United States Department of the Interior

U. S. GEOLOGICAL SURVEY

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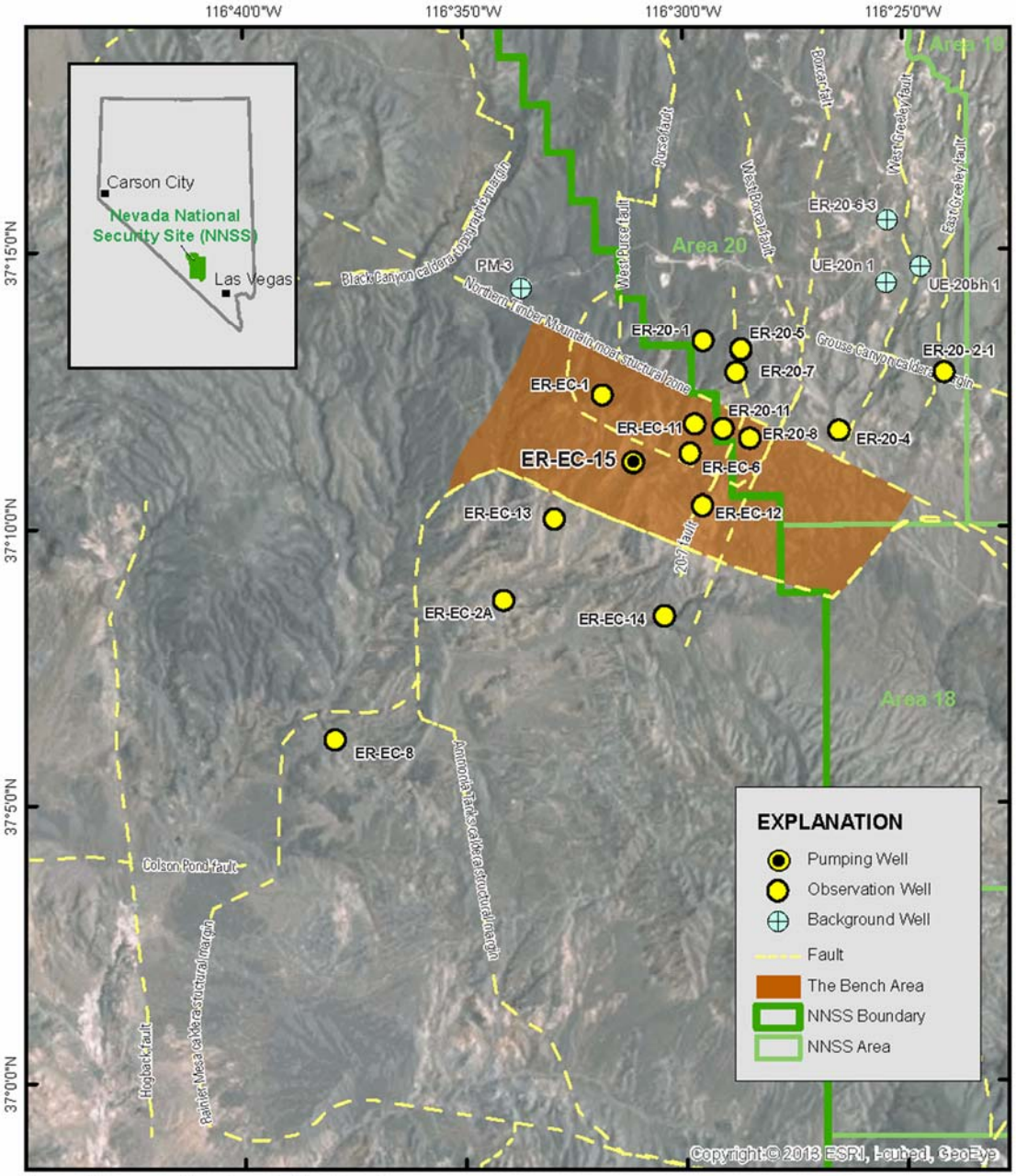
MEMORANDUM

To: Devin Galloway, WSFT-West Groundwater Specialist, Sacramento, CA

From: Keith J. Halford and Steve Reiner, Hydrologists, Nevada WSC, USGS

Subject: AQUIFER TESTS—Analyses of *ER-EC-15 main upper zone*, *ER-EC-15 main intermediate zone*, and *ER-EC-15 main lower zone*, single-well aquifer tests of volcanic rocks, Pahute Mesa, Nevada National Security Site

Three aquifer tests were conducted by Navarro-Intera, LLC (N-I) in wells *ER-EC-15 main upper zone*, *ER-EC-15 main intermediate zone*, and *ER-EC-15 main lower zone* at Pahute Mesa on the Nevada National Security Site (NNSS) in southern Nevada (Figure 1). The three wells are three completions isolated with packers in a single wellbore. Transmissivities of Upper Paintbrush/Benham, Tiva Canyon, and Topopah Spring aquifers within the central Bench area were estimated independently because interference was not observed between wells in the ER-EC-15 well cluster site which includes the main well and three other wells: shallow, intermediate and deep (Table 1; appendix 1). Well *ER-EC-15 main upper zone* was pumped intermittently for purposes of well development and to perform a constant-rate pumping test between September 19, 2013 and October 29, 2013. Well *ER-EC-15 main intermediate zone* was pumped erratically between December 31, 2013 and January 8, 2014, because of excessive drawdowns in the pumping zone—the specific capacity was less than 0.1 gallons per minute (gal/min) per foot. Well *ER-EC-15 main lower zone* was pumped for purposes of well development and to perform a constant-rate pumping test between January 22, 2014 and February 18, 2014. Hydraulic properties estimated from aquifer tests in wells *ER-EC-15 main upper zone*, *ER-EC-15 main intermediate zone*, and *ER-EC-15 main lower zone* can be used to constrain estimates of radionuclide transport through volcanic rocks beneath Pahute Mesa, NNSS.



Universal Transverse Mercator projection, Zone 11. North American Datum of 1983. Aerial imagery base from ESRI online services, 2013. Geologic structures modified from U.S. Department of Energy (2009) and Sigmund L. Drellack, National Security Technologies, LLC, written commun. (2011).

Figure 1.—Well construction, lithology, and location of ER-EC-15 well cluster, Pahute Mesa, Nevada National Security Site and vicinity. (Observation and background wells were monitored, but not used in this interpretation.)

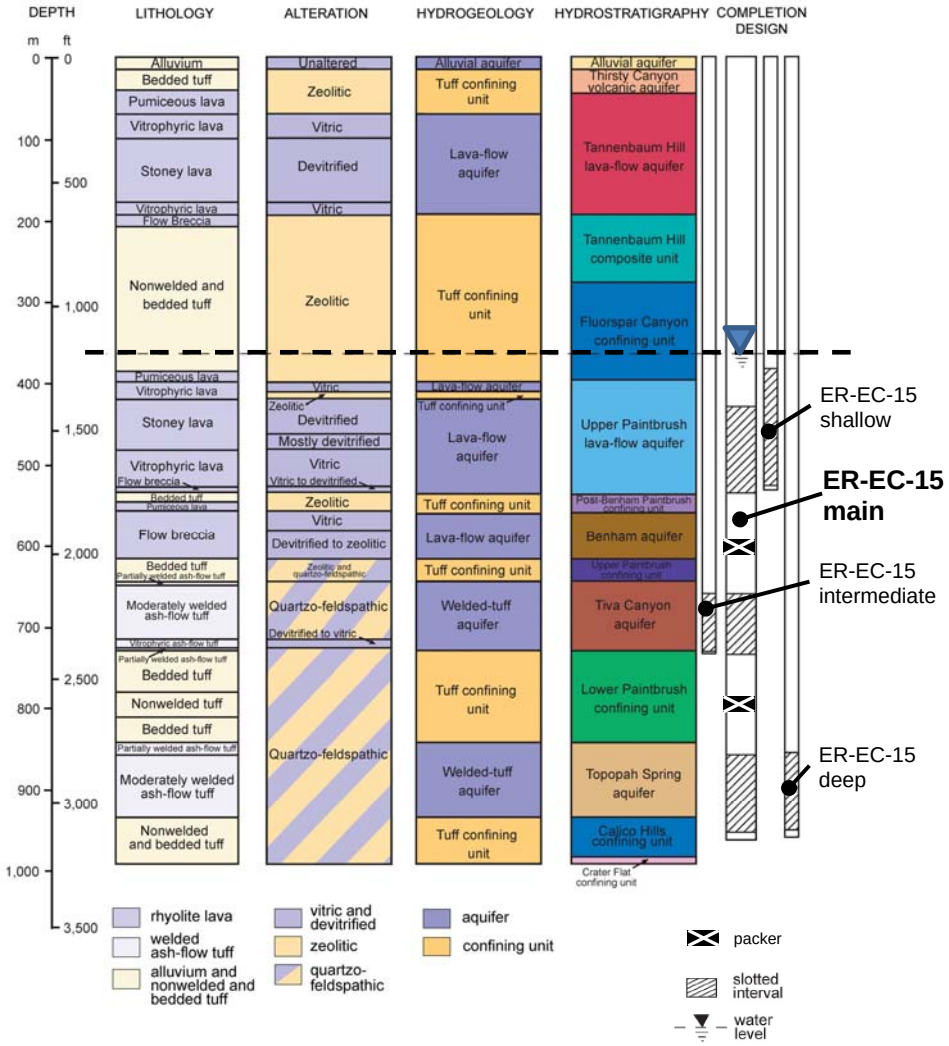
Table 1.—Well location and construction data for analyzed wells in ER-EC-15 cluster, Pahute Mesa, Nevada National Security Site.

[Latitude and longitude are in degrees, minutes, and seconds and referenced to North American Datum of 1927 (NAD27); ft amsl, feet above National Geodetic Vertical Datum of 1929 (NGVD29); ft bgs, feet below ground surface.]

Map Identifier	Site Identifier	Latitude	Longitude	Ground surface elevation, ft amsl	Depth to Static Water Level, ft bgs	Diameter Screen, in inches	Top Screen, ft bgs	Bottom Screen, ft bgs
ER-EC-15 main upper zone	371110116310501	N37°11'10"	W116°31'05"	5,365	1,191	7 5/8	1,393	1,739
ER-EC-15 main intermediate zone	371110116310501	N37°11'10"	W116°31'05"	5,365	1,191	5 1/2	2,157	2,408
ER-EC-15 main lower zone	371110116310501	N37°11'10"	W116°31'05"	5,365	1,191	5 1/2	2,807	3,122
ER-EC-15 deep	371110116310502	N37°11'10"	W116°31'05"	5,365	1,187	2 7/8	2,800	3,120
ER-EC-15 intermediate	371110116310503	N37°11'10"	W116°31'05"	5,365	1,189	2 7/8	2,156	2,395
ER-EC-15 shallow	371110116310504	N37°11'10"	W116°31'05"	5,365	1,191	2 7/8	1,381	1,741

Site and Geology

The aquifer tests occurred beneath Pahute Mesa in the northwest corner of NNSS where transport of radionuclides is a concern (Laczniak and others, 1996). The three wells that were monitored during aquifer testing at Pahute Mesa are completed in Tertiary volcanic rocks. The volcanic rocks of Pahute Mesa are dominated by lavas and tuffs of rhyolitic composition (Laczniak and others, 1996). Geologic structures at Pahute Mesa include normal faults with surface exposure and buried structural zones and caldera margins. The ER-EC-15 well cluster is located in the Bench area (Figure 1). Well *ER-EC-15 main* penetrates about 1,300 ft of unsaturated rock, and 2,000 ft of saturated rock where water enters from Upper Paintbrush, Tiva Canyon, and Topopah Spring aquifers (Figure 2). The lithologies of major water-producing hydrostratigraphic units in the aquifer-test area are stoney lavas, vitrophyric lavas, and moderately welded, ash-flow tuff (U.S. Department of Energy, 2011).



(Modified from U.S. Department of Energy, 2011)

Figure 2.—Lithology, alteration, hydrogeology, and well completion at ER-EC-15 well cluster Pahute Mesa, Nevada National Security Site.

Pumping and Water-Level Changes

Well *ER-EC-15 main* has upper, intermediate, and lower screened intervals that were isolated with packers (Figure 2). The upper, intermediate, and lower screens of well *ER-EC-15 main* are coincident with the open intervals of wells ER-EC-15 shallow, intermediate, and deep, respectively. Upper, intermediate, and lower screens of well *ER-EC-15 main* primarily produce water from Upper Paintbrush, Tiva Canyon, and Topopah Spring aquifers, respectively.

Water-levels were measured in wells *ER-EC-15 shallow*, *ER-EC-15 intermediate*, and *ER-EC-15 deep* during development and testing of *ER-EC-15 main* upper, intermediate, and lower zones. Drawdowns in all wells were estimated by subtracting water levels prior to pumping from measured water levels. Environmental fluctuations (atmospheric loading and earth tides) during the tests were assumed minimal and were not accounted for in the drawdown calculation. Water-level changes from pumping were not observed in wells that were not screened adjacent to the pumping zone.

Approximately 1.6 million gallons were withdrawn from *ER-EC-15 main upper zone* for well development prior to the constant-rate pumping test. The constant-rate test lasted about 181 hours from 10/21/2013 to 10/29/2013. Discharge during the constant-rate test averaged 124 gal/min with a total groundwater withdrawal of about 1.3 million gallons. Total withdrawal during the period of well development and testing was about 2.9 million gallons (Figure 3). Maximum drawdown in well *ER-EC-15 shallow*, adjacent to the pumping well, during the constant-rate test was about 90 ft (Figure 3).

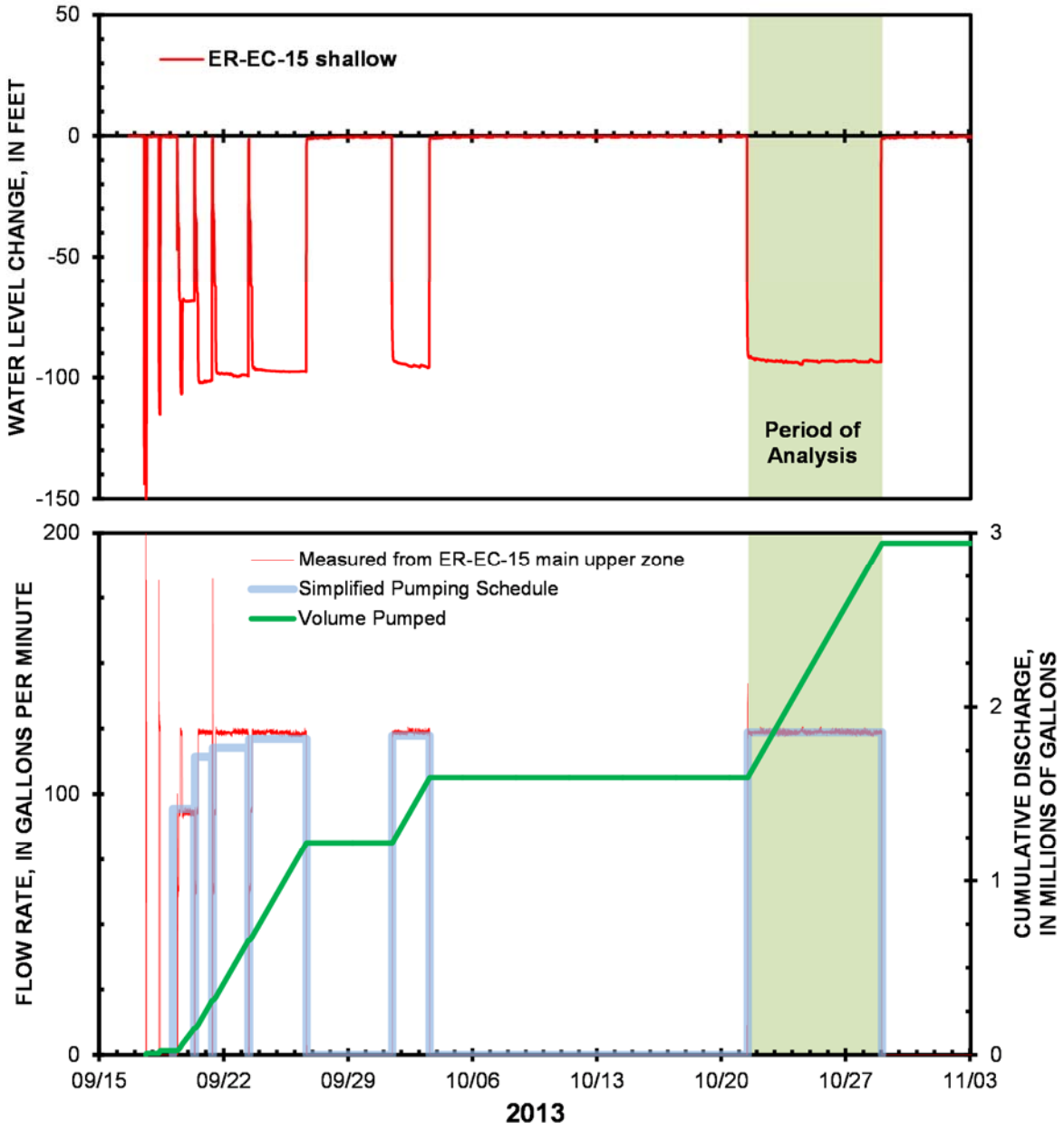


Figure 3.—Pumping from *ER-EC-15 main upper zone* during well development and aquifer testing, September-October, 2013.

Less than 0.02 million gallons were withdrawn from *ER-EC-15 main intermediate zone* for well development and testing between 12/31/2013 to 1/10/2014. Step and constant-rate pumping tests were not conducted in this zone because it was not possible to maintain the low discharge rates (less than 10 gal/min) without pumping water levels falling below the pump intake. Water was pumped cyclically during 6 days of development (Figure 4). Each cycle consisted of pumping 500 gallons of water during a 40-minute period, water levels declining 150 ft in well *ER-EC-15 intermediate*, and recovering 60 minutes after pumping ceased.

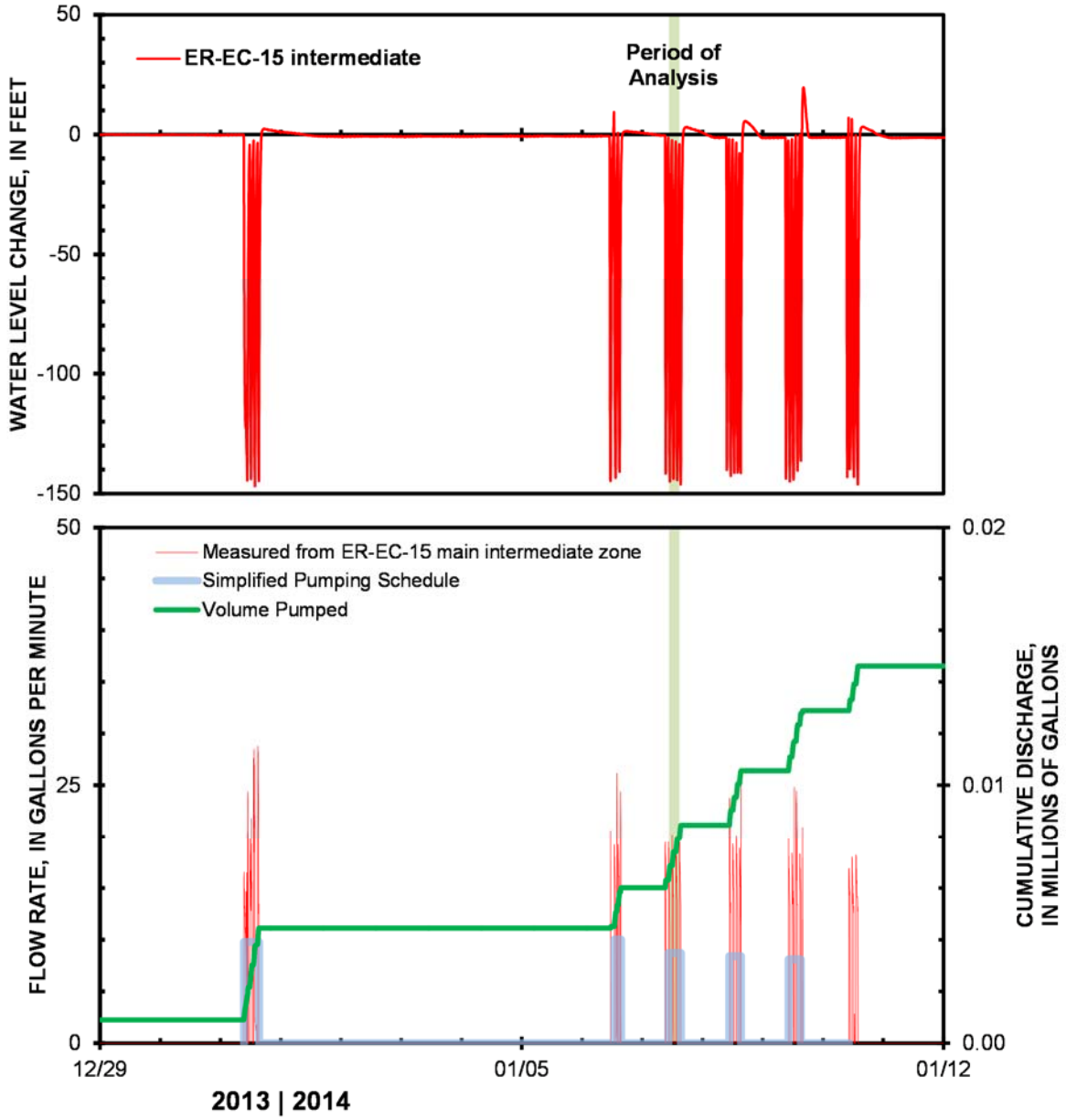


Figure 4.—Pumping from *ER-EC-15 main intermediate zone* during well development and aquifer testing, December 2013-January 2014.

Approximately 0.52 million gallons were withdrawn from *ER-EC-15 main lower* zone during well development and the constant-rate test pumping test. The constant-rate test lasted about 145 hours and was conducted from 2/12/2014 to 2/18/2014 (Figure 5). Discharge during the constant-rate test averaged 20 gal/min with a total groundwater withdrawal of about 0.2 million gallons.

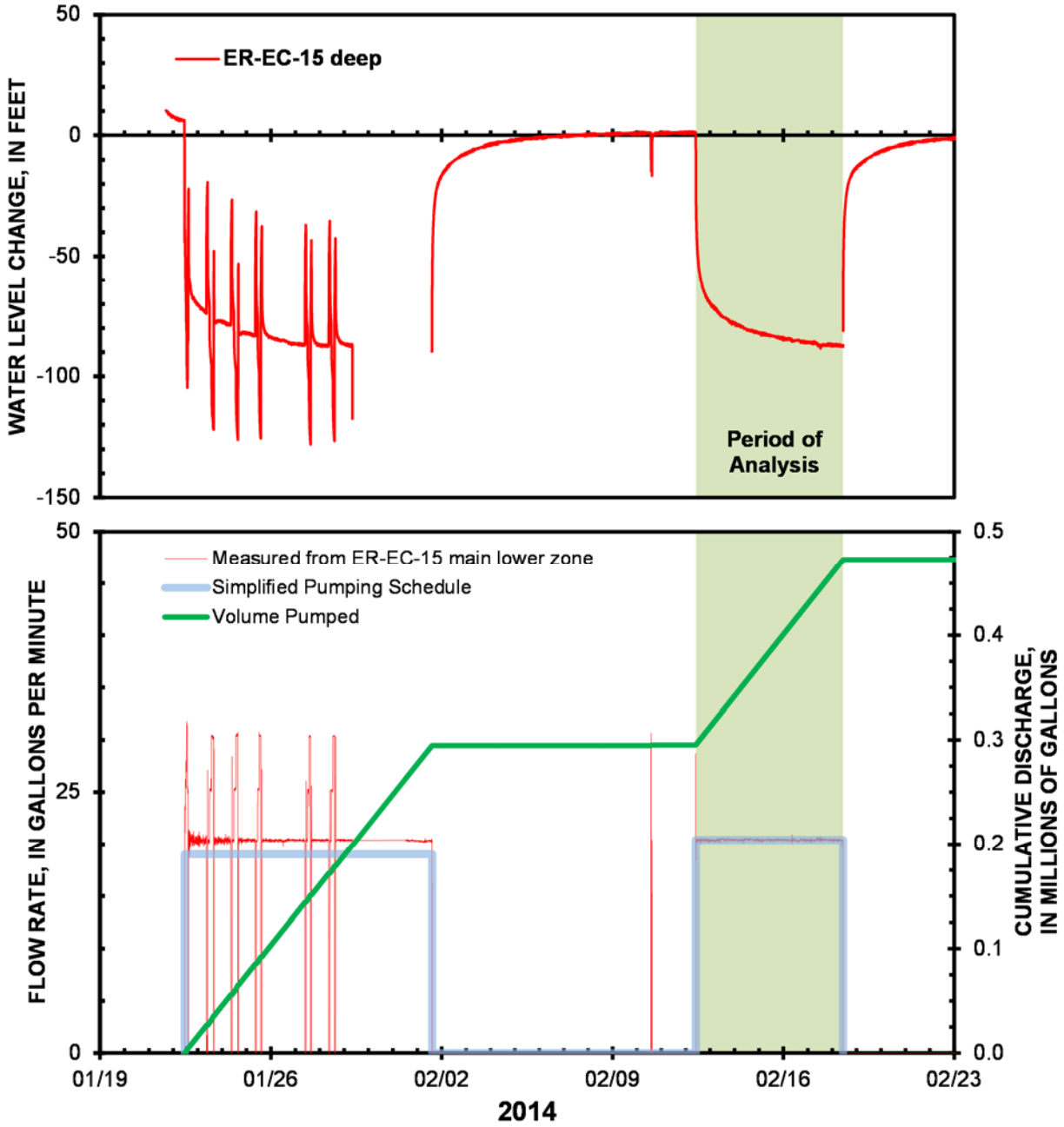


Figure 5.—Pumping from *ER-EC-15 main lower zone* during well development and aquifer testing, January-February, 2014.

Analysis

Transmissivities of Upper Paintbrush/Benham, Tiva Canyon, and Topopah Spring aquifers (Figure 2; Table 2) were estimated independently because pumping effects were not observed in wells at the ER-EC-15 well cluster that were not adjacent to the pumping intervals associated with these aquifers. Drawdowns from pumping wells

ER-EC-15 main upper zone and *ER-EC-15 main lower zone* were interpreted with the Cooper-Jacob method (Cooper and Jacob, 1946). Drawdowns from pumping well *ER-EC-15 main intermediate zone* was interpreted with superimposed Theis functions (Halford and others, 2012) because pumping rates varied continuously.

Table 2.—Transmissivity and hydraulic conductivity estimates at ER-EC-15 well cluster.

Aquifer	Top of Unit, feet BLS	Bottom of Unit, feet BLS	Transmissivity, feet²/day	Hydraulic Conductivity, feet/day
Upper Paintbrush lava-flow aquifer	1,300	2,020	3,200	4.4
Benham aquifer				
Tiva Canyon aquifer	2,100	2,400	< 20	< 0.07
Topopah Spring Aquifer	2,760	3,070	40	0.1

Based on late-time data, the estimated transmissivity from *ER-EC-15 main upper zone* aquifer test was 3,200 ft^2/d (Figure 6). Transmissivity near the pumping well was about 100 ft^2/d based on drawdowns during the first hour of pumping. More permeable material was encountered after the first hour of pumping which caused the semi-log slope to decline more than 30 times (Figure 6). The more permeable material could be attributed to the underlying Benham aquifer, lateral changes in the Upper Paintbrush, or both.

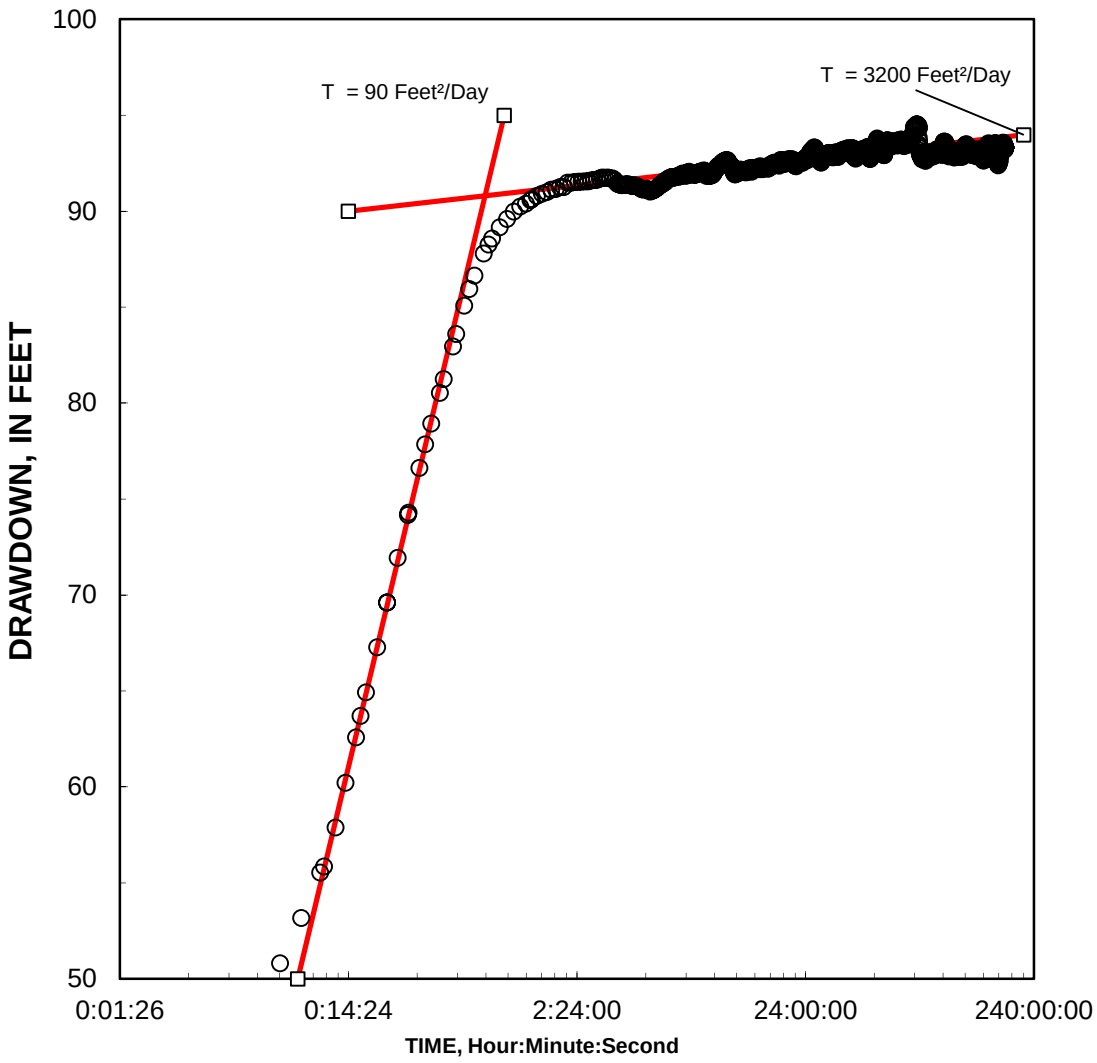


Figure 6.—Drawdowns and straight-line approximations during the constant-rate aquifer test of well *ER-EC-15 main upper zone*.

The estimated transmissivity from *ER-EC-15 main lower zone* aquifer test was 40 ft²/d (Figure 7). All of the transmissivity was attributed to the Topopah Spring aquifer because the semi-log drawdown curve was minimally deflected by leakage from adjacent units.

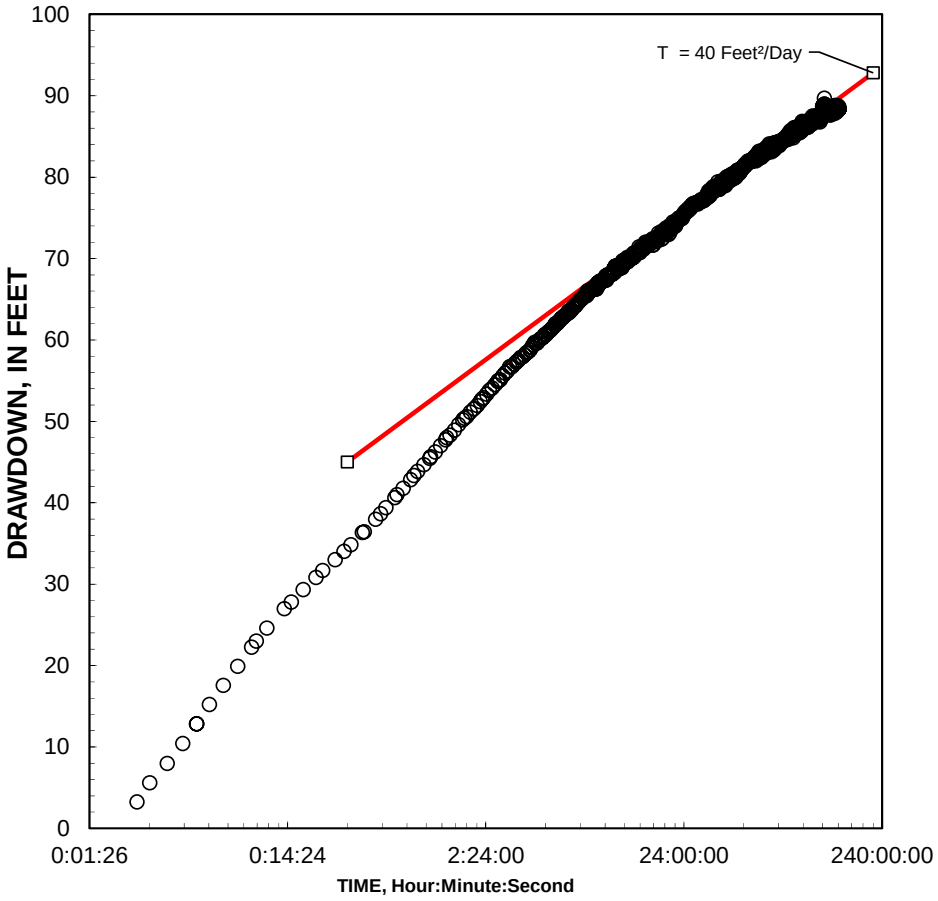


Figure 7.—Drawdowns and straight-line approximations during the constant-rate aquifer test of well *ER-EC-15 main lower zone*.

The estimated transmissivity from *ER-EC-15 main intermediate zone* test was less than 20 ft²/d. Water-level changes were simulated with superimposed Theis functions (Halford and others, 2012) and fit to three pumping and recovery cycles during well development (Figure 8). Water levels were modeled with superimposed Theis functions because steady periods of pumping did not occur and recovery periods were affected by return flow from the pumping column. Return flow was suspected because after each 8-hr period of development water-levels rose 3 to 20 ft higher than prior to a development period (Figure 4).

Flow from the aquifer to the well differed greatly from measured discharges at the surface because of wellbore storage effects. Wellbore storage was 1.35 gal/ft for the annular space between pipes of 5 and 7 5/8 inch diameters. Wellbore storage comprised about 200 gallons of the 500 gallons discharged at the surface during each pumping cycle. Flow from the aquifer was estimated by calculating changes in wellbore storage from measured water-level changes and subtracting wellbore storage rates from surface discharge rates (Figure 8). Water-level changes were simulated with estimated flows from the aquifer.

Transmissivity of the Tiva Canyon aquifer is reported as less than 20 ft^2/d because of uncertainties in flow from aquifer to the well. Simulated water-level changes fluctuate 100 ft which is less than 70 percent of the observed range of fluctuations (Figure 8). This suggests that transmissivity should be less than the estimate of 20 ft^2/d. Further refinement was not pursued because estimated flow from aquifer to the well cannot be refined further.

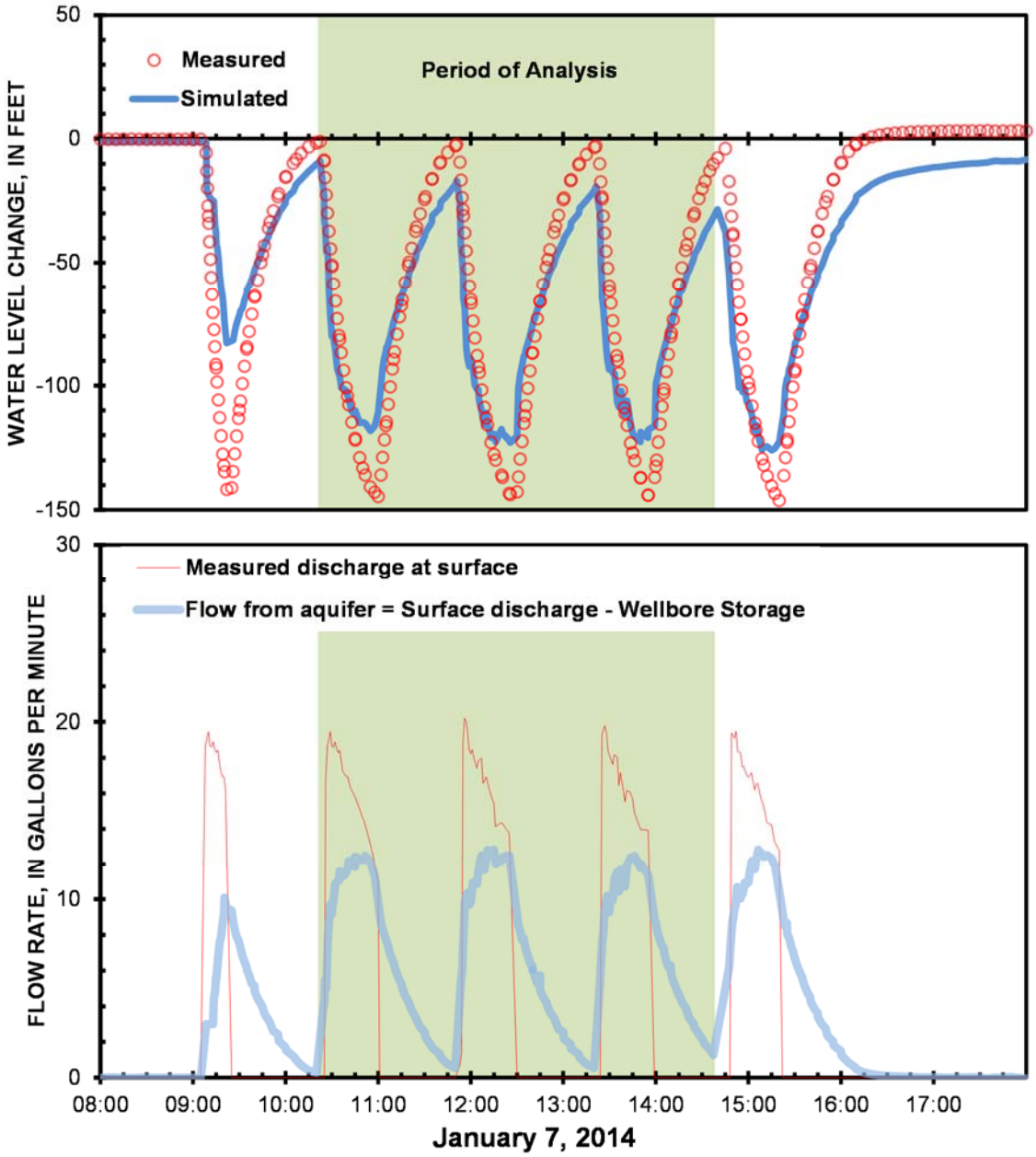


Figure 8.—Measured water-level changes, simulated water-level changes, measured discharge at surface, and flow from aquifer during development of well *ER-EC-15 main intermediate zone*.

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Appendix A. Construction diagram well cluster ER-EC-15

As-built diagram of the well completion for well cluster ER-EC-15 which includes the wells *ER-EC-15 main, ER-EC-15 deep, ER-EC-15 intermediate,* and *ER-EC-15 shallow* (U.S. Department of Energy, 2011).

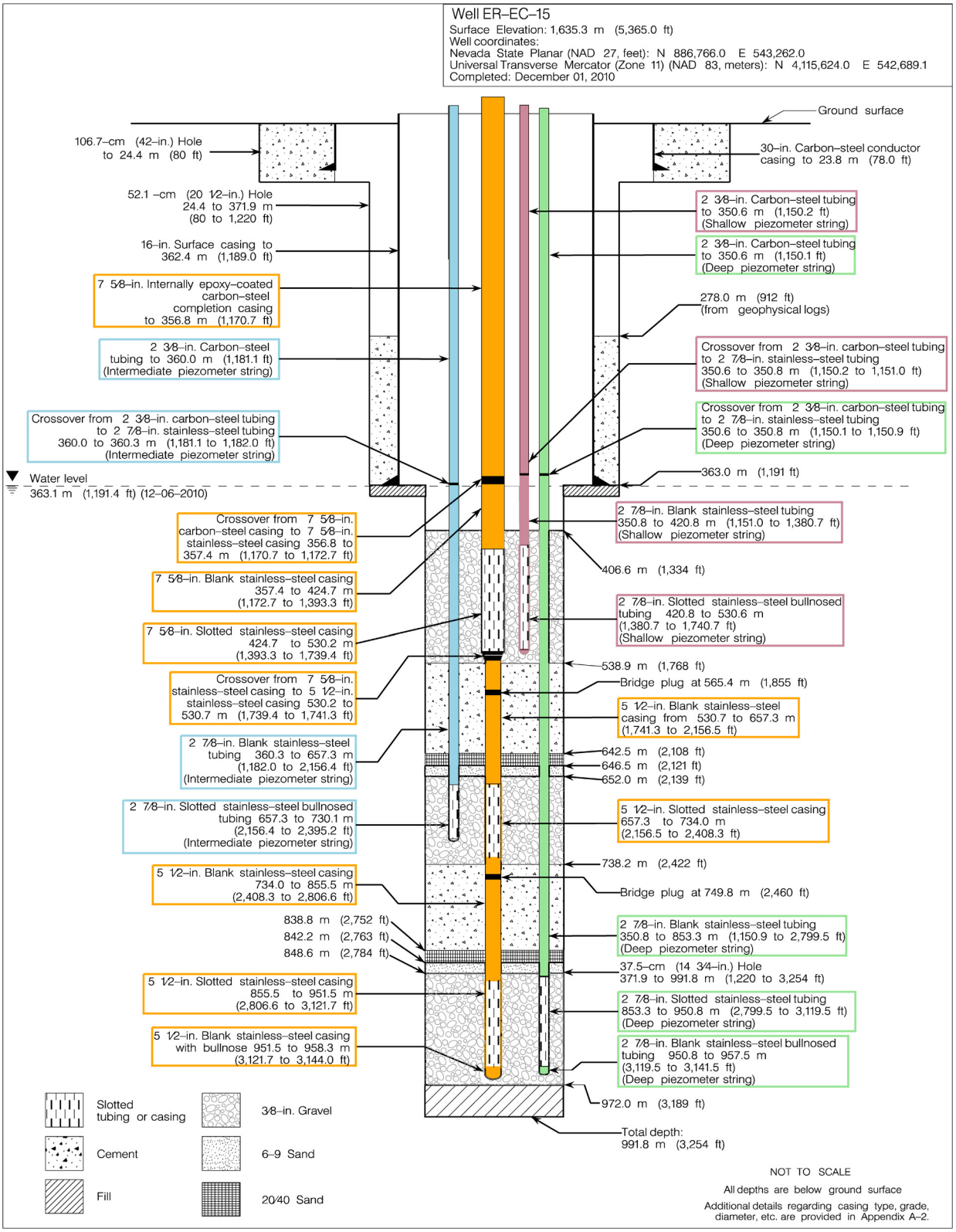

Figure 7-1
As-Built Completion Schematic for Well ER-EC-15