United States Department of the Interior

U. S. GEOLOGICAL SURVEY

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MEMORANDUM

To: Devin Galloway, Ground-Water Specialist, Western Region, USGS

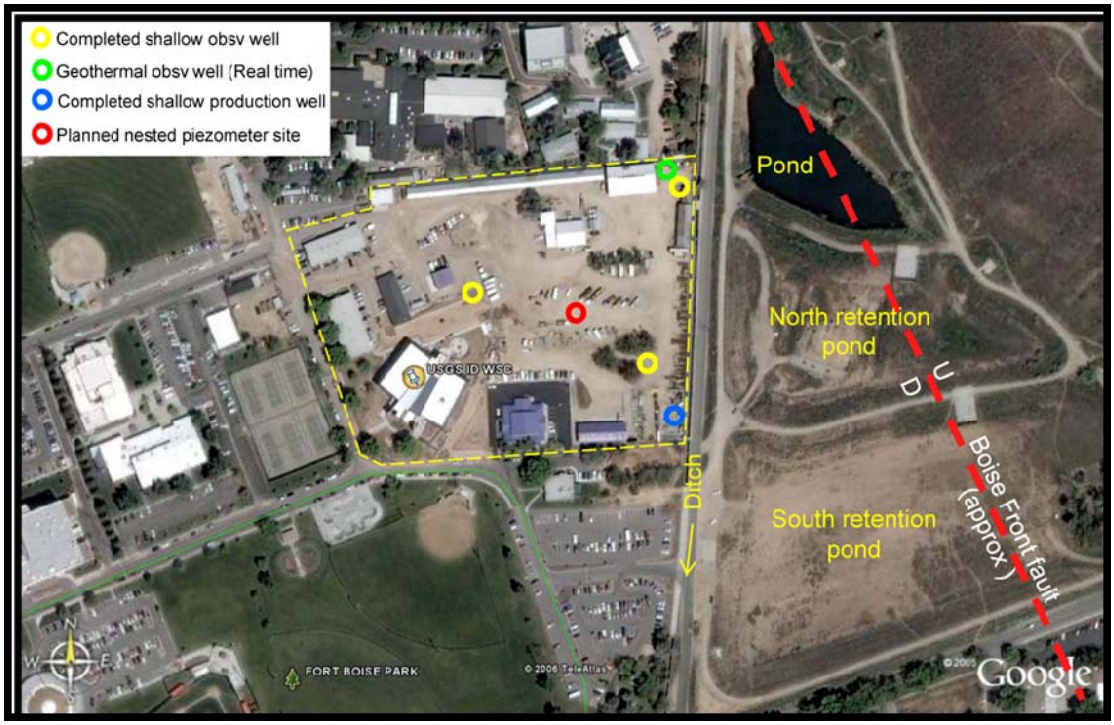
From: Keith J. Halford, Ground-Water Specialist, Nevada WSC, USGS

Subject: AQUIFER TEST—Analysis of multiple-well aquifer test of alluvial fill, Idaho WSC, Boise, Idaho

A multiple-well aquifer test was conducted at the Idaho Water Science Center (IDWSC) field site by the participants of the Groundwater Field Techniques/Groundwater Data for Users/Aquifer Test Analysis Workshop, August 23–27, 2010, USGS IDWSC, Boise, ID (The Class) in Treasure Valley, Boise, ID to estimate the hydraulic properties of the shallow alluvial aquifer system (Figure 1). Well IdWSCO3 was pumped for 26.3 hours at 64 gpm between August 24 and 25, 2010. Results from the well IdWSCO3 aquifer test were interpreted to characterize the hydraulic properties of the field site. These estimates will refine groundwater flow estimates in Treasure Valley, Idaho.

Site and Geology

The IDWSC site lies on the northern edge of the Western Snake River Plain, or Treasure Valley, and is directly underlain by Idaho Group sediments. Hydrogeologic units defined in the area by Squire and others (1992) are: (1) Lake margin sands of northeast Boise, (2) Clean sands and gravels, and (3) Confining units that tend to contain more silt than clay. A major basin bounding fault, the East Boise fault (herein referred to as the Boise Range Front fault) of Squire and others (1992), lies about 500 feet east-northeast of the pumping well IdWSCO3. The Treasure Valley aquifer system described by Petrich (2004) “is comprised of a complex series of interbedded, tilted, faulted, and eroded sediments, extending to a depth of over 6,000 feet in the deepest parts of the basin.” Three aquifers are present: a shallow unconfined alluvial aquifer, a deeper confined aquifer, and an underlying geothermal aquifer.



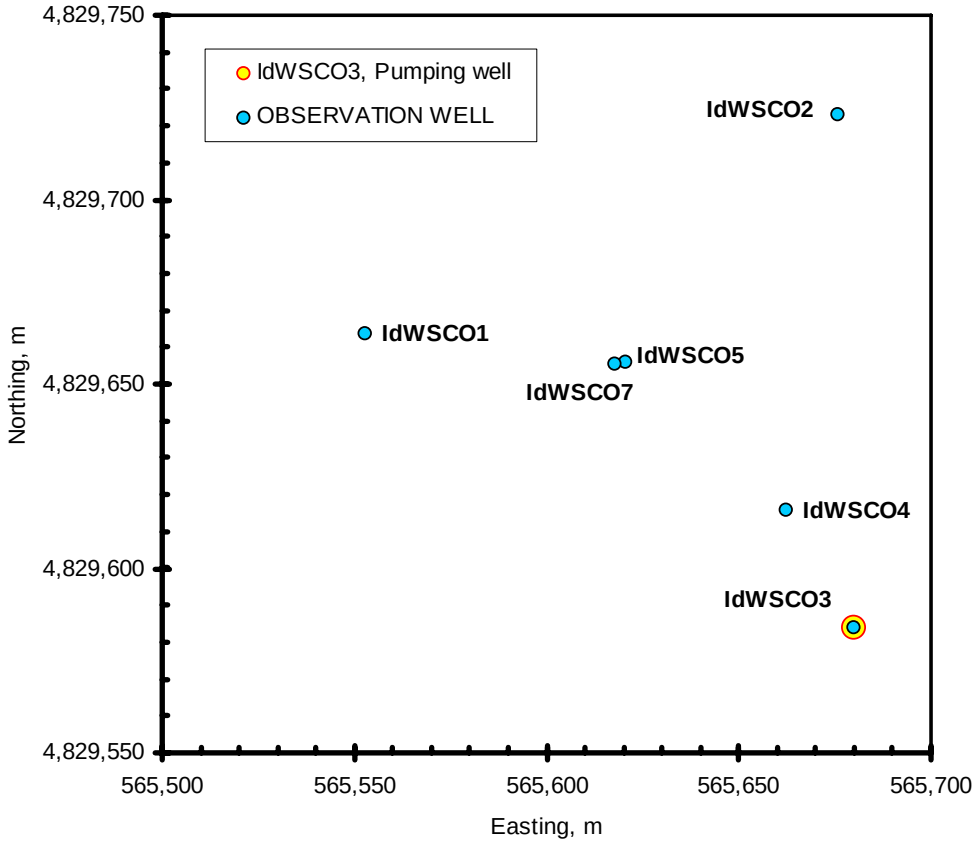


Figure 1.—Location of wells at USGS IDWSC, Boise, Idaho.

Observation wells IdWSCO1, IdWSCO2, IdWSCO4, and IdWSCO5 were completed with 2-in. PVC screens in 6-in. diameter boreholes (Table 1, Figure 1). All wells, except IdWSCO7, were completed in the shallow aquifer (Figure 2). Screen lengths ranged between 10 and 90 ft where wells IdWSCO1 and IdWSCO2 were screened across the water table (Figure 2).

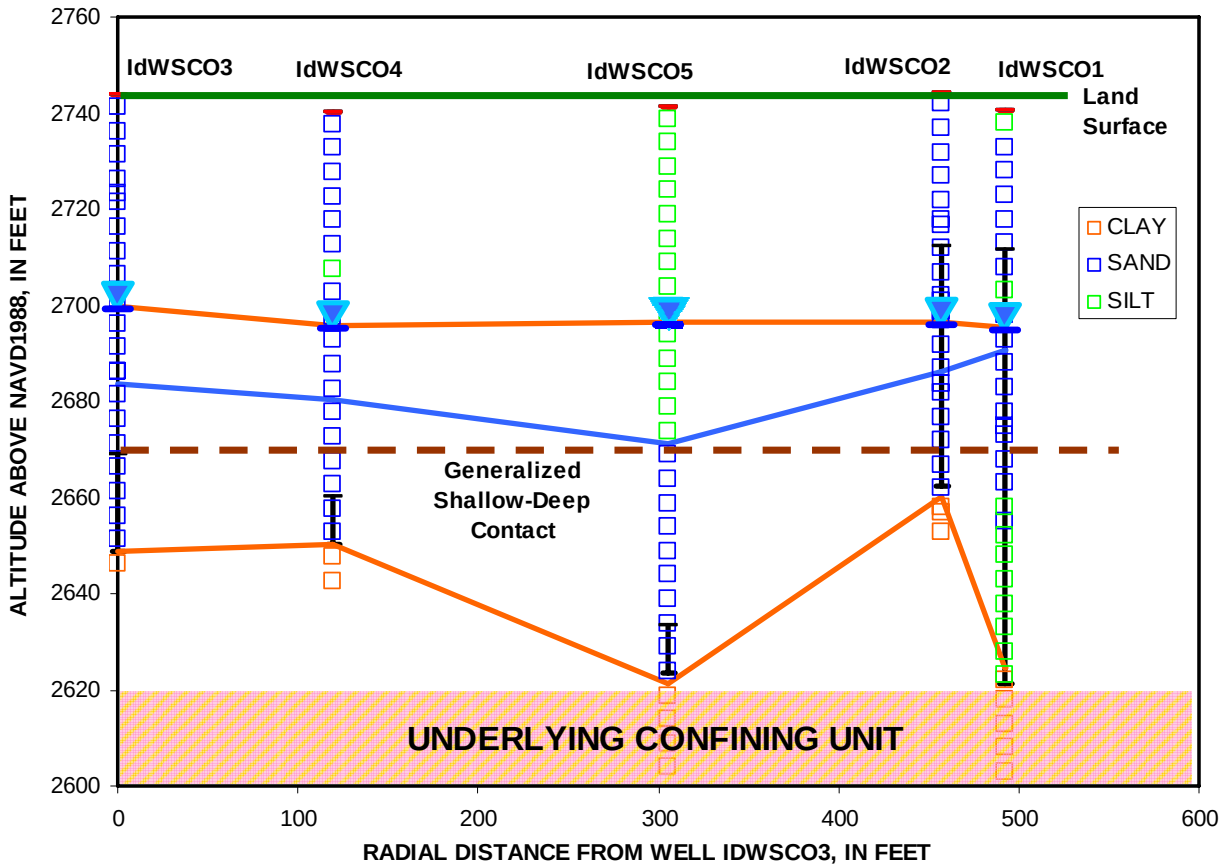


Figure 2.—Radial cross-section about pumping well IdWSCO3.

Table 1.—Well location and construction data for pumping and observation wells.

[Latitude and longitude are in degrees, minutes, and seconds and referenced to North American Datum of 1983 (NAD 83); ft amsl, feet above North American Vertical Datum of 1988 (NAVD 88); ft bgs, feet below ground surface; na, not available.]

Map Identifier	SITE IDENTIFIER	Latitude	Longitude	Ground surface elevation, ft amsl	Total Depth, ft bgs	Depth to Static Water Level, ft bgs	Elevation of static water, ft amsl
IdWSCO1	433701116111501	43°37'01"	116°11'15"	2,740.46	124	45.02	2,695.44
IdWSCO2	433703116111001	43°37'03"	116°11'10"	2,744.35	87	47.76	2,696.59
IdWSCO3	433659116111001	43°36'59"	116°11'10"	2,743.83	100	43.86	2,699.97
IdWSCO4	433700116111001	43°36'60"	116°11'10"	2,740.20	95	44.41	2,695.79
IdWSCO5	na	na	na	2,741.37	123	44.96	2,696.41
IdWSCO7	na	na	na	2,741.52	206	90.73	2,650.79

Water Levels and Pumping

Water levels in observation wells IdWSCO1, IdWSCO2, IdWSCO4, and IdWSCO7 were monitored continuously with 5-psi gage transducers from July 21, 2010 to August 27, 2010 (Table 1, Figure 1). Barometric changes, pumping from the deeper confined aquifer, and injection into the underlying geothermal aquifer affected water levels in the shallow unconfined alluvial aquifer (Figure 3). Water levels in observation well IdWSCO5 and pumping well IdWSCO3 were measured manually, periodically prior to the aquifer test, while pumping, and during recovery.

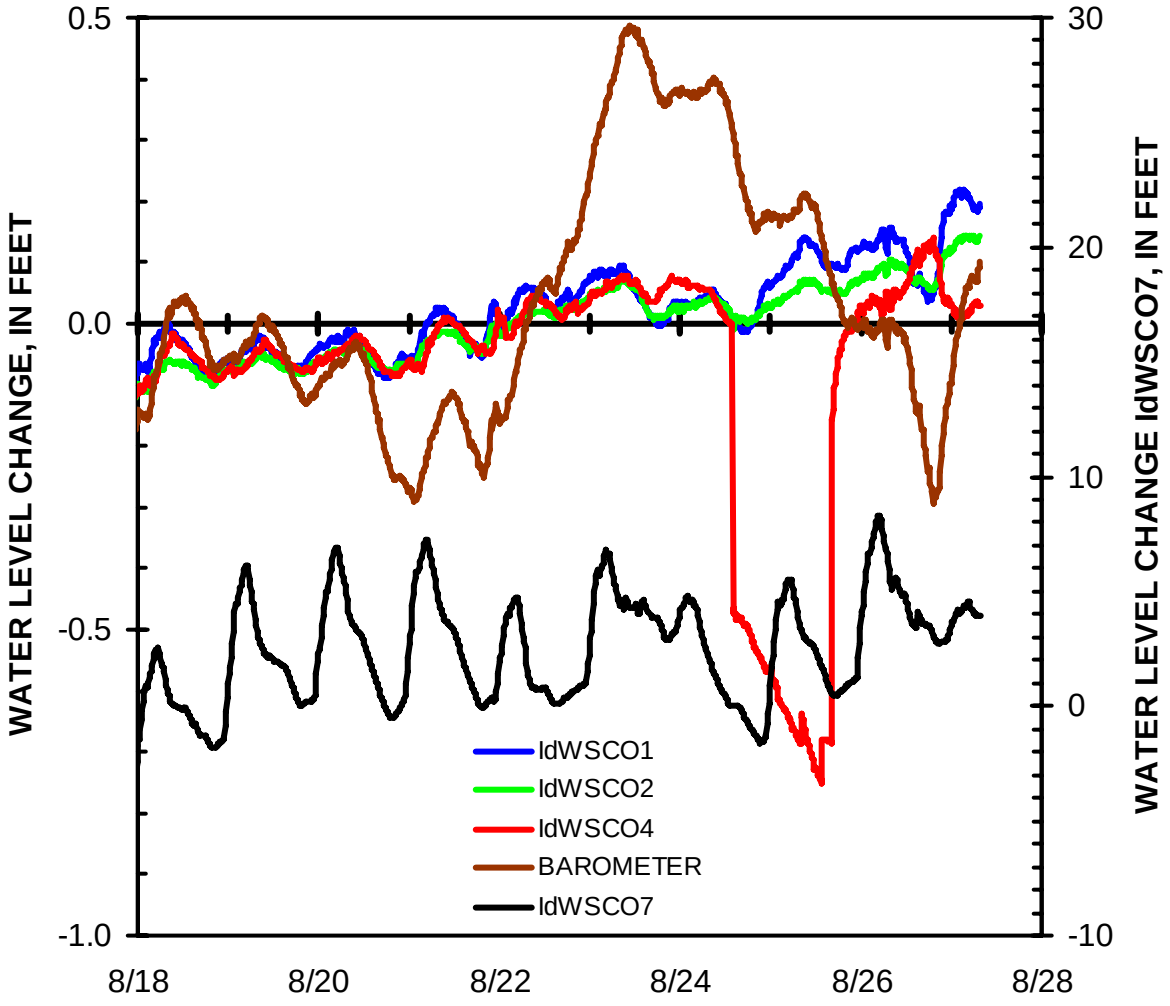


Figure 3.—Water level and barometric changes that were monitored continuously.

Pumping started on 8/24/10 13:57 PDT and ended on 8/25/10 16:17 PDT. A discharge of 64 gpm was measured with an in-line, totalizing flow meter. Discharge rates were verified with a portable acoustic-velocity flow meter that consistently reported 59 gpm. Both devices measured less than 1 gpm of variation during the 26.3 hour test. Discharge estimates from the in-line, totalizing flow meter were used in subsequent analyses and the cumulative discharge totaled 101,000 gallons.

Drawdown Estimation

Pumping responses in wells IdWSCO1, IdWSCO2, and IdWSCO4 were estimated by minimizing the differences between synthetic and measured water levels (Halford, 2006a). The formulation of synthetic water levels typically focuses on simulating water-level changes in a well that are caused by only non-pumping stresses. This approach was modified to simulate pumping and non-pumping stresses because pumping effects were slight in wells IdWSCO1 and IdWSCO2. Non-pumping responses were simulated with time series of barometric pressure, earth tides, and water-level changes in the deeper confined aquifer, IdWSCO7. The predicted response at observation wells IdWSCO1 and IdWSCO2 from pumping in well IdWSCO3 was generated with a Theis (1935) approximation where a cycle of pumping and recovery were simulated with superposition. The synthetic water levels were the summation of predicted pumping response and previously specified non-pumping responses.

The amplitude and phase for each of the non-pumping-stress time series and the transmissivity (T) and storativity (S) for the pumping-stress time series were estimated by minimizing the difference between the synthetic and measured water levels (Halford, 2006a). Barometric changes had the largest short-term influence on measured water levels and visually masked most or all of the pumping response in wells IdWSCO1 and IdWSCO2 (Figure 3). Drawdown and recovery were observed in well IdWSCO1 after differencing measured and synthetic water levels without the Theis component (Figure 4). Pumping responses were not detected in well IdWSCO2.

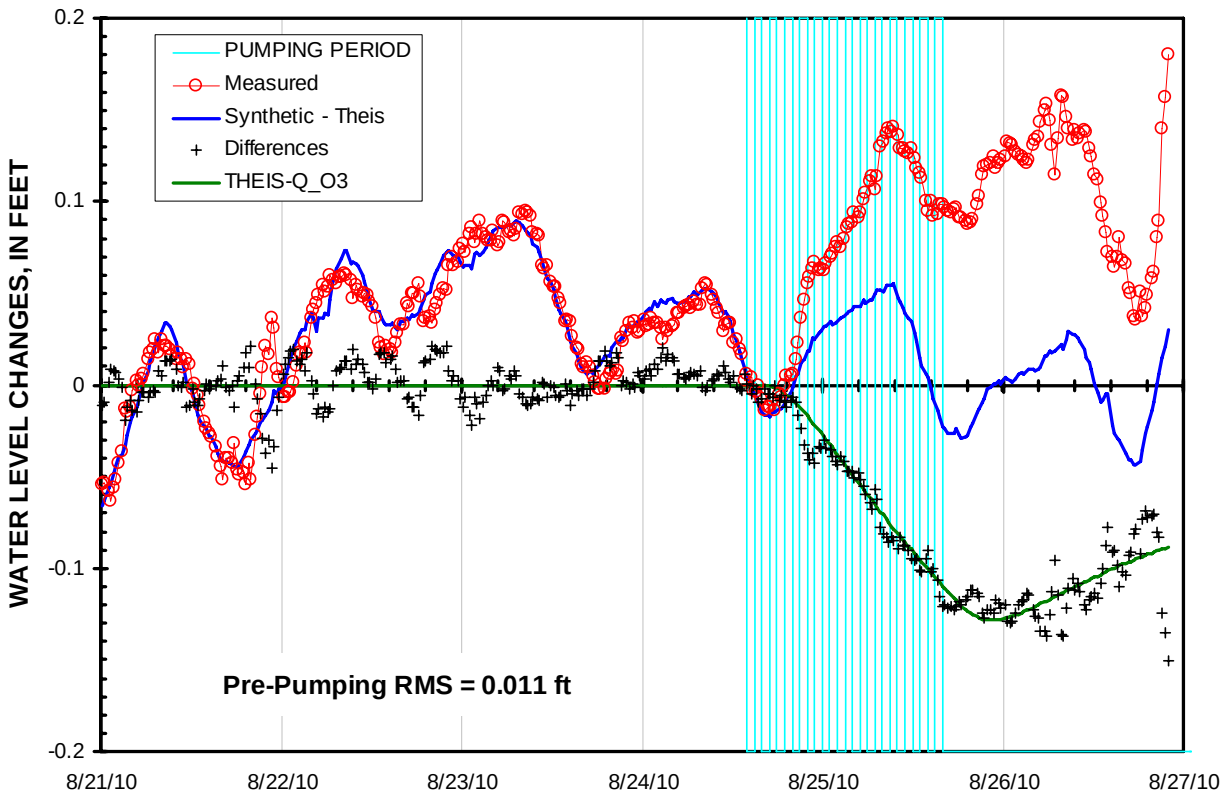


Figure 4.—Measured water-level changes, simulated water-level changes without the Theis superposition estimate of pumping responses, differences, and Theis superposition estimate of pumping responses in well IdWSCO1.

Analysis

The shallow unconfined alluvial aquifer was conceptualized as a sequence of deposits that were homogeneous parallel to the Boise Range Front fault and graded from fine-grained material near the fault to generally coarser material along the western edge of the wareyard. Assumed gradation occurred perpendicular to the fault which has a strike of 154º.

Drawdown responses in observation wells IdWSCO1 and IdWSCO2 and lithologic logs supported the assumptions of a heterogeneous aquifer where permeability increased downgradient (basinward) of the Boise Range Front fault. Wells IdWSCO1 and IdWSCO2 are 490 and 460 ft, respectively, from pumping well IdWSCO3 so drawdowns should be similar in an infinite, isotropic homogeneous aquifer. Drawdowns in excess of 0.1 ft were detected in well IdWSCO1 while drawdown

estimates in well IdWSCO2 remained in the noise, 0.02 ft. Lithologic logs report undifferentiated silt, sand, and gravel in all intervals except where clay was present. Ambiguity of the lithologic logs allows a wide range of interpretations.

Aquifer-test results were analyzed with a three-dimensional, MODFLOW model (Harbaugh and McDonald, 1996) because of the lack of radial symmetry and because heterogeneity precluded the application of most analytical solutions. The model domain was discretized into 11 layers of 139 rows and 136 columns and aligned with the Boise Range Front fault (Figure 5). The model was discretized finely around wells IdWSCO3, IdWSCO1, and IdWSCO2 because IdWSCO3 was the pumping well and wells IdWSCO1 and IdWSCO2 had long screens. Pumping induced flow in these long-screened observation wells can affect measured drawdowns. Pumping effects were more significant because these screens crossed the water table. Each well was simulated as a zone of virtually infinite hydraulic conductivity, 500 million ft/d, to account for the composite, measured drawdowns in these wells. Columns and rows expanded successively by a factor of 1.25 away from the wells until a mid-point between wells or the model edge was reached.

The numerical model extended laterally 200,000 ft away from the pumping well IdWSCO3 in all directions except to the east. The eastern edge was 500 ft east of well IdWSCO3 and approximated contact with the Boise Range Front fault. The vertical extent was from 45 to 190 ft below land surface, which were the general depths to the water table and the top of the deeper confined aquifer, respectively (Figure 5). Layer thicknesses ranged from 1 ft at the water table to 30 ft in the center of the underlying confining unit (Figure 5). All external boundaries were no-flow. Changes in the wetted thickness of the aquifer were not simulated because the maximum drawdown near the water table was small relative to the total thickness. The aquifer test was simulated with a 1.09-day pumping period and a 1.5-day recovery period.

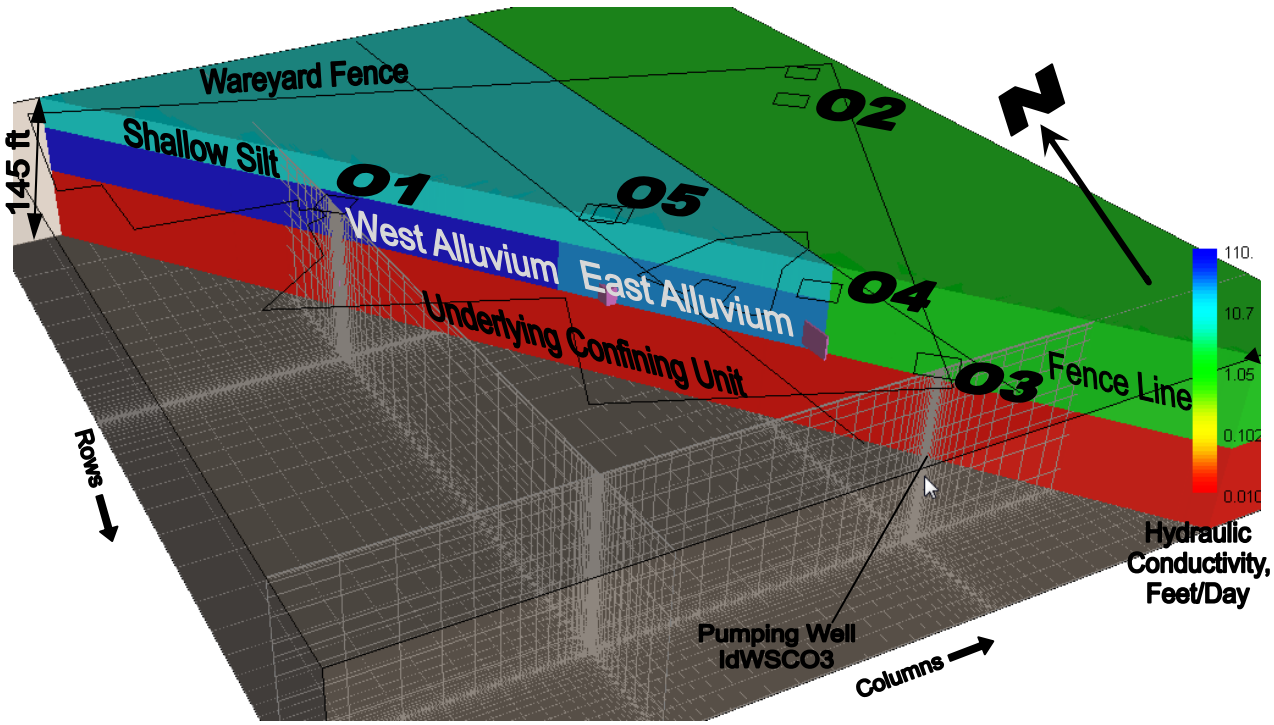


Figure 5.—Discretization of three-dimensional model in the vicinity of the IDWSC wareyard and distribution of hydraulic conductivity estimates.

Hydraulic conductivity was distributed with five discrete zones that were assumed internally homogeneous and vertically anisotropic (Figure 5). The Fence-Line unit extended from 45 to 120 ft below land surface and east of IdWSCO3 to the Boise Range Front fault. The Shallow-Silt unit extended from 45 to 75 ft below land surface and west of IdWSCO3. The alluvium units extended from 75 to 120 ft below land surface west of IdWSCO3. These units were subdivided into East Alluvium and West Alluvium units to approximate coarsening of material away from the Boise Range Front fault. The Underlying Confining unit extended from 120 to 190 ft below land surface and was laterally continuous throughout the model domain.

Hydraulic properties of the shallow unconfined alluvial aquifer were estimated by minimizing differences between simulated and measured drawdowns. Observations were weighted so drawdowns from all wells affected hydraulic property estimates. The weighted sum-of-squares objective function was minimized with MODOPTIM (Halford, 2006).

Simulated and measured drawdowns matched within 0.04 ft in the observation wells which was 4 percent of the 1-ft drawdown range analyzed (Figure 1). The root-

mean-square error of drawdown change and recovery in the pumping well (IdWSCO3) was 0.07 ft (Figure 7). Residuals of greater magnitude partly occurred in the pumping well because water levels were not monitored continuously. This precluded estimating drawdowns by differencing measured and synthetic water levels. Drawdown estimation was handicapped similarly in well IdWSCO5.

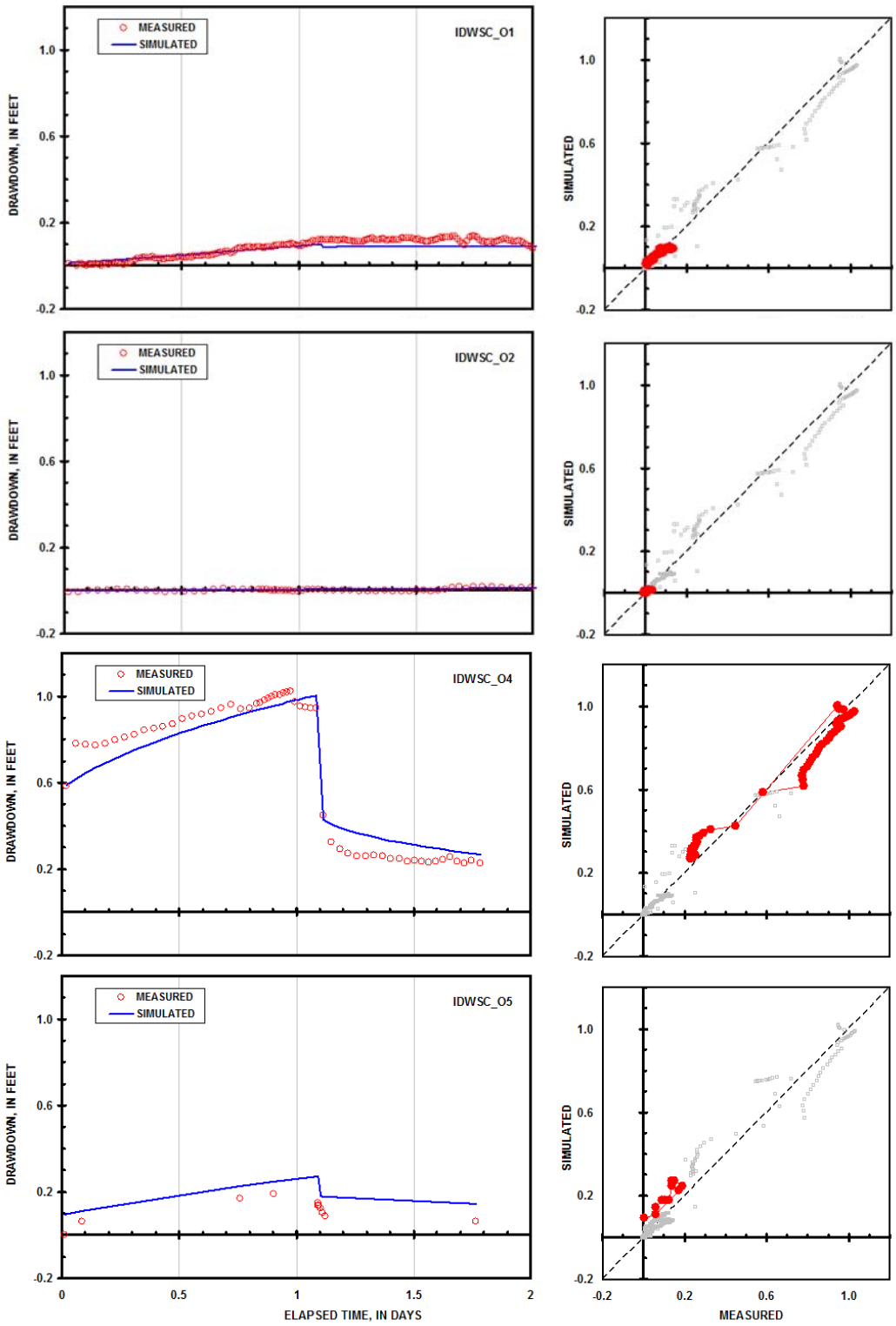


Figure 6.—Measured and simulated drawdowns in observation wells IdWSCO1, IdWSCO2, IdWSCO4, and IdWSCO5 during pumping and recovery.

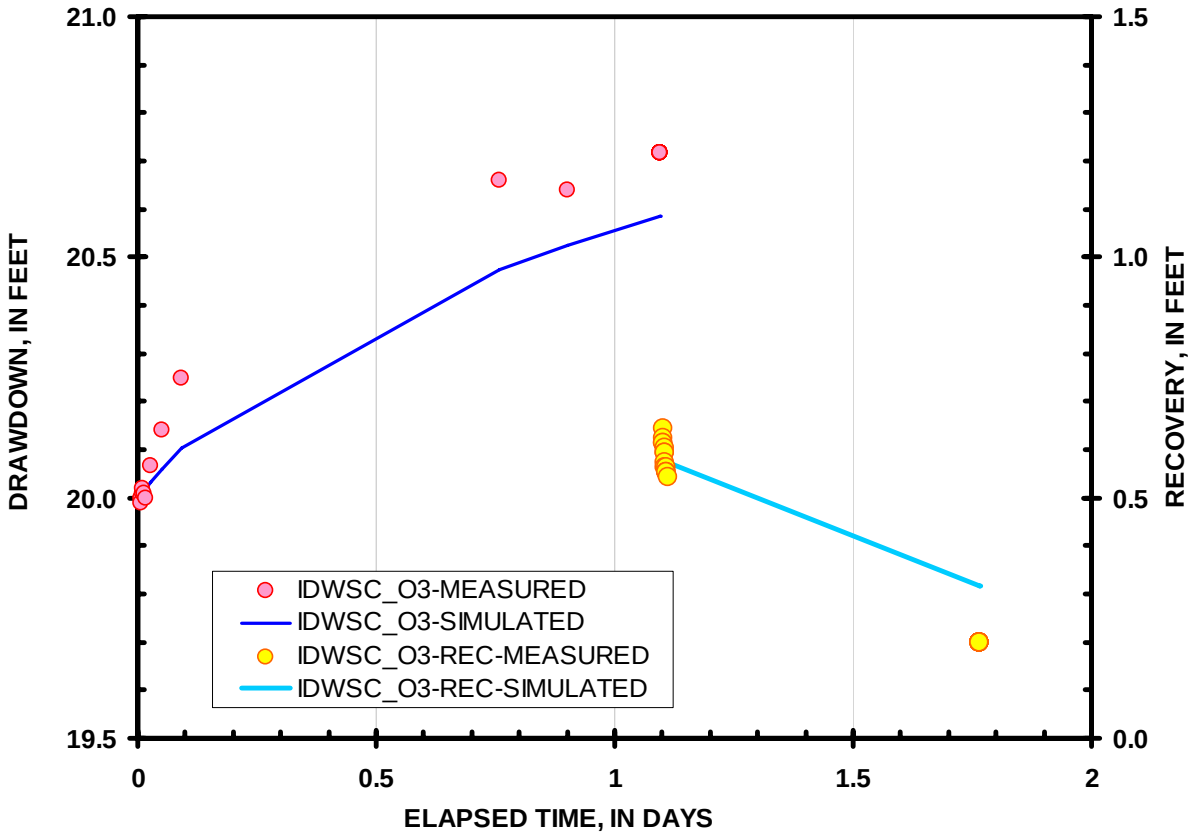


Figure 7.—Measured and simulated drawdowns and recovery in pumping well IdWSCO3.

Simulated drawdown surfaces were predominantly spherical shells between pumping well IdWSC03 and well IdWSC04 (Figure 8). Drawdown propagation more than 300 ft from the pumping well was limited at the water table and beneath the shallow unconfined alluvial aquifer. Drainage from the water table damped drawdown propagation at the top of the aquifer. Low permeability material in the underlying confining unit and fence-line unit limited drawdown more than 120 ft below land surface and east of the pumping well, respectively. Induced wellbore flow in well IdWSC01 pulls 0.1-ft drawdown surface to the water table.

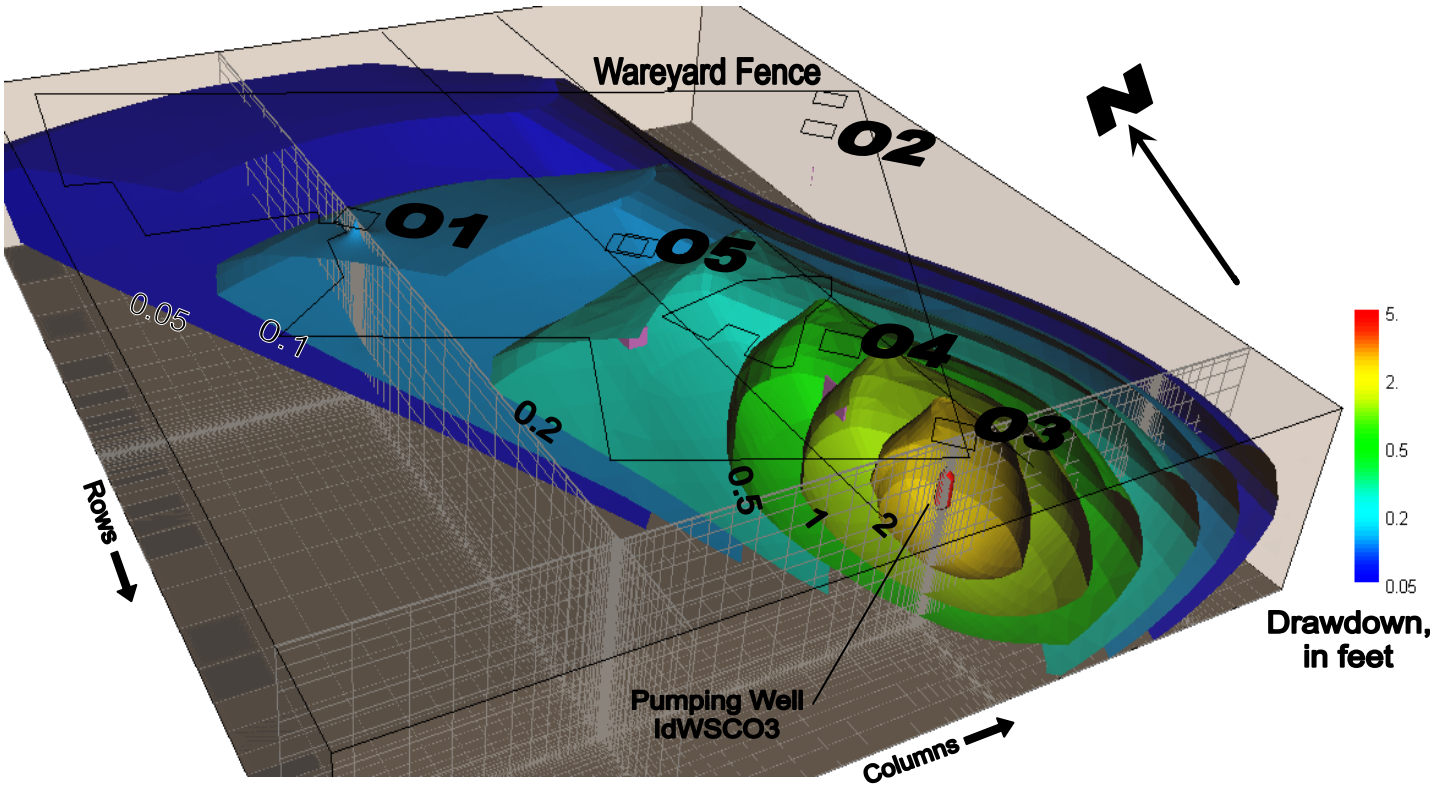


Figure 8.—Simulated drawdown surfaces after 1.09 days of pumping well IdWSCO3 at 64 gpm.

Hydraulic Property Estimates

Hydraulic conductivity estimates that generally increased from east to west agreed with the conceptual model of the shallow unconfined alluvial aquifer (Table 2).

Table 2.—Estimated hydraulic properties of the shallow unconfined alluvial aquifer.

[Vertical-to-horizontal anisotropy of 0.25 d'less was assigned. Hydralic conductivity of 0.01 ft/d was assigned to underlying confining unit.]

Lithology	INTERVAL, Feet		Hydraulic Conductivity, Feet per Day	Transmissivity, Feet Squared per Day	Specific yield, d'less	Specific Storage, 1/Feet
	Top	Bottom				
Fence Line	45	120	1.9	140	0.08	1.5E-06
Shallow Silt	45	75	15	500	0.08	1.5E-06
Deeper Alluvium, East	75	120	40	1,900	0.08	1.5E-06
Deeper Alluvium, West	75	120	130	6,000	0.08	1.5E-06

Transmissivity of the shallow unconfined alluvial aquifer increased downgradient of the Boise Front Fault (Figure 1). Transmissivity estimates were less than 200 ft^2/d east of the wareyard and greater than 6,000 ft^2/d west of the wareyard (Table 2). A specific yield of 0.08 agrees with other aquifer test results for alluvial sediments. Specific-storage was 1.5×10^{-6} ft^{-1} which is an expected value for sedimentary systems. Reasonable values of vertical-to-horizontal anisotropy were assigned to the shallow unconfined alluvial aquifer because this property could not be estimated.

References

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