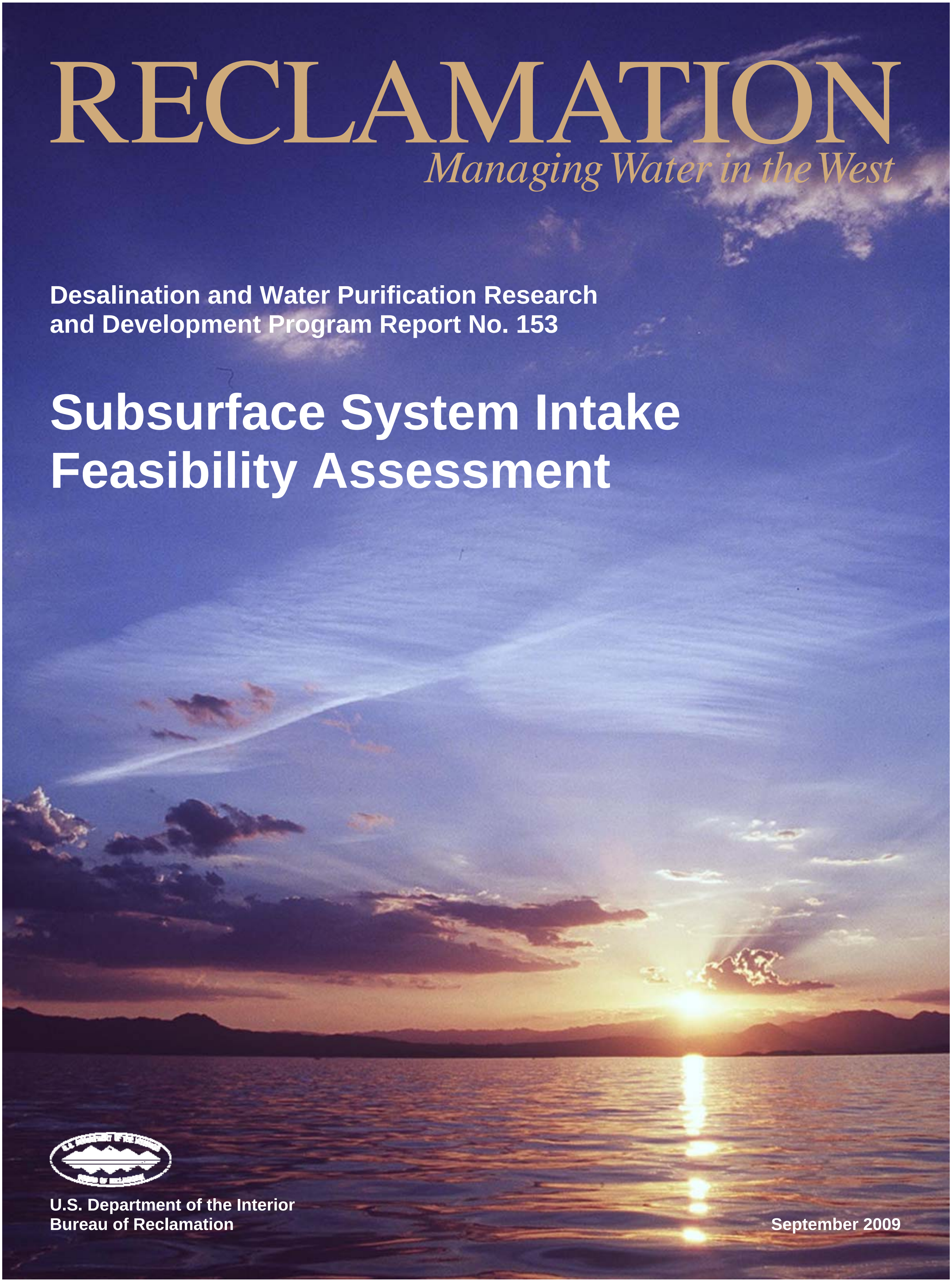

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and Development Program Report No. 153

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14. ABSTRACT ***(Maximum 200 words)***

Full-scale desalination plant operations for a 15-million-gallon-per-day (mgd) plant would require a total of seven operating slant wells and two backup slant wells of similar construction to provide 30 mgd of feed water supply. A variable density ground water model was developed to analyze the feasibility of using a system of slant wells for the 30-mgd feed water intake supply. The model was developed to provide an initial assessment of potential impacts to water quality, quantity, and ground water levels from the slant wells. The model found that 93 percent (%) of recharge to the 30-mgd slant well intake system will be derived from the ocean with only 7% occurring from the inland source. Additionally, impacts to water levels in the riparian zone due to pumping are similar under drier hydrologic conditions (maximum 36-foot drawdown) as under wet hydrologic conditions (maximum 39-foot drawdown).

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Subsurface System Intake Feasibility Assessment

Prepared for Reclamation Under Agreement No. 05-FC-81-1152

by

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GEOSCIENCE Support Services, Inc.

Municipal Water District of Orange County, California
San Francisco Public Utilities

U.S. Environmental Protection Agency

California Department of Water Resources

U.S. Department of the Interior
Bureau of Reclamation
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MISSION STATEMENTS

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Disclaimer

Acknowledgement

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GEOSCIENCE Support Services, Inc., under the overall project management of the firm's principal, Dr. Dennis E. Williams, was responsible for evaluating the slant well drilling technology and proposed slant well design and layout for the 30-million-gallon-per-day feedwater supply. GEOSCIENCE also developed the ground water flow and variable density solute transport model used to evaluate impacts of the project on ground water levels and quality.

Special appreciation goes to Project Manager Mr. Richard Bell, Mr. Kevin Hunt, Mr. Karl Seckel, and Ms. Michelle Tuchman from the Municipal Water District of Orange County, and to the Board of Directors of the Municipal Water District of Orange County for their stewardship and leadership in supporting this assessment.

Acronyms

acre-ft	acre-foot (feet)
acre-ft/yr	acre-foot per year
DEM	Digital elevation model
DWR	California Department of Water Resources
EPA	United States Environmental Protection Agency
ft	feet, foot
ft bgs	feet below ground surface
gpd/ft	gallons per day per foot, a unit of aquifer transmissivity
gpd/ft^2	gallons per day per square foot, a unit of aquifer hydraulic conductivity
gpm	gallons per minute
ID	inside diameter
HDD	horizontal directional drilling
mgd	million gallons per day
mg/L	milligrams per liter
OD	outside diameter
ORP	oxidation reduction potential
SDI	silt density index
SCWD	South Coast Water District
SJBA	San Juan Basin Authority
SOCWA	South Orange County Wastewater Authority
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
Reclamation	Bureau of Reclamation
USGS	United States Geological Survey
µg/L	micrograms per liter
%	percent

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1. Introduction

Municipal Water District of Orange County (MWDOC) is conducting a phased investigation into the feasibility of using subsurface intakes for feed water supply to a proposed desalination plant located at the mouth of San Juan Creek in Dana Point, California (see figure 1; all figures are presented at the end of this document). The investigation has been partially funded by the California Department of Water Resources (DWR) Proposition 50 Desalination Grant (2005) under Agreement No. 4600004110, entitled Horizontal/Slant Well Technology Application in Alluvial Marine Aquifers for Feedwater Supply and Pretreatment. Under Task 2 of the phased investigation, the dual rotary drilling method was used to successfully construct a Test Slant Well at the mouth of San Juan Creek. Full-scale desalination plant operations for a 15-million-gallon-per-day (mgd) plant would require a total of seven operating slant wells and two backup slant wells of similar construction to provide 30 mgd of feed water supply (see figure 2). Modeling full-scale system operations was undertaken as part of Task 4 of the DWR grant agreement. This report presents results of a variable density ground water model which was developed to analyze the feasibility of using a system of slant wells for the feed water intake supply. The model incorporates comments from a peer review panel of experts in the field of ground water modeling, as well as feedback received from the San Juan Basin Authority (see Appendix A for comment letters).[1] The variable density ground water model was developed in order to provide an initial assessment of potential impacts to water quality, quantity, and ground water levels from the slant wells.

Evaluation of the feasibility of using slant wells for desalination plant intake entailed modeling a 30-mgd ground water extraction scenario, including pumping under both wet and drier hydrologic conditions. The ground water model was calibrated using data obtained during the Test Slant Well pumping test, conducted during the spring of 2006 (during wet hydrologic conditions). The modeling scenarios discussed in this report are in the table on the following page.

The 30-mgd feedwater supply requirements simulated for the full-scale project consisted of a slant well field providing 30-mgd supply. The well field consists of seven production wells and two backup wells. The benefits of having two backup wells include operational reliability and the ability to cycle well production to minimize encrustation and clogging of well screens. With the backup wells, sufficient long-term capacity will be maintained for periodic rehabilitation. It is planned that the associated brine discharge from the desalination facility would be discharged to the ocean approximately 2 miles offshore through the nearby sewer outfall owned by South Orange County Wastewater Authority.

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[1] A draft modeling report was submitted for review on October 19, 2006.

Description of modeling scenarios

Model Run	Slant Well Configuration	Duration	Stress Period	Hydrologic Conditions	Project Extraction Quantity
1	Test well	3 years	Monthly	Above normal (wet)	2.88 mgd
2	7 wells	10 years	Annual	Above normal (wet)	30 mgd
2A	No project	10 years	Annual	Above normal (wet)	0 mgd
3	7 wells	1 year	Annual	Below normal (drier)	30 mgd

Slant well drilling technology provides an attractive option for seawater desalination plant intake supply because slant wells drilled at relatively low angles below horizontal (approximately 20 degrees) allow a longer length of well screen to be placed within the aquifer than is possible in either vertical wells or radial collector wells. Slant wells make it possible to pump offshore saline ground water from aquifers below the sea floor with most of the recharge to the wellfield (93 percent [%]) originating from the ocean. Because of limited ground water resources in the San Juan Ground Water Basin, it is critical that the amount of basin ground water drawn into the proposed plant intake system is minimized. Slant wells with screened sections located several hundred feet offshore will have a substantially higher production capability than either onshore vertical or radial collector wells. That is, aquifers located farther offshore and in hydraulic continuity with the ocean will supply a much higher percentage of recharge originating from the ocean than recharge originating from onshore sources.

1.1 Purpose and Scope

The purpose of the Task 3 investigation is to assess the feasibility of obtaining a desalination intake supply with a well field consisting of seven slant wells located at Doheny State Beach. The ground water modeling work was performed to determine the potential yield of a slant well intake system, to predict water quality variations with time, and to predict effects on ground water levels in the onshore ground water basin. Tasks in support of construction of a three-dimensional ground water flow and variable density solute transport model included:

- Review of background reports and data including past and current modeling work undertaken by the San Juan Basin Authority
- Mechanical grading analyses of Test Slant Well borehole materials to complement all previous Phase 1 testing (GEOSCIENCE, 2005)
- Generation of model input files

- Model calibration to test well pumping test data and monitoring well observations

- Preliminary design of slant well configurations, including preliminary technical drawings of well intake systems

- Consultation with the slant well drilling contractor on feasible well design

- Preliminary modeling of potential well configurations

- Preparation of a draft model report

- Review of expert peer review and other comments on the draft report

- Revision of model calibration and model runs, incorporating comments from experts in ground water modeling

- Preliminary cost estimate for well construction

- Preparation of the final Subsurface System Intake Feasibility Assessment Task 3 Report

1.2 Previous Work

Previous work for the Dana Point Ocean Desalination Project to date has included research on well design strategies and technology needed to adapt slant well drilling methods for the construction of near-shore intake wells for the Dana Point Ocean Desalination Project. Specifically, the work included:

- Evaluation of geohydrology in the vicinity of the proposed Dana Point desalination plant, including review of data on existing wells, borings,[2] geologic maps, cross sections, water levels, published reports, informal reports, and other relevant data. Field work included drilling and continuously coring four boreholes using the sonic drilling method and completing two of the boreholes as multilevel monitoring wells (DWR Task 1, GEOSCIENCE, 2005).

- Investigation of technology needed to drill and complete slant wells followed by the selection of the dual rotary drilling method. Field work included drilling, construction, development, and testing of a successful artificially filter-packed 350-foot (ft) 23-degree slant well tested at 1,660 gallon per minute (gpm) (DWR Task 2 and Reclamation Task 1, reported in GEOSCIENCE, 2006).

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[2] Table 1 summarizes available information for local wells and boreholes.

Table 1. Summary of well information near the mouth of San Juan Creek, Dana Point, Organge County, California

Well Name	Owner	Type	Well Status	Depth (ft bgs)	Screen (ft bgs)	Screen (ft bgs)	Date Constructed	Diameter (inches)	Source
B-2/MW-1	Municipal Water District of Orange County	Nested Monitoring Well	Monitoring	175	10	166	2005	2	GEOSCIENCE, 2005
B-4/MW-2	Municipal Water District of Orange County	Nested Monitoring Well	Monitoring	188	10	165	2005	2	GEOSCIENCE, 2005
SL-1	Municipal Water District of Orange County	Test Slant Well	Inactive	141	51	137	2006	12	GEOSCIENCE, 2006
B-3	Municipal Water District of Orange County	Borehole	None	181	None	None	2005	None	GEOSCIENCE, 2005
B-1	Municipal Water District of Orange County	Borehole	None	60	None	None	2005	None	GEOSCIENCE, 2005
CPBCWD Test Well	South Coast Water District	Future Desalter Well	Inactive	267	48	108	1992	18	Boyle, 1993
Victoria Well, 23A4?	Capistrano Beach County Water District	Municipal Well	Abandoned or Inactive	144	96	136	1956	12	Boyle, 1993, Geopentech, 2002
Price Club Well, 23A1?	Capistrano Beach County Water District	Municipal Well	Abandoned or Inactive	140	86	Unknown	Unknown	14	Boyle, 1993
8S/8W-14Q1	San Juan Water Company	Municipal Well	Abandoned or Inactive	120	50	120	1956	10	Geopentech, 2002
8S/8W-14Q2	San Juan Capistrano Water Co.	Municipal Well	Abandoned or Inactive	156	35	145	1956	14	Geopentech, 2002
8S/8W-14H	H.L. Remmers	Irrigation Well	Abandoned or Inactive	112	45	98	1951	16	Geopentech, 2002, Drillers Log
8S/8W-14H4	Kato Bros.	Irrigation Well	Abandoned or Inactive	Unknown	Unknown	Unknown	Unknown	Unknown	Geopentech, 2002
8S/8W-14H3	Norio Iwata	Irrigation Well	Abandoned or Inactive	132	96	116	1953	12	Geopentech, 2002, Drillers Log
8S/8W-23A7	San Juan Water Company	Municipal Well	Abandoned or Inactive	140	86	140	1959	14	Geopentech, 2002
8S/8W-23A5	A.T. & S.F. Railroad	Unknown	Abandoned or Inactive	123	Unknown	Unknown	1930	10	Geopentech, 2002
North Kinoshita Test Well	City of San Juan Capistrano	Test Hole	None	87	None	None	2004	None	Geotechnical Consultants, 2004
City Hall Test Well	City of San Juan Capistrano	Test Hole	None	117	None	None	2004	None	Geotechnical Consultants, 2004
8S/8W-12L3, SJBA #1	Mission Viejo Company	Industrial Well	Abandoned or Inactive	160	30	150	1978	16	Geopentech, 2002
8S/8W-12L1, SJBA #2	Mission Viejo Company	Irrigation Well	Abandoned or Inactive	150	60	140	1978	16	Geopentech, 2002
8S/8W-12L5	Kinoshita Farms	Irrigation Well	Abandoned or Inactive	114	48	98	1970	16	Geopentech, 2002
8S/8W-12C	Orange County Land Development Co.	Unknown	Abandoned or Inactive	158	105	150	1965	16	Drillers Log
8S/8W-12A1	T.R. Drummond	Irrigation Well	Abandoned or Inactive	80	58	75	1951	8	Drillers Log
8S/8W-12B2	E. Oyharzabal	Irrigation Well	Abandoned or Inactive	128	80	118	1955	12	Drillers Log
8S/8W-12L2	W.T. Honsberger	Domestic Well	Abandoned or Inactive	136	80	120	1955	12	Drillers Log
8S/8W-12P1	Buddy Forster	Irrigation Well	Abandoned or Inactive	118	80	112	1952	16	Drillers Log
8S/8W-12P5	George Caperon	Irrigation Well	Abandoned or Inactive	92	24	92	1965	12	Drillers Log
8S/8W-14A	Norio Iwata	Irrigation Well	Abandoned or Inactive	200	30	200	1955	12	Drillers Log
Tirador	City of San Juan Capistrano	Desalter Well	Active	104	75	100	2004	16	Drillers Log
Dancehall	City of San Juan Capistrano	Desalter Well	Active	108	75	105	2004	16	Drillers Log
Kinoshita	City of San Juan Capistrano	Desalter Well	Active	103	65	100	2004	16	Drillers Log
Mariner	City of San Juan Capistrano	Desalter Well	Inactive	80	52	65	2004	16	Drillers Log
South Alipaz	City of San Juan Capistrano	Test Hole	None	138	None	None	2004	None	Drillers Log
SJBA #4	City of San Juan Capistrano	Desalter Well	Active	131	85	128	2004	16	Drillers Log
SJBA #2	City of San Juan Capistrano	Desalter Well	Active	133	75	115	2004	16	Drillers Log
CVWD #1	City of San Juan Capistrano	Desalter Well	Active	164	90	161	2004	16	Drillers Log
MW-01S	San Juan Basin Authority	Monitoring Well	Monitoring	125	115	125	Unknown	4	Drillers Log
MW-02	San Juan Basin Authority	Monitoring Well	Monitoring	74	14	74	Unknown	4	Drillers Log
MW-03	San Juan Basin Authority	Monitoring Well	Monitoring	126	Unknown	Unknown	Unknown	18	Drillers Log
FUTURE WELLS (NOT YET CONSTRUCTED)									
Ramos St (Ricardo)	City of San Juan Capistrano	Desalter Well	City of San Juan Capistrano will use two of these four well sites as future desalter wells.						
MW07	City of San Juan Capistrano	Desalter Well							
North Cooks	City of San Juan Capistrano	Desalter Well							
South Cooks	City of San Juan Capistrano	Desalter Well							
New SCWD Well	South Coast Water District	Desalter Well	Location of the new SCWD well is approximate - it may be located on west side of San Juan Creek.						

- Evaluation of research and development needs for horizontal and angle well technology (DWR Task 3).

2. Slant Well Drilling Technology

The dual rotary drilling method was selected for construction of MWDOC's Test Slant Well at Dana Point[3] as it enabled the construction of a large-diameter, high-capacity, artificially filter-packed well within a cased borehole. In selecting this method, "risk avoidance" was a major consideration as, until this well was constructed and developed, no artificially filter-packed well with the length and capacity of the Dana Point Test Slant Well had been successfully completed beneath the ocean floor.

The dual rotary method was a proven method for constructing vertical wells and had been successfully used to construct a shallow-angle well (however, without an artificial filter pack) along the Missouri River for the Lewis and Clark Water District in South Dakota. Also, relatively short-length filter-packed shallow-angle wells have also been constructed parallel to the Hudson River in New York. The Dana Point Test Slant Well constructed by MWDOC between February and May 2006 represents the first time a high capacity artificially filter-packed well has been successfully completed beneath the ocean floor.

The dual rotary drilling method allowed the slant well to extend as far as possible beneath the ocean, with the least amount of risk. Traditional Ranney-type collector wells are limited in length to approximately 150 ft and require the construction of a very large diameter caisson, which would be expensive, take a long time to construct, and would be aesthetically infeasible for the beach environment. Horizontal directional drilling (HDD) was considered; however, the method has yet to be proven for constructing water wells (especially artificially filter-packed – not "prepacked"[4] water wells). HDD drilling contractors contacted in California and Texas would not guarantee borehole stability in the very loose and coarse (i.e., large gravel and cobbles) unconsolidated sediments encountered at Dana Point, nor would they guarantee satisfactory removal of the drilling mud from the borehole which is essential for well performance. Construction of a near-horizontal slant well near the shore allowed the screen section to be located closer to the seawater interface, increasing the likelihood of producing seawater while allowing placement of a longer length of screen within the aquifer. This also resulted in a higher production capacity due to the greater length of aquifer penetrated by the slant well.

---

[3] Field work for drilling, constructing, developing and testing of the 12¾-in outside diameter (OD) artificially filter-packed Test Slant Well (350-lineal-ft depth) took place from January 31 to May 18, 2006. The contractor was the Geo-Tech division of Boart Longyear, Tualatin, Oregon. The slant well produced 1,660 gpm continuously over a 5-day period.

[4] Prepacked wells were not considered due to potential for "clogging" and the inability to properly develop the "near-well zone."

Additionally, by constructing the shallow angle Test Slant Well, it was possible to obtain additional lithologic information regarding the seaward extent of the San Juan Creek alluvium.

3. Geology and Geohydrology

3.1 Regional Geology

San Juan Creek drains the western slopes of the Santa Ana Mountains, part of the Peninsular Range geomorphic province[5] of southern California which extends from the tip of Baja California to the Palos Verdes Peninsula and includes Santa Catalina Island. The Santa Ana Mountains descend to broad marine terraces that front the Pacific Ocean. The southwest-trending narrow alluvial valley of San Juan Creek divides the Santa Ana Mountains to the east and the San Joaquin Hills to the west (see figure 1).

The project area overlies the Capistrano Syncline, a geologic structure bounded on the north by the Santa Ana Mountains and extending about 10 miles in width from the San Joaquin Hills eastward to the northwest trending Cristianitos Fault (Drewry and Victor, 1995, Fischer et al., 1992). The Cristianitos Fault crosses San Juan Creek approximately 6.5 miles upstream of the creek mouth and is overlain by undisturbed terrace deposits, indicating that it has not experienced movement in recent time (Shlemon, 1987). The Capistrano Syncline developed in the late Neogene,[6] when a thick section of deep-basin sediments were deposited within the Capistrano embayment, including the submarine fans and channels of the Capistrano Formation (Fischer et al., 1992).

During the late Pliocene, regional uplift and erosion was followed by subsidence. During Pleistocene time (10,000 years to 1.8 million years ago), the region emerged from the sea, and wave-cut terraces were created as the sea receded. Elevation and erosion of the Santa Ana Mountains produced deposits of gravel and finer sediments (Edgington, 1974). At the end of the last ice age (18,000 years ago), the sea level off Dana Point was at an approximate elevation of 400 feet below mean sea level. Since that time and until approximately 6,000 years ago, the sea advanced landward (Converse Davis Dixon Associates, 1977). In the vicinity of Dana Point today, the shelf break (edge of the continental shelf) lies approximately 5 miles off the coast (Fischer et al., 1992).

3.2 Stratigraphy

The proposed slant well intake system would be located on the beach sands which overlie alluvial sediments at the mouth of San Juan Creek. Figure 3 shows the surficial geology in the model area. Based on drilling and testing results from the

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[5] The Peninsular Range province consists of uplifted and westward-tilting granitic fault block ranges (California Division of Mines, 1954).

[6] The period between 14 and 2.4 million years ago.

Phase 1 borehole investigation (GEOSCIENCE, 2005), it is known that the alluvium associated with San Juan Creek reaches a depth greater than 188 ft at the coastline. In the vicinity of the proposed slant well field, the bedrock underlying the alluvium consists primarily of nonwater-bearing marine siltstone and shale of the Capistrano Formation. In the Dana Point quadrangle, bedrock consists of, from youngest to oldest: Niguel Formation, Capistrano Formation, Monterey Formation, San Onofre Breccia, and Topanga Formation (see figure 4). The sedimentary bedrock formations are generally not considered to have significant water-bearing potential, although they may contain sands that yield small amounts of water to wells (DWR, 1972). There is evidence that offshore outcrops of San Onofre breccia and/or Capistrano Formation exist southwest of Doheny State Beach (see figures 5 and 6; Lowry and Associates, 1977).

3.3 Ground Water Basin

The proposed desalination intakes are located at the southern boundary of the San Juan Ground Water Basin (see figure 1). The San Juan Basin is bounded on the southwest by the Pacific Ocean, and elsewhere by Tertiary semipermeable marine deposits (DWR, 2004) and has a tributary area of approximately 26 square miles (16,700 acres, DWR, 2004). Ground water flows southwest, towards the Pacific Ocean. Appropriation of subsurface water from the alluvium of San Juan Creek is subject to the jurisdiction of the State Water Resources Control Board (SWRCB), as the agency classifies the San Juan Basin as a subterranean stream flowing through known and definite channels (SWRCB, 1989).

The total storage capacity of San Juan Basin has been calculated to be 90,000 acre-feet (acre-ft) (DWR, 1972) and 63,220 acre-ft (NBS Lowry, 1992). The maximum perennial yield of the basin has been estimated to be approximately 4,000 acre-feet per year (acre-ft/yr) (NBS Lowry, 1992). Recharge of the basin is from percolation of stream flow in San Juan Creek, Oso Creek, and Arroyo Trabuco, as well as from precipitation to the valley floor and from springs originating in Hot Spring Canyon and flowing into San Juan Creek (DWR, 1972). Average annual subsurface outflow to the ocean has been estimated to be 450 acre-ft/yr (DWR, 1972). In recent unpublished modeling work, Psomas estimated annual subsurface outflow to be 800 to 1,300 acre-ft/yr (Psomas, 2005). Ground water modeling in this report estimates a subsurface outflow of approximately 850 acre-ft/year.

3.4 Aquifers

The alluvial portions of San Juan Creek contain the primary aquifers in the area, and are for the most part composed of interbedded cobbles, gravel, sand, silt, and clay overlying sedimentary basement rocks. The San Juan Creek alluvium ranges in thickness from 65 to 200 ft (DWR, 1972; Edgington, 1974).

In the vicinity of Doheny State Beach, the Phase 1 Hydrogeology Investigation (GEOSCIENCE, 2005) identified shallow, middle, and deep aquifer zones based on the lithology encountered in the three boreholes drilled west of San Juan Creek (see figure 5). Borehole B-1 was drilled approximately 1,400 ft east of the current San Juan Creek channel and is presumed to be outside the extent of the alluvial aquifers associated with the creek. In this borehole, beach sands were encountered at a depth of 20 feet below ground surface (ft bgs), below which was 40 ft of clay representing Capistrano Formation bedrock. Bedrock may also have been encountered in borehole B-3, located approximately 850 ft west of the creek, at a depth of approximately 155 ft bgs. Borehole B-3 contained interbedded clayey sand and sand with clay from 155 ft bgs to the total borehole depth of 181 ft bgs. The dark greenish-gray color, moderate cementation, and presence of mica suggest that these materials may represent the Capistrano Formation. In the two boreholes drilled immediately west of San Juan Creek (B-2/MW-1 and B-4/MW-2), lithology becomes finer-grained and moderately cemented at depths greater than 158 ft bgs and 166 ft bgs, respectively. However, these boreholes were terminated in dark gray fine- to coarse-grained sand at depths of 175 ft and 188 ft and are not considered to have penetrated bedrock.

It is unknown how far offshore the San Juan Creek alluvium extends, although it likely extends a considerable distance beneath the ocean floor and is in hydraulic continuity with seawater. The shallow jet probe and vibracore investigation (maximum depth 32 ft) conducted offshore in the 1970s (see figures 5 and 6) followed the alignment of the SOCWA sewer outfall for a distance of approximately 1.5 miles encountering cobbles, gravel, silty sand, and clay layers and did not penetrate bedrock. Additionally, the Test Slant Well did not encounter bedrock within its maximum vertical depth of 137 ft (terminating 170 ft horizontally offshore from Thor's Hammer[7]). For comparison, the continental shelf near Doheny State Beach extends approximately 5 miles offshore.

3.4.1 Shallow Zone Aquifer

The shallow aquifer zone is located above a fine-grained zone (clay and clayey sand) that was encountered at depths of approximately 25 ft to 40 ft bgs in the three boreholes drilled west of San Juan Creek (B-2/MW-1, B-3, B-4/MW-2). The clay layers in this zone are approximately 4 to 5 ft thick and associated with layers of clayey sand approximately 3.5 to 5 ft thick. The lithologic sample data show the clayey zones appear thicker near the San Juan Creek channel and appear to thin away from the channel. Monitoring wells MW-1S[8] and MW-2S are screened in this aquifer zone, approximately 10 to 25 ft bgs. Based on ground water level fluctuations and response to the test well pumping, the layer does not

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[7] Thor's Hammer is the colloquial name for the concrete structure at the terminus of the groin along the western bank of San Juan Creek and approximately coincides with the shoreline.

[8] In reference to the nested monitoring wells MW-1 and MW-2, "S" denotes the well is screened in the shallow aquifer zone, while "M" denotes the middle zone and "D" denotes the deep zone.

appear to be an extensive aquiclude (i.e., confining layer) but may be a localized aquitard (i.e., leaky layer). Further long-term pumping tests are needed to verify this observation.

Ground water elevations in the shallow zone measured using pressure transducers indicated that the water levels in this zone are weakly affected by the tide, fluctuating by less than 1 ft and coincident with tidal fluctuations, which vary as much as 8 ft in a tidal cycle. Water level data also shows that the shallow aquifer is in hydraulic continuity with the nearby San Juan Creek, as indicated by ground water levels gradually building in the shallow zone when the berm across the mouth of San Juan Creek closes forming a lagoon, and falling rapidly when the berm is broken allowing the creek to drain to the Pacific Ocean.

3.4.2 Middle Zone Aquifer

The middle aquifer zone is located at approximately 40 to 130 ft bgs and is characterized by mostly medium- to coarse-grained sand and cobbles and is monitored by wells MW-1M and MW-2M. Some interbedded finer-grained materials (clayey gravel and sand with clay and gravel) were encountered during drilling of boreholes B-2/MW-1 and B-4/MW-2 at a depth of approximately 140 ft.

Water levels in MW-1M and MW-2M are affected by tidal pressure, fluctuating by as much as 3 ft in a tidal cycle. The location of the well screen in the Test Slant Well (approximately 51 to 137 vertical ft bgs) generally corresponds to the location of the Middle Zone aquifer.

3.4.3 Deep Zone Aquifer

The deep aquifer zone refers to the sand and gravel materials underlying the finer grained materials located at approximately 140 ft bgs in boreholes B-2/MW-1 and B-4/MW-2. Monitoring wells MW-1D and MW-2D are screened in this zone at approximately 140 to 165 ft bgs. There is a greater amount of fine-grained materials in the deep zone aquifer than the middle zone aquifer. Additionally, several lithologic samples from these depths in boreholes B-2/MW-1 and B-3 were characterized by a slight hydrogen sulfide odor.

3.5 Water Quality

Both the Phase 1 Hydrogeology Investigation and the Phase 2 Test Slant Well encountered brackish ground water at the mouth of San Juan Creek. Water quality information obtained included laboratory water quality analyses, field testing for silt density index, field monitoring of test slant well water quality parameters, and continuous monitoring of monitoring well ground water quality using Troll 9000 multiparameter instruments made by In-Situ. The results of water quality analyses conducted during the Test Slant Well aquifer pumping tests are discussed below.

3.5.1 Laboratory Water Quality Analyses

During the Phase 1 Hydrogeology Investigation water quality samples were collected from nested monitoring wells MW-1 and MW-2. Additional samples from monitoring wells MW-1M, MW-1D, MW-2M, and MW-2D were collected in March and October 2005 and were analyzed for a list of constituents important for desalination feedwater supply considerations. Samples from MW-1S and MW-2S (shallow zone) were analyzed only for bacteriological parameters. Samples from Test Slant Well SL-1 were collected for water quality analyses at the end of 5-day and 48-hour constant rate pumping tests.

Both the middle and deep zones in both monitoring wells MW-1 and MW-2 showed brackish water quality, with total dissolved solids (TDS) ranging from 2,000 to 2,700 milligrams per liter (mg/L). The deep zone in each well showed a slightly higher TDS than the middle zone, and the water from each zone became slightly fresher in the time period from March 2005 to October 2005 (the two sampling events). The Test Slant Well also showed brackish water quality, with a TDS of 2,600 mg/L after 5 days of pumping at a discharge rate of 1,660 gpm. Plotting the data from the monitoring wells and Test Slant Well on a trilinear diagram shows the water type to be the same, and different from seawater, reflecting recharge from the nearby San Juan Creek channel (see figure 7).

Ground water collected from monitoring wells MW-1, MW-2 and the Test Slant Well contained a high concentration of dissolved iron and dissolved manganese, with dissolved iron ranging from 1,180 to 3,800 micrograms per liter (µg/L), and dissolved manganese ranging from 1,200 to 2,100 µg/L.

3.5.2 Field Measurement of Water Quality Parameters During the Test Slant Well Pumping Test

The TDS concentration measured in the Test Slant Well during the 5-day pumping test increased slightly with time, by a rate of approximately 60 mg/L per day (GEOSCIENCE, 2005). The water quality was consistently brackish (approximately 2,500 mg/L TDS), dissolved oxygen was generally less than 0.5 mg/L, pH was approximately 7, turbidity was generally less than 1 nephelometric turbidity unit, silt density index averaged 0.58, and oxidation reduction potential (ORP) was negative.

3.5.3 Continuous Water Quality Measurements in MW-1S and MW-1M

Multiparameter instruments equipped to monitor conductivity, ORP, and pH at 15-minute intervals were placed within monitoring wells MW-1S and MW-1M in

October 2005 through May 2006. The trend in the conductivity data shows stable concentrations in the middle zone and variable concentration in the shallow zone. The variability in the shallow zone is likely due to hydraulic continuity between the shallow zone and recharge from nearby San Juan Creek. When a sand berm forms across the mouth of the creek (separating the creek from the ocean), seawater entering the lower portion of the creek during high tide events is prevented from flowing back to the ocean. During these events, highly saline water significantly impacts the water quality (as well as water levels) in the shallow aquifer zone, resulting in clearly increased measurements. By comparison, specific conductivities measured in MW-1M remained relatively constant during these events, showing that the creek does not immediately influence water quality in the middle aquifer zone but would eventually interact with deeper zones through vertical leakage.

3.5.4 Water Quality Measured in Nearby Wells

The San Juan Basin Authority (SJBA) monitors ground water quality in three monitoring wells located within the model area (MW-01S, MW-02, and MW-03). As part of their integrated environmental monitoring program, SJBA evaluates potential changes resulting from implementation of the San Juan Basin Groundwater Management and Facility Plan, including Phase I desalter operations (see figure 5). Monitoring during 2004 to 2005 indicated brackish ground water quality. TDS ranged from 470 to 1,900 mg/L at MW-01S, from 1,800 to 1,900 mg/L at MW-02, and from 940 to 1,700 mg/L at MW-03. The three monitoring wells also exhibited relatively high iron and manganese concentrations (Psomas, 2006). The Test Well constructed by Capistrano Beach County Water District in 1992 (see figure 5) also exhibited brackish water quality (2,198 mg/L) and high iron (5.13 mg/L) and manganese (0.93 mg/L) concentrations (Boyle, 1993). Water quality samples collected from former production wells in the model area during 1988 to 2001 are characterized by TDS concentrations ranging from 1,100 to 1,800 mg/L (Geotechnical Consultants, Inc., 2001).

3.6 Aquifer Parameters

To verify aquifer parameters in the project area initially determined from the Phase 1 test borings, a 5-day pumping test was conducted in the Test Slant Well (SL-1) from March 31 to April 5, 2006, at a constant discharge rate of 1,660 gpm. Ground water levels were measured in the pumping well (SL-1) and observation wells (MW-1M and MW-2M) using pressure transducers. A summary of the aquifer parameters calculated from data obtained during the 5-day constant rate pumping test is shown on the following table.

During the Phase 1 Hydrogeology Investigation, estimates of hydraulic conductivity were obtained from borehole lithologic samples using grain-size

Summary of aquifer parameters obtained from 5-day test slant well (SL-1) pumping test

Analytical Method	Transmissivity (gpd/ft)[1]	Storativity (fraction)	Leakance (1/days)
SL-1 Time Drawdown	122,000	NA	NA
SL-1 Calculated Recovery	169,000	NA	NA
MW-1M Time Drawdown (Jacob's Method)	91,300	0.0014	NA
MW-1M Time Drawdown (Hantush Inflection Point Method)	76,400	0.0017	0.005
MW-2M Time Drawdown (Jacob's Method)	115,000	0.0010	NA
MW-2M Time Drawdown (Hantush Inflection Point Method)	93,000	0.0012	0.003
SL-1, MW-1M and MW-2M Distance Drawdown	146,000	0.0040	NA
Average	116,000	0.0019	0.004

[1] gpd/ft = gallons per day per foot.

analyses and the Hazen approximation as well as a laboratory permeameter. The mean horizontal hydraulic conductivity estimated using the Hazen approximation and the permeameter was 1,200 gallons per day per square foot (gpd/ft^2), a unit of aquifer hydraulic conductivity gpd/ft^2. The mean vertical hydraulic conductivity was determined to be approximately 150 gpd/ft^2 (GEOSCIENCE, 2005).

As part of the Task 3 scope, additional sieve analyses were performed on lithologic samples from the screened interval of SL-1. Grain sizes of borehole materials ranged from very fine sand to very coarse gravels. Cobbles were also present in some samples but limited in size by the diameter of the 4-inch core. Mean grain size diameter of the samples ranged from medium sand to coarse gravel (see figure 8). Hydraulic conductivities representative of medium to coarse sands and coarse gravels are shown in the following reference table:

Representative values of hydraulic conductivity

Material	Hydraulic Conductivity (pd/ft^2)
Coarse gravel	3,681
Medium gravel	6,626
Fine gravel	11,044
Coarse sand	1,104
Medium sand	295

Source: Todd and Mays, 2005.

Values of aquifer hydraulic conductivities at Doheny State Beach are within the range between coarse sand and fine gravel reported in the above table.

4. Proposed Slant Well Design and Layout

4.1 Slant Well Designs

The 30-mgd project feedwater supply wells will be constructed using a dual rotary drilling rig capable of drilling at a 20-degree angle below horizontal. An optimum configuration of seven supply wells was modeled, consisting of three groups of two to three wells each, extending radially outward from a common entry location (see figure 2). The minimum amount of space that would be required between the entry points for each group, or array, of slant wells is approximately 5 feet. The wells will be designed to be completed (screened) within the middle and deep aquifer zones (i.e., from 40 to 165 vertical ft bgs). The slant well arrays are conceptualized as straight wells drilled at a 20-degree angle below horizontal and to a total lineal length of 500 lineal ft. The total vertical depth at maximum well length would be 171 vertical (see figure 2).

Well materials will consist of either Type 904 or AL-6XN® stainless steel[9] to minimize corrosion from constant exposure to seawater. Preliminary design of the well screen consists of 12¾-inch OD by 5/16-inch wall thickness Ful-Flo louvered well screen, with 3/32-inch (0.094-inch) slot openings. The screened intervals will be placed from approximately 200 to 500 lineal ft bgs.[10] A larger pump-house casing consisting of a 16-inch inside diameter (ID) with 5/16-inch wall thickness (16⅝-inch OD) Type 904 or AL-6XN® stainless steel materials will be installed in the upper portion of the well to house the permanent pump. The lower portion of the pump house casing would contain a reducing section to allow joining to the 12¾-inch OD well screen section. The inside diameter of the Ful-Flo screen will be 12⅛ inches, which results in acceptable head losses when discharge rates are approximately 3,000 gpm.

Following installation of the casing and screen, a custom-graded artificial filter pack will be pumped under pressure into the annular space between the well screen and temporary casing. This will stabilize fine-grained formation materials in the near-well zone. The filter pack material will consist of well-rounded particles with high silica content and would be made up of a blend of approximately 4 x 16[11] aggregate.

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[9] This type of steel has been used in seawater desalination facilities such as in Tampa Bay as it is proven to be corrosion resistant to seawater.

[10] The length of blank section (pump house casing) may vary somewhat in the final design, depending upon results from extended test well pumping and final well locations.

[11] U.S. Standard Sieve Numbers

Once each slant well has been constructed, it will be developed to remove fine-grained materials from both the filter pack and near-well zone. Each slant well will be initially developed using a combination of airlifting and swabbing. This will help consolidate the filter pack and remove fine-grained materials from the filter pack and near-well zone.

Final development of the wells will consist of installing submersible test pumps and pumping at increasing discharge rates, as determined both by the sand content and specific capacities. The wells will be developed at a greater rate than the design capacity of 3,000 gpm.[12] Once each well is fully developed, aquifer pumping tests will be performed, and water quality samples collected.

Permanent submersible pumps will be placed in each well which are capable of operating at the 20-degree slant well angle. Centralizers consisting of an inert but abrasion-resistant material will be fabricated to support and center the pump column and bowl assembly within the casing. In the draft Task 3 report, a centralized collector system was evaluated. In this method, each slant well was connected to a central vertical “caisson” or vault which acted as a common pumping chamber. In this manner, a standard vertical turbine line-shaft pump could be used to draw water from the entire group of wells at one time (see figure 9). However, based on costs and reliability risk factors, it was determined that an individual well/pump system was the more feasible design.

4.2 Selection of Optimum Slant Well Field Layout

Three sites containing clusters of two to three wells each are proposed to model the full-scale desalination intake system (see figures 2 and 10). The seven wells are designed to produce a 30-mgd total intake supply (2,976 gpm each). The optimum seven-well layout which minimizes interference was based on several “trial and error” configuration runs.

The slant wells will be completed (i.e., screened) within the middle and deep aquifer zones and are located near an existing ocean sewer outfall, which will be used to dispose of brine following the desalination process.

An option which was considered was constructing slant wells spaced across the beach perpendicular to the shoreline. However, this layout was rejected as it required establishing multiple construction and staging areas, which proved infeasible considering the Doheny State Beach environment. By constructing the slant wells in clusters of up to three wells, the number of construction and staging areas minimizes impacts to the beach environment.

The project also includes two backup wells to ensure production reliability and maintenance flexibility.

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[12] Typically, wells are developed at a rate of 1½ times the design discharge rate.

5. Ground Water Flow and Variable Density Solute Transport Model

5.1 Purpose of the Model

To facilitate future planning and evaluate potential impacts on ground water levels and quality from the proposed project, a ground water flow and variable density solute transport model was developed. Specifically, the SEAWAT ground water flow and variable density solute transport model was used. The model was developed to assess the layout and sustainable yield of the 30-mgd slant well intake system and project impacts on aquifers in the lower San Juan Basin area.

5.2 Description of Model Code

The SEAWAT ground water model used for simulating the subsurface intake system was developed by the United States Geologic Survey (USGS) (Guo and Langevin, 2002) to simulate three-dimensional, variable-density, ground water flow and solute transport in porous media. The source code for SEAWAT was developed by combining MODFLOW[13] and MT3DMS[14] into a single program that solves the coupled flow and solute transport equations.

SEAWAT modifies the MODFLOW code to solve the variable density flow equation by reformulating the matrix equations in terms of fluid mass rather than fluid volume and by including the appropriate density terms. Fluid density is assumed to be solely a function of the concentration of dissolved constituents; the effects of temperature on fluid density are not considered.

The SEAWAT code follows a modular structure, so new capabilities can be added with only minor modifications to the source code. The following modules or packages were used in the model:

- Basic (BAS6, Harbaugh, et al., 2000)
- Layer-Property Flow (LFP6, Harbaugh, et al., 2000)
- Preconditioned Conjugate-gradient Method (PCG2, Harbaugh, et al., 2000)

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[13] MODFLOW is a block-centered, three-dimensional, finite difference groundwater flow model developed by the USGS to model groundwater flow.

[14] MT3DMS is a modular three-dimensional multispecies transport model for simulating advection, dispersion, and chemical reactions of contaminants in ground water systems (Zheng and Wang, 1998).

- Well (WEL6, Harbaugh, et al., 2000)
- River (RIV6, Harbaugh, et al., 2000)
- Basic Transport (BTN5, Zheng and Wang, 2005)
- Advection (ADV5, Zheng and Wang, 2005)
- Dispersion (DSP5, Zheng and Wang, 2005)
- Source/Sink Mixing (SSM5, Zheng and Wang, 2005)
- Generalized Conjugate Gradient Solver (GCG5, Zheng and Wang, 2005)
- Flow Model Interface (FMI5, Zheng and Wang, 2005)

5.3 Conceptual Model

The ground water model for the full-scale intake system was developed for the unconsolidated to semiconsolidated alluvial sediments related to San Juan Creek. The base of the model is represented by the underlying bedrock, comprised of the marine Capistrano Formation. The bedrock surface was developed in a geographic information system (GIS), based on review of geologic logs in published reports and drillers logs for local wells available from Psomas (consultant to San Juan Basin Authority) (see figure 11).

The ground water model consists of 11 model layers. Layer 1 is only active beneath the ocean and is assumed to be 1 ft thick.[15] Layer 2 was assigned 30 ft of thickness and incorporates the shallow aquifer zone identified in the Phase 1 beach monitoring wells and Phase 2 Test Slant Well. Layers 3 through 11 are each 20 ft thick. The layer thickness was chosen mainly to discretize the aquifer system and is not based on lithology (see figure 12). Model layers are assumed to be parallel to the ground surface and are bounded on the lowermost layer by the generalized bedrock surface.

5.4 Model Grid and Boundary Conditions

The 11-layer ground water flow model grid covers an area of approximately 8 square miles with a finite-difference grid consisting of 268 rows in the north to south direction and 423 columns in the west to east direction for a total of 1,247,004 cells. The smallest model cells are in the area of interest (i.e., the slant

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[15] The sole purpose of model layer 1 is to allow vertical leakage from the ocean into underlying aquifers.

well sites) and measure 10 ft by 10 ft. Model cells vary towards the edges of the model. See figure 13 for the location and layout of the model grid.

The boundary conditions used in the model are no-flow (constant flux-Neumann) and constant head (Dirichlet) boundaries. No-flow cells were assigned to the nonalluvial or bedrock portions of the model area. The no-flow cells in model layers 1 through 11 are shown in figure 14.

Two constant head boundaries were used—one at the northern boundary of the model and the other in the Pacific Ocean to the south. The northern constant head boundary consists of a ground water elevation of 43 ft NAVD88 and a TDS of 1,300 mg/L. These conditions are based on the static ground water elevation at MW-03 in March 2006 prior to the 5-day Test Slant Well pumping test (see figure 15). The southern constant head boundary extends from the shoreline to the southern end of model. The southern constant head boundary at the ocean was specified only in model layer 1 between the shoreline and the southern model boundary to allow vertical leakage from the ocean into the uppermost aquifer (model layer 2). This boundary condition consists of a ground water elevation of 2.54 ft NAVD88 (equivalent to zero ft above mean sea level).

Similarly, a constant concentration boundary (as measured in MW-03 during 2004-2005 (Psomas, 2005) was used in the northern model area. A constant TDS concentration of 35,000 mg/L was assigned to the southern constant head boundary at the ocean.

5.5 Aquifer Parameters

5.5.1 Top and Bottom Elevations of Model Layers

Land surface elevations, as determined from the standard 10-m resolution USGS DEM, were used as the top elevation of the uppermost aquifer layer (model layer 2).[16] The bottom elevation of the model was considered to be the top of the Capistrano Formation as determined from geologic logs in published reports and unpublished drillers logs provided by Psomas in 2006. Generalized bedrock contours for the model area are presented in figure 11. Cross sections across the alluvial channel and along the axis of the channel are presented in figures 16 to 18, and figure 12, respectively.

5.5.2 Hydraulic Conductivity

Initial horizontal hydraulic conductivity values were estimated based on the 5-day pumping test conducted in the Test Slant Well. For the area without pumping test data, initial horizontal hydraulic conductivity values were estimated based on lithology from wells and boreholes. During model calibration, the horizontal

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[16] Model layer 1 is a 1-ft-thick aquitard layer active only beneath the ocean to allow vertical leakage from the ocean to underlying aquifers.

hydraulic conductivity values were adjusted so that the water level residuals (observed ground water elevation minus model-generated ground water elevation) were minimized. The final calibrated horizontal hydraulic conductivity values are shown in figure 19. In the Test Slant Well area, the horizontal hydraulic conductivity values range from approximately 15 feet per day (ft/day) (112 gpd/ft^2) for model layer 2 to 180 ft/day (1,346 gpd/ft^2) for model layers 3 through 11. The values for model layer 2 are consistent with the finer grained materials encountered in the Test Slant Well area during the Phase 1 Hydrogeology Investigation. The values for layers 3 through 11 are consistent with the hydraulic conductivity values estimated from analysis of the 5-day pumping test data.

Vertical hydraulic conductivity values were also estimated from pumping test data initially and adjusted during model calibration. A vertical hydraulic conductivity value of 0.05 ft/day (0.37 gpd/ft^2) to 1.2 ft/day (9.0 gpd/ft^2) was used based on final model calibration results.

5.5.3 Storativity and Effective Porosity

An unconfined storage value (i.e., specific yield or effective porosity) of 0.15 was assigned for model layer 2 based on the character of aquifer materials encountered. A uniform storativity value was used for model layers 3 through 11. This value was initially estimated based on the pumping test data and adjusted during model calibration. Based on model calibration results, a storativity value of 0.000335 was used.

5.5.4 Dispersivity

Longitudinal dispersivity was estimated initially from the relationship between longitudinal dispersivity and scale of observation (Zheng and Bennett, 2002) and adjusted during model calibration. A longitudinal dispersivity of 40 ft results in a good match between model-calculated and measured TDS concentrations. The ratio of horizontal transverse dispersivity to longitudinal dispersivity was assumed to be 0.1, while the ratio of vertical transverse dispersivity to longitudinal dispersivity was assumed to be 0.01.

5.5.5 Low Permeability Shallow Zone

The lower permeability materials encountered between approximately 25 and 40 ft bgs in the Phase 1 test boreholes and Test Slant Well are believed to be incised and not continuous throughout the model area. Figure 19 depicts the estimated areal extent of the lower permeability zone used in the modeling.

Vertical hydraulic gradients exist under both nonpumping and pumping conditions. Rising water (see figure 19) is due to vertical migration from the shallow layer to the San Juan Creek channel. Recharge to the slant well field under pumping conditions is due to vertical migration of ocean water downward into the aquifer.

5.6 Recharge and Discharge

5.6.1 Rising Water and the River Package

The ground water model River package was used to simulate the interaction between the San Juan Creek and aquifers in the model area. Based on steady state and transient model calibration, a vertical hydraulic conductivity of 0.1 ft/day was used for the streambed layer, and the creek stage was assumed to be 1 foot above the bottom elevation of the streambed. Steady state model calibration yields a rising water of approximately 670 acre-ft/yr in the reach depicted in figure 19. Total river percolation to ground water in the entire model area is 1,700 acre-fr/yr.

DWR (1972) states that rising water occurs in “the last 1 to 2 miles of San Juan Creek nearest the coastline.” A portion of San Juan Creek approximately 6,000 ft long, beginning approximately 1,700 ft from the coastline, has been identified from model calibration as an area where initial (spring 2006) ground water elevations exceed land surface elevation (see figure 19). DWR estimated the annual amount of rising water at the coastline for the base period (1951-52 through 1967-68) as the minimum estimated surface outflow for that period (approximately 1,700 acre-ft/yr). DWR then divided that estimate by 0.92 to obtain an estimate of 1,900 acre-ft/yr for long-term conditions (historical period 1883-84 through 1965-66). Present model calibration (this report) shows less than 1,900 acre-ft/year of rising water at the present time (see table 2).

5.6.2 Ground Water Pumping – Well Package

Ground water pumping was simulated using the Well package. There are four existing pumping wells in the model area owned by the city of San Juan Capistrano (see figure 5).[17] The South Coast Water District is planning to produce ground water from two wells in the future, using one existing and one new well. South Coast Water District (SCWD) has not yet sited the new well, and its location in figure 5 is preliminary. The following table summarizes the annual production rate for these wells.

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[17] The San Juan Basin Authority has an appropriative right of 10,702 acre-ft/yr of ground water with the San Juan Basin; and the city of San Juan Capistrano has an additional water right of 3,325 acre-ft/yr under application at the State Water Resources Control Board. The city of San Juan Capistrano desalter wells within the model boundary use a fraction of the total San Juan Basin Authority/city of San Juan Capistrano water rights. The South Coast Water District has an appropriative right to 1,300 acre-ft/yr and would like to expand their use to approximately 2,000 acre-ft/yr using San Juan Basin rights.

Table 2. Summary of water budget for each model run

		Inflow Terms[1]			Outflow Terms[1]				
Model Run	**Year**	**Northern Model Boundary (Underflow)** (acre-ft/yr)	**San Juan Creek Recharge** (acre-ft/yr)	**Ocean Inflow** (acre-ft/yr)	**Ocean Outflow** (acre-ft/yr)	**Rising Water in San Juan Creek** (acre-ft/yr)	**Well Production (Other Wells)[2]** (acre-ft/yr)	**Slant Well Field Production** (acre-ft/yr)	**Change in Ground Water Storage** (acre-ft/yr)]
Steady State	NA	4,322	1,707	0	854	667	4,517	0	NA
1	1	4,716	2,367	2,011	0	186	6,453	3,226	-771
	2	4,813	2,589	2,222	0	84	6,453	3,226	-139
	3	4,829	2,610	2,251	0	73	6,453	3,226	-62
2	1	4,878	2,952	29,453	0	53	6,453	33,606	-2,829
	2	5,292	3,038	30,825	0	0	6,453	33,606	-904
	3	5,514	3,038	31,083	0	0	6,453	33,606	-423
	4	5,596	3,038	31,168	0	0	6,453	33,606	-257
	5	5,624	3,038	31,197	0	0	6,453	33,606	-200
	6	5,633	3,038	31,206	0	0	6,453	33,606	-182
	7	5,636	3,038	31,209	0	0	6,453	33,606	-176
	8	5,637	3,038	31,210	0	0	6,453	33,606	-173
	9	5,638	3,038	31,210	0	0	6,453	33,606	-173
	10	5,638	3,038	31,210	0	0	6,453	33,606	-173
2A	1	4,719	2,230	0	783	190	6,453	0	-477
	2	4,765	2,337	0	752	144	6,453	0	-248
	3	4,765	2,337	0	752	144	6,453	0	-247
	4	4,765	2,337	0	752	144	6,453	0	-247
	5	4,765	2,337	0	752	144	6,453	0	-247
	6	4,770	2,344	0	746	141	6,453	0	-226
	7	4,770	2,344	0	746	141	6,453	0	-226
	8	4,770	2,344	0	746	141	6,453	0	-226
	9	4,770	2,344	0	746	141	6,453	0	-226
	10	4,770	2,344	0	746	141	6,453	0	-226
3	1	3,366	2,991	30,869	0	36	6,453	33,606	-2,869

[1] Average annual inflow and outflow.

[2] During the steady state calibration, four city of San Juan Capistrano desalter wells are pumping, including Kinoshita, SJBA #4, SJBA #2, and CVWD #1 (total of 4,517 acre-ft/yr). During Model Runs 1, 2, 2A, and 3, these wells and an additional two South Coast Water District desalter wells (pumping 1,936 acre-ft/yr) are pumping, for a total of 6,453 acre-ft/yr.

Ground water pumping from the existing wells was included in the steady state and transient model calibration runs. Ground water pumping from the existing and proposed wells were used for the model operational runs 1 through 3.

Summary of production wells within the model area

Well	Owner	Status	Annual Production (acre-ft/yr)
Capitrano Valley Water District #1	San Juan Capistrano	Existing	1,210
SJBA #2	San Juan Capistrano	Existing	1,210
SJBA #4	San Juan Capistrano	Existing	1,290
Kinoshita	San Juan Capistrano	Existing	807
New Well 1	SCWD	Proposed	968
Capitrano Beach County Water District Test Well	SCWD	Proposed	968

5.7 Model Calibration

5.7.1 Calibration Methodology

Model calibration is performed to compare model-simulated water levels and TDS concentrations to field-measured values (Anderson and Woesnsner, 1992). The method of calibration used by the ground water model was the industry standard "history matching" technique. In this method, a steady state calibration of March 2006 and a transient calibration period from March 31, 2006, to April 5, 2006, were chosen.[18]

To assist in the trial-and-error adjustment of parameters, the software package Visual Parameter ESTimation (PEST) (Doherty, 2000) was used to aid in the calibration of both the steady-state and transient ground water models. PEST was used to optimize aquifer parameters in the model, based on observed water levels and TDS concentrations over time. These aquifer parameters included horizontal hydraulic conductivity, vertical hydraulic conductivity, storativity and dispersivity. Aquifer parameters were input to PEST in the form of ranges of acceptable values for each established parameter zone. Through a nonlinear estimation technique known as the Gauss-Marquardt-Levenberg method, PEST adjusted the values assigned to each of the parameter zones to best fit the model-generated heads and TDS concentrations to the observed heads and TDS concentrations (reduce residual error) at wells across the model area.

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[18] These periods were chosen based on available data in the proposed project and nearby areas.

The calibration process requires using calibration target wells from which to match model-generated head values and TDS concentrations against measured values. Target wells used for model calibration include SL-1, MW-1S, MW-1M, MW-2S, and MW-2M (see figure 5 for well locations).

5.7.2 Initial Conditions

Initial conditions for the steady state calibration of the ground water model included measured ground water elevations and estimated TDS concentrations for March 2006. Ground water elevation contours in the basin were generated for static conditions prior to the 5-day pumping test in Test Slant Well SL-1. The initial ground water elevations incorporated data collected from SL-1, MW-1M, MW-2M, and data collected by Psomas at San Juan Basin Authority monitoring wells MW-01S, MW-02, and MW-03 (see figures 15 and 31 for hydrographs of available historical ground water elevation data). TDS concentrations for the steady state calibration incorporated data collected from SL-1, MW-1, and MW-2 in March 2006. Concentrations were estimated for the upstream basin area based on average historical values of TDS reported in Psomas (2006) and Geotechnical Consultants, Inc. (2001).

Initial conditions for the transient model calibration used the results of the steady state calibration. Initial conditions for model operational scenarios consisted of output at the end of the transient model calibration. Figure 20 depicts initial ground water elevations, and figure 21 depicts initial TDS concentrations used for the model operational scenarios. The initial conditions assume that upstream production wells owned by the city of San Juan Capistrano are pumping within the model area. However, they do not reflect pumping by two future wells planned by the South Coast Water District.

5.7.3 Steady State Calibration Results

A graphical comparison between measured and model predicted ground water levels (from the five target wells) for the steady-state calibration is shown in figure 22 and summarized in the table below. In figure 22, the closer the ground water elevations fall on the straight line, the better the "goodness-of-fit."

Ground water elevation steady state calibration statistics

Mean residual[1]	1.08 ft
Standard deviation of residual	2.06 ft
Relative error[2]	5.5%

[1] Residual = measured head less predicted head.

[2] Relative error = standard deviation of the residuals divided by the observed head range.

Apart from the calibration evaluation of "goodness of fit," another more quantitative approach is to calculate the relative error of the residuals (i.e., standard deviation of the residuals divided by the observed ground water elevation range). Common modeling practice is to consider a good fit between historical and model predicted data if the relative error is below 10 percent (%) (Spitz and Moreno, 1996; and Environmental Simulations, Inc., 1999). As seen in the table above, the relative error for the five target wells is 5.5% which is well below the recommended error of 10%.

5.7.4 Transient Calibration Results

The results of the initial steady-state calibration provided initial aquifer parameter estimates and ground water elevations for the transient calibration. Measured ground water elevation data from the 5-day pumping test of SL-1 was used in the transient calibration. PEST was used to iteratively adjust horizontal hydraulic conductivity and storativity/specific yield until a good match between measured and model-generated ground water elevation was achieved. The resultant calibration statistics are provided in the table below. Figures 23 to 27 show the hydrographs of the five target wells showing model-generated water levels compared to measured levels.

Transient calibration statistics

Statistic	Flow Model	Solute Transport Model
Mean Residual[1]	0.18 ft	0.9 mg/L
Standard Deviation of Residual	0.97 ft	17.9 mg/L
Relative Error[2]	5.7%	6.1%

[1] Residual = measured head less predicted head.

[2] Relative error = standard deviation of the residuals divided by the observed head range. A relative error of 10% or less is considered acceptable for model calibration.

Figure 28 shows a cross-plot of model-calculated changes versus measured changes in water level from initial conditions. The relative error of the residuals calculated by this method of analyzing model calibration results was 5.7%, which is below the recommended error of 10%.

Figure 29 shows that model-calculated and measured TDS concentrations have similar trends. The relative error for the transient calibration of the water quality component (TDS) of the ground water model was 6%.

5.8 Operational Scenarios

In addition to model calibration runs, three operational scenarios and one sensitivity scenario were run.

Description of modeling operational scenarios

Model Run	Slant Well Configu- ration	Duration[1]	Stress Period	Hydrologic Conditions	Project Extraction Quantity	Well Pumping Rate
1	Test well	3 years	Monthly	Above normal (wet)	2.88 mgd	2,000 gpm
2	7 wells	10 years	Annual	Above normal (wet)	30 mgd	2,976 gpm
2A	No project	10 years	Annual	Above normal (wet)	0 mgd	0 gpm
3	7 wells	1 year	Annual	Below normal (drier)	30 mgd	2,976 gpm

[1] Length of model time was somewhat arbitrary and was determined based on initial trial and error model runs to establish predictability in both ground water levels and TDS concentrations. It was soon determined that the total length of the model time period was not that critical.

5.8.1 Model Run 1 (Test Slant Well 2,000 gpm, Wet Hydrologic Conditions)

Run 1 simulated the current Dana Point Test Slant Well pumping 2,000 gpm continuously for a 3-year period under wet (above normal rainfall) hydrologic conditions. The wet hydrologic period was simulated using static ground water levels prior to the 5-day pumping test conducted during the spring of 2006. For this scenario, the model budget (inflow and outflows) was as follows (see table 2 for quantities):

Inflow:	Northern model boundary underflow San Juan Creek recharge Ocean inflow
Outflow:	Test Slant Well City of San Juan Capistrano desalter wells Rising water in San Juan Creek

5.8.2 Model Run 2 (30 mgd, Wet Hydrologic Conditions)

Run 2 simulated feedwater intake supply of 30 mgd for a 10-year period under wet hydrologic conditions. In this scenario, the model budget (inflow and outflows) was as follows (see table 2 for quantities):

Inflow:	Northern model boundary underflow San Juan Creek recharge Ocean inflow

Outflow: Slant well field
City of San Juan Capistrano desalter wells
South Coast Water District desalter wells
Rising water in San Juan Creek

5.8.3 Model Run 2A (No Project Pumping, Wet Hydrologic Conditions)

Run 2A simulated baseline conditions in the basin under wet hydrologic conditions, without pumping the project extraction wells. Run 2A (with no project pumping) was performed to determine impacts on upstream desalter wells owned by South Coast Water District and city of San Juan Capistrano. In this scenario, the model budget (inflow and outflows) was as follows (see table 2 for quantities):

Inflow: Northern model boundary underflow
San Juan Creek recharge

Outflow: City of San Juan Capistrano desalter wells
South Coast Water District desalter wells
Rising water in San Juan Creek
Ocean outflow

5.8.4 Model Run 3 (30 mgd, Drier Hydrologic Conditions)

Sensitivity of "drier" hydrologic conditions was simulated by lowering ground water elevations at the northern constant head boundary by 5 feet. Based on a comparison of cumulative departure from mean annual precipitation (see figure 30) and monitoring well ground water elevations, it is estimated that under drier hydrologic conditions, water levels at former pumping well SJBA No. 2, located in the northeastern corner of the model area, were approximately 5 feet less than under "wet" conditions (see figure 31). The sensitivity run (Model Run 3) simulated a feedwater intake supply of 30 mgd over a 1-year period.[19] In this scenario, the model budget (inflow and outflows) was as follows (see table 2 for quantities):

Inflows: Northern model boundary underflow
San Juan Creek recharge
Ocean inflow

Outflow: Slant well field
City of San Juan Capistrano desalter wells
South Coast Water District desalter wells
Rising water in San Juan Creek

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[19] For relative comparison of water level impacts of the drier conditions scenario, model predictability (i.e.,stability) was obtained after 1 year.

Figures 32 and 33 show the model input parameters for the slant well configurations and discharge rates for Model Runs 1 through 3.

5.9 Model Results

Results of the ground water simulations are presented for Model Runs 1, 2, and 3 as hydrographs of ground water elevations at the screened intervals of the extraction wells.[20] In addition, results are spatially presented in terms of predicted average ground water elevations and regional drawdowns averaged for all model layers for Model Runs 1, 2, and 2A. Maps of average elevations and drawdowns are averaged for all model layers. Hydrographs of ground water drawdowns in model layer 2 (shallow aquifer) for Model Runs 1, 2, and 3 are also presented to assess potential impact to riparian habitat alongside San Juan Creek south of the Pacific Coast Highway due to slant well field pumping. Plots of TDS concentrations throughout the modeling period are presented for the slant well field for Model Runs 1 and 2. The water budget (i.e., recharge source to the extraction wells) was calculated for Model Run 2 to quantify the contribution of water from both ocean and upstream sources to the extraction wells.

5.9.1 Model Run 1 (Test Slant Well Pumping)

5.9.1.1 Ground Water Elevations and Drawdown

The hydrograph of the Test Slant Well (see figure 34) shows that ground water elevation is relatively stable, reaching a minimum elevation in 3 years of approximately -17 ft NAVD88.

Figure 35 shows average ground water elevations, and figure 36 shows average drawdown after 3 years of pumping both the Test Slant Well and the two new SCWD desalter wells. Average drawdown would be approximately 8 ft at upstream well MW-01S, 16 ft at the future proposed SCWD desalter wells; and approximately 2 ft average drawdown would be experienced by the southernmost city of San Juan Capistrano desalter well (see figure 36).

The maximum average drawdown in Layer 2 at the end of 3 years in the vicinity of riparian vegetation alongside the mouth of San Juan Creek is approximately 1.8 ft (see figure 37).

5.9.1.2 TDS Concentrations

Figure 38 shows TDS concentration in the Test Slant Well throughout the Model Run 1 simulation (i.e., period of 3 years). The TDS concentration increases from

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[20] Average ground water elevations in the extraction wells were created by averaging ground water elevations in all model layers transected by the well screen. Thus, the elevations in the hydrographs are lower than ground water elevations presented in maps showing the average elevation of all model layers.

approximately 2,700 to 23,100 mg/L over 3 years. TDS concentration continues to increase at the end of 3 years and would likely increase with continued pumping.

5.9.2 Model Run 2 (30 mgd, Seven Project Wells Pumping)

5.9.2.1 Ground Water Elevations and Drawdown

The extraction well hydrographs (see figure 39) show that ground water elevations are relatively stable after 1 year of pumping, reaching minimum elevations ranging between approximately -82 and -86 ft NAVD88 at the end of 10 years.

Figure 40 shows average ground water elevations, and figure 41 shows average drawdown after 10 years of pumping. Average drawdown would be approximately 65 ft in the vicinity of the slant wellfield, approximately 53 ft at upstream well MW-01S, approximately 50 ft at the future proposed SCWD desalter wells (CBCWD Test Well and Future Well); and approximately a 5-ft average drawdown would be experienced by the southernmost city of San Juan Capistrano desalter well (Kinoshita Well) (see figure 41).

The maximum average drawdown in Layer 2 at the end of 10 years in the vicinity of riparian vegetation alongside the mouth of San Juan Creek is approximately 39 ft (see figure 42).

5.9.2.2 TDS Concentrations

Figure 43 shows TDS concentration in the extraction wells throughout the Model Run 2 simulation (i.e., period of 10 years). The average TDS concentration at the extraction wells increases from approximately 2,900 to 33,000 mg/L over 10 years.

5.9.3 Model Run 2A (No Project Condition)

5.9.3.1 Ground Water Elevations and Drawdown

Figure 44 shows average ground water elevations, and figure 45 shows average drawdown after 10 years under “no project” conditions. Under no project conditions, there is no pumping from the slant wells, and only upstream wells are pumping (i.e., SCWD and city of San Juan Capistrano desalter wells). There would be no drawdown in the vicinity of the slant wellfield, approximately 4 ft at upstream well MW-01S, and approximately 14 ft at the future proposed SCWD desalter wells; and approximately a 2-ft average drawdown would be experienced by the southernmost city of San Juan Capistrano desalter well (see figure 45). The following table summarizes drawdown that occurs under Model Runs 2 and 2A:

Comparison of drawdown in model runs 2 (30 mgd) and 2A (No Project)

Model Location	Drawdown in Run 2	Drawdown in Run 2A	Drawdown Due to Slant Well Pumping
Slant Well Field	65 ft	0 ft	65 ft
MW-01S	53 ft	4 ft	49 ft
Future SCWD Desalter Wells	50 ft	14 ft	36 ft
San Juan Capistrano Desalter Well (Kinoshita)	5 ft	2 ft	3 ft

5.9.4 Model Run 3 (Sensitivity Run of Drier Conditions)

5.9.4.1 Ground Water Elevations

The extraction well hydrographs (see figure 46) show that ground water elevations range between approximately -82 and -86 ft NAVD88. Ground water elevations show a similar pattern to ground water elevations in Model Run 2, except that they are approximately 1 to 2 ft lower.

The maximum average drawdown in Layer 2 at the end of 10 years in the vicinity of riparian vegetation alongside the mouth of San Juan Creek is approximately 36 ft (see figure 47).

5.9.5 Water Budget

A water balance (i.e., hydrologic budget) was performed for the area in the vicinity of the extraction wells for Model Run 2 (wet hydrologic conditions, 30 mgd). Ocean and offshore recharge accounts for 93% of the recharge to the slant well intake system with only 7% of the total well field recharge originating from inland sources. The following table summarizes the water balance at the end of each year for the 10-year model period in Model Run 2:

Figure 48 graphically depicts the water budget analysis and shows the breakdown of the contribution from vertical recharge (ocean source) and horizontal recharge (offshore aquifer source). For example, after 14 days of pumping 30 mgd from the slant well field, ocean water[21] and offshore sources contribute 83.4% of the total slant well field water supply (see figure 48). The percentage contribution from ocean water increases with time, and by years 5 through 10, 100% of the ocean and offshore recharge is predicted to consist of ocean water recharge. Also, by the end of approximately 3 years, ocean and offshore recharge make up 93% of the recharge to the slant well field with only 7% of the recharge coming from onshore sources.

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[21] In this report, ocean water recharge is vertical leakage from the ocean through model layer 1, and offshore recharge is lateral movement from the southern model area offshore through model layers 2-11.

Slant well field production contribution from seawater and freshwater (Model Run 2 – 30 mgd, above-normal (wet) hydrologic conditions)

Year	Seawater (acre-ft/yr) % of Total	Freshwater (acre-ft/yr) % of Total
1	30,676 91%	2,862 9%
2	31,141 93%	2,522 7%
3	31,277 93%	2,419 7%
4	31,322 93%	2,385 7%
5	31,339 93%	2,374 7%
6	31,141 93%	2,371 7%
7	31,345 93%	2,369 7%
8	31,343 93%	2,369 7%
9	31,346 93%	2,369 7%
10	31,346 93%	2,369 7%

6. Preliminary Cost Estimate for Construction of Slant Well Field

The attached cost proposal (see appendix B) for drilling, construction, and testing eight slant wells[22] was provided by Geo-Tech Division of Boart Longyear Company. Due to time constraints imposed by the beach location, drilling activities are planned to take place over a 2-year period. During year 1, six slant wells are planned to be drilled (in clusters of three wells each) on the east and west banks of San Juan Creek at Doheny State Beach. During year 2, the remaining two slant wells (in one cluster) are planned to be drilled approximately 1,000 ft west of San Juan Creek.

The cost proposal provided by Boart was based on using ¼-inch wall thickness AL-6XN® "super-alloy" stainless steel casing and screen. Because ¼-inch wall thickness material does not provide the level of strength that is desired for these slant wells, the costs require adjustment to reflect an increase in the wall thickness of both the 16-inch ID casing and 12-inch ID screen materials to 5/16 inches. The increase in wall thickness increases the collapse strength of the casing and screen by approximately 75% while increasing the weight (in pounds per foot of casing or screen) by approximately 25%. As a result, the total amount of the cost proposal to drill, construct, and test a wellfield of seven slant wells plus one backup well is increased from $12,137,787 to $13,562,494 for both year 1 and year 2, or an increased cost of $1,424,708. This cost assumes that 5/16-inch-thick super-alloy stainless steel plate material is available and assumes a change in weight per foot from ¼-inch wall (as quoted by the contractor) to a 5/16-inch wall thickness.

The contractor has not included California State sales taxes in the proposal. At the current rate of 7.75%,[23] this could amount to an additional $ 610,654 for the casing, screen, and filter pack materials.

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[22] As the current project configuration consists of a total of nine slant wells (seven active plus two standby), the cost estimate should be adjusted accordingly.

[23] Rate specified by California State Board of Equalization, City and County Tax and Use Rates for Dana Point, Orange County, California, July 2006.

7. Findings

Results from the Subsurface Feasibility Intake System modeling and analysis are summarized in the following main findings:

- Ground water model predictions show that the Test Slant Well pumping at a discharge rate of 2,000 gpm for a 3-year period will have a water level elevation of approximately -17 ft. This corresponds to a drawdown in the aquifer of approximately 8 ft. Based on a well efficiency of 78%, the drawdown in the Test Slant Well would be 10 ft.

- The shallow ground water levels near the banks of the San Juan Creek Channel would be lowered approximately 1.8 ft after 3 years of pumping the Test Slant Well at a rate of 2,000 gpm.

- After 3 years of continuous pumping, the TDS in the Test Slant Well discharge would be approximately 23,100 mg/L.

- Depth to bedrock varies from approximately 100 ft in the central model area (approximately 4,000 ft from the shore), to approximately 210 ft near the shoreline.

- The ground water outflow to the ocean under wet hydrologic conditions was estimated as 850 acre-ft/yr.

- The feasible design for the production slant well field would consist of seven wells (plus two backup wells) with each well capable of up to 3,000 gpm. The slant wells would be constructed and artificially filter-packed at a 20-degree angle below horizontal and have approximately 200 ft of 16 in. by 5/16-in. wall blank casing and 300 ft of 12- by 5/16-in. wall AL-6XN well screen.

- 93% of recharge to the 30-mgd slant well intake system is derived from the ocean with only 7% occurring from the inland source.

- Model runs have shown that stabilization of ground water levels and TDS concentration in the vicinity of the slant well field occurs after approximately 1 year of continuous production.

- Under above-normal (wet) hydrologic conditions, in the vicinity of the slant well field, average regional drawdown after 10 years of continuous production is approximately 65 ft for the 30-mgd production scenario. It is expected that drawdown would be similar under drier hydrologic conditions because of the similar ground water elevations observed in the production wells after 1 year of pumping.

- Impact to water levels in the riparian zone due to pumping is similar under the drier hydrologic condition (maximum 36-ft drawdown) as under the wet hydrologic condition (maximum 39-ft drawdown).

- TDS concentrations in the production wells under wet hydrologic conditions average approximately 33,000 mg/L in the production wells after 10 years of continuous pumping.

- Periodic rehabilitation of the slant well field will be necessary due to a decline in well efficiency and resulting decline in production over time.

8. Recommendations

- Conduct a 1-year pumping test on the test slant well to verify and refine ground water model parameters and predictive runs.

- Perform verification model runs after data is available from the 1-year Test Slant Well pumping test by comparing model-generated ground water elevations versus measured levels in the shallow middle and deep monitoring wells and the test well.

- Further exploration of the extent and permeability of any offshore bedrock outcrops in the southwest model area.

- Further studies and analysis are recommended regarding impacts of ground water level changes on riparian vegetation and the relationship of ground water level changes to evapotranspiration.

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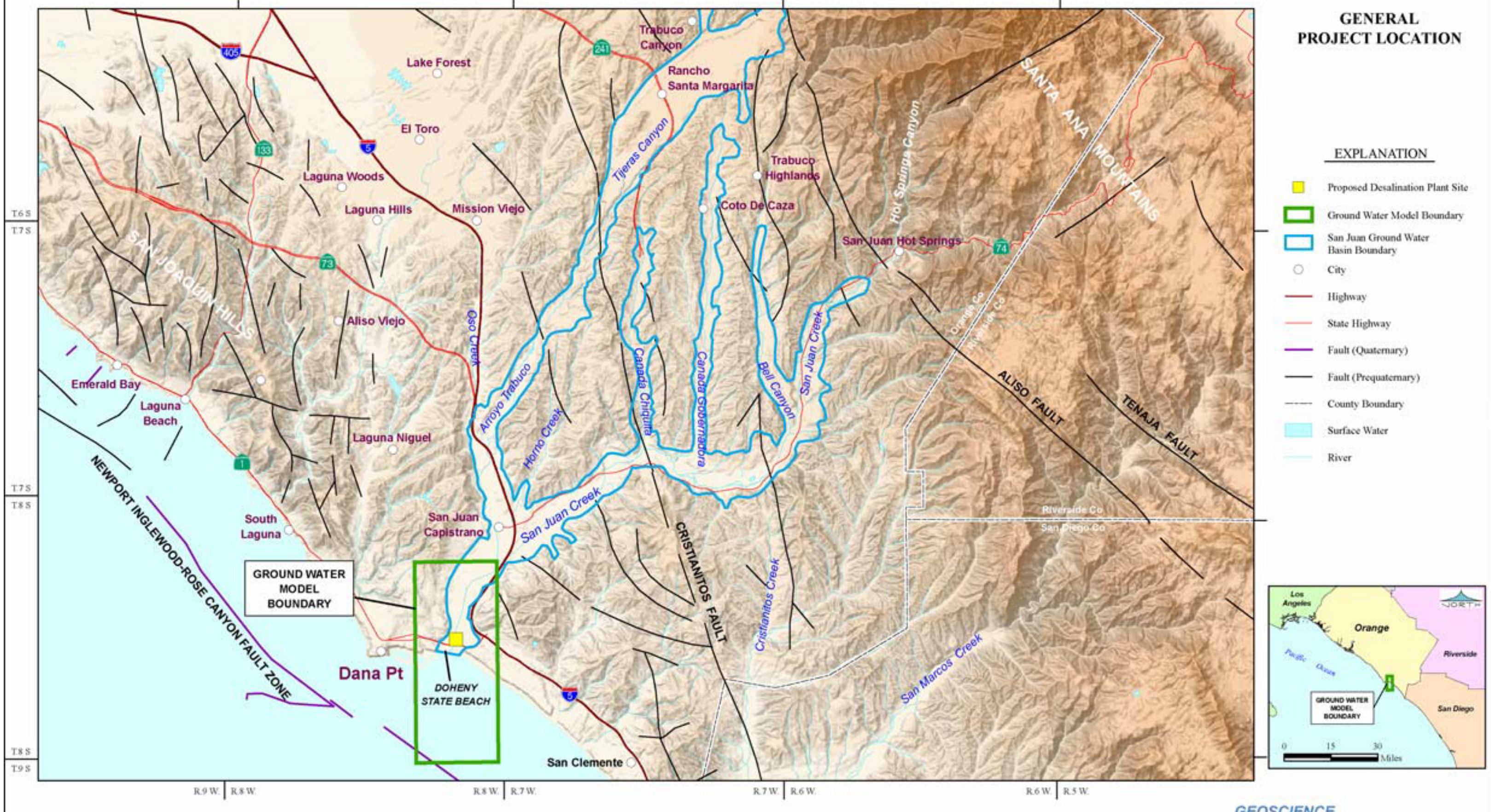
Zheng and Bennett, 2002. *Applied Contaminant Transport Modeling*. Wiley-Interscience.

Figures

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

SUBSURFACE SYSTEM INTAKE FEASIBILITY ASSESSMENT
TASK 3 REPORT

GENERAL PROJECT LOCATION



Apr-08

Prepared by: DWB

Map Projection:
State Plane, Zone 6 (1983)

GIS_proj/mwdoc_model_3-07/0_Fig_01_proj_loc.mxd

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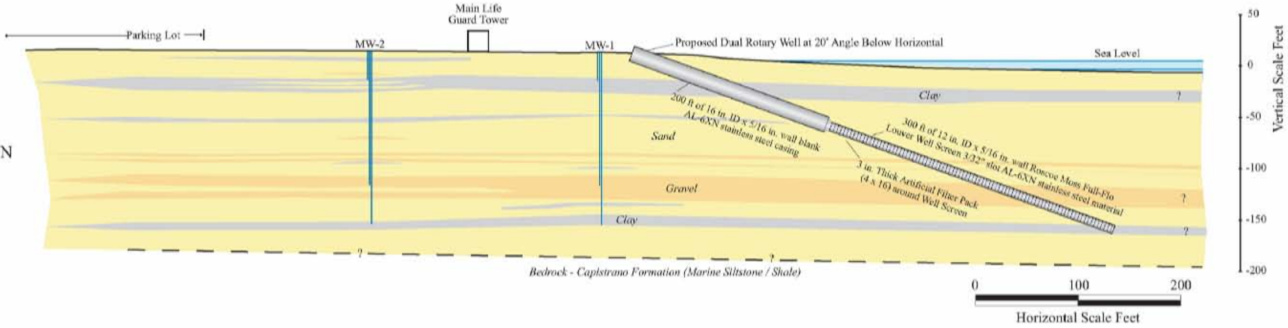
Figure 1

PLAN VIEW OF WELL LAYOUT FOR 30 MGD PRODUCTION

(2,976 gpm/well)

CROSS-SECTION



X:\MWDOC\Model_and_Engineering_Feasibility\Report\Figures\Slant_well_construction_details.ai

Figure 2

Drawn: DEW/SJB
Checked:
Approved:
Date: Apr-08

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

SUBSURFACE SYSTEM INTAKE FEASIBILITY ASSESSMENT - TASK 3 REPORT

SLANT WELL CONSTRUCTION DETAILS AND FULL-SCALE CONFIGURATION

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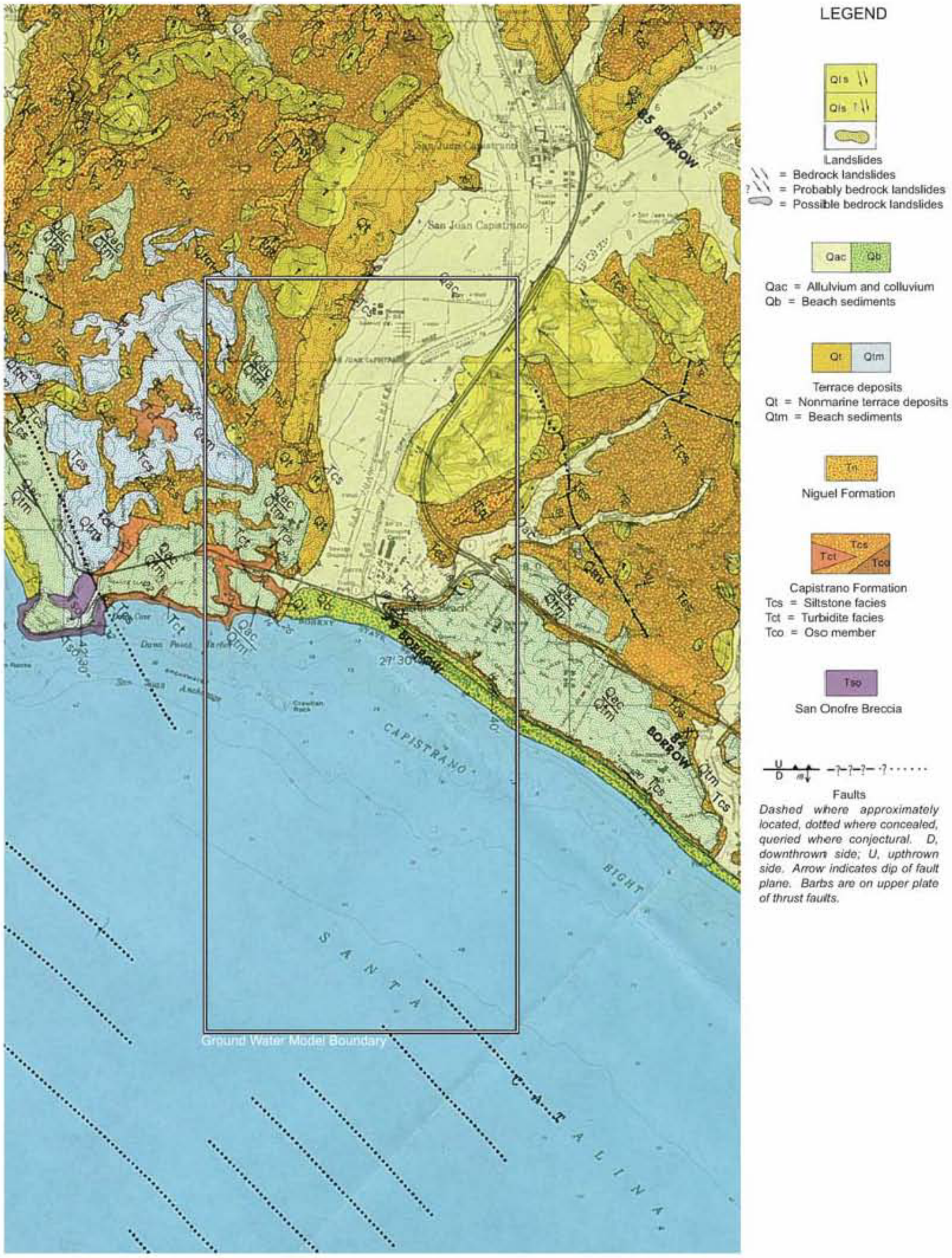

Source: Morton and Miller, 1981. Geologic Map of Orange County California, Showing Mines and Mineral Deposits. California Division of Mines and Geology Bulletin 204, Plate 1.

NORTH

Figure 3	Drawn: SJB	MUNICIPAL WATER DISTRICT OF ORANGE COUNTY	GEOSCIENCE
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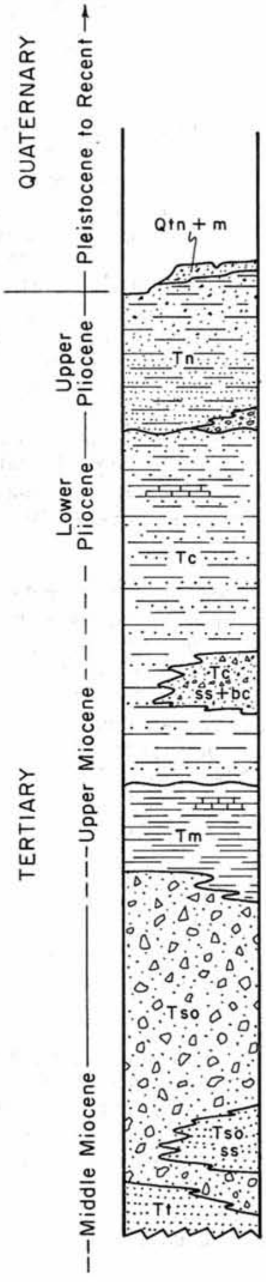
	Approved:	SURFICIAL GEOLOGY	
	Date: Apr-08		

Note: Variations occur within the immediate study area.



Marine and Continental Terrace Deposits --- conglomerate, gravel, sand and silt commonly interbedded.

Niguel Formation --- fine sandstone and sandy siltstone, locally with basal conglomerate.

Capistrano Formation --- siltstone, mudstone and soft diatomaceous and silty shale with minor sandstone beds and lenses, locally with channels filled by coarse sandstone, breccia and conglomerate, and minor calcareous shale beds and lenses.

Monterey Formation --- interbedded diatomaceous, silty and siliceous shale and siltstone with minor chert, limestone and calcareous shale beds and lenses.

San Onofre Breccia --- sedimentary breccia and conglomerate with coarse sand, angular to rounded boulders, cobbles and pebbles of schist, quartzite and gabbro in sandy and earthy matrices, locally interbedded with sandstone and sandy siltstone.

Topanga Formation --- sandstone and conglomeratic sandstone.

From Edgington, W.J., 1974. Geology of the Dana Point Quadrangle, Orange County, California, California Division of Mines and Geology Special Report 109.

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Drawn:
Checked:
Approved:
Date: Apr-08

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

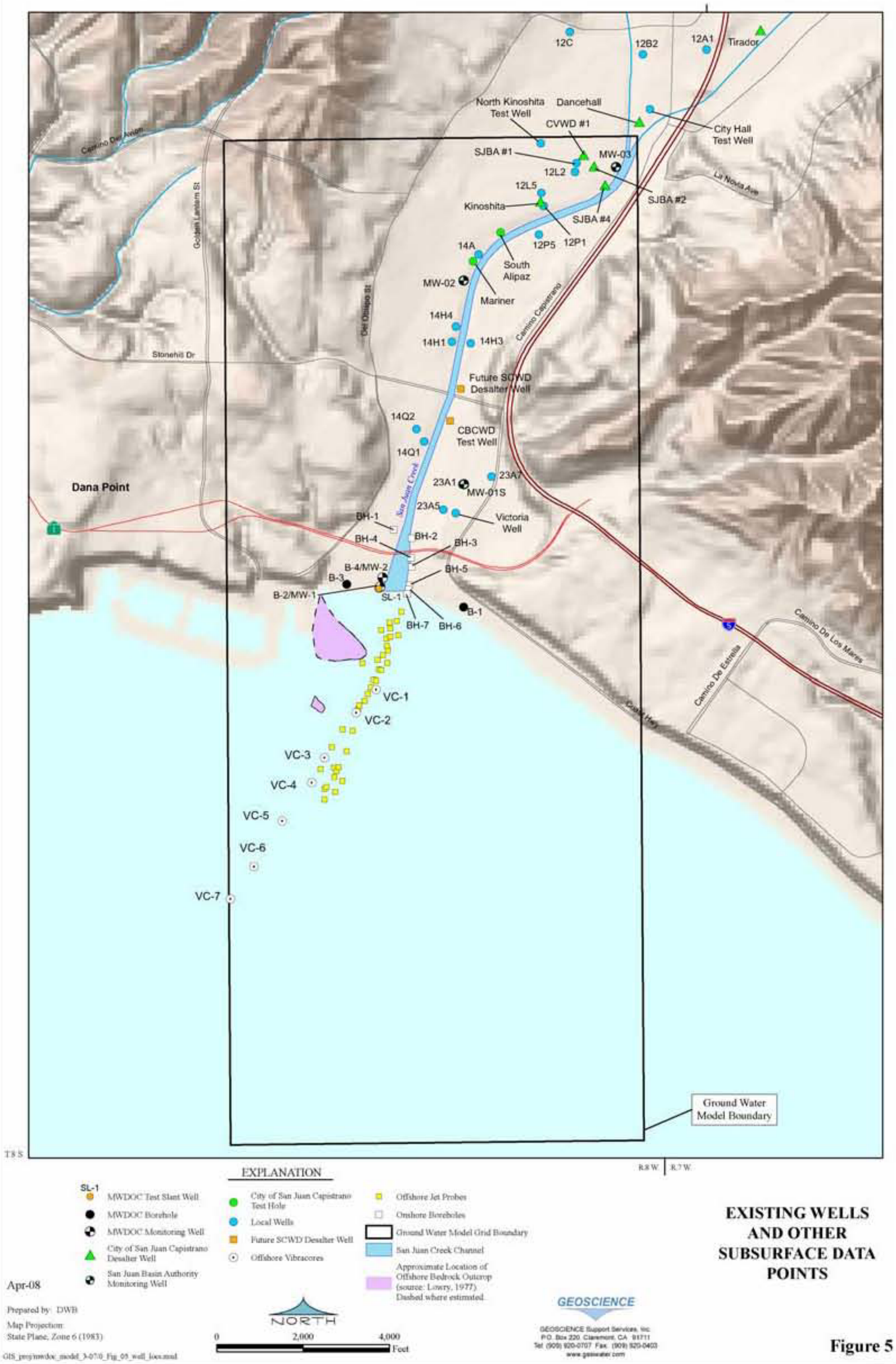
GENERAL STRATIGRAPHIC COLUMN

Figure
4

X:Projects\Dana Point Hydrogeology Invest\01 Phase I Report\Figures\Figure 6 Stratigraphic Column.ai

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

SUBSURFACE SYSTEM INTAKE FEASIBILITY ASSESSMENT
TASK 3 REPORT



Apr-08

Prepared by: DWB

Map Projection:
State Plane, Zone 6 (1983)

GIS_proj/mwdoc_model_3-07/0_Fig_05_well_locs.mxd

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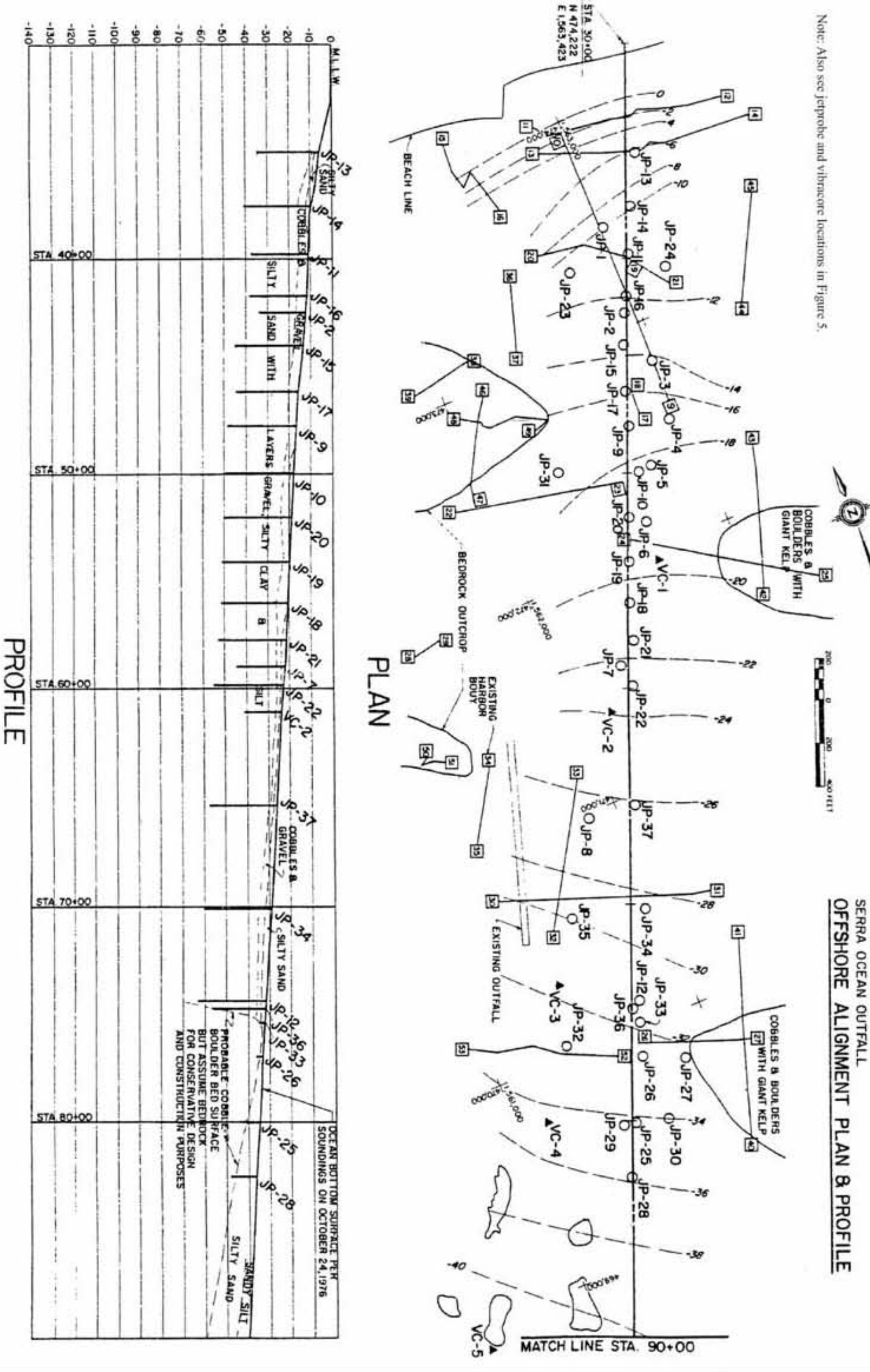
EXISTING WELLS AND OTHER SUBSURFACE DATA POINTS

Figure 5

Note: Also see jetprobe and vibracore locations in Figure 5.



Source: Lowry & Associates, 1977, Plate 4-3, Prepared for the South East Regional Reclamation Authority of Orange County, California, January 1977.

Figure	Drawn: SJB	MUNICIPAL WATER DISTRICT OF ORANGE COUNTY	GEOSCIENCE
6	Checked:	SUBSURFACE SYSTEM INTAKE FEASIBILITY ASSESSMENT - TASK 3 REPORT	GEOSCIENCE Support Services, Incorporated P.O. Box 220, Claremont, CA 91711 Tel: (909)920-0707 Fax: (909)920-0403 www.gssiwater.com
	Approved:	PROFILE OF OFFSHORE JETPROBE DATA FROM LOWRY & ASSOCIATES (1977)	
	Date: Apr-08		

Figure 7

Trilinear Diagram
Monitoring Wells MW-1M, MW-1D, MW-2M, and MW-2D, and Test Slant Well SL-1

Notes:

SL-1 is screened approximately 51-137 vertical feet below ground surface (ft bgs), and a deep zone was isolated and pumped correlating to a depth of approximately 117-137 ft bgs.

MW-1M and MW-2M are both screened 40-130 ft bgs.

MW-1D is screened from 141-166 ft bgs and MW-2D is screened from 140-165 ft bgs.

The typical composition of seawater (from Hem, 1985) has been added for comparison.

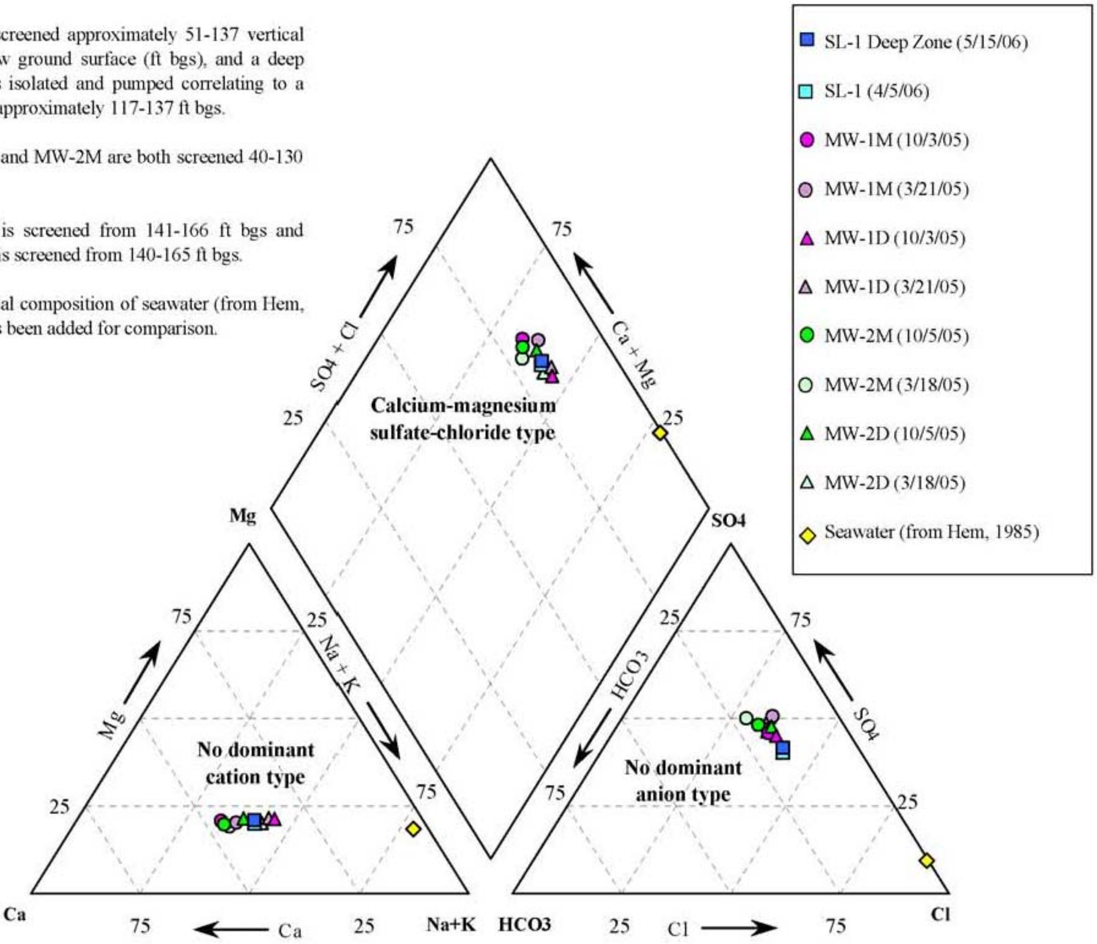
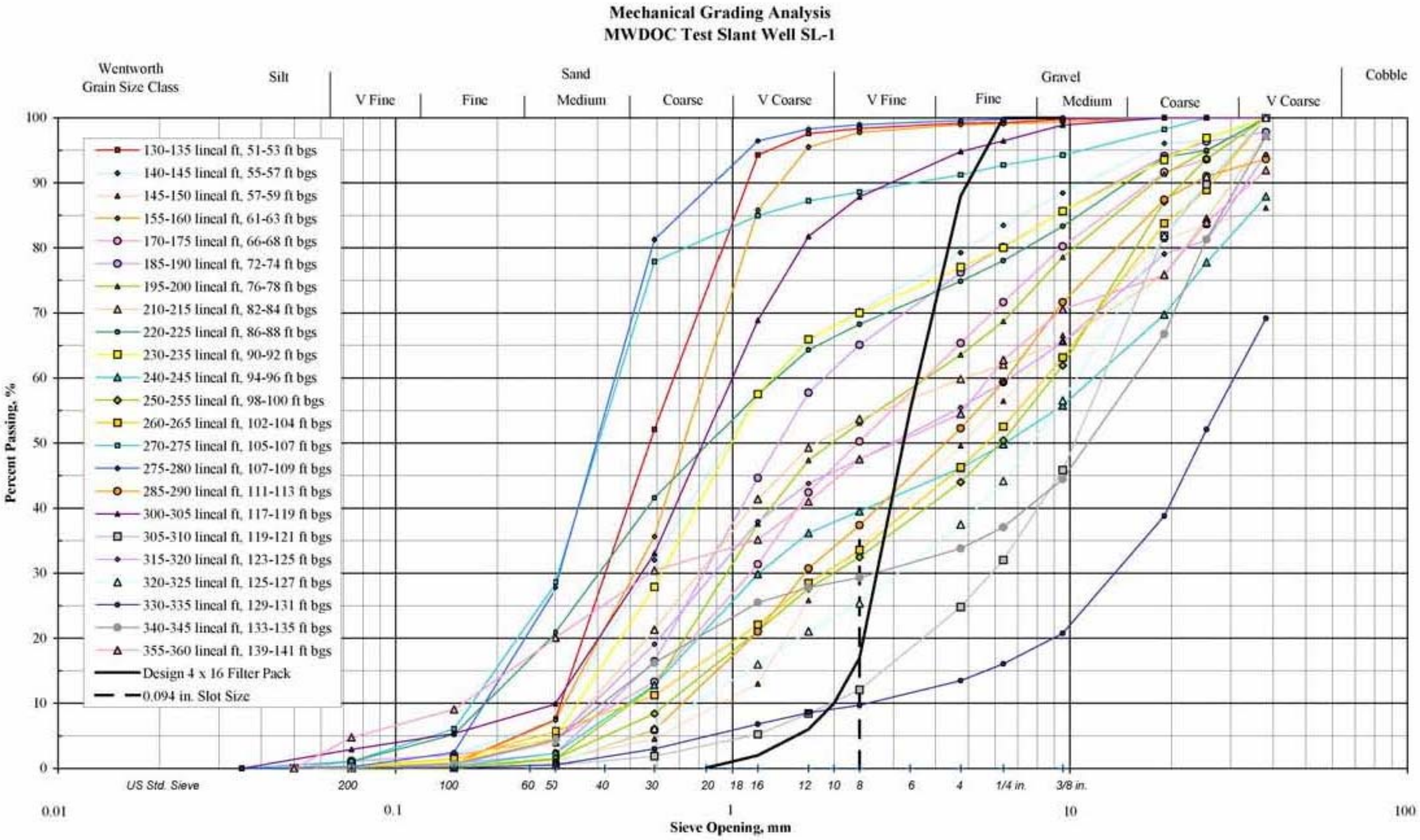
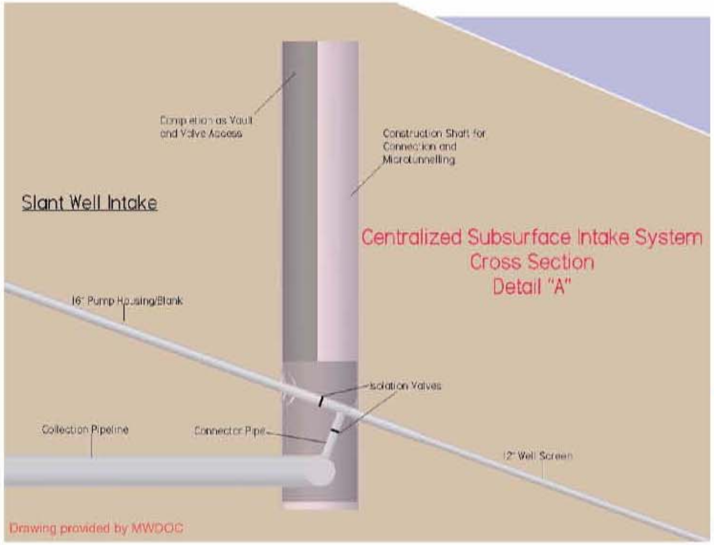


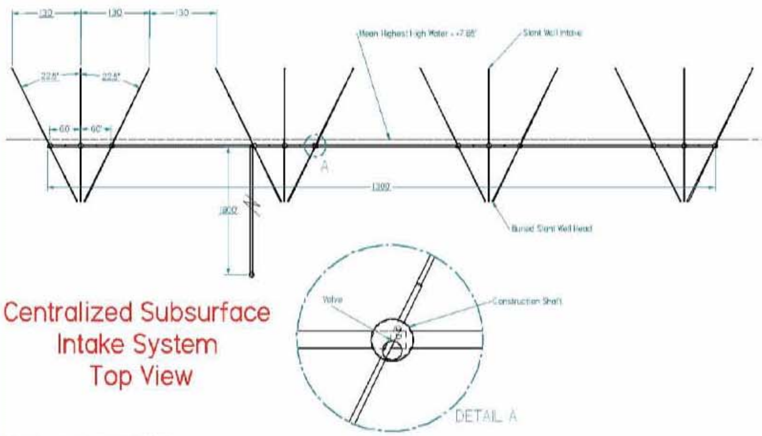
Figure 8


Mechanical Grading Analysis
MWDOC Test Slant Well SL-1
Wentworth Grain Size Class
Silt
Sand
V Fine
Fine
Medium
Coarse
V Coarse
Gravel
V Fine
Fine
Medium
Coarse
V Coarse
Cobble
Percent Passing, %
0
10
20
30
40
50
60
70
80
90
100
130-135 lineal ft, 51-53 ft bgs
140-145 lineal ft, 55-57 ft bgs
145-150 lineal ft, 57-59 ft bgs
155-160 lineal ft, 61-63 ft bgs
170-175 lineal ft, 66-68 ft bgs
185-190 lineal ft, 72-74 ft bgs
195-200 lineal ft, 76-78 ft bgs
210-215 lineal ft, 82-84 ft bgs
220-225 lineal ft, 86-88 ft bgs
230-235 lineal ft, 90-92 ft bgs
240-245 lineal ft, 94-96 ft bgs
250-255 lineal ft, 98-100 ft bgs
260-265 lineal ft, 102-104 ft bgs
270-275 lineal ft, 105-107 ft bgs
275-280 lineal ft, 107-109 ft bgs
285-290 lineal ft, 111-113 ft bgs
300-305 lineal ft, 117-119 ft bgs
305-310 lineal ft, 119-121 ft bgs
315-320 lineal ft, 123-125 ft bgs
320-325 lineal ft, 125-127 ft bgs
330-335 lineal ft, 129-131 ft bgs
340-345 lineal ft, 133-135 ft bgs
355-360 lineal ft, 139-141 ft bgs
Design 4 x 16 Filter Pack
0.094 in. Slot Size
US Std. Sieve
200
100
60
50
40
30
20
18
16
12
10
8
6
4
1/4 in.
3/8 in.
0.01
0.1
1
10
100
Sieve Opening, mm



Centralized Subsurface Intake System
Cross Section
Detail "A"

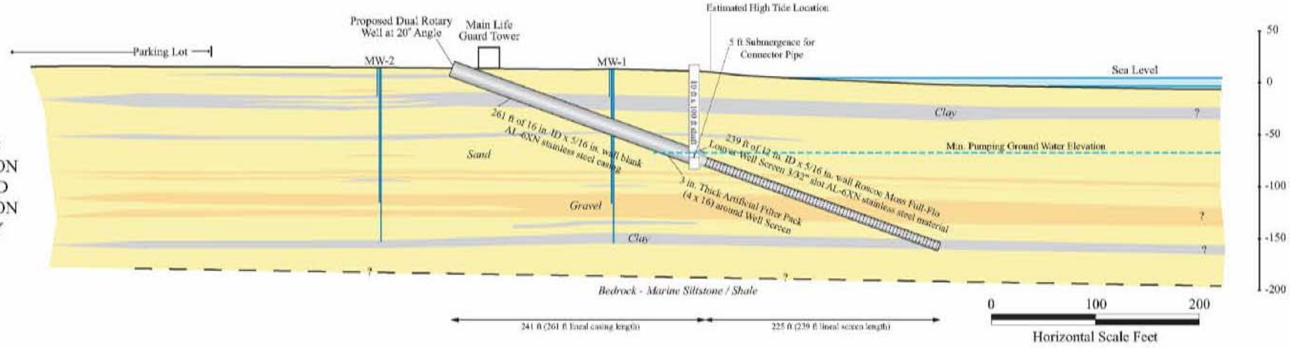
Drawing provided by MWDOC



Centralized Subsurface Intake System
Top View

Drawing provided by MWDOC

SCHEMATIC
CROSS-SECTION
OF WELL AND
CONSTRUCTION
SHAFT ONLY



Note: This system was evaluated in the Draft Task 4 Report and subsequently determined to be less feasible than the individual well/pump system due to both cost and reliability factors.

Figure 9	Drawn: DEW/SJB	MUNICIPAL WATER DISTRICT OF ORANGE COUNTY	GEOSCIENCE
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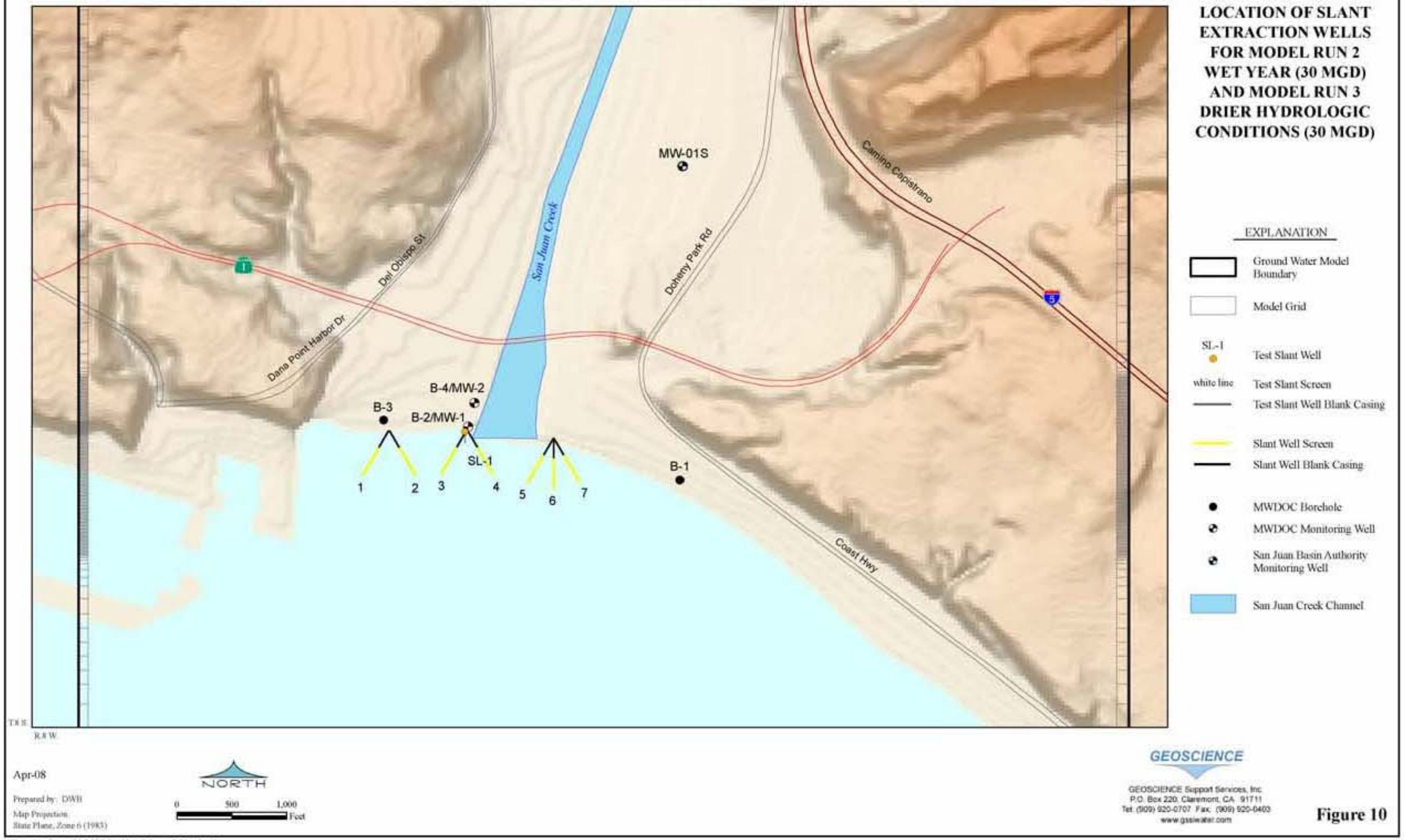
	Approved:	CENTRALIZED SUBSURFACE INTAKE SYSTEM SCHEMATIC	
	Date: Apr-08		

LOCATION OF SLANT EXTRACTION WELLS FOR MODEL RUN 2 WET YEAR (30 MGD) AND MODEL RUN 3 DRIER HYDROLOGIC CONDITIONS (30 MGD)



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Prepared by: DWB

Map Projection
State Plane, Zone 6 (1983)

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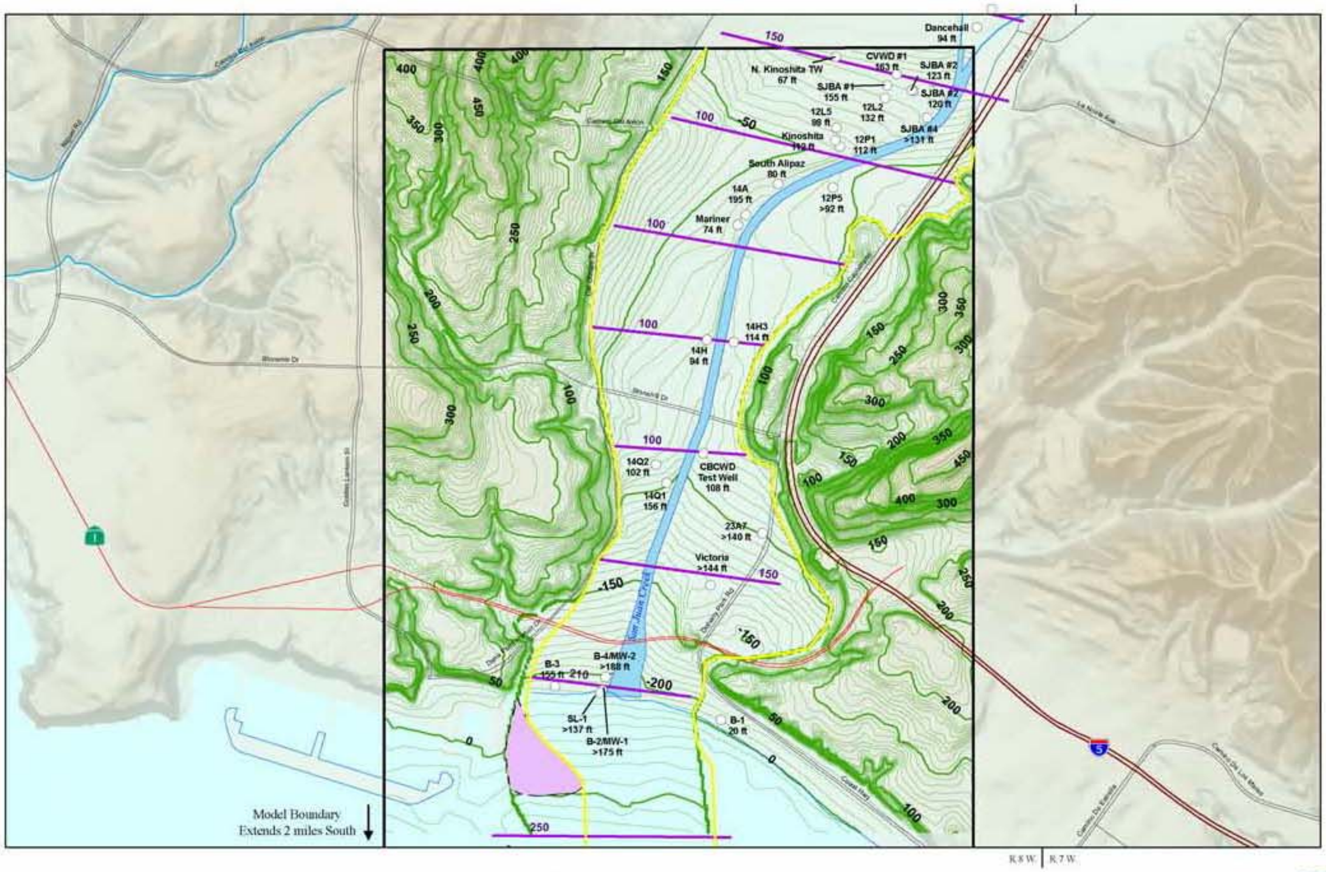
Figure 10

GIS_proj/mwdoc_model_3-07/0_Fig_10_well_loc_run2_30mgd.mxd

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

SUBSURFACE SYSTEM INTAKE FEASIBILITY ASSESSMENT
TASK 3 REPORT

GENERALIZED BEDROCK ELEVATION IN MODEL AREA



Model Boundary
Extends 2 miles South ↓

EXPLANATION

14H 94 ft ○	Local Wells or Boreholes with Estimated Depth to Capistrano Formation (ft) Based on Available Geologic Logs
250	Generalized Bedrock Elevation (ft, NAVD88) (labeled every 50 ft)
100	Estimated Thickness of Alluvium (ft) (used to construct bedrock elevation contours)
yellow line	Model Alluvium Boundary
🟪	Approximate Location of Offshore Bedrock Outcrop (source: Lowry, 1977). Dashed where estimated.
☐	Ground Water Model Boundary
🟦	San Juan Creek Channel

Apr-08

Prepared by: DWB
Map Projection:
State Plane, Zone 6 (1983)

NORTH

0 1,000 2,000 Feet

Sources of Data:
Geoscience 2005, 2006;
Boyle 1993, Geopentech 2002;
Geotechnical Consultants 2004;
Psomas 2006.

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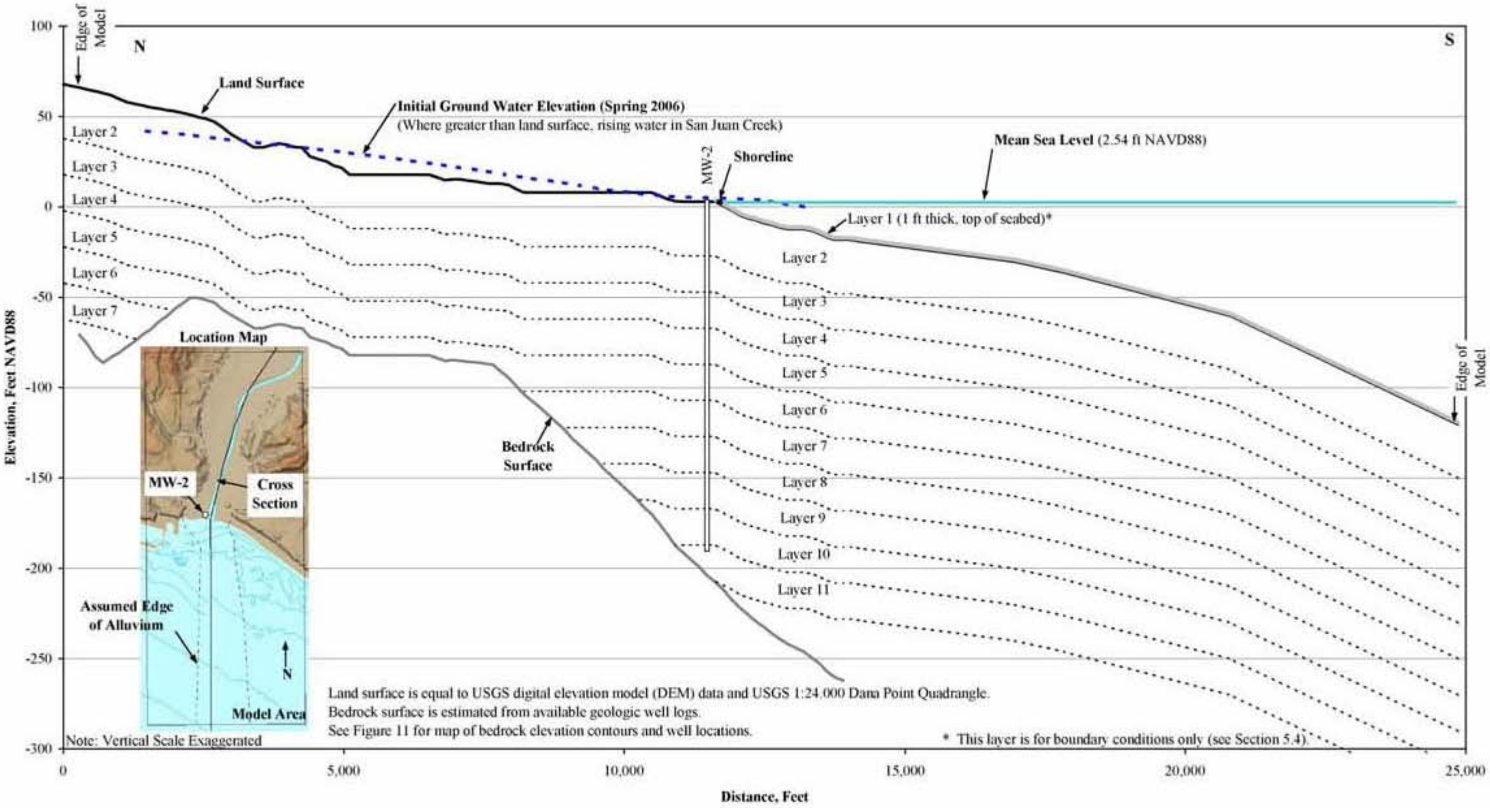
Figure 11

GIS_proj/mwdoc_model_3-07/0_Fig_11_bedrock elev.mxd

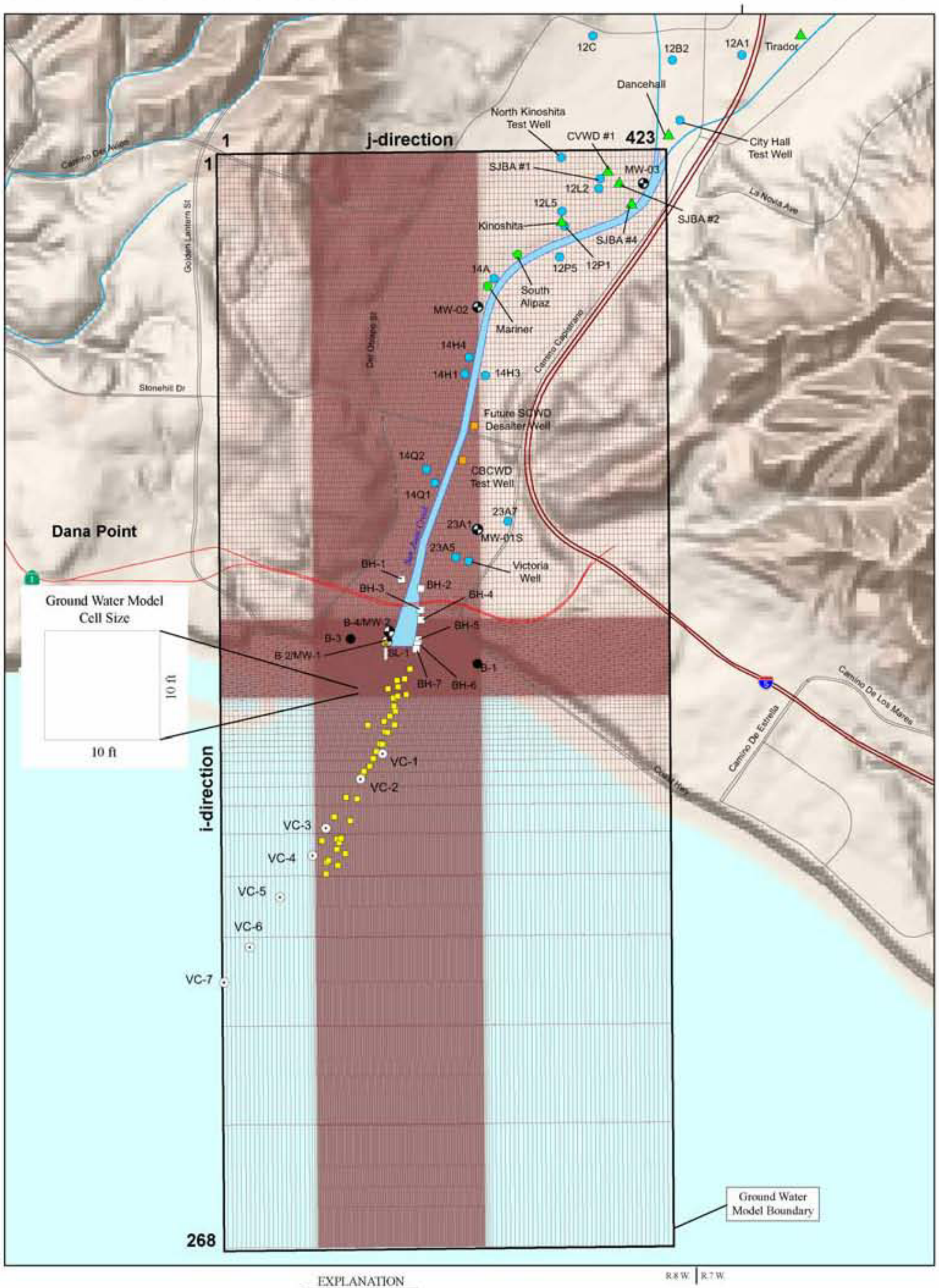
Cross Section of Model Layers



Note: Vertical Scale Exaggerated

Land surface is equal to USGS digital elevation model (DEM) data and USGS 1:24,000 Dana Point Quadrangle.
Bedrock surface is estimated from available geologic well logs.
See Figure 11 for map of bedrock elevation contours and well locations.

* This layer is for boundary conditions only (see Section 5.4).



EXPLANATION

1-Apr-08

Prepared by: DWB

Map Projection:
State Plane, Zone 6 (1983)

GIS_proj/mwdoc_model_3-07/0_Fig_13_model_grid.mxd

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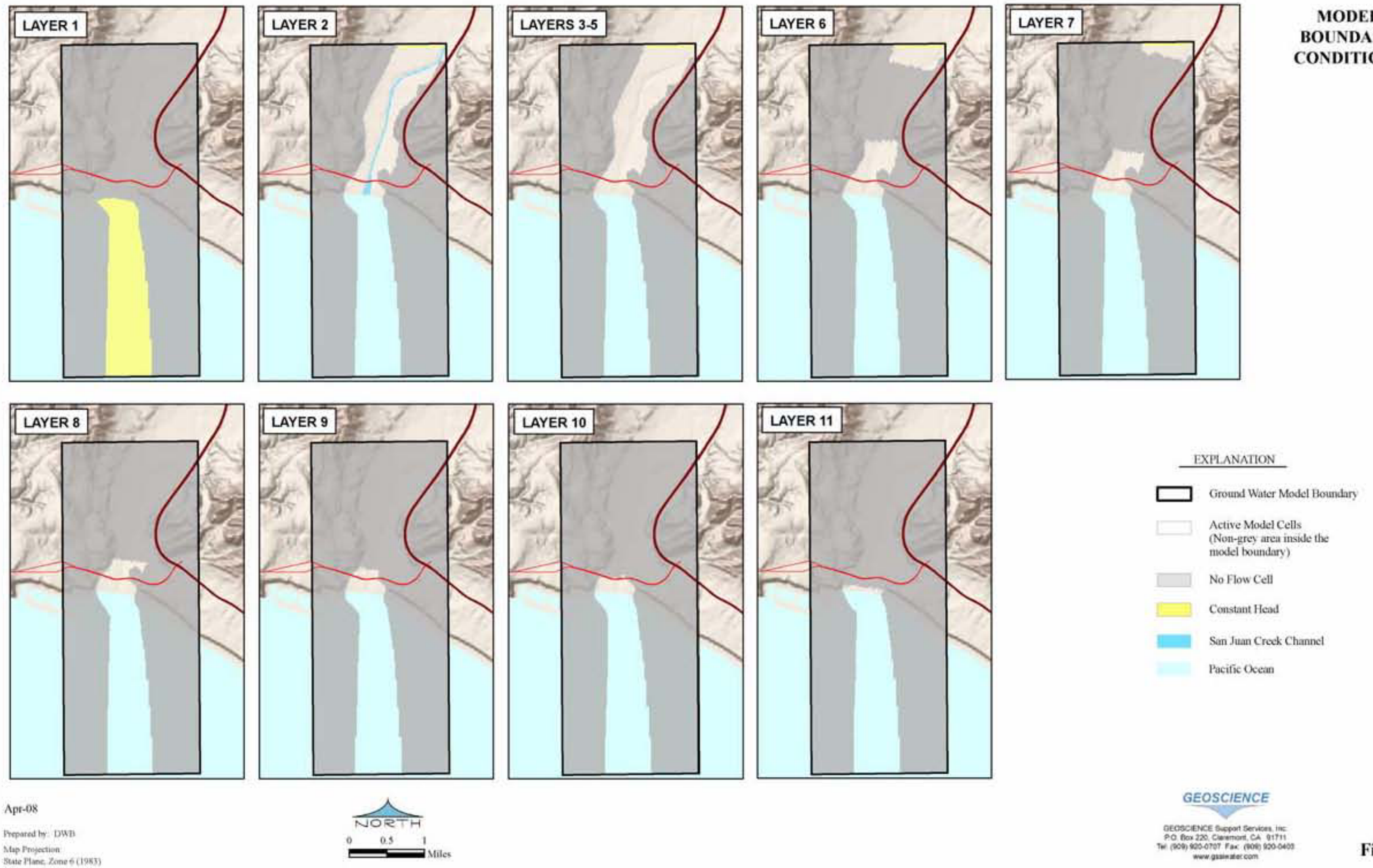
MODEL AREA GRID AND BOUNDARY

Figure 13

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

SUBSURFACE SYSTEM INTAKE FEASIBILITY ASSESSMENT
TASK 3 REPORT

MODEL BOUNDARY CONDITIONS



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Prepared by: DWB

Map Projection:
State Plane, Zone 6 (1983)

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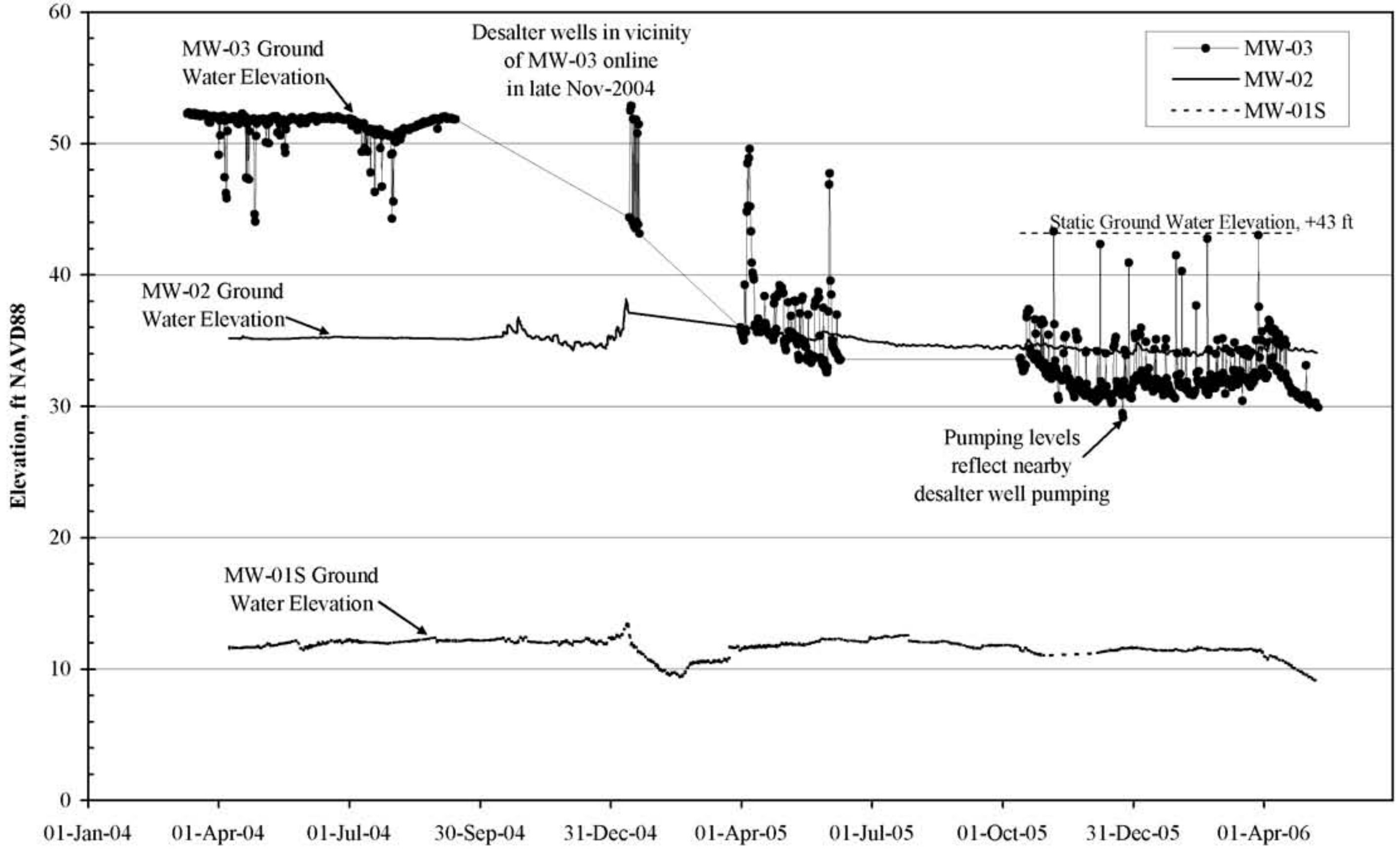
Figure 14

GIS_proj/mwdoc_model_3-07\0_Fig_14_bndy_cond.mxd

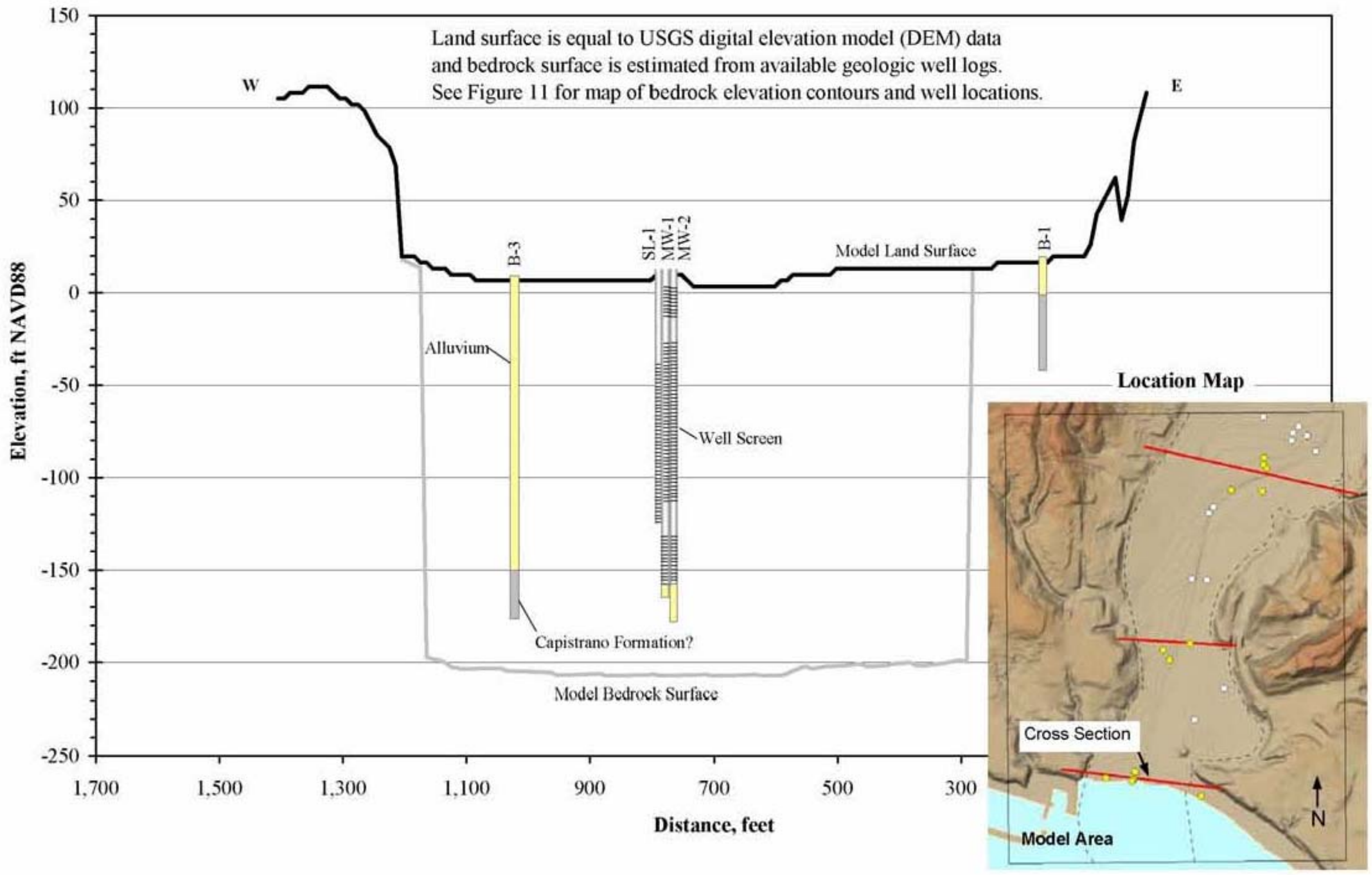
Ground Water Elevations in Nearby Monitoring Wells
of the San Juan Basin Authority



Source of Data: Psomas, 2006

Figure 15

Bedrock Cross Section
(Near Shoreline)



Land surface is equal to USGS digital elevation model (DEM) data and bedrock surface is estimated from available geologic well logs. See Figure 11 for map of bedrock elevation contours and well locations.

Figure 16

**Bedrock Cross Section
(Middle Model Area)**

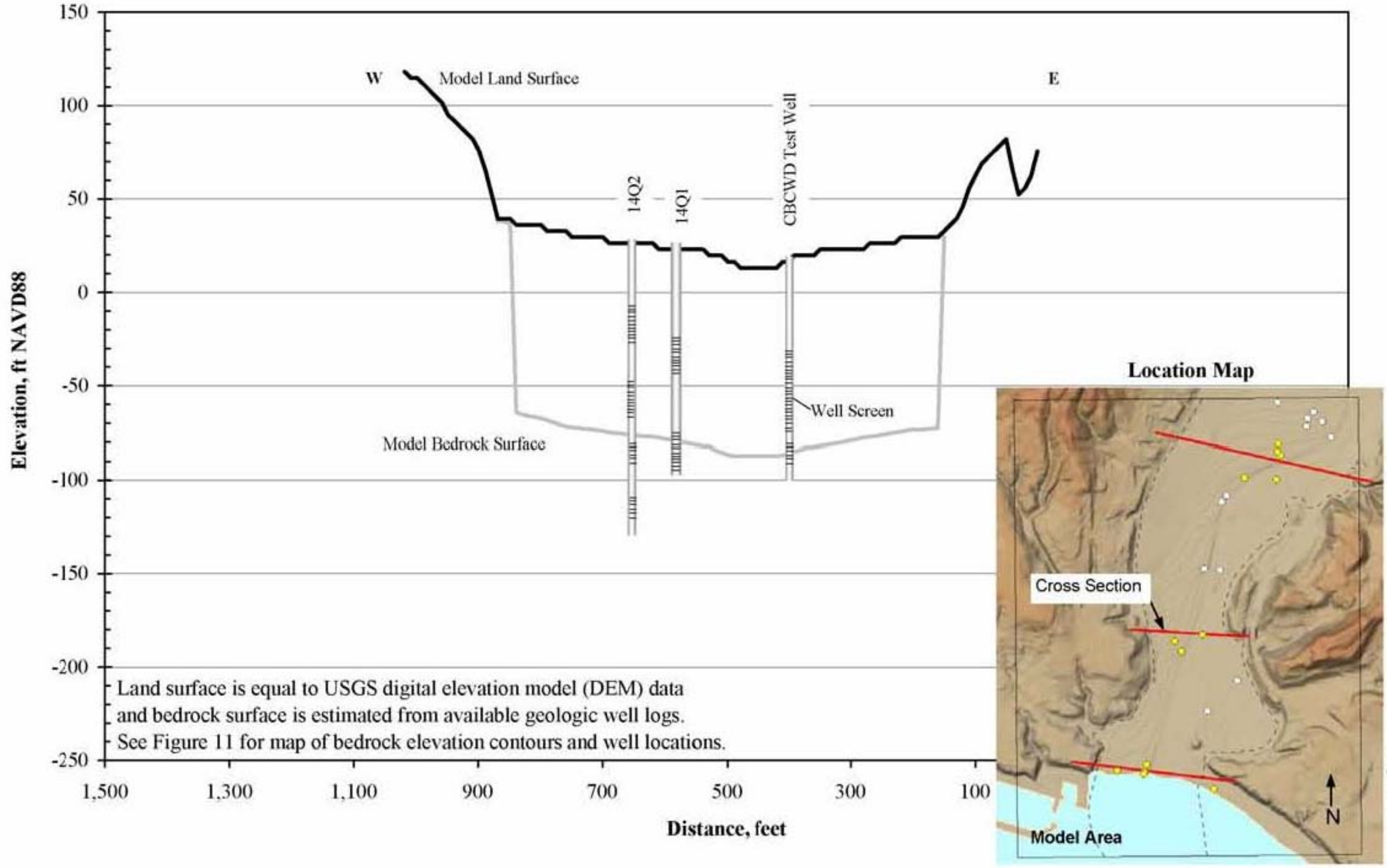
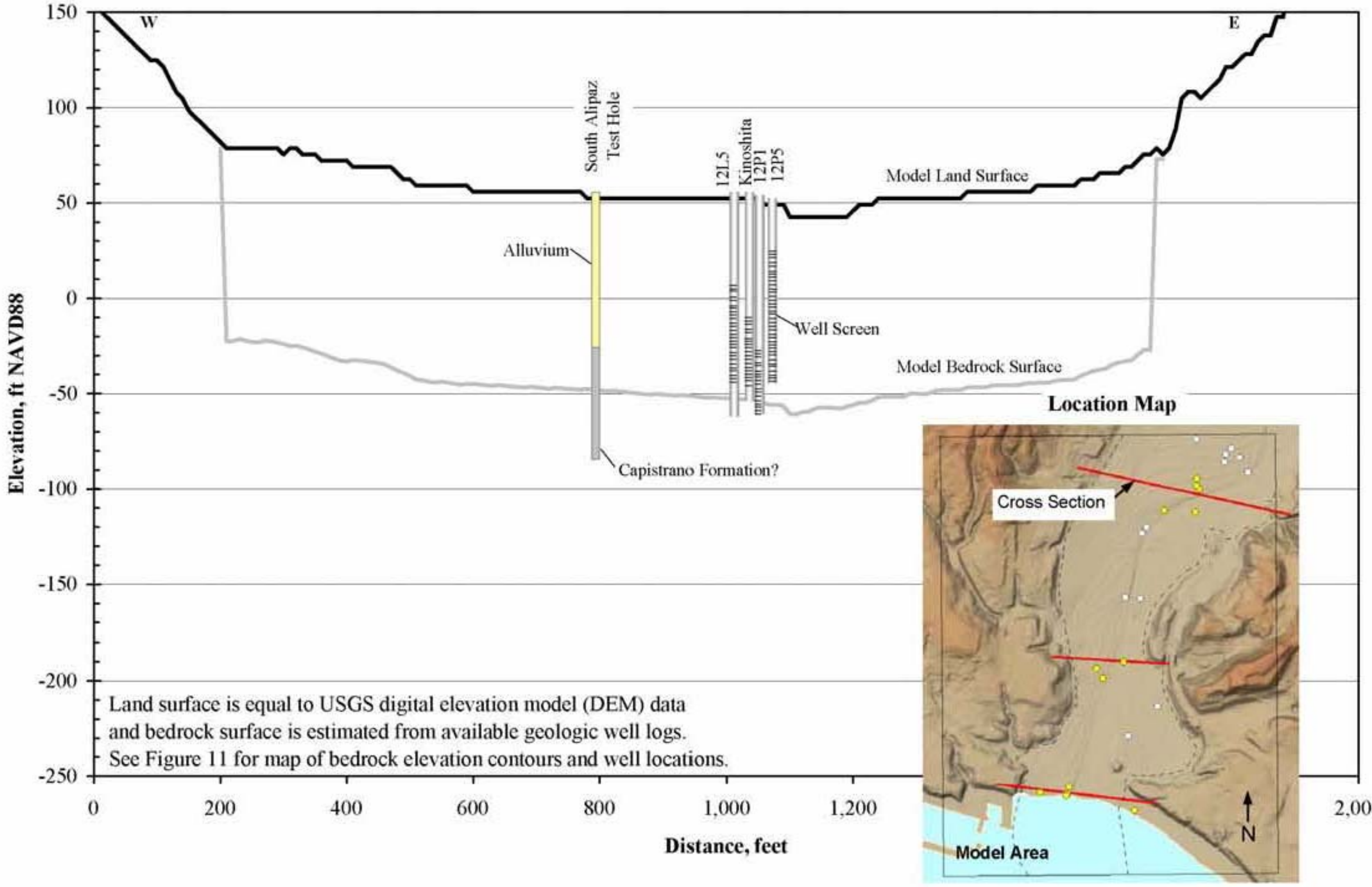


Figure 17

Bedrock Cross Section
(Northern Model Area)



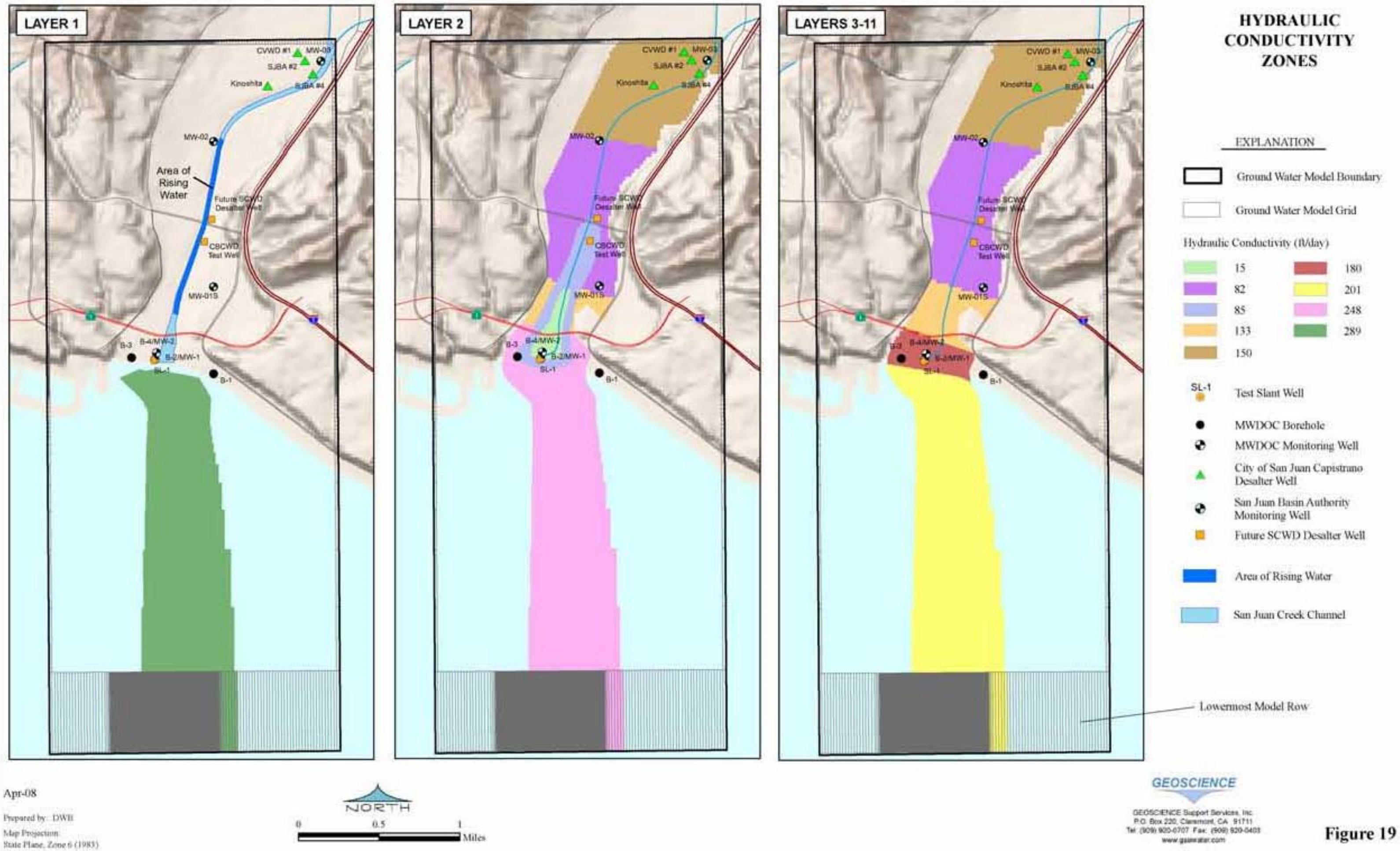
Land surface is equal to USGS digital elevation model (DEM) data and bedrock surface is estimated from available geologic well logs.
See Figure 11 for map of bedrock elevation contours and well locations.

Figure 18

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

SUBSURFACE SYSTEM INTAKE FEASIBILITY ASSESSMENT
TASK 3 REPORT

HYDRAULIC CONDUCTIVITY ZONES



Apr-08

Prepared by: DWB
Map Projection:
State Plane, Zone 6 (1983)

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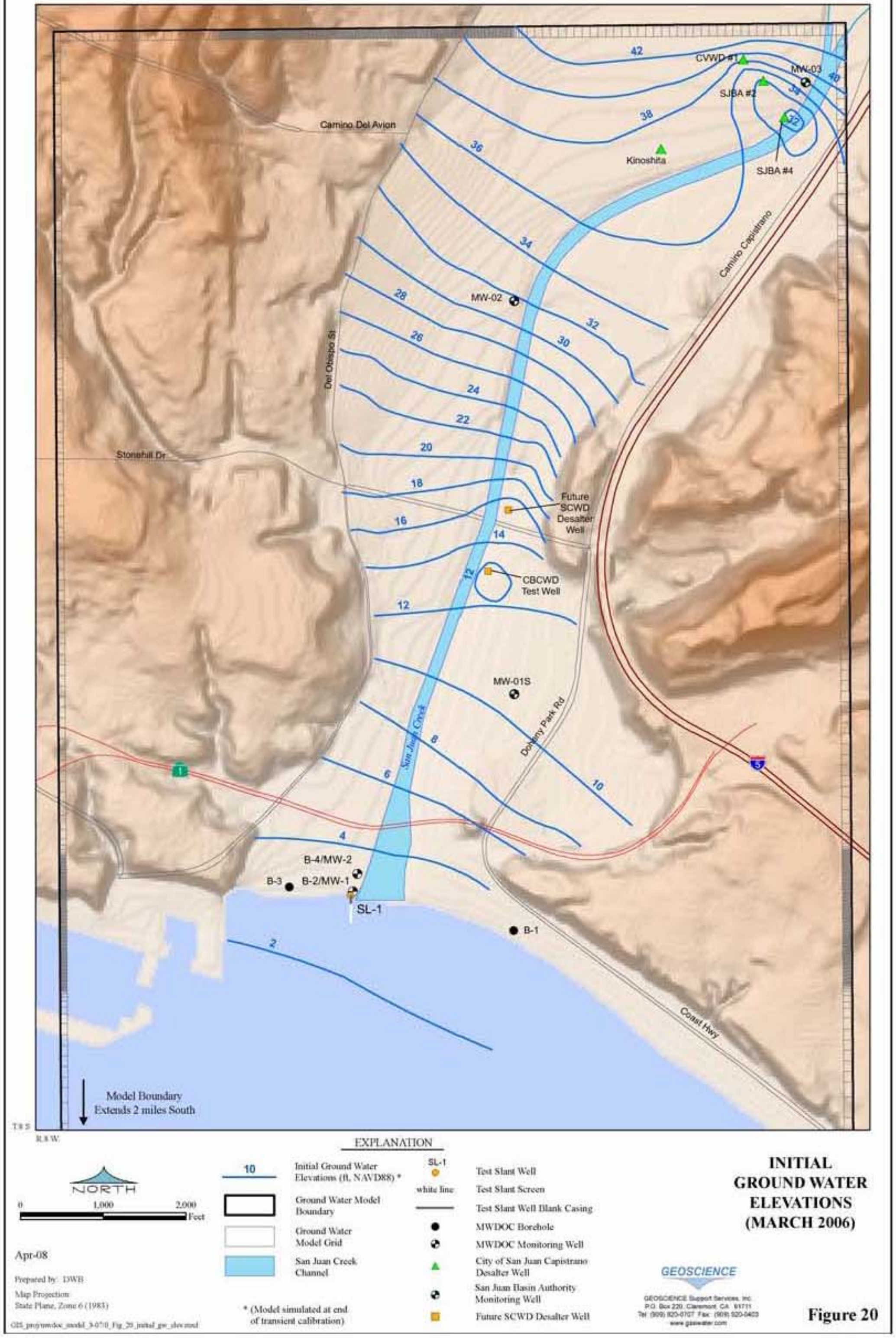
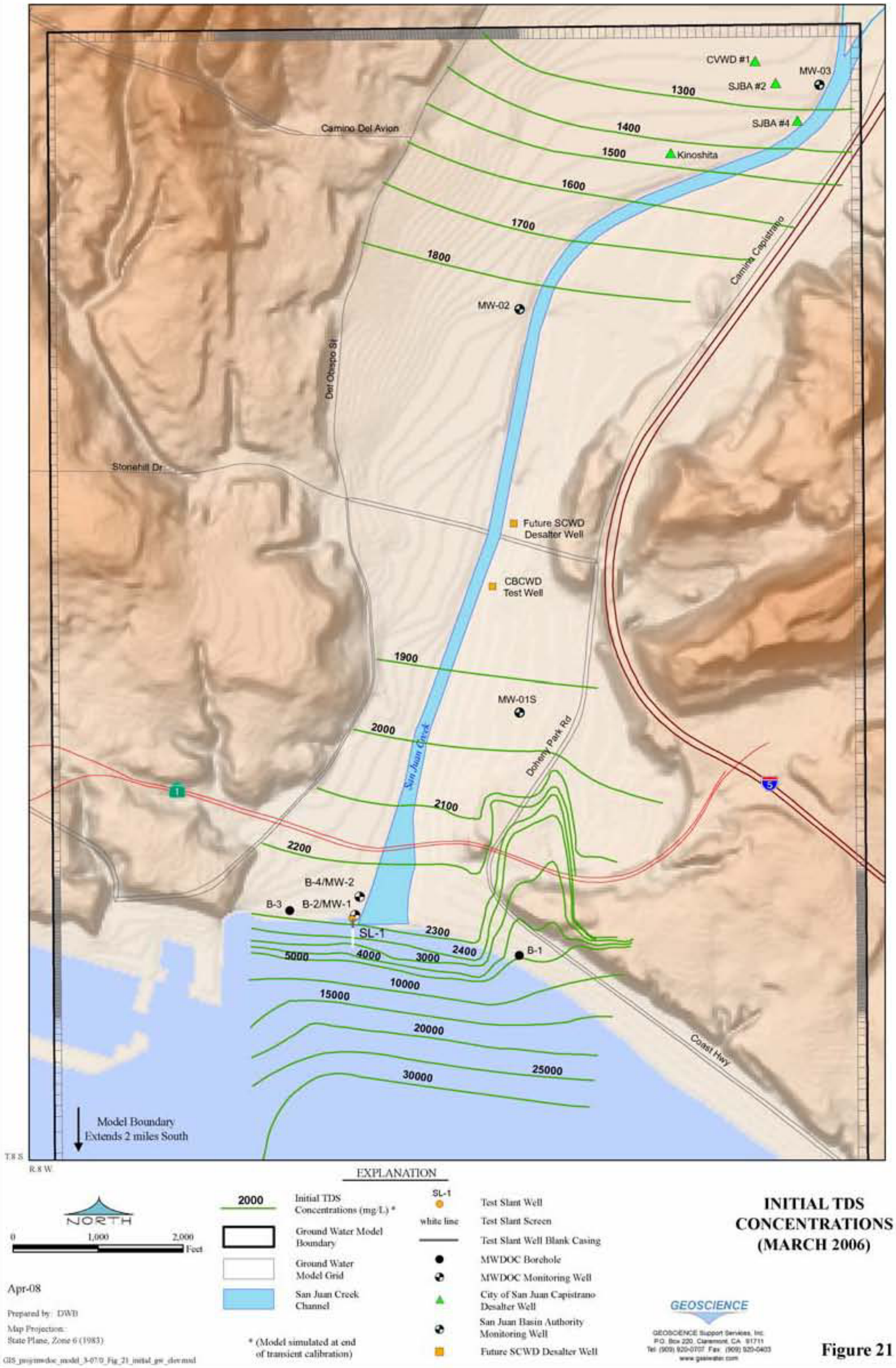
Figure 19

GIS_proj\mwdoc_model_3-07\0_Fig_19_hy_cond.mxd



INITIAL GROUND WATER ELEVATIONS (MARCH 2006)

Figure 20



INITIAL TDS CONCENTRATIONS (MARCH 2006)

Figure 21

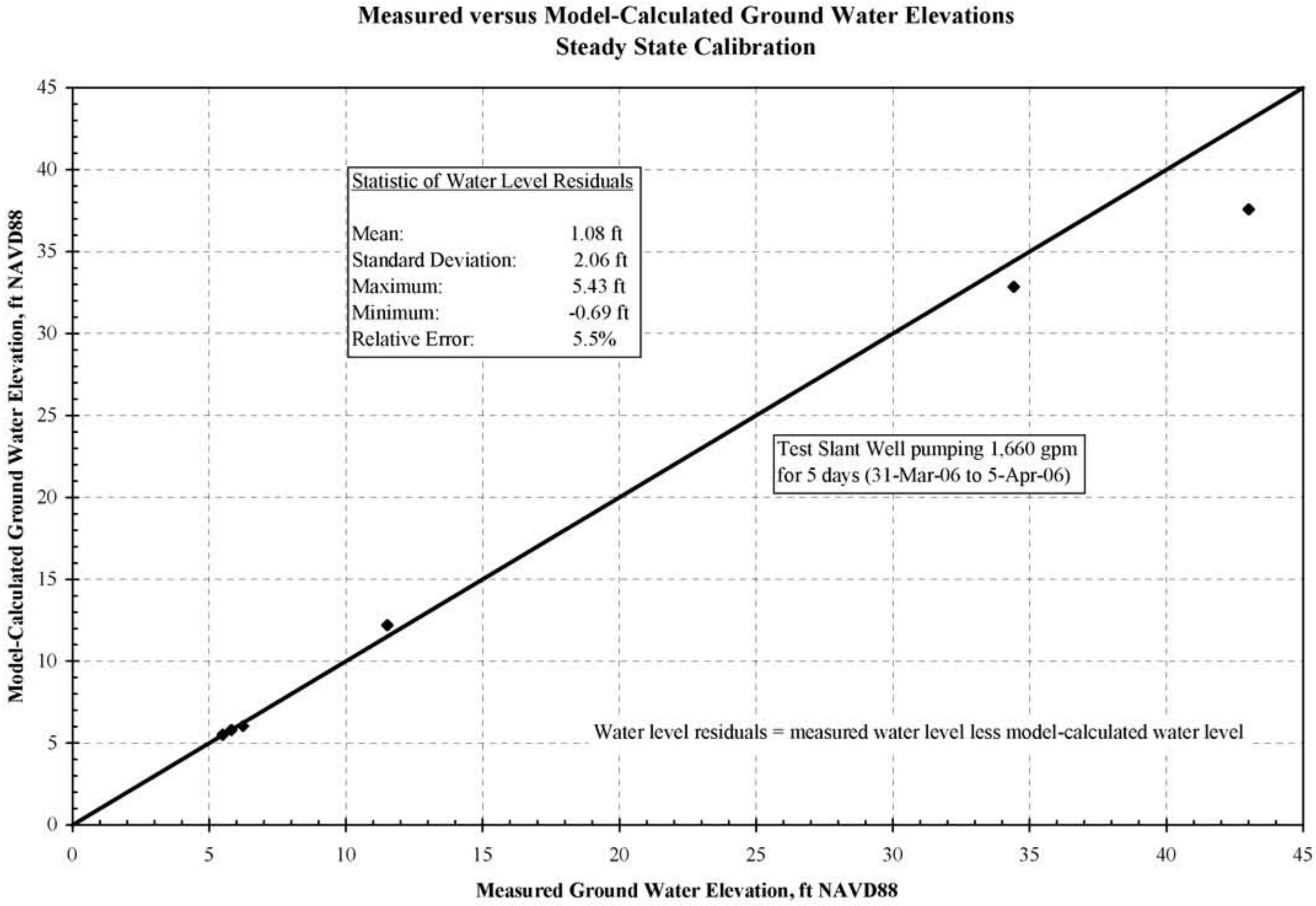

Measured versus Model-Calculated Ground Water Elevations
Steady State Calibration
Statistic of Water Level Residuals
Mean: 1.08 ft
Standard Deviation: 2.06 ft
Maximum: 5.43 ft
Minimum: -0.69 ft
Relative Error: 5.5%
Test Slant Well pumping 1,660 gpm
for 5 days (31-Mar-06 to 5-Apr-06)
Water level residuals = measured water level less model-calculated water level
Model-Calculated Ground Water Elevation, ft NAVD88
Measured Ground Water Elevation, ft NAVD88
0
5
10
15
20
25
30
35
40
45

Figure 22

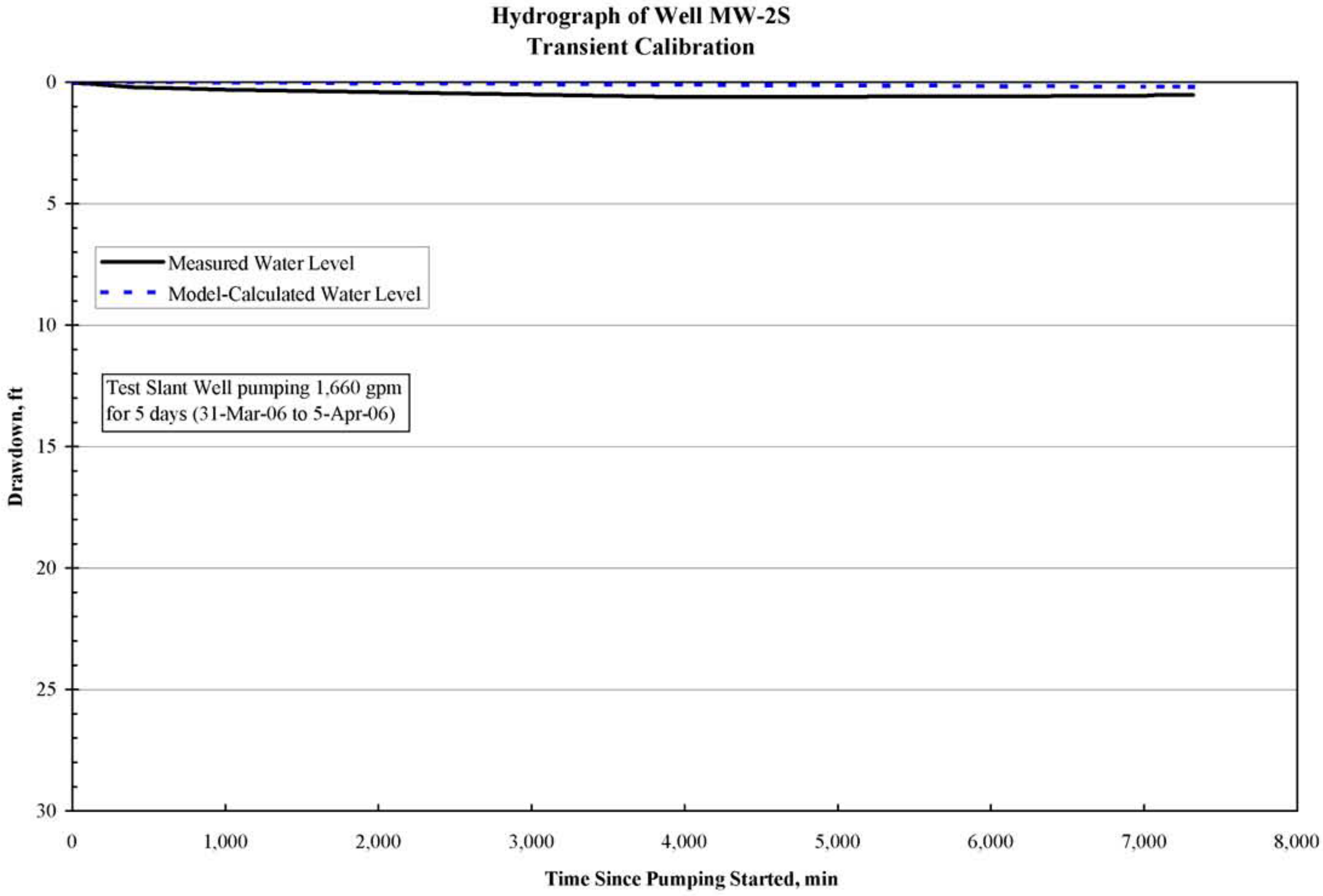

Hydrograph of Well MW-2S
Transient Calibration
Measured Water Level
Model-Calculated Water Level
Test Slant Well pumping 1,660 gpm
for 5 days (31-Mar-06 to 5-Apr-06)
Drawdown, ft
0
5
10
15
20
25
30
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Time Since Pumping Started, min

Figure 23

Hydrograph of Well MW-2M
Transient Calibration

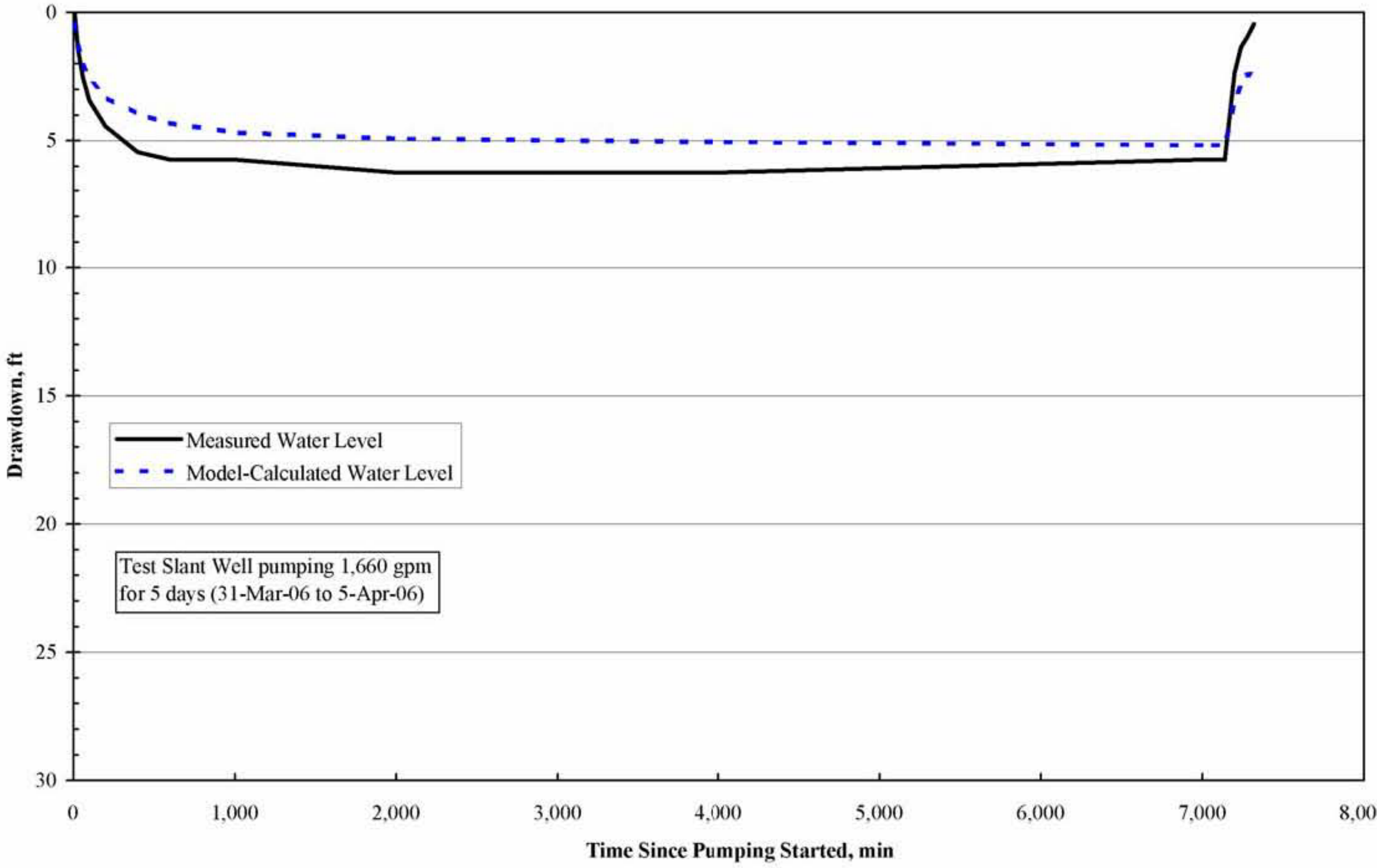


Figure 24

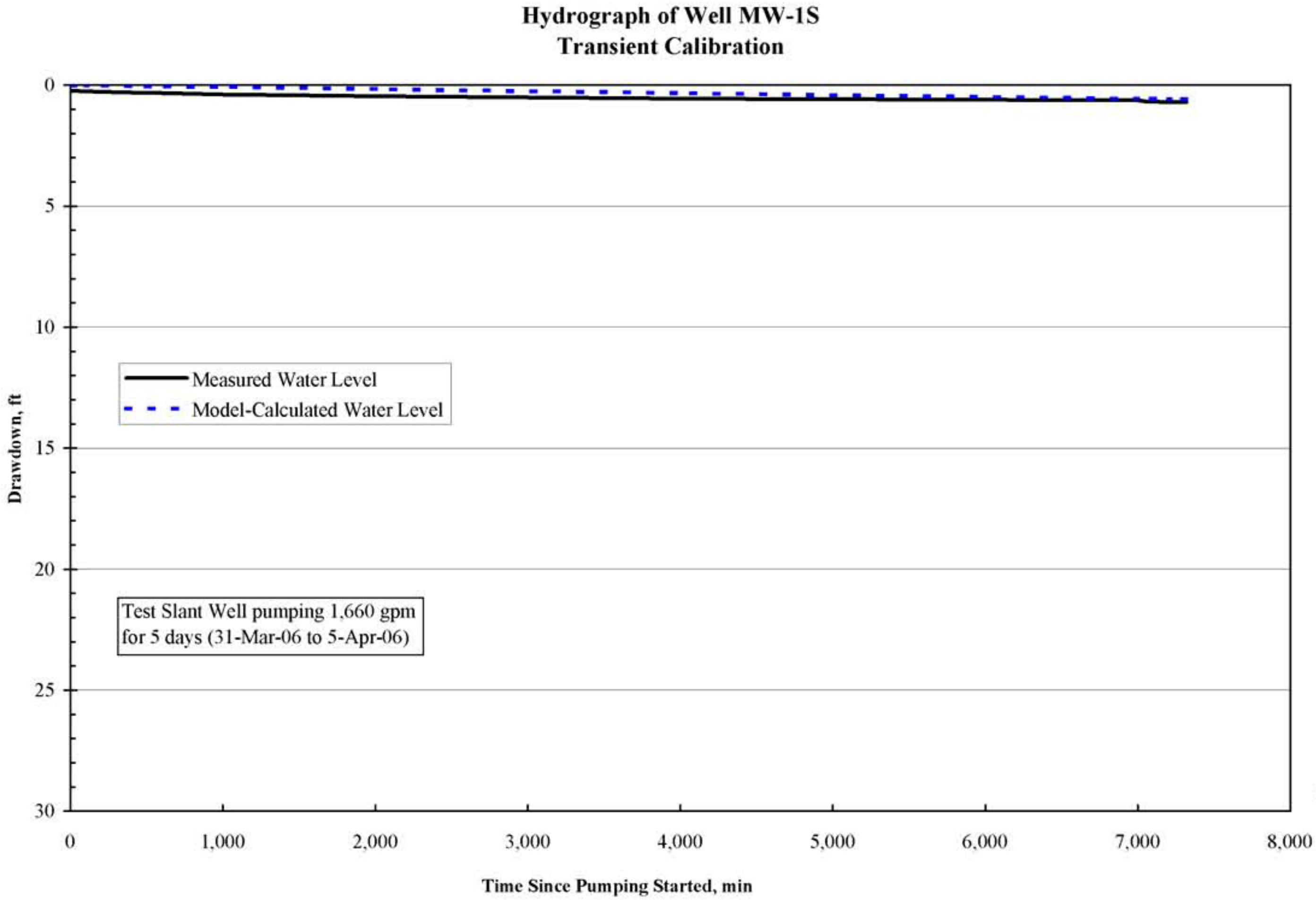

Hydrograph of Well MW-1S
Transient Calibration
Drawdown, ft
0
5
10
15
20
25
30
Time Since Pumping Started, min
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Measured Water Level
Model-Calculated Water Level
Test Slant Well pumping 1,660 gpm
for 5 days (31-Mar-06 to 5-Apr-06)

Figure 25

Hydrograph of Well MW-1M
Transient Calibration

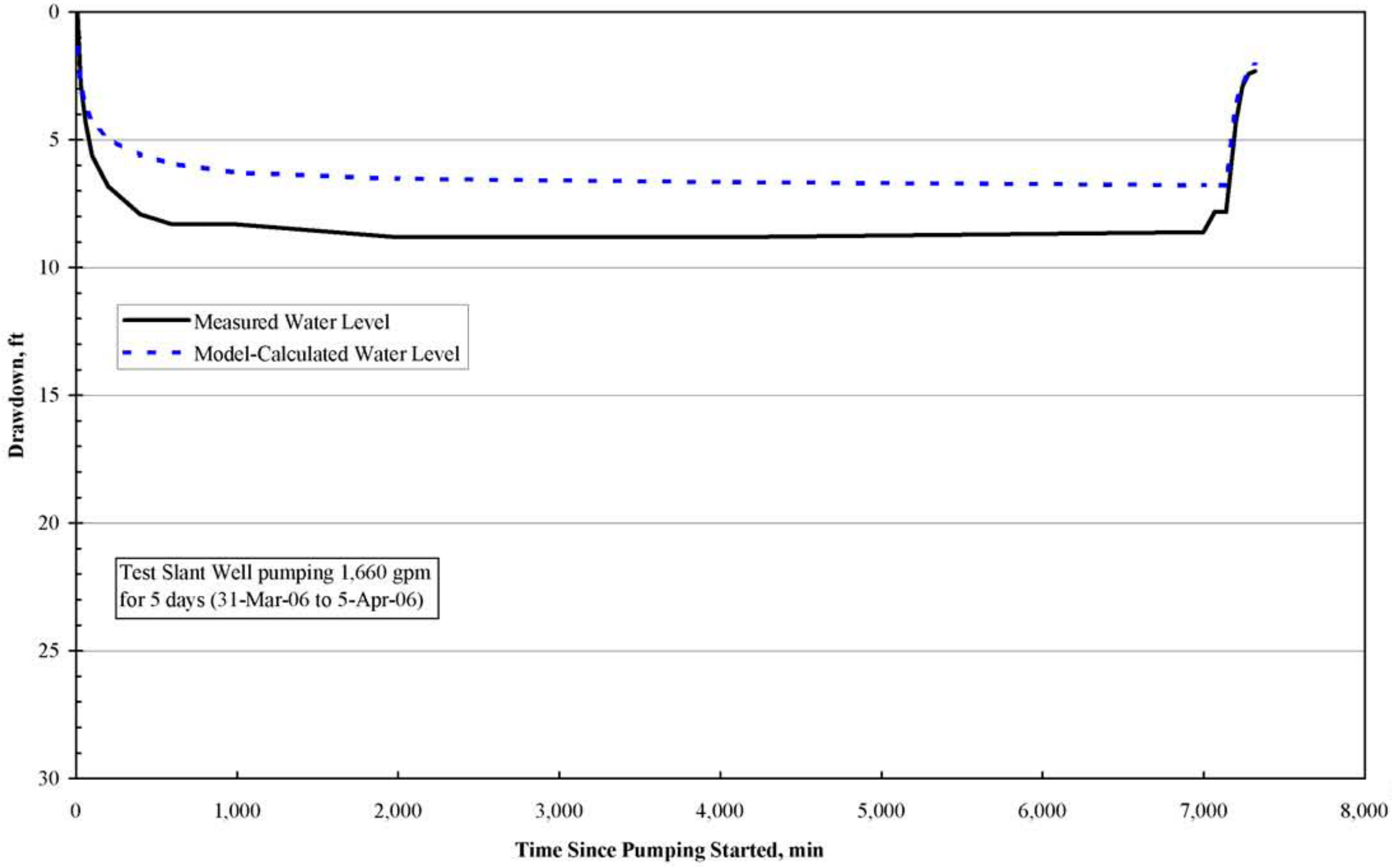


Figure 26

Hydrograph of Well SL-1
Transient Calibration

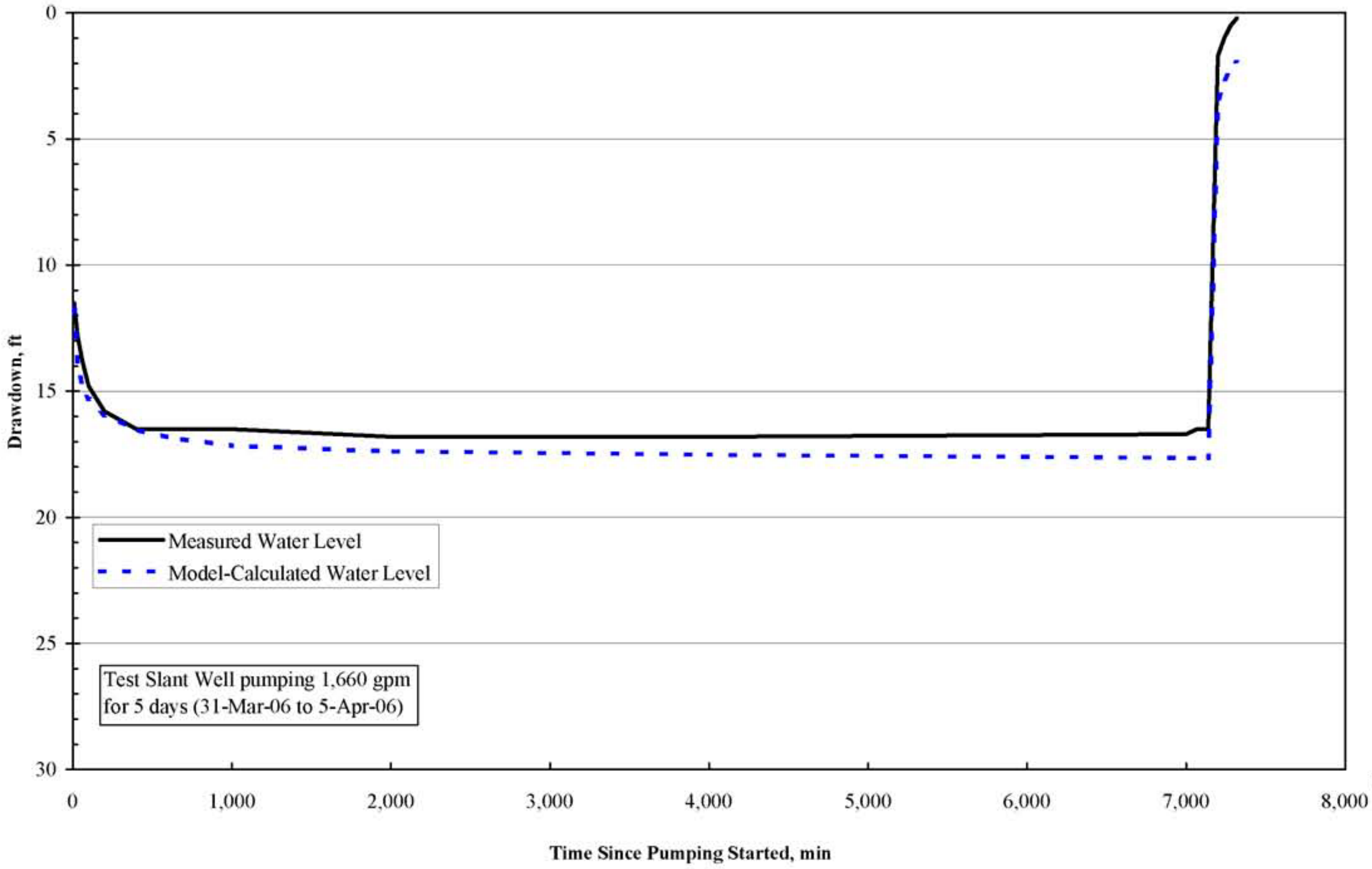


Figure 27

Measured versus Model-Calculated Changes in Water Level
Transient Calibration

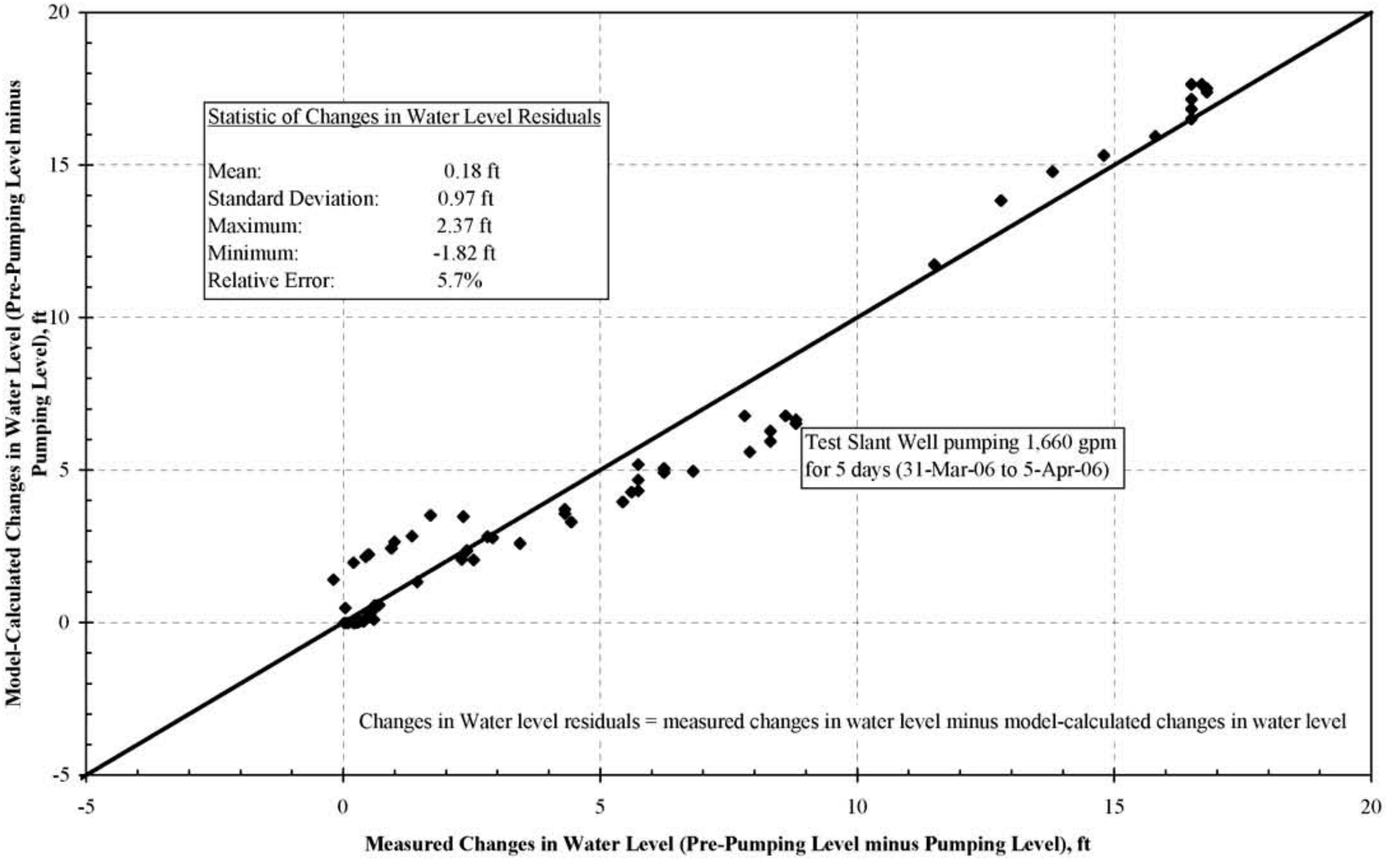


Figure 28

Total Dissolved Solids Concentration in Well SL-1
Transient Model Calibration

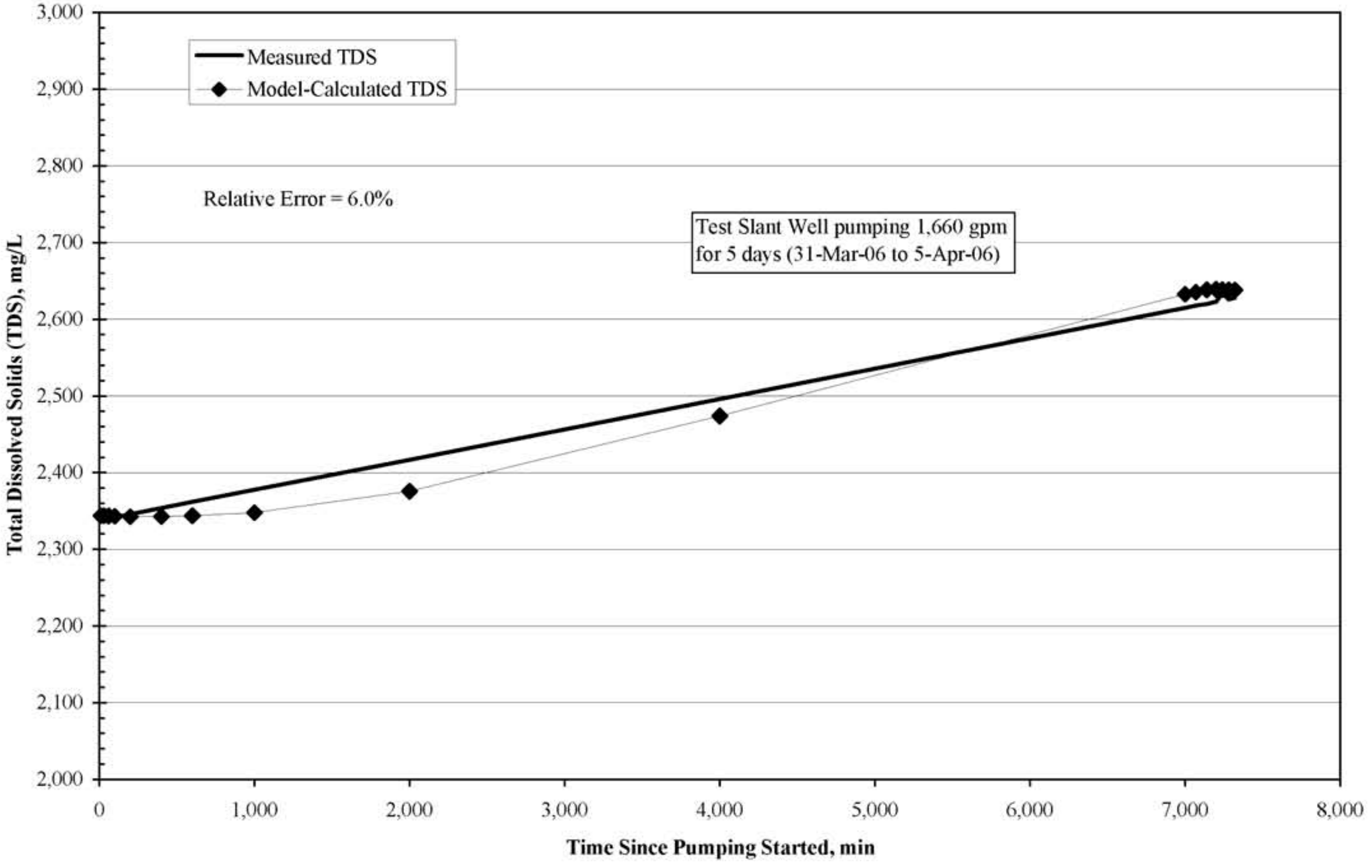
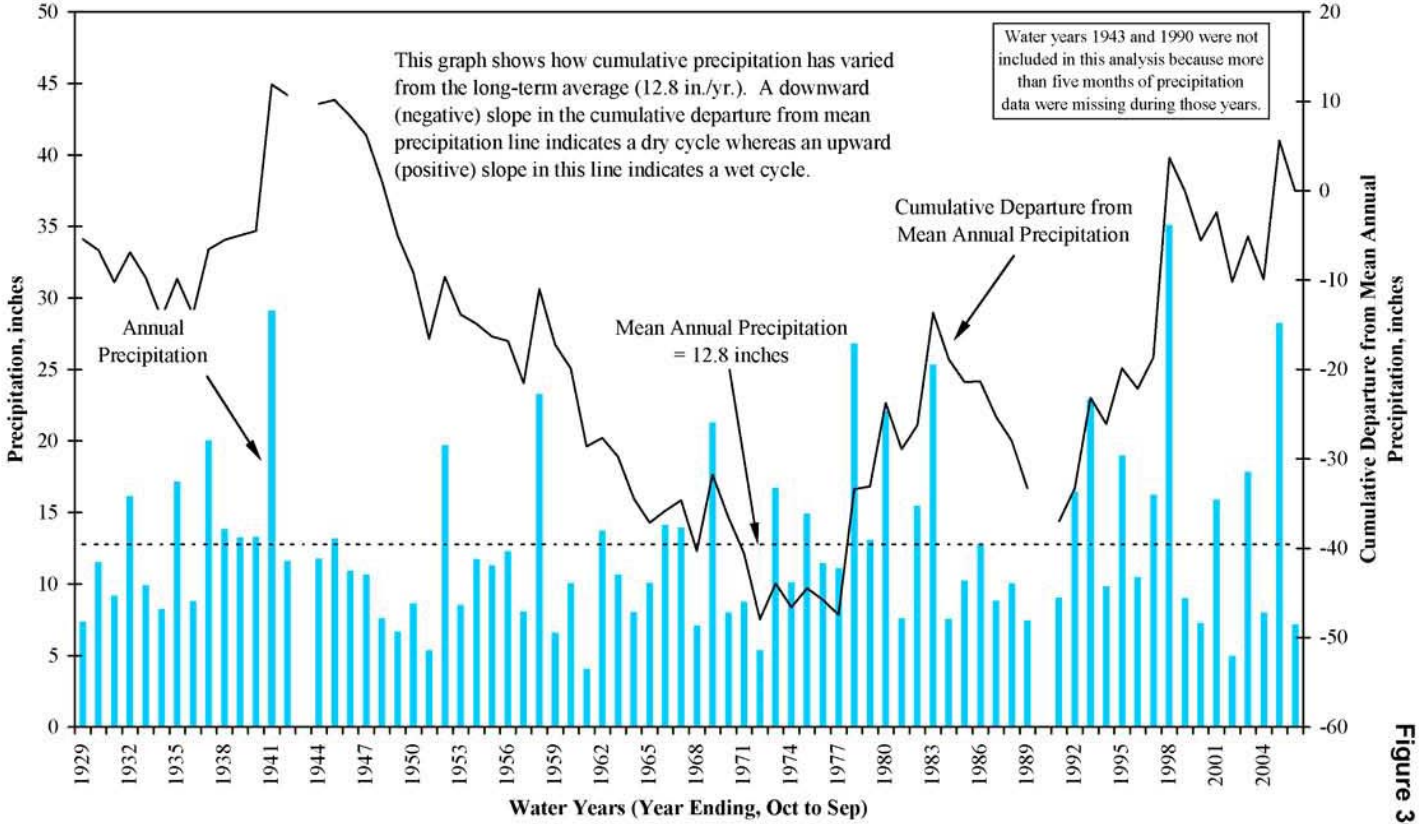


Figure 29

Annual Precipitation and Cumulative Departure from Mean Annual Precipitation
Laguna Beach, California
(1929-2006)



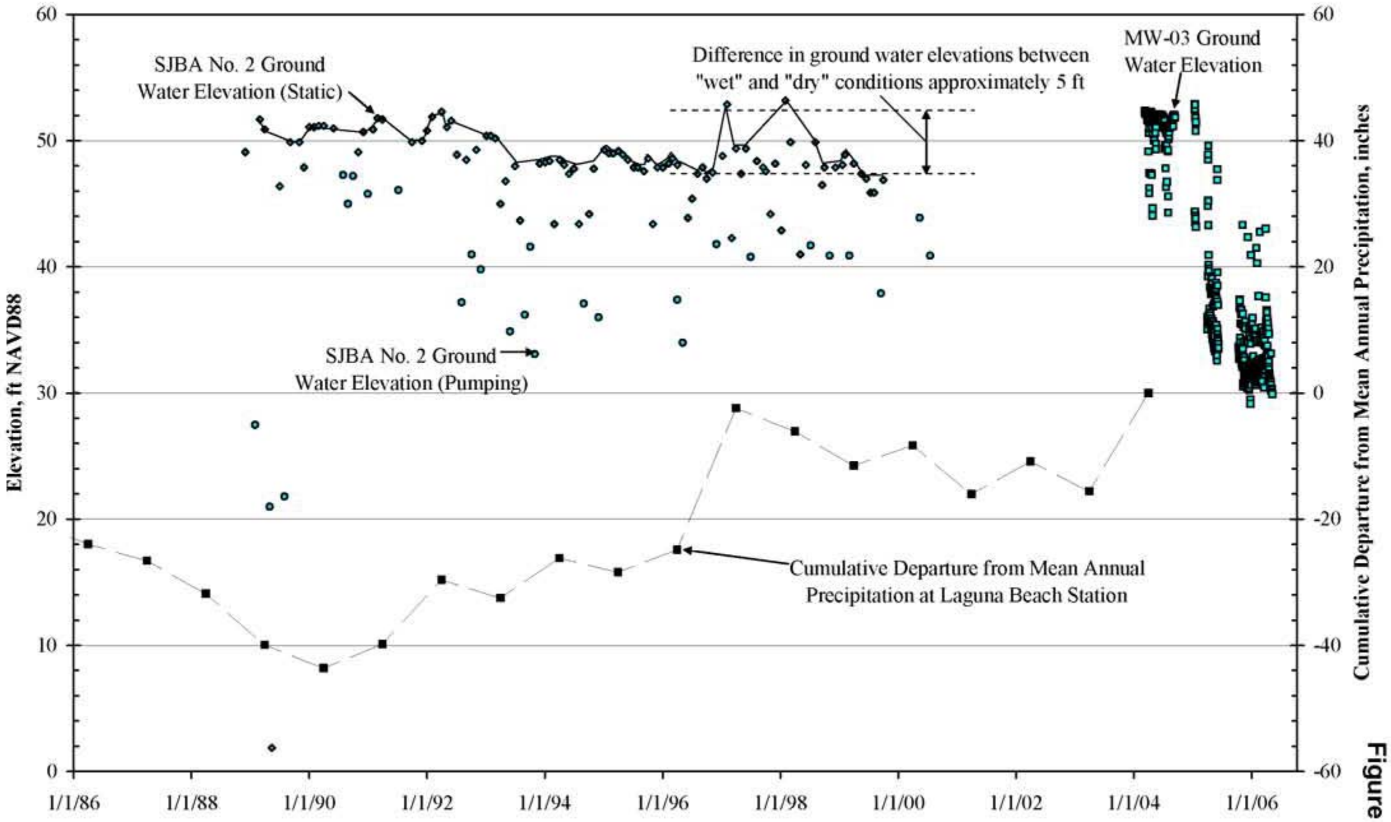
This graph shows how cumulative precipitation has varied from the long-term average (12.8 in./yr.). A downward (negative) slope in the cumulative departure from mean precipitation line indicates a dry cycle whereas an upward (positive) slope in this line indicates a wet cycle.

Water years 1943 and 1990 were not included in this analysis because more than five months of precipitation data were missing during those years.

Source of Data: Western Regional Climate Center, 2006

Figure 30

Ground Water Elevations and Cumulative Departure from Mean Annual Precipitation

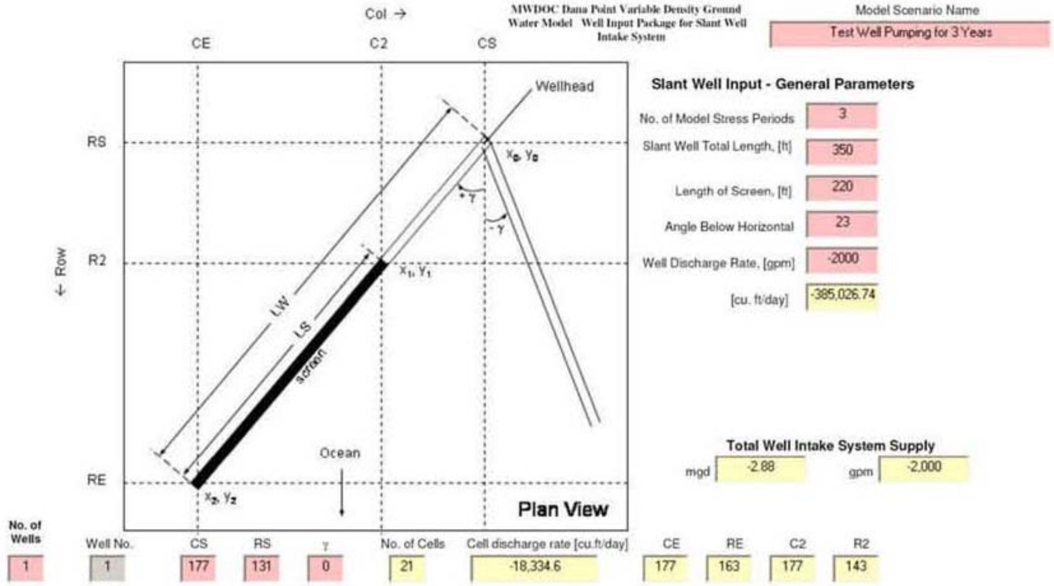


Sources of Data: Psomas, 2006; Geotechnical Consultants, Inc., 2001; EarthInfo, 2006

Figure 31

Figure 32

Slant Well Orientation within Model Grid and Discharge Rate for Model Run 1 (Test Well Pumping at 2.88 mgd)



MWDOC Dana Point Variable Density Ground Water Model Well Input Package for Slant Well Intake System

Model Scenario Name: Test Well Pumping for 3 Years

Slant Well Input - General Parameters

No. of Model Stress Periods	3
Slant Well Total Length, [ft]	350
Length of Screen, [ft]	220
Angle Below Horizontal	23
Well Discharge Rate, [gpm]	-2000
[cu. ft/day]	-385,026.74

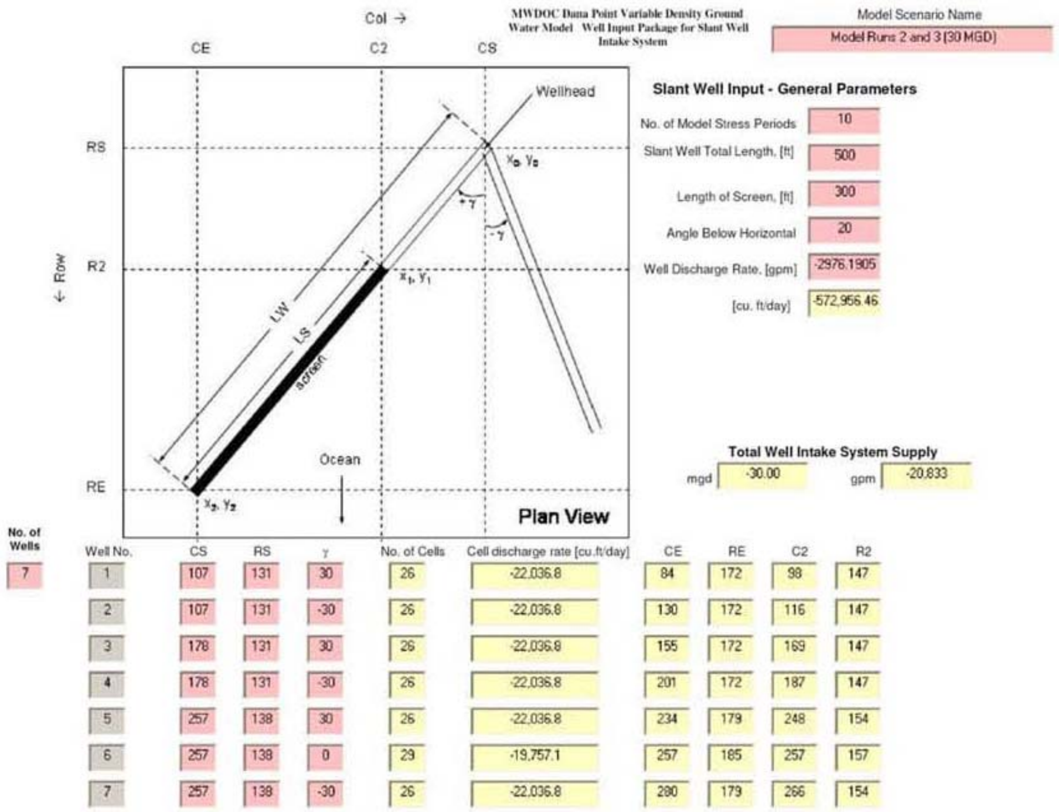
Total Well Intake System Supply

mgd -2.88 gpm -2,000

No. of Wells	Well No.	CS	RS	γ	No. of Cells	Cell discharge rate [cu.ft/day]	CE	RE	C2	R2
1	1	177	131	0	21	-18,334.6	177	163	177	143

Figure 33

Slant Well Orientation within Model Grid and Discharge Rate for Model Runs 2 and 3 (30 mgd)



MWDOC Dana Point Variable Density Ground Water Model Well Input Package for Slant Well Intake System

Model Scenario Name: Model Runs 2 and 3 (30 MGD)

Slant Well Input - General Parameters

No. of Model Stress Periods	10
Slant Well Total Length, [ft]	500
Length of Screen, [ft]	300
Angle Below Horizontal	20
Well Discharge Rate, [gpm]	-2976.1905
[cu. ft/day]	-572,956.46

Total Well Intake System Supply

mgd	gpm
-30.00	-20,833

No. of Wells: 7

Well No.	CS	RS	γ	No. of Cells	Cell discharge rate [cu.ft/day]	CE	RE	C2	R2
1	107	131	30	26	-22,036.8	84	172	98	147
2	107	131	-30	26	-22,036.8	130	172	116	147
3	178	131	30	26	-22,036.8	155	172	169	147
4	178	131	-30	26	-22,036.8	201	172	187	147
5	257	138	30	26	-22,036.8	234	179	248	154
6	257	138	0	29	-19,757.1	257	185	257	157
7	257	138	-30	26	-22,036.8	280	179	266	154

Model Run 1 (Test Well Pumping at 2.88 mgd - Wet Hydrologic Conditions)
Ground Water Elevations in Test Slant Well SL-1

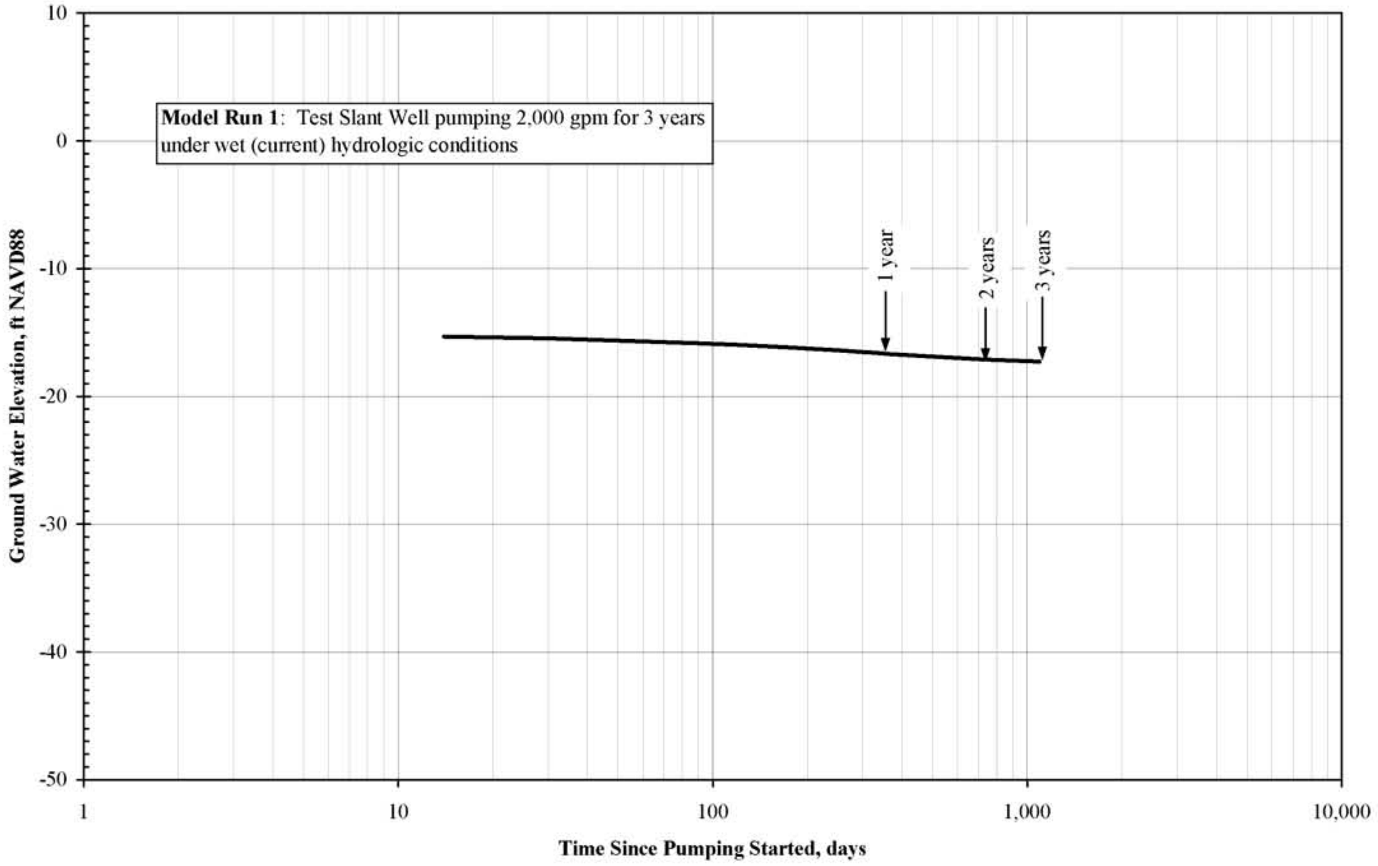
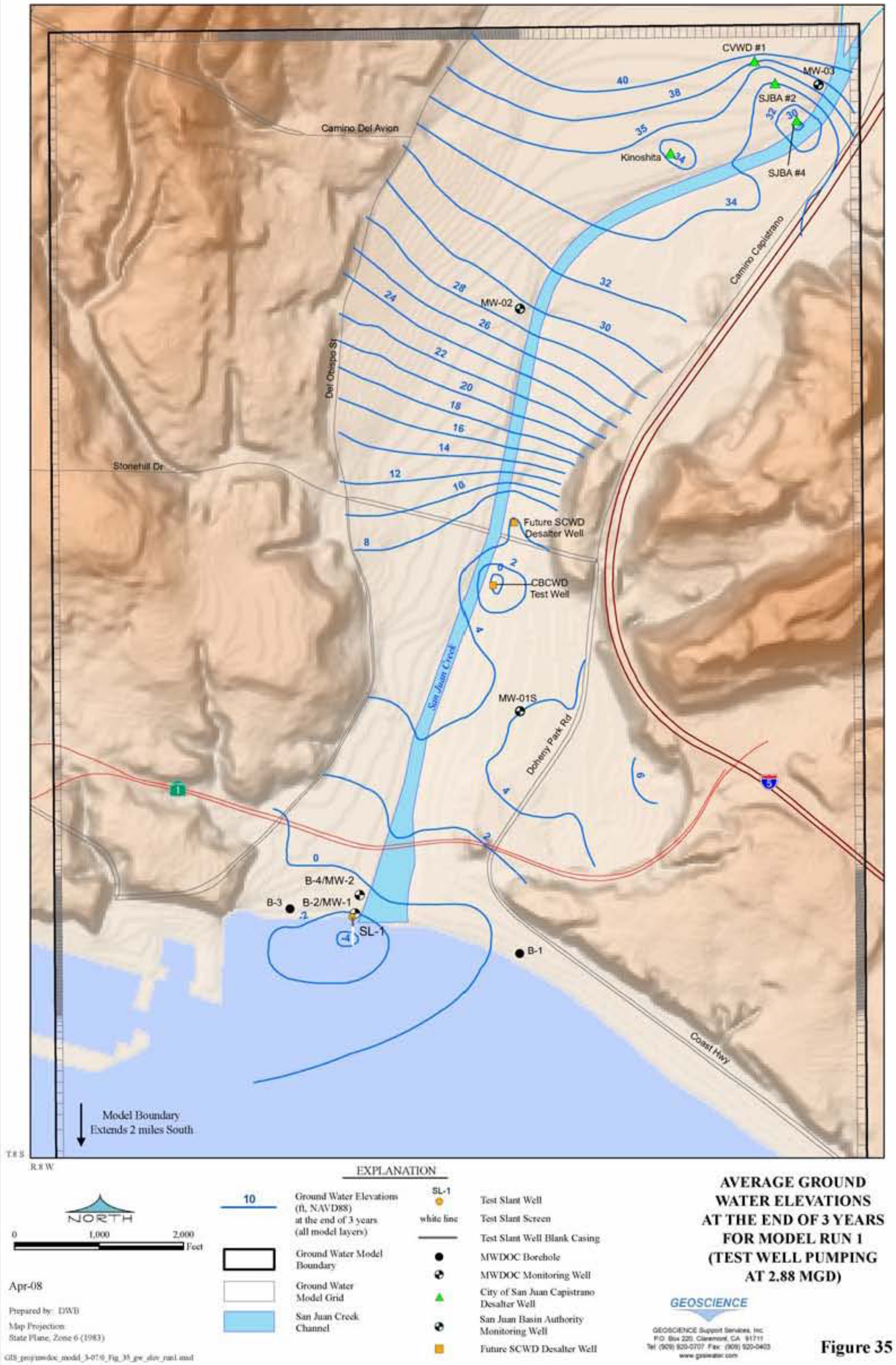
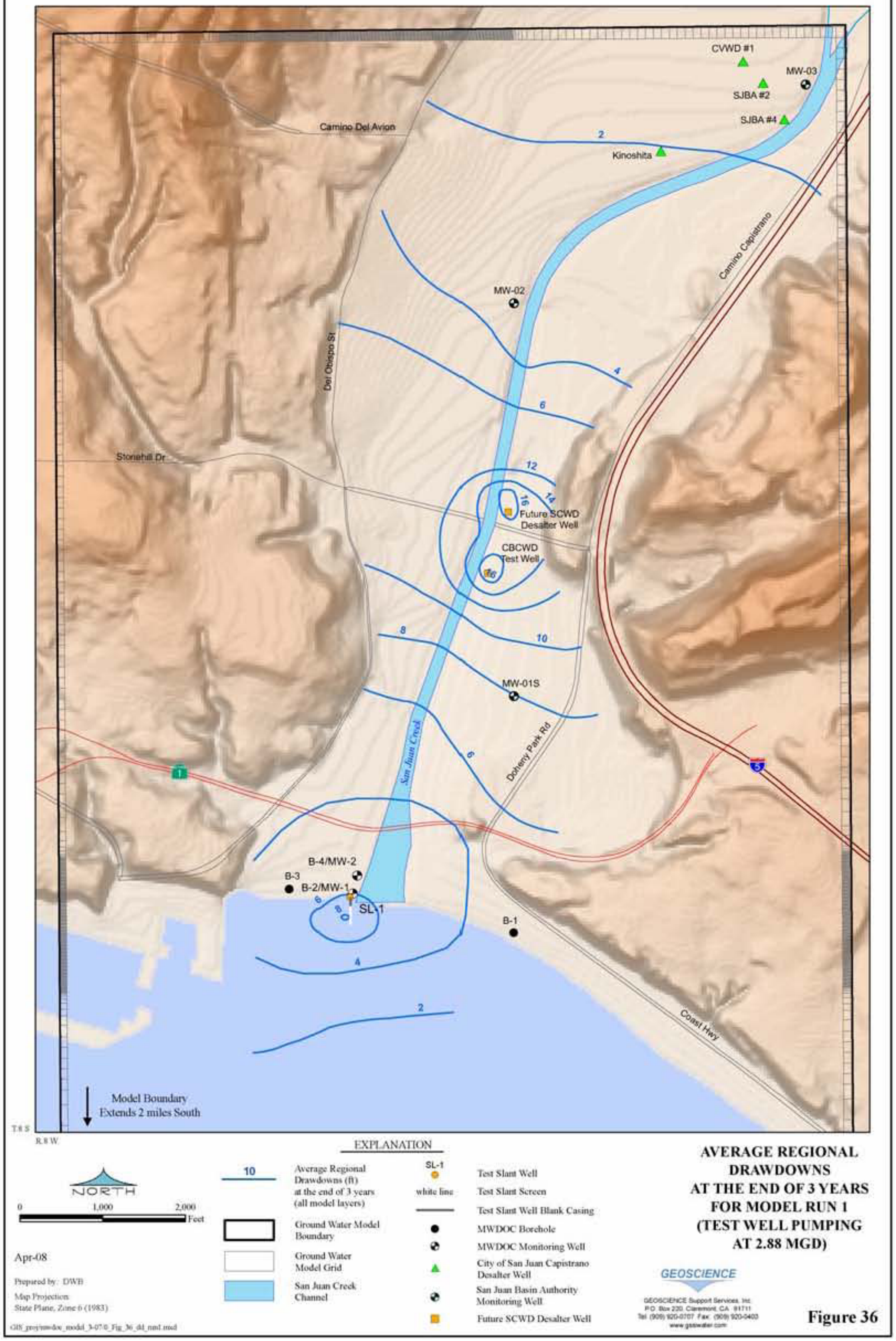


Figure 34



AVERAGE GROUND WATER ELEVATIONS AT THE END OF 3 YEARS FOR MODEL RUN 1 (TEST WELL PUMPING AT 2.88 MGD)

Figure 35



AVERAGE REGIONAL DRAWDOWNS AT THE END OF 3 YEARS FOR MODEL RUN 1 (TEST WELL PUMPING AT 2.88 MGD)

Figure 36

Predicted Shallow Zone Drawdown in Riparian Vegetation Area for Model Run 1 (Test Well Pumping at 2.88 mgd - Wet Hydrologic Conditions)

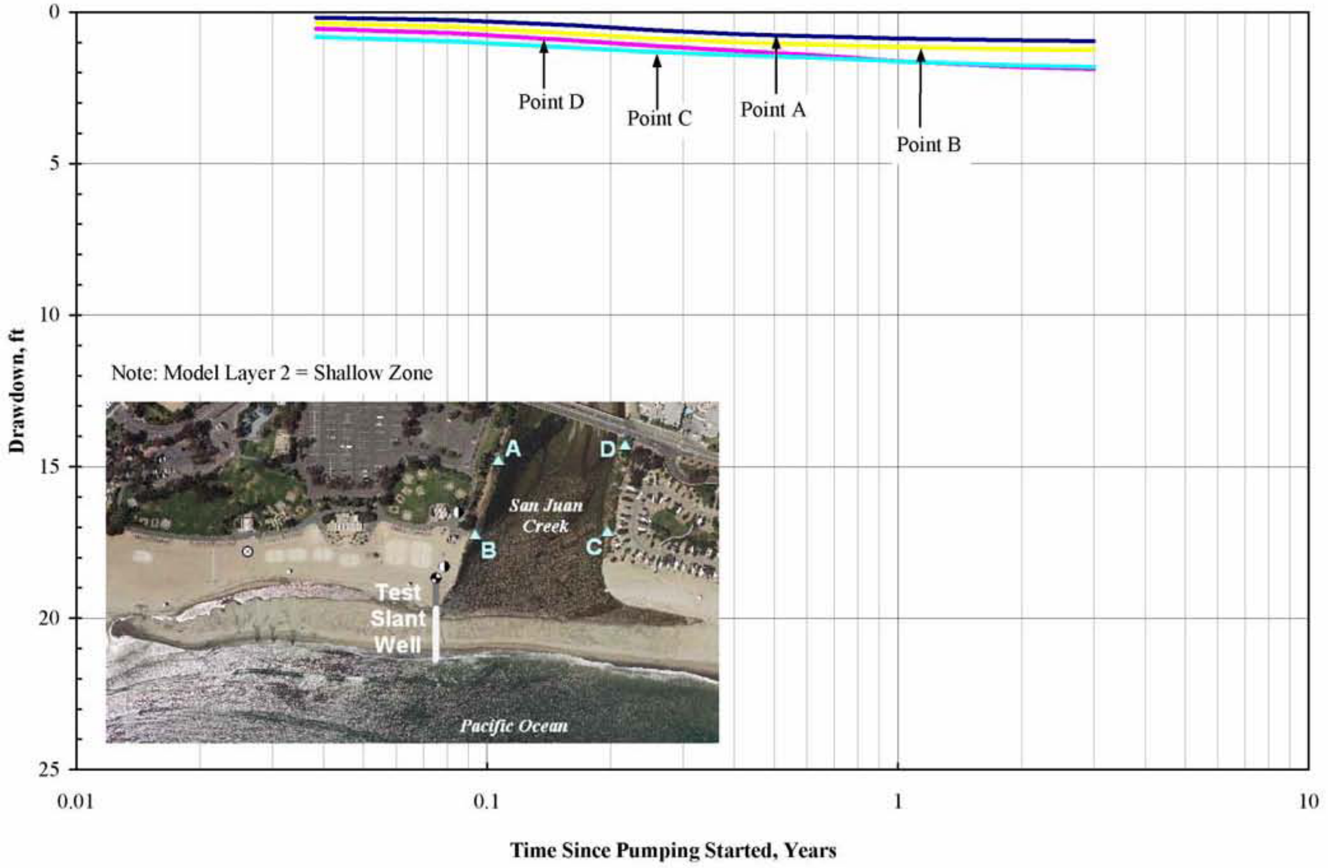


Figure 37

Model Run 1 (Test Well Pumping at 2.88 mgd - Wet Hydrologic Conditions)
Total Dissolved Solids Concentration in Test Slant Well SL-1

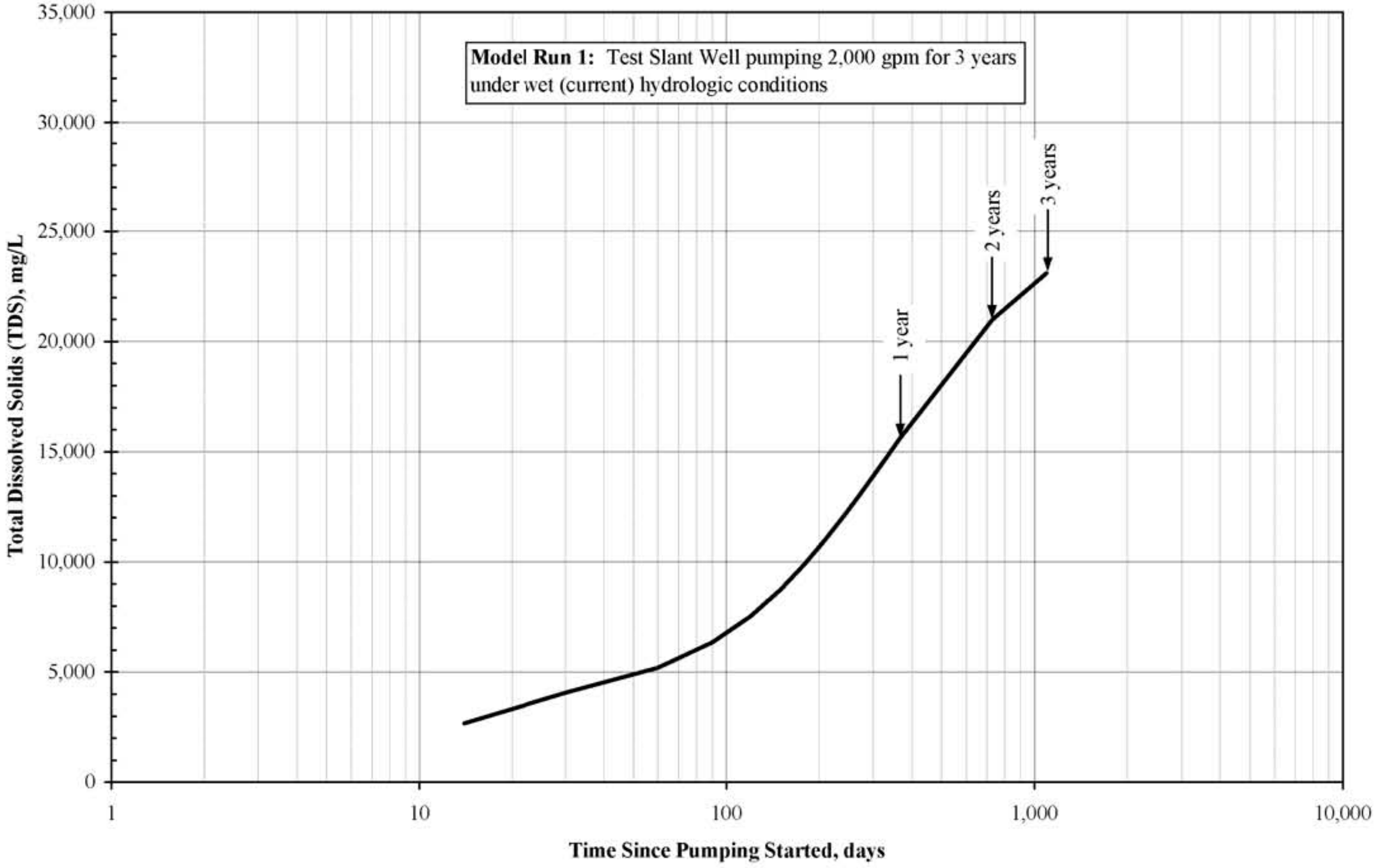

Model Run 1: Test Slant Well pumping 2,000 gpm for 3 years under wet (current) hydrologic conditions

Figure 38

Model Run 2 (30 mgd - Wet Hydrologic Conditions)
Ground Water Elevations at Extraction Wells 1 through 7

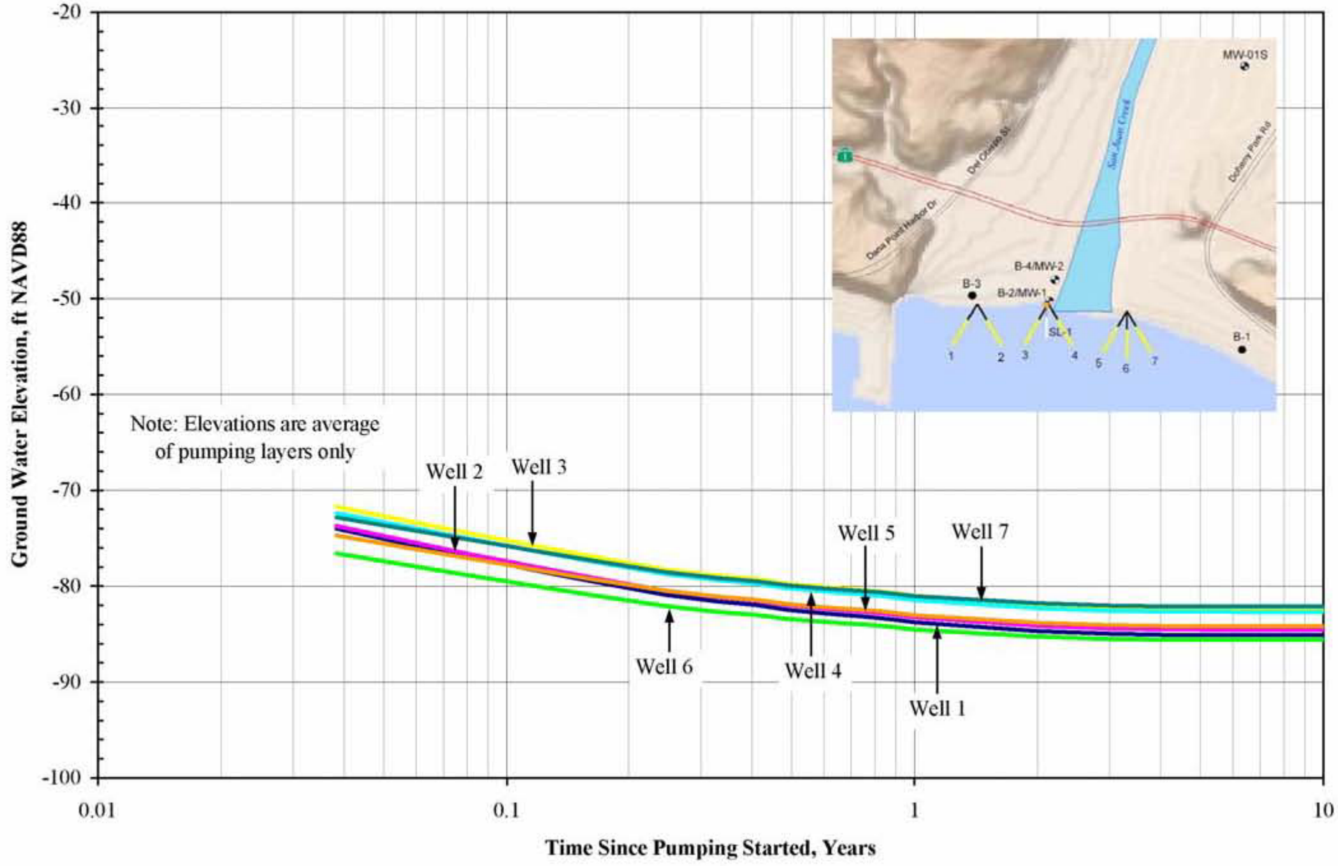
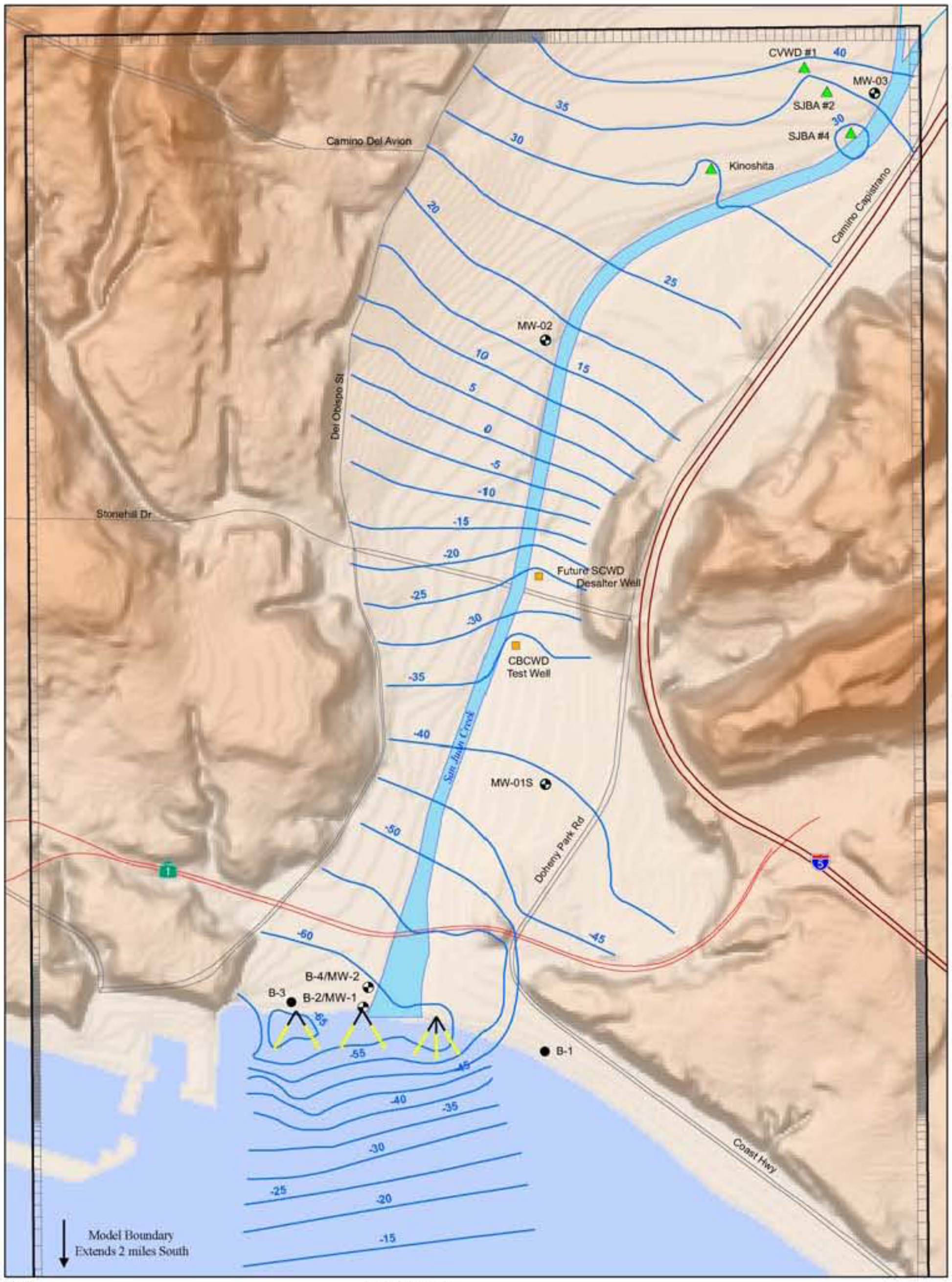


Figure 39



EXPLANATION

10 Ground Water Elevations (ft, NAVD88) at the end of 10 years Wet Year (30MGD) (all model layers)

▭ Ground Water Model Boundary

▭ Ground Water Model Grid

🟦 San Juan Creek Channel

— Slant Well Screen

— Slant Well Blank Casing

● MWDOC Borehole

◕ MWDOC Monitoring Well

▲ City of San Juan Capistrano Desalter Well

◕ San Juan Basin Authority Monitoring Well

🟧 Future SCWD Desalter Well

Apr-08

Prepared by: DWB

Map Projection:
State Plane, Zone 6 (1983)

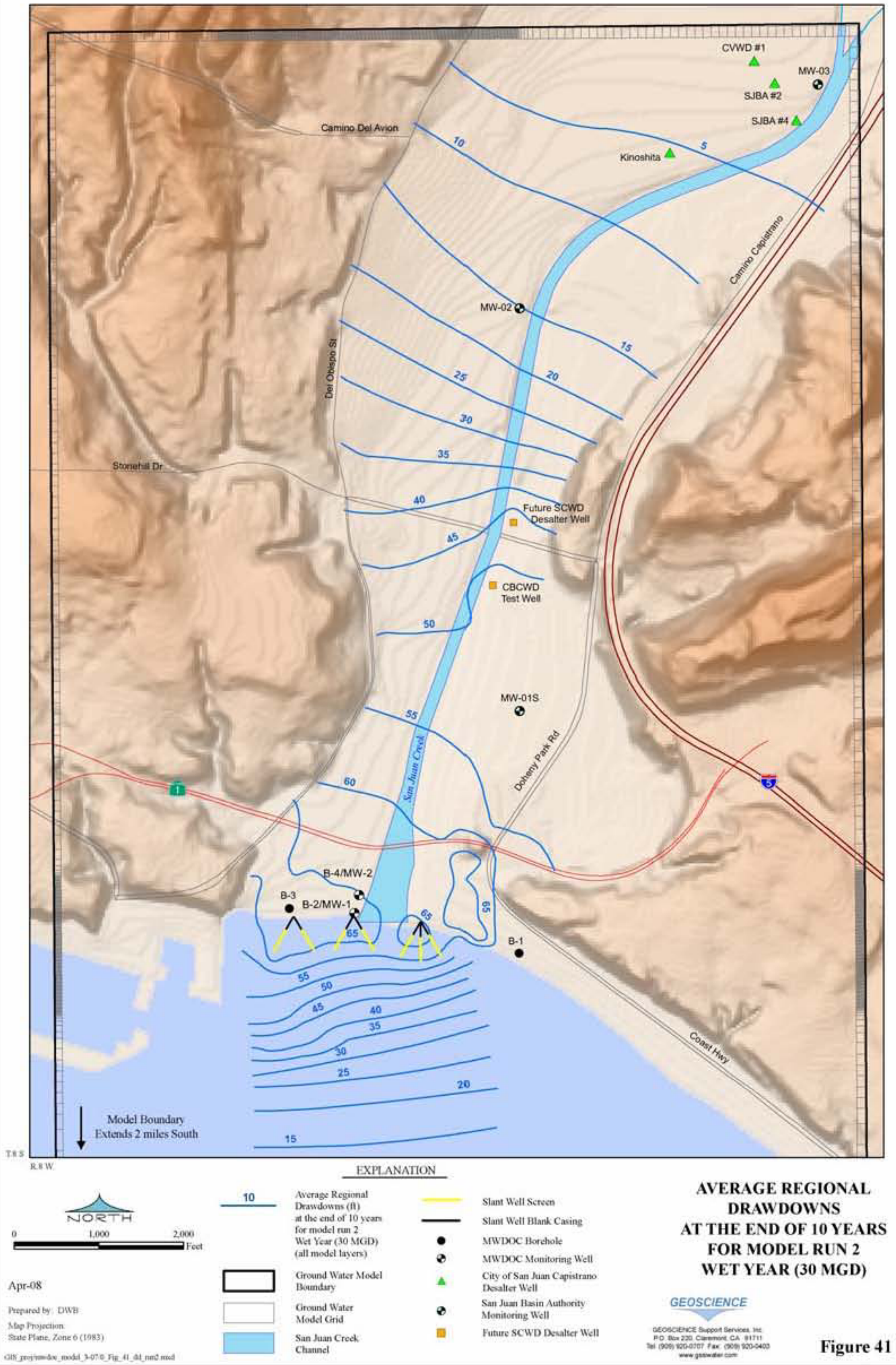
GIS_proj/mwdoc_model_3-07/0_Fig_40_gw_elev_run2.mxd

AVERAGE GROUND WATER ELEVATIONS AT THE END OF 10 YEARS FOR MODEL RUN 2 WET YEAR (30 MGD)

GEOSCIENCE

GEOSCIENCE Support Services, Inc.
P.O. Box 220, Claremont, CA 91711
Tel: (909) 920-0707 Fax: (909) 920-0403
www.gssiwater.com

Figure 40



AVERAGE REGIONAL DRAWDOWNS
AT THE END OF 10 YEARS
FOR MODEL RUN 2
WET YEAR (30 MGD)

Figure 41

Predicted Shallow Zone Drawdown in Riparian Vegetation Area for Model Run 2 (30 mgd - Wet Hydrologic Conditions)

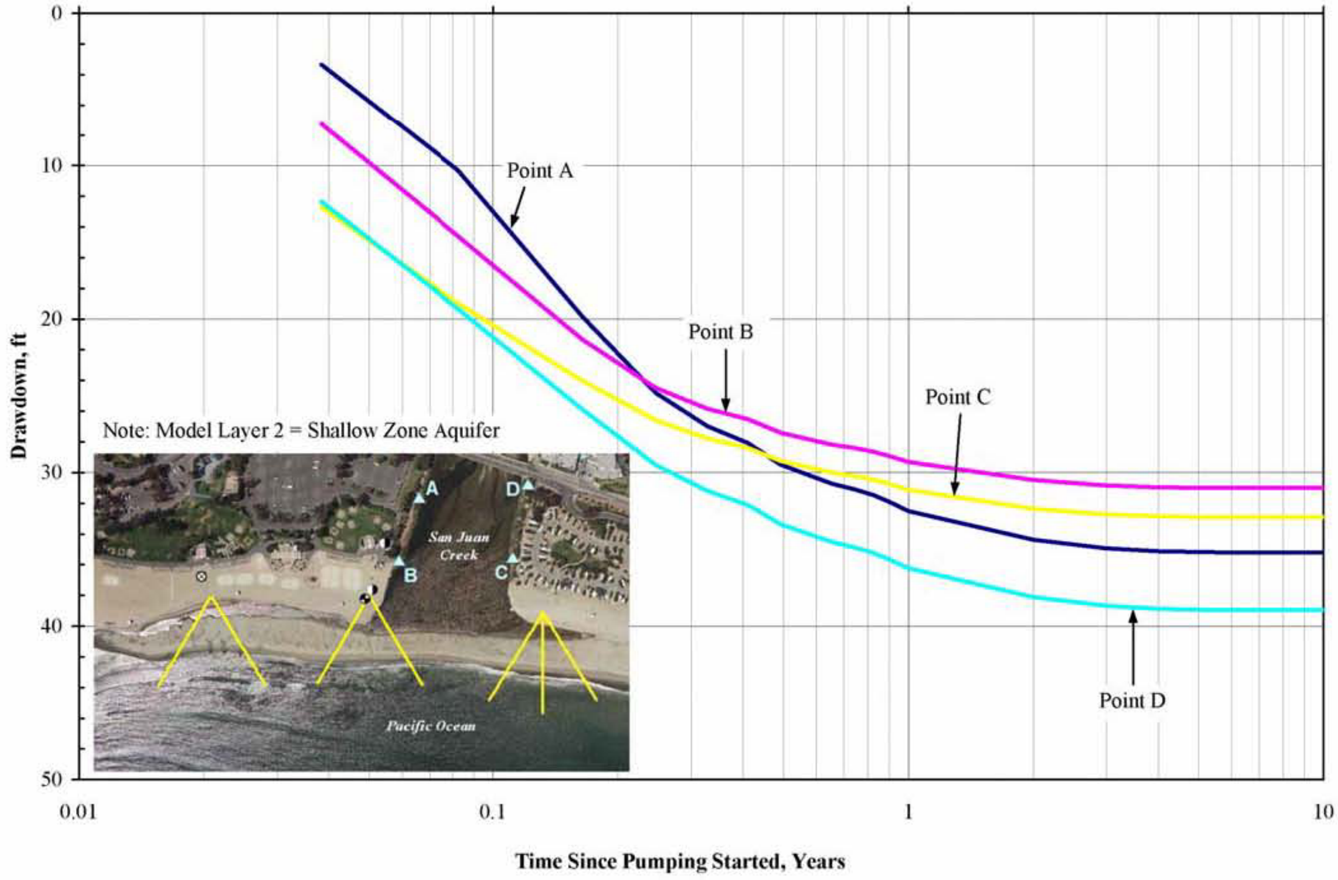


Figure 42

Model Run 2 (30 mgd - Wet Hydrologic Conditions)
Total Dissolved Solids Concentration at Extraction Wells 1 through 7

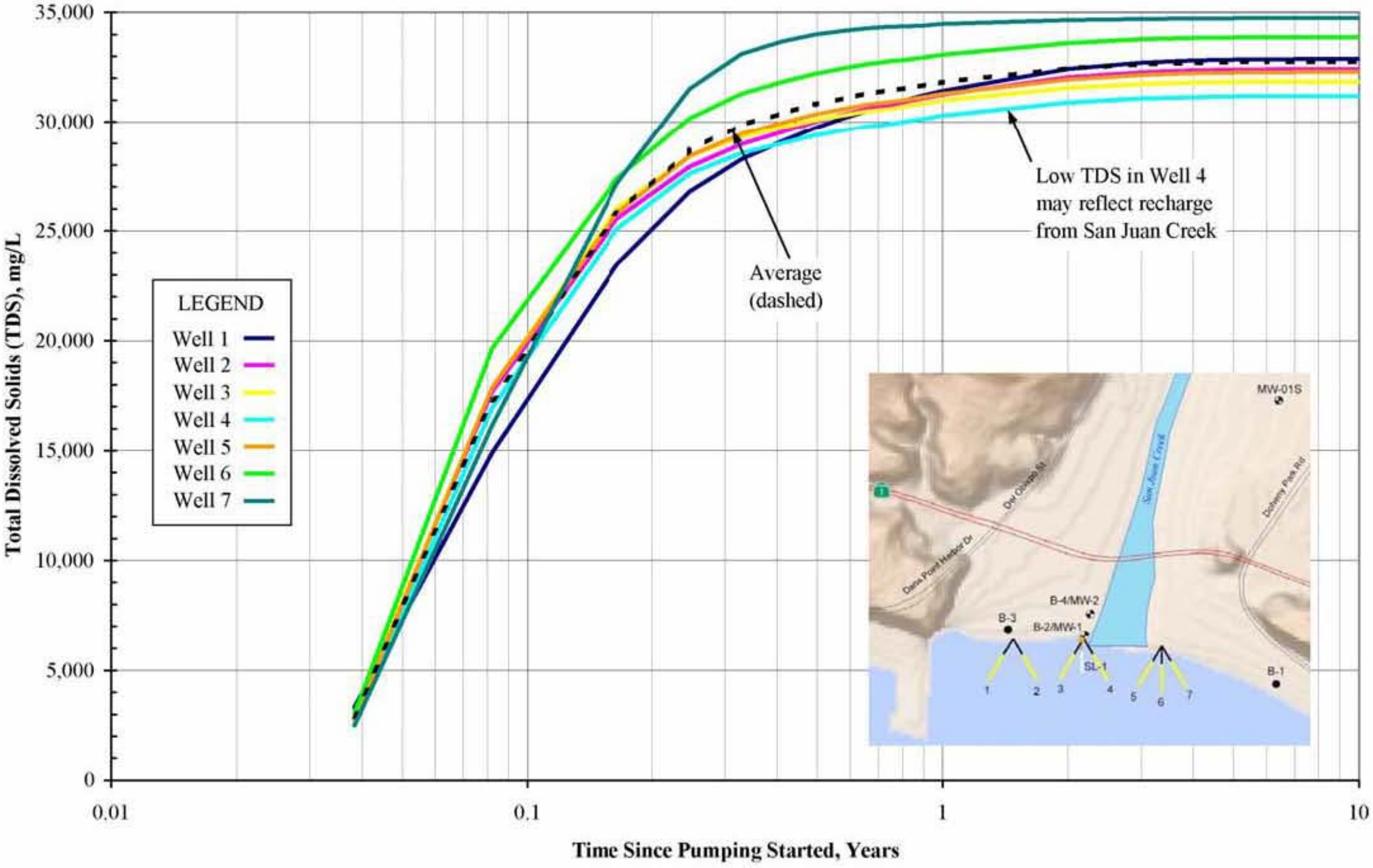
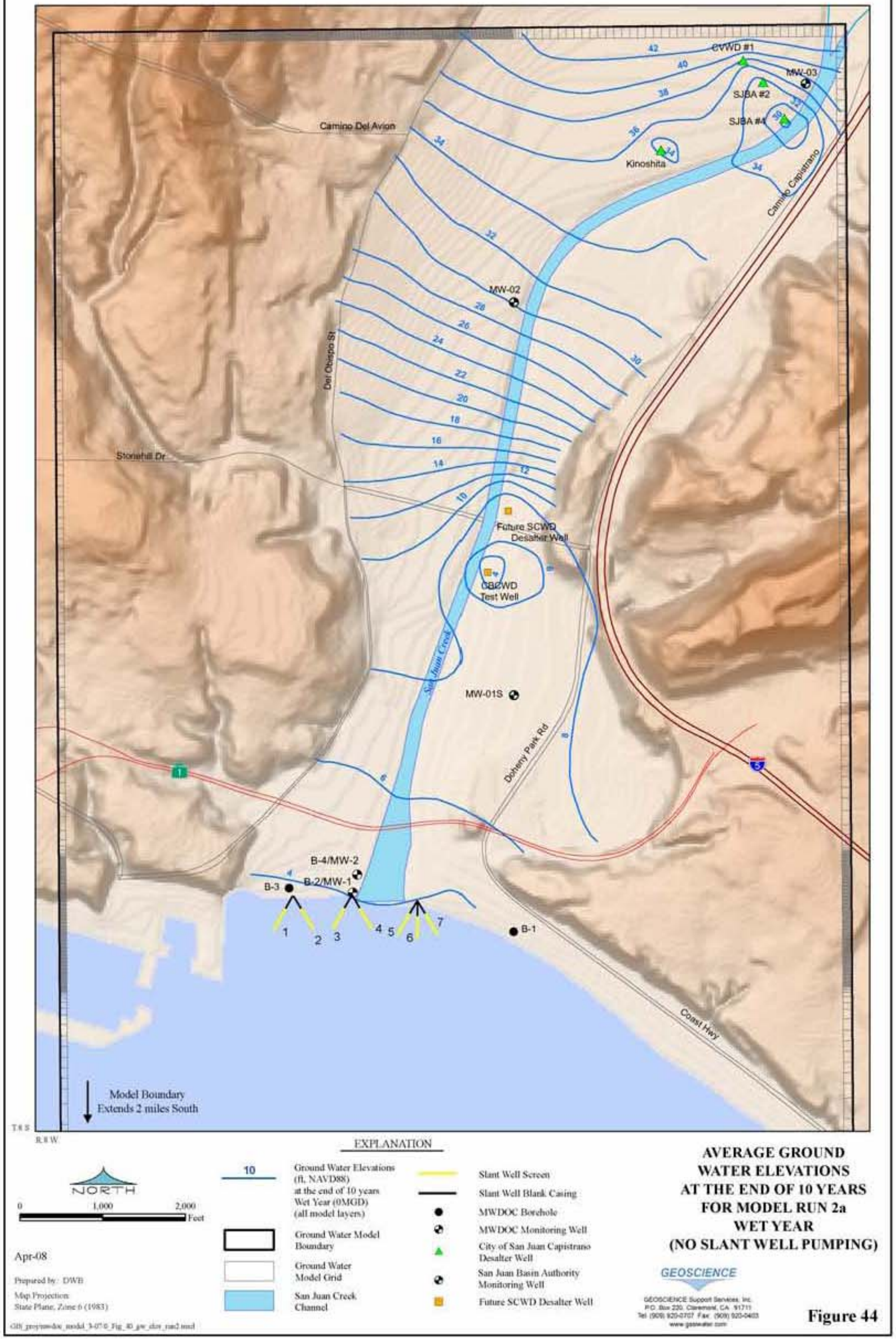


Figure 43



AVERAGE GROUND WATER ELEVATIONS AT THE END OF 10 YEARS FOR MODEL RUN 2a WET YEAR (NO SLANT WELL PUMPING)

GEOSCIENCE
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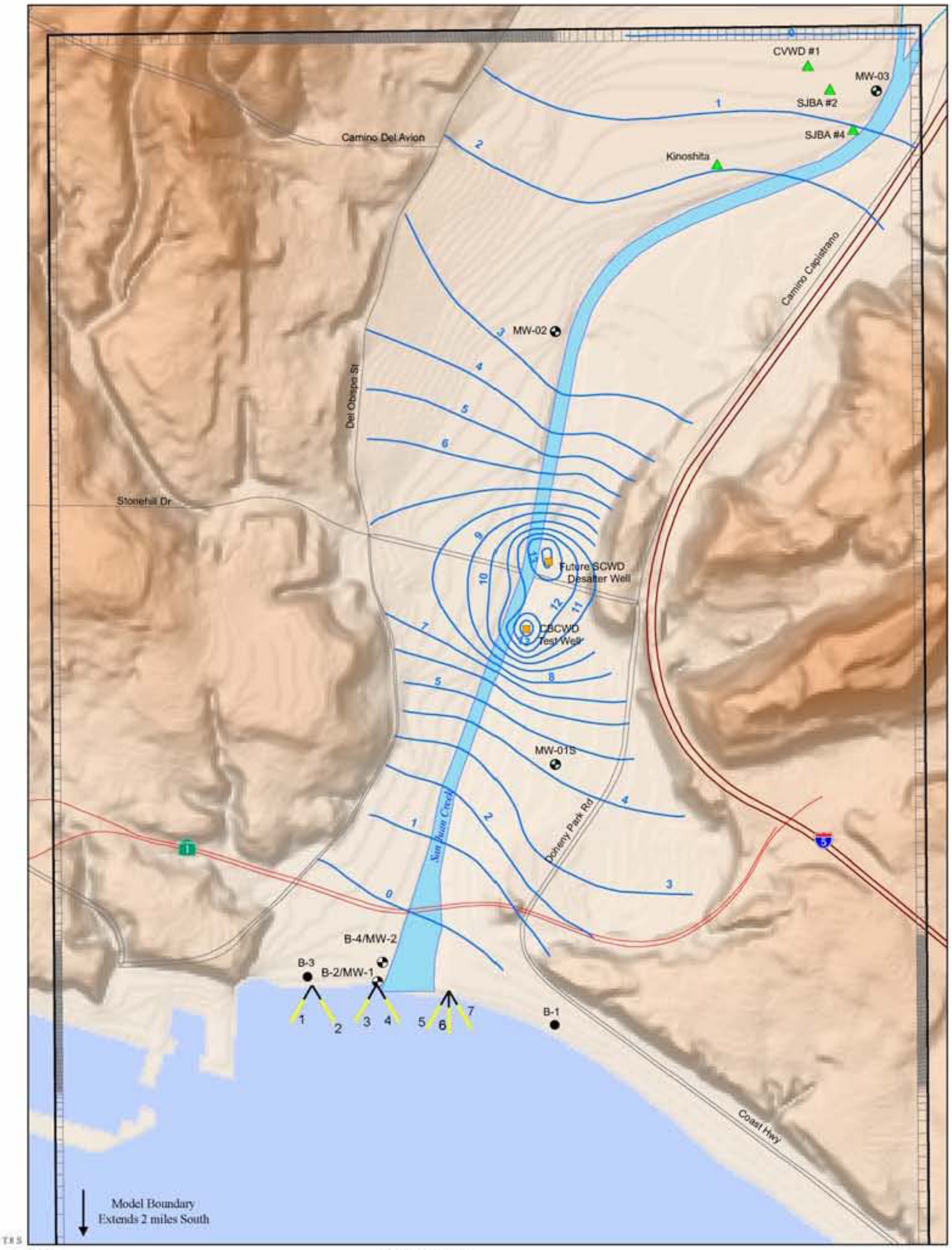
P.O. Box 220, Claremont, CA 91711
Tel: (909) 920-0707 Fax: (909) 920-0403
www.gssiwater.com

Figure 44



EXPLANATION

10	Average Regional Drawdowns (ft) at the end of 10 years for model run 2a Wet Year (0 MGD) (all model layers)
▭	Ground Water Model Boundary
▭	Ground Water Model Grid
🟦	San Juan Creek Channel
—	Slant Well Screen
—	Slant Well Blank Casing
●	MWDOC Borehole
◉	MWDOC Monitoring Well
▲	City of San Juan Capistrano Desalter Well
◉	San Juan Basin Authority Monitoring Well
■	Future SCWD Desalter Well

Apr-08

Prepared by: DWB

Map Projection:
State Plane, Zone 6 (1983)

GIS_proj/mwdoc_model_3-07/0_Fig_45_dd_run2a.mxd

AVERAGE REGIONAL DRAWDOWNS AT THE END OF 10 YEARS FOR MODEL RUN 2a WET YEAR (NO SLANT WELL PUMPING)

GEOSCIENCE

GEOSCIENCE Support Services, Inc.
P.O. Box 220, Claremont, CA 91711
Tel: (909) 920-0707 Fax: (909) 920-0403
www.gssiwater.com

Figure 45

Model Run 3 (30 mgd - Drier Hydrologic Conditions)
Ground Water Elevations at Extraction Wells 1 through 7

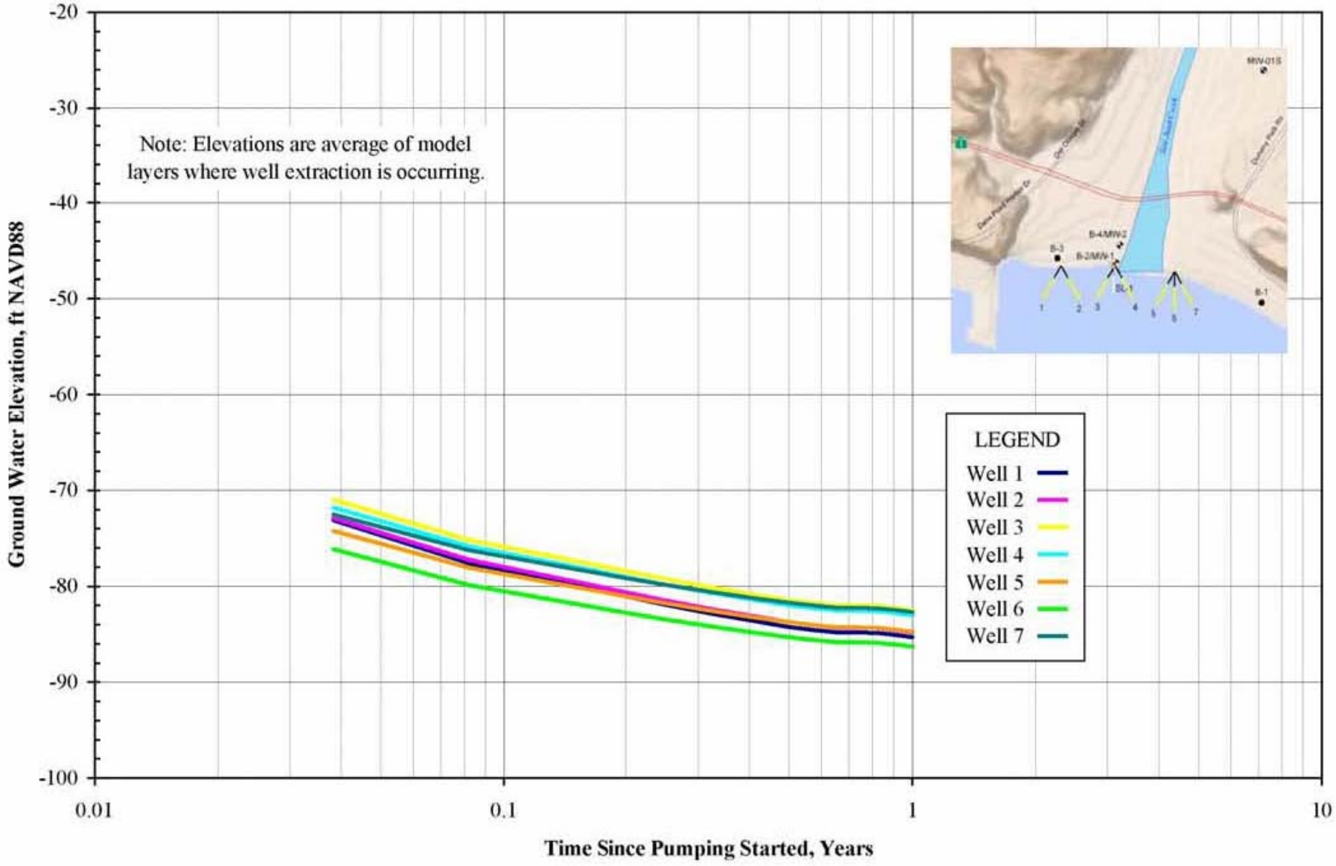


Figure 46

Predicted Shallow Zone Drawdown in Riparian Vegetation Area for Model Run 3 (30 mgd - Drier Hydrologic Conditions)

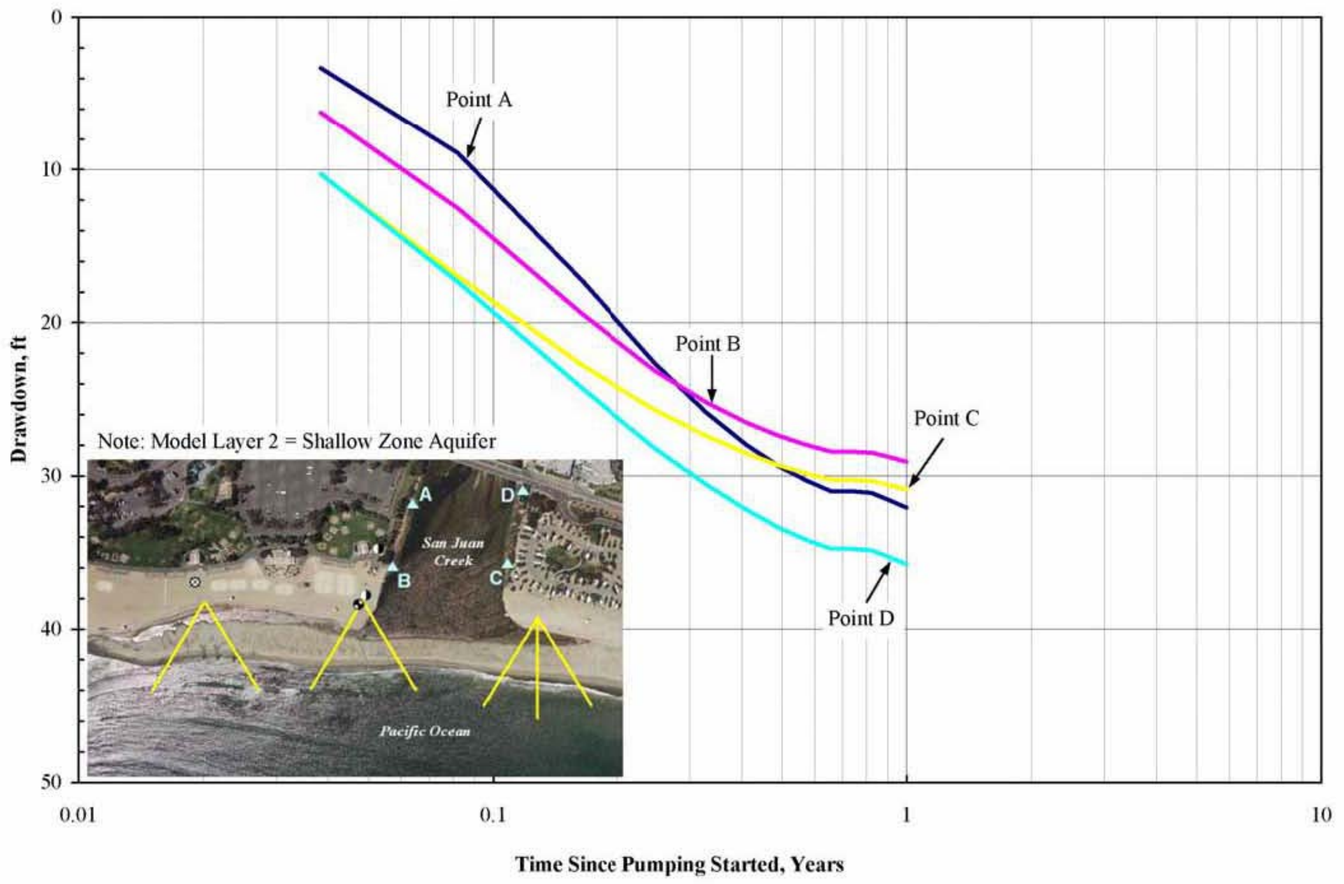
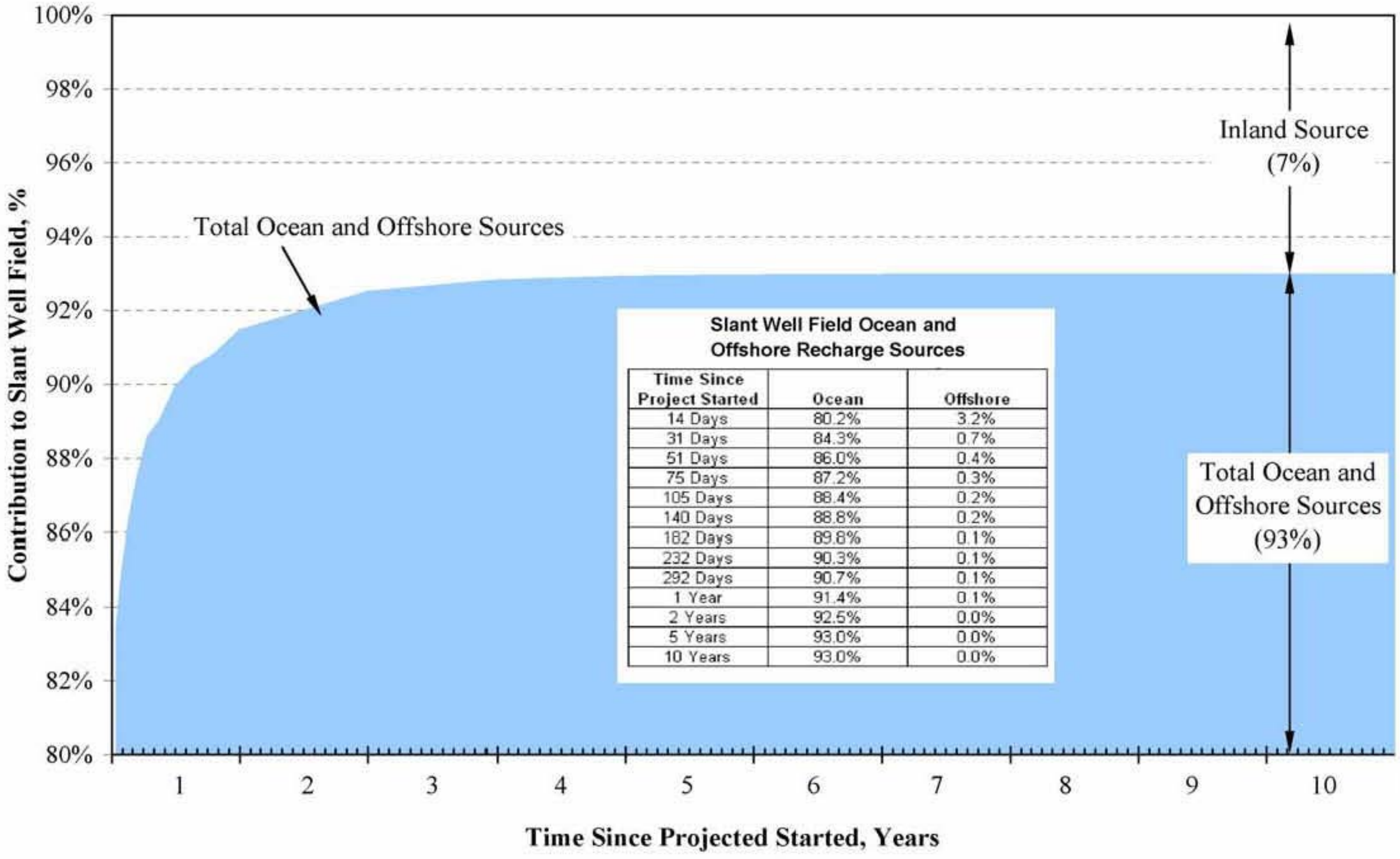


Figure 47

Seawater Recharge Sources for 30 mgd Slant Well Field



Slant Well Field Ocean and Offshore Recharge Sources

Time Since Project Started	Ocean	Offshore
14 Days	80.2%	3.2%
31 Days	84.3%	0.7%
51 Days	86.0%	0.4%
75 Days	87.2%	0.3%
105 Days	88.4%	0.2%
140 Days	88.8%	0.2%
182 Days	89.8%	0.1%
232 Days	90.3%	0.1%
292 Days	90.7%	0.1%
1 Year	91.4%	0.1%
2 Years	92.5%	0.0%
5 Years	93.0%	0.0%
10 Years	93.0%	0.0%

Figure 48

Appendix A — Comment Letters from Ground Water Modeling Peer Review Experts and San Juan Basin Authority Consultants

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
California Water Science Center
San Diego Projects Office
4165 Spruance Road, Suite 200
San Diego, California 92101-0812
Office: (619) 222-2243 Fax: (619) 225-6101
http://water.wr.usgs.gov

Date: January 17, 2007

From: Wesley R. Danskin, Research Hydrologist

To: Dr. Dennis Williams, President
Geoscience Support Services, Inc.
1326 Monte Vista Avenue, Suite 3
Upland, CA 91386

Subject: Review of draft report dated October 19, 2006, entitled "Subsurface system intake feasibility assessment task 4 report" by Geoscience Support Services, Inc.

Thank you for the opportunity to review the subject report. I enjoyed the opportunity to learn about another application of desalination of brackish ground water and in particular your design of a novel extraction system. My review is separated into general and specific comments itemized below. You may find that additional simulations testing stream-aquifer response and effect on riparian fluxes may be desirable.

SCOPE OF REVIEW

My review included the entire report including all figures and tables, but my review focused on the geology, hydrogeology, and modeling. I reviewed the general hydrogeologic reasonableness of the different well designs and evaluated the model and results for the different designs. Please note, however, that I have limited experience in the specifics of designing production wells; I am not a professional engineer though I do hold California certification as a geologist and a hydrogeologist.

GENERAL COMMENTS

In general, I found the approach, scope, and quality of the work described in the report to be appropriate and reasonable for the stated goal of developing a set of wells to pump brackish ground water from beach deposits at the mouth of a small stream in southern California. The description of the local geology and hydrogeology in the report is limited and would benefit by reference to more extensive descriptions in previous reports. The general quantity of data seems adequate for the analysis. The conceptual model of the geologic setting also appears adequate for the intended purpose of the modeling, and the magnitude of the uncertainty of the setting is typical of many geologic settings. Additional model runs may aid in evaluating and better understanding this uncertainty. The calibration data are somewhat limited for the model, and may create additional uncertainty in the model results. A proposed long-term pumping test will significantly augment the calibration data and likely will aid in reducing uncertainty of the model. The software used for the modeling analysis (MODFLOW and SEAWAT) and the numerical resolution of the finite-difference grid are appropriate. The scenarios appeared to be well posed and appropriate for the state goals. The extensive number of figures were helpful to understand the specific effects of the pumping relative to the actual field site.

SPECIFIC COMMENTS

1. A cross section showing the geologic units would be helpful in order to better and more quickly understand the relation between the wells, land-surface features, geologic units, and proposed wells. Figure 6 is difficult to interpret and some of the labeled features are not on figure 4. Although I found the description of the geologic setting to be a bit difficult to absorb quickly (e.g multiple names, different names for the same thing–bedrock, Capistrano Fm, siltstone), after closer and repeated reading, the geologic setting seemed plausibly constructed, and the modeling approach seemed appropriate for the geologic setting.
2. The hydraulic connection of the various units to each other, to the ocean, and to the stream are critically important and should be addressed more fully in the text. Preferably, the real physical setting would be described including uncertainties, and then the method described to simulate this setting (for example constant heads, head-dependent boundaries). Observed fluctuations in ground-water levels and salinity may aid in this understanding and in illustrating the characteristics of the aquifers and their connection to the ocean and stream.
3. The stream does not appear to be simulated in the model as an additional source of water (head-dependent line source/sink) so the effect of the pumping on the stream may not be well described. The wells could significantly affect streamflow, potentially in different areas of the stream reach, potentially wherever the middle aquifer is connected to the stream runoff, even at some distance from the wells. The purpose of the model is stated on page 20 "to assess … the effect of proposed intake operations on … fresh water aquifers." It is not clear that this has been achieved for the shallow zone and in particular for the surface-water/ground-water interaction as much as may be requested or required for adequate environmental documentation.
4. Similarly, the effect of the pumping on the riparian vegetation should be clarified in terms of changes in evapotranspiration. The effect is shown only as changes in ground-water levels. If the likely changes to the riparian vegetation are important, testing of different ways to simulate the near-surface environment may be warranted.
5. The length of the transient calibration (5 days) seems remarkably short to then evaluate the effects of the pumping over a 10-year period. The system is relatively small, is highly stressed by the new pumping, and therefore appears to equilibrate rapidly. Perhaps with these characteristics, a short, generalized calibration are adequate to answer the engineering questions about well capacity and likely salinity flowing to the wells. Questions about effects of the new pumping on seasonal streamflow, on changes in riparian vegetation, on other wells, and on offshore discharge of fresh water may not be well answered by the short transient calibration period. The proposed long-term, multi-month pumping test using the existing test slant well will help to clarify these issues.
6. The SEAWAT 2000 computer code uses actual heads in the aquifer and converts these to equivalent fresh-water heads for internal calculations. Actual heads may infer or disguise important vertical gradients. For example, the apparent hydraulic head ranges from +2 in the shallow aquifer to –2 at depth, inferring a downward gradient, if differences in salinity are neglected. Some discussion of the actual vertical flow direction and approximate magnitude would be helpful.
7. The use of the term "conservative" in the report has meaning relative to the operation of the pumping wells, resulting changes in ground-water levels, and the

likely TDS of the pumped water. Conservative may not have the same meaning in other contexts.

8. The TDS variations for MW-03 are larger than I would expect considering the narrow range of fluctuations in MW-02. Because MW-03 is essentially a boundary condition, the fluctuations may be important to understand, though the maximum TDS is significantly below that induced by seawater intrusion.
9. The conclusion that the effect of the wells on riparian vegetation (page 46) is less during dry conditions is not intuitive. Some additional description would be helpful. For example, the constant-head boundary representing the ocean is closer to the shoreline during dry periods, which results in more recharge to the wellfield and less effect on riparian vegetation.
10. The description of the location of the saltwater/freshwater interface and effect of bedrock was helpful for wet and dry conditions. It is not intuitively obvious to me why the bedrock would have more effects during wet conditions when the saturated thickness is greater. Perhaps check this assessment and ensure it is correct.

Σ²Π

S.S. PAPADOPULOS & ASSOCIATES, INC.
ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS

January 30, 2007

Dennis Williams
GEOSCIENCES, Support Services, Inc.
P.O. Box 220
Claremont, CA 91711

Subject: **Review of Subsurface System Intake Feasibility Assessment – Task 4 Report Dated October 19, 2006**

Dear Mr. Williams:

I have reviewed the above referenced document. My major comment regards the southern boundary conditions of the model. This boundary condition, as I understand it, is a constant head boundary near the position of the freshwater-saltwater interface. Most groundwater that is pumped from the slant wells enters the model domain via this boundary.

I have two concerns with this boundary condition: 1) no physical reason to locate the boundary at the assumed location of the interface as the position of this boundary is not constant and 2) lack of explicit simulation of flux at the seabed interface. In the general case, the use of this type of boundary condition causes drawdown in the vicinity of pumping wells to be underestimated.

In my opinion, it would be preferable to use a no-flow boundary condition at the southern limit of the model domain, and to specify a constant head at the seabed interface. With boundary conditions specified in this manner, most water pumped from the slant wells would originate within the model domain. The current model domain is inappropriate for use with these boundary conditions; to have a useful model it would be necessary to extend the model domain further to the south – either to the limit of the alluvial deposits or sufficiently far to the south such that pumping of the slant wells would cause negligible drawdown at the southern boundary. The constant head condition at the seabed interface is typically created by assigning a constant head to layer 1 in areas where the ocean overlies active model cells. When this is done, layer 1 is defined such that the center of layer 1 corresponds with the interface. An alternative method of specifying a constant-head type boundary condition would be to use "river" type boundary conditions where the conductance term is defined on the basis of the vertical hydraulic conductivity and the depth of the center of the node in layer 1 from the interface.

A related issue is the assignment of no-flow boundary conditions at the seabed interface. As most of the groundwater that is pumped from the slant well will ultimately come from infiltration at the seabed interface, it makes little physical sense to assign this as a no-flow boundary. I understand that in some areas a thin-fine grained unit is present just below the seabed that would impede infiltration; rather than assume no infiltration occurs it would be preferable to specify the correct vertical hydraulic conductivity of the fine-grained unit and have the model calculate the infiltration. Even if the vertical permeability is relatively low, the total flux across this unit is likely to be very significant as the result of the large surface area involved. This would be consistent with the text of the report which states on page 9 *"...likely extends [San Juan Creek Alluvium] a considerable distance beneath the ocean floor and is in hydraulic continuity with seawater."*

I have not examined the model results in detail as I have the concerns stated above regarding the appropriateness of the boundary conditions for long-term simulations. For short-term simulations, such as simulating the aquifer test that boundary condition likely has little effect on the simulated results.

Some other comments (in no particular order):

1) I do not think the method used to simulate "wet" and "dry" hydrologic conditions is appropriate, in part for the reasons noted above. The position of the freshwater-saltwater interface changes as the result of changes in the flux of freshwater towards the sea; it would seem that this could be simulated with a lower flux at the northern boundary (which could be created by specifying a lower head for dry conditions than for the wet conditions along the boundary).
2) Figure 4 shows the location of off-shore jet probes and vibracore samples. Even though these borings only went to a depth of 32 feet, would be useful to see a section displaying the geology within the upper 32 feet. I am curious to know if the low permeability unit shown on Figure 2 is continuous.
3) Not clear to me why the "off-shore bedrock outcrop" is not included in all model runs. On page 30 of report it is noted that there is evidence that the outcrop exists.
4) Page 15 presents average transmissivity values obtained by averaging estimates derived from various analytical solutions. In general, it is better to base estimate on basis of analytical model thought to best represent the system.
5) Page 25 – a dispersivity of 200 feet is large relative to the scale of measurements for the calibration. In general, would expect the value to be smaller.
6) Figure 24 – it is unclear to which layers these properties are assigned. Are they assigned to layers 2 through 10?
7) Page 24, section 5.5.2. Is a hydraulic conductivity of 15 ft/day really consistent with clay?
8) Page 24 – A constant vertical hydraulic conductivity of 0.05 feet throughout the model domain does not appear to be consistent with cross section shown on Figure 2. From this section, it would appear that effective vertical conductivity in many layers should be significantly greater than 0.05 ft/day.

9) Page 25 – Section 5.5.6. This section notes that it is a conservative assumption that low permeability is assigned to layer 1. Technically this is true, but in reality the assignment of low permeability in this layer has little effect on model results as the upper boundary of this layer is no flow everywhere.
10) Figures 29+ -- no real problem with these plots but in general would have been better to plot as drawdown from start of test.
11) Not clear if there is much significance to plot of water level changes in vicinity of riparian vegetation. I reach this conclusion since leakage from San Juan Creek is not included in the model even though it is concluded that the creek is in hydraulic continuity with creek.
12) The number of scenarios in mind numbing to the reader; would be useful if a simple way of reducing the number of scenarios depicted in figures could be developed.
13) Page 42, second bullet. Not clear to me how average regional drawdowns were computed. Is this average drawdown in model domain?
14) Page 42, fifth bullet. The "impact on riparian vegetation due to pumping" is an incorrect statement as model does not calculate impacts on vegetation rather it calculates impact on water levels in riparian zone.
15) Page 42, third bullet. The conclusion presented in this bullet is solely the result of the boundary conditions imposed; actual drawdowns will not be less for drier conditions.

If you have any questions on my comments, please give me a call.

Sincerely,

S.S. PAPADOPULOS & ASSOCIATES, INC.

Charles Andrews

Charles B. Andrews
President

November 7, 2006

Mr. Richard Bell
Municipal Water District of Orange County
10500 Ellis Avenue
Fountain Valley, CA 92728

Re: Review of Subsurface System Intake Feasibility Assessment Task 4 Report – Draft October 19, 2006

Dear Richard:

Psomas has reviewed the draft document titled "Subsurface System Intake Feasibility Assessment Task 4 Report - Draft" prepared for the Municipal Water District of Orange County prepared by Geoscience Support Services, Inc. dated October 19, 2006. The purpose of the report was to assess the feasibility of obtaining desalination intake supply from a well field consisting of five to nine wells located at Doheny State Beach using a groundwater model.

While an exhaustive review has not been conducted, we did note several important issues that need to be addressed in the document these issues include:

Assumptions in Model Calibration

Layer 1

The model assumed a low conductivity layer as the first upper layer of the model based on data collected from the Phase I beach monitoring wells and the slant boring. It appears that this layer was extended as far as the desalter well field. It is unclear whether data collected as part of the desalter well installation program supports this conceptualization for the groundwater modeling effort.

Recharge along San Juan Creek

The model appears to have assumed that no recharge was occurring from San Juan Creek into the underlying alluvium. It is unclear why this assumption was used other than to indicate a "conservative estimate." Monitoring efforts by Psomas for the San Juan Basin Authority strongly suggests that recharge does occur and plays an important role in the groundwater management of the basin. If changes in groundwater levels occur as described in the 10 year modeling scenarios, it will play an even bigger role.

Above Normal (Wet) and Drier Conditions Hydrologic Regimes

The modeling effort assumed two types of hydrologic regimes, an above-normal (wet) condition and a drier condition. Our understanding of the modeling effort indicated that these scenarios were represented by placing the constant head boundary for the wet condition at 1,300 feet offshore as opposed to the drier condition which would put the constant head boundary at 600 feet offshore. What this does is to move the boundary condition for a drier condition closer to the well field thus for the same pumping rate the drier condition shows less of a drawdown than a wet condition. These assumptions should be revisited.

10-Year Scenario

It is unclear why the 10-year scenario was selected for model runs 2-7. It is unclear whether the drawdown predicted in the modeling effort had achieved equilibrium or were continuing to decline after the end of the 10-year scenario.

Percent of Contribution from San Juan Basin Groundwater System

The way in which the modeling scenarios were devised tends to mask the true contribution of groundwater for each of the scenarios developed. For example, the only short term (1 year modeling scenario) indicated a contributory percent from the groundwater basin of 32% after 1 year pumping, whereas no 10 year scenario was provided. Since an analysis was not provided from the 2-10 year scenario, it is impossible to understand how the contributory percent might change over time. Moreover, in the other scenarios, only a 10-year scenario was provided and most indicated a 4-9 percent contribution from freshwater (from the groundwater basin) at the end of 10-years. We suspect that the contributory percentage would be higher in the early years and taper off as the basin achieved equilibrium. Consequently, the 4-9 percent contributory amount from freshwater stated for year 10 is probably not representative of conditions in the preceding years. A more thorough analysis needs to be performed to understand how the contributory percentage changes and what it is in the years from start-up to reaching equilibrium.

Loss in Groundwater Storage

The modeling for the various scenarios at year 10 indicates that portions of the basin will observe a decline in the water table as much as 55 feet. In some instance, the measurable decline will extend as much as 9,000 feet inland from the shoreline. This decline represents a loss in storage to the alluvial aquifer system and it is unclear whether this is a permanent loss or temporary loss.

Impacts to Existing Groundwater Users

As previously stated, groundwater level declines in portions of the basin may exceed 55 feet after 10 years of operation of the proposed 40 MGD operational scenario. These declines may have an adverse effect on existing and future groundwater users in the lower basin.

Water Rights

As you may be aware, the San Juan Basin Authority has obtained an appropriative water rights permit to divert 8,026 AFY. The permit ultimately allows up to 10,702 AFY. The premise of this appropriation is that groundwater that would otherwise discharge into the ocean (approximately 2,000-3,000 AFY) is captured and used as part of the desalter program currently underway in the basin. Based on the discussion in the document, it appears that the proposed program would capture and divert approximately 4-7% (at year 10)

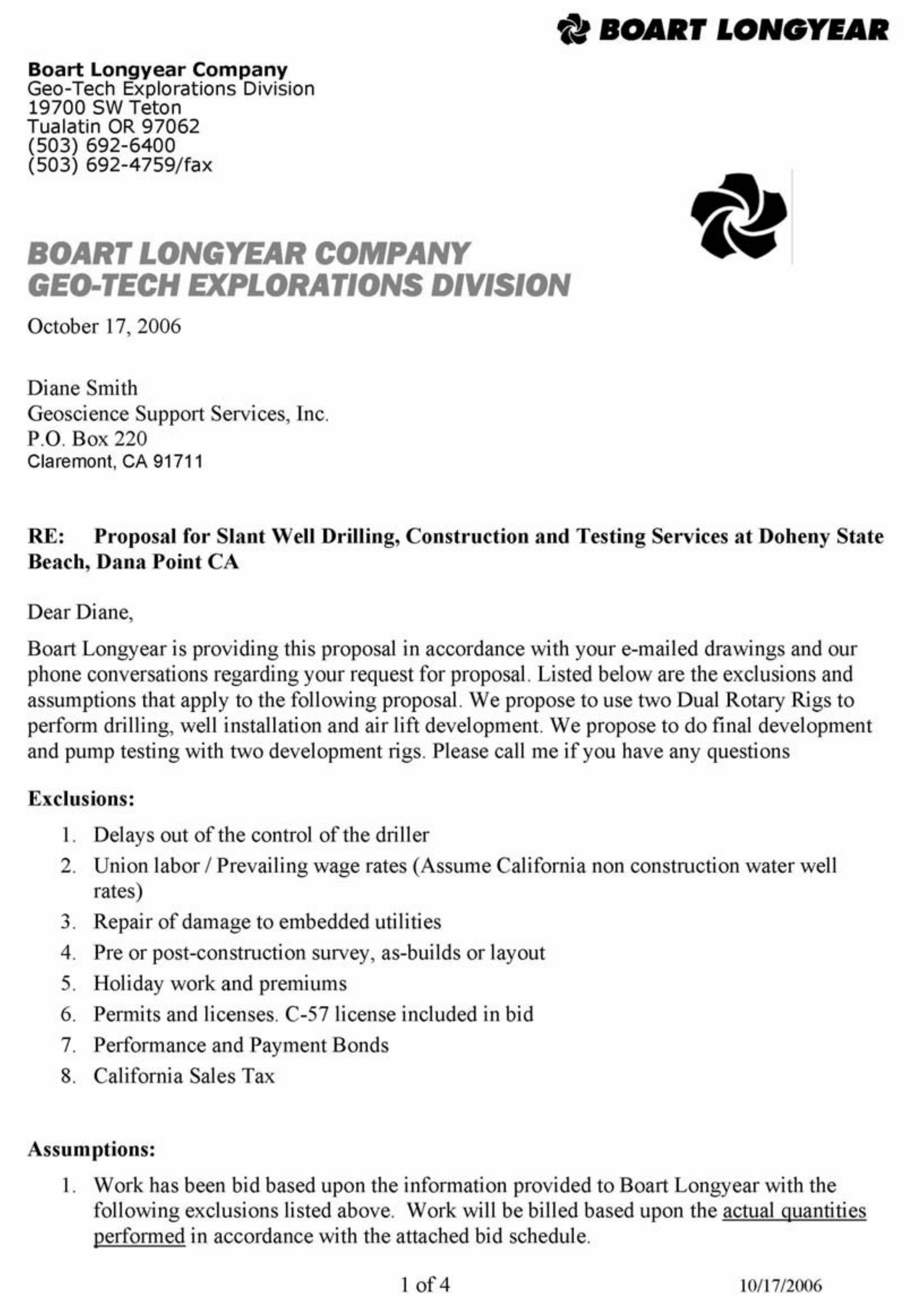
Sincerely,

John R. Thornton, P.E.
Principal and Vice President

Michael P. Donovan, P.G., C.Hg.
Senior Hydrogeologist

cc. Don Martinson, San Juan Basin Authority

Appendix B — Preliminary Cost Estimate



BOART LONGYEAR

Boart Longyear Company
Geo-Tech Explorations Division
19700 SW Teton
Tualatin OR 97062
(503) 692-6400
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BOART LONGYEAR COMPANY
GEO-TECH EXPLORATIONS DIVISION

October 17, 2006

Diane Smith
Geoscience Support Services, Inc.
P.O. Box 220
Claremont, CA 91711

RE: Proposal for Slant Well Drilling, Construction and Testing Services at Doheny State Beach, Dana Point CA

Dear Diane,

Boart Longyear is providing this proposal in accordance with your e-mailed drawings and our phone conversations regarding your request for proposal. Listed below are the exclusions and assumptions that apply to the following proposal. We propose to use two Dual Rotary Rigs to perform drilling, well installation and air lift development. We propose to do final development and pump testing with two development rigs. Please call me if you have any questions

Exclusions:

1. Delays out of the control of the driller
2. Union labor / Prevailing wage rates (Assume California non construction water well rates)
3. Repair of damage to embedded utilities
4. Pre or post-construction survey, as-builds or layout
5. Holiday work and premiums
6. Permits and licenses. C-57 license included in bid
7. Performance and Payment Bonds
8. California Sales Tax

Assumptions:

1. Work has been bid based upon the information provided to Boart Longyear with the following exclusions listed above. Work will be billed based upon the actual quantities performed in accordance with the attached bid schedule.

2. Adequate space to set up work area at each well array including staging area off of beach to accommodate work for two rigs working simultaneously
3. An adequate water supply for closed loop reverse circulation drilling will be provided by the owner at no expense to BLC.
4. BLC will not be responsible for quality of water provided.

Pricing:

See the attached bid schedule.

Standard Contract Conditions:

The contract sum will be determined based upon the unit prices provided below. These prices are based upon standard wage rates, unless special rates have been provided by the CLIENT, as stated above. The terms for payment are net 30 days (two week invoice schedule). Interest will be charged at the rate of 1-1/2% per month on any over due balance that remains after said date. Periodic invoicing for materials on hand will be allowed, with the same terms as above.

Due to extreme volatility in the cost of steel, fuel and other materials included within this scope of work, the prices are good for 30 days from the date of this proposal to the date of contract. Thereafter, the prices quoted are subject to adjustment based upon market conditions at the time of acceptance.

BLC, its suppliers and subcontractors will be responsible for acceptable workmanship, confirmed daily on-site between the BLC Project Supervisor and Client's Project Manager. Payment to BLC will not be contingent upon receipt of payment by any other party.

Thank you for requesting this proposal from Boart Longyear Company. We look forward to the opportunity to work with you on this project.

Sincerely,
BOART LONGYEAR COMPANY

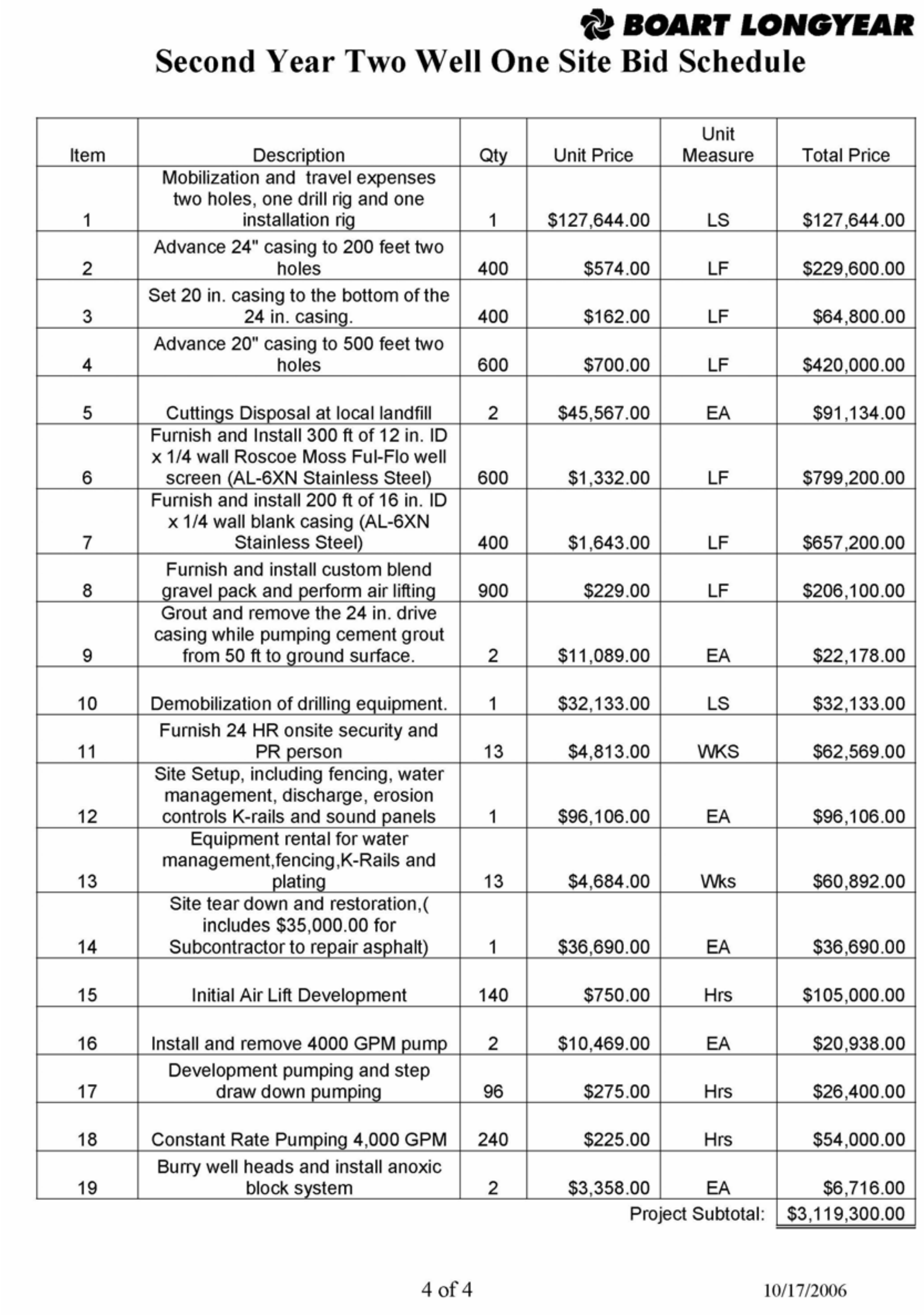
Robert Stadeli
Boart Longyear Company
Geo-Tech Explorations Division
Tualatin, OR
(503) 692-6400
rstadeli@boartlongyear.com

BOART LONGYEAR

First Year Six Well Two Site Bid Schedule

Item	Description	Qty	Unit Price	Unit Measure	Total Price
1	Mobilization and travel expenses six holes, two drill rigs and two installation rigs	1	$302,029.00	LS	$302,029.00
2	Advance 24" casing to 200 feet six holes	1200	$558.00	LF	$669,600.00
3	Set 20 in. casing to the bottom of the 24 in. casing.	1200	$160.00	LF	$192,000.00
4	Advance 20" casing to 500 feet six holes	1800	$671.00	LF	$1,207,800.00
5	Cuttings Disposal at local landfill	6	$45,567.00	EA	$273,402.00
6	Furnish and Install 300 ft of 12 in. ID x 1/4 wall Roscoe Moss Ful-Flo well screen (AL-6XN Stainless Steel)	1800	$1,332.00	LF	$2,397,600.00
7	Furnish and install 200 ft of 16 in. ID x 1/4 wall blank casing (AL-6XN Stainless Steel)	1200	$1,607.00	LF	$1,928,400.00
8	Furnish and install custom blend gravel pack and perform air lifting	2700	$229.00	LF	$618,300.00
9	Grout and remove the 24 in. drive casing while pumping cement grout from 50 ft to ground surface.	6	$11,089.00	EA	$66,534.00
10	Demobilization of drilling equipment.	1	$70,963.00	LS	$70,963.00
11	Furnish 24 HR onsite security and PR person	37	$4,376.00	WKS	$161,912.00
12	Site Setup, including fencing, water management, discharge, erosion controls K-rails and sound panels	2	$102,489.00	EA	$204,978.00
13	Equipment rental for water management,fencing,K-Rails and plating	37	$5,461.00	Wks	$202,057.00
14	Site tear down and restoration,(includes $35,000.00 for Subcontractor to repair asphalt)	2	$41,695.00	EA	$83,390.00
15	Initial Air Lift Development	420	$750.00	Hrs	$315,000.00
16	Install and remove 4000 GPM pump	6	$10,450.00	EA	$62,700.00
17	Development pumping and step draw down pumping	288	$275.00	Hrs	$79,200.00
18	Constant Rate Pumping 4,000 GPM	720	$225.00	Hrs	$162,000.00
19	Burry well heads and install anoxic block system	6	$3,437.00	EA	$20,622.00
				Project Subtotal:	$9,018,487.00

10/17/2006



BOART LONGYEAR

Second Year Two Well One Site Bid Schedule

Item	Description	Qty	Unit Price	Unit Measure	Total Price
1	Mobilization and travel expenses two holes, one drill rig and one installation rig	1	$127,644.00	LS	$127,644.00
2	Advance 24" casing to 200 feet two holes	400	$574.00	LF	$229,600.00
3	Set 20 in. casing to the bottom of the 24 in. casing.	400	$162.00	LF	$64,800.00
4	Advance 20" casing to 500 feet two holes	600	$700.00	LF	$420,000.00
5	Cuttings Disposal at local landfill	2	$45,567.00	EA	$91,134.00
6	Furnish and Install 300 ft of 12 in. ID x 1/4 wall Roscoe Moss Ful-Flo well screen (AL-6XN Stainless Steel)	600	$1,332.00	LF	$799,200.00
7	Furnish and install 200 ft of 16 in. ID x 1/4 wall blank casing (AL-6XN Stainless Steel)	400	$1,643.00	LF	$657,200.00
8	Furnish and install custom blend gravel pack and perform air lifting	900	$229.00	LF	$206,100.00
9	Grout and remove the 24 in. drive casing while pumping cement grout from 50 ft to ground surface.	2	$11,089.00	EA	$22,178.00
10	Demobilization of drilling equipment.	1	$32,133.00	LS	$32,133.00
11	Furnish 24 HR onsite security and PR person	13	$4,813.00	WKS	$62,569.00
12	Site Setup, including fencing, water management, discharge, erosion controls K-rails and sound panels	1	$96,106.00	EA	$96,106.00
13	Equipment rental for water management,fencing,K-Rails and plating	13	$4,684.00	Wks	$60,892.00
14	Site tear down and restoration,(includes $35,000.00 for Subcontractor to repair asphalt)	1	$36,690.00	EA	$36,690.00
15	Initial Air Lift Development	140	$750.00	Hrs	$105,000.00
16	Install and remove 4000 GPM pump	2	$10,469.00	EA	$20,938.00
17	Development pumping and step draw down pumping	96	$275.00	Hrs	$26,400.00
18	Constant Rate Pumping 4,000 GPM	240	$225.00	Hrs	$54,000.00
19	Burry well heads and install anoxic block system	2	$3,358.00	EA	$6,716.00
				Project Subtotal:	$3,119,300.00