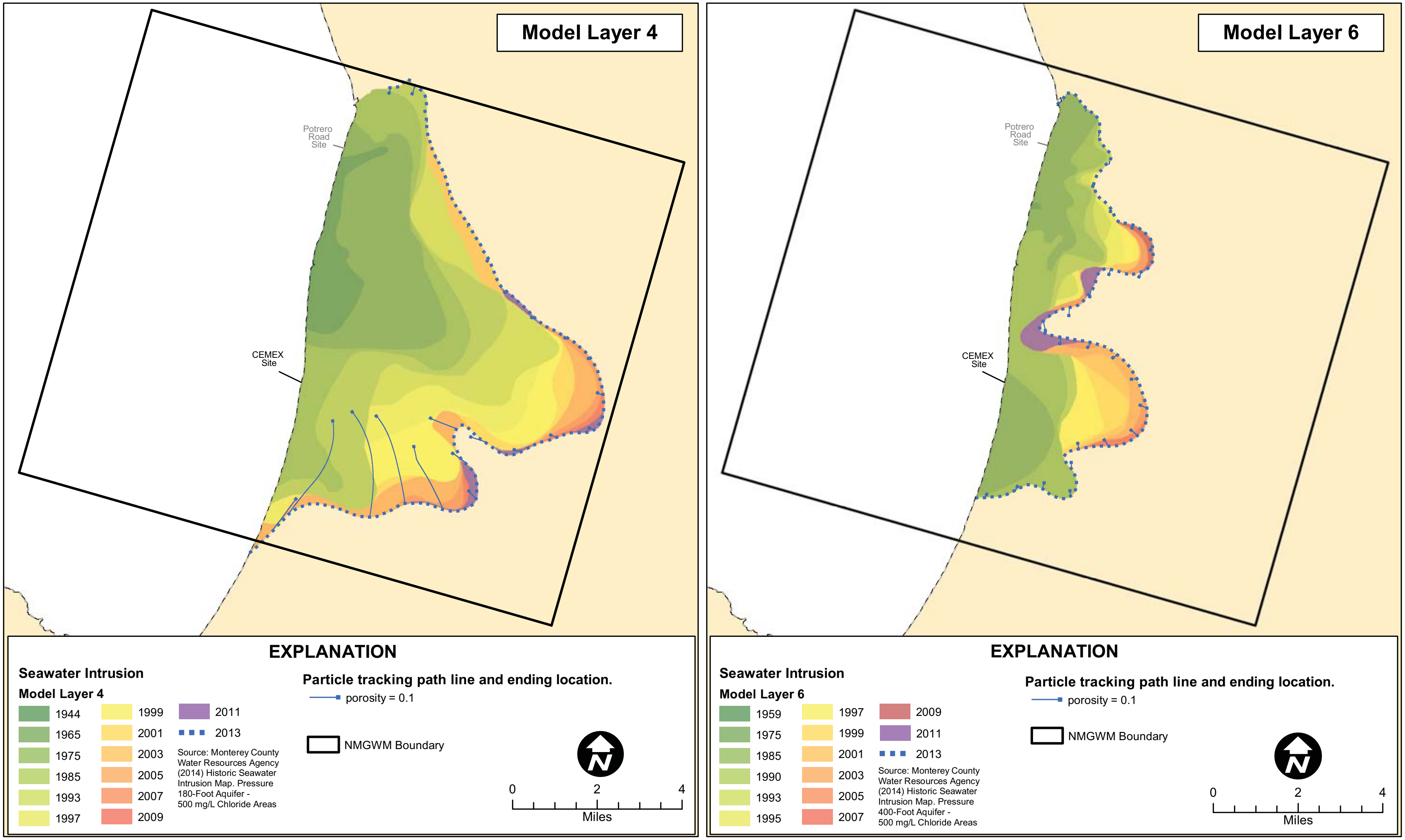
Miles

HYDROFOCUS INC. Solutions for Land and Water Resources

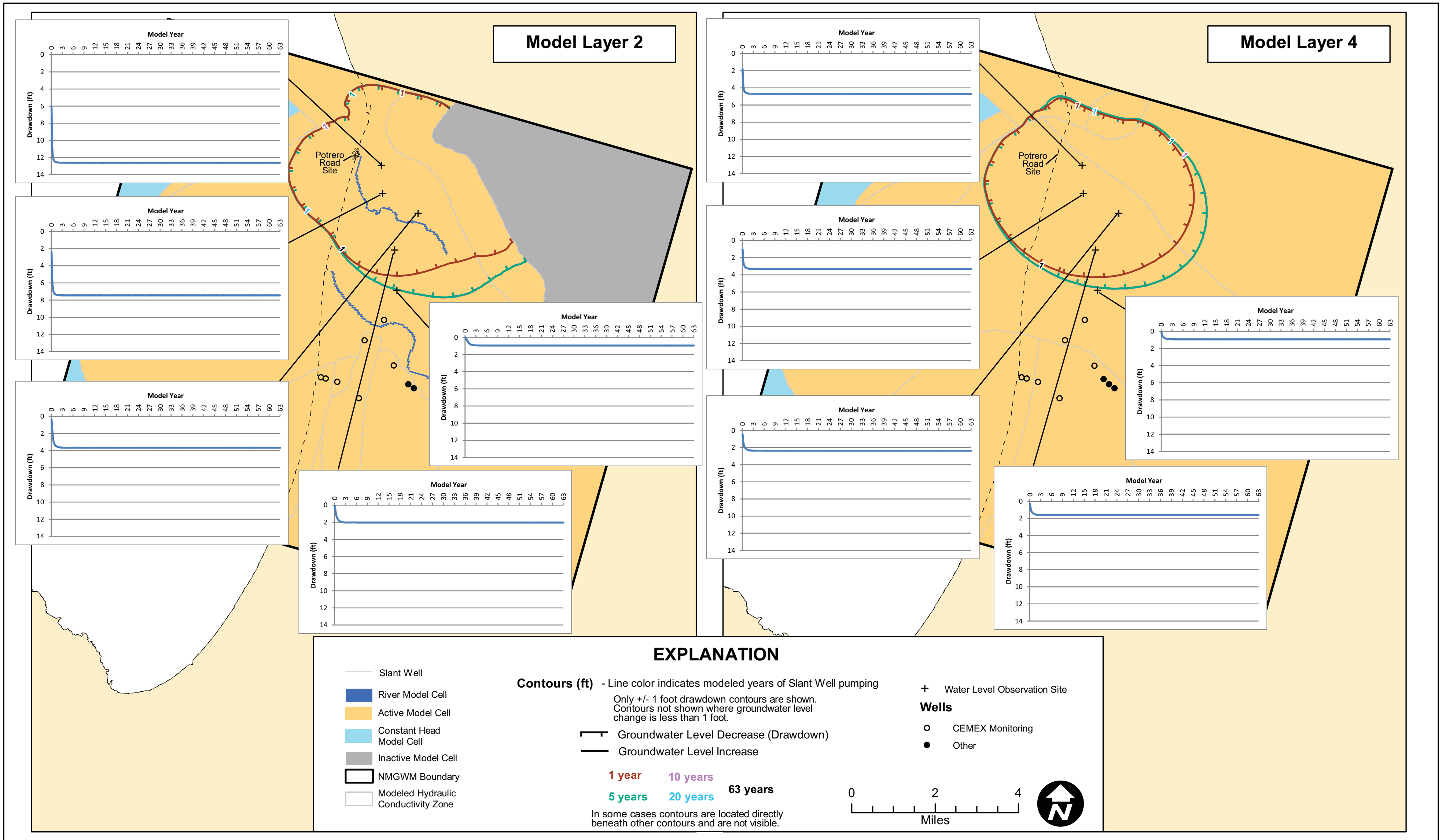
NMGWM[2016] calculated ocean capture zone with variable regional gradients, 63 years of slant well pumping (24.1 and 15.5 MGD), 44/56 Layer 2/Layer 4 distribution, 2012 sea level, CEMEX site.

Figure 5.7

PROJECT: 5073 DATE: 11/15/2016



HYDROFOCUS INC. Solutions for Land and Water Resources	NMGWM[2016] particle tracking changes at mapped saltwater intrustion front after 63 years of slant well pumping (24.1 MGD), 44/56 Layer 2/Layer 4 distribution, 2012 sea level, with no return water, CEMEX site.	Figure 5.8
PROJECT: 5073	DATE: 7/11/2017	

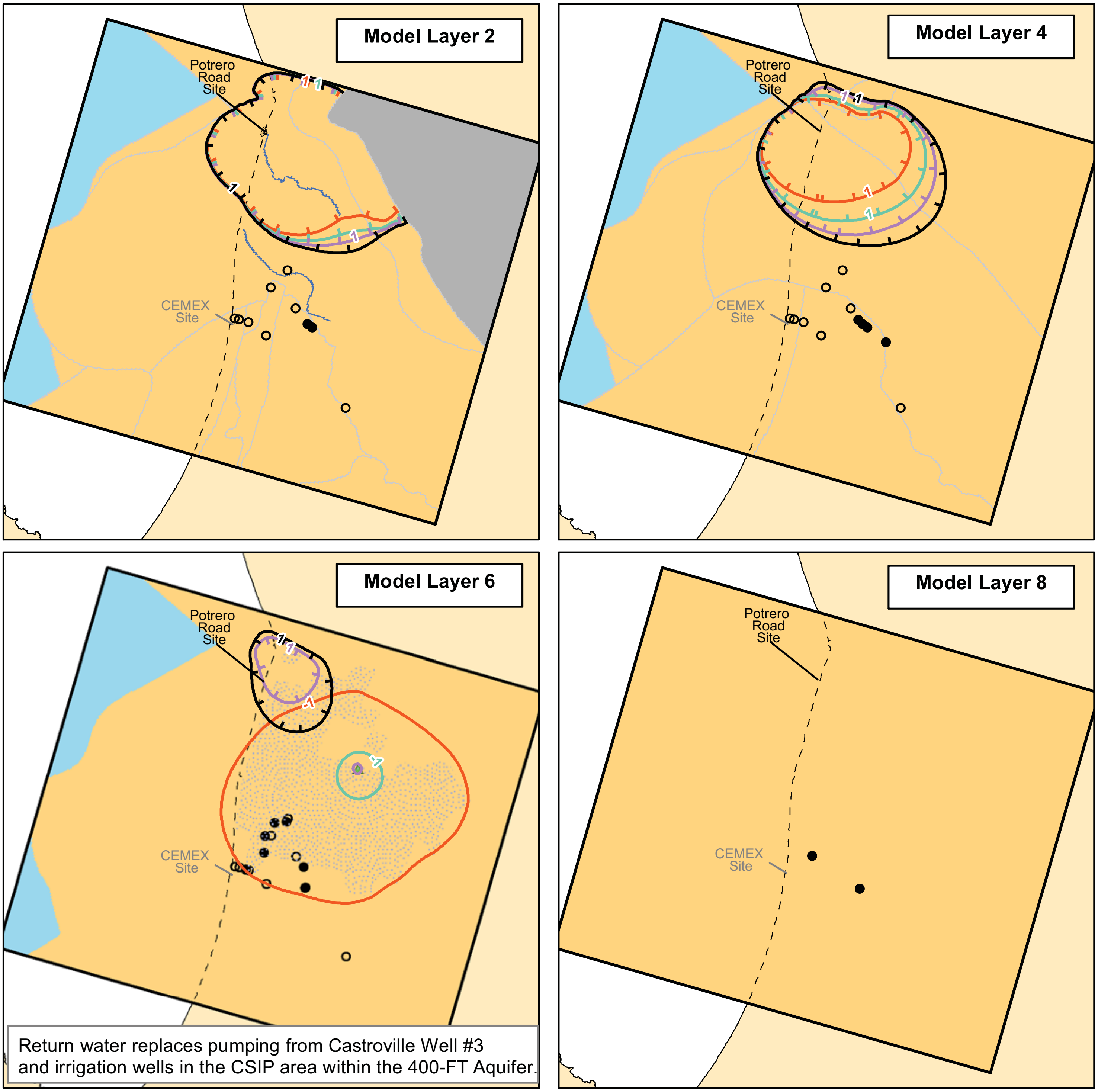


HYDROFOCUS INC. Solutions for Land and Water Resources

Annual NMGWM^{2016} calculated drawdown from slant well pumping (24.1 MGD), 2012 sea level, with no return water, Potrero Road site.

Figure 5.9

PROJECT: 5073 | DATE: 7/11/2017



EXPLANATION

- Model Layer 6 area underlying CSIP
- River Model Cell
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell
- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone

Contours (ft) - Line color indicates % return water

Only +/- 1 foot drawdown contours are shown. Contours not shown where groundwater level change is less than 1 foot.

- Groundwater Level Decrease (Drawdown)
- Groundwater Level Increase

0% Return Water **6% Return Water**
3% Return Water **12% Return Water**

In some cases contours are located directly beneath other contours and are not visible.

Wells

- Slant Well
- Castroville Well #3, 400-FT Aquifer
- CEMEX Monitoring
- Other

0 2 4
Miles

HYDROFOCUS INC.
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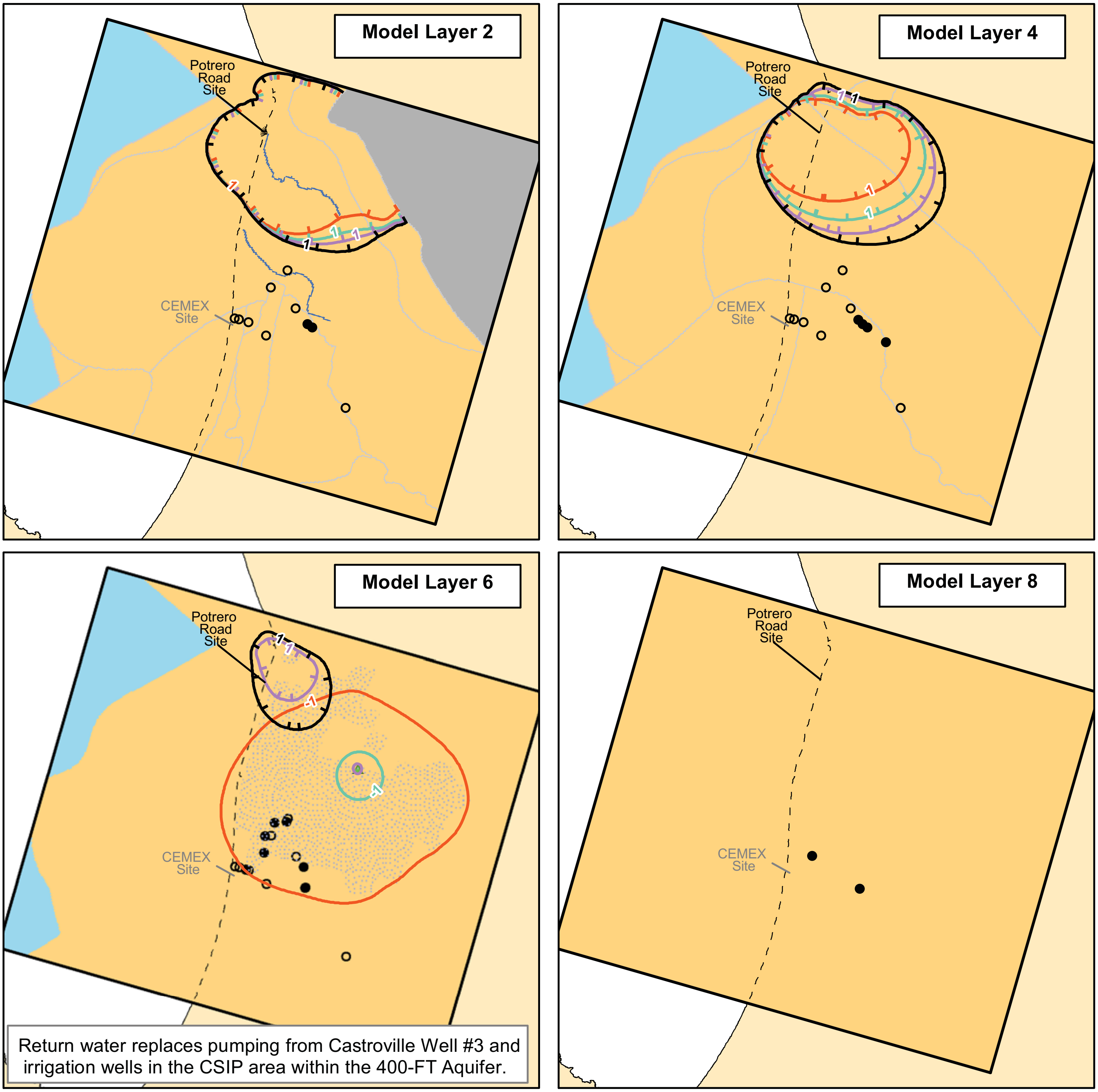
NMGWM^{2016} calculated drawdown
63 years of slant well pumping (24.1 MGD),
2012 sea level, with variable return water, Potrero Road site.

Figure 5.10a

PROJECT: 5073

DATE: 8/30/2016



EXPLANATION

- Model Layer 6 area underlying CSIP
- River Model Cell
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell
- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone

Contours (ft) - Line color indicates % return water

Only +/- 1 foot drawdown contours are shown. Contours not shown where groundwater level change is less than 1 foot.

- Groundwater Level Decrease (Drawdown)
- Groundwater Level Increase

0% Return Water **6% Return Water**
3% Return Water **12% Return Water**

In some cases contours are located directly beneath other contours and are not visible.

Wells

- Slant Well
- Castroville Well #3, 400-FT Aquifer
- CEMEX Monitoring
- Other

0 2 4
Miles

HYDROFOCUS INC.
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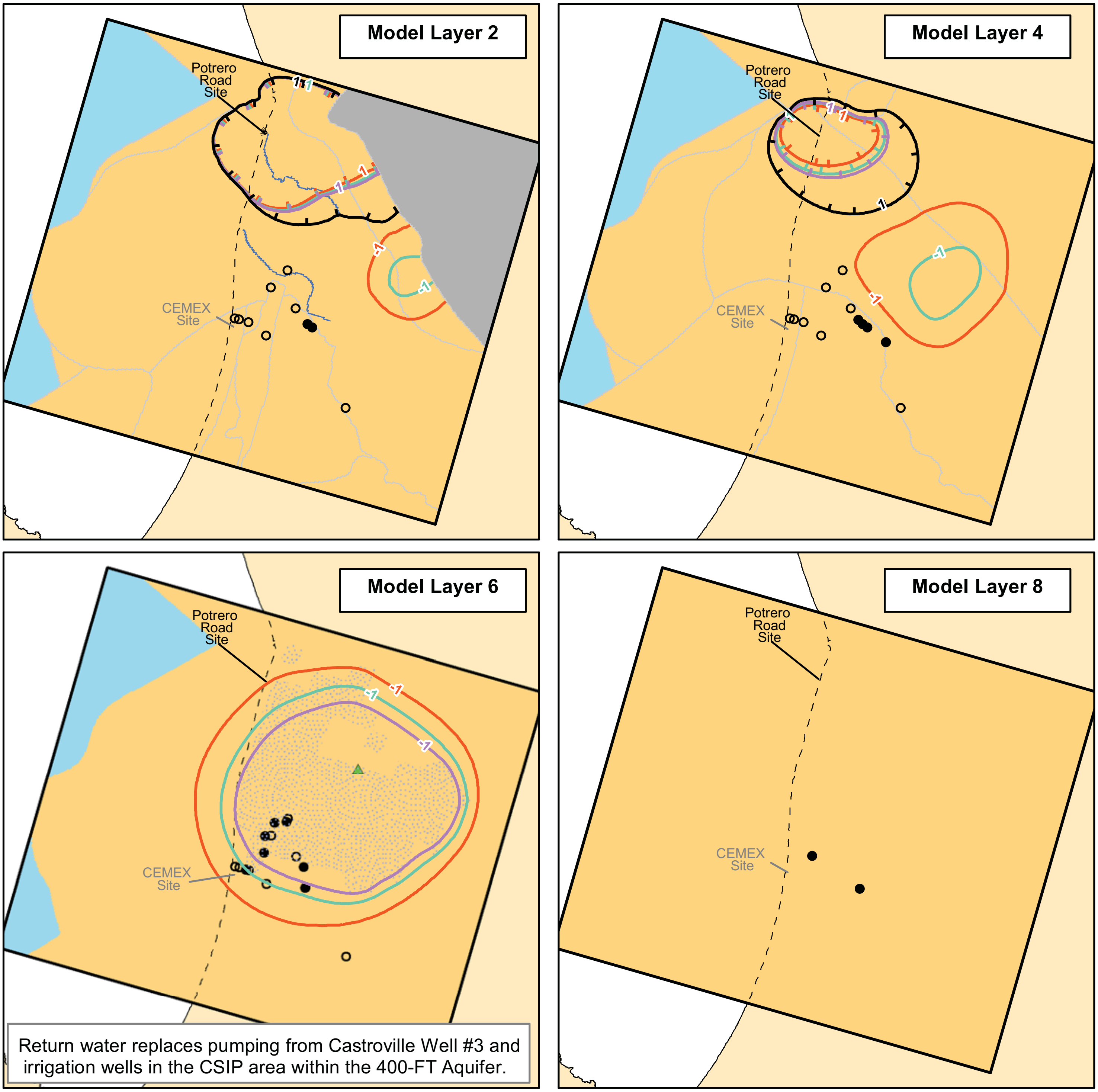
NMGWM[2016] calculated drawdown
63 years of slant well pumping (24.1 MGD),
2073 sea level, with variable return water, Potrero Road site.

Figure 5.10b

PROJECT: 5073 | DATE: 8/30/2016



EXPLANATION

- Model Layer 6 area underlying CSIP
- River Model Cell
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell
- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone

Contours (ft) - Line color indicates % return water

Only +/- 1 foot drawdown contours are shown. Contours not shown where groundwater level change is less than 1 foot.

- Groundwater Level Decrease (Drawdown)
- Groundwater Level Increase

0% Return Water **6% Return Water**
3% Return Water **12% Return Water**

In some cases contours are located directly beneath other contours and are not visible.

Wells

- Slant Well
- Castroville Well #3, 400-FT Aquifer
- CEMEX Monitoring
- Other

0 2 4
Miles

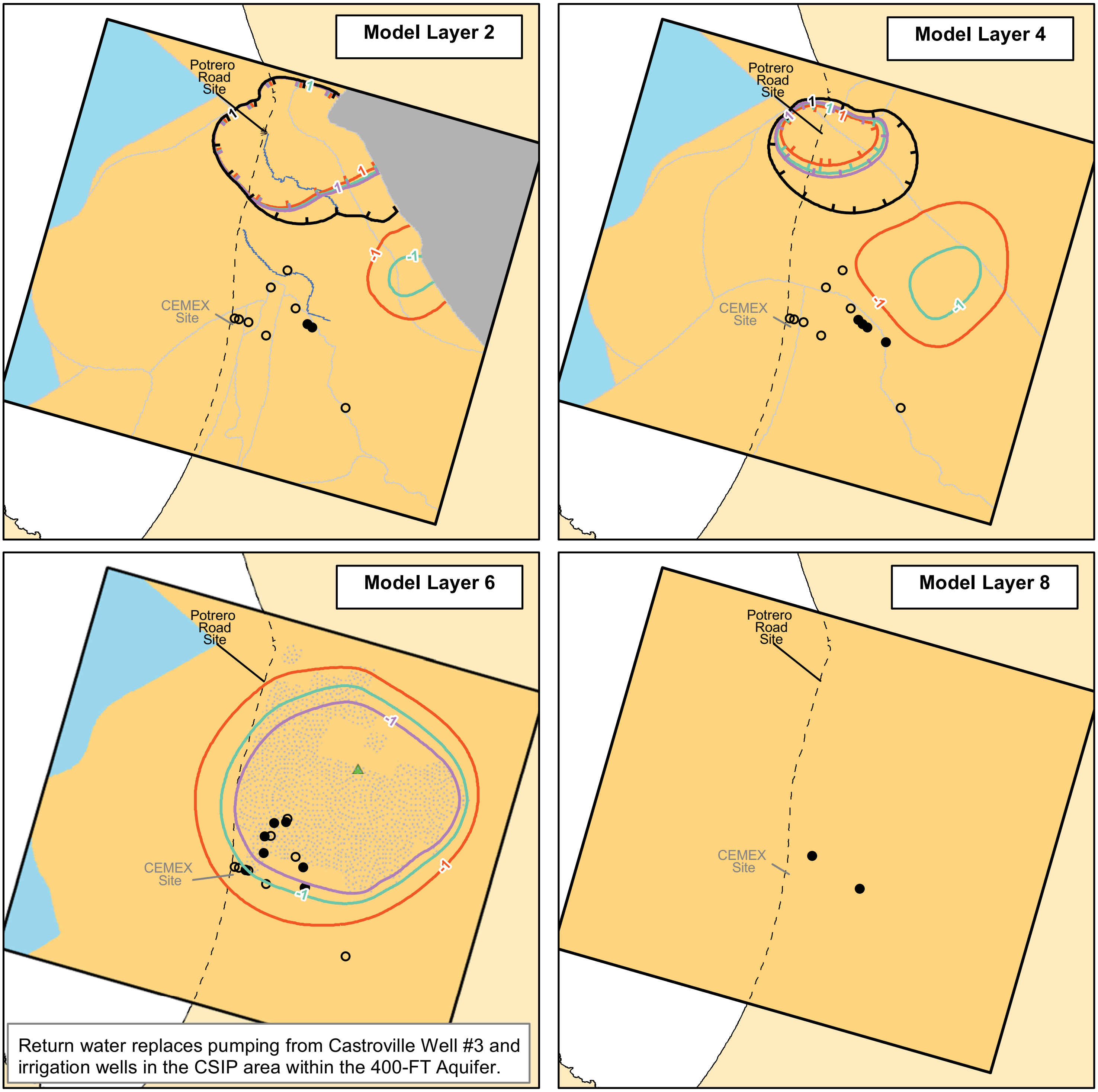
HYDROFOCUS INC. Solutions for Land and Water Resources

NMGWM2016 calculated drawdown
63 years of slant well pumping (15.5 MGD),
2012 sea level, with variable return water, Potrero Road site.

Figure 5.11a

PROJECT: 5073

DATE:7/11/2017



EXPLANATION

- Model Layer 6 area underlying CSIP
- River Model Cell
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell
- NMGWM Boundary
- Modeled Hydraulic Conductivity Zone

Contours (ft) - Line color indicates % return water

Only +/- 1 foot drawdown contours are shown. Contours not shown where groundwater level change is less than 1 foot.

- Groundwater Level Decrease (Drawdown)
- Groundwater Level Increase

0% Return Water **6% Return Water**
3% Return Water **12% Return Water**

In some cases contours are located directly beneath other contours and are not visible.

Wells

- Slant Well
- Castroville Well #3, 400-FT Aquifer
- CEMEX Monitoring
- Other

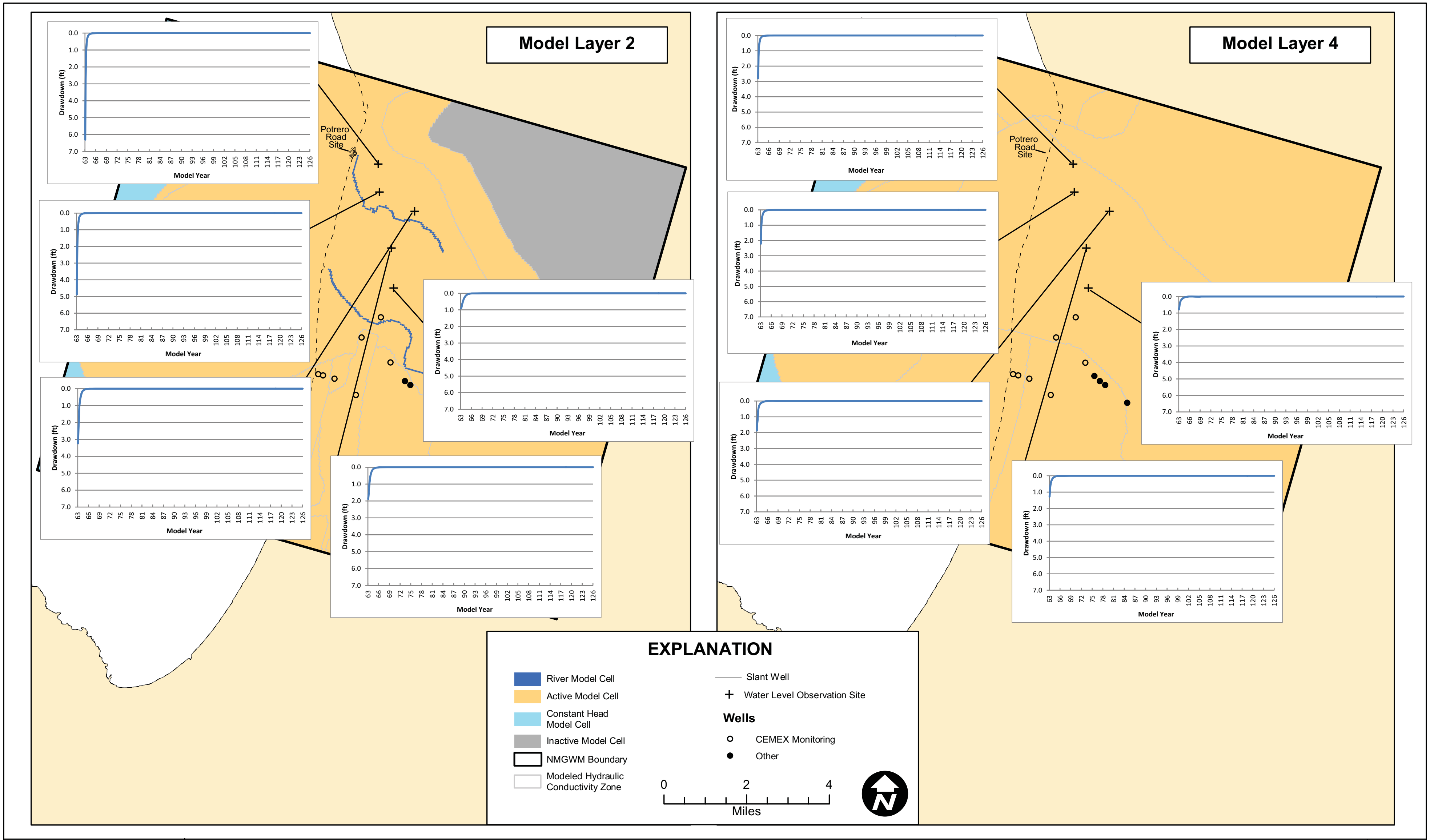
0 2 4
Miles

HYDROFOCUS INC. Solutions for Land and Water Resources

NMGWM2016 calculated drawdown
63 years of slant well pumping (15.5 MGD),
2073 sea level, with variable return water, Potrero Road site.

Figure 5.11b

PROJECT: 5073 | DATE: 8/30/2016



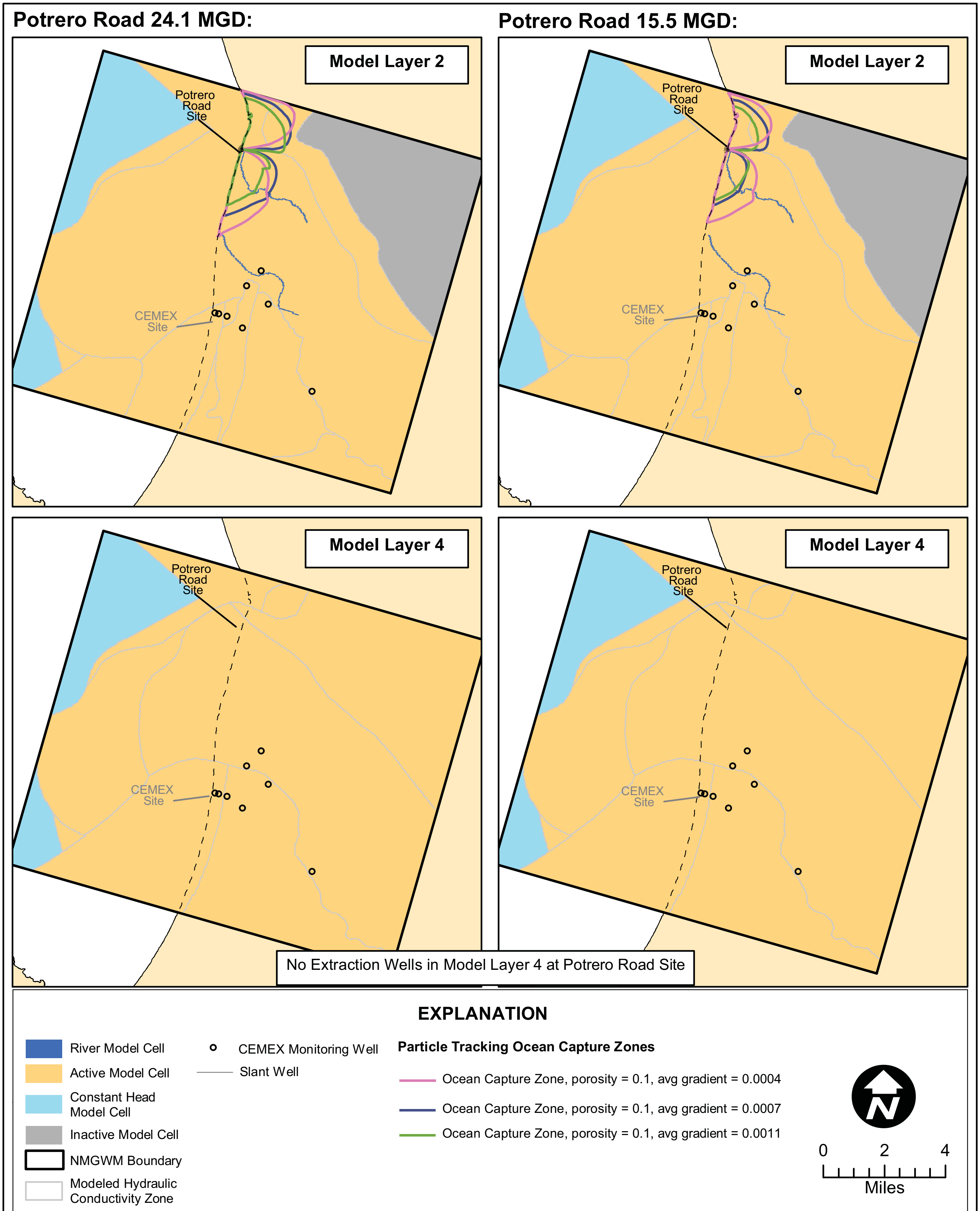
HYDROFOCUS INC. Solutions for Land and Water Resources

NMGWM[2016] calculated recovery hydrographs
post-Potrero Road site, 2073 sea level.

Figure 5.12

PROJECT: 5073

DATE: 7/11/2017



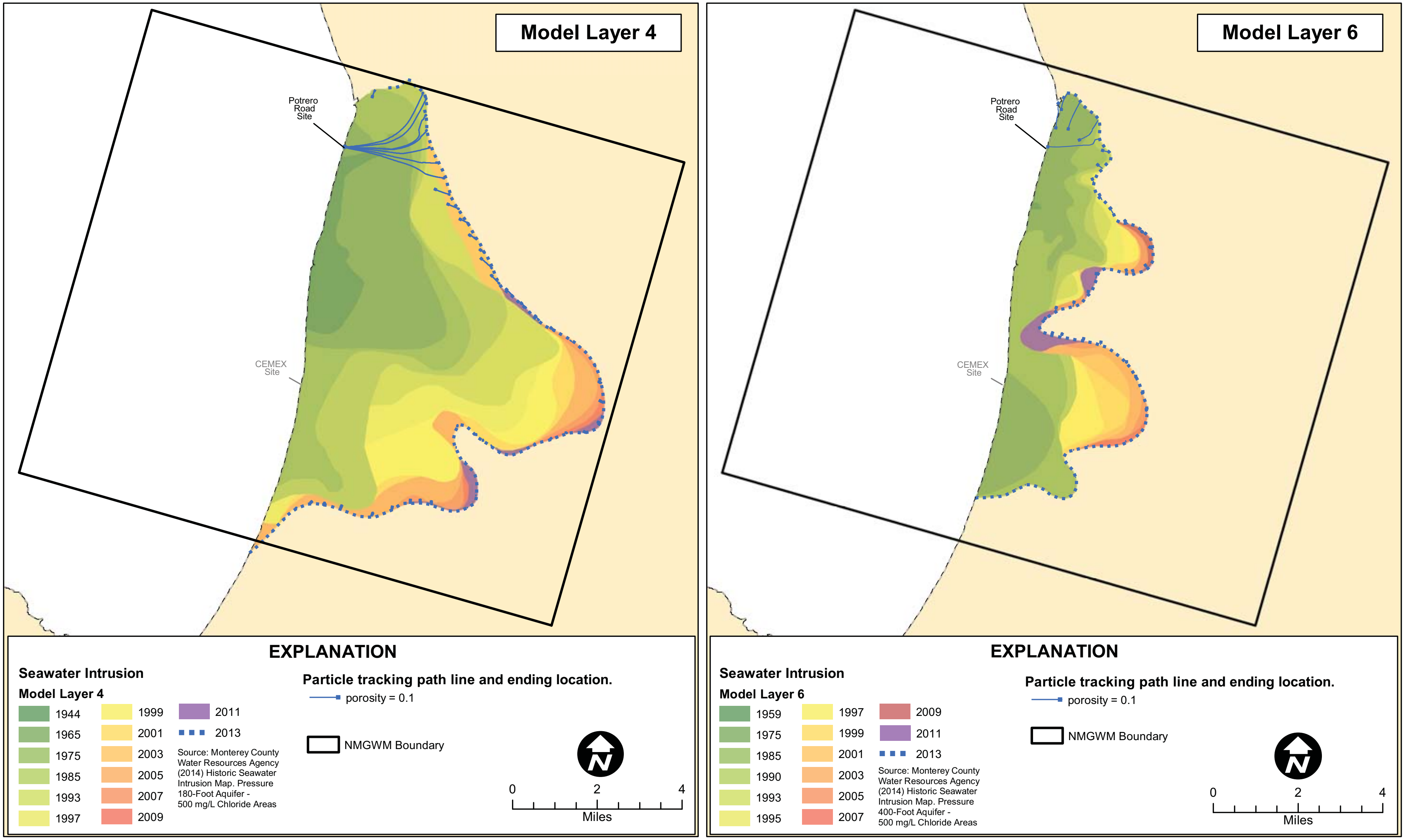
HYDROFOCUS INC. Solutions for Land and Water Resources

NMGWM[2016] calculated ocean capture zone with variable regional gradients, 63 years of slant well pumping (24.1 and 15.5 MGD), 2012 sea level, Potrero Road site.

Figure 5.13

PROJECT: 5073

DATE: 8/30/2016

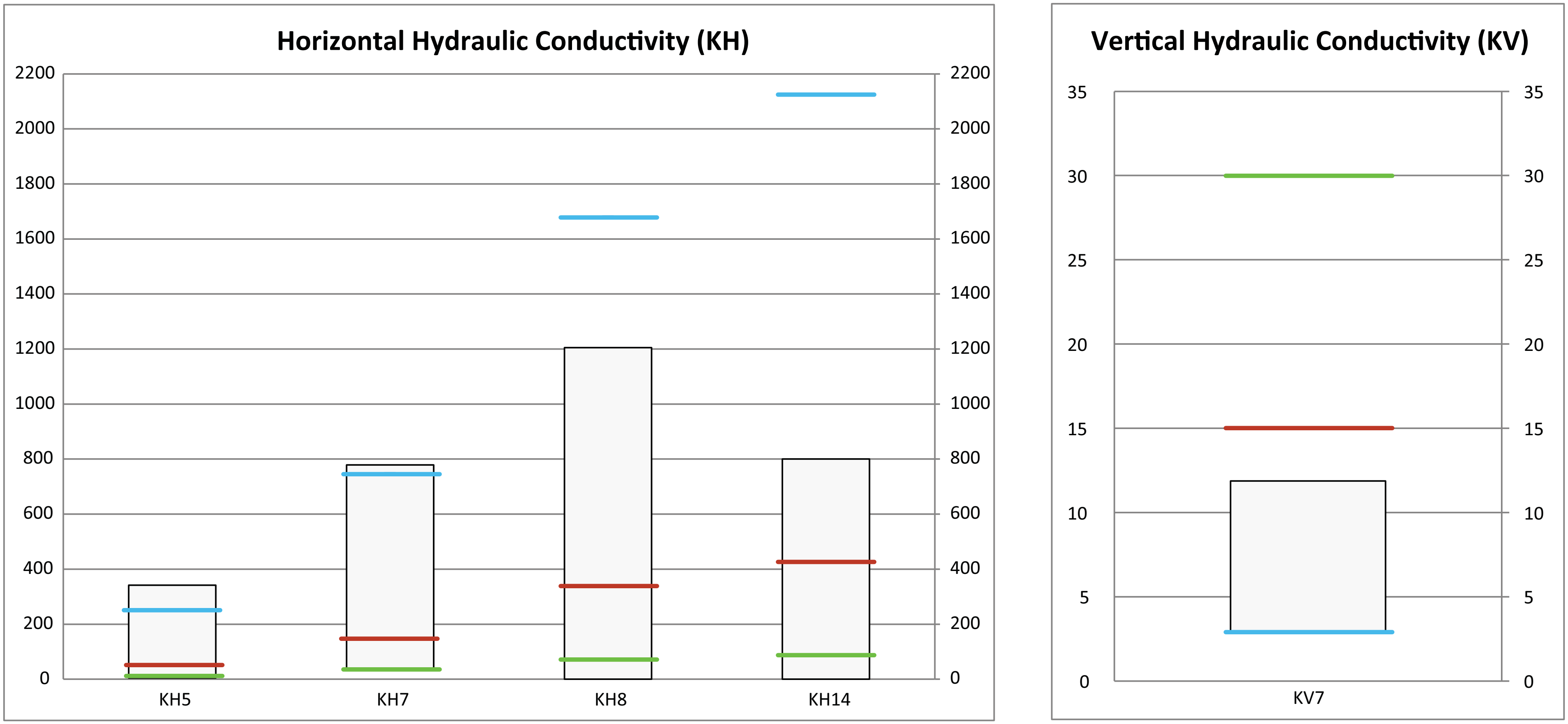


HYDROFOCUS INC. Solutions for Land and Water Resources

NMGWM[2016] particle tracking changes at mapped saltwater intrusion front after 63 years of slant well pumping (24.1 MGD), 2012 sea level, with no return water, Potrero Road site.

Figure 5.14

PROJECT: 5073 | DATE: 7/11/2017



EXPLANATION

max / min — Range of values from other sources

Model value

Sensitivity Runs:

Maximum anisotropy

Minimum anisotropy

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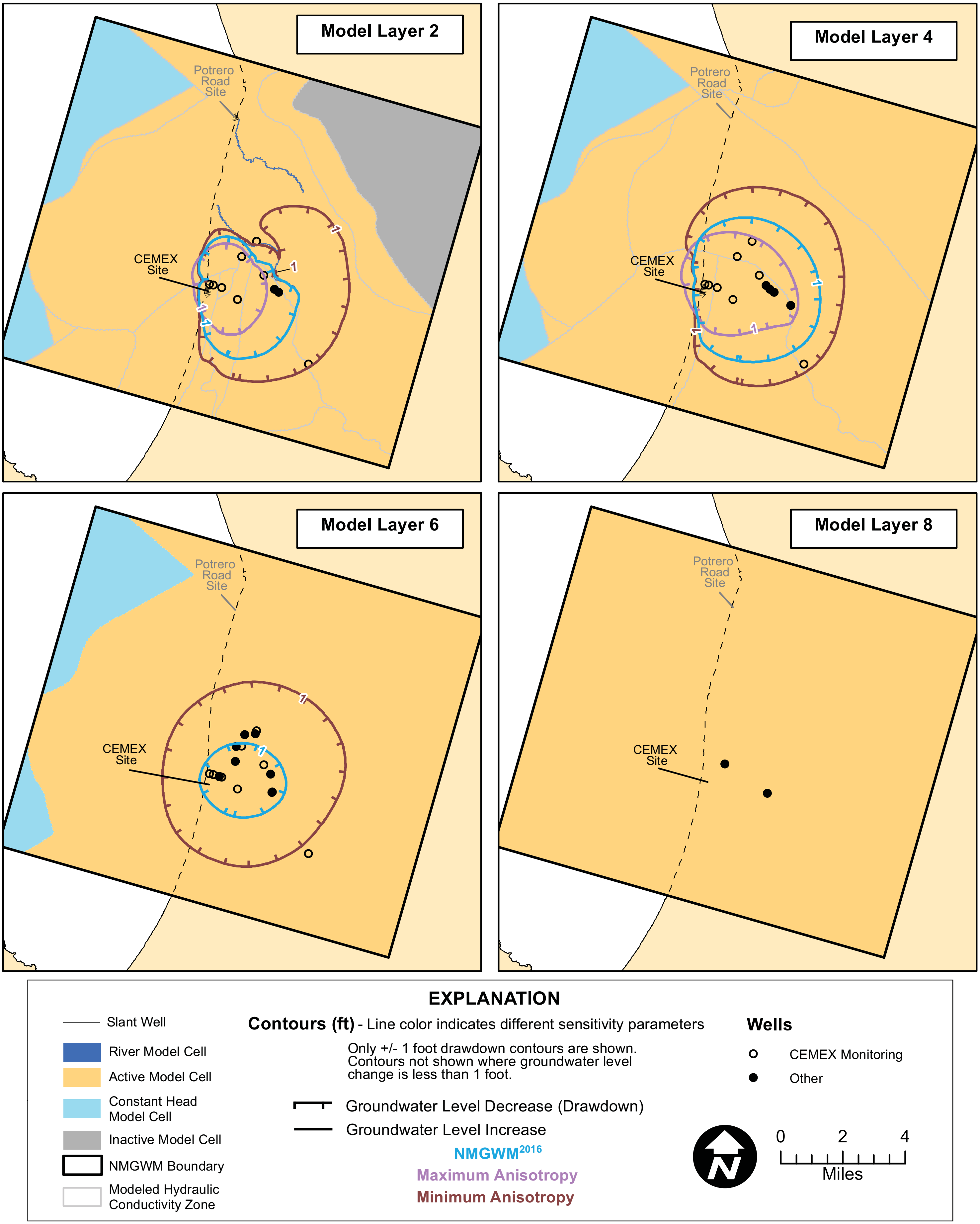
Alternative NMGWM^{2016} hydraulic conductivity values employed to simulate maximum and minimum anisotropy (ratio of horizontal to vertical hydraulic conductivity).

Figure 6.1

PROJECT: 5073

DATE: 8/12/2016



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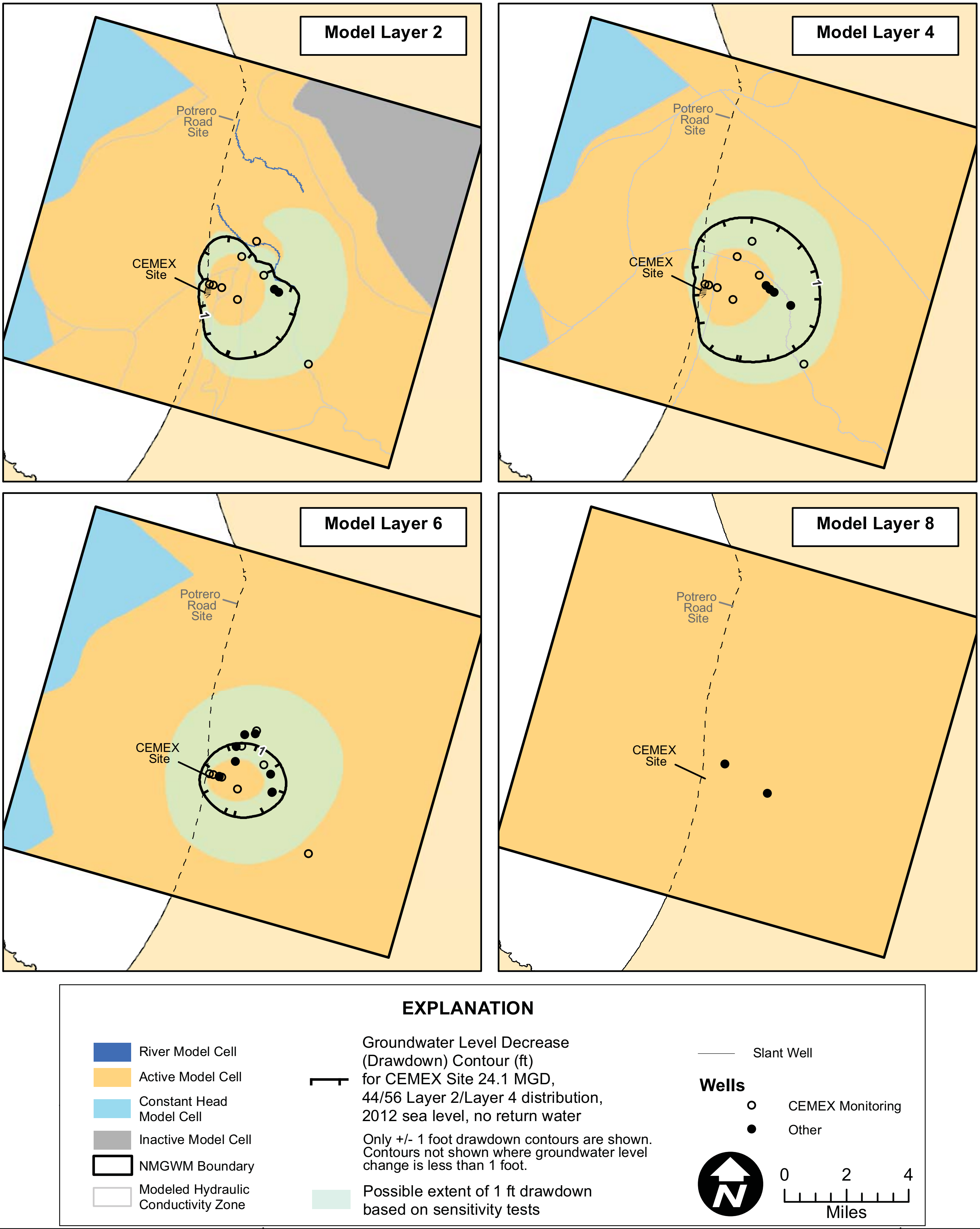
Sensitivity of calculated drawdown to hydraulic conductivity after 63 years of slant well pumping (24.1 MGD), 44/56 Layer 2/Layer 4 distribution, 2012 sea level with no return water, CEMEX site.

Figure 6.2

PROJECT: 5073

DATE: 8/30/2016



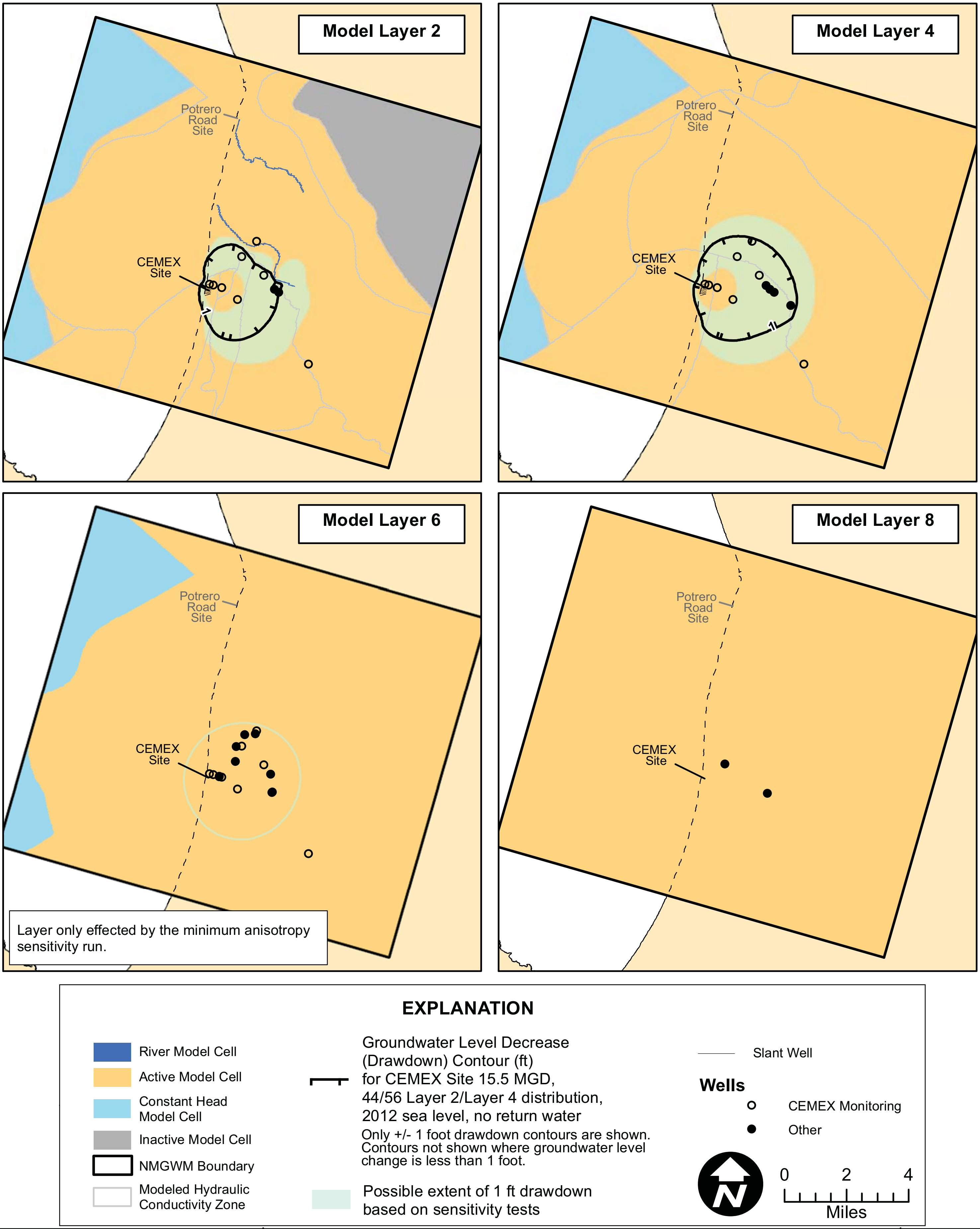
HYDROFOCUS INC. Solutions for Land and Water Resources

Uncertainty in calculated drawdown from slant well pumping at CEMEX site due to projected sea level rise, layer distribution, and hydraulic conductivity; 24.1 MGD.

Figure 6.3a

PROJECT: 5073

DATE: 8/19/2016



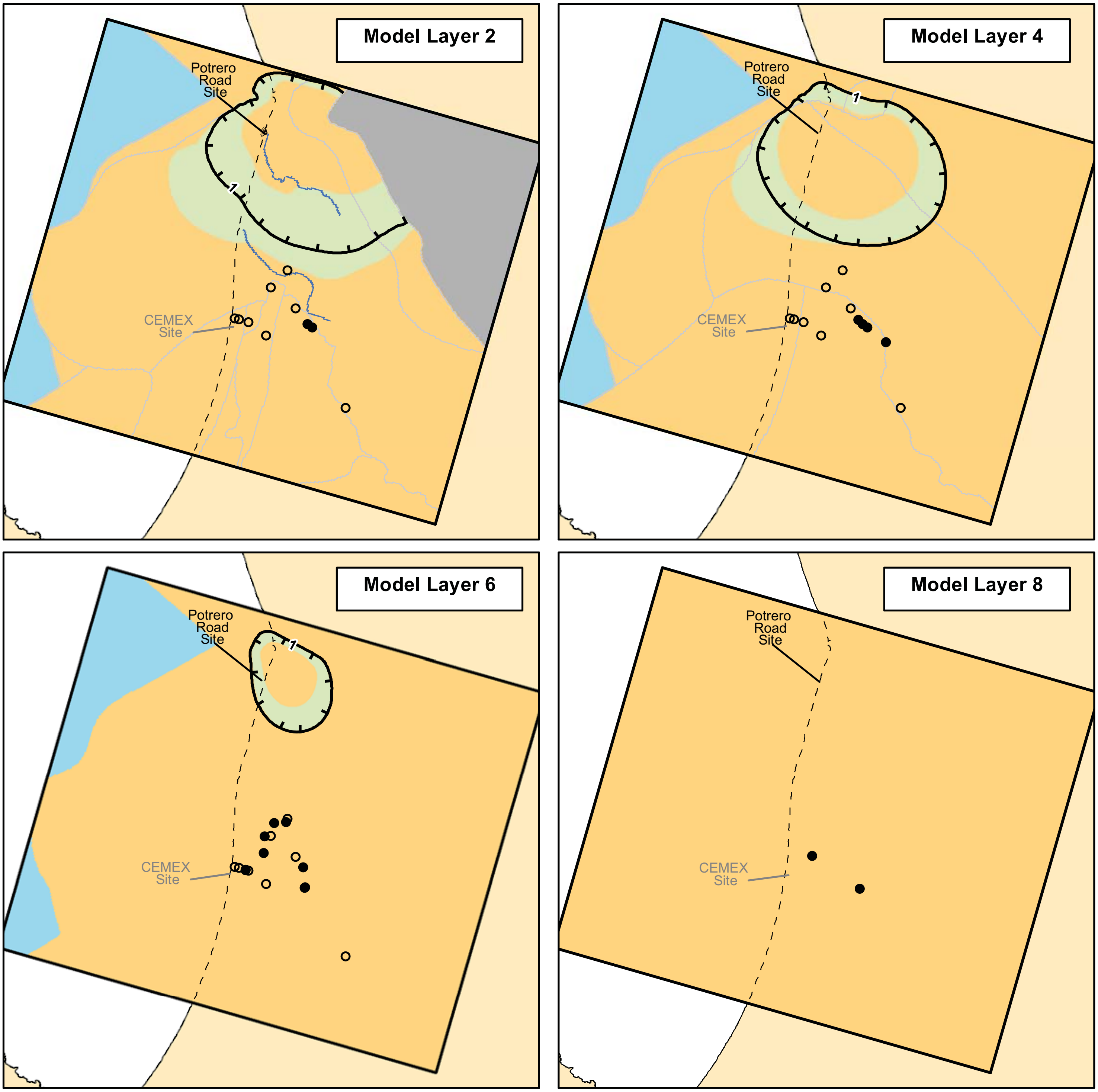
HYDROFOCUS INC. Solutions for Land and Water Resources

Uncertainty in calculated drawdown from slant well pumping at CEMEX site due to projected sea level rise, layer distribution, and hydraulic conductivity; 15.5 MGD.

Figure 6.3b

PROJECT: 5073

DATE: 8/19/2016



EXPLANATION

River Model Cell
Active Model Cell
Constant Head Model Cell
Inactive Model Cell
NMGWM Boundary
Modeled Hydraulic Conductivity Zone

Groundwater Level Decrease (Drawdown) Contour (ft) for Potrero Road Site 24.1 MGD, 2012 sea level, no return water

Only +/- 1 foot drawdown contours are shown. Contours not shown where groundwater level change is less than 1 foot.

Possible extent of 1 ft drawdown based on sensitivity tests

Slant Well

Wells

CEMEX Monitoring
Other

0 2 4
Miles

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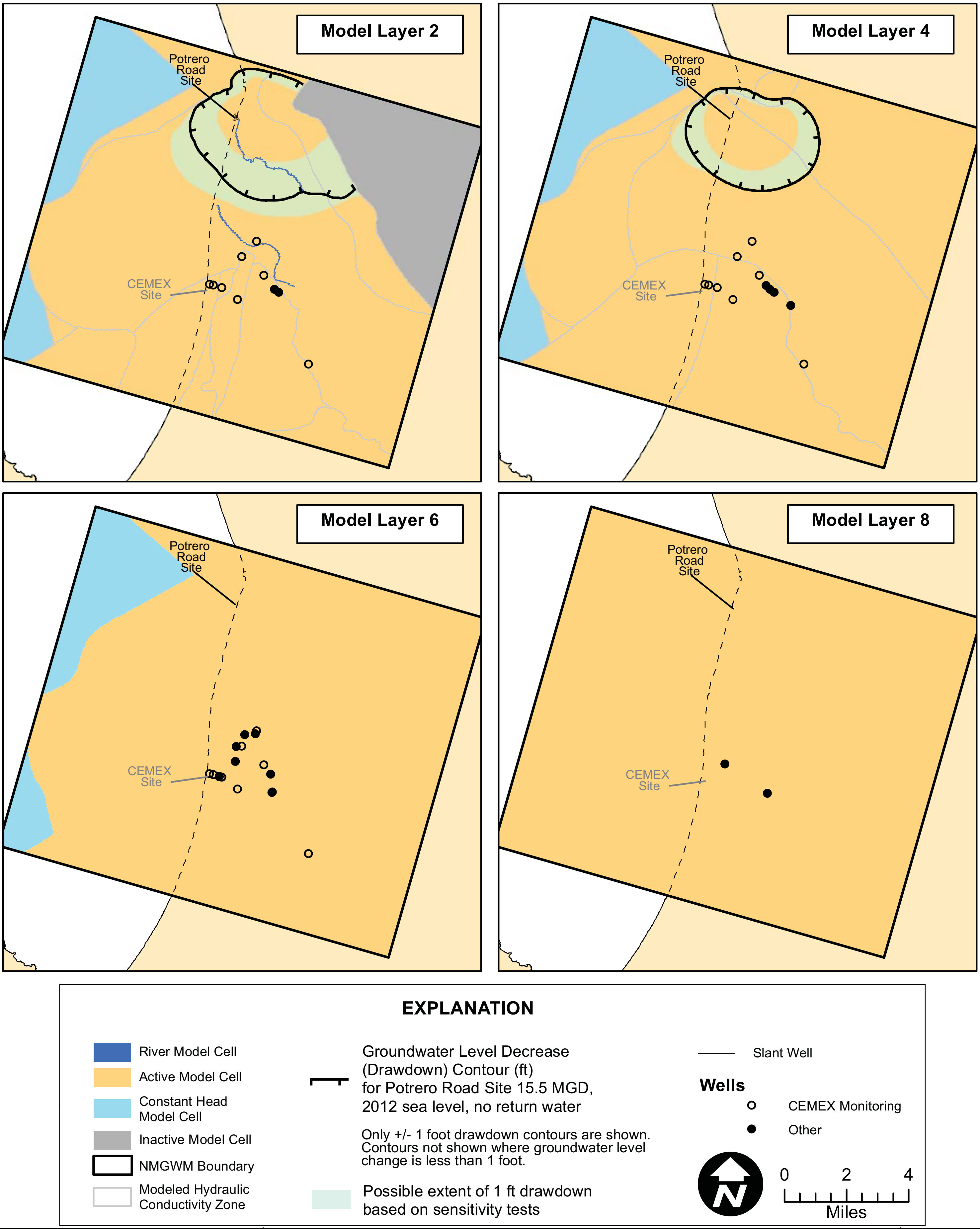
Uncertainty in calculated drawdown from slant well pumping at Potrero Road site due to projected sea level rise and hydraulic conductivity; 24.1 MGD.

Figure 6.4a

PROJECT: 5073

DATE: 8/12/2016



HYDROFOCUS INC. Solutions for Land and Water Resources

Uncertainty in calculated drawdown from slant well pumping at Potrero Road site due to projected sea level rise and hydraulic conductivity; 15.5 MGD.

Figure 6.4b

PROJECT: 5073

DATE: 8/19/2016

Attachment 1
Example Analysis Using Superposition

We modeled a hypothetical groundwater basin to provide an example application of superposition (**Figure A1.1**). The model represents a 10 mile by 5 mile hypothetical multi-aquifer groundwater system, and it employs monthly stress periods to simulate 4 years of variable recharge and pumping. The hypothetical basin is represented by 5 model layers, 3 layers represent aquifers (upper, middle, and deep aquifers), and 2 layers represent aquitards separating the aquifers. Constant-head cells are assigned to the western-most model boundary to represent a large surface-water body like the ocean (water level specified as zero), and head-dependent flux boundary cells assigned to the eastern-most boundary to represent inland groundwater conditions beyond the extent of the model grid (external water level specified as 55 feet above mean sea level). The northern and southern boundaries are contacts between the aquifers and non-water bearing sediments. Groundwater does not move in or out of the basin across these boundaries, and they are represented in the model as no-flow boundaries. A river is simulated in model layer 1, and the river stage ranges from 0 at the coast to 58 feet above mean sea level at the eastern-most boundary. The river channel bed bottom is assumed to be 14 feet below land surface, and the spatially varying elevation of the channel bed bottom calculated as land surface elevation minus 14 feet.

Background hydrologic conditions in the hypothetical basin include rainfall recharge and pumping. Variable monthly rainfall recharge is simulated for 6-months of the year (4,381 AF/yr average annual rainfall recharge), followed by a 6-month dry period. Groundwater is extracted by three wells at a continuous pumping rate of 2,001 AF/yr per well (6,004 AF/yr total). Each well extracts groundwater from one of the three aquifers.

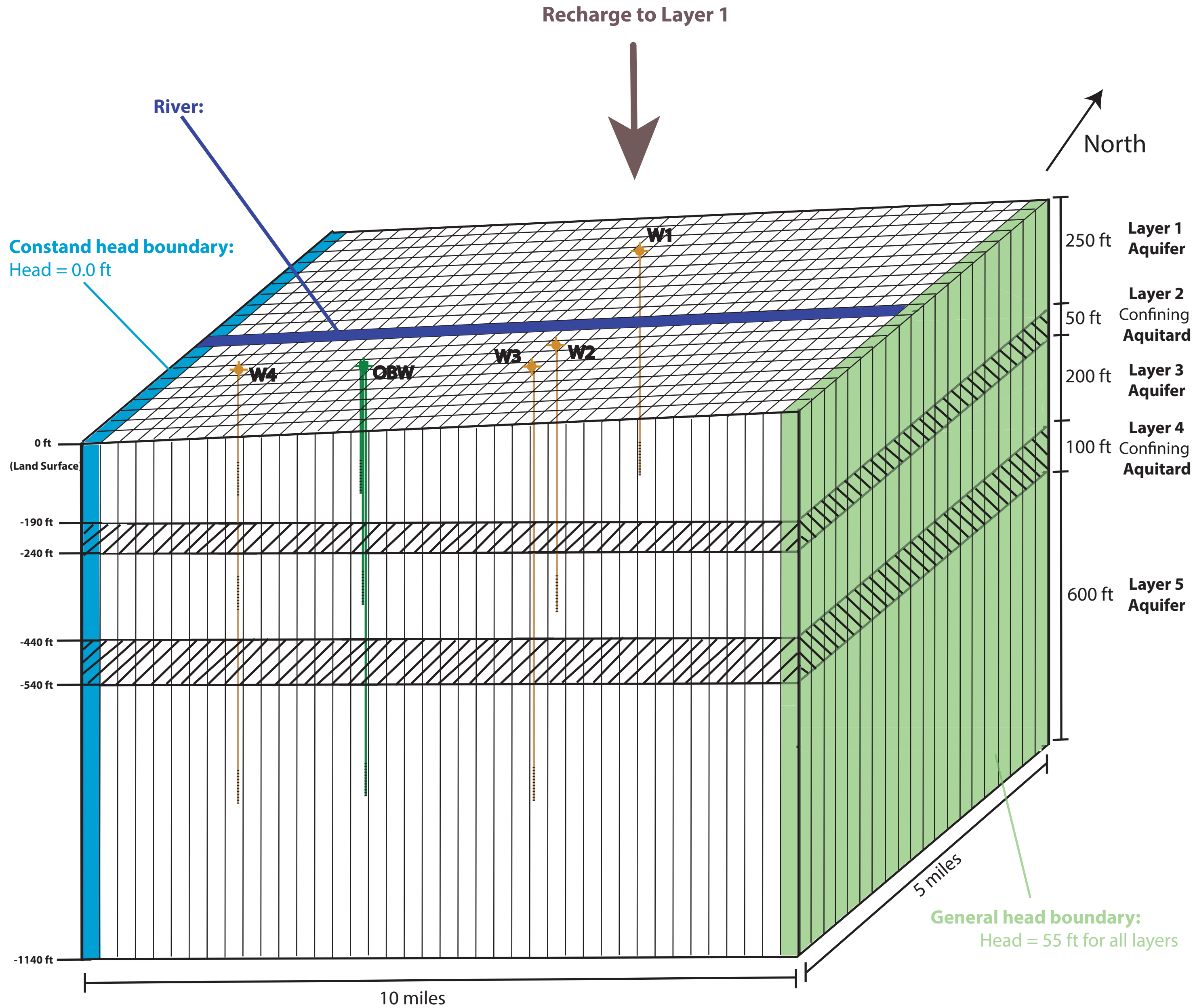
Model calculated water levels and annual average volumetric water budgets for background recharge and pumping conditions are shown in **Figure A1.2a**. The water levels at the observation wells show seasonal variation as a result of monthly varying recharge and extractions by pumping wells. Pumping exceeds rainfall recharge by over 1,620 AF/yr, and the additional water supply to the pumped wells is provided by river losses (12,185 AF/yr) and groundwater inflow from basin areas east of the model represented by the head-dependent flux boundary cells (5,461 AF/yr). Total water inflow to the hypothetical basin exceeds pumping, and recharge in excess of pumping discharges to the constant-head boundaries (16,034 AF/yr). The model calculates a nominal 11 AF/yr reduction in groundwater storage under background recharge and pumping conditions.

The model was used to project the water level and volumetric budget changes in response to a new well that is constructed and operated in the basin. The new well is screened in all three aquifers and extracts groundwater at a pumping rate of 6,004 AF/yr, effectively doubling total pumping in the basin (from 6,004 to12,008 AF/yr). The model-calculated water levels and volumetric budget in response to the new well is shown in **Figure A1.2b**. Contours of equal water level elevations show increased water losses from the river to the aquifer, and groundwater movement toward the well. The water extracted by the new well is therefore supplied primarily by increased river losses, groundwater inflow from basin areas east of the model represented by the head-dependent flux model cells, and groundwater discharge to the constant-head cells that is now captured by the pumping well. As a result of increased pumping, the river losses increased from 12,185 AF/yr to 13,859 AF/yr (a net increase of 1,674 AF/yr), inflow from the head-dependent flux model cells increased from 5,461 AF/yr to 5,532 AF/yr (net increase of 71 AF/yr), and groundwater discharge to the constant-head model cells decreased from 16,034 AF/yr to 11,781 AF/yr (a net decrease of 4,253 AF/yr). The model calculates a nominal 6 AF/yr increase in storage depletion as a result of the new well pumping. The accumulated change in model-calculated fluxes equals the 6,004 AF/yr pumping increase exactly (1,674 + 71 + 4,253 + 6 = 6,004 AF/yr).

Figure A1.3a compares the model-calculated hydrographs before and after the new well started operation. The seasonal variability in the water levels is similar, but their magnitude decreases as a result of the new pumpage. By subtracting the model-calculated water levels with the new well from the model-calculated background water levels provides the net water level change as a result of the new pumping, effectively isolating the drawdown due solely to the new well. We calculated these differences and show the results in **Figure A1.3b**. Although the model simulates groundwater changes for four years of new well operations, the drawdown attributed to the new well stabilizes in about 100 days (approximately 3 months), and the maximum drawdown at observation wells constructed in each of the three aquifers decline 0.96 foot in layer 1 (upper aquifer), 1.07 feet in layer 3 (middle aquifer), and 1.35 feet in layer 5 (deep aquifer).

We utilized the example model and superposition to calculate the drawdown from the new pumping well directly. The superposition modeling approach solves for changes in water levels and fluxes directly, and therefore the background recharge and pumping are set to zero. The only stress simulated is pumping from the new well. Additionally, the initial head distribution and specified boundary conditions are also defined in terms of changes rather than actual measured values. In the example model, the initial water levels are set to zero, and the specified water levels for the constant-head cells, head-dependent boundary flux cells, and river cells are also all set to zero. Because pumping causes a decline in water levels, only water level changes relative to the elevation of the channel bed bottom effect model-calculated river losses. The available drawdown is the difference between the groundwater level and the river channel bottom. Employing superposition, the river channel bottom elevation is therefore lowered to maintain the available drawdown in each river cell when the initial water levels are changed to zero.

The calculated drawdown hydrographs and cone of depression using superposition are provided in **Figure A1.4**, and agree exactly with the water level differences calculated by subtracting the new well water levels from the background water levels reported in **Figure A1.3**. The model-calculated cone of depression shows the area influenced by the new pumping well, and the simulated water budget components reported in **Figure A1.4** represent the net flux changes in response to the new well pumping. The superposition budget components agree exactly with the differences in budget components reported in **Figure A1.2** and summarized above.



Wells:

W1- Screened in layer 1.
Pumping 2,001 AF/yr
W2- Screened in layer 3.
Pumping 2,001 AF/yr
W3- Screened in layer 5.
Pumping 2,001 AF/yr
W4- Screened in Layers 1, 3 and 5.
Pumping from Layer 1 3,901 AF/yr
Pumping from Layer 3 1,051 AF/yr
Pumping from Layer 5 1,051 AF/yr
OBW- Observation well cluster. Wells screened in Layers 1, 3 and 5.

Recharge:

Year	Months	Recharge (ft/day)
1	Jan-June	0.000685
1	July-Dec	0
2	Jan-June	0.0003425
2	July-Dec	0
3	Jan-June	0.00137
3	July-Dec	0
4	Jan-June	0.000685
4	July-Dec	0

Aquifer Properties:

Layer	Kx	Ky	Kz	S	Ss	Sy
1	220	220	2	2.5x10-4	1x10-6	0.2
2	1	1	0.03	5x10-5	1x10-6	0.2
3	75	75	0.75	2x10-4	1x10-6	0.2
4	1	1	0.004	1x10-4	1x10-6	0.2
5	25	25	0.25	6x10-4	1x10-6	0.2

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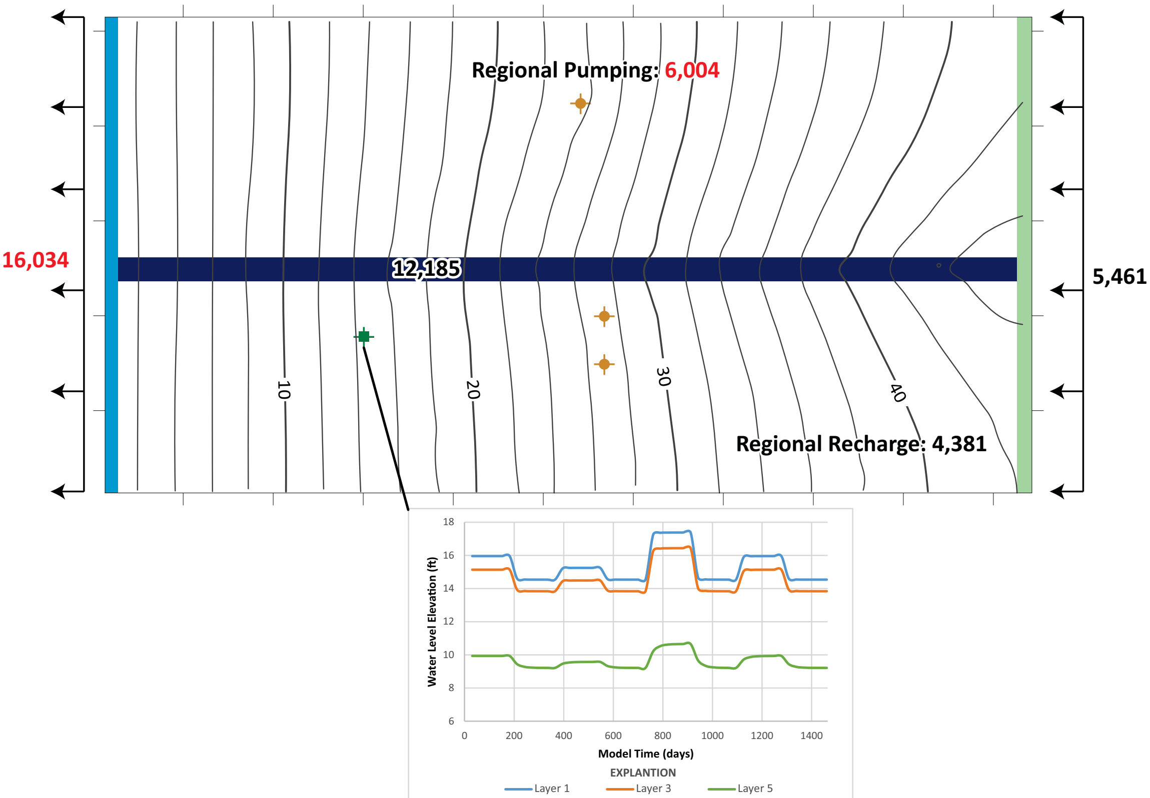
Example problem.

Figure A1.1

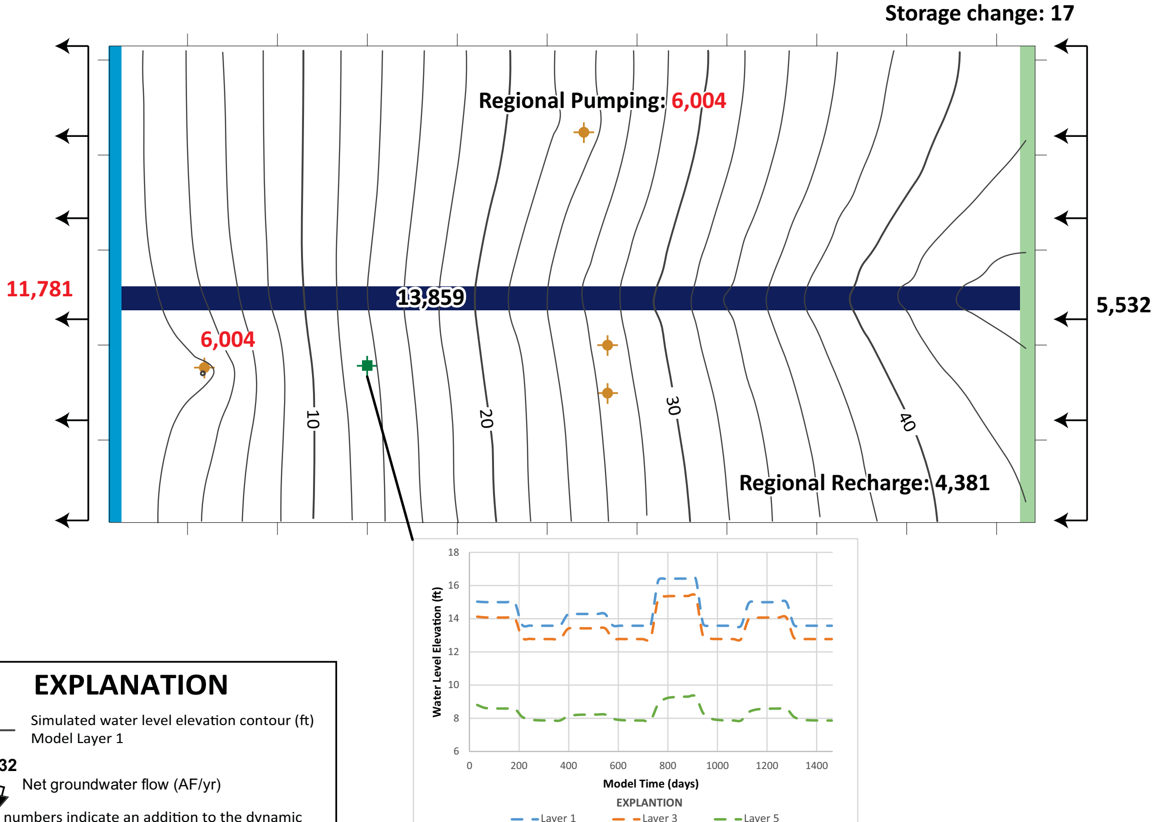
PROJECT: 5073

DATE: 8/8/2016

A. background conditions



B. new well conditions



EXPLANATION

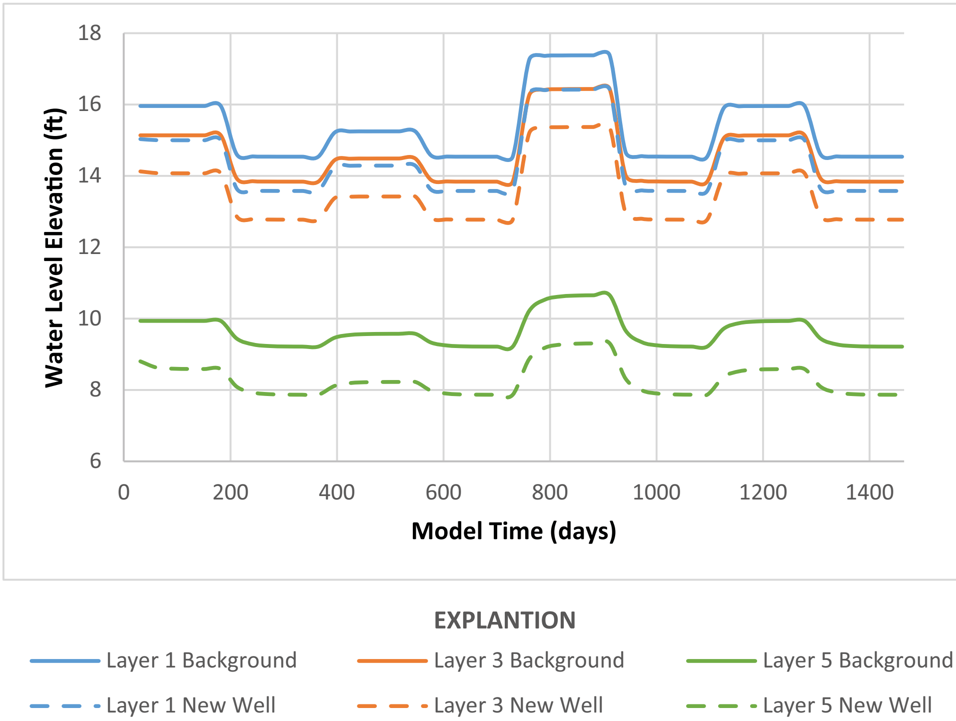
Simulated water level elevation contour (ft) Model Layer 1

5,532 Net groundwater flow (AF/yr)

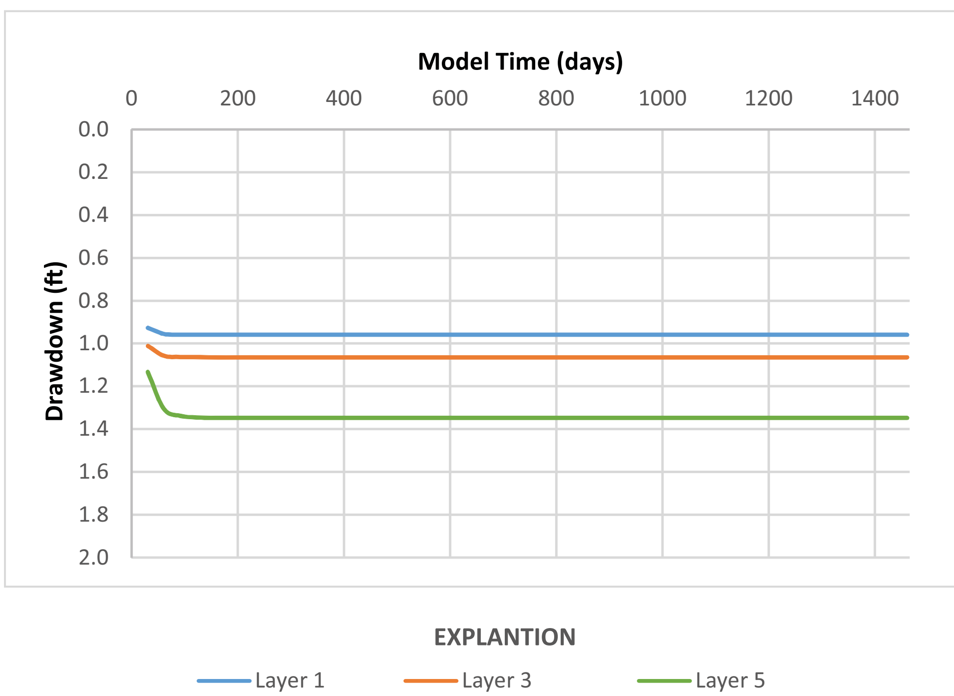
Black numbers indicate an addition to the dynamic groundwater system, and red numbers indicate a subtraction from the dynamic groundwater system.

HYDROFOCUS INC. Solutions for Land and Water Resources	Example Problem - average annual volumetric water budget, water elevation contours, and hydrographs.	Figure A1.2
PROJECT: 5073	DATE: 8/16/2016	

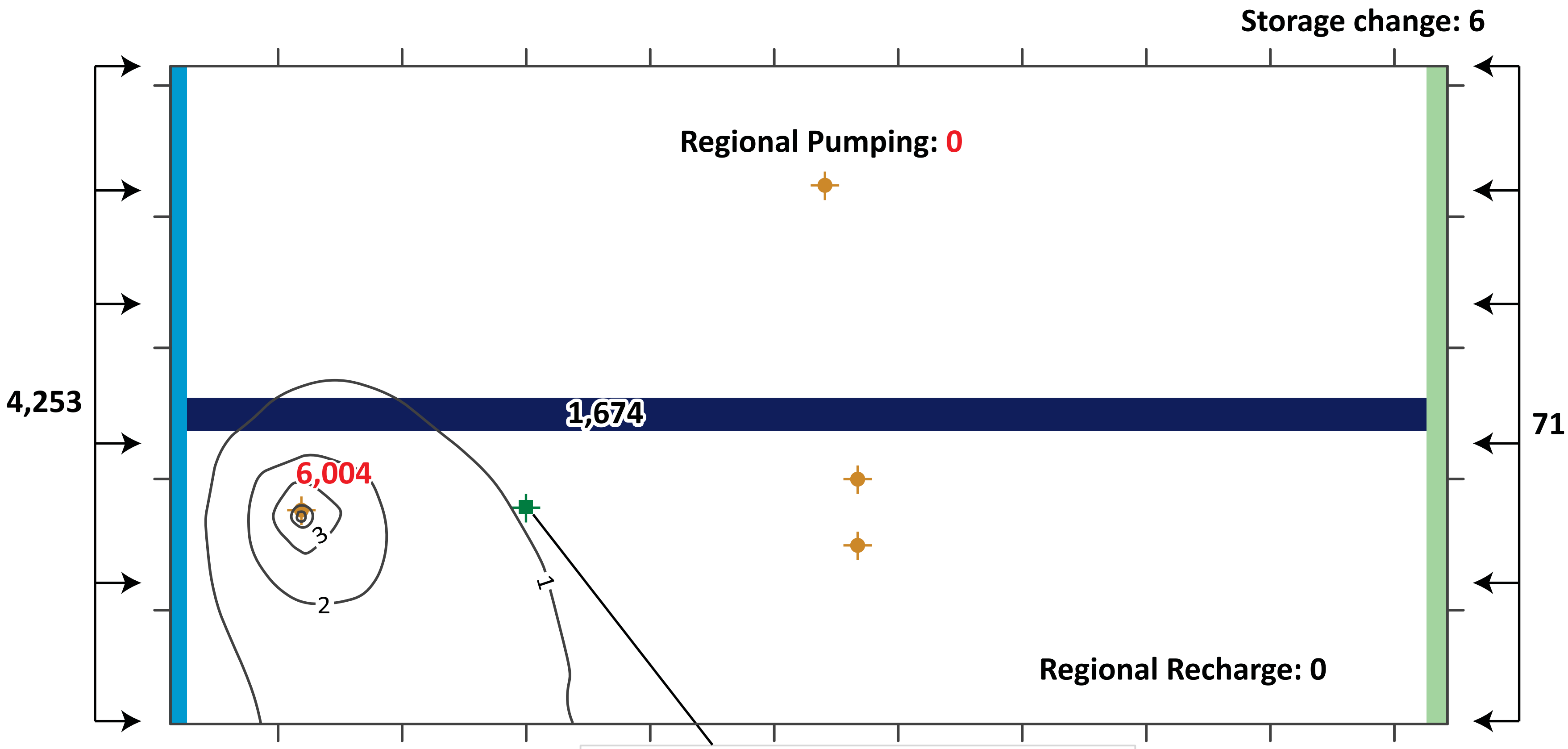
a) background and new well conditions

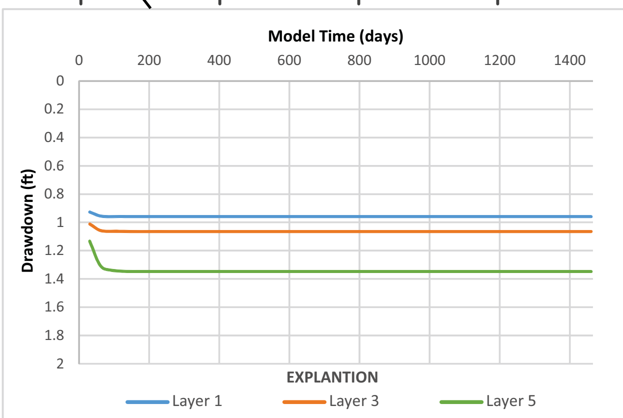


b) background conditions minus new well conditions



HYDROFOCUS INC. Solutions for Land and Water Resources	Example problem - (a) model calculated water levels, background and new well conditions; (b) water level difference (drawdown) between background and new well conditions	Figure A1.3
PROJECT: 5073	DATE: 8/16/2016	





EXPLANATION

Simulated drawdown contour (ft)
Model Layer 1

71
Net groundwater flow (AF/yr)

Black numbers indicate an addition to the dynamic groundwater system, and red numbers indicate a subtraction from the dynamic groundwater system.

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Example problem - average annual volumetric water budget, water elevation contours, and hydrographs calculated with superposition model.

Figure A1.4

PROJECT: 5073

DATE: 8/16/2016

Attachment 2
Simple Expanded Test Model

We examined the sensitivity of model-calculated drawdown to the northern head-dependent flux boundary (general-head boundary) by creating a simple test model that included the $NMGWM^{2016}$ area and southern portion of the Pajaro Valley represented by the Pajaro Valley Hydrologic Model (PVHM).[95] We extended the northern boundary of the $NMGWM^{2016}$ to include an additional 150 rows (approximately 5.5 miles), and the model layering and aquifer properties in the NMGWM area was kept consistent except for a transition zone where the two models met. Model layering and model parameter zones were smoothed in the transition zone between the $NMGWM^{2016}$ and the PVHM, generally consisting of the upper 30 rows representing the $NMGWM^{2016}$ and the lower 30 rows representing the PVHM. For the expanded model grid in the north, we used the corresponding average layer thickness from the PVHM.

The ocean was represented with constant head model cells and projected 2012 sea level. General-head boundaries were assigned to the northern- and southern-most boundaries of the expanded model, the eastern-most boundaries of the $NMGWM^{2016}$, and the PVHM cells influenced by Carneros Creek. In both the PVHM and our simplified model, Elkhorn Slough is simulated with general-head boundaries; we adjusted the PVHM general-head boundary conductance values to account for the cell size difference between the PVHM and the simplified model. As with the $NMGWM^{2016}$, Salinas River and Tembladero Slough were simulated by river cells. We specified initial water levels, constant head cell water levels, general-head boundary external water levels, and river cell stage all to zero.

Figure A2.1 shows model calculated drawdown at Potrero Road using the $NMGWM^{2016}$ and simple expanded test model. The cone of depression is similar towards the center of the model, however it does extend further into the Pajaro Valley than simulated by the $NMGWM^{2016}$. The cone of depression extends northward into the Pajaro Valley by approximately one-half mile in Model Layer 2, and approximately three-quarter mile for Model Layers 3 and Model Layer 4. However, the calculated drawdown in Model Layer 6 is less than 1 foot and smaller than the drawdown calculated by the $NMGWM^{2016}$. This is consistent with subsurface geologic conditions north of the $NMGWM^{2016}$, where a localized clay bed near Elkhorn Slough inhibits horizontal groundwater flow north of the $NMGWM^{2016}$ boundary[96] (see **Figure 3.2e** of the main report, which shows representation of the clay bed by the model parameter zones). We therefore concluded that the general-head boundary in the $NMGWM^{2016}$ has a modest effect on the model-calculated cone of

[95] Hanson RT, Schmid W, Faunt CC, Lear J, Lockwood B, 2014, "Integrated Hydrologic Model of Pajaro Valley, Santa Cruz and Monterey Counties, California," U.S. Geological Survey Scientific Investigations Report 2014-5111. Prepared in cooperation with the Pajaro Valley Water Management Agency.

[96] *Ibid* [26] and Yates EB, 1988, "Simulated Effects of Ground-Water Management Alternatives for the Salinas Valley, California," U.S. Geological Survey Water-Resources Investigations Report 87-4066. Prepared in cooperation with the Monterey County Flood Control and Water Conservation District

depression, but the effect is fairly insignificant for making drawdown comparisons between the CEMEX and Potrero Road Sites.

EXPLANATION

- River Model Cell
- General Head Boundary Model Cell
- Active Model Cell
- Constant Head Model Cell
- Inactive Model Cell
- NMGWM Boundary
- Simple Expanded Model Boundary
- Modeled Hydraulic Conductivity Zone

Contours (ft) - Line color indicates model version

Only +/- 1 foot drawdown contours are shown. Contours not shown where groundwater level change is less than 1 foot.

- Groundwater Level Decrease (Drawdown)
- Groundwater Level Increase

NMGWM2016

Simple expanded test model

In some cases contours are located directly beneath other contours and are not visible.

Wells

- Other
- CEMEX Monitoring
- Slant Well

0 2 4
Miles

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Model Calculated Drawdown
63 years of slant well pumping (24.1 MGD), 2012 Sea Level, Potrero Road Site, NMGWM2016 and simple expanded test model.

Figure A2.1

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