ECF-200BP5-15-0124
Revision 0

200-BP-5 Treatability Test: Analysis of the Step Drawdown and Constant Rate Pumping Tests at Well 299-E33-268

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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APPROVED
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Terms

BRF	Barometric response function
HISI	Hanford Information Systems Inventory
MRCX	Multiple Regression Correction in Excel
PDT	Pacific Daylight Time
PSIA	Per square inch absolute
PST	Pacific Standard Time

1 Purpose

This document describes the analyses of the step drawdown and constant rate discharge tests conducted at pumping well 299-E33-268 for the 200-BP-5 treatability test (DOE/RL-2010-74, Rev. 2, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit*). This well is located in the B Complex of the Hanford Site 200 East Area.

2 Background

From the 1940s until the 1980s, the Hanford Site produced plutonium for national defense. During that time operations used many chemical and radiological constituents which potentially can migrate to groundwater from waste sites. In the 1990s, the Hanford mission changed to environmental cleanup, including remediation of known groundwater contamination under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*.

A treatability test was conducted in the unconfined aquifer beneath the B Tank Farm Complex in the 200-BP-5 Operable Unit between September and November 2015 to determine the practicality of operating a pump-and-treat system to remediate the uranium and technetium-99 plumes in that area (DOE/RL-2010-74, Rev. 2). The test was conducted in 4 parts: 1) collection of baseline water level measurements, 2) a 1-day step drawdown test, 3) a 3-day constant rate discharge test (at 125 gpm), and 4) a 27-day constant rate discharge test (at 100 gpm). Well 299-E33-268 was the pumping well, and there were 10 observation wells (Figure 1). Purge water was transferred via pipeline to the 200 West Groundwater Treatment Facility for treatment and subsequent injection into the aquifer.

Baseline water level measurements were collected from the pumping and observation wells for a minimum of 30 days prior to the start of the step drawdown test. The data were used to determine the water-level barometric response characteristics for each well, which allowed the water level measurements collected during the test to be corrected for fluctuations caused by barometric pressure changes. Drawdown in the pumping and observation wells was expected to be small due to the high transmissivity of the aquifer, so it was important to remove barometric effects from the data so the drawdown could be discerned.

The step drawdown test was conducted on 9/30/2015. Well 299-E33-268 was pumped at flow rates of 50 gpm (189 L/min), 100 gpm (378 L/min), and 150 gpm (568 L/min) for 2 hours each. The data were analyzed to determine the efficiency of the pumping well. The 3-day constant rate discharge test was conducted at 125 gpm (473 L/min). Pumping for this test began on 10/13/2015 at 6:44:57 AM (Pacific Standard Time [PST]) and ended on 10/16/2015 at 12:15:17 PM PST. The data were analyzed to determine aquifer properties (transmissivity, hydraulic conductivity, and specific yield). After a recovery period, the 3-day test was followed by the 27-day constant rate discharge test. Pumping for this test began on 10/22/2015 at 6:32:19 AM PST and ended on 11/19/2015 at 8:05:27 AM PST.

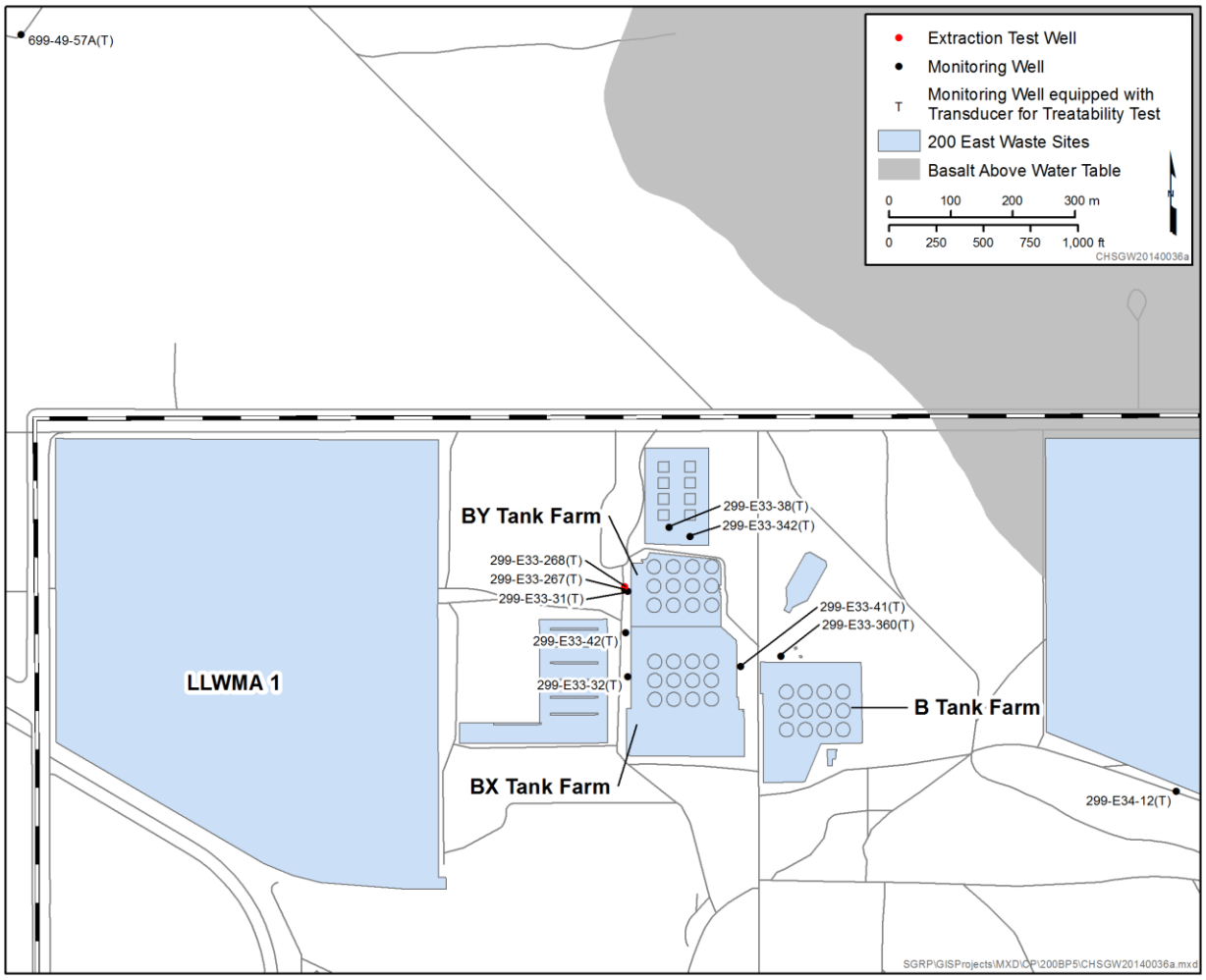

Figure 1. Well Location Map for the 200-BP-5 Treatability Test

3 Methodology

This section describes the analysis of the baseline water level data to determine barometric response characteristics, the method of normalizing the water level measurements to a constant barometric pressure, the method of analysis of the step drawdown test, and the methods used to analyze data from both the 3-day and 27-day constant rate discharge tests.

3.1 Normalization of Hydraulic Heads to a Constant Barometric Pressure

Within unconfined aquifers, changes in ambient barometric pressure can cause changes in well water level elevations if the barometric change causes an imbalance of air pressure between the well and the adjacent vadose zone at the water table. This occurs in relatively deep wells because of the thick vadose zone, and in other wells where low-permeability units within the vadose zone inhibit the migration of air pressure pulses. Barometric pressure changes introduce variability into water-level measurements in two ways: (1) barometric pressure may change during the time period in which a set of water-level measurements is collected from a well network, and (2) different wells may respond differently to barometric pressure changes. To account for these sources of variability, the water-level measurements collected for the treatability test were normalized to a constant barometric pressure using multiple regression/deconvolution ("Identifying and Removing Barometric Pressure Effects in Confined and Unconfined Aquifers" [Rasmussen and Crawford, 1997]; "Considering Barometric Pressure in Groundwater Flow Investigations" [Spane, 2002]).

Using the baseline water level data for the pumping well and each observation well, multiple regression was used to determine the quantitative relationship between barometric pressure and well water-level response (using time series data for both parameters). This relationship was then used to determine a barometric response function (BRF) describing how the well water level would change to an instantaneous unit change in barometric pressure.

The multiple regression was performed using the MRCX software developed by Pacific Northwest National Laboratory (PNNL-19775, *Guide to Using Multiple Regression in Excel [MRCX v. 1.1] for Removal of River Stage Effects from Well Water Levels*), which is based on Microsoft[1] Excel. Although this software was specifically designed for assessing river stage effects, it can also be used for barometric pressure effects because the mathematical equations are identical. The water-level measurements and barometric pressure time series were detrended (using Excel) and then input into MRCX. The regression was performed using either the "original data" or "first differences" options in MRCX, whichever provided the best results. The "original data" option corresponds to the following regression equation from Rasmussen and Crawford (1997, Equation 7):

$$h_O(t) = \beta_0 + \beta_1 t + \Delta u_0 B(t) + \Delta u_1 B(t-1) + \ldots + \Delta u_n B(t-n) \qquad \textbf{(Equation 1)}$$

where:

h_O = observed well water-level elevation (m) as a function of time t (hr)

β_0 = offset coefficient (m)

β_1 = linear trend coefficient (m/hr) (which was determined to be zero during the regression analysis because the data were detrended beforehand)

[1] The Microsoft® products identified in this calculation are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or in other countries.

Δu_n = fitted barometric response coefficient (i.e., regression coefficients) for time lags of 0 to n (m/m)

B = barometric pressure measurements (m of water) as a function of time

n = maximum time lag (hr)

The "first differences" option uses an equation of the same form, except that changes in the water levels are related to changes in barometric pressure:

$$\Delta h_O(t) = \beta_0 + \beta_1 t + \Delta u_0 \Delta B(t) + \Delta u_1 \Delta B(t-1) + \ldots + \Delta u_n \Delta B(t-n) \qquad \textbf{(Equation 2)}$$

where:

Δh_O and ΔB = change in observed well water-level elevation and change in barometric pressure, respectively, between successive times

When performing the multiple regression in MRCX, the maximum time lag (n) was increased to a value at which a good fit was achieved between the predicted and measured water levels and a further increase did not substantially improve the fit. The BRF was determined by MRCX from the regression coefficients as follows (Rasmussen and Crawford, 1997, Equation 5):

$$u(\tau) = \sum_{i=0}^{\tau} \Delta u_i \qquad \textbf{(Equation 3)}$$

where:

u = water-level response (m) to an instantaneous unit change in barometric pressure as a function of the time lag, τ (hr)

The BRFs for each well used in this test are provided in Appendix A.

Deconvolution was used to normalize the water-level measurements collected for this test to a constant barometric pressure using Excel. The net change in well water-level in response to a recent history of barometric pressure changes (n + 1 hourly measurements total) was computed using the following numerical approximation of a convolution integral (Rasmussen and Crawford, 1997, Equation 4):

$$\Delta h_B(t) = \sum_{\tau=0}^{n} u(\tau) \cdot \Delta B(t-\tau) \qquad \textbf{(Equation 4)}$$

where:

Δh_B = change in well water-level elevation (m) at some time t (hr) due to changes in barometric pressure for the previous n time lags

τ = time lag (hr) between a previous hourly barometric pressure change and the associated well water-level response at the current time

ΔB = change in barometric pressure (m of water) over the previous hourly time steps

Finally, the change in well water-level elevation was added to the observed well water-level elevation (i.e., deconvolved) to produce an adjusted well water-level elevation in which barometric pressure effects had been removed (i.e., normalized to a constant barometric pressure).

It should be noted that the equations presented in Rasmussen and Crawford (1997) are written in terms of total head (i.e., the sum of hydraulic head and barometric pressure head), whereas the equations presented in this section are in terms of hydraulic head (i.e., well water-level elevation). To normalize water-level

measurements to a constant barometric pressure, well water-level response functions are needed instead of total head response functions. The use of well water-level elevations instead of total head is valid because convolution can be used on any pair of variables exhibiting a linear stress-response relationship (Olsthoorn, 2008, "Do a Bit More with Convolution").

3.2 Analysis of the Step Drawdown Test

Drawdown observed during the step-drawdown test was used to calculate the specific capacity for each flow rate (as flow rate divided by drawdown). Further, it was intended that the theoretical maximum yield of the pumping well (i.e., the pumping rate correlating to 100 percent drawdown) would be estimated. This was to be done by using the drawdown observed at multiple pumping rates to predict by regression a pumping rate associated with full drawdown (i.e., the total thickness of the aquifer, which is 2.2 m [7.2 ft]). However, the aquifer beneath the 200 East Area is so highly transmissive that the maximum drawdown observed was only 4.7% of the total drawdown available. Because of this low value, it was deemed not feasible to predict a meaningful pumping rate for 100% drawdown. Thus, the maximum theoretical yield was reported simply as being much higher than the maximum flow rate during the step-drawdown test (i.e., >>150 gpm).

3.3 Analysis of the Constant Rate Discharge Tests

Data from the 3-day and 27-day constant rate discharge tests were analyzed using the AQTESOLV[2] software. AQTESOLV allows for the display of aquifer test data, calculation of pressure derivatives, and analysis of the data to determine aquifer properties. It includes a large number of analysis methods applicable to a wide variety of situations (e.g., slug tests, pump tests, confined aquifers, unconfined aquifers, leaky confined aquifers, etc.).

The solution methods used for this analysis were Theis (1935, "The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage") as modified by Hantush (1961a, "Drawdown around a partially penetrating well") and Hantush (1961b, "Aquifer tests on partially penetrating wells"), Neuman (1974, "Effect of partial penetration on flow in unconfined aquifers considering delayed gravity response"), and Moench (1997, "Flow to a well of finite diameter in a homogeneous, anisotropic, water-table aquifer"). Pressure derivatives were calculated using the method of Spane and Wurstner (1993, "DERIV: A computer program for calculating pressure derivatives for use in hydraulic test analysis").

3.3.1 Pressure Derivatives

The pressure derivative consists of the change of drawdown water level measurements with respect to the natural logarithm of time. The shape of the resulting curve can be used diagnostically to identify test conditions not as easily identified by examining the drawdown measurements directly (e.g., wellbore storage, vadose zone gravity drainage, infinite acting radial flow conditions, recharge boundary conditions, etc.) (Spane and Wurstner [1993]).

The method of Spane and Wurstner (1993), which is implemented in the AQTESOLV software, was used to calculate pressure derivatives. The user can specify the L-spacing, which is the portion of a log cycle used in calculating the derivative. An L-spacing of 1 (the maximum allowed) was used which resulted in the most smoothing of the data. This was done because the water level measurements collected during the tests were noisy compared to the magnitude of the drawdown observed.

[2] AQTESOLV is copyrighted by HydroSOLVE, Inc., Reston, Virginia.

3.3.2 Theis (1935) / Hantush (1961a,b) Method

The method of Theis (1935) was developed for nonsteady flow to a fully penetrating well in a confined aquifer. The equations are (Freeze and Cherry, 1979, *Groundwater*):

$$s = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-u}}{u}\,du \qquad \textbf{(Equation 5)}$$

in which

$$u = \frac{r^2 S}{4Tt} \qquad \textbf{(Equation 6)}$$

where:

- s = drawdown from static water level (length)
- Q = pumping rate (length^3/time)
- T = transmissivity (length^2/time)
- r = radial distance from the pumping well to the observation well (length)
- S = storage coefficient (unitless)
- t = time (time)

The integral in Equation 5 is the exponential integral and is commonly represented as a function, $W(u)$, known as the well function. Values of the well function can be determined numerically.

Hantush (1961a,b) extended the Theis (1935) method to account for partially penetrating wells and anisotropy (vertical hydraulic conductivity can differ from the horizontal hydraulic conductivity). The equations are more complex and the reader is referred to Hantush (1961a,b) or the AQTESOLV online help for details.

Although developed for confined aquifers, the method of Theis (1935) / Hantush (1961a,b) can be used to determine hydraulic properties for unconfined aquifers if the amount of drawdown is small relative to the aquifer thickness (Freeze and Cherry, 1979). Once infinite acting radial flow conditions have been achieved during the test, straight line analysis methods can be used (e.g., Cooper and Jacob, 1946, "A generalized graphical method for evaluating formation constants and summarizing well field history"). This condition is indicated by a constant pressure derivative following the wellbore storage and gravity drainage responses (PNL-8359, 1993, *Selected Hydraulic Test Analysis Techniques for Constant-Rate Discharge Tests*). The advantage of the straight line method is that it can be easily implemented graphically. However, type curves were used for analyzing the 200-BP-5 data because these are automatically implemented in AQTESOLV.

3.3.3 Neuman (1974) Method

The method of Neuman (1974) was developed for nonsteady flow to a fully or partially penetrating well in a homogeneous, anisotropic unconfined aquifer with delayed gravity drainage from the vadose zone. The anisotropy component refers only to differences between the horizontal and vertical hydraulic conductivity; horizontal hydraulic conductivity is isotropic (i.e., constant regardless of direction). The equations are complex and the reader is referred to Neuman (1974) or the AQTESOLV online help for details.

3.3.4 Moench (1997) Method

Like Neuman (1974), the method of Moench (1997) also applies to nonsteady flow to a fully or partially penetrating well in a homogeneous, anisotropic (horizontal versus vertical hydraulic conductivity only) unconfined aquifer with delayed gravity drainage from the vadose zone. However, the method also includes wellbore storage and skin effects. Thus, drawdown in the pumping well can be included in the analyses, whereas with the other methods, only observation wells are used. The equations are complex and the reader is referred to Moench (1997) or the AQTESOLV online help for details.

3.3.5 Recovery Data

Drawdown data from constant rate discharge tests can be directly analyzed to determine hydraulic properties by application of the methods described in Sections 3.3.2, 3.3.3, and 3.3.4. To analyze recovery data using these methods, the buildup of the water level after the termination of pumping has to be expressed in terms of the Agarwal equivalent time (Agarwal, 1980, "A New Method to Account for Producing Time Effects when Drawdown Type Curves are used to Analyze Pressure Buildup and other Test Data"), as follows:

$$t_e = \frac{t \cdot t'}{t + t'} \qquad \textbf{(Equation 6)}$$

where:

t_e = Agarwal equivalent time

t = duration of pumping

t' = time since pumping terminated

4 Assumptions and Inputs

This section lists the assumptions and inputs applicable to the 200-BP-5 treatability test analyses.

4.1 Assumptions

The main assumption regarding normalizing water level measurements to a constant barometric pressure is that the response of the well water level to a barometric pressure change is linear. In other words, if the barometric pressure change is doubled, the water level response doubles; if the pressure changed is halved, the water level response is halved. Linearity allows for the method of convolution to be applied in which the known response of the water level to a unit, step change in barometric pressure is used to determine the water level response to an arbitrary time-series of barometric pressure changes using superposition.

Several assumptions apply to the aquifer test analysis methods described in Section 3. Because many of the assumptions are common to more than one method, they are listed in Table 1 and the applicable method(s) are indicated.

Table 1. Constant Rate Discharge Test Analysis Methods and Assumptions

Assumption	Theis (1935) / Hantush (1961a,b)	Neuman (1974)	Moench (1997)
Aquifer is of infinite lateral extent	X	X	X
Aquifer is of constant thickness	X	X	X
Aquifer is homogeneous	X	X	X
Aquifer slope is negligible	X	X	X
The lower boundary of the aquifer is impermeable	X	X	X
The water table is initially horizontal	X	X	X
Drawdown is small relative to the aquifer thickness	X	X	X
Aquifer is anisotropic (i.e., $K_x = K_y \neq K_z$)	X	X	X
Water is discharged instantaneously from storage	X		
Wellbore storage/skin effects are negligible	X	X	

4.2 Inputs

Input data to the test analyses consisted of the following:

- Barometric pressure measurements from Hanford meteorology stations 6 (200 East Area) and 21 (200 West Area). Data from station 6 were primarily used; data from station 21 were used only fill gaps in the station 6 data.
- Time series water level measurements from the pumping and observation wells. These data were collected using absolute pressure transducers (Model 3001 LeveLogger Gold® and Model 3001 BaroLogger Gold™ both manufactured by Solinst[3]), as opposed to vented transducers, following the recommendations in SGW-49700, 2011, *Comparison of Vented and Absolute Pressure Transducers for Water-Level Monitoring in Hanford Site Central Plateau Wells*.
- Pumping well flow rates. These data were obtained from the pump-and-treat operation organization which collects flow rate data on a very frequent basis from all operating pumping wells. These data were reduced to specific time/flow rate pairs to represent the main changes in flow rates during test startup. The reduced data input into AQTESOLV are given in Table 2 for both the 3-day and 27-day tests.
- Well location and construction characteristics. This information was obtained from as-built diagrams and survey reports and is listed in Table 3 for the pumping well (299-E33-268) and those observation wells with discernable drawdown (299-E33-31, 299-E33-267, and 299-E33-342). All of the wells fully penetrated the 2.2 m thickness aquifer.

[3] Model 3001 LeveLogger Gold® is a registered trademark and the Model 3001 BaroLogger Gold™ is a trademark of Solinst Canada, Ltd., Georgetown, Ontario, Canada.

Table 2. Pumping Rates Input into AQTESOLV for the Constant Rate Discharge Tests

Time (days)	Flow Rate (gpm)		Time (days)	Flow Rate (gpm)		Time (days)	Flow Rate (gpm)
3-Day Test							
0	164.4632568		0.006944444	123.6388168		0.180555556	124.0922227
0.000694444	156.5557505		0.013888889	123.1247823		0.222222222	123.8409323
0.001388889	140.8461151		0.020833333	123.2649743		0.263888889	123.8435286
0.002083333	142.2113698		0.027777778	123.3387348		0.305555556	123.9935702
0.002777778	137.4971085		0.034722222	123.8152012		0.347222222	124.1912576
0.003472222	134.5970764		0.041666667	124.0703861		0.388888889	124.5991547
0.004166667	131.7153727		0.048611111	124.1010817		0.430555556	124.9021388
0.004861111	128.7649473		0.055555556	123.9962428		0.472222222	124.9998716
0.005555556	126.4101067		0.097222222	123.9957854		3.229166667	0
0.00625	125.4021975		0.138888889	124.1671291			
27-Day Test							
0	126.3093109		0.000347222	131.9444427		0.00150463*	100
0.000231481	147.5578766		0.001388889	76.58275604			

* Constant flow rate from this time on.

Table 3. Well Location and Characteristics Information Input into AQTESOLV

Parameter	299-E33-268	299-E33-267	299-E33-31	299-E33-342
Easting coordinate (m)[a]	573519.25	573519.51	573524.98	573625.68
Northing coordinate (m)[a]	137498.67	137494.16	137491.439	137579.96
Inside radius of well casing (m)	0.1016[b]	0.0508	0.0508	0.0508
Radius of downhole equipment (m)	0.0381	0.0127	0.0127	0.0127
Radius of well open interval (m)	0.1016	0.0508	0.0508	0.0508
Fully penetrating?	Yes	Yes	Yes	Yes

a. North American Datum (1983) state plane, Washington south zone (4602)
b. This value was a solution parameter by the Moench (1997) method, so the final value determined by that method differs from the value entered into the AQTESOLV software.

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5 Software Applications

The software applications used for this work were MRCX, AQTESOLV, and MS Excel. Both MRCX Version 1.1 (HISI ID: 3385) and AQTESOLV Version 4.50 Professional (HISI ID: 3219) are registered in Hanford Information Systems Inventory (HISI) and are approved for use. Other than for MRCX, Excel was used as a desktop calculator and is exempt from controlled software management procedures. Both MRCX and AQTESOLV® were used within their limitations.

6 Calculations

The time-series water level measurements collected during the baseline period were analyzed using MRCX to determine BRFs for the pumping and observation wells used in this test. The baseline data were collected on a one-hour frequency, so the BRFs consist of time-varying barometric coefficients at hourly intervals. Charts of the baseline water level measurements and the BRFs are provided in Appendix A.

Automated water level measurements were collected in the pumping well (299-E33-268) during the step drawdown test at a 2-second frequency. Due to a logger programming issue, data collection did not actually begin until the test was underway at the first flow rate (50 gpm). The data were used to calculate the drawdown associated with each pumping rate (the static water level was determined from the recovery data collected after pumping was terminated). The data were not normalized to a constant barometric pressure due to the short duration of the test. Results of the step-drawdown test are provided in Section 7.

The time-series water level measurements collected for the 3-day and 27-day constant rate discharge tests were normalized to a constant barometric pressure using deconvolution, as described in Section 3.1. During this analysis, it was discovered that the LeveLogger in well 299-E33-38 had failed, so data from this well were not available for analysis. Further, the cable on the LeveLogger for 699-49-57A was damaged (apparently by animals), so data from this well were not available for analysis. Charts of the data for the remaining wells were examined to determine if drawdown could be discerned in each well. Drawdown was obvious in the pumping well, 299-E33-268, but because of the high transmissivity of the aquifer, drawdown was discernable in only 3 of the observation wells: 299-E33-267 (4.5 m [15 ft] south of the pumping well), 299-E33-31 (9.2 m [30 ft] southeast of the pumping well), and 299-E33-342 (134 m [440 ft] northeast of the pumping well). Data from these 4 wells were used to determine aquifer hydraulic properties. Charts of the automated water level measurements collected from the pumping and observation wells are provided in Appendices B and E for the 3-day and 27-day constant rate discharge tests, respectively.

Large data sets were collected during the test. Because the start of pumping could not be timed precisely, the loggers were set to record on a 2-second frequency for 6 hours during the startup period. The 2-second frequency allowed for good resolution on the initial drawdown in the wells. This period was followed by a 5-minute frequency lasting for much of the pumping phase of the test. When pumping was terminated, the loggers were set to record again at a 2-second frequency for 6 hours to resolve the initial rapid water level changes during recovery. This was followed by measurements at a 5-minute frequency for the remainder of the recovery period. This resulted in the collection of over 23,000 water level measurement records from each of the wells during the 3-day test, and over 30,000 records during the 27-day test. To reduce this data set to a reasonable size for analysis, the data were resampled on a log frequency. The initial frequency was 2 seconds for 10 records commencing at the start of pumping (or recovery). Then, the sample interval was doubled to 4 seconds for another 10 records, followed by 8 seconds for 10 records, etc. By this method, the approximately 20,000 to 30,000 measurements collected for each well

during the tests were reduced to between 122 and 153 measurements during either the pumping or recovery phases. These data were then imported into the AQTESOLV software for analysis.

The water levels in 299-E34-12 were used to identify temporal trends in the water table during both the 3-day and 27-day tests. During the 3-day test, the background water table elevation was stable, but it declined about 0.014 m during the 27-day test. Because the rate of decline was stable, linear regression was used to identify the slope of the declining trend and then this slope was used to detrend all the water level measurements collected during the 27-day test (a comparison of the original and detrended measurements for 299-E34-12 is shown in Figures E-9 and E-10 in Appendix E). This was done so the background water table decline did not affect the drawdown determinations.

It should be noted that the cable to the BaroLogger in 299-E33-32 failed during the 27-day test, so downhole barometric pressure measurements were not directly available. However, the relationship between the downhole barometric pressure and the barometric pressure measurements at meteorology station 6 were determined by multiple linear regression on the background measurements, and then convolution was used to estimate the downhole pressure from the station 6 measurements during the 27-day test (using the same method described Section 3.1).

The pressure derivative was examined for the pumping well and the 3 observation wells with discernable drawdown. The pressure derivative was used to assist in determining the time period for which curve matching would be performed. Aquifer properties were then determined by fitting of type curves to the data using the automatic curve matching feature of AQTESOLV. The variables allowed to vary and their limits are shown in Table 4 for each solution method. At the start of the 3-day test, the pumping rate varied for a few minutes until it stabilized near the planned rate of 125 gpm. For this reason, the period used for curve matching (i.e., the analysis window) was usually set to begin at either 0.01 days (2.4 minutes) or 0.1 days (2.4 hours) after pumping began, and the analysis window typically extended the duration of the pumping phase (3.3 days). During startup of the 27-day test, the pumping rate stabilized at 100 gpm more quickly and drawdown in the wells had stabilized after about 1 day. For these reasons, the period used for curve matching typically started at 0.0001 days (8 seconds) and ended at 1 day.

Table 4. Variables and Limits used for the Automatic Curve Matching Feature of AQTESOLV

Variable	Theis (1935) / Hantush (1961a,b)		Neuman (1974)		Moench (1997)	
	Min	Max	Min	Max	Min	Max
Transmissivity (T) (m^2/d)	1	1×10^6	1	1×10^6	1	1×10^6
Storativity (S)	1×10^{-3} [a]	n/a [a]	1×10^{-5}	1×10^{-3}	1×10^{-3} [b]	1×10^{-3} [b]
Specific Yield (S_y)	n/a [a]	1.0 [a]	1×10^{-3}	1.0	0.21 [b]	0.21 [b]
Anisotropy Ratio (K_z/K_r)	0.001	1.0	Not used	Not used	0.01	1.0
Wellbore Skin Factor (S_w)	n/a	n/a	n/a	n/a	-5	100

a. The Theis (1935) / Hantush (1961a,b) method uses only a single storage coefficient variable; the minimum was set to 1×10^{-3} and the maximum was set to 1.0.
b. Storativity and specific yield were held constant at the indicated values for the Moench (1997) method.

Curve matching using the Theis (1935) / Hantush (1961a,b) method and the Neuman (1974) method was performed for each observation well separately, for observation wells 299-E33-267 and 299-E33-31 together (these are closest to the pumping well), and for all three observation wells together. The Moench (1997) method was applied to all 4 wells.

Recovery data for the 3-day and 27-day tests were also analyzed. Buildup of the water level after the termination of pumping was calculated in a similar manner as for drawdown. The recovery times were then converted to Agarwal equivalent times using Equation 6. The recovery data were analyzed in the same manner as for the drawdown data, except that the method of Moench (1997) was not employed (because there was no active pumping). A large barometric pressure change occurred just as the recovery portion of the 27-day test began. Because normalization of the water level measurements to a constant barometric pressure contains some residual error, the recovery data at well 299-E33-342 (which had the lowest drawdown) was adversely affected. Because of this, hydraulic property determinations for this well were very sensitive to the period of analysis chosen, so the results for this well when analyzed by itself were determined not to be reliable.

Charts of the fitted curves for the drawdown and recovery portions of the 3-day test are provided in Appendices C and D, respectively. Charts of the fitted curves for the drawdown and recovery portions of the 27-day test are provided in Appendices F and G, respectively. Appendices C and F also contain charts of the pressure derivative for wells 299-E33-268, 299-E33-31, 299-E33-267, and 299-E33-342 for the drawdown portion of the 3-day and 27-day tests, respectively.

7 Results

The automated water level measurements collected during the step-drawdown test are shown in Figure 2, and results of the test are shown in Table 5. The maximum drawdown was 0.104 m (10.4 cm) at the 150 gpm flow rate, which is only 4.7 % of the theoretical maximum drawdown of 2.2 m (220 cm). Thus, drawdown was not a limiting factor on pumping, and the theoretical maximum yield is greater than 150 gpm. Specific capacity ranged from a high of 2,500 gpm/m (762 gpm/ft) at the 50 gpm flow rate to a low of 1,442 gpm/m (440 gpm/ft) at the 150 gpm flow rate. These specific capacity values are quite high. For comparison, the pump-and-treat extraction well in the 200 West Area with the highest specific capacity is 299-W14-22 with a value of 45.9 gpm/m (13.7 gpm/ft) at a flow rate of approximately 100 gpm.

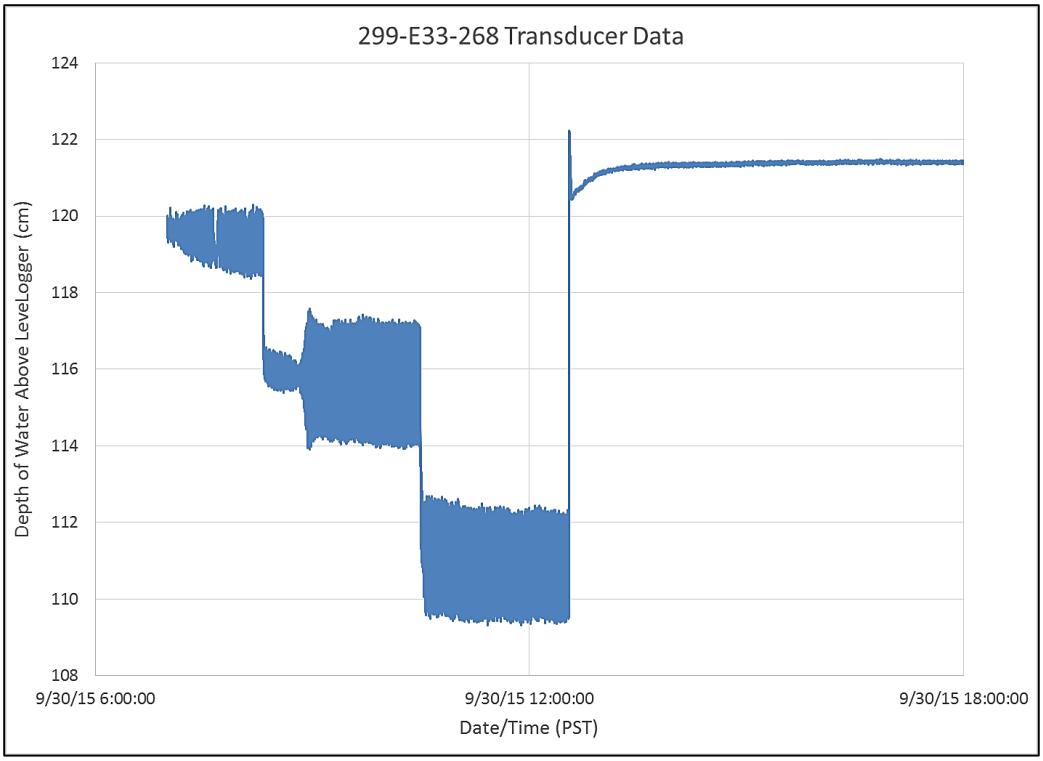

Figure 2. Automated Water Level Measurements Collected in Pumping Well 299-E33-268 during the Step-Drawdown Test

Table 5. Results of the Step-Drawdown Test

Pumping Rate (gpm)	Drawdown		Specific Capacity	
	cm	Percent of Total Available Drawdown*	gpm/m	gpm/ft
50	2.0	0.9 %	2,500	762
100	5.7	2.6 %	1,754	535
150	10.4	4.7 %	1,442	440

* Total available drawdown is equal to the aquifer thickness of 2.2 m (220 cm).

Results of determining hydraulic properties for the drawdown and recovery portion of the 3-day test are provided in Table 6. Transmissivity ranged from 34,800 to 46,900 m^2/day with an average value of 41,300 m^2/day. Hydraulic conductivity ranged from 15,800 to 21,300 m/day with an average value of 18,800 m/day. Specific yield values for several of the tests were unrealistically high. This may be caused by assumptions of the analytical models not being fully met. Those results that were unrealistically high were not included in calculating the range and average result, which was 0.11 to 0.31 with an average of 0.21.

Table 6. Results of Determining Hydraulic Properties for the 3-Day Constant Rate Discharge Test

Analysis Type			Results		
Wells	**Test Type**	**Solution Method**	**Transmissivity (m^2/day)**	**Hydraulic Conductivity (m/day)**	**Specific Yield**
299-E33-31	Drawdown	Theis (1935)	4.36E+04	1.98E+04	0.25
299-E33-31	Drawdown	Neuman (1974)	4.56E+04	2.07E+04	0.18
299-E33-31	Recovery	Theis (1935)	4.12E+04	1.87E+04	0.63[a]
299-E33-31	Recovery	Neuman (1974)	4.13E+04	1.88E+04	0.62[a]
299-E33-267	Drawdown	Theis (1935)	3.53E+04	1.60E+04	1.00[a]
299-E33-267	Drawdown	Neuman (1974)	4.26E+04	1.94E+04	0.23
299-E33-267	Recovery	Theis (1935)	3.48E+04	1.58E+04	1.00[a]
299-E33-267	Recovery	Neuman (1974)	3.53E+04	1.60E+04	1.00[a]
299-E33-342	Drawdown	Theis (1935)	4.22E+04	1.92E+04	0.21
299-E33-342	Drawdown	Neuman (1974)	4.20E+04	1.91E+04	0.22
299-E33-342	Recovery	Theis (1935)	3.54E+04	1.61E+04	0.11
299-E33-342	Recovery	Neuman (1974)	3.54E+04	1.61E+04	0.11
299-E33-31 & 299-E33-267	Drawdown	Theis (1935)	4.15E+04	1.89E+04	0.31
299-E33-31 & 299-E33-267	Drawdown	Neuman (1974)	3.96E+04	1.80E+04	0.45[a]
299-E33-31 & 299-E33-267	Recovery	Theis (1935)	4.27E+04	1.94E+04	0.28
299-E33-31 & 299-E33-267	Recovery	Neuman (1974)	4.25E+04	1.93E+04	0.28
E33-31, E33-267, & E33-342	Drawdown	Theis (1935)	4.37E+04	1.99E+04	0.21
E33-31, E33-267, & E33-342	Drawdown	Neuman (1974)	4.36E+04	1.98E+04	0.21
E33-31, E33-267, & E33-342	Recovery	Theis (1935)	4.69E+04	2.13E+04	0.14
E33-31, E33-267, & E33-342	Recovery	Neuman (1974)	4.68E+04	2.13E+04	0.14
All Wells	Drawdown	Moench (1997)	4.50E+04	2.05E+04	0.21[b]
		Minimum:	3.48E+04	1.58E+04	0.11
		Maximum:	4.69E+04	2.13E+04	0.31
		Average:	**4.13E+04**	**1.88E+04**	**0.21**

a. Unrealistic specific yield value – not used in the minimum, maximum, or average determinations.
b. The specific yield for the Moench (1997) method was held constant at the average value of 0.21 determined from the other analyses.

Results of determining hydraulic properties for the drawdown and recovery portion of the 27-day test are provided in Table 7. The results confirmed the properties determined during the 3-day test. Transmissivity ranged from 33,200 to 46,400 m^2/day with an average value of 40,100 m^2/day. Hydraulic conductivity ranged from 15,100 to 21,100 m/day with an average value of 18,200 m/day. Many of the specific yield determinations came out unrealistically high, so the range and average was not determined. This was a consequence of curve matching to earlier data than during the 3-day test. Although the transmissivity and hydraulic conductivity results of the 27-day test were similar to the results of the 3-day test, the 3-day test is considered to be the better test because of a higher pumping rate (125 gpm) which stressed the aquifer a little more than the pumping rate during the 27-day test (100 gpm), as well as more realistic specific yield values. Thus, the average values for the 3-day test are considered to be the final results.

Table 7. Results of Determining Hydraulic Properties for the 27-Day Constant Rate Discharge Test

Analysis Type			Results		
Wells	**Test Type**	**Solution Method**	**Transmissivity (m^2/day)**	**Hydraulic Conductivity (m/day)**	**Specific Yield[a]**
299-E33-31	Drawdown	Theis (1935)	4.38E+04	1.99E+04	0.38
299-E33-31	Drawdown	Neuman (1974)	4.36E+04	1.98E+04	0.38
299-E33-31	Recovery	Theis (1935)	4.19E+04	1.90E+04	0.82
299-E33-31	Recovery	Neuman (1974)	4.20E+04	1.91E+04	0.80
299-E33-267	Drawdown	Theis (1935)	3.32E+04	1.51E+04	1.00
299-E33-267	Drawdown	Neuman (1974)	3.32E+04	1.51E+04	1.00
299-E33-267	Recovery	Theis (1935)	4.18E+04	1.90E+04	1.00
299-E33-267	Recovery	Neuman (1974)	4.20E+04	1.91E+04	0.80
299-E33-342	Drawdown	Theis (1935)	4.64E+04	2.11E+04	0.36
299-E33-342	Drawdown	Neuman (1974)	4.56E+04	2.07E+04	0.37
299-E33-342	Recovery	Theis (1935)	Not reliable[b]	n/a[b]	n/a[b]
299-E33-342	Recovery	Neuman (1974)	Not reliable[b]	n/a[b]	n/a[b]
299-E33-31 & 299-E33-267	Drawdown	Theis (1935)	3.60E+04	1.64E+04	0.76
299-E33-31 & 299-E33-267	Drawdown	Neuman (1974)	3.58E+04	1.63E+04	0.77
299-E33-31 & 299-E33-267	Recovery	Theis (1935)	3.93E+04	1.79E+04	1.00
299-E33-31 & 299-E33-267	Recovery	Neuman (1974)	3.92E+04	1.78E+04	0.57
E33-31, E33-267, & E33-342	Drawdown	Theis (1935)	3.71E+04	1.69E+04	0.65
E33-31, E33-267, & E33-342	Drawdown	Neuman (1974)	3.70E+04	1.68E+04	0.65
E33-31, E33-267, & E33-342	Recovery	Theis (1935)	4.08E+04	1.85E+04	0.88
E33-31, E33-267, & E33-342	Recovery	Neuman (1974)	4.07E+04	1.85E+04	0.89

Table 7. Results of Determining Hydraulic Properties for the 27-Day Constant Rate Discharge Test

Analysis Type			Results		
Wells	**Test Type**	**Solution Method**	**Transmissivity (m^2/day)**	**Hydraulic Conductivity (m/day)**	**Specific Yield[a]**
All Wells	Drawdown	Moench (1997)	4.32E+04	1.96E+04	0.21[c]
		Minimum:	3.32E+04	1.51E+04	ND
		Maximum:	4.64E+04	2.11E+04	ND
		Average:	**4.01E+04**	**1.82E+04**	ND

a. The specific yield results were unrealistically high and are not representative of aquifer conditions.
b. Results were very sensitive to the analysis window chosen due to the low observed drawdown and a large barometric pressure change that occurred during initiation of the recovery portion.
c. The specific yield for the Moench (1997) method was held constant at the average value of 0.21 determined for the 3-day test.

ND = not determined

8 References

Agarwal, R. G., 1980, "A New Method to Account for Producing Time Effects when Drawdown Type Curves are used to Analyze Pressure Buildup and other Test Data", SPE Paper 9289, presented at the 55th Annual Fall Technical Conference and Exhibition of the Society of Petroleum Engineers, September 21-24, 1980, Dallas, Texas.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9601, et seq. Available at: http://www.epa.gov/oecaagct/lcla.html#Hazardous%20Substance%20Responses.

DOE/RL-2010-74, 2015, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081243H

Freeze, R.A. and J.A. Cherry, 1979, *Groundwater*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Hantush, M. S., 1961a, "Drawdown around a partially penetrating well", *Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division*, Vol. 87, No. HY4, pp. 83-98.

Hantush, M. S., 1961b, "Aquifer tests on partially penetrating wells", *Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division*, Vol. 87, No. HY5, pp. 171-194.

Moench, A. F., 1997, "Flow to a well of finite diameter in a homogeneous, anisotropic, water-table aquifer", *Water Resources Research*, Vol. 33, No. 6, pp. 1397-1407.

Neuman, S. P., 1974, "Effect of partial penetration on flow in unconfined aquifers considering delayed gravity response", *Water Resources Research*, Vol. 10, No. 2, pp. 303-312.

Olsthoorn, T.N., 2008, "Do a Bit More with Convolution," *Ground Water* 46(1):13-22.

PNL-8539, 1993, *Selected Hydraulic Test Analysis Techniques for Constant-Rate Discharge Tests*, Pacific Northwest Laboratory, Richland, Washington. Available at: http://www.osti.gov/scitech/servlets/purl/6585821

PNNL-19775, 2010, *Guide to Using Multiple Regression in Excel [MRCX v. 1.1] for Removal of River Stage Effects from Well Water Levels*, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19775rev1.pdf.

Rasmussen, T.C. and L.A. Crawford, 1997, "Identifying and Removing Barometric Pressure Effects in Confined and Unconfined Aquifers," *Ground Water* 35(3):502-511.

SGW-49700, 2011, *Comparison of Vented and Absolute Pressure Transducers for Water-Level Monitoring in Hanford Site Central Plateau Wells*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://www.osti.gov/scitech/servlets/purl/1028215.

Spane, F. A. and S. K. Wurstner, 1993, "DERIV: A computer program for calculating pressure derivatives for use in hydraulic test analysis", *Ground Water*, Vol. 31, No. 5, pp. 814-822.

Spane, F.A., 2002, "Considering Barometric Pressure in Groundwater Flow Investigations," *Water Resources Research* 38(6):14-1–14-18.

Theis, C. V., 1935, "The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage", *American Geophysical Union Transactions*, Vol. 16, pp. 519-524.

Appendix A
Baseline Data Analysis and Barometric Response Functions

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This appendix provides charts of the barometric response functions generated using the MRCX software. This is followed by charts of the baseline water level measurements and the measurements normalized to a constant barometric pressure by the deconvolution technique described in Section 3.1. A portion of one of the Excel spreadsheets used for performing the deconvolution is provided as an example.

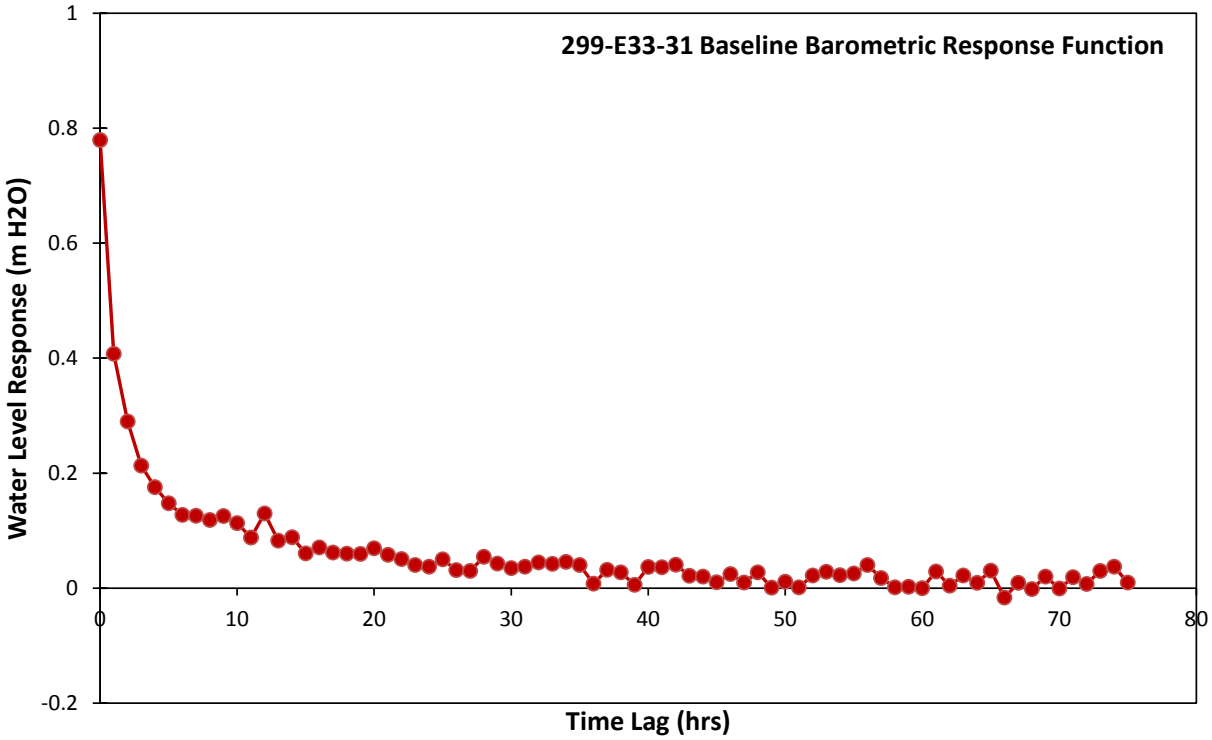

Figure A-1. Barometric Response Function for 299-E33-31.

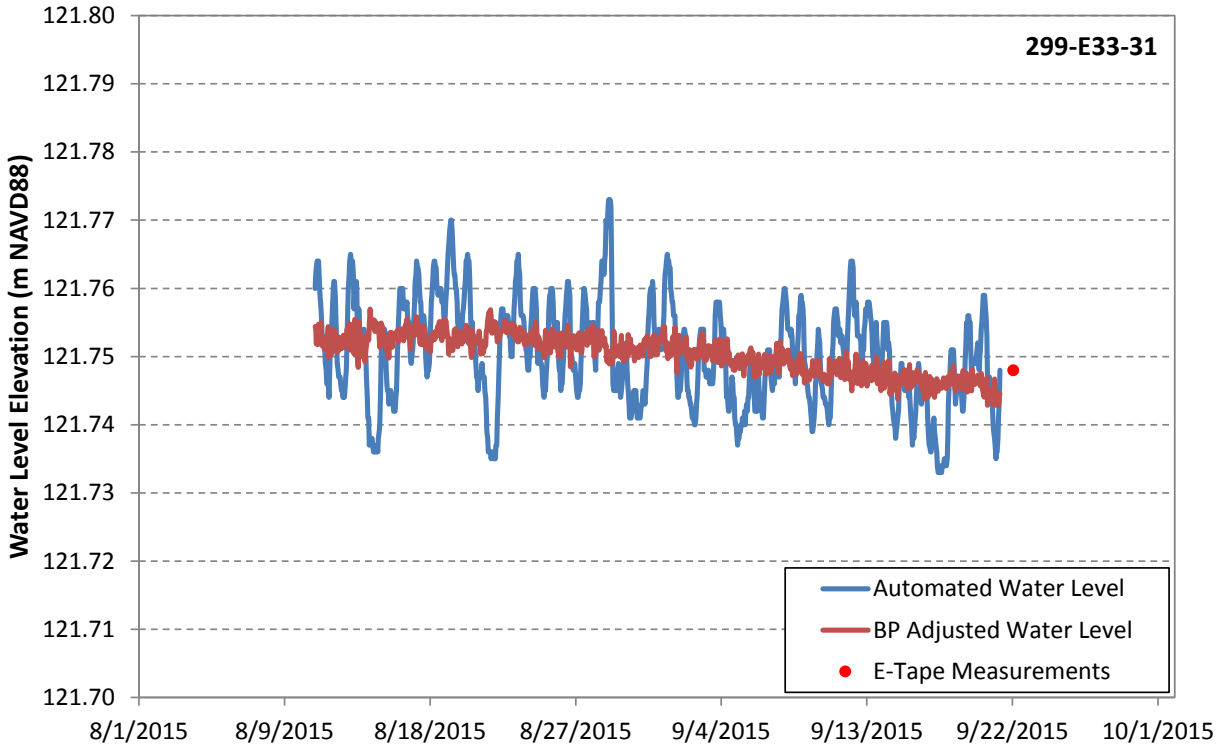

Figure A-2. Baseline Water Level Measurements for 299-E33-31.

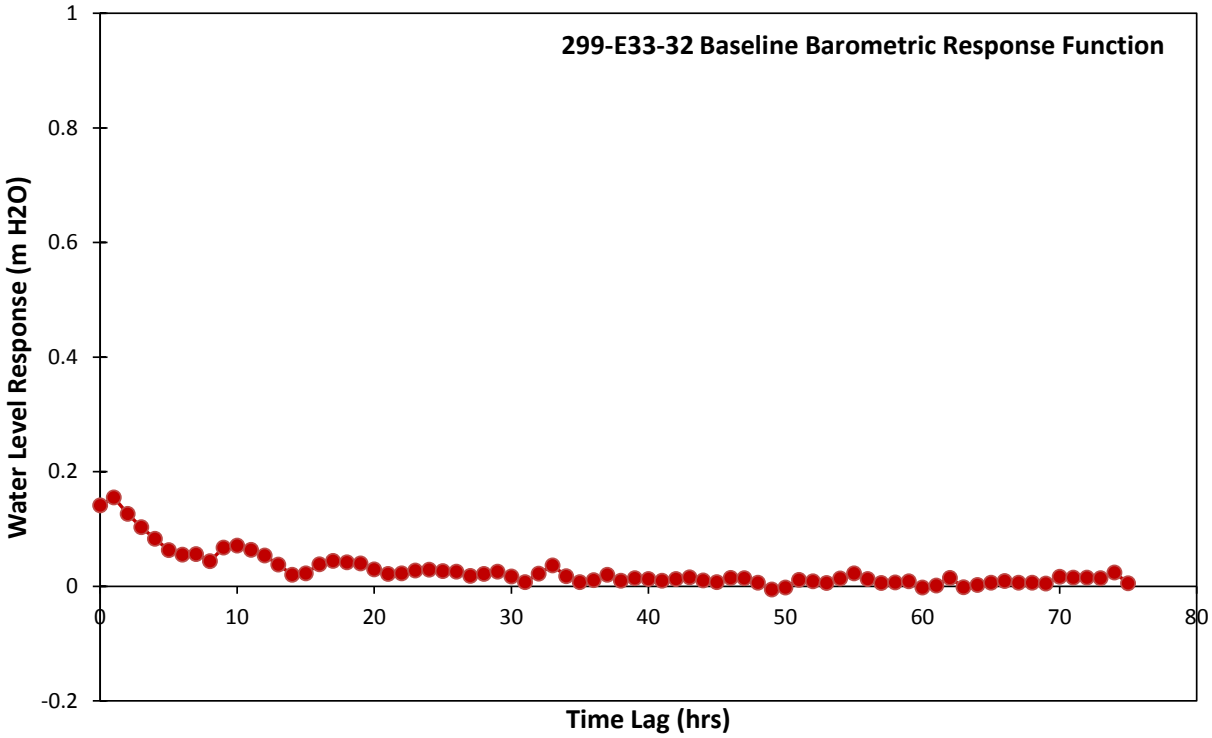

Figure A-3. Barometric Response Function for 299-E33-32.

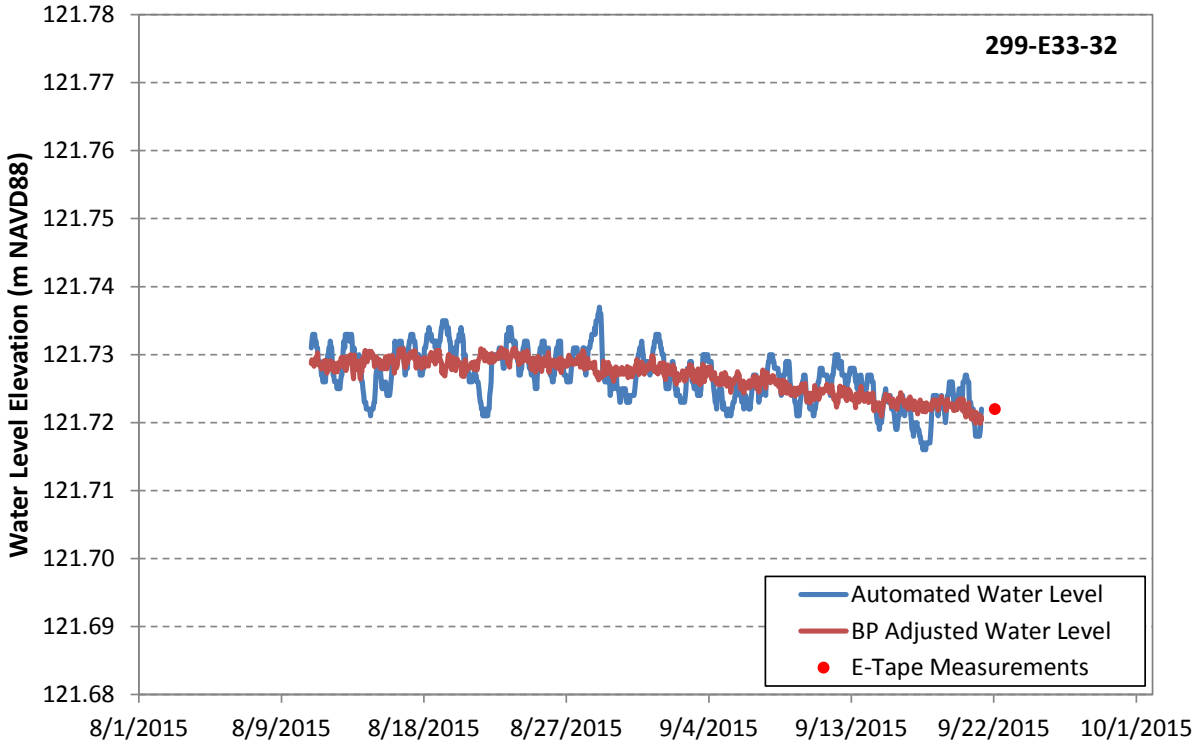

Figure A-4. Baseline Water Level Measurements for 299-E33-32.

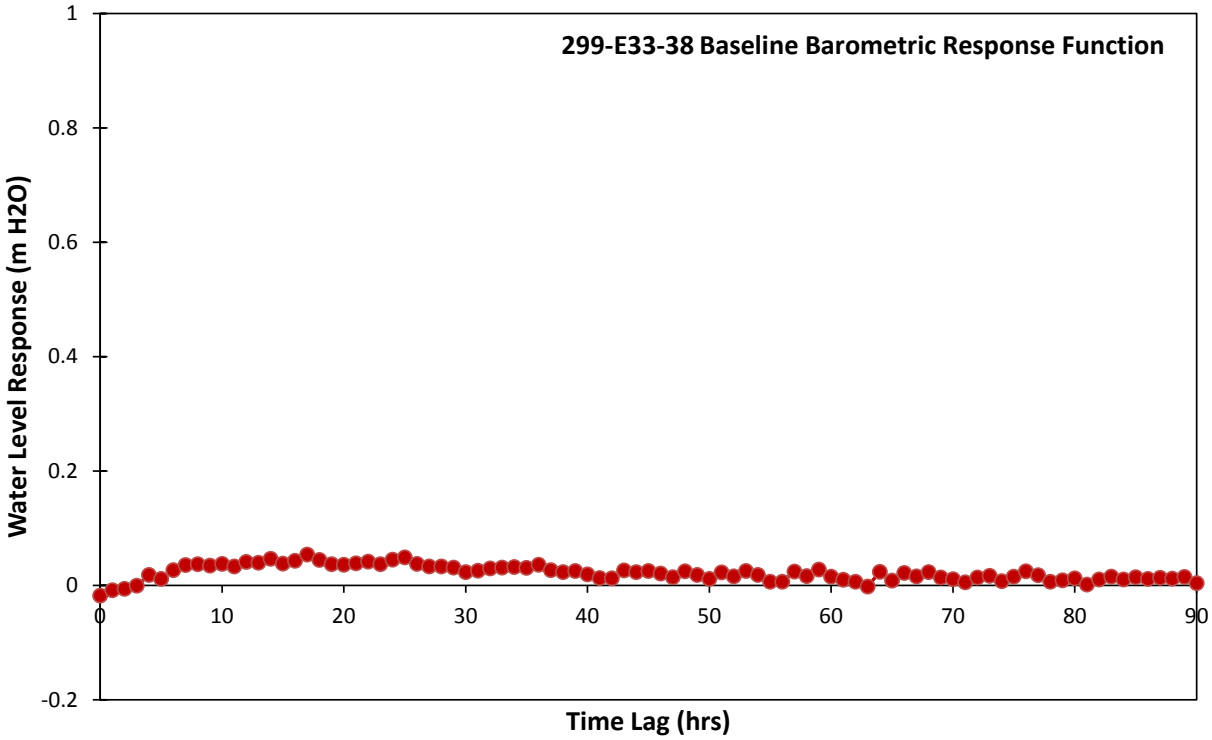

Figure A-5. Barometric Response Function for 299-E33-38.

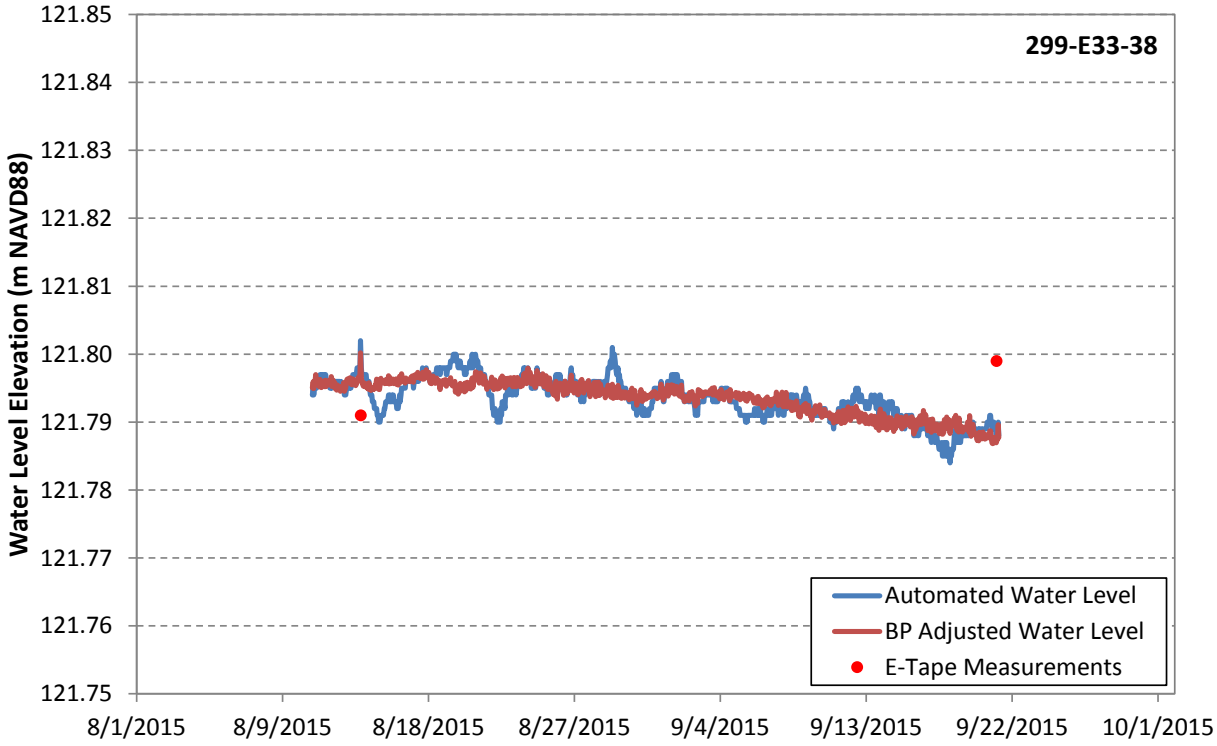

Figure A-6. Baseline Water Level Measurements for 299-E33-38.

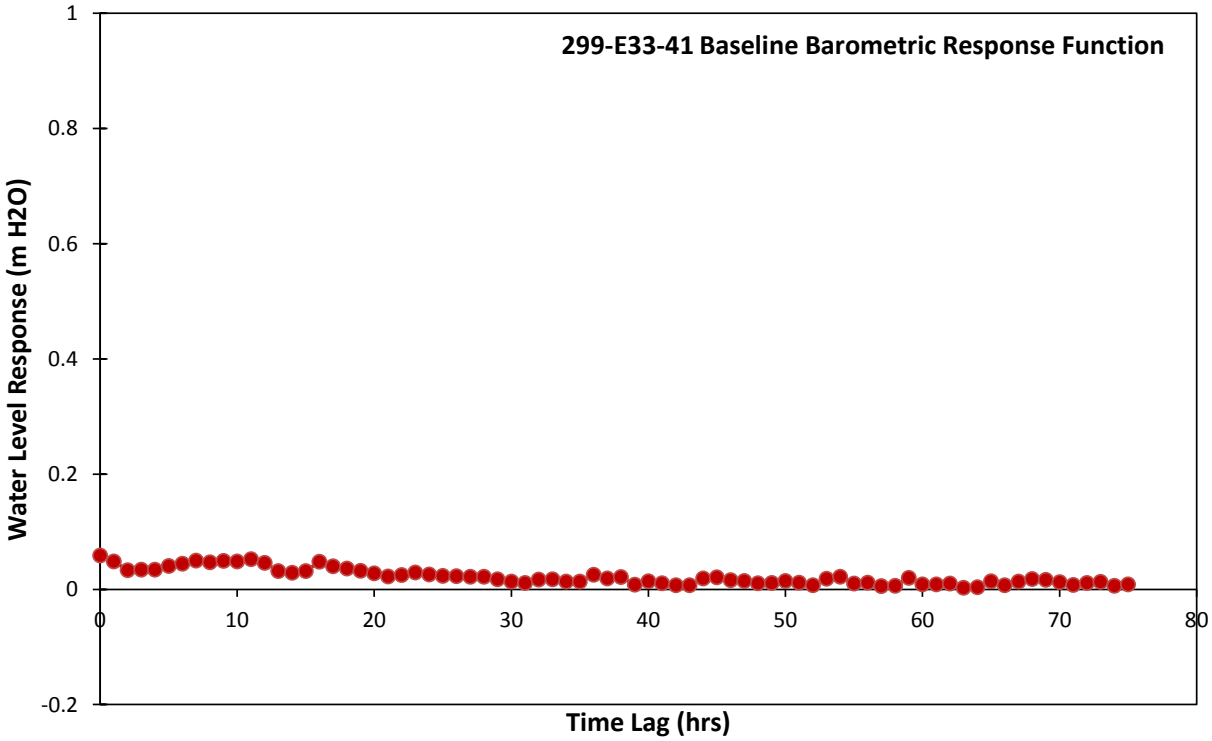

Figure A-7. Barometric Response Function for 299-E33-41.

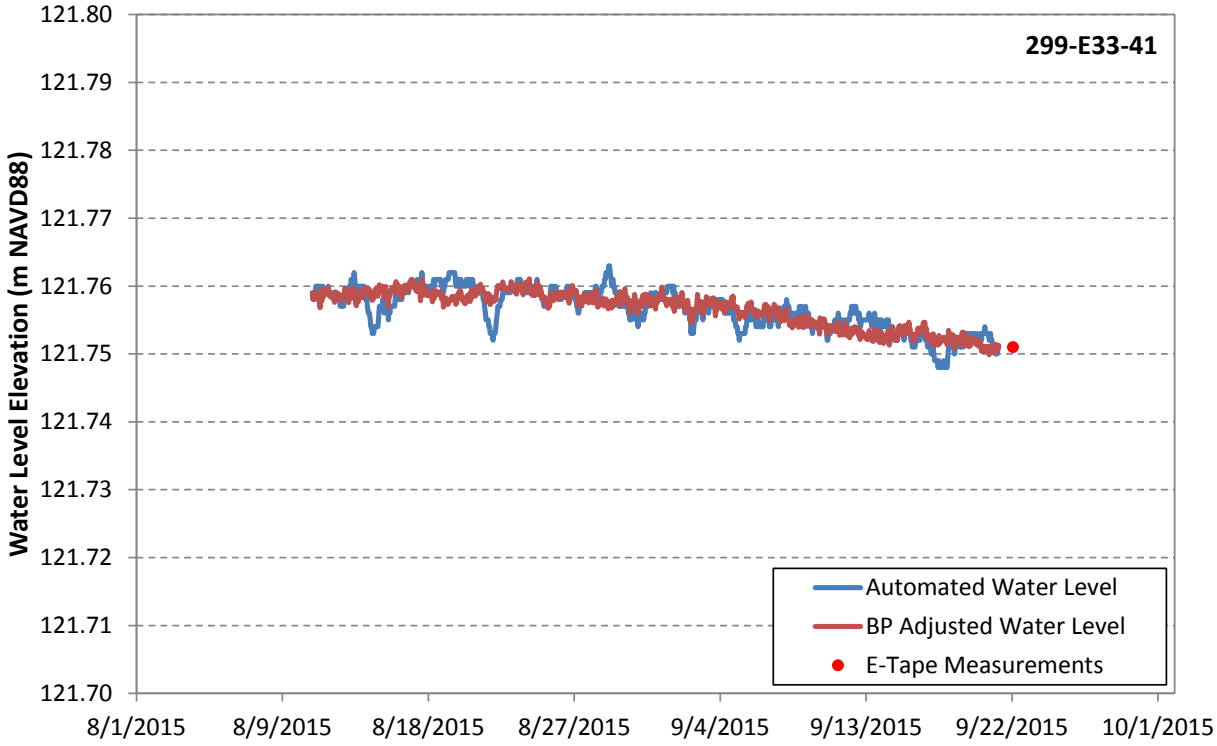

Figure A-8. Baseline Water Level Measurements for 299-E33-41.

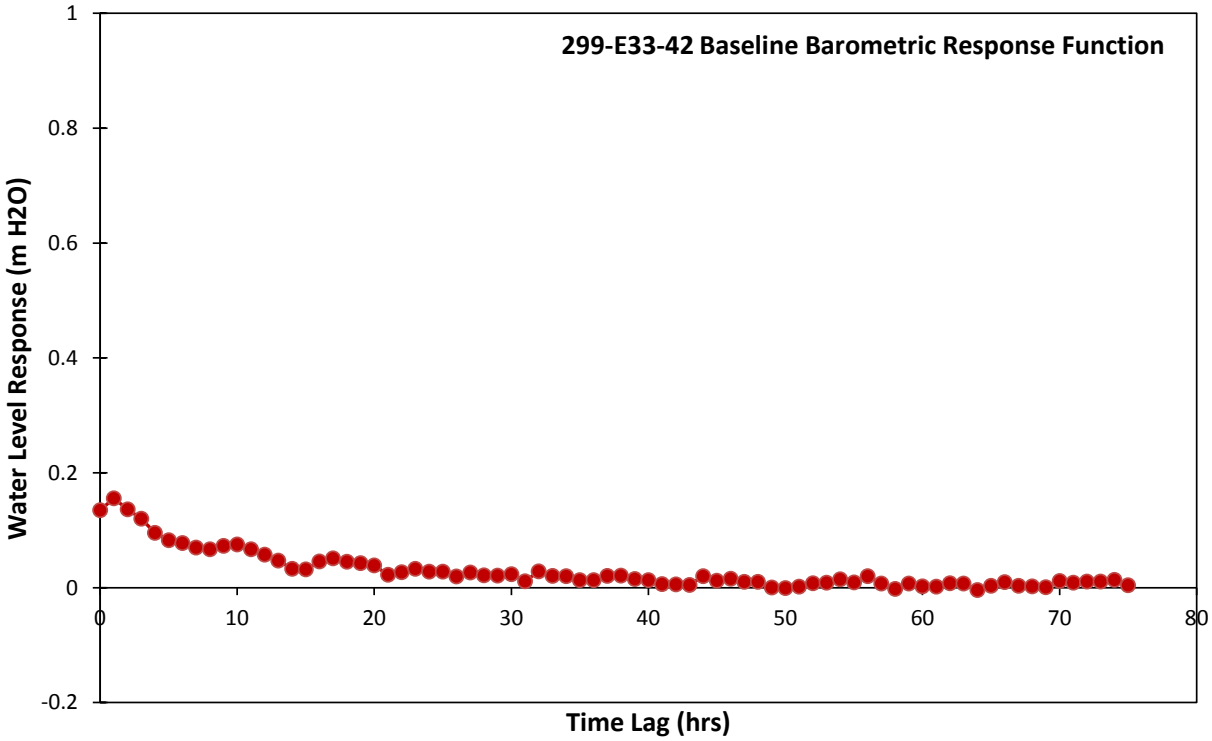

Figure A-9. Barometric Response Function for 299-E33-42.

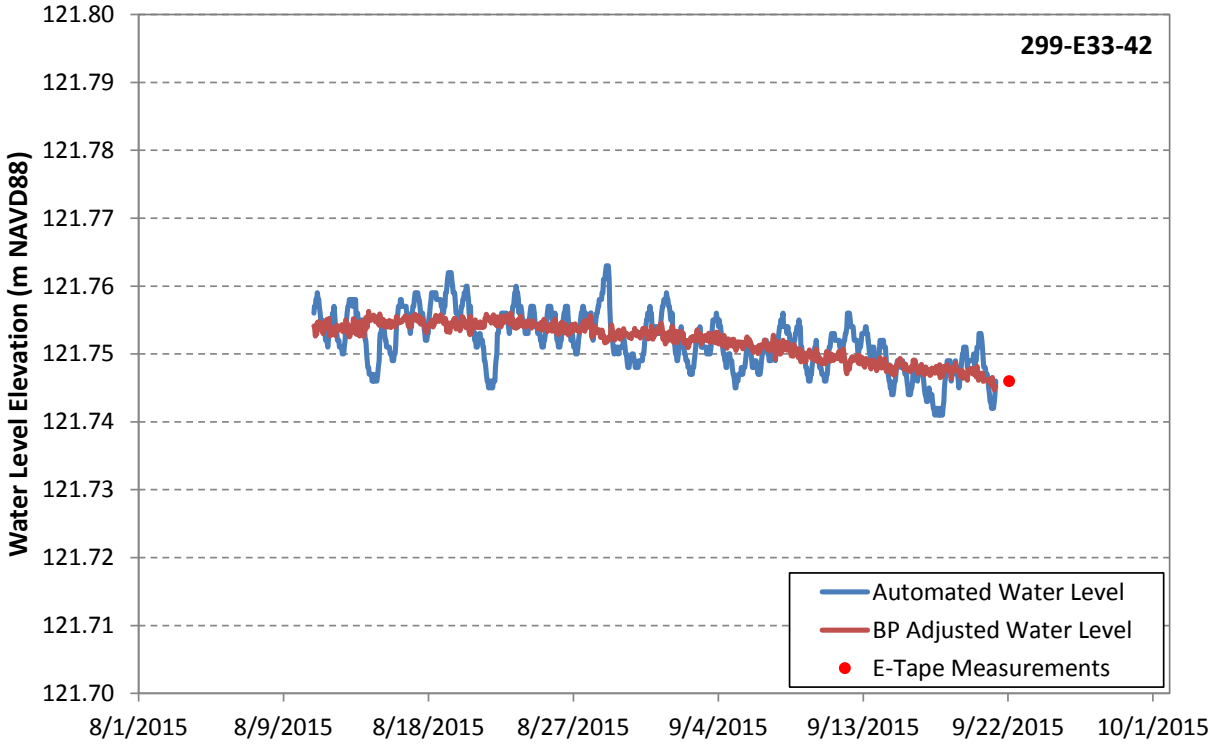

Figure A-10. Baseline Water Level Measurements for 299-E33-42.

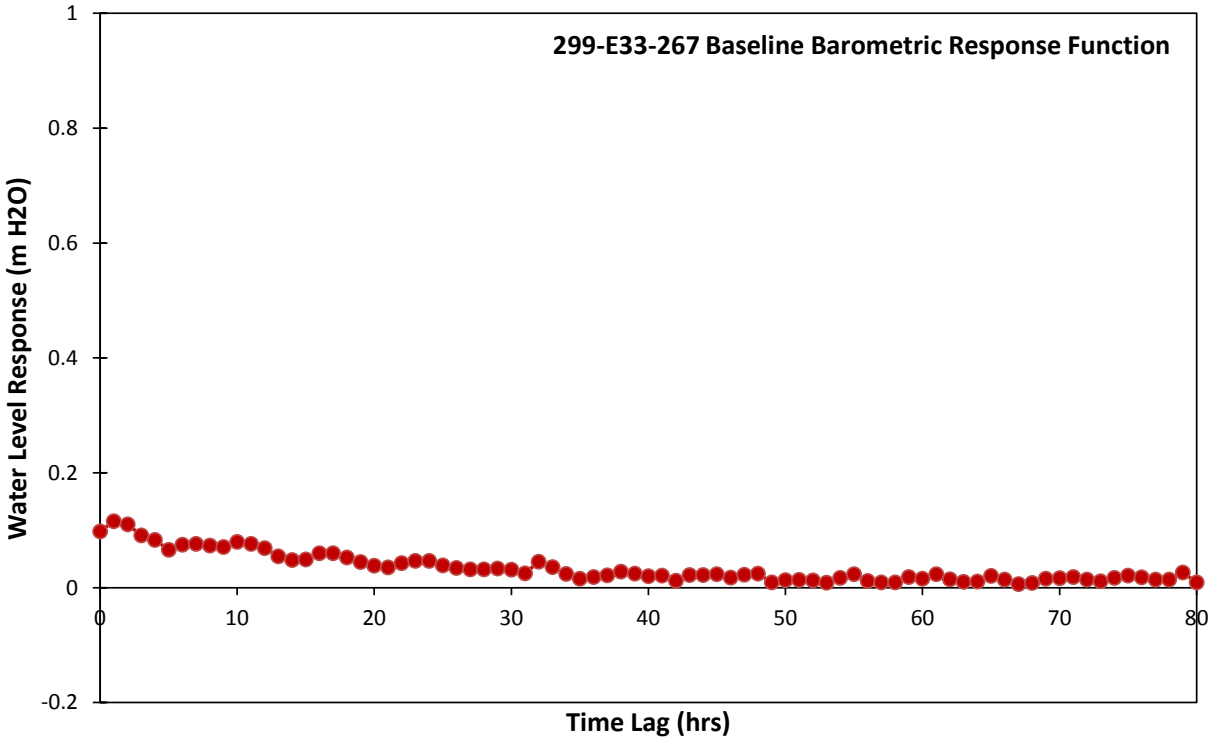

Figure A-11. Barometric Response Function for 299-E33-267.

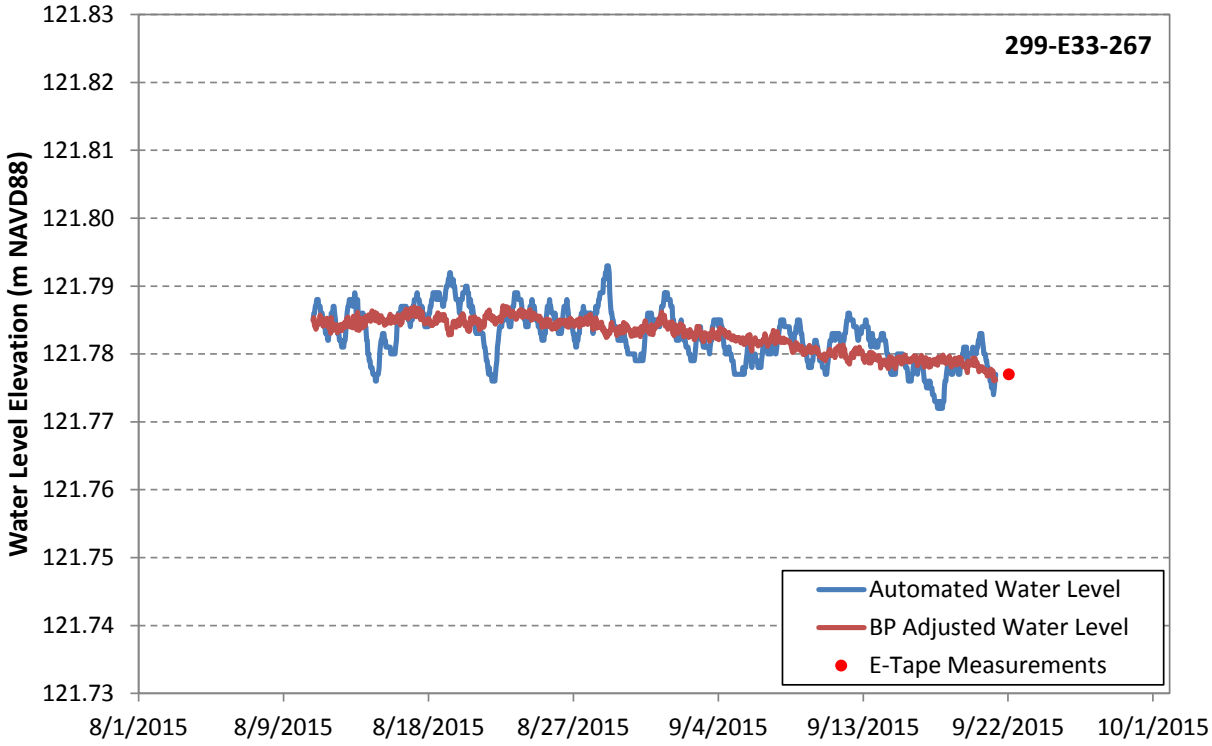

Figure A-12. Baseline Water Level Measurements for 299-E33-267.

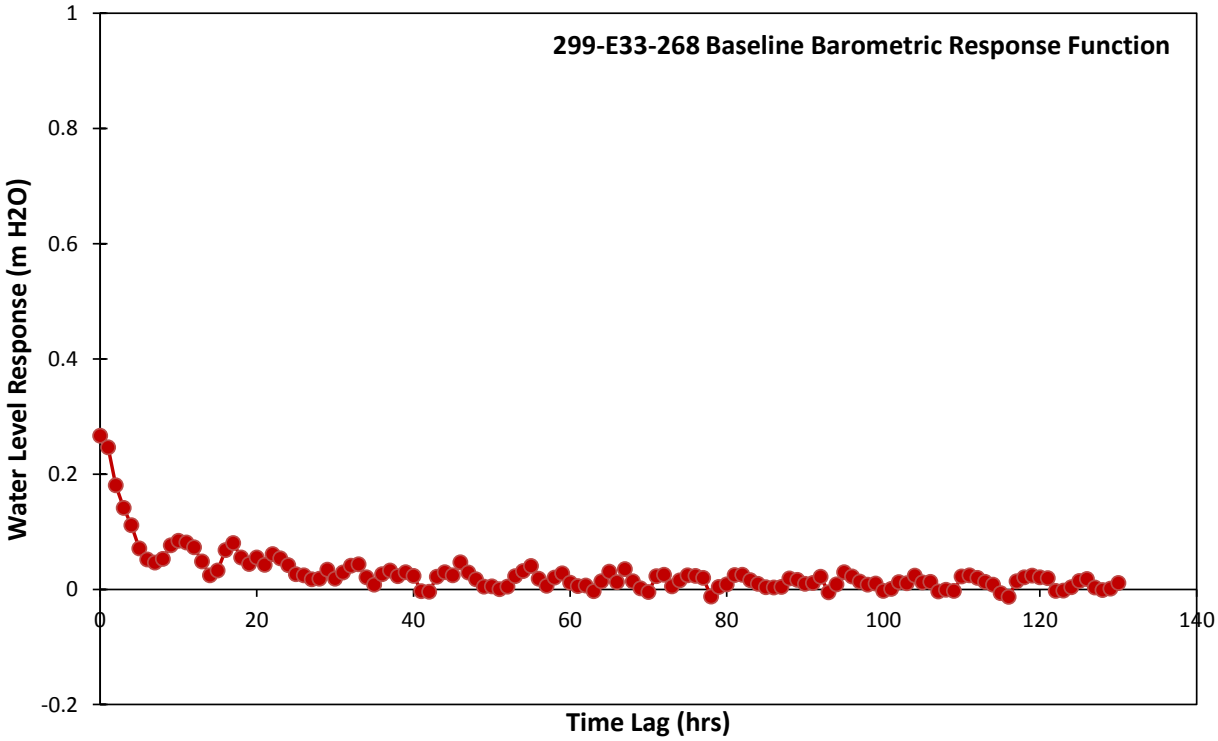

Figure A-13. Barometric Response Function for 299-E33-268.

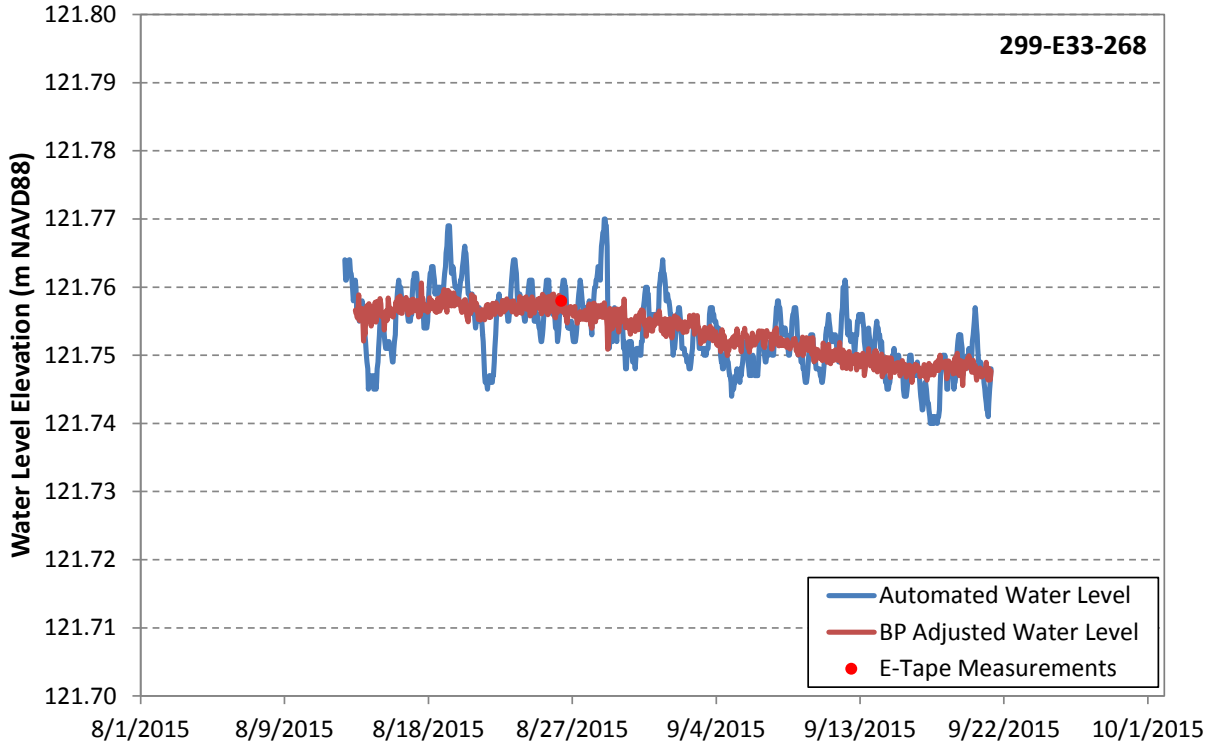

Figure A-14. Baseline Water Level Measurements for 299-E33-268.

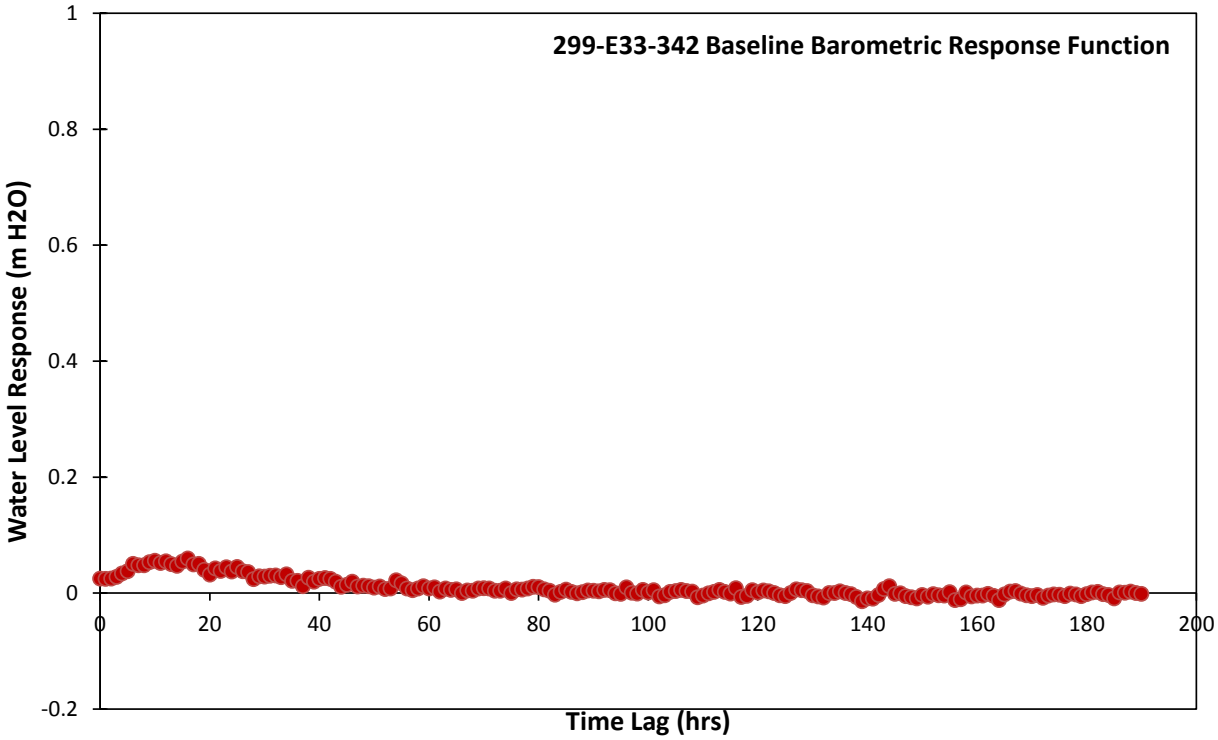

Figure A-15. Barometric Response Function for 299-E33-342.

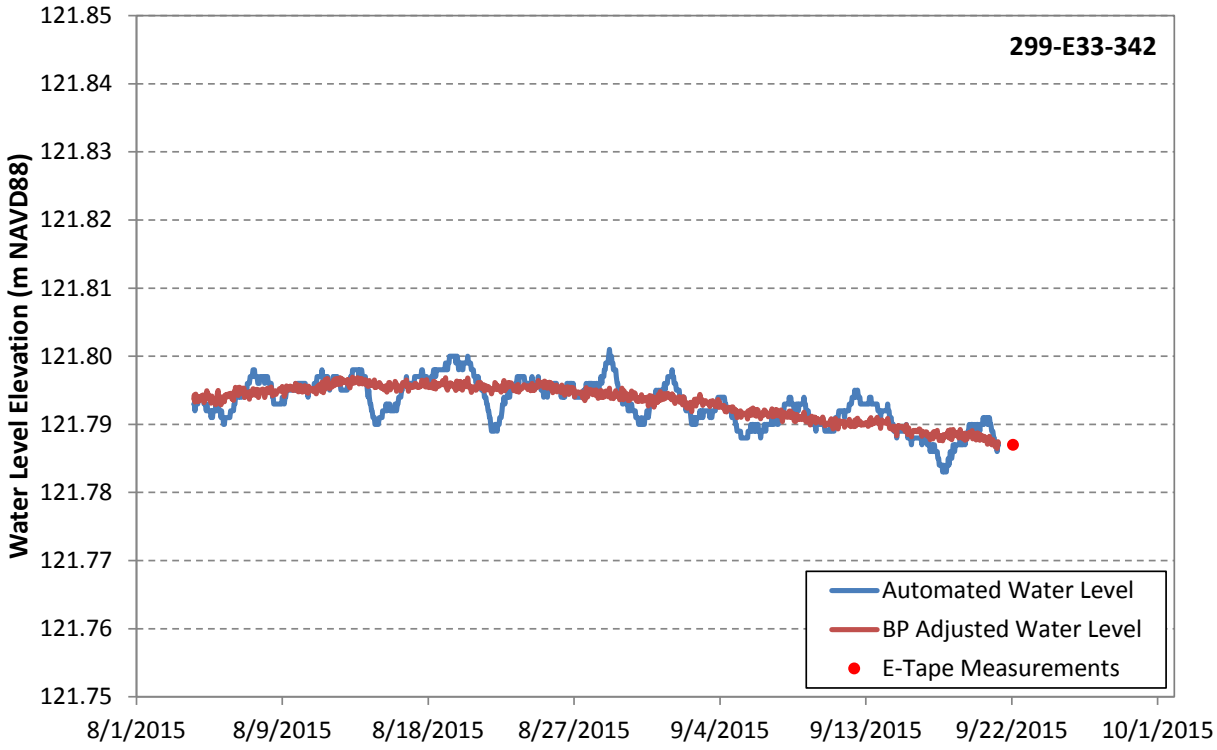

Figure A-16. Baseline Water Level Measurements for 299-E33-342.

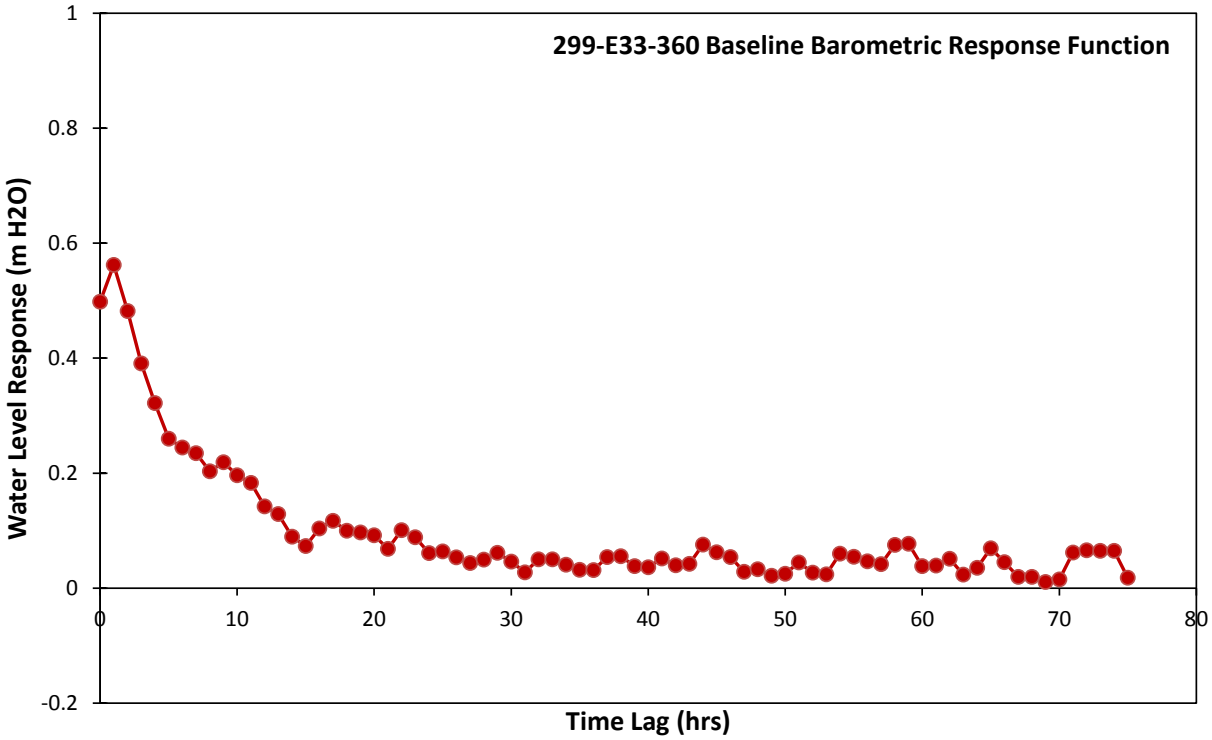

Figure A-17. Barometric Response Function for 299-E33-360.

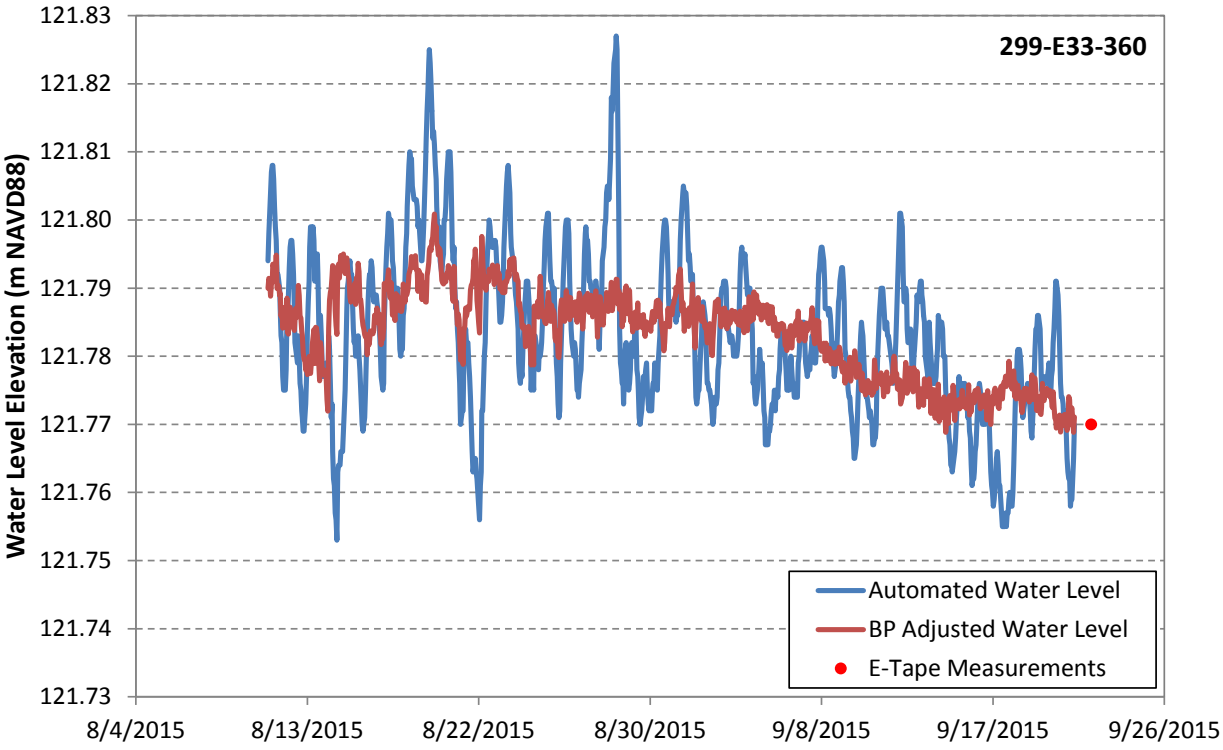

Figure A-18. Baseline Water Level Measurements for 299-E33-360.

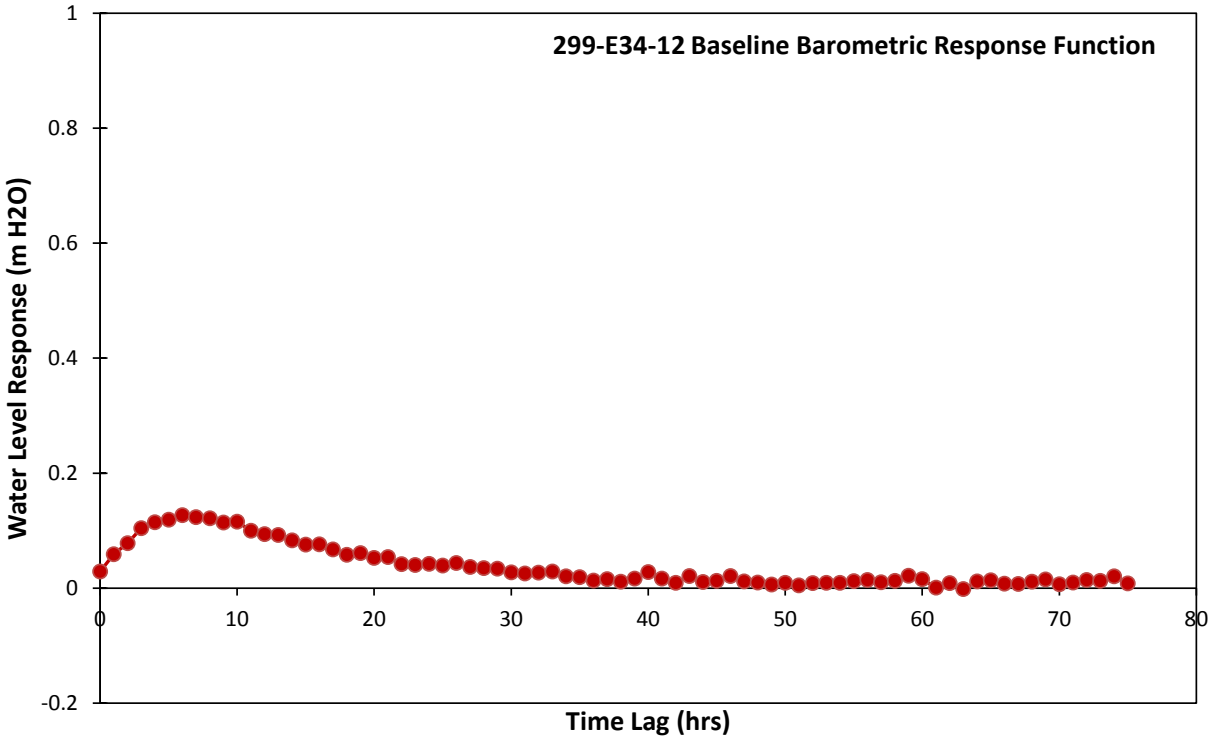

Figure A-19. Barometric Response Function for 299-E34-12.

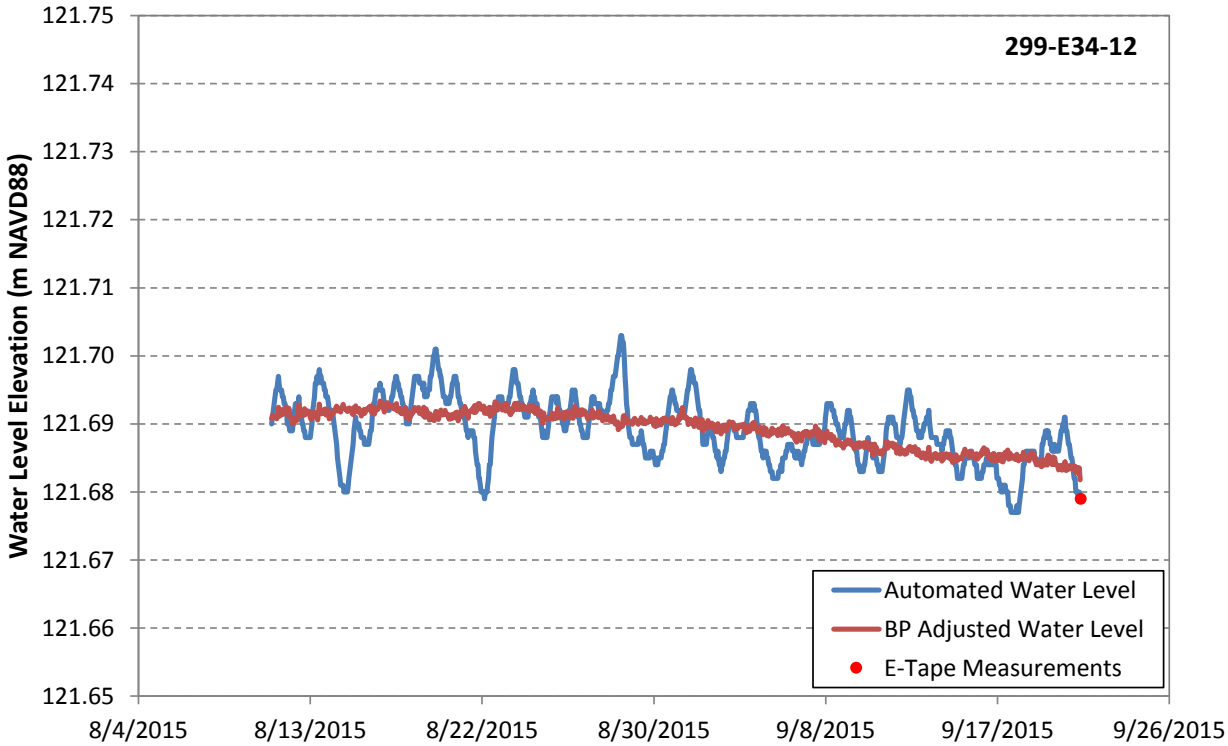

Figure A-20. Baseline Water Level Measurements for 299-E34-12.

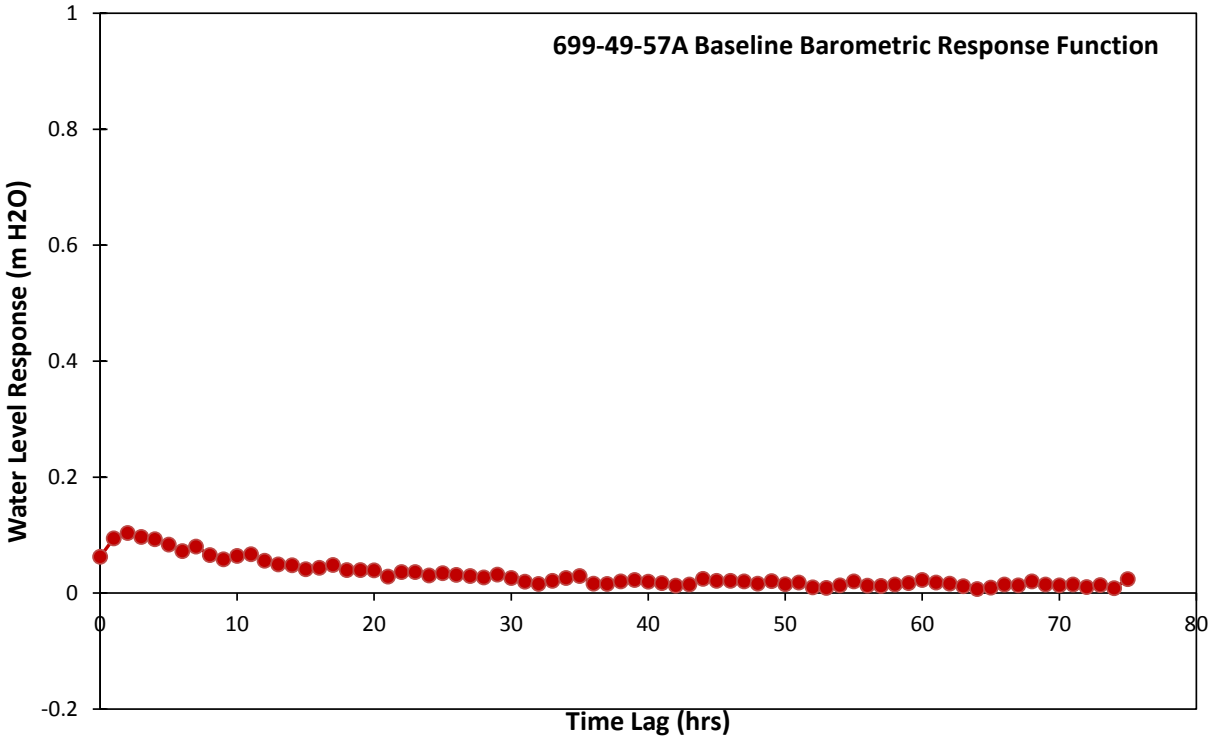

Figure A-21. Barometric Response Function for 699-49-57A.

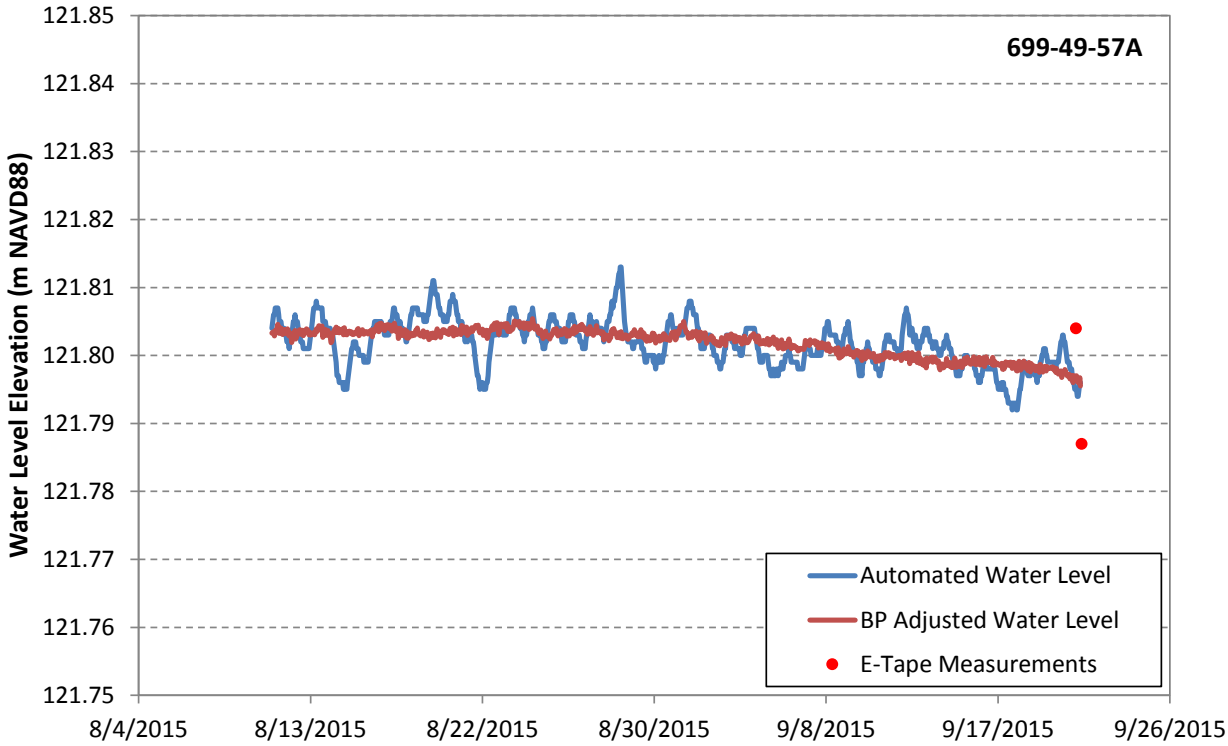

Figure A-22. Baseline Water Level Measurements for 699-49-57A.

The portion of the spreadsheet below shows how the data logger files are processed to convert the units of measurement from centimeters to pounds per square inch absolute (PSIA). This is followed by a graphic showing the formulas used. The timestamps are converted from Pacific Daylight Time (PDT) to Pacific Standard Time (PST) by subtracting 1/24th of a day. This example is the BaroLogger file for the baseline monitoring data collected from 299-E33-31. LeveLogger files are processed in the same manner.

Serial_number:										
1052634										
Project ID:										
BP-5 Treatabiliy est						Altitude Compensation Factor:		1.21	m per 1000 m elevation	
Location:						Unadjusted Zero Point:		950	pressure as cm H2O	
299-E33-31 Baro						Altitude Setting:		0	m elevation	
LEVEL						Adjusted Zero Point:		950	pressure as cm H2O	
UNIT: cm										
Offset: 0.000000 cm				Water Column to Pressure Conversion Factor:				0.70307	m H2O per psia	
Altitude: 0.000000 m										
TEMPERATURE										
UNIT: Deg C										
Date	Time	Date/Time (PST)	ms	LEVEL	TEMPERATURE		psia	in-Hg	m-H2O	
8/11/2015	14:00:00	8/11/15 13:00	0	63.58	17.967		14.41649	29.35197	10.1358	
8/11/2015	15:00:00	8/11/15 14:00	0	62.97	17.947		14.40781	29.3343	10.1297	
8/11/2015	16:00:00	8/11/15 15:00	0	62.31	17.947		14.39842	29.31519	10.1231	
8/11/2015	17:00:00	8/11/15 16:00	0	61.64	17.952		14.38889	29.29579	10.1164	

Serial_number:									
1052634									
Project ID:									
BP-5 Treatabiliy est						Altitude Compensation Factor:	1.21	m per 1000 m elevation	
Location:						Unadjusted Zero Point:	950	pressure as cm H2O	
299-E33-31 Baro						Altitude Setting:	0	m elevation	
LEVEL						Adjusted Zero Point:	=I5-I6/1000*I	pressure as cm H2O	
UNIT: cm									
Offset: 0.000000 cm				Water Column to Pressure Conversion Factor:			0.70307	m H2O per psia	
Altitude: 0.000000 m									
TEMPERATURE									
UNIT: Deg C									
Date	Time	Date/Time (PST)	ms	LEVEL	TEMPERATURE	psia	in-Hg	m-H2O	
42227	0.583333333333333	=A14+B14-1/24	0	63.58	17.967	=(E14+$I$7)/100/$I$9	=H14*2.036	=H14*$I$9	
42227	0.625	=A15+B15-1/24	0	62.97	17.947	=(E15+$I$7)/100/$I$9	=H15*2.036	=H15*$I$9	
42227	0.666666666666667	=A16+B16-1/24	0	62.31	17.947	=(E16+$I$7)/100/$I$9	=H16*2.036	=H16*$I$9	
42227	0.708333333333333	=A17+B17-1/24	0	61.64	17.952	=(E17+$I$7)/100/$I$9	=H17*2.036	=H17*$I$9	

The graphic below shows a portion of a spreadsheet used to normalize the water level measurements to a constant barometric pressure. Column B contains the timestamp for the barometric pressure data, and column C contains the change in barometric pressure between hourly timesteps. Column E contains the automated water level elevations. The deconvolution is performed in column F in which the previous *n* hourly barometric pressure changes are multiplied by the BRF coefficients one element at a time and then summed (*n* is the number of coefficients in the BRF) by an array formula. This provides the change in the water level caused by barometric pressure fluctuations, which is removed (by addition in the formula due to sign conventions) from the measurement.

	A	B	C	D	E	F
1	**Water-Level Barometric Pressure Response for 299-E33-31**					
2	Deconvolved Transducer Data (i.e., Normalized to a Constant Barometric Pressure)					
3						
4		***Deconvolved Using Station #6 BP Measurements***				
5			Station #6			BP Normalized
6			Change in		Absolute x-ducer	Absolute x-ducer
7			Barometric Pres.		Water Level Elev.	Water Level Elev.
8		DATE_TIME_PST	(m H2O)		(m NAVD88)	(m NAVD88)
9		8/7/15 23:00	0.00020719			
10		8/8/15 0:00	0.00324597			
11		8/8/15 1:00	-0.001761112			
12		8/8/15 2:00	0.003280502			
13		8/8/15 3:00	0.000621569			
14		8/8/15 4:00	0.002279086			
15		8/8/15 5:00	0.002693465			
16		8/8/15 6:00	0.004834424			
17		8/8/15 7:00	0.000517974			
18		8/8/15 8:00	0.006181156			
19		8/8/15 9:00	-0.004938019			
20		8/8/15 10:00	-0.005801309			
21		8/8/15 11:00	-0.0079768			
22		8/8/15 12:00	-0.001208606			
23		8/8/15 13:00	-0.001622985			
24		8/8/15 14:00	-0.00583584			
25		8/8/15 15:00	-0.003073312			
26		8/8/15 16:00	-0.004143792			
27		8/8/15 17:00	0.001761112			
28		8/8/15 18:00	-0.000138126			
29		8/8/15 19:00	0.005594119			
30		8/8/15 20:00	0.008563837			

30		8/8/15 20:00	0.008563837			
31		8/8/15 21:00	0.005455993			
32		8/8/15 22:00	0.009565253			
33		8/8/15 23:00	0.008701963			
34		8/9/15 0:00	0.006595536			
35		8/9/15 1:00	0.003315034			
36		8/9/15 2:00	0.005076145			
37		8/9/15 3:00	0.005214272			
38		8/9/15 4:00	0.001381264			
39		8/9/15 5:00	0.00669913			
40		8/9/15 6:00	0.001657517			
41		8/9/15 7:00	0.006112093			
42		8/9/15 8:00	0.000414379			
43		8/9/15 9:00	0.004558171			
44		8/9/15 10:00	-0.004489108			
45		8/9/15 11:00	0.002140959			
46		8/9/15 12:00	-0.005904904			

	A	B	C	D	E	F
47		8/9/15 13:00	-0.003280502			
48		8/9/15 14:00	-0.006353814			
49		8/9/15 15:00	-0.010532138			
50		8/9/15 16:00	0.00193377			
51		8/9/15 17:00	-0.003591286			
52		8/9/15 18:00	-0.007458826			
53		8/9/15 19:00	-0.002486275			
54		8/9/15 20:00	0.004765361			
55		8/9/15 21:00	0.004938019			
56		8/9/15 22:00	0.00107048			
57		8/9/15 23:00	-0.001035948			
58		8/10/15 0:00	-0.005594119			
59		8/10/15 1:00	-0.000794227			
60		8/10/15 2:00	0.006077562			
61		8/10/15 3:00	-0.001208606			
62		8/10/15 4:00	0.001795643			
63		8/10/15 5:00	0.001864706			
64		8/10/15 6:00	0.001553922			
65		8/10/15 7:00	-3.45316E-05			

66		8/10/15 8:00	0.003556755			
67		8/10/15 9:00	0.00172658			
68		8/10/15 10:00	-0.00107048			
69		8/10/15 11:00	-0.007009915			
70		8/10/15 12:00	-0.009012748			
71		8/10/15 13:00	-0.003867539			
72		8/10/15 14:00	0.001381264			
73		8/10/15 15:00	0.005628651			
74		8/10/15 16:00	-0.015850004			
75		8/10/15 17:00	-0.002210022			
76		8/10/15 18:00	-0.001415796			
77		8/10/15 19:00	0.013501856			
78		8/10/15 20:00	-0.001381264			
79		8/10/15 21:00	0.00324597			
80		8/10/15 22:00	0.004385513			
81		8/10/15 23:00	-0.003971134			
82		8/11/15 0:00	0.002417212			
83		8/11/15 1:00	0.009254469			
84		8/11/15 2:00	-0.006561004			
85		8/11/15 3:00	0.00669913			
86		8/11/15 4:00	0.000828758			
87		8/11/15 5:00	0.003625818			
88		8/11/15 6:00	0.005525056			
89		8/11/15 7:00	0.002831591			
90		8/11/15 8:00	-0.0006561			
91		8/11/15 9:00	0.001139543			
92		8/11/15 10:00	-0.005628651			

	A	B	C	D	E	F
93		8/11/15 11:00	-0.006975383			
94		8/11/15 12:00	-0.006319283			
95		8/11/15 13:00	-0.007009915		121.76	121.7543926
96		8/11/15 14:00	-0.008183989		121.762	121.7544074
97		8/11/15 15:00	-0.011671681		121.763	121.7518648

Below is the same spreadsheet with formulas displayed.

	A	B	C	D	E	F
1	**Water-Level Barometric Pressure Response for 299-E33-31**					
2	Deconvolved Transducer Data (i.e., Normalized to a Constant Barometric Pressure)					
3						
4		***Deconvolved Using Station #6 BP Measurements***				
5			Station #6			BP Normalized
6			Change in		Absolute x-ducer	Absolute x-ducer
7			Barometric Pres.		Water Level Elev.	Water Level Elev.
8		DATE_TIME_PST	(m H2O)		(m NAVD88)	(m NAVD88)
9		=TransducerData!O326	=TransducerData!Q326			
10		=TransducerData!O327	=TransducerData!Q327			
11		=TransducerData!O328	=TransducerData!Q328			
12		=TransducerData!O329	=TransducerData!Q329			
13		=TransducerData!O330	=TransducerData!Q330			
14		=TransducerData!O331	=TransducerData!Q331			
15		=TransducerData!O332	=TransducerData!Q332			
16		=TransducerData!O333	=TransducerData!Q333			
17		=TransducerData!O334	=TransducerData!Q334			
18		=TransducerData!O335	=TransducerData!Q335			
19		=TransducerData!O336	=TransducerData!Q336			
20		=TransducerData!O337	=TransducerData!Q337			
21		=TransducerData!O338	=TransducerData!Q338			
22		=TransducerData!O339	=TransducerData!Q339			
23		=TransducerData!O340	=TransducerData!Q340			
24		=TransducerData!O341	=TransducerData!Q341			
25		=TransducerData!O342	=TransducerData!Q342			
26		=TransducerData!O343	=TransducerData!Q343			
27		=TransducerData!O344	=TransducerData!Q344			
28		=TransducerData!O345	=TransducerData!Q345			
29		=TransducerData!O346	=TransducerData!Q346			
30		=TransducerData!O347	=TransducerData!Q347			
31		=TransducerData!O348	=TransducerData!Q348			
32		=TransducerData!O349	=TransducerData!Q349			
33		=TransducerData!O350	=TransducerData!Q350			
34		=TransducerData!O351	=TransducerData!Q351			
35		=TransducerData!O352	=TransducerData!Q352			
36		=TransducerData!O353	=TransducerData!Q353			
37		=TransducerData!O354	=TransducerData!Q354			
38		=TransducerData!O355	=TransducerData!Q355			
39		=TransducerData!O356	=TransducerData!Q356			
40		=TransducerData!O357	=TransducerData!Q357			
41		=TransducerData!O358	=TransducerData!Q358			
42		=TransducerData!O359	=TransducerData!Q359			
43		=TransducerData!O360	=TransducerData!Q360			
44		=TransducerData!O361	=TransducerData!Q361			
45		=TransducerData!O362	=TransducerData!Q362			
46		=TransducerData!O363	=TransducerData!Q363			
47		=TransducerData!O364	=TransducerData!Q364			
48		=TransducerData!O365	=TransducerData!Q365			
49		=TransducerData!O366	=TransducerData!Q366			
50		=TransducerData!O367	=TransducerData!Q367			
51		=TransducerData!O368	=TransducerData!Q368			
52		=TransducerData!O369	=TransducerData!Q369			
53		=TransducerData!O370	=TransducerData!Q370			
54		=TransducerData!O371	=TransducerData!Q371			
55		=TransducerData!O372	=TransducerData!Q372			

56		=TransducerData!O373	=TransducerData!Q373			
57		=TransducerData!O374	=TransducerData!Q374			
58		=TransducerData!O375	=TransducerData!Q375			
59		=TransducerData!O376	=TransducerData!Q376			
60		=TransducerData!O377	=TransducerData!Q377			
61		=TransducerData!O378	=TransducerData!Q378			
62		=TransducerData!O379	=TransducerData!Q379			
63		=TransducerData!O380	=TransducerData!Q380			

	A	B	C	D	E	F
64		=TransducerData!O381	=TransducerData!Q381			
65		=TransducerData!O382	=TransducerData!Q382			
66		=TransducerData!O383	=TransducerData!Q383			
67		=TransducerData!O384	=TransducerData!Q384			
68		=TransducerData!O385	=TransducerData!Q385			
69		=TransducerData!O386	=TransducerData!Q386			
70		=TransducerData!O387	=TransducerData!Q387			
71		=TransducerData!O388	=TransducerData!Q388			
72		=TransducerData!O389	=TransducerData!Q389			
73		=TransducerData!O390	=TransducerData!Q390			
74		=TransducerData!O391	=TransducerData!Q391			
75		=TransducerData!O392	=TransducerData!Q392			
76		=TransducerData!O393	=TransducerData!Q393			
77		=TransducerData!O394	=TransducerData!Q394			
78		=TransducerData!O395	=TransducerData!Q395			
79		=TransducerData!O396	=TransducerData!Q396			
80		=TransducerData!O397	=TransducerData!Q397			
81		=TransducerData!O398	=TransducerData!Q398			
82		=TransducerData!O399	=TransducerData!Q399			
83		=TransducerData!O400	=TransducerData!Q400			
84		=TransducerData!O401	=TransducerData!Q401			
85		=TransducerData!O402	=TransducerData!Q402			
86		=TransducerData!O403	=TransducerData!Q403			
87		=TransducerData!O404	=TransducerData!Q404			
88		=TransducerData!O405	=TransducerData!Q405			
89		=TransducerData!O406	=TransducerData!Q406			
90		=TransducerData!O407	=TransducerData!Q407			
91		=TransducerData!O408	=TransducerData!Q408			
92		=TransducerData!O409	=TransducerData!Q409			
93		=TransducerData!O410	=TransducerData!Q410			
94		=TransducerData!O411	=TransducerData!Q411			
95		=TransducerData!O412	=TransducerData!Q412		=TransducerData!L12	=E95+SUM(C20:C95*TransducerData!$V$12:$V$87)
96		=TransducerData!O413	=TransducerData!Q413		=TransducerData!L13	=E96+SUM(C21:C96*TransducerData!$V$12:$V$87)
97		=TransducerData!O414	=TransducerData!Q414		=TransducerData!L14	=E97+SUM(C22:C97*TransducerData!$V$12:$V$87)

Appendix B
Automated Water Level Measurements for the 3-Day Constant Rate Discharge Test

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Charts of the automated water level measurements collected during the 3-day test are shown in Figures B-1 through B-9. The pumping well, 299-E33-268, is shown first (Figure B-1) and then the observation wells are shown in order of increasing distance from the pumping well (Figures B-2 to B-9). Drawdown was discernable in the pumping well and in 299-E33-267, 299-E33-31, and 299-E33-342. Some drawdown may also have occurred at 299-E33-42, but this could not be confirmed because the amount of apparent drawdown (0.002 m) is about the same as the remaining error when the water levels are normalized to a constant barometric pressure as can be seen in the post pumping measurements (10/17/2015 to 10/20/2015 in Figure B-4). For this reason, 299-E33-42 was not included in the hydraulic property determinations.

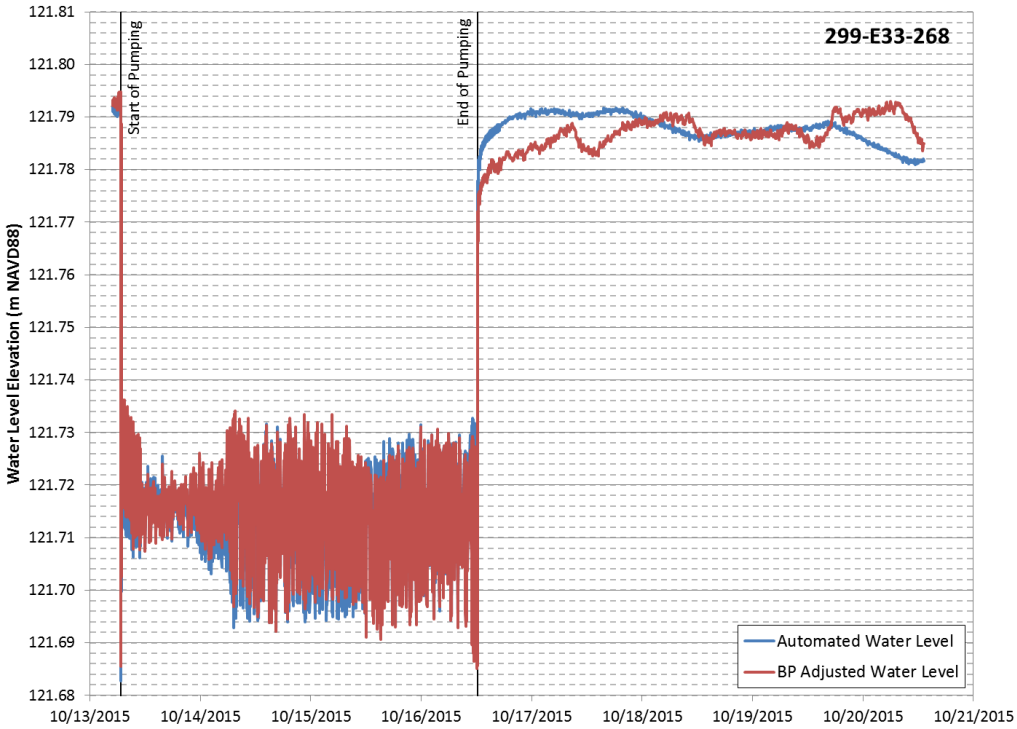

Figure B-1. Automated Water Level Measurements Collected for Well 299-E33-268 (Pumping Well) during the 3-Day Constant Rate Discharge Test

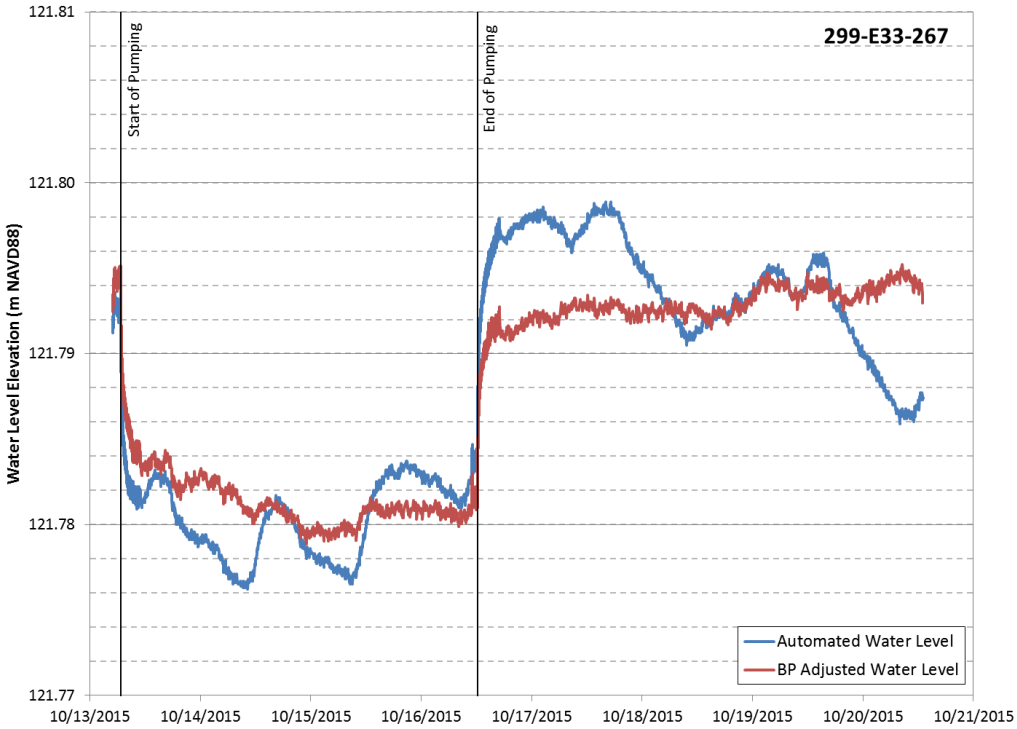

Figure B-2. Automated Water Level Measurements Collected for Well 299-E33-267 (4.5 m [15 ft] South of the Pumping Well) during the 3-Day Constant Rate Discharge Test

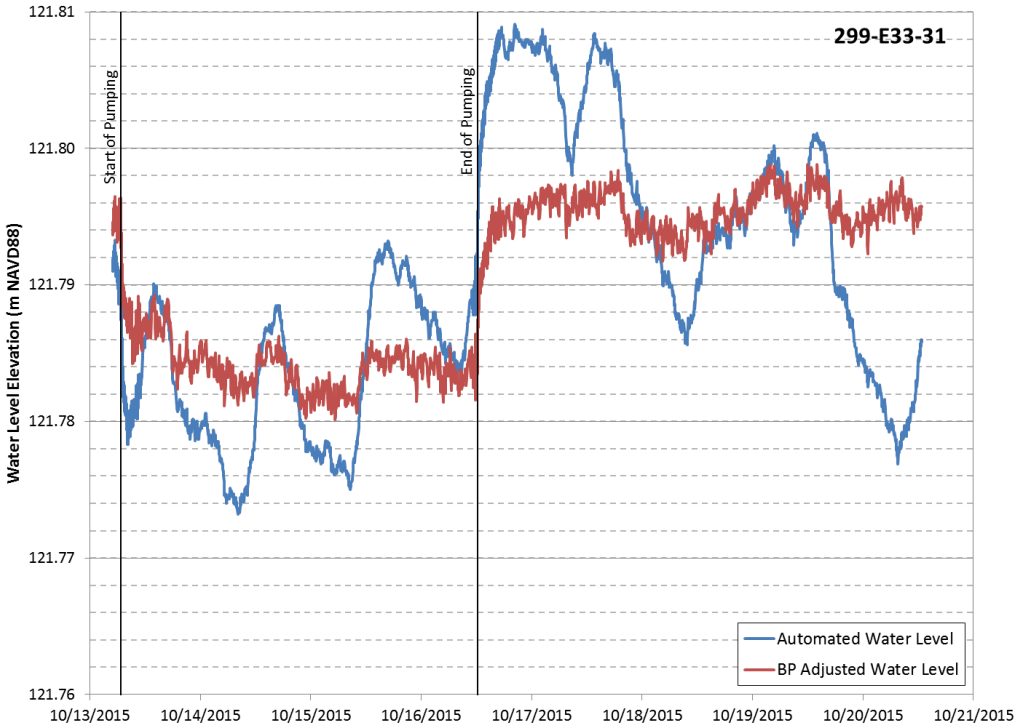

Figure B-3. Automated Water Level Measurements Collected for Well 299-E33-31 (9.2 m [30 ft] South-Southeast of the Pumping Well) during the 3-Day Constant Rate Discharge Test

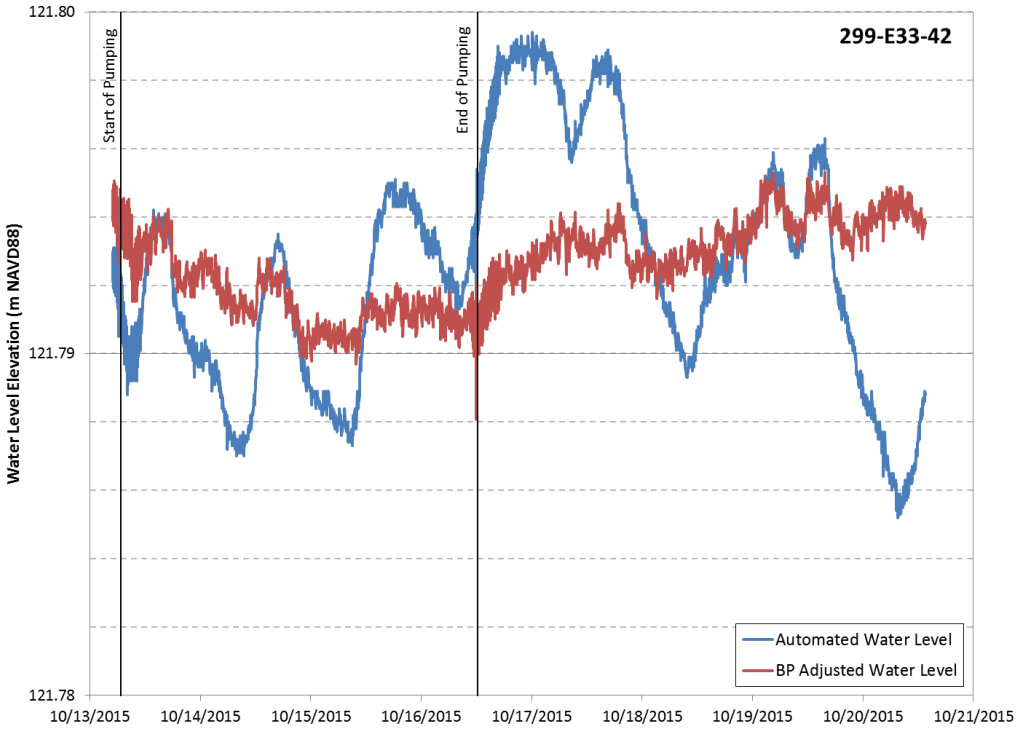

Figure B-4. Automated Water Level Measurements Collected for Well 299-E33-42 (74 m [240 ft] South of the Pumping Well) during the 3-Day Constant Rate Discharge Test

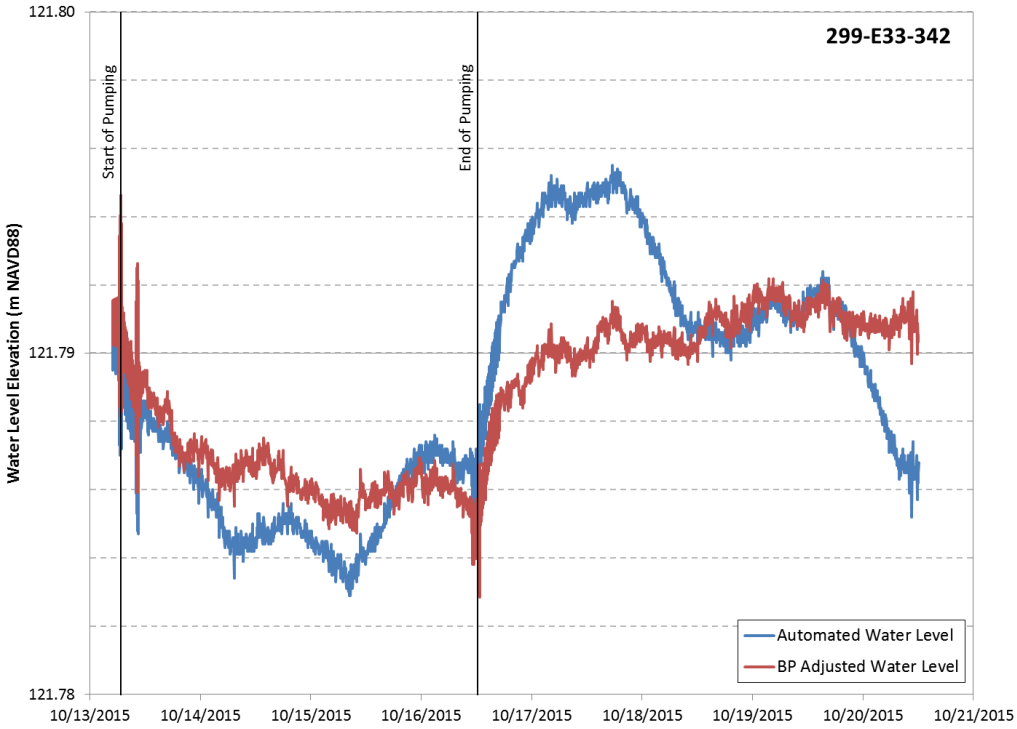

Figure B-5. Automated Water Level Measurements Collected for Well 299-E33-342 (134 m [440 ft] Northeast of the Pumping Well) during the 3-Day Constant Rate Discharge Test

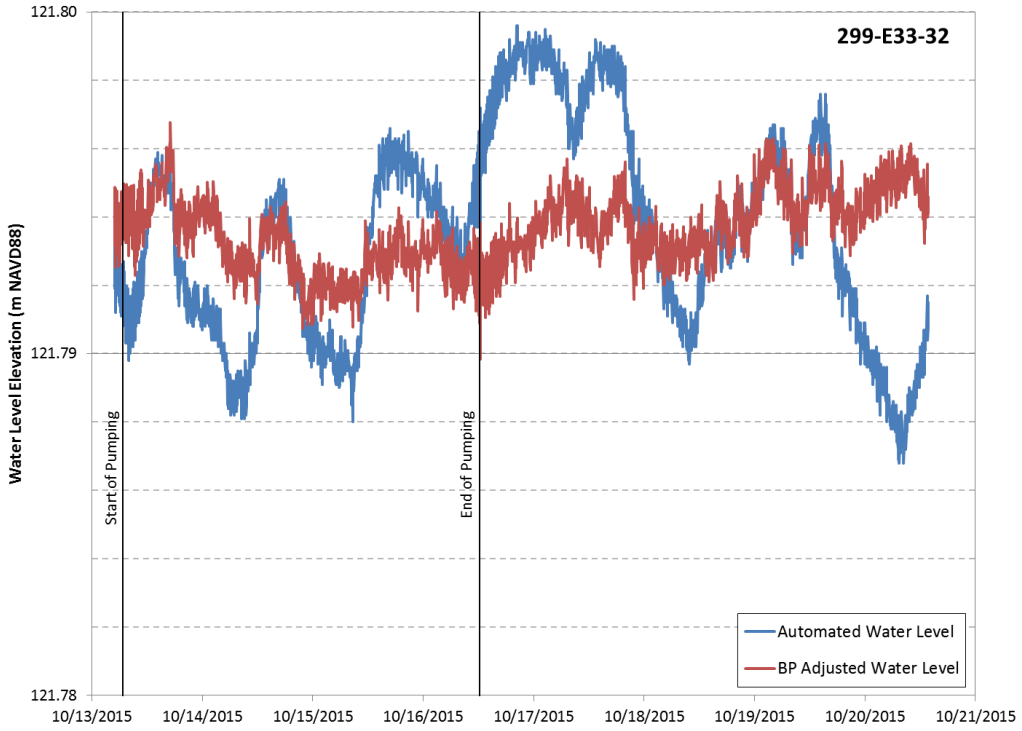

Figure B-6. Automated Water Level Measurements Collected for Well 299-E33-32 (145 m [479 ft] South of the Pumping Well) during the 3-Day Constant Rate Discharge Test

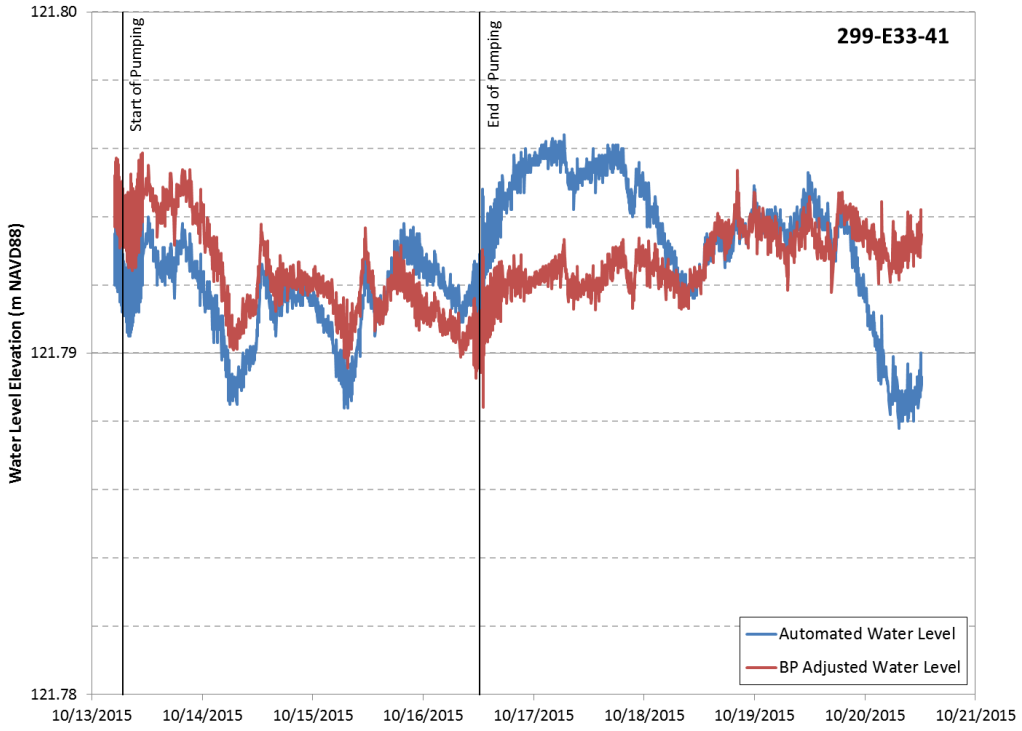

Figure B-7. Automated Water Level Measurements Collected for Well 299-E33-41 (228 m [748 ft] Southeast of the Pumping Well) during the 3-Day Constant Rate Discharge Test

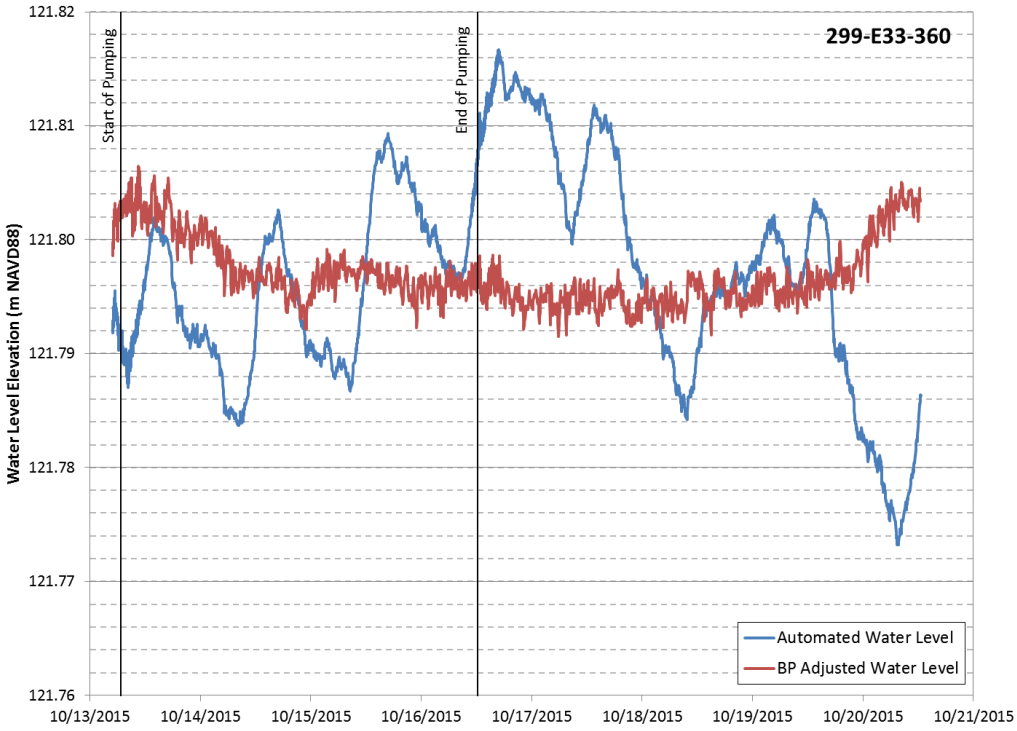

Figure B-8. Automated Water Level Measurements Collected for Well 299-E33-360 (276 m [906 ft] East-Southeast of the Pumping Well) during the 3-Day Constant Rate Discharge Test

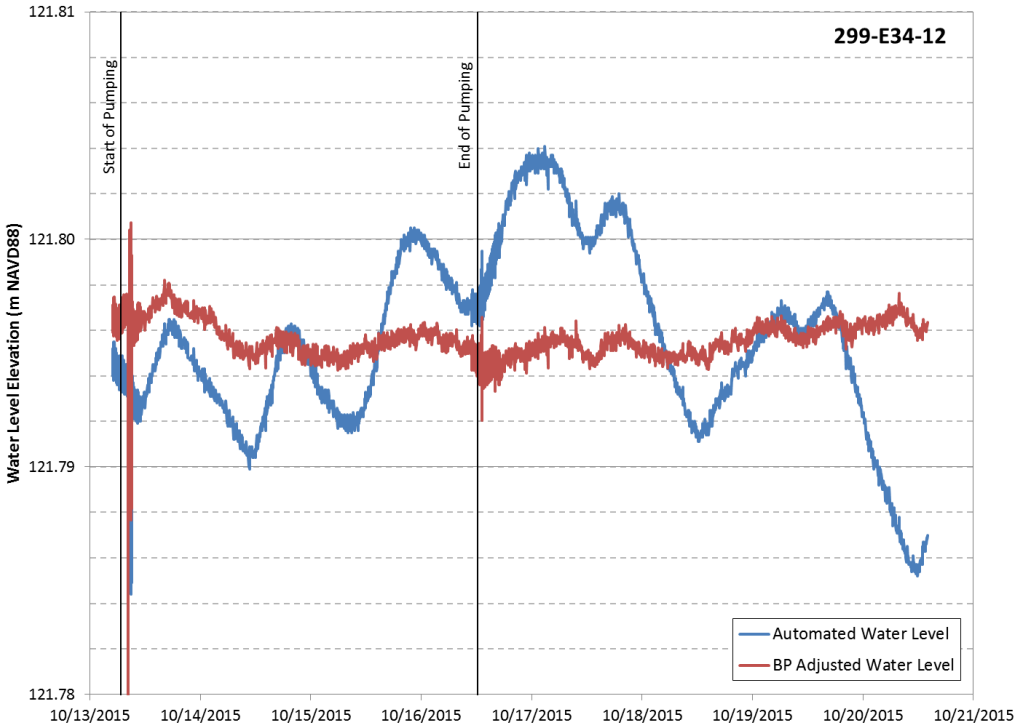

Figure B-9. Automated Water Level Measurements Collected for Well 299-E34-12 (951 m [3,120 ft] East-Southeast of the Pumping Well) during the 3-Day Constant Rate Discharge Test

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Appendix C
AQTESOLV Results for the 3-Day Constant Rate Discharge Test - Drawdown

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This appendix provides charts of the curves matched to the drawdown data from the 3-day constant rate discharge test conducted between 10/13/2015 and 10/16/2015. The pumping well was 299-E33-268 and drawdown was observed in wells 299-E33-31, 299-E33-267, and 299-E33-342. Pressure derivatives for these 4 wells are also provided.

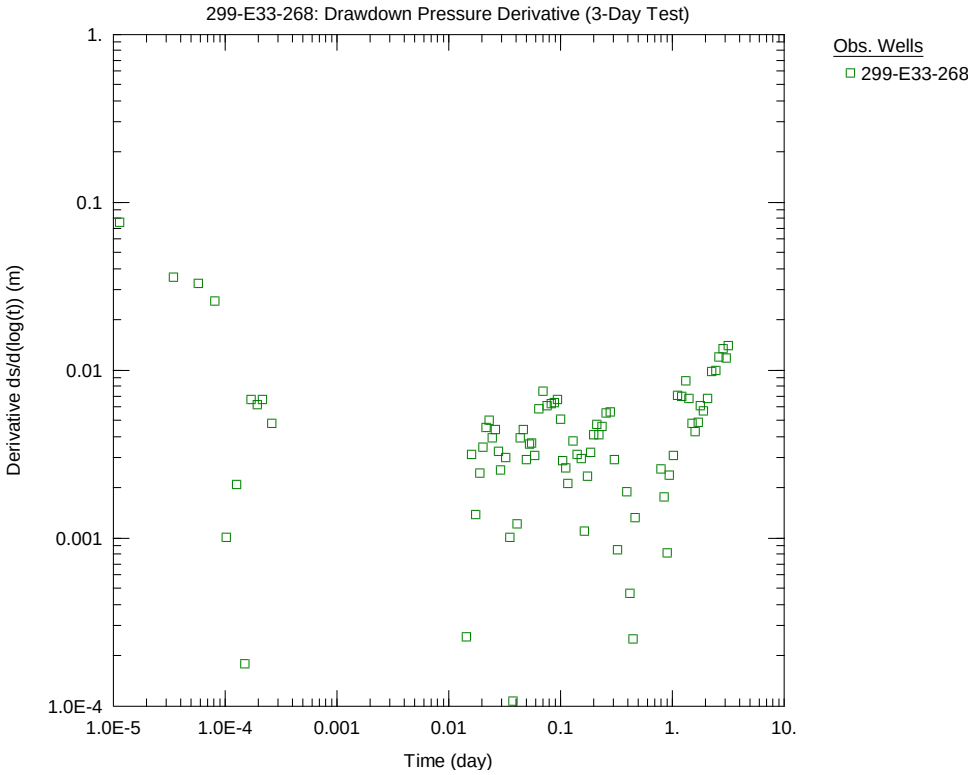

Figure C-1. AQTESOLV Pressure Derivative for Drawdown at 299-E33-268 (Pumping Well).

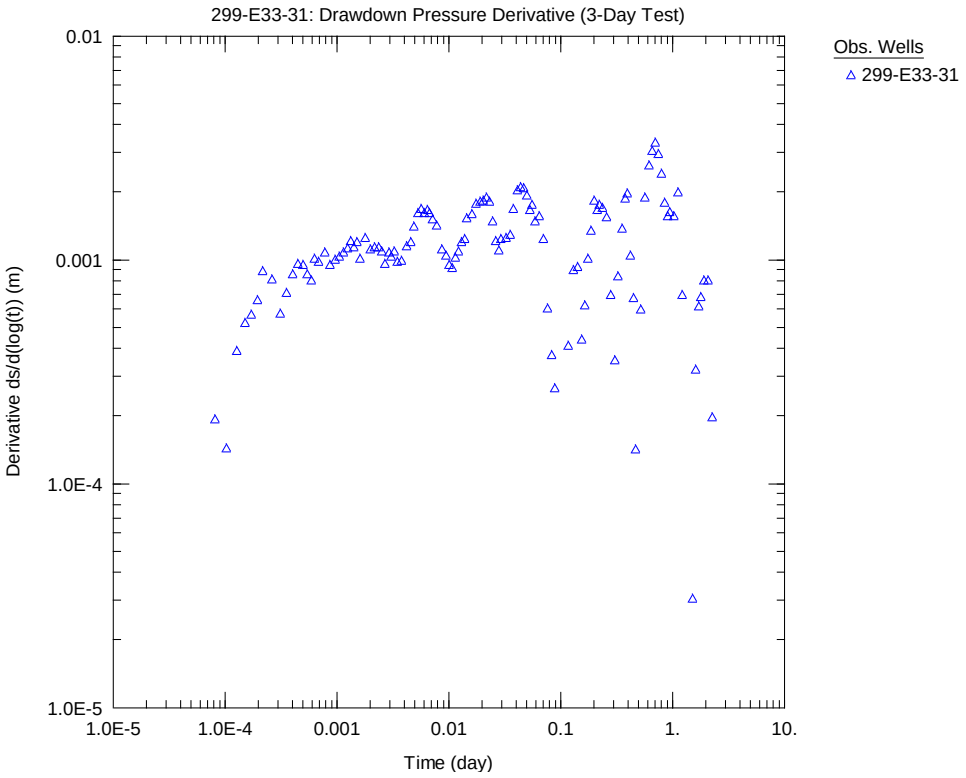

Figure C-2. AQTESOLV Pressure Derivative for Drawdown at 299-E33-31

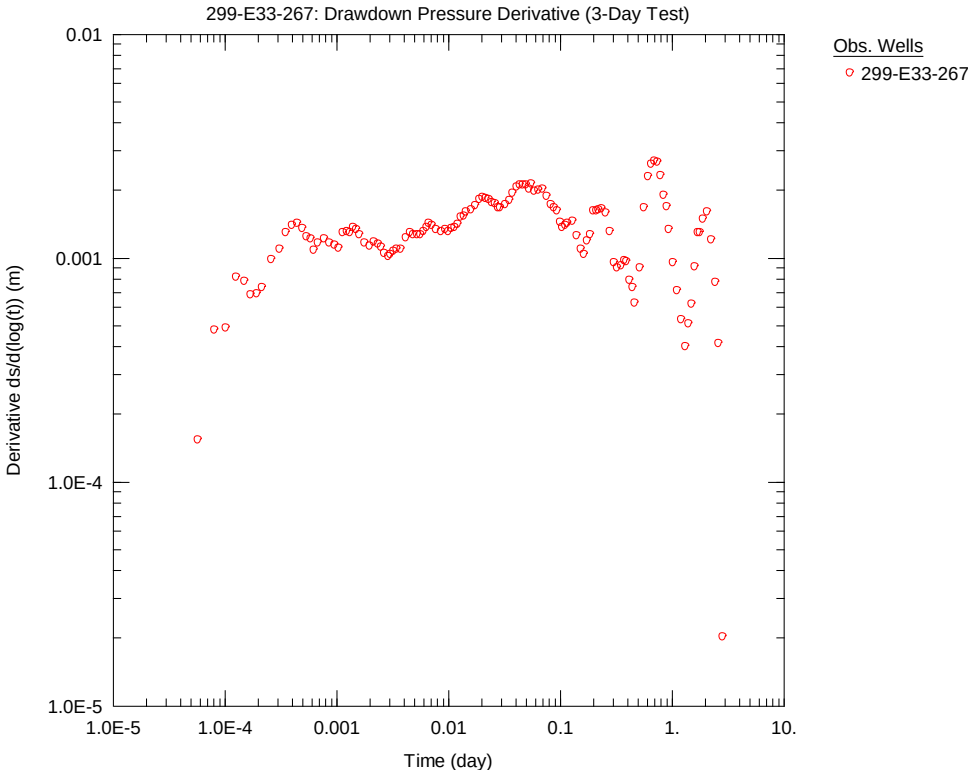

Figure C-3. AQTESOLV Pressure Derivative for Drawdown at 299-E33-267.

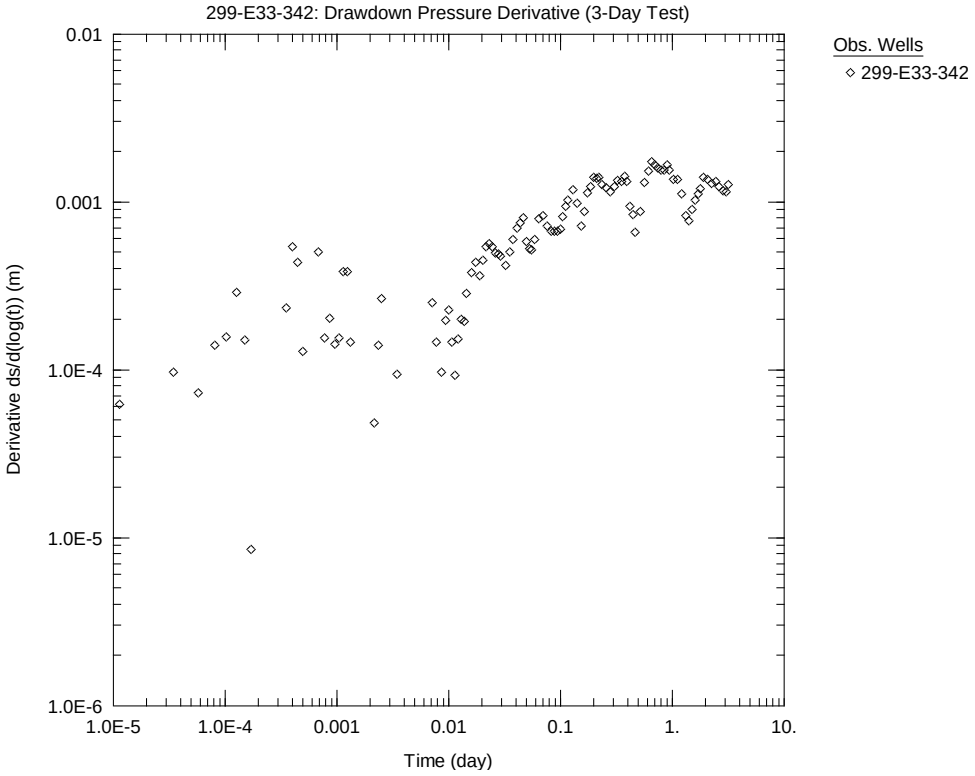

Figure C-4. AQTESOLV Pressure Derivative for Drawdown at 299-E33-342.

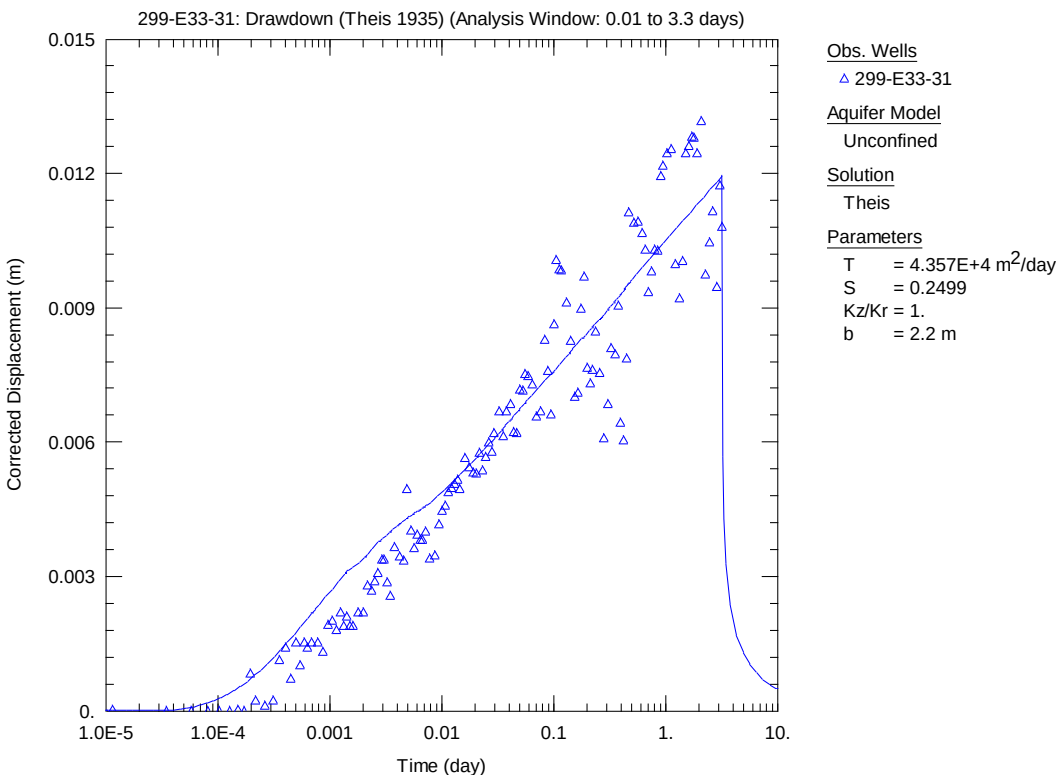

Figure C-5. AQTESOLV Results for Drawdown at 299-E33-31 by the Theis (1935)/Hantush (1961a,b) Method.

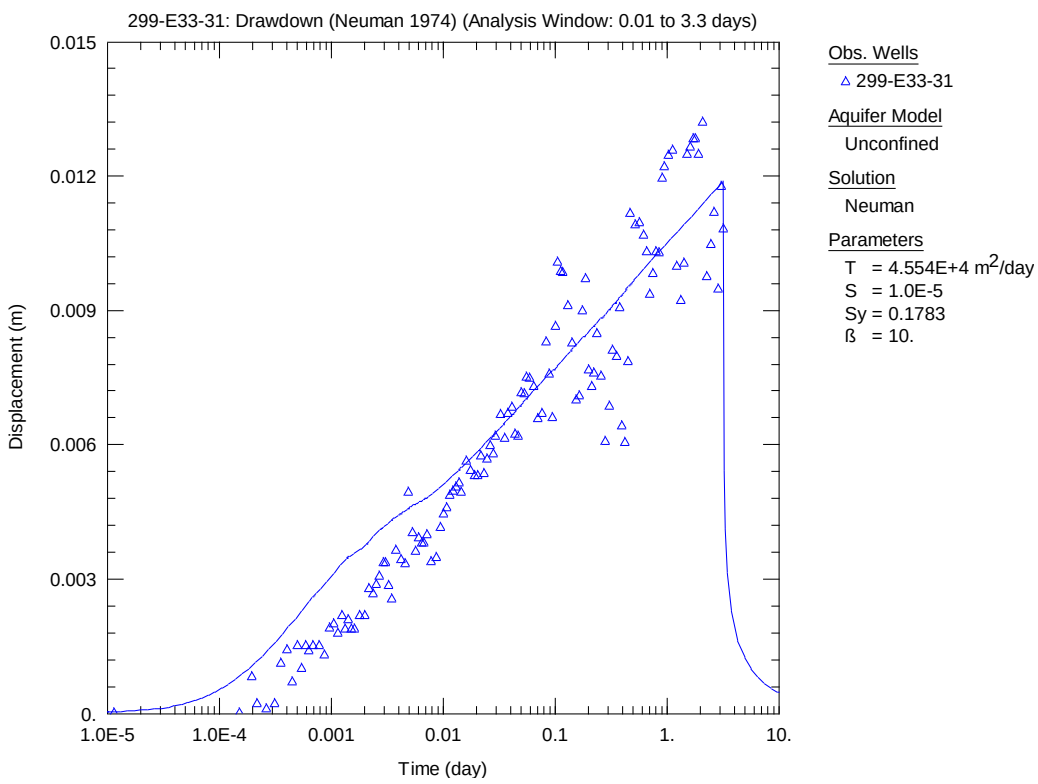

Figure C-6. AQTESOLV Results for Drawdown at 299-E33-31 by the Neuman (1974) Method.

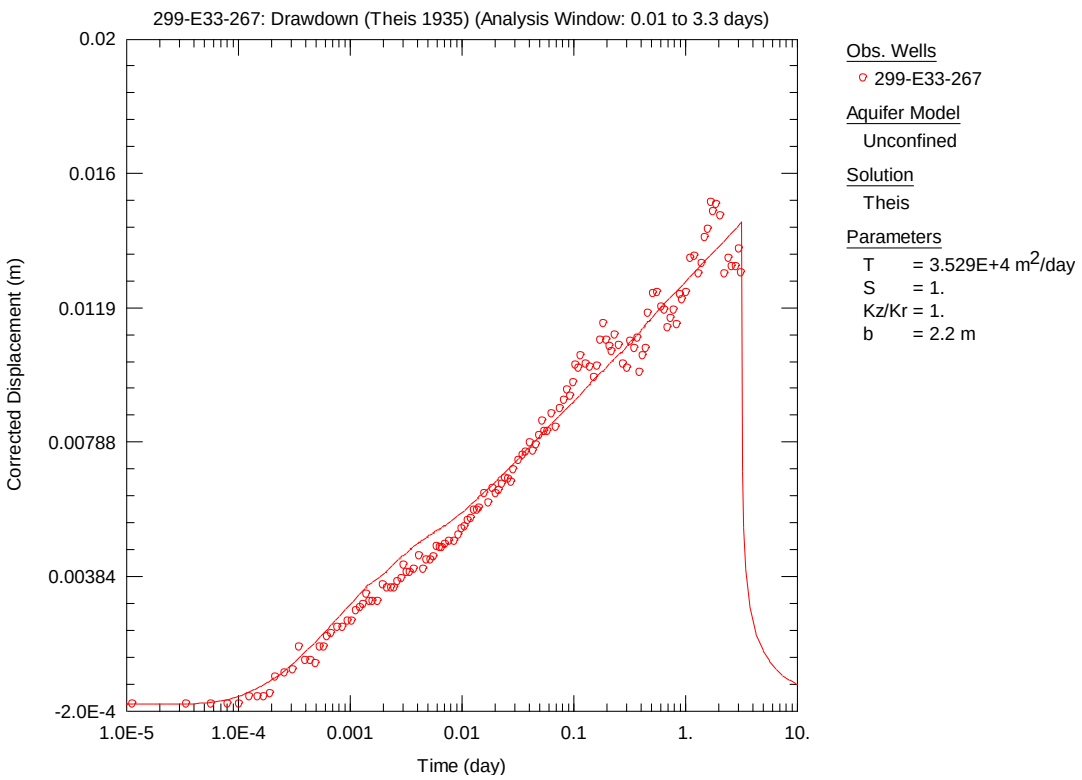

Figure C-7. AQTESOLV Results for Drawdown at 299-E33-267 by the Theis (1935)/Hantush (1961a,b) Method.

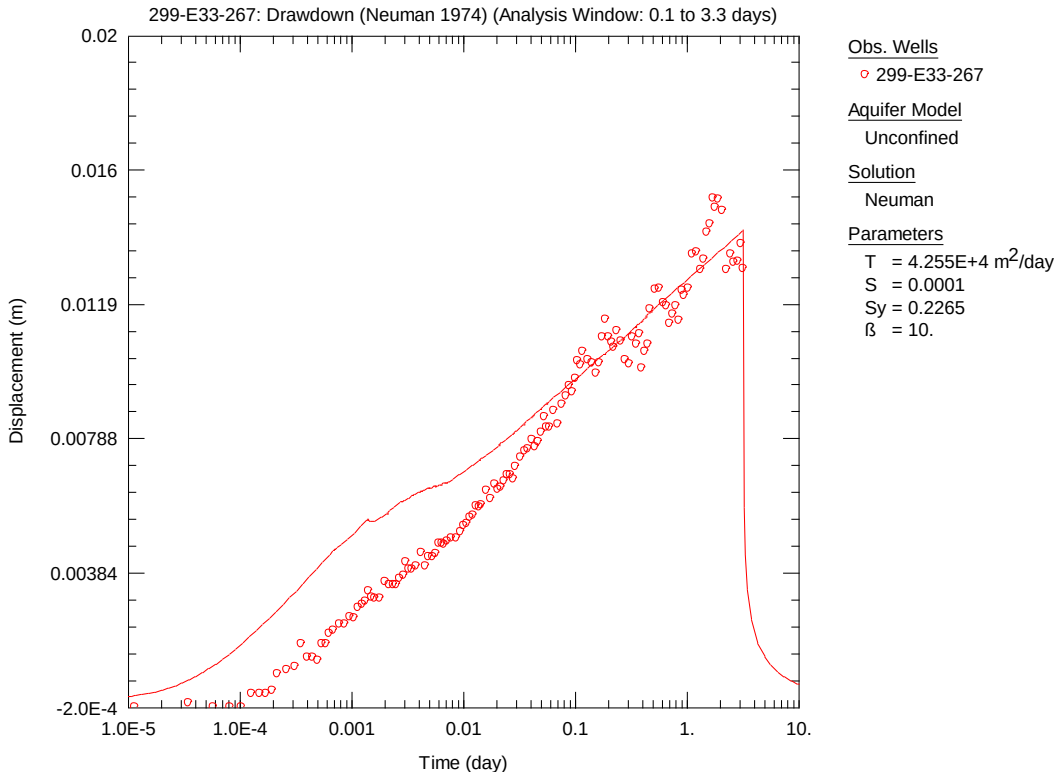

Figure C-8. AQTESOLV Results for Drawdown at 299-E33-267 by the Neuman (1974) Method.

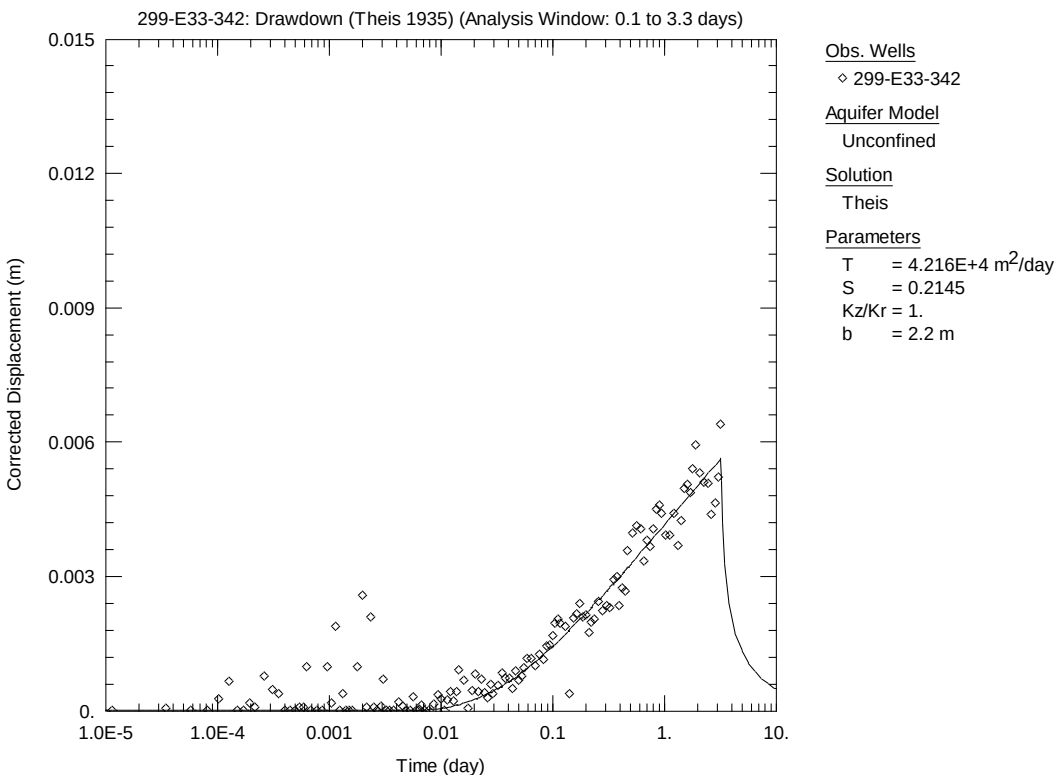

Figure C-9. AQTESOLV Results for Drawdown at 299-E33-342 by the Theis (1935)/Hantush (1961a,b) Method.

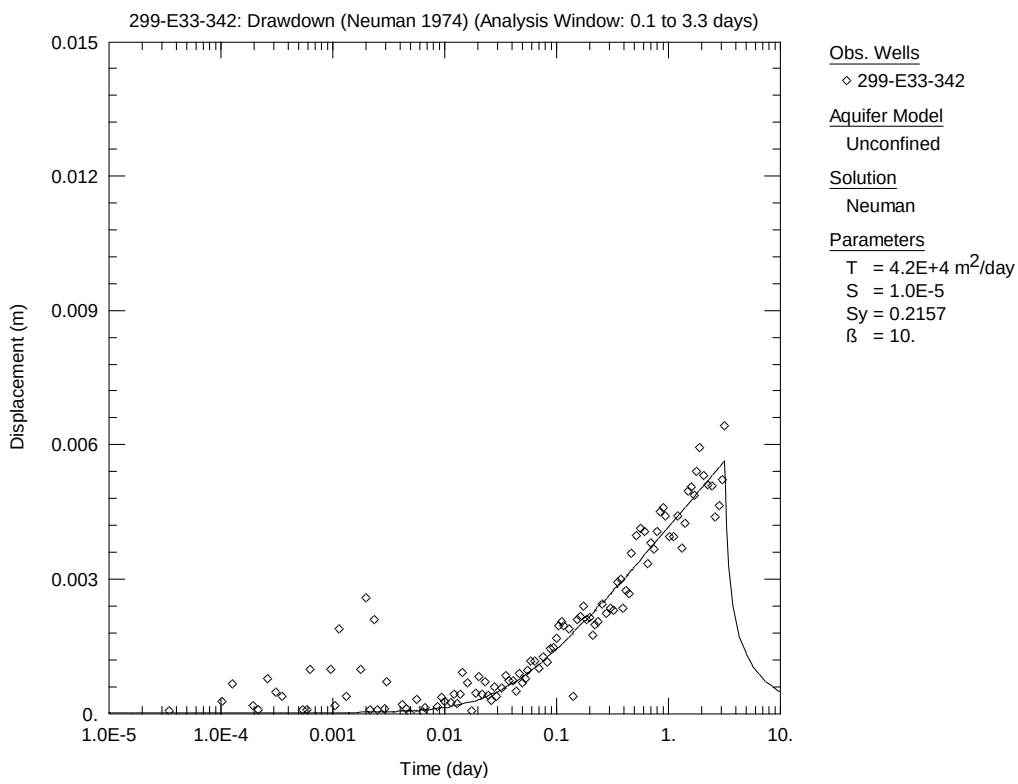

Figure C-10. AQTESOLV Results for Drawdown at 299-E33-342 by the Neuman (1974) Method.

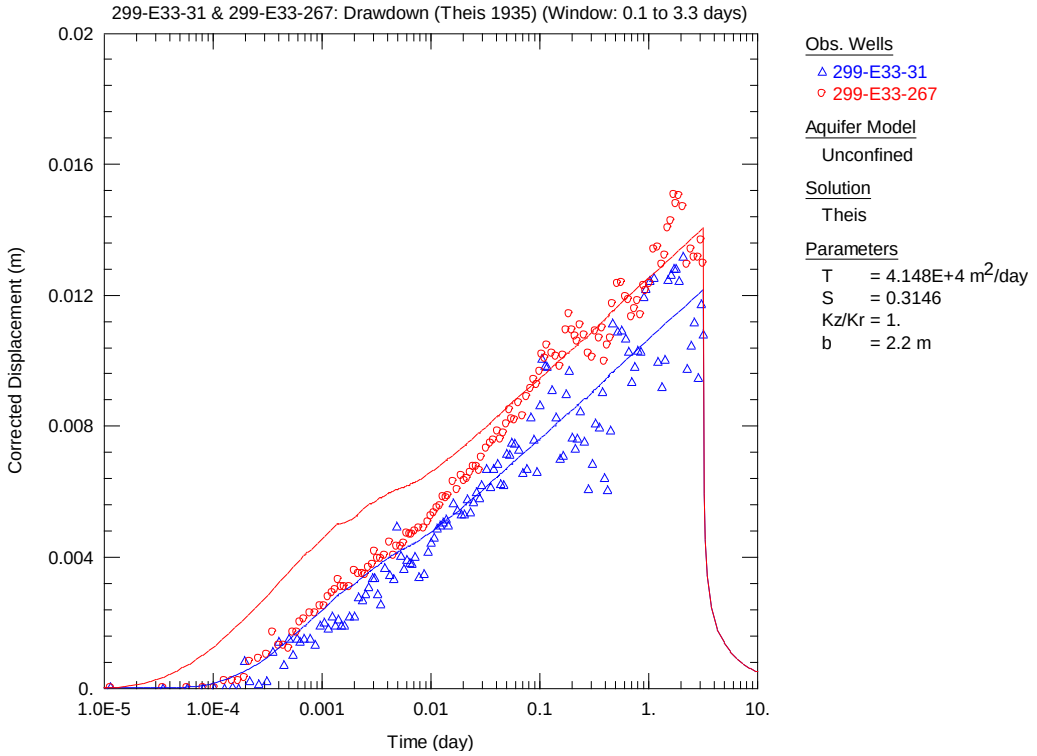

Figure C-11. AQTESOLV Results for Drawdown at 299-E33-31 and 299-E33-267 by the Theis (1935)/Hantush (1961a,b) Method.

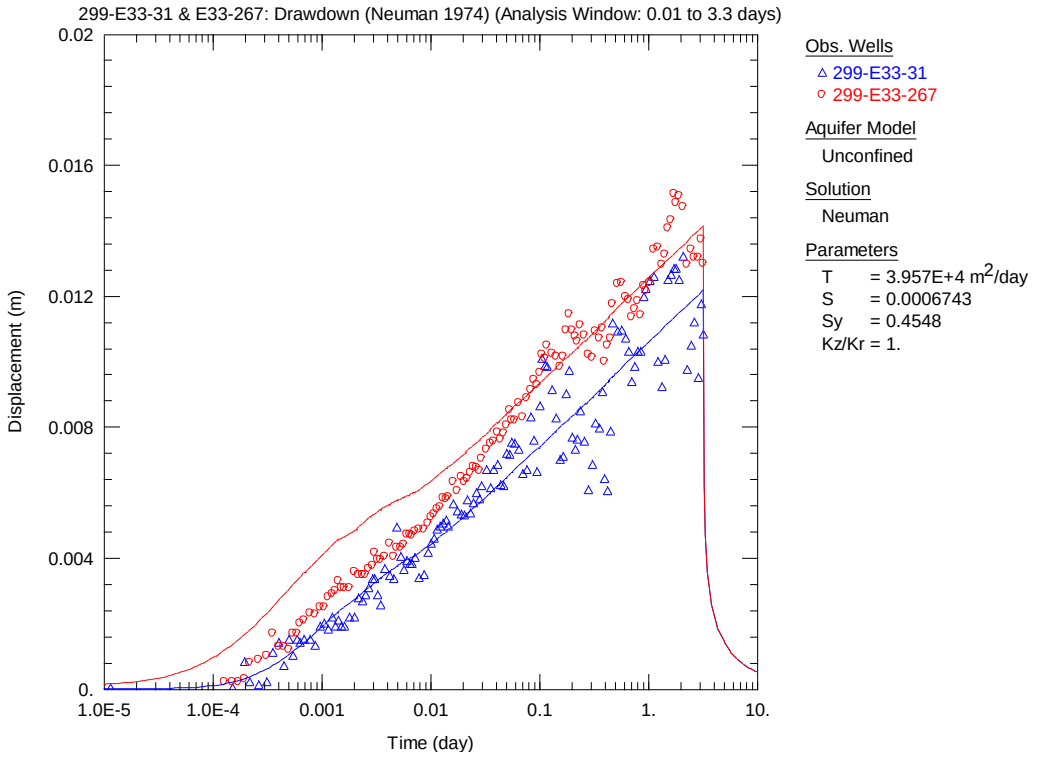

Figure C-12. AQTESOLV Results for Drawdown at 299-E33-31 and 299-E33-267 by the Neuman (1974) Method.

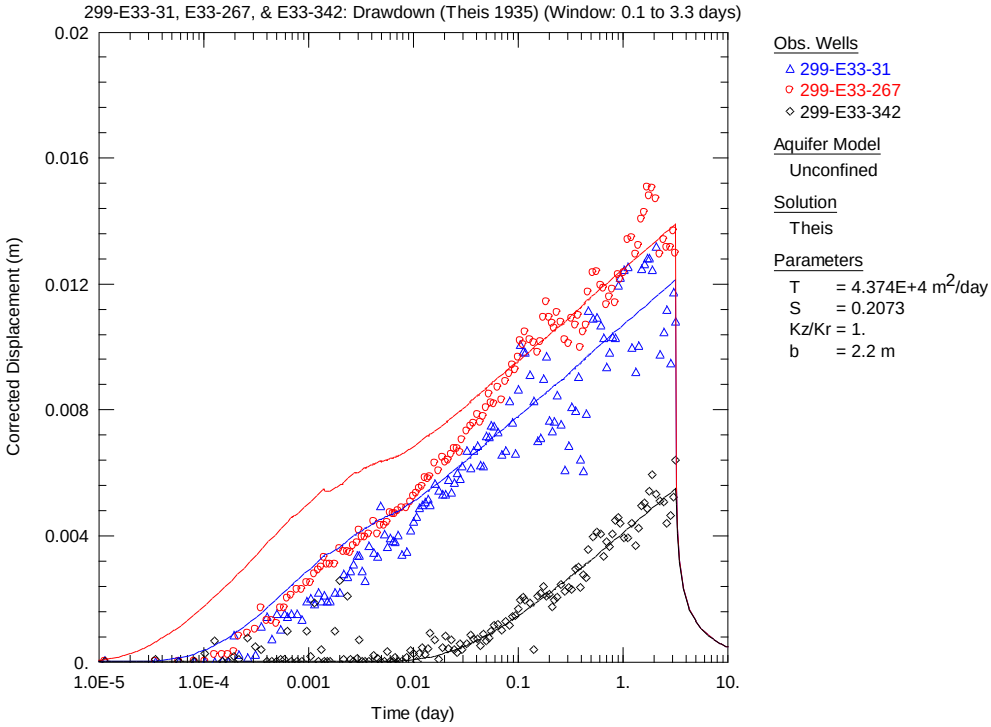

Figure C-13. AQTESOLV Results for Drawdown at 299-E33-31, 299-E33-267, and 299-E33-342 by the Theis (1935)/Hantush (1961a,b) Method.

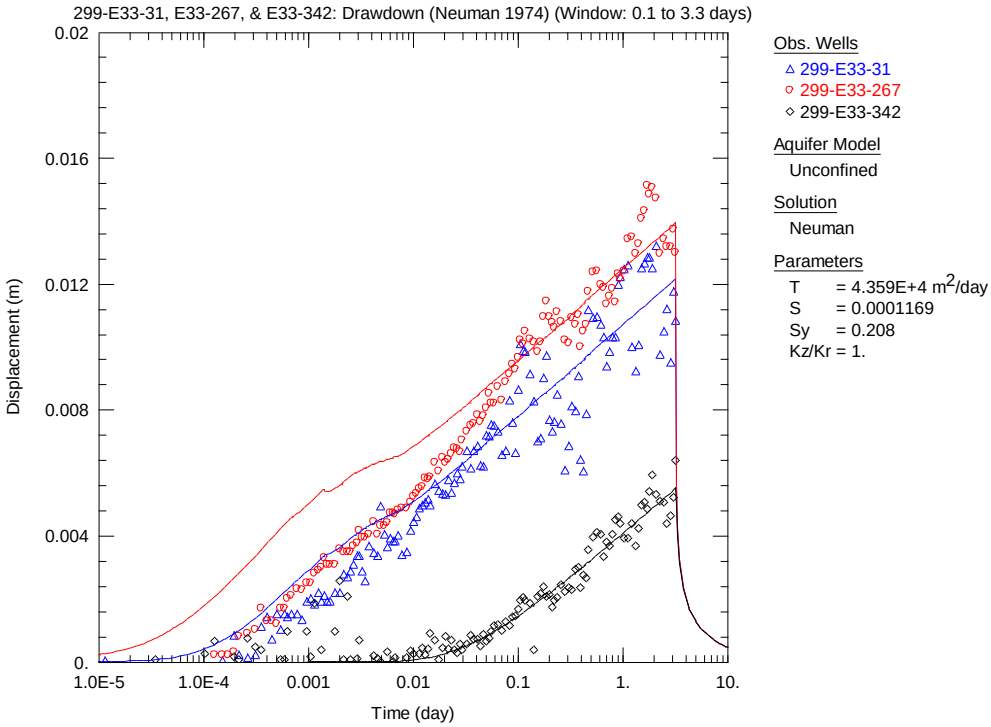

Figure C-14. AQTESOLV Results for Drawdown at 299-E33-31, 299-E33-267, and 299-E33-342 by the Neuman (1974) Method.

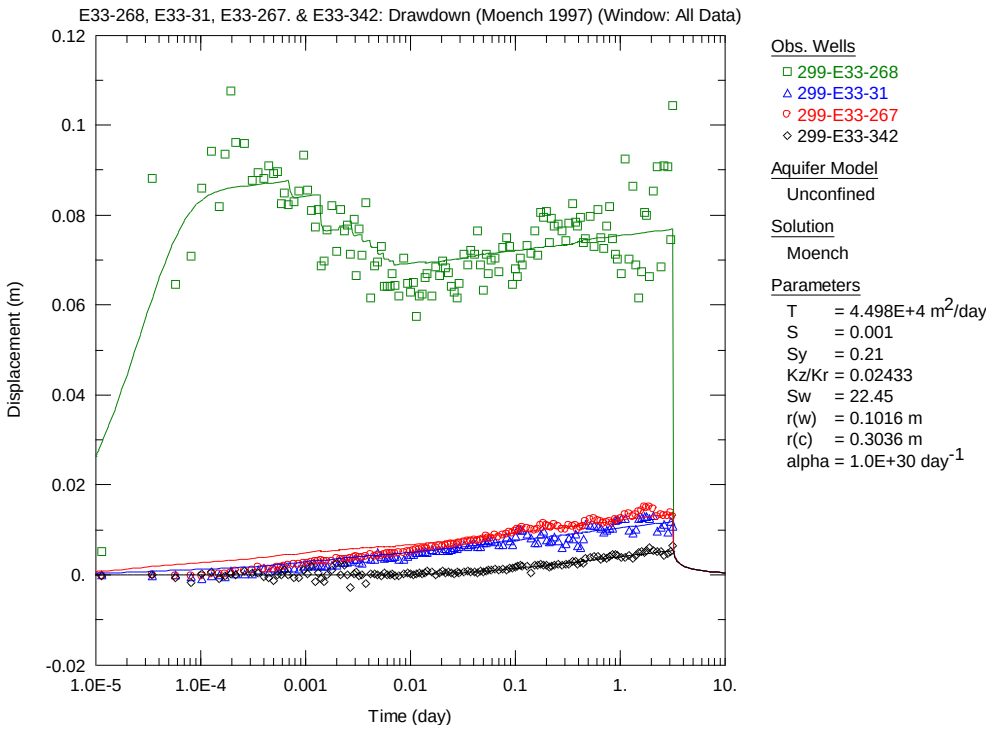

Figure C-15. AQTESOLV Results for Drawdown at Pumping Well 299-E33-268 and Observation Wells 299-E33-31, 299-E33-267, and 299-E33-342 by the Moench (1997) Method.

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Appendix D
AQTESOLV Results for the 3-Day Constant Rate Discharge Test - Recovery

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This appendix provides the curves matched to the recovery data from the 3-day constant rate discharge test conducted between 10/13/2015 and 10/16/2015. The pumping well was 299-E33-268 and because drawdown was observed in wells 299-E33-31, 299-E33-267, and 299-E33-342, these wells were analyzed for buildup.

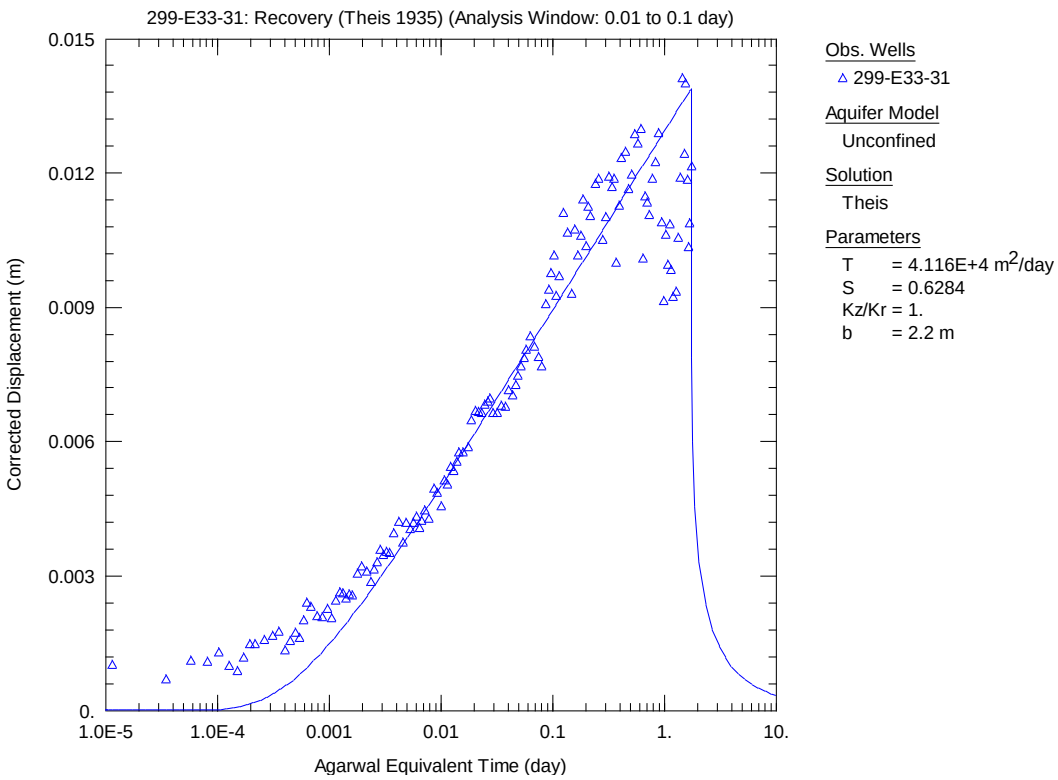

Figure D-1. AQTESOLV Results for Recovery at 299-E33-31 by the Theis (1935)/Hantush (1961a,b) Method.

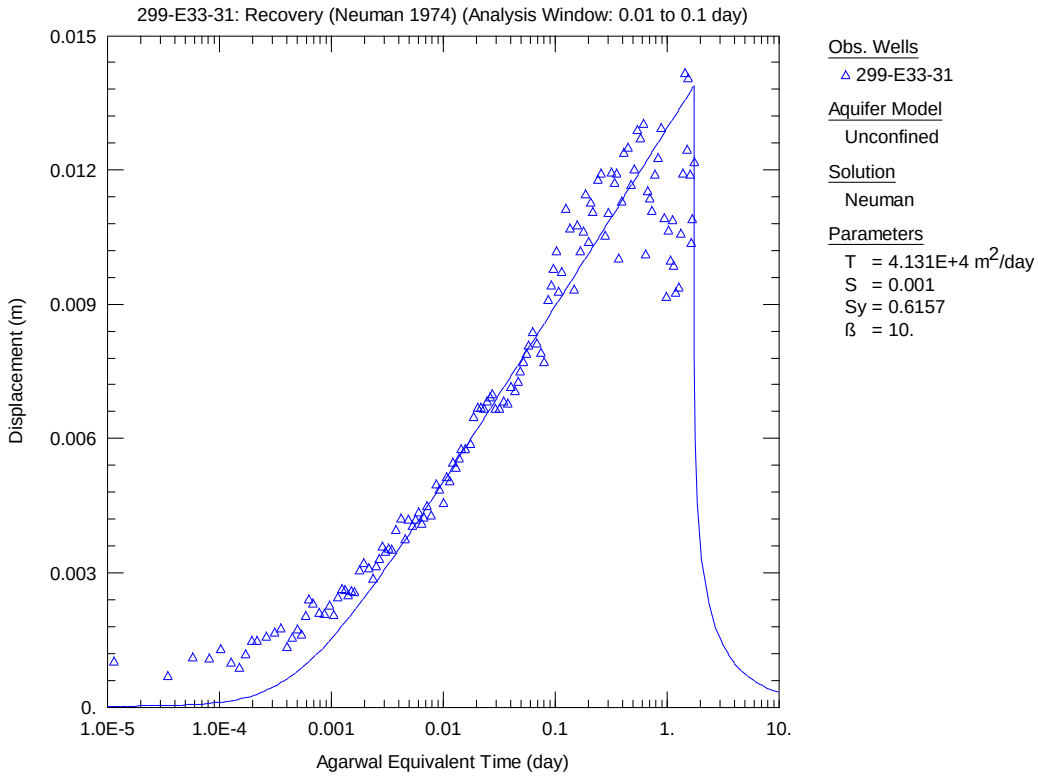

Figure D-2. AQTESOLV Results for Recovery at 299-E33-31 by the Neuman (1974) Method.

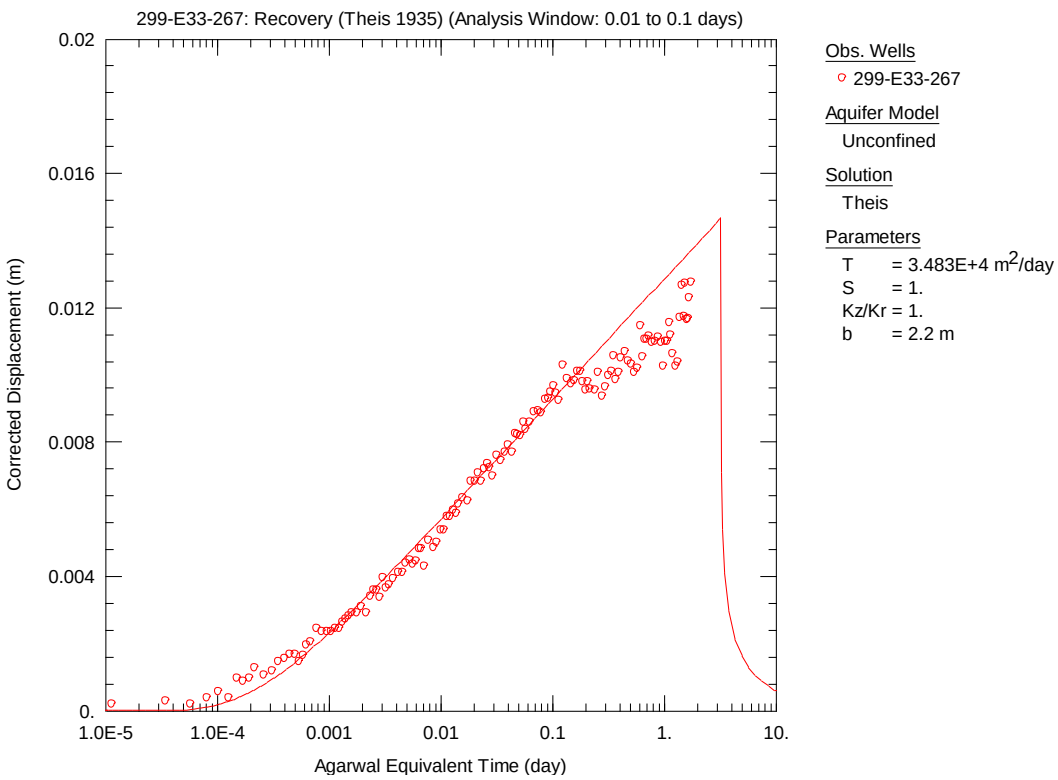

Figure D-3. AQTESOLV Results for Recovery at 299-E33-267 by the Theis (1935)/Hantush (1961a,b) Method.

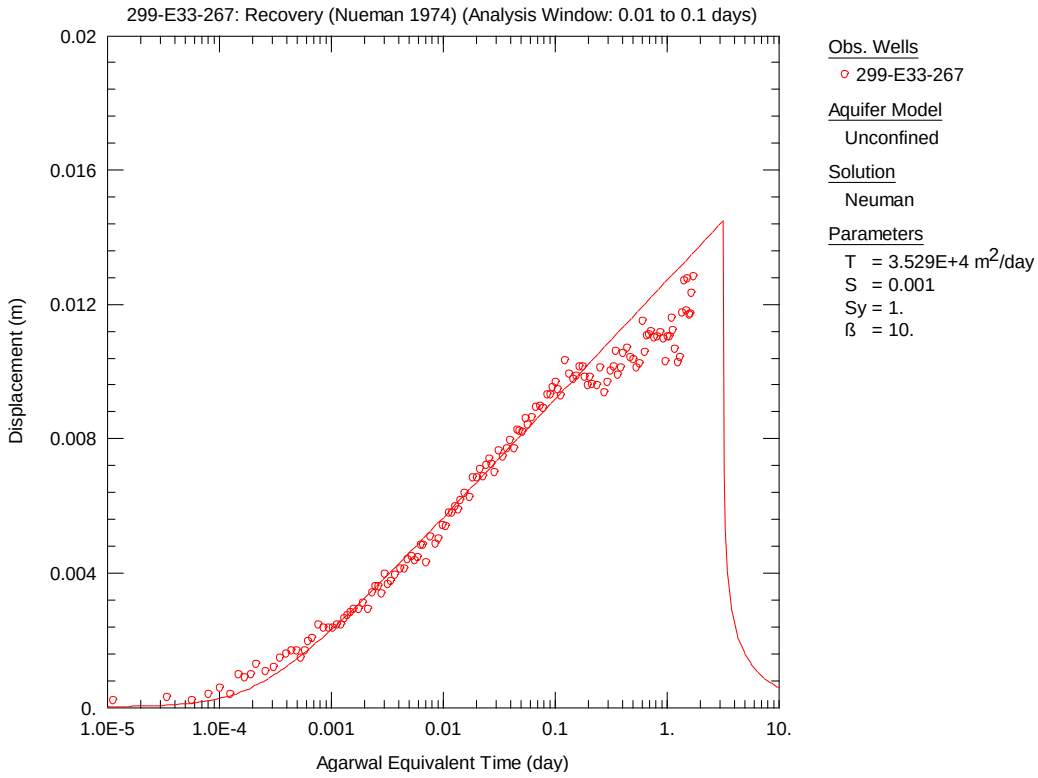

Figure D-4. AQTESOLV Results for Recovery at 299-E33-267 by the Neuman (1974) Method.

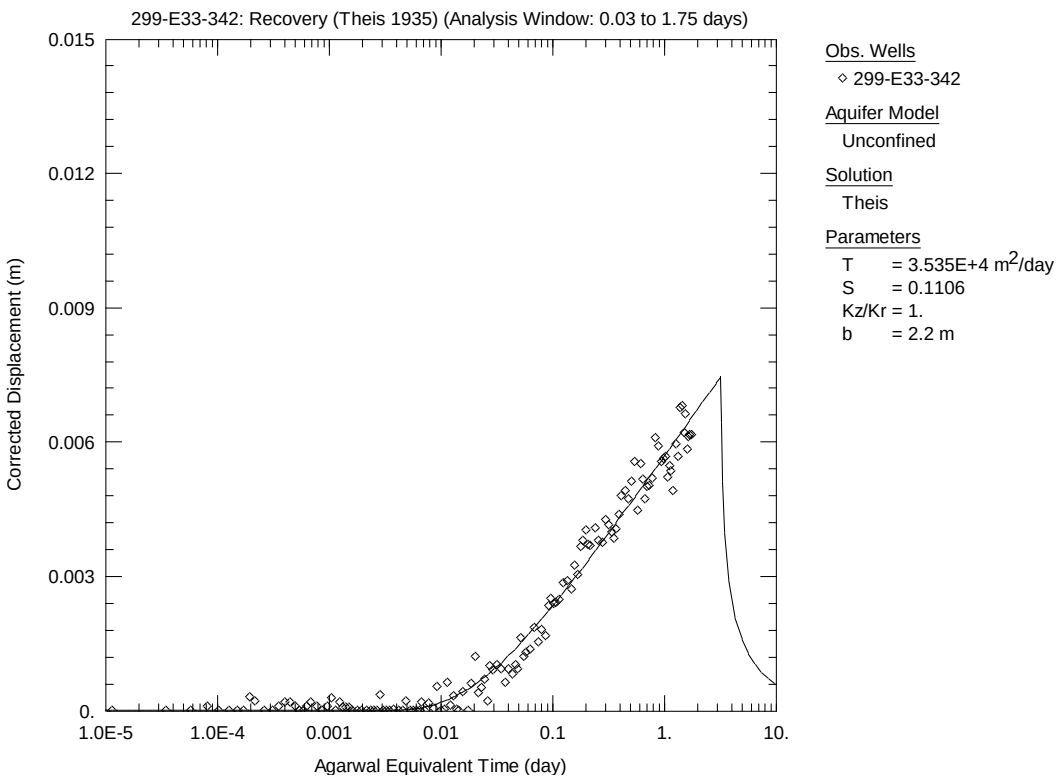

Figure D-5. AQTESOLV Results for Recovery at 299-E33-342 by the Theis (1935)/Hantush (1961a,b) Method.

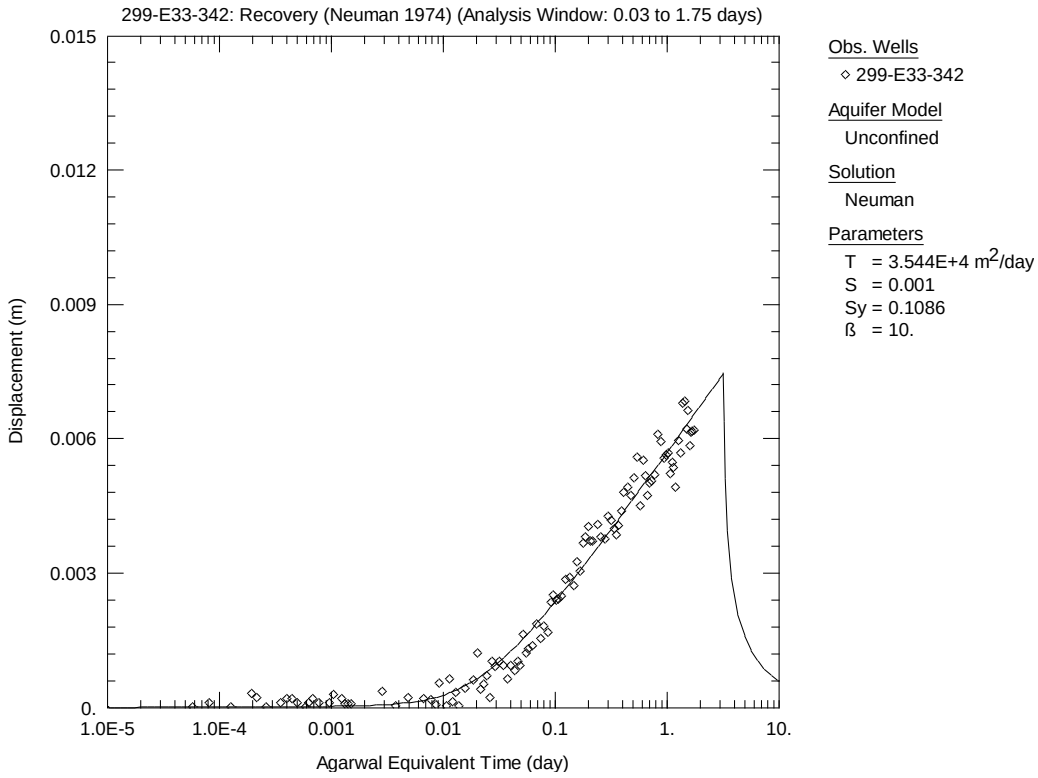

Figure D-6. AQTESOLV Results for Recovery at 299-E33-342 by the Neuman (1974) Method.

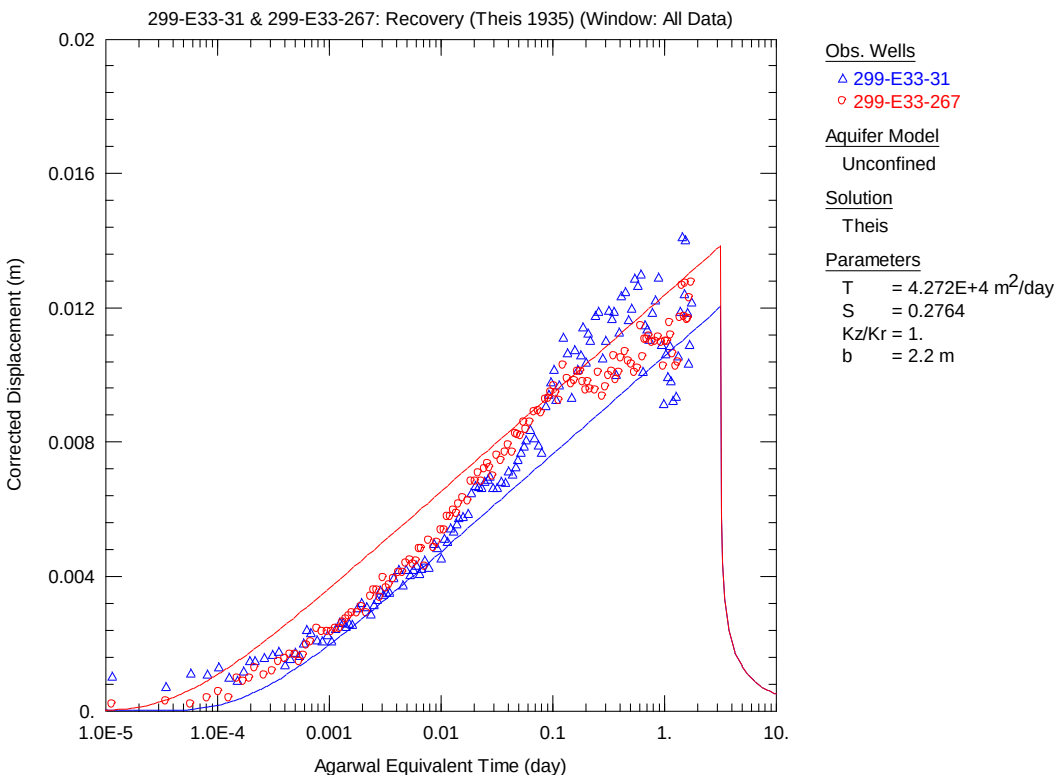

Figure D-7. AQTESOLV Results for Recovery at 299-E33-31 and 299-E33-267 by the Theis (1935)/Hantush (1961a,b) Method.

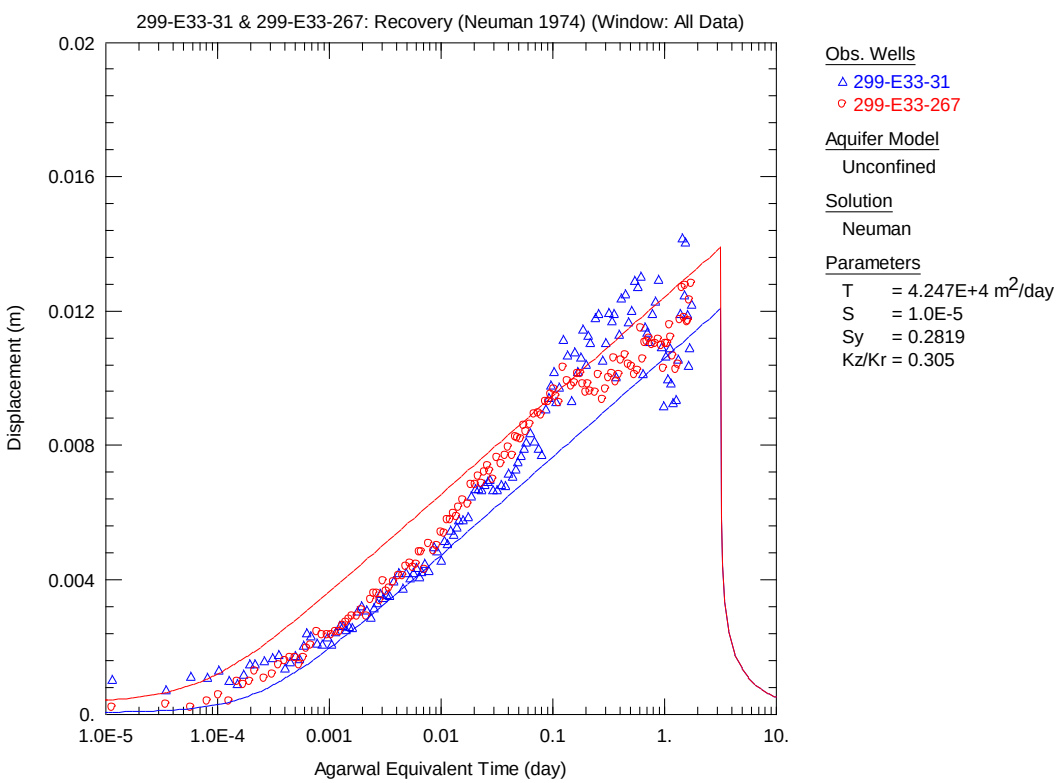

Figure D-8. AQTESOLV Results for Recovery at 299-E33-31 and 299-E33-267 by the Neuman (1974) Method.

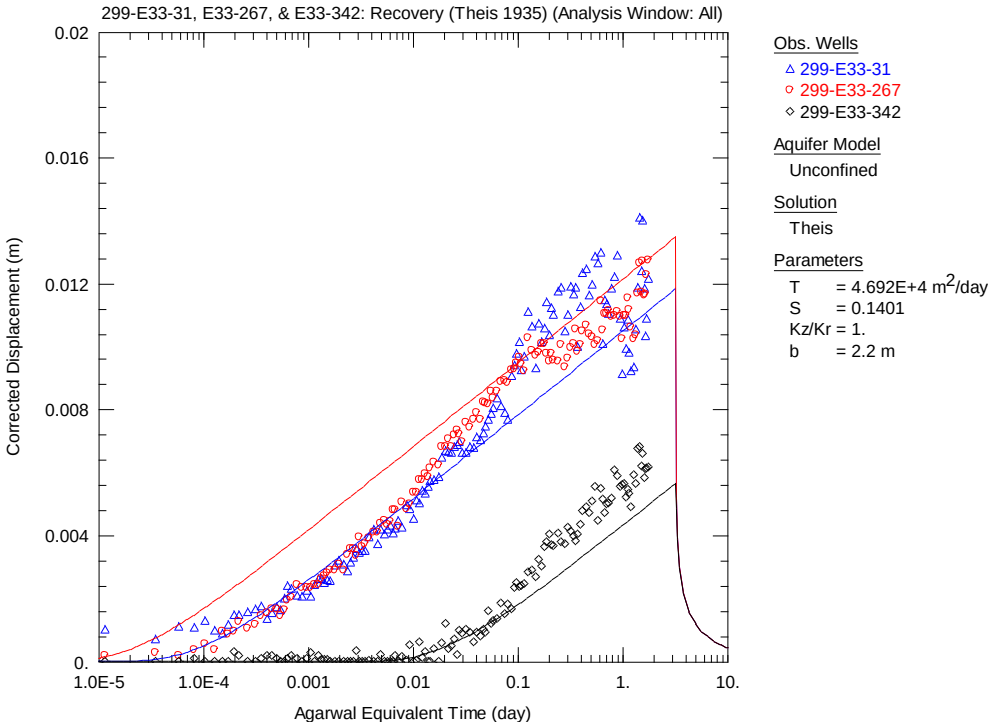

Figure D-9. AQTESOLV Results for Recovery at 299-E33-31, 299-E33-267, and 299-E33-342 by the Theis (1935)/Hantush (1961a,b) Method.

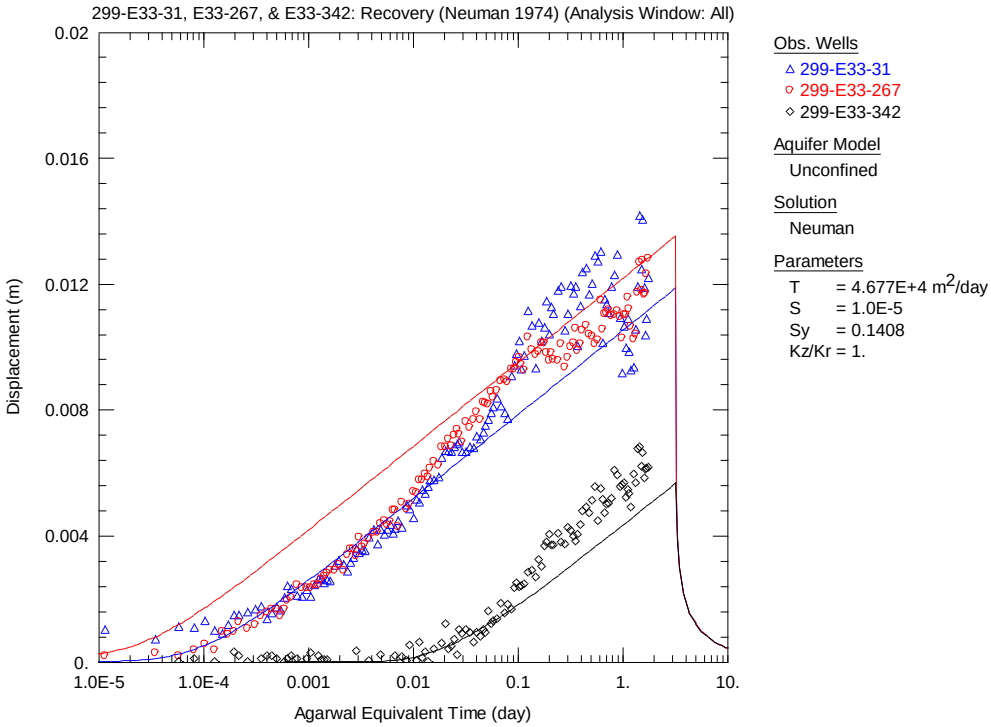

Figure D-10. AQTESOLV Results for Recovery at 299-E33-31, 299-E33-267, and 299-E33-342 by the Neuman (1974) Method.

Appendix E
Automated Water Level Measurements for the 27-Day Constant Rate Discharge Test

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Charts of the automated water level measurements collected during the 27-day test are shown in Figures E-1 through E-10. The pumping well, 299-E33-268, is shown first (Figure E-1) and then the observation wells are shown in order of increasing distance from the pumping well (Figures E-2 to E-10). Two charts are provided for 299-E34-12. The first (Figure E-9) shows the unmodified water level in the well during the test period. The water level exhibits a declining trend during this time. This is the background trend of the water table because 299-E34-12 is 951 m (3,120 ft) from the pumping well and did not experience any drawdown during the test. Because the background water table declined during the test, it was important to remove that decline from the measurements so it would not affect the drawdown determinations. After the measurements from 299-E34-12 were normalized to a constant barometric pressure, a line was fit to the data by linear regression. The slope of the line was then used to detrend all the measurements for all the wells before data analysis. The detrended measurements for 299-E34-12 are shown in Figure E-10, and all the other figures (i.e., E-1 to E-8) show the detrended data for the remaining wells.

Like for the 3-day test, drawdown was discernable in the pumping well and in 299-E33-267, 299-E33-31, and 299-E33-342 (pumping was resumed after the recovery period, hence the resumption of drawdown on the charts on 11/20/2015). Some drawdown may also have occurred at 299-E33-42, but this could not be confirmed because the amount of apparent drawdown (0.001 to 0.002 m) is about the same as the remaining error when the water levels are normalized to a constant barometric pressure. For this reason, 299-E33-42 was not included in the hydraulic property determinations.

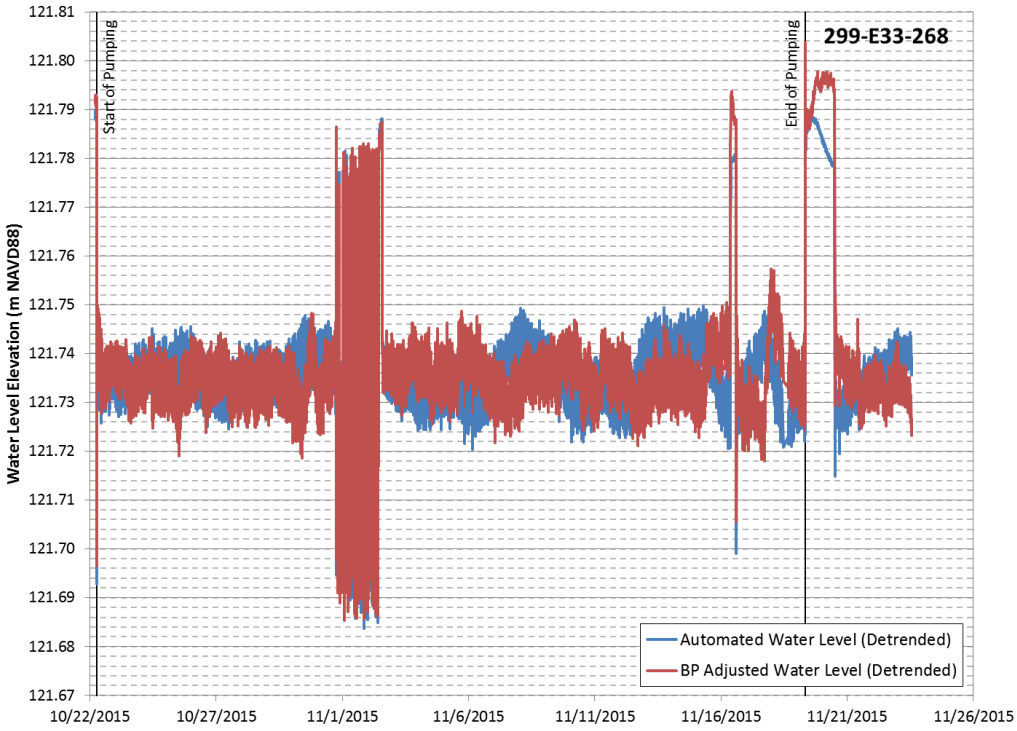

Figure E-1. Automated Water Level Measurements Collected for Well 299-E33-268 (Pumping Well) during the 27-Day Constant Rate Discharge Test (Detrended)

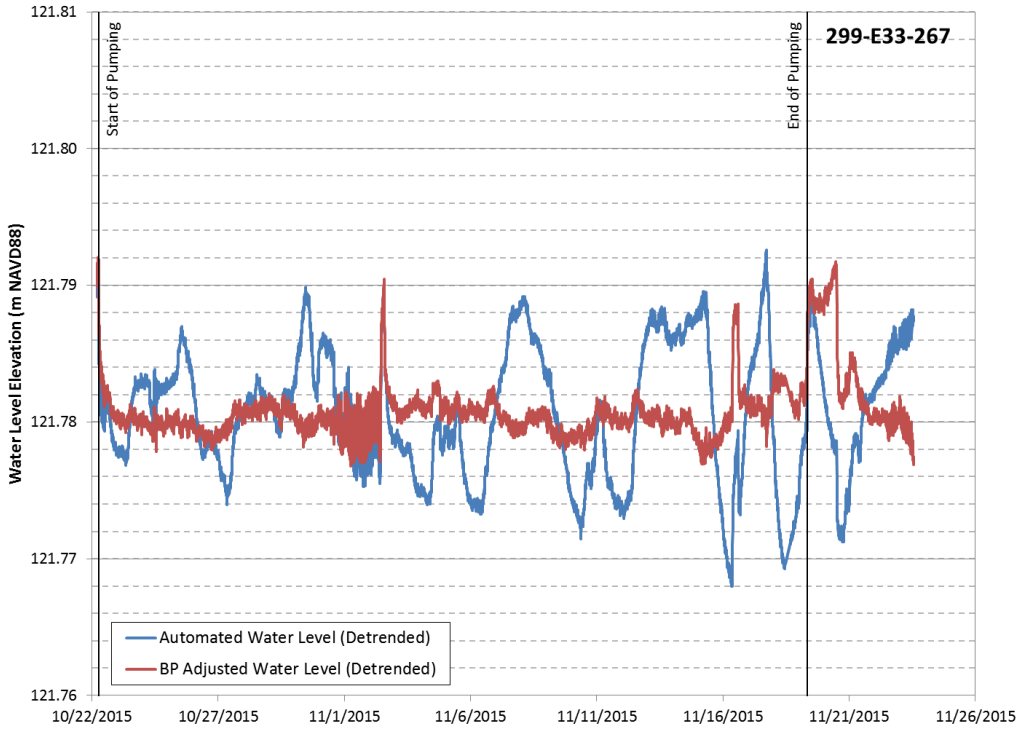

Figure E-2. Automated Water Level Measurements Collected for Well 299-E33-267 (4.5 m [15 ft] South of the Pumping Well) during the 27-Day Constant Rate Discharge Test (Detrended)

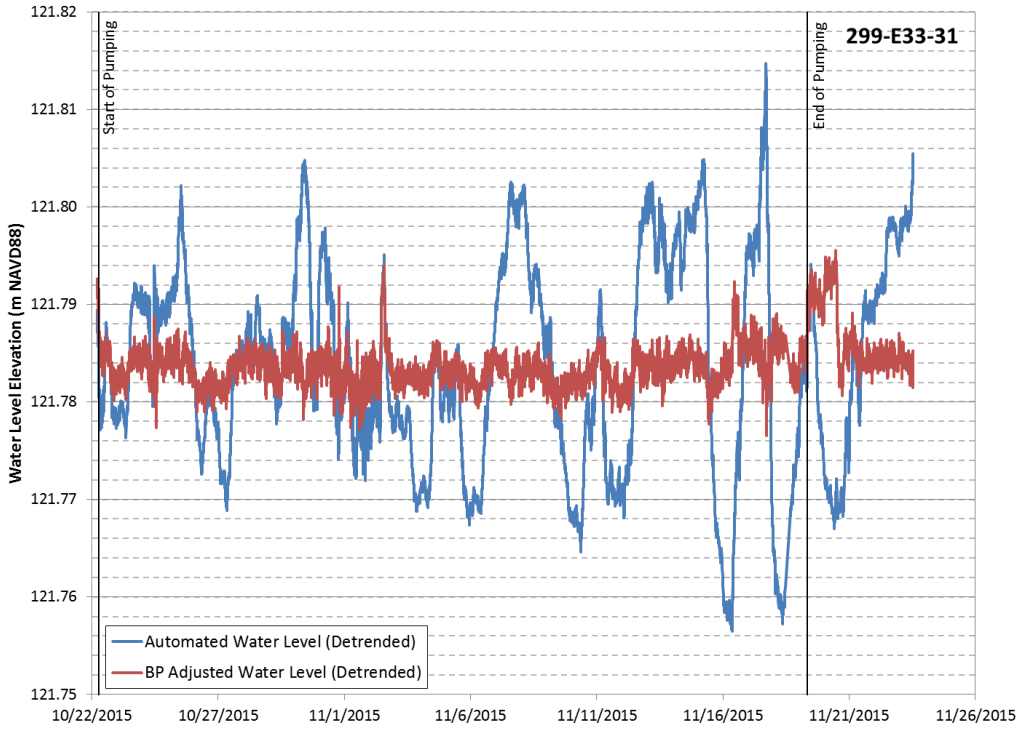

Figure E-3. Automated Water Level Measurements Collected for Well 299-E33-31 (9.2 m [30 ft] South-Southeast of the Pumping Well) during the 27-Day Constant Rate Discharge Test (Detrended)

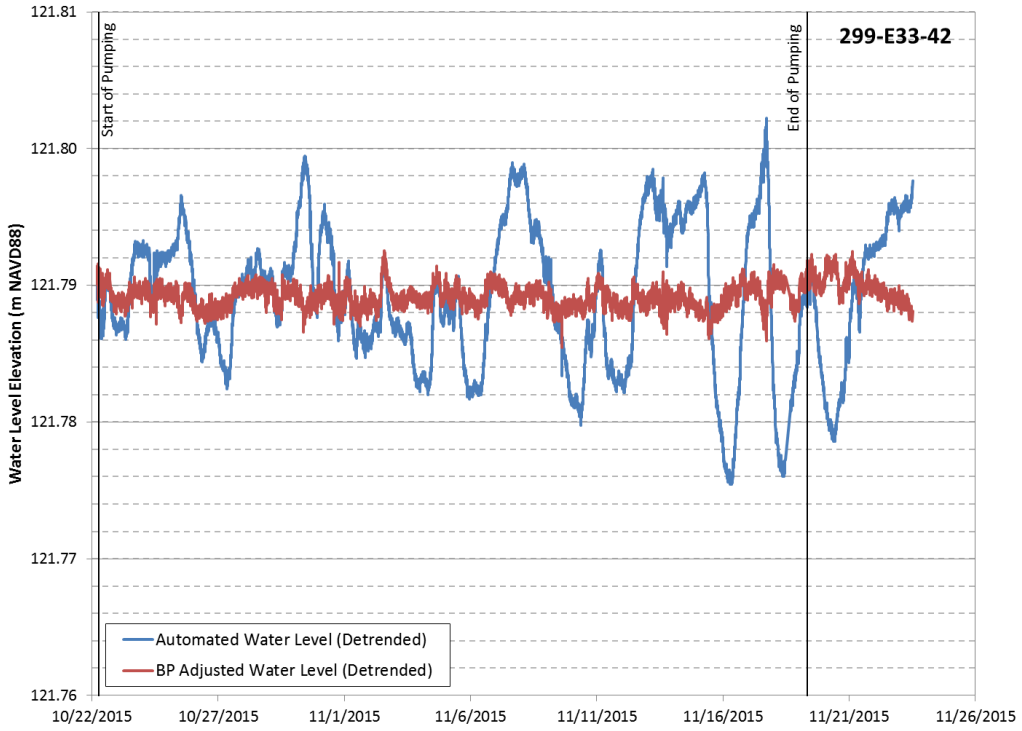

Figure E-4. Automated Water Level Measurements Collected for Well 299-E33-42 (74 m [240 ft] South of the Pumping Well) during the 27-Day Constant Rate Discharge Test (Detrended)

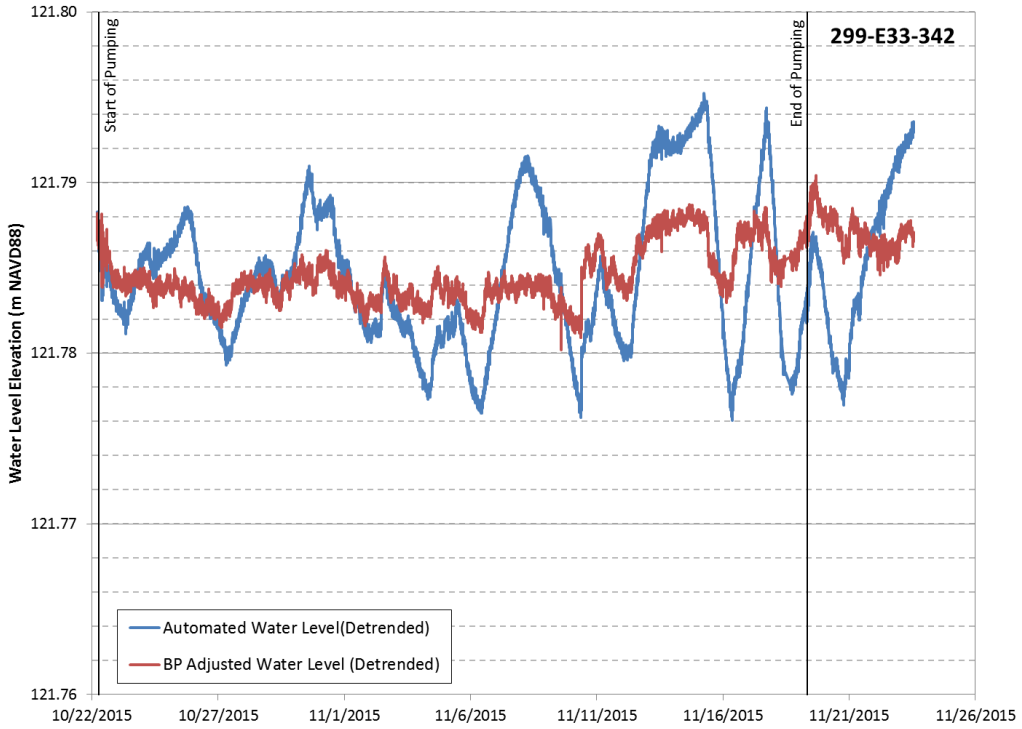

Figure E-5. Automated Water Level Measurements Collected for Well 299-E33-342 (134 m [440 ft] Northeast of the Pumping Well) during the 27-Day Constant Rate Discharge Test (Detrended)

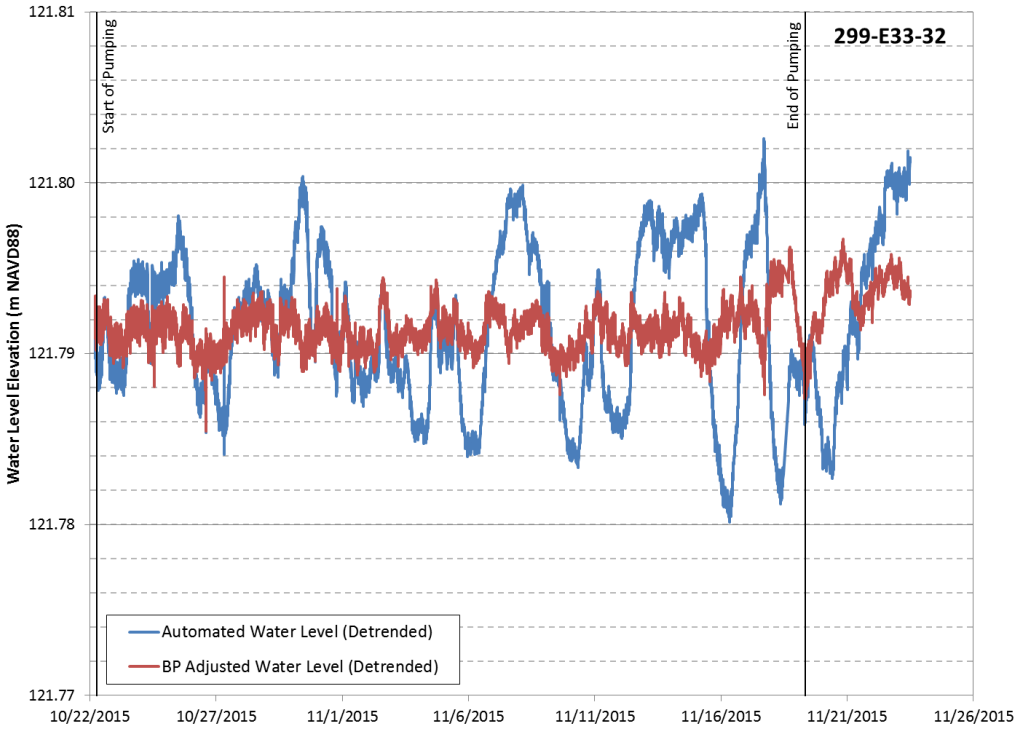

Figure E-6. Automated Water Level Measurements Collected for Well 299-E33-32 (145 m [476 ft] South of the Pumping Well) during the 27-Day Constant Rate Discharge Test (Detrended)

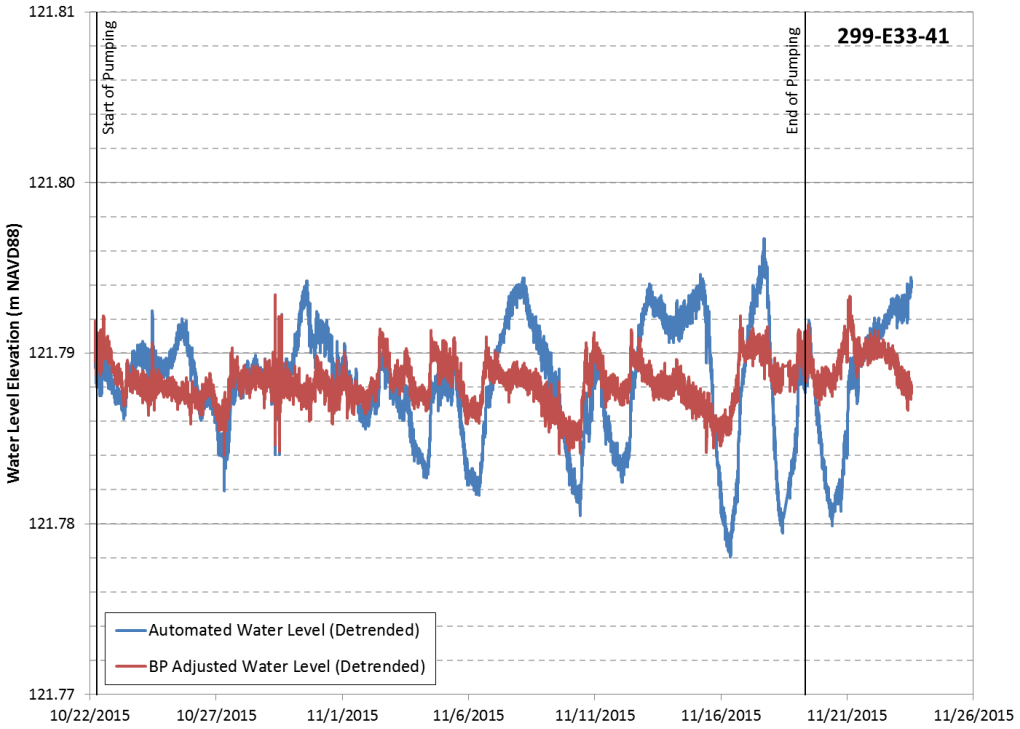

Figure E-7. Automated Water Level Measurements Collected for Well 299-E33-41 (228 m [748 ft] Southeast of the Pumping Well) during the 27-Day Constant Rate Discharge Test (Detrended)

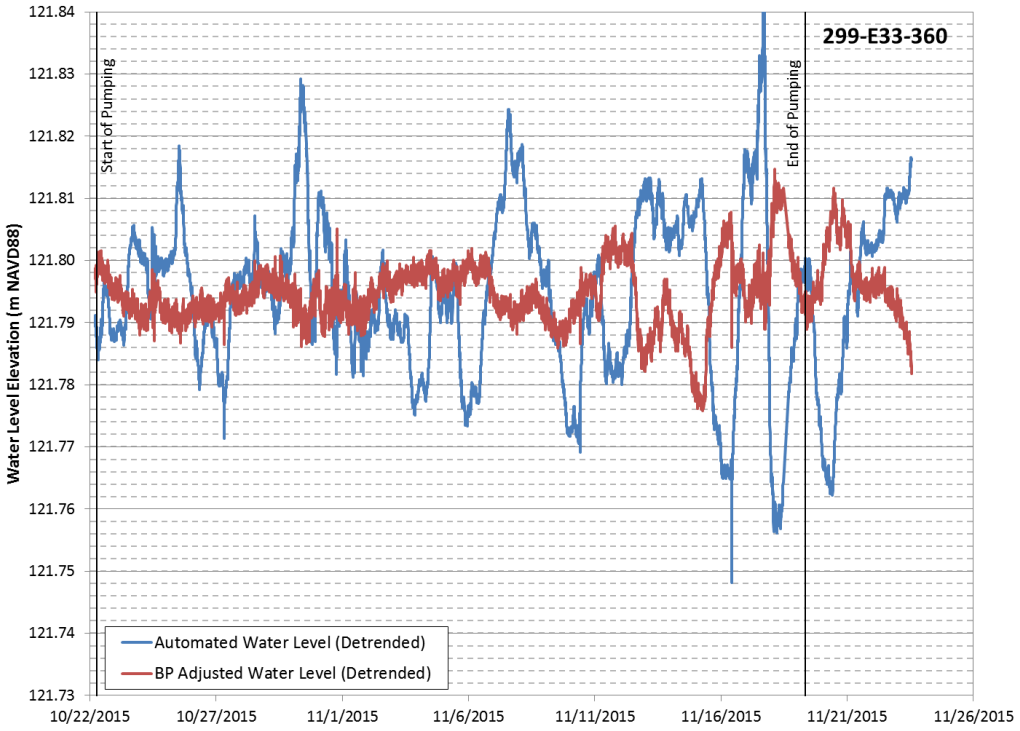

Figure E-8. Automated Water Level Measurements Collected for Well 299-E33-360 (276 m [906 ft] East-Southeast of the Pumping Well) during the 27-Day Constant Rate Discharge Test (Detrended)

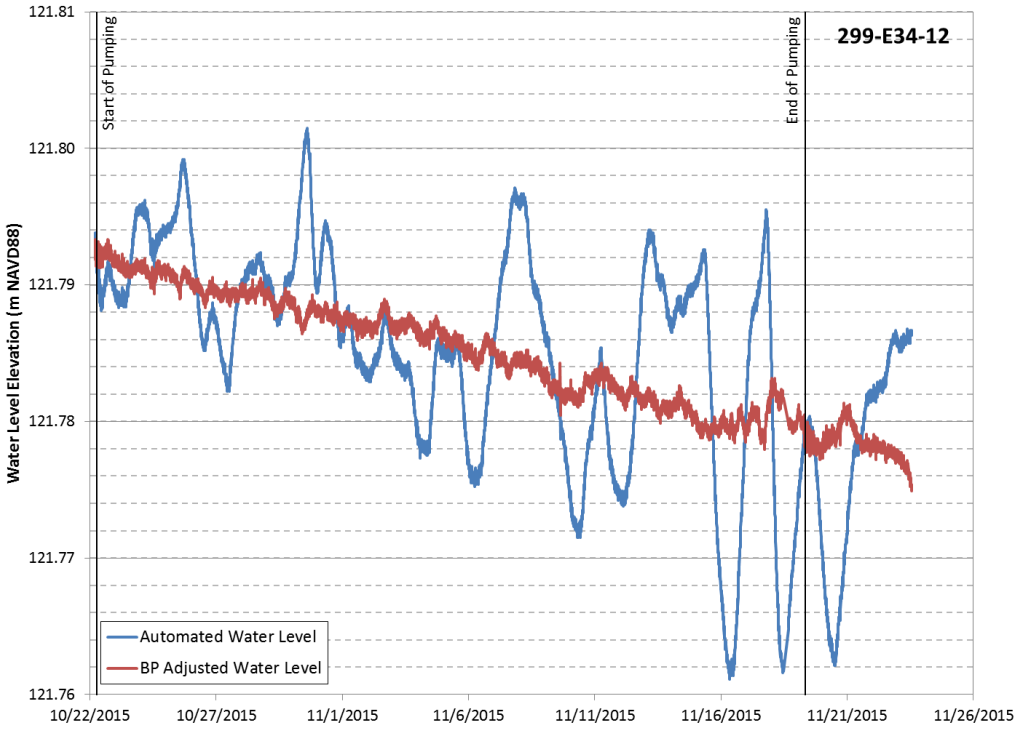

Figure E-9. Automated Water Level Measurements Collected for Well 299-E34-12 (951 m [3,120 ft] East-Southeast of the Pumping Well) during the 27-Day Constant Rate Discharge Test (Original Data)

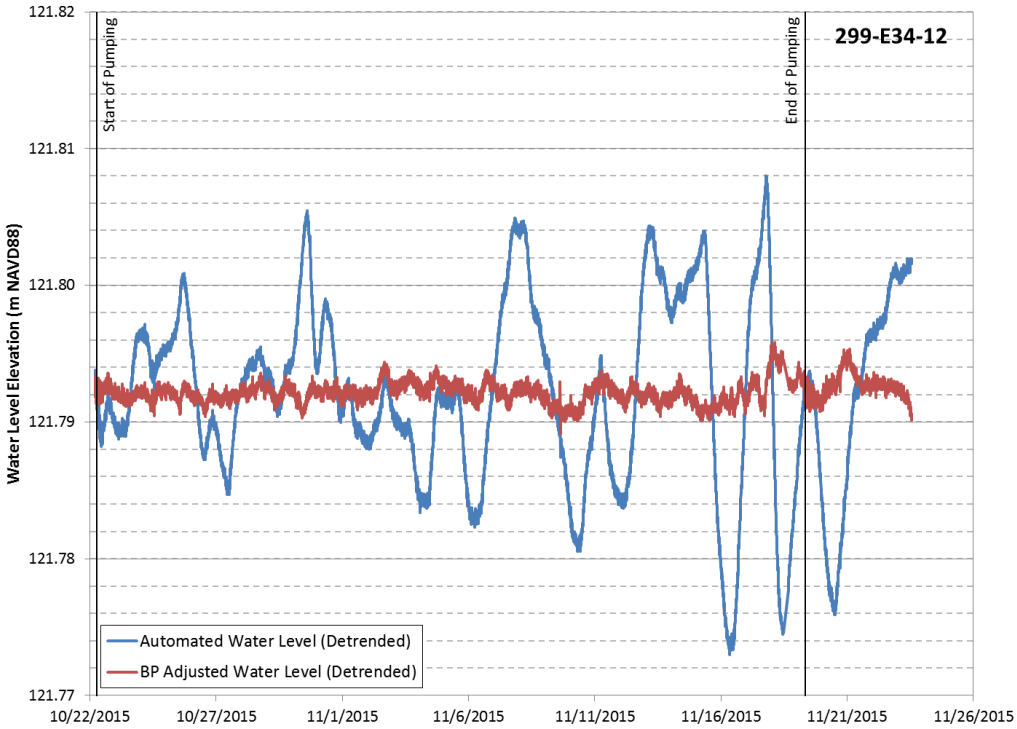

Figure E-10. Automated Water Level Measurements Collected for Well 299-E34-12 (951 m [3,120 ft] East-Southeast of the Pumping Well) during the 27-Day Constant Rate Discharge Test (Detrended)

Appendix F
AQTESOLV Results for the 27-Day Constant Rate Discharge Test - Drawdown

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This appendix provides the curves matched to the drawdown data from the 27-day constant rate discharge test conducted between 10/22/2015 and 11/18/2015. The pumping well was 299-E33-268 and drawdown was observed in observation wells 299-E33-31, 299-E33-267, and 299-E33-342. Pressure derivatives for these 4 wells are also provided.

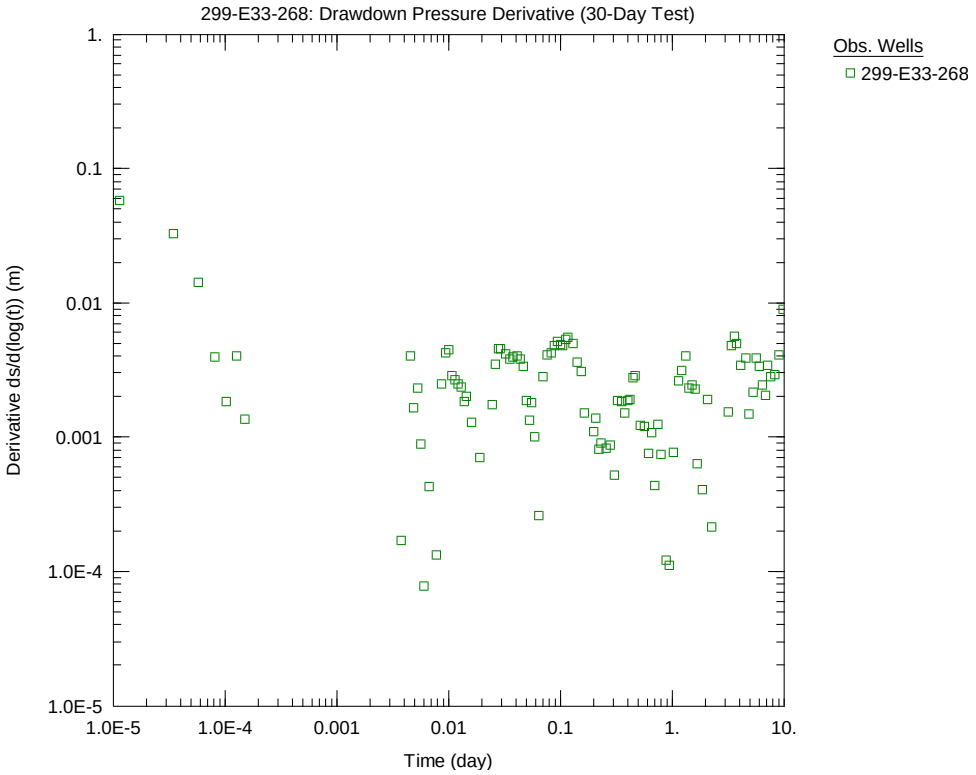

Figure F-1. AQTESOLV Pressure Derivative for Drawdown at 299-E33-268 (Pumping Well).

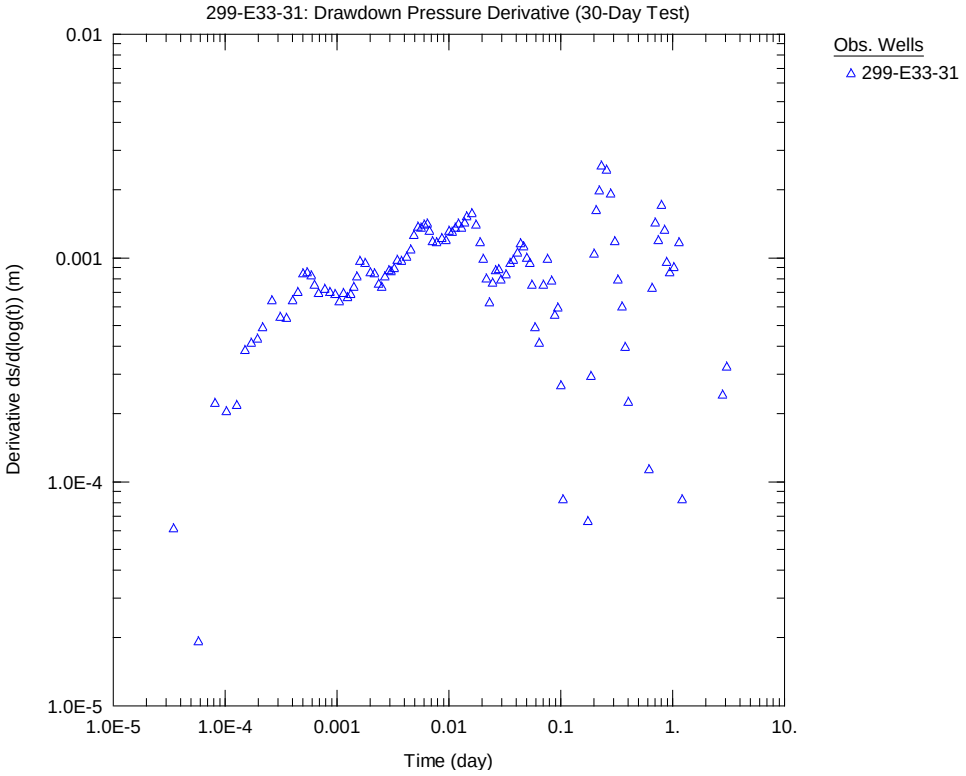

Figure F-2. AQTESOLV Pressure Derivative for Drawdown at 299-E33-31.

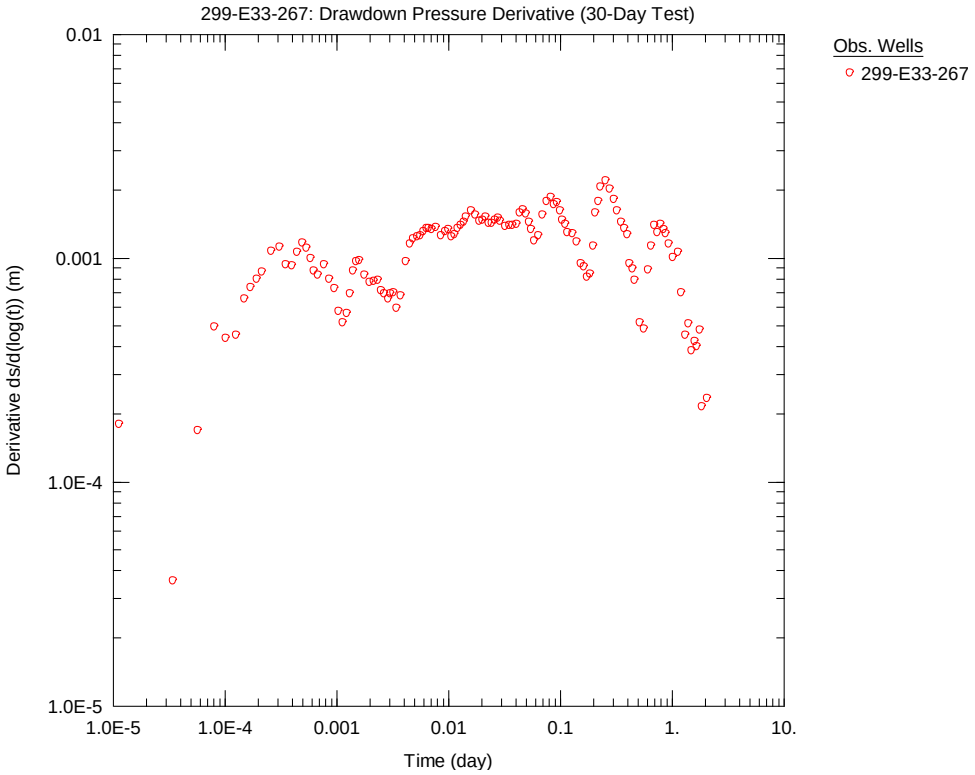

Figure F-3. AQTESOLV Pressure Derivative for Drawdown at 299-E33-267.

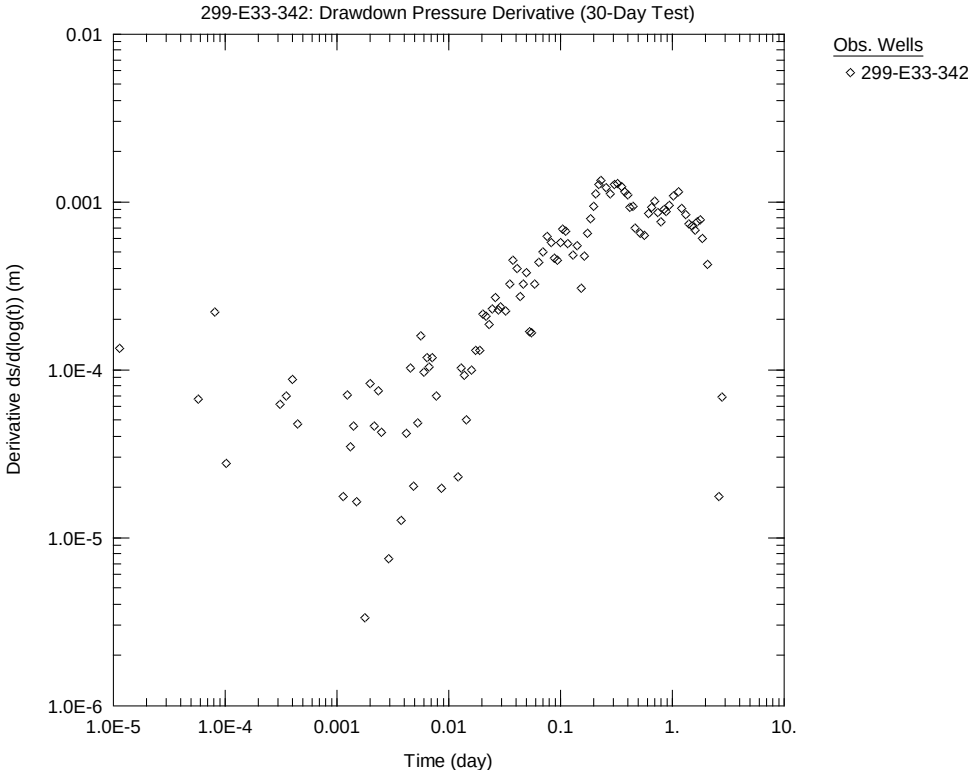

Figure F-4. AQTESOLV Pressure Derivative for Drawdown at 299-E33-342.

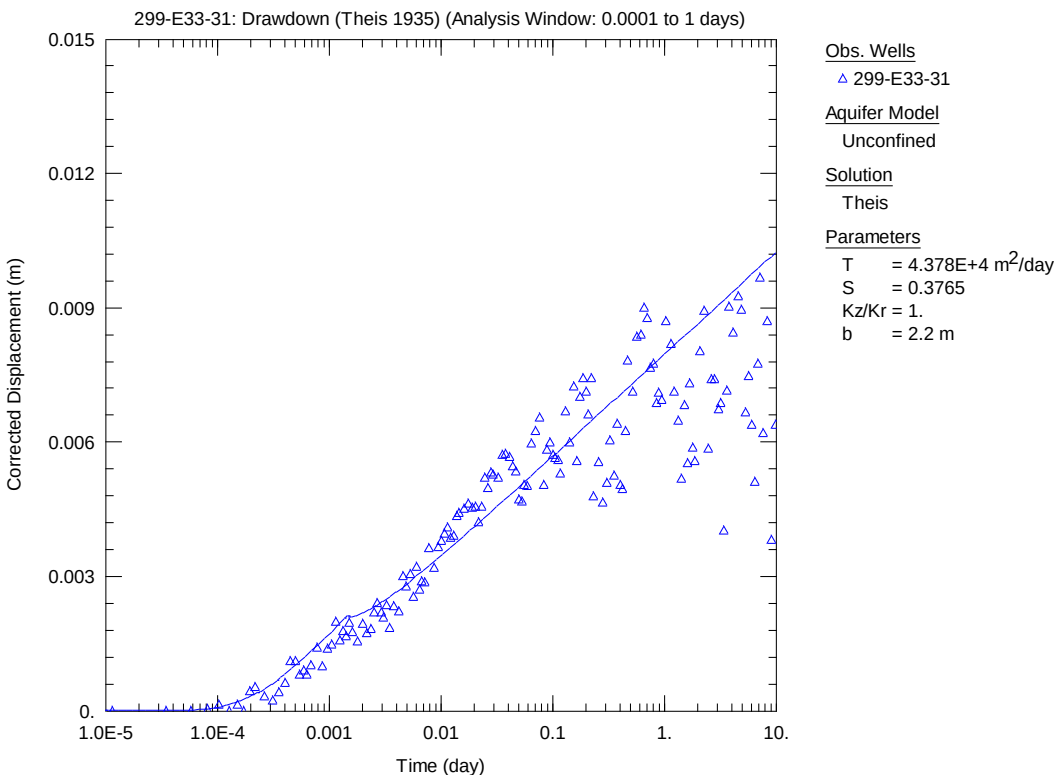

Figure F-5. AQTESOLV Results for Drawdown at 299-E33-31 by the Theis (1935)/Hantush (1961a,b) Method.

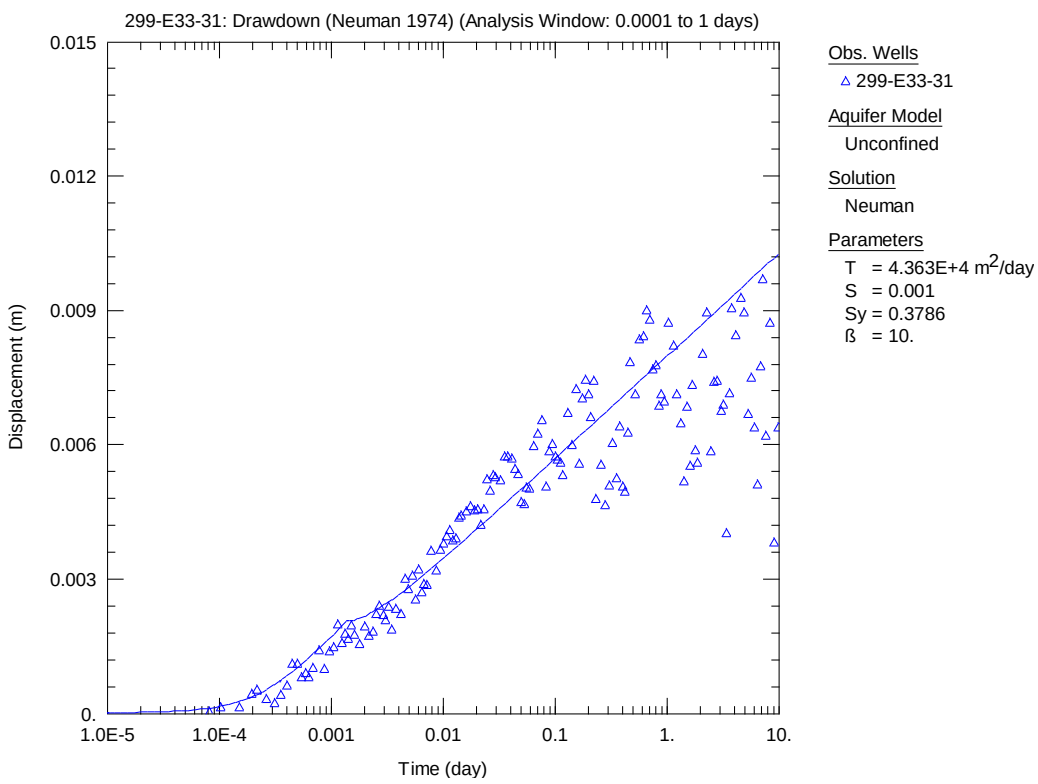

Figure F-6. AQTESOLV Results for Drawdown at 299-E33-31 by the Neuman (1974) Method.

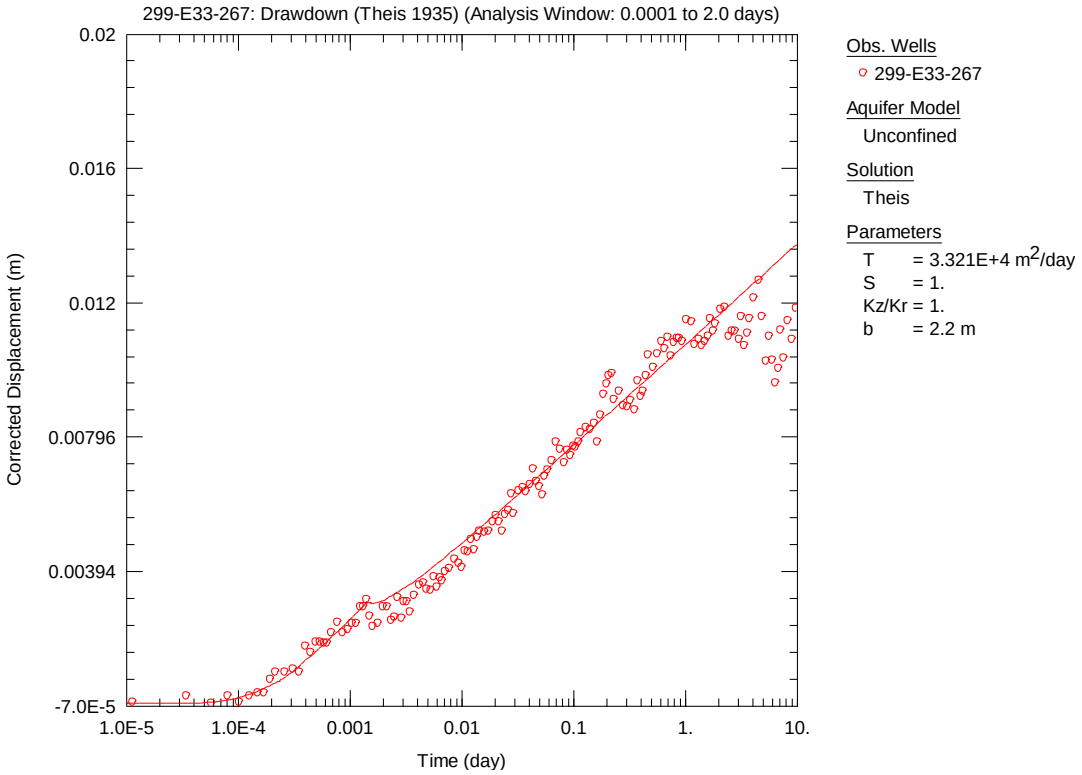

Figure F-7. AQTESOLV Results for Drawdown at 299-E33-267 by the Theis (1935)/Hantush (1961a,b) Method.

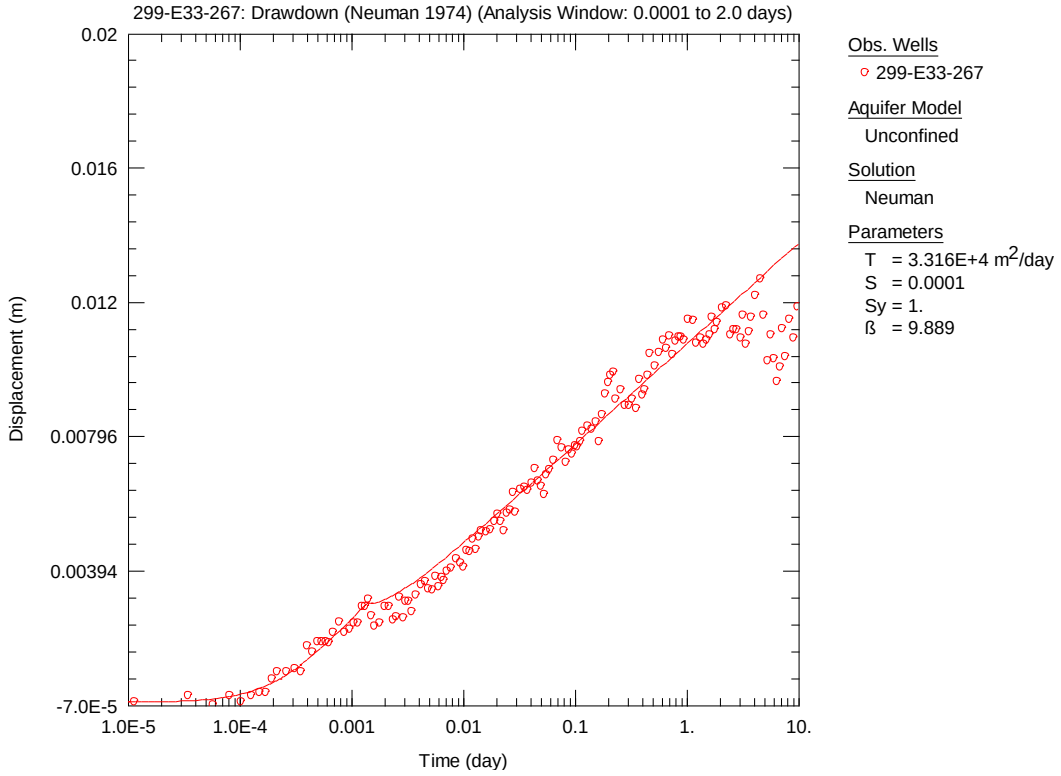

Figure F-8. AQTESOLV Results for Drawdown at 299-E33-267 by the Neuman (1974) Method.

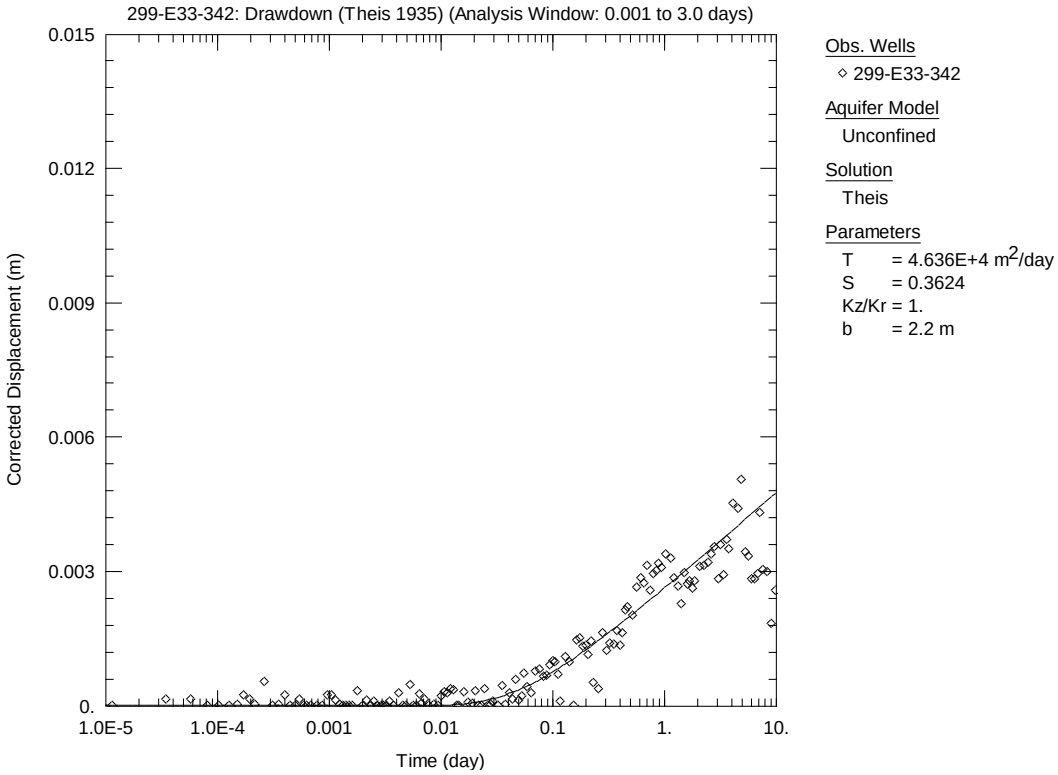

Figure F-9. AQTESOLV Results for Drawdown at 299-E33-342 by the Theis (1935)/Hantush (1961a,b) Method.

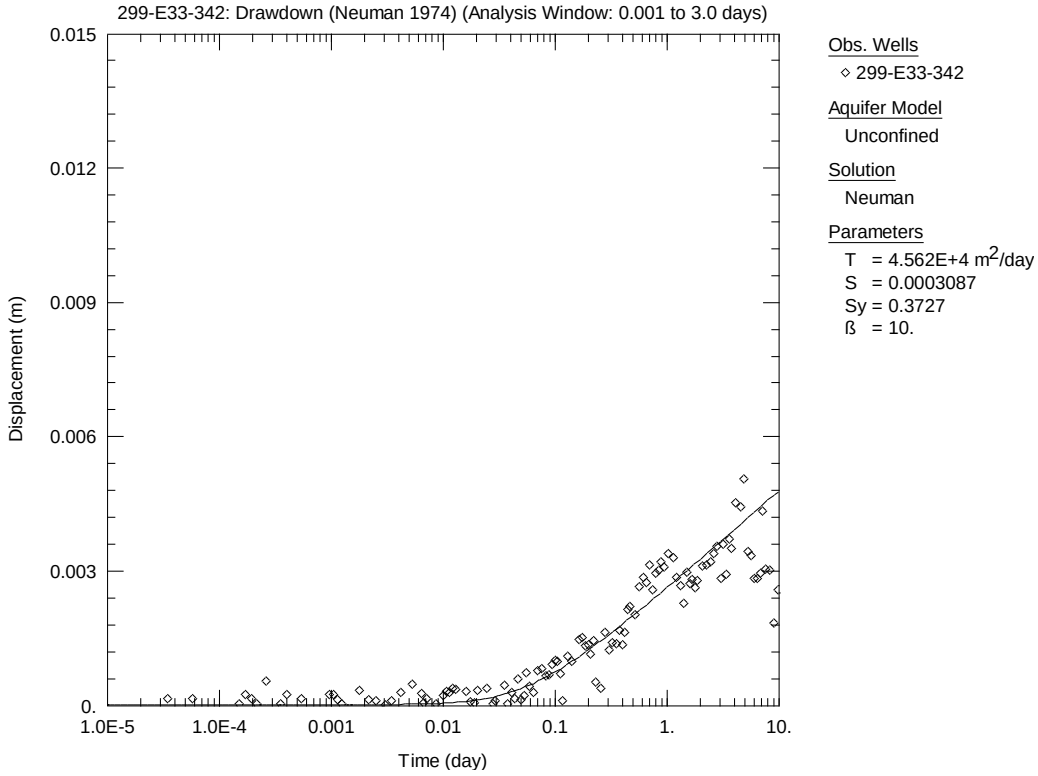

Figure F-10. AQTESOLV Results for Drawdown at 299-E33-342 by the Neuman (1974) Method.

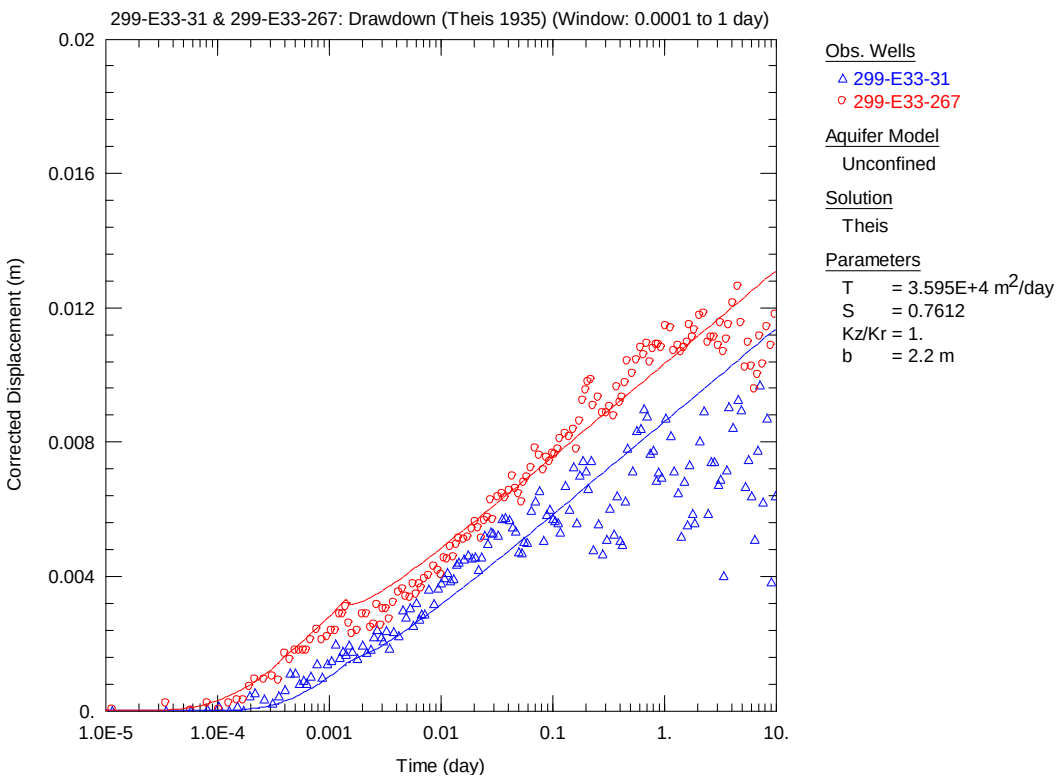

Figure F-11. AQTESOLV Results for Drawdown at 299-E33-31 and 299-E33-267 by the Theis (1935)/Hantush (1961a,b) Method.

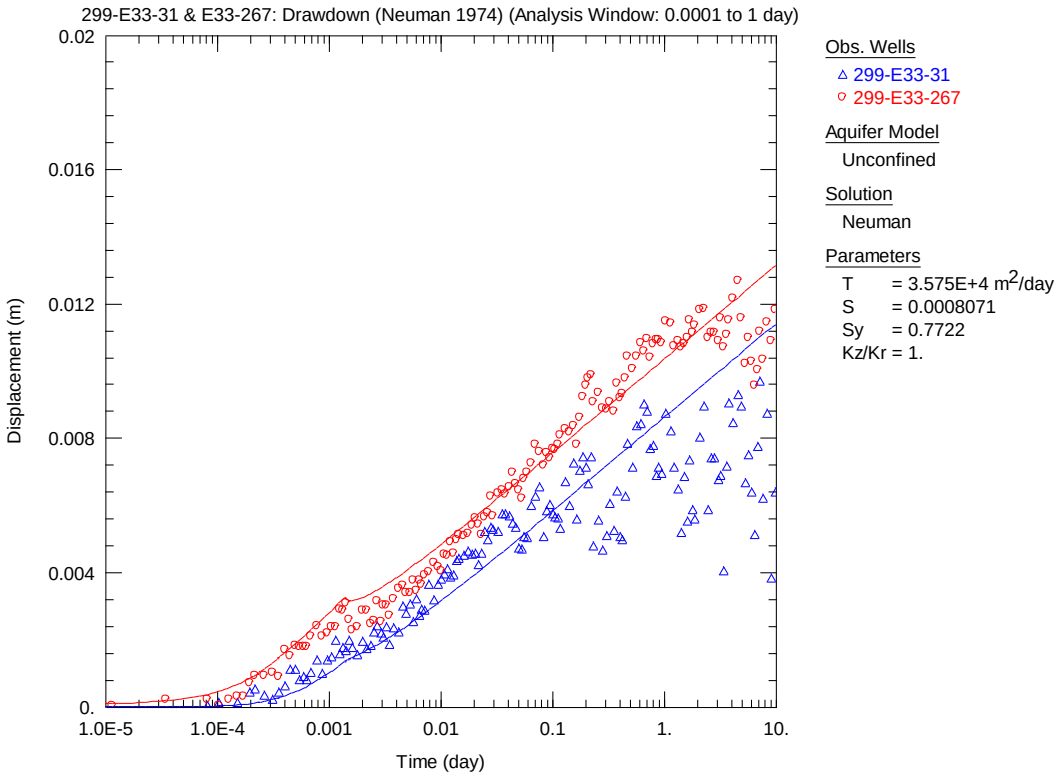

Figure F-12. AQTESOLV Results for Drawdown at 299-E33-31 and 299-E33-267 by the Neuman (1974) Method.

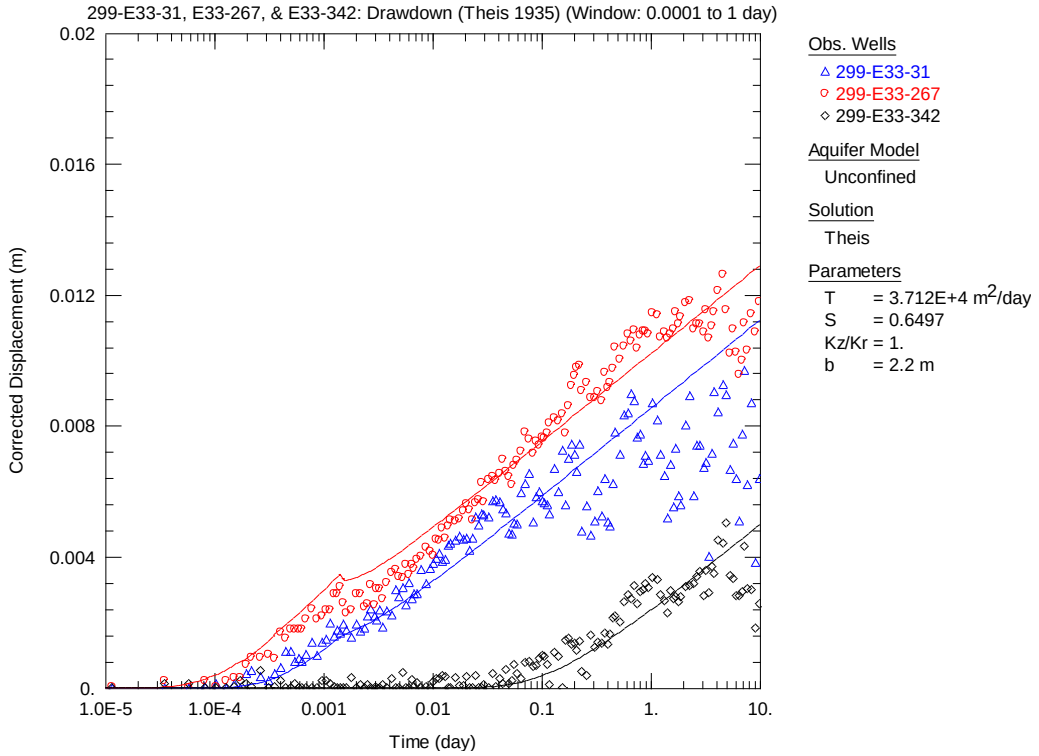

Figure F-13. AQTESOLV Results for Drawdown at 299-E33-31, 299-E33-267, and 299-E33-342 by the Theis (1935)/Hantush (1961a,b) Method.

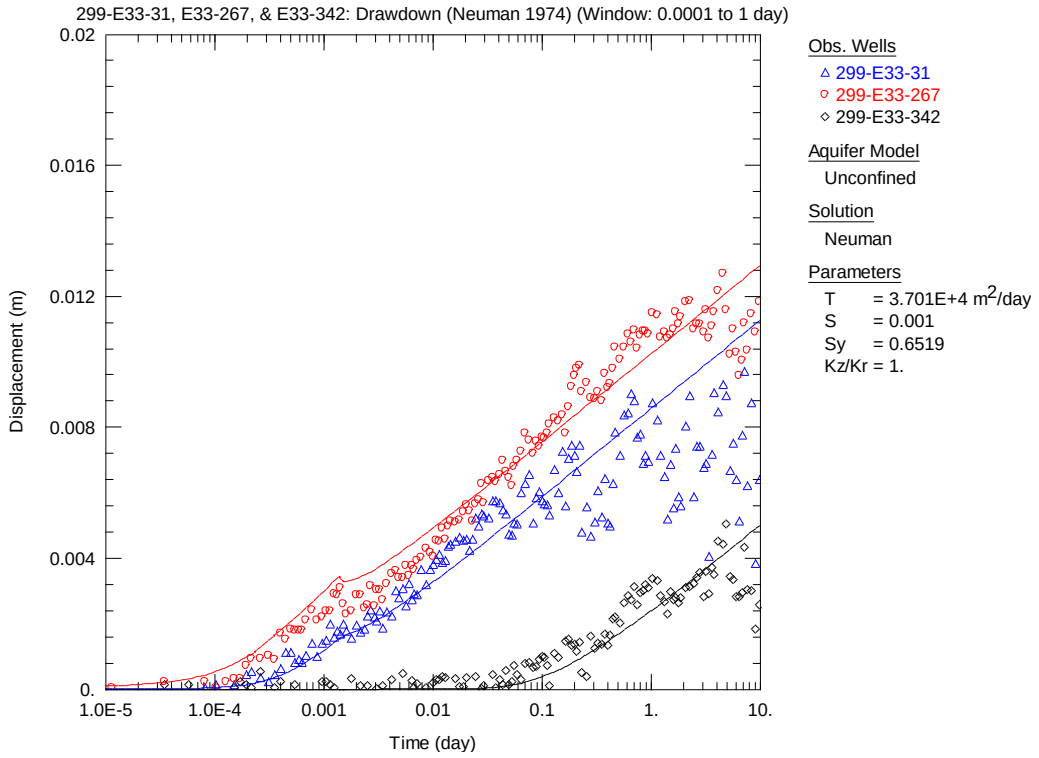

Figure F-14. AQTESOLV Results for Drawdown at 299-E33-31, 299-E33-267, and 299-E33-342 by the Neuman (1974) Method.

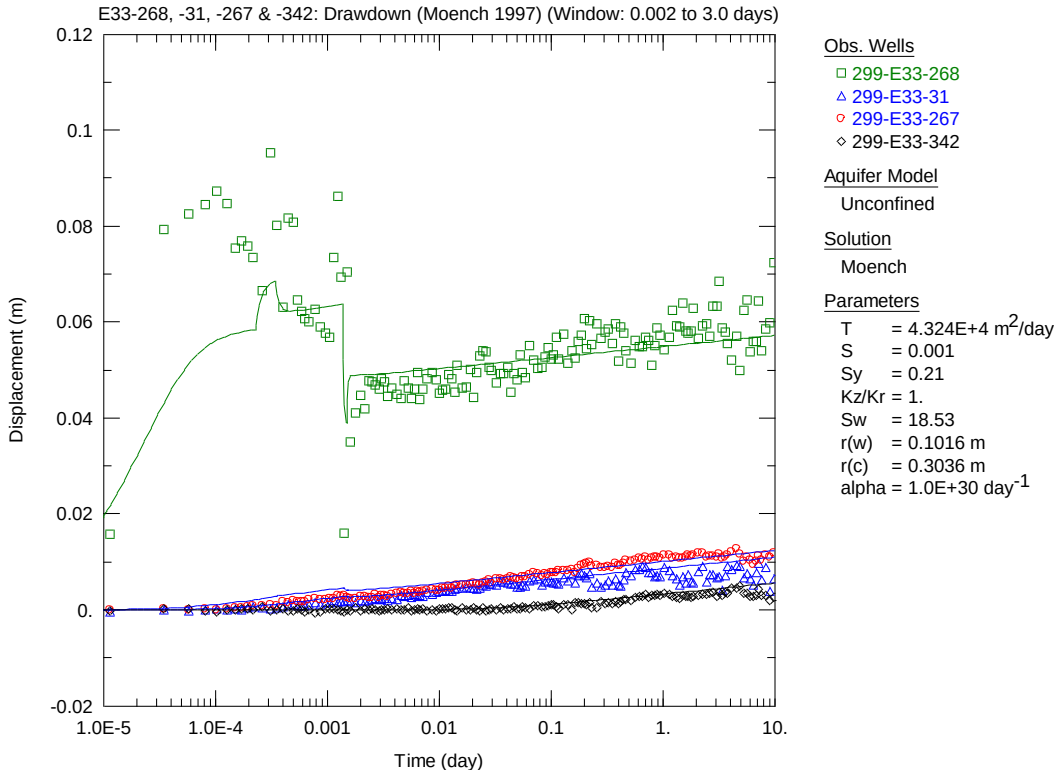

Figure F-15. AQTESOLV Results for Drawdown at Pumping Well 299-E33-268 and Observation Wells 299-E33-31, 299-E33-267, and 299-E33-342 by the Moench (1997) Method.

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Appendix G
AQTESOLV Results for the 27-Day Constant Rate Discharge Test - Recovery

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This appendix provides the curves matched to the recovery data from the 27-day constant rate discharge test conducted between 10/22/2015 and 11/18/2015. Because drawdown was observed in observation wells 299-E33-31, 299-E33-267, and 299-E33-342, these wells were analyzed for buildup.

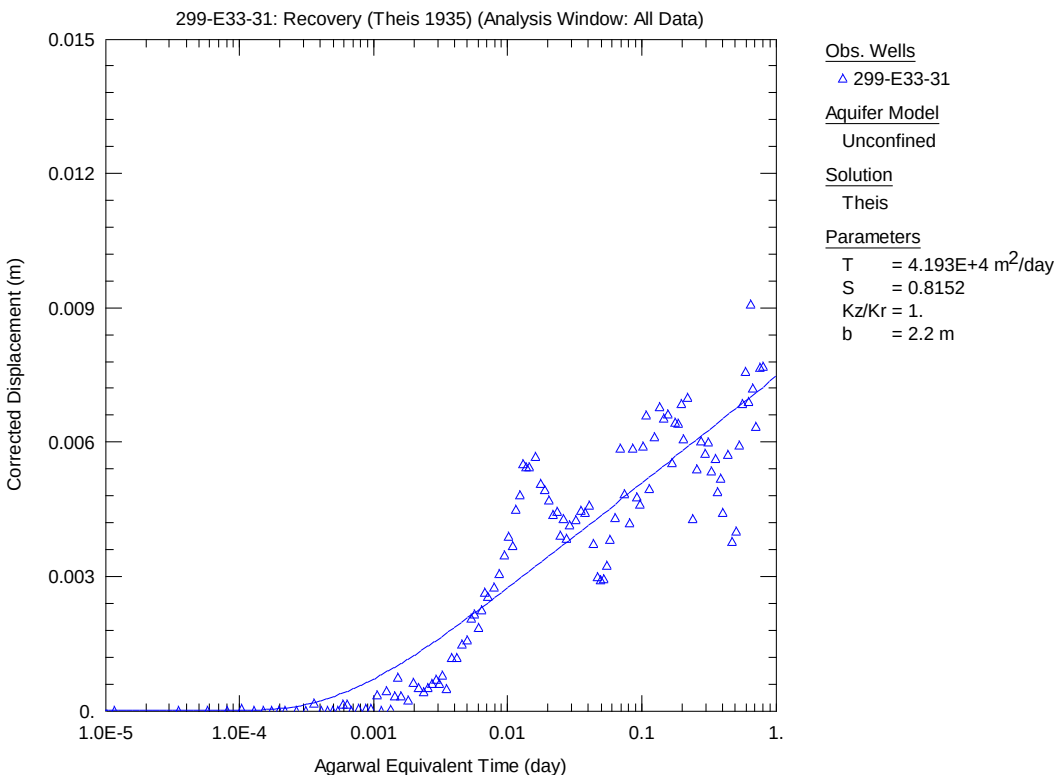

Figure G-1. AQTESOLV Results for Recovery at 299-E33-31 by the Theis (1935)/Hantush (1961a,b) Method.

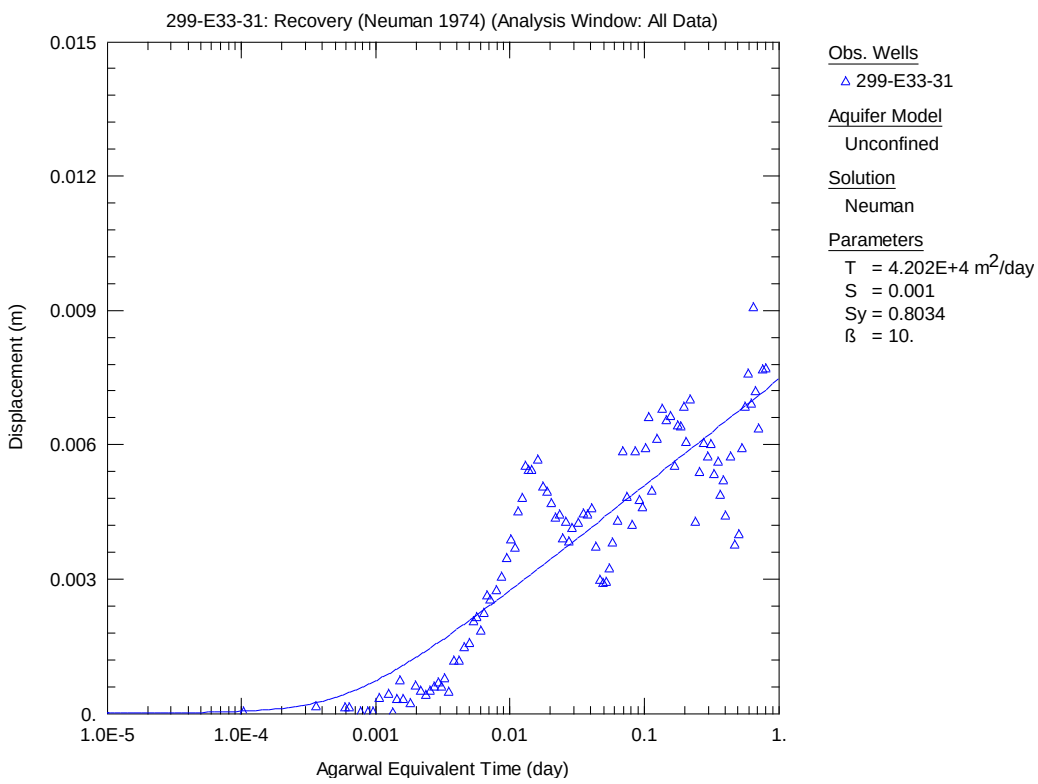

Figure G-2. AQTESOLV Results for Recovery at 299-E33-31 by the Neuman (1974) Method.

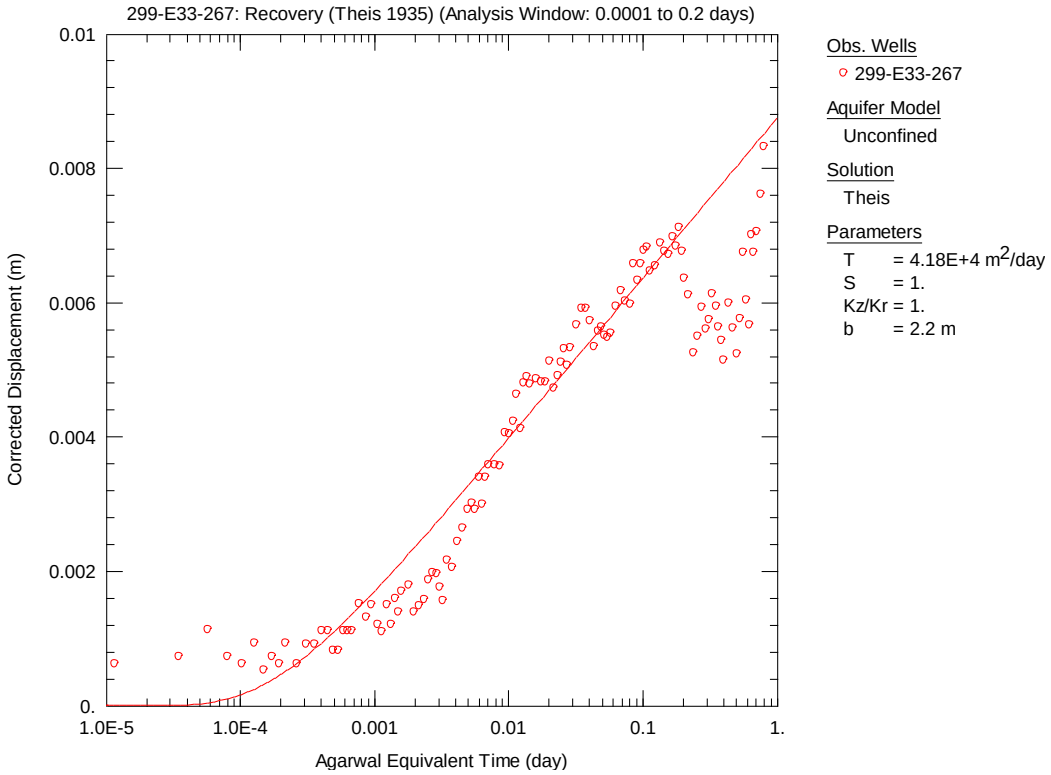

Figure G-3. AQTESOLV Results for Recovery at 299-E33-267 by the Theis (1935)/Hantush (1961a,b) Method.

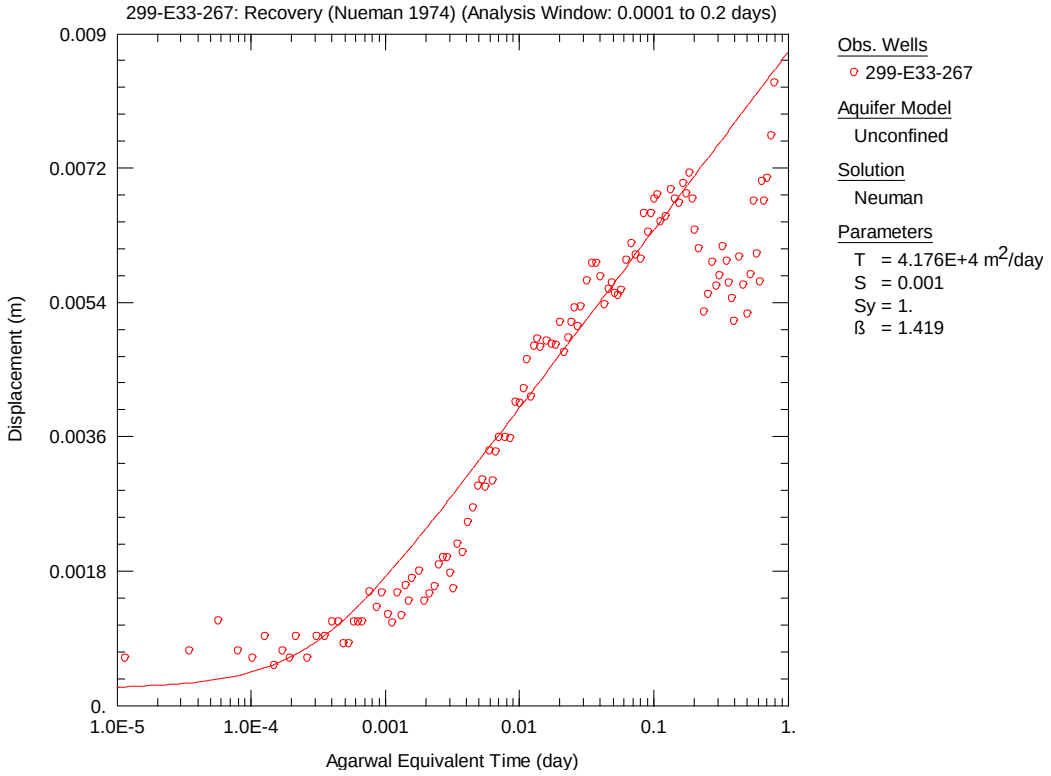

Figure G-4. AQTESOLV Results for Recovery at 299-E33-267 by the Neuman (1974) Method.

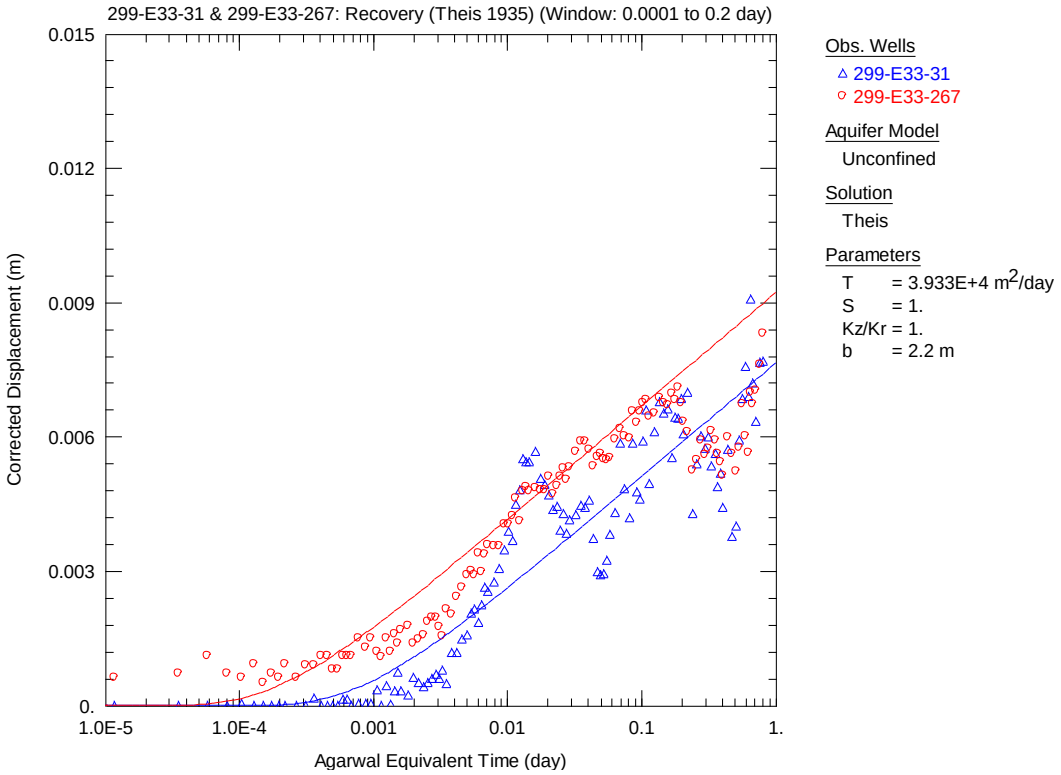

Figure G-5. AQTESOLV Results for Recovery at 299-E33-31 and 299-E33-267 by the Theis (1935)/Hantush (1961a,b) Method.

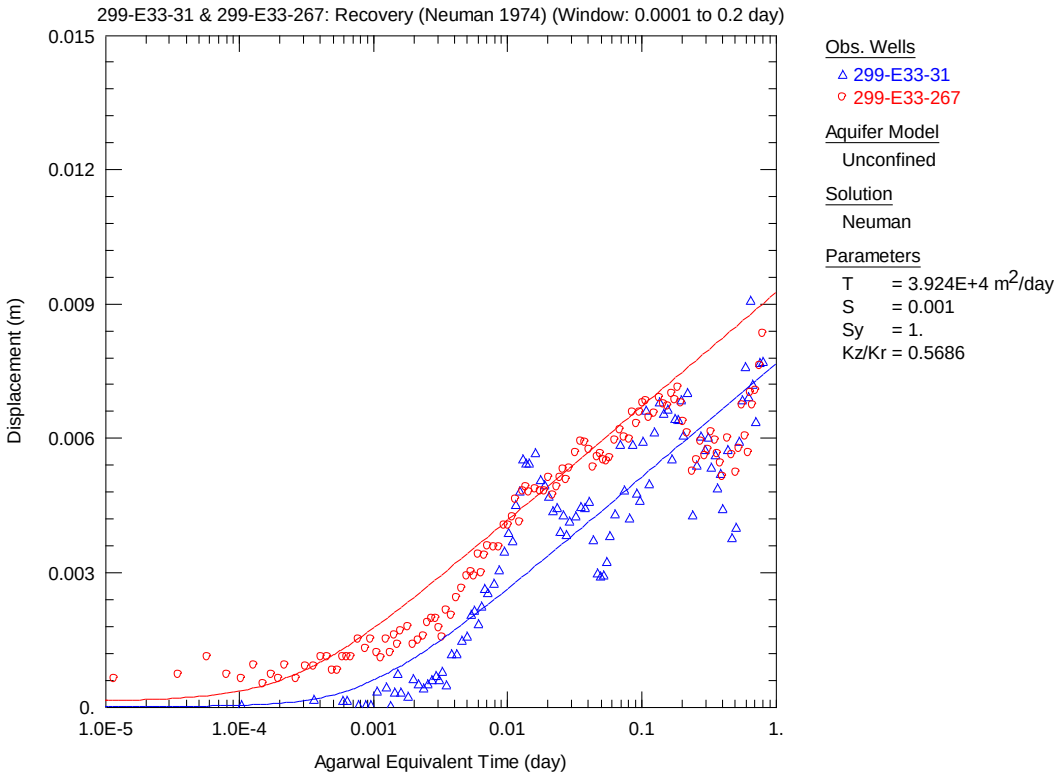

Figure G-6. AQTESOLV Results for Recovery at 299-E33-31 and 299-E33-267 by the Neuman (1974) Method.

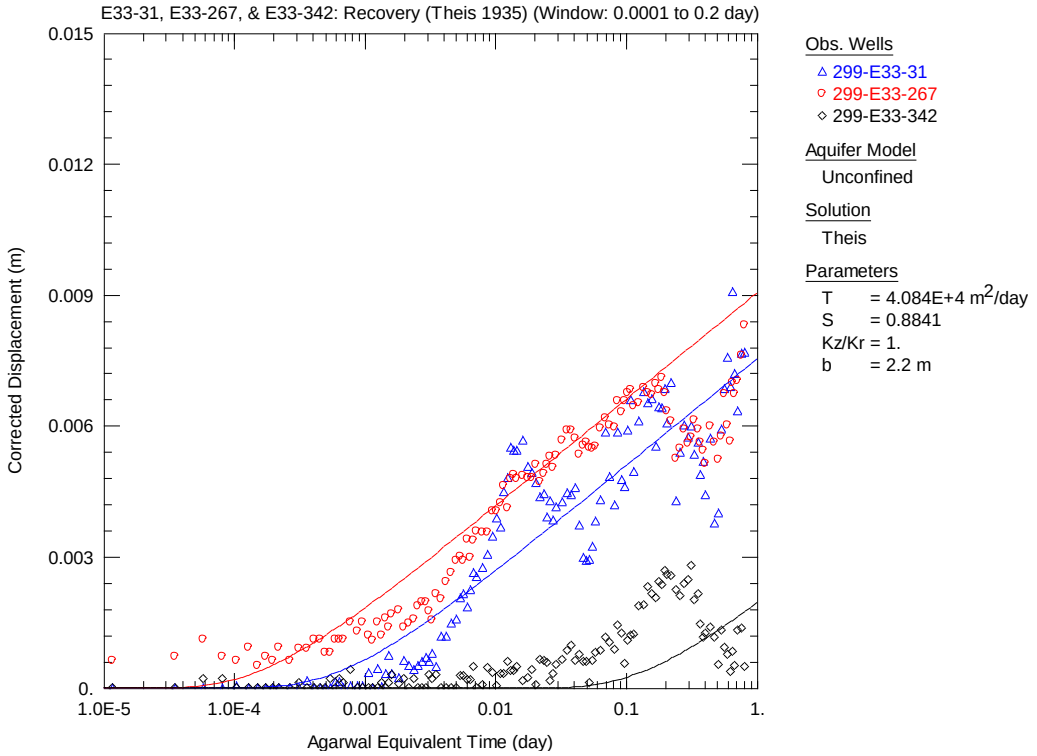

Figure G-7. AQTESOLV Results for Recovery at 299-E33-31, 299-E33-267, and 299-E33-342 by the Theis (1935)/Hantush (1961a,b) Method.

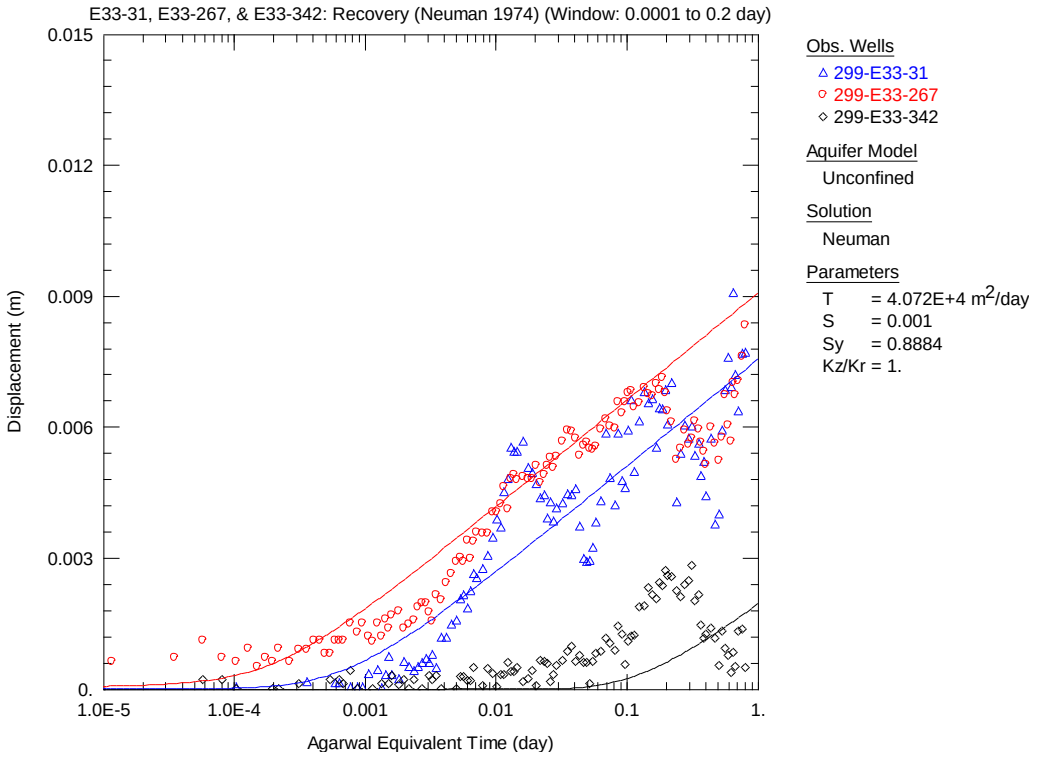

Figure G-8. AQTESOLV Results for Recovery at 299-E33-31, 299-E33-267, and 299-E33-342 by the Neuman (1974) Method.

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