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Analysis of Well ER-EC-7 Testing, Western Pahute Mesa - Oasis Valley FY 2000 Testing Program

Revision No.: 0

September 2002

Prepared for U.S. Department of Energy under Contract No. DE-AC08-97NV13052.

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Las Vegas, Nevada 89193

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Approved by: Signature Approved Date: 09-13-02

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IT Corporation

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List of Acronyms and Abbreviations

A	Amps
atoms/mL	Atoms per milliliter
bgs	Below ground surface
BN	Bechtel Nevada
C	Carbon
°C	Degrees Celsius
CAU	Corrective Action Unit
CD	Compact disc
Cl	Chlorine
CRDL	Contract-required detection limit
DIC	Dissolved inorganic carbon
DO	Dissolved oxygen
DOE	U.S. Department of Energy
DOP	Detailed Operating Procedure
DRI	Desert Research Institute
EC	Electrical conductivity
ESP	Electrical Submersible Pump
fpm	Feet per minute
FS	Full scale
ft	Feet
ft/d	Feet per day
ft^2/d	Square feet per day
ft/min	Feet per minute
FY	Fiscal year
gal	Gallons
gpd/ft	Gallons per day per foot
gpm	Gallon per minute
He	Helium
hr	Hour
HSU	Hydrostratigraphic unit
Hz	Hertz
in.	Inch(es)
ITLV	IT Corporation, Las Vegas

List of Acronyms and Abbreviations *(continued)*

K	Hydraulic conductivity
LANL	Los Alamos National Laboratory
LiBr	Lithium bromide
LLNL	Lawrence Livermore National Laboratory
m	Meter
mbar	Millibar
MDC	Minimum detectable concentration
mg/L	Milligrams per liter
msld	Mean sea level datum
NDEP	Nevada Division of Environmental Protection
NDWS	*Nevada Drinking Water Standards*
NM	Nanometer
NNSA/NV	U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office
NTU	Nephelometric turbidity
od	Outside diameter
pCi/L	Picocuries per liter
psi	Pounds per square inch
psig	Pounds per square inch gauge
PXD	Pressure transducer
rev/sec	Revolution per second
S	Storage coefficient
SQP	Standard Quality Practice
T	Transmissivity
TDH	Total dynamic head
TOC	Top of casing
UGTA	Underground Test Area
UNLV-HRC	University of Nevada, Las Vegas - Harry Reid Center
USGS	U.S. Geological Survey
VSD	Variable speed drive
WPM-OV	Western Pahute Mesa - Oasis Valley
WRL	Wireline
µg/L	Micrograms per liter
µmhos/cm	Micromhos per centimeter

1.0 Introduction

This report documents the analysis of the data collected for Well ER-EC-7 during the Western Pahute Mesa - Oasis Valley (WPM-OV) well development and testing program that was conducted during fiscal year (FY) 2000. The data collection for that program was documented in Appendix A, *Western Pahute Mesa - Oasis Valley, Well ER-EC-7 Data Report for Development and Hydraulic Testing*.

1.1 Well ER-EC-7

Well ER-EC-7 is one of eight groundwater wells that were tested as part of FY 2000 activities for the U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office (NNSA/NV), Underground Test Area (UGTA) Project. Figure 1-1 shows the location of the WPM-OV wells. Drilling and well construction information for Well ER-EC-7 was obtained from a draft of the *Completion Report for Well ER-EC-7* (Townsend, 2000).

Hydraulic testing and groundwater sampling were conducted at Well ER-EC-7 to provide information on the hydraulic characteristics of hydrostratigraphic units (HSUs) and the chemistry of local groundwater. Well ER-EC-7 is constructed with two completion intervals which are isolated from each other by blank casing sections with annular seals. The completion intervals extend over substantial vertical distances and access different HSUs and/or lithologies. A difference in the construction of this well as compared to other WPM-OV wells is that the screening was continuous through the completion interval rather than alternating slotted and blank casing joints used in wells with very long completion intervals. Figures illustrating the well construction and lithology are provided in Section 3.0. The testing and sampling activities were designed to assess the completion intervals individually.

1.2 WPM-OV Testing Program

The testing program included:

1. Discrete pressure measurements for each completion interval
2. Well development and step-drawdown tests
3. Flow logging at three pumping rates
4. Collection of discrete groundwater sample(s) with a downhole sampler

5. Constant-rate pumping test and subsequent recovery
6. Collection of composite groundwater characterization samples
7. Flow measurements and water quality parameter logging under natural gradient flow

1.3 Analysis Objectives and Goals

The testing program was designed to provide information about the local hydrologic conditions and HSU hydraulic parameters for use in the Corrective Action Unit (CAU)-scale flow and transport model. In addition, groundwater quality information from samples collected was intended for use in geochemistry-based analyses of hydrologic conditions and groundwater flow as well as to detect the presence of any radionuclides. The primary objective for this analysis was to evaluate all of the data collected and to derive the maximum information about the hydrology. A secondary objective was to evaluate the functionality of the well design for use in future investigation and testing activities, and evaluate this well for use in future monitoring.

General goals for the analysis were determine the discrete head for each completion interval and the resultant vertical gradient profile, determine representative hydraulic parameter(s) for the formation(s) in each completion interval, and determine representative groundwater quality for the formation(s) in each completion interval. With regard to the well, specific goals included determination of the well hydraulics of the multiple completion interval design under both natural gradient and pumping conditions, and the effectiveness of development and testing methodologies.

Section 2.0 of this report discusses the analysis of the nonpumping natural-gradient well hydrology, and evaluates opportunities for deriving hydraulic parameters for the completion intervals. Section 3.0 discusses the well hydraulics during pumping and the flow logging results. Hydraulic parameters for the well in general and for the upper completion interval in particular are presented. This section is completed with comments on working with these deep, multiple completion wells. Section 4.0 discusses the groundwater samples that were collected and the analytical results, as well as how this information fits into the general geochemistry of the groundwater in the area. Finally, concerns pertinent to the future use of Well ER-EC-7 for monitoring are discussed.

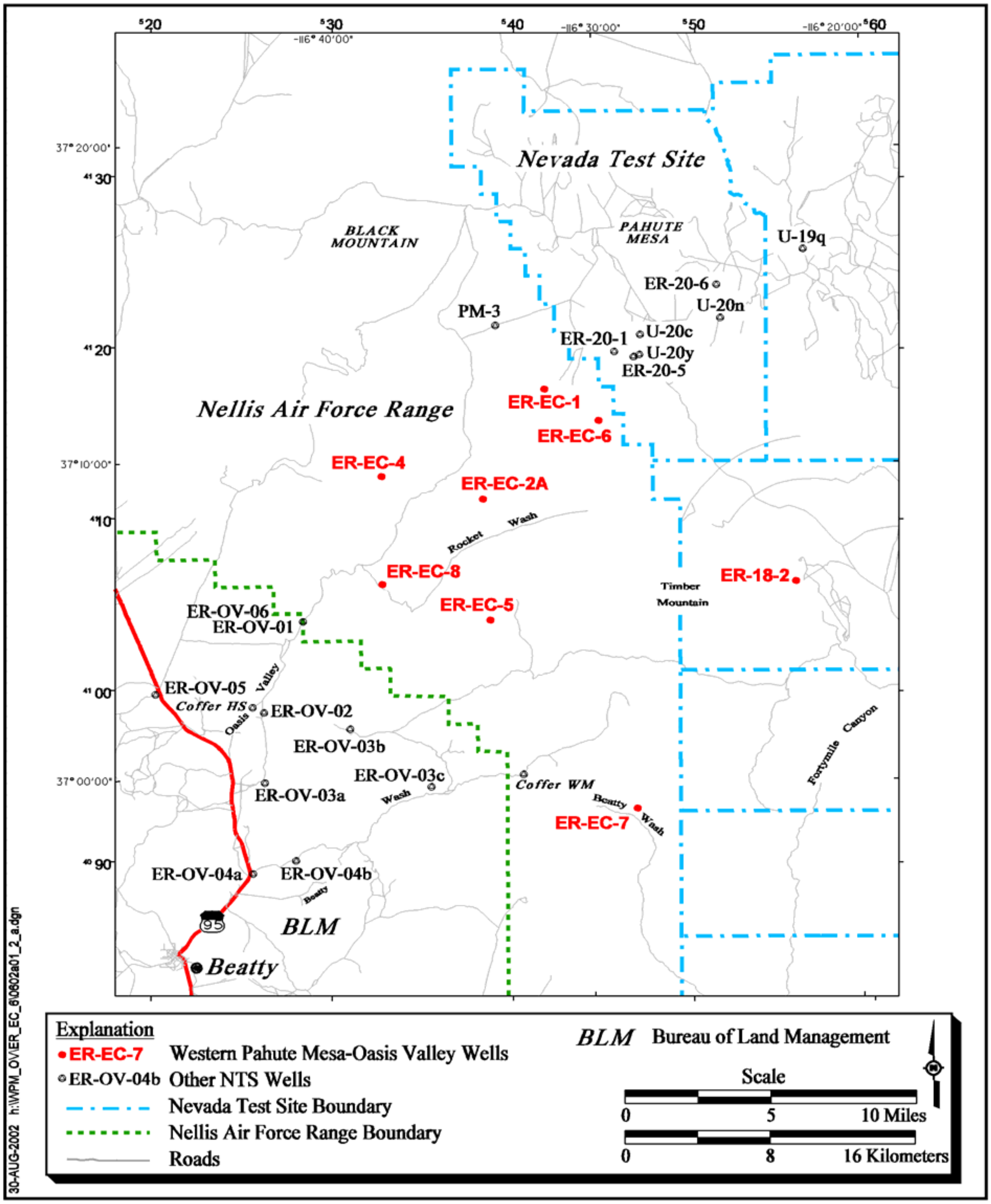


Figure 1-1
Location Map for WPM-OV ER Wells

2.0 Equilibrium Well Hydraulics

This section discusses many aspects of well hydraulics for Well ER-EC-7 in the equilibrium, nonpumping condition relating to the individual completion intervals. This material updates the initial analysis of the data in Appendix A and further develops some of the concepts and concerns that were presented in that report.

The well is constructed with two separate completion intervals, each composed of continuous joints of slotted casing. The completion intervals are isolated from each other outside the well casing by cement annular seals. Within each completion interval, the annulus is filled with continuous gravel pack extending above and below the screens. Downhole flow features are often discussed with reference to individual screens. The convention for referencing screens is by the consecutive number (e.g., first, second, third) of the screen from the top of the completion interval.

2.1 Composite Equilibrium Water Level

Table A.2-2 in Section A.2.0 of Appendix A presents all of the measurements of composite water level (depth-to-water) made during the testing program. The measurements reported in that table were very consistent, and there was no further information collected during the testing program to indicate that these values are not representative.

2.2 Barometric Efficiency

The barometric efficiency of the well is used in the analysis of the hydraulic tests to refine the analysis and produce more accurate results. The importance of determining the correct value for barometric efficiency is somewhat dependent on the magnitude of the drawdown of the well during testing; the greater the drawdown, the less important the barometric correction. However, in circumstances requiring accurate knowledge of the status of a well relative to equilibrium with the natural state of the groundwater system, the refinement offered by correcting a water level monitoring record for barometric efficiency can be important. This is particularly important when making decisions based on a short or sparse record.

The methodology used for determining barometric efficiency has been improved since the data report in Appendix A. The revised methodology involves overlaying a graph of the barometric pressure onto a graph of the water level record (as pressure transducer [PXD] pressure) after converting the barometric data to consistent units and inverting the trace. The processed barometric trace is then trended and scaled until a best-fit match to the water level record is determined. The scaling factor is equal to the barometric efficiency. This method assumes that the well is in basic equilibrium with the groundwater head, and that long-term trends in groundwater levels can be represented by a linear trend. The final requirement for applying this methodology to a record is that the record must contain changes in barometric pressure that occur on a scale greater than several days and substantially exceed the magnitude of semidiurnal fluctuations. This requirement is necessary to separate the barometric response of the well from earth tide-related responses.

The PXD record for the long-term water level monitoring record, shown in Figure 2-1, was used to determine barometric efficiency. This record shows the water level response to barometric trends, with the general features of the two records appearing as mirror images. The barometric response is clear in the features occurring over multiple days, even though the barometric variation spans a range of less than 20 millibar (mbar). However the record also shows significant semidiurnal variations, interpreted to be earth tides, superimposed on the barometric response. Figure 2-2 shows the overlay of the adjusted barometric trace on the PXD record. This trace is presented with an efficiency of 95 percent, which was determined to be the best fit, although the earth tides obscure the detail.

The combination of barometric response and earth tides is illustrated in Figure 2-3, which shows the PXD record corrected for barometric variation. The resulting record shows a fairly consistent slight trend upward in the water level, which is buried in the earth tide response and shows its own periodic variation in magnitude. The period of the variation is about 14 days. The varying magnitude of the earth tide variation obscures the fitting of the barometric efficiency in the uncorrected record because it is difficult to judge how to fit the barometric efficiency within the semidiurnal variation. This pattern in the corrected record has been observed in other records, although the relative magnitude of the earth tides versus the barometric response appears to be greater in this record than others.

2.3 Completion Interval Heads

Table 2-1 lists the revised head values for the composite and individual completion interval. The head differences represent the apparent equilibration of the different intervals to the isolation of the interval. Interpretation of the water level and pressure records is discussed below. Head values are presented rounded to the nearest 0.01 feet (ft) and pressure values are reported to the nearest 0.02 pounds per square inch (psi) as recorded by the instrumentation. Note that the measurements were made progressively during the day as the equipment was installed, not a contemporaneously. The reported differences may include some change resulting from trends in head, barometric changes, and earth tides.

An initial rise in water level of 0.85 ft in the upper interval immediately occurred following installation of the bridge plug while there was no immediate change in pressure in the lower interval. The head difference of 0.85 ft, after flow to the

Table 2-1
Well ER-EC-7 Composite and Interval-Specific Head Measurements

Location in Well	Initial Equilibration: Head as Depth Below Ground Surface		Change from Composite Head	End of Monitoring: Head as Depth Below Ground Surface	
	Feet	Meters	Feet	Feet	Meters
Composite Static WL (e-tape)	747.71	227.90	--	N/A	N/A
Upper Interval (e-tape)	746.86	227.64	+ 0.85	746.50	227.53
Lower Interval (calculated)	747.71	227.90	0.00	747.46	227.83

lower completion interval ceased, indicates that there was drawdown in the upper interval associated with flow under the natural gradient. This is consistent with the downward flow condition observed during the thermal flow logging (Table A.2-10, Appendix A).

Both intervals rose during the course of monitoring, and the head difference between them was 1.04 ft when monitoring was stopped. These increases are attributed to a trend in the water level rather than a head adjustment due to isolation of the interval. The head increase in the lower interval during the week of monitoring was associated with a temperature increase in the interval of 2.72 degrees Fahrenheit (°F). This presumably results from the cessation of flow of cooler water from the upper interval.

The calculated head changes are relatively small and the values may be substantially affected by measurement uncertainty, especially the apparent change for the lower interval. The accuracy of the head computed for each completion interval is the result of the accuracy of the water level measurement used for the reference head and the accuracy of the measurement of head change. The depth to water was measured in the well before and after installing the bridge plug using the same e-tape. Measurements with an e-tape are generally repeatable within 0.10 ft or less per 1,000 ft. The measured change in the water level of 0.85 ft is considerably larger than the maximum combined uncertainties of the two e-tape measurements of 0.15 ft (0.075 ft per measurement).

The manufacturer’s specification for accuracy of the PXD is 0.1 percent of the full-scale measurement. The PXD used in the lower interval, a 750 psi unit (SN# 21013), has a nominal accuracy of 0.75 psi. The absolute uncertainty (about 1.8 ft) based on this accuracy specification is greater than the head change derived from the measurement (0.25 ft). The calibration certificate supplied for this PXD indicates that the PXD had calibrated within -0.35 psi or less through the operational range of the PXD. The uncertainty associated with this apparent accuracy is about 0.81ft. However, the PXD measurements were only used to determine the change in pressure. The calibration record shows the maximum variation of the calibration between 15 psi and 300 psi @ 72.62° F, bracketing the actual pressure measurements, to have been -0.09 psi equivalent to 0.21 ft of head.

This should be a better indication of the accuracy of a measurement of change in pressure. There is no independent measure of the accuracy of the PXD calibration at the time of the measurements at this level. The PXD measurement record appears stable, shown in Figure 2-5, which indicates that the measured pressure increase was progressive and consistent, suggesting that it was the result of a systematic change rather than random noise. The combined uncertainty from all of the component measurements used to determine head change is 0.36 ft, substantially less than the apparent head change of 0.85 ft. The estimated range of the initial head difference between the completion intervals is 1.21- 0.49 ft.

The record shows several types of fluctuations. The most obvious fluctuation is the band of measurement values resulting from the resolution of the instrumentation. There are two elements of this behavior; the major element is the pressure resolution, and the minor element is the temperature compensation resolution. Another interesting feature of the PXD record is the periodic variations on the order of 0.1 psi with a period of about 12 hours, which are thought to be earth tides. Figure 2-5 shows this feature at the beginning of the record. There may also be longer-term earth tide amplitude variations, as were observed in the long-term monitoring record (Figure 2-3), with a period of about 14 days. The increase in head observed during the 5-day record may reflect such a fluctuation.

As mentioned previously, there was little barometric pressure difference between the beginning and end of the record, although there was increased barometric pressure during the middle of the period of record. The PXD pressure record for the lower interval does not appear to reflect this barometric change, indicating that it is not sensitive to the variation of barometric pressure.

2.4 Variable Density/Viscosity of Water in the Wellbore

The measurements of pressure at various depths in the well have indicated a variation in density of the water with depth that results in a nonlinear pressure-depth relationship. The variation in density is significant, and it is important to use the appropriate composite density when interpreting the bridge-plug pressure measurements to determine the head in a completion interval. The variation of temperature with depth is thought to be the primary factor in the density variation and can be shown to account for most of the variation. However, there may be other factors such as dissolved gasses and solids, suspended solids that vary with depth, and compressibility of the water. No information was collected that provides any understanding of these other factors, although it was noted during the development that there seemed to be a significant amount of entrained air in the produced water. The viscosity of the water also varies with temperature and perhaps other variables. Both the density and the viscosity variation may affect the flowmeter calibration and consistency of results.

Figure 2-6 shows the result of calculating the theoretical variation in density of water as a function of the temperature variation in the well. The temperature variation was derived from the posttesting ChemTool log, further discussed in Section 2.5.1. The pressures calculated from this exercise are within -0.28 to

-0.34 psi (-0.15 to -0.24 percent) at the depth of 1,118.20 ft (370.49 ft) below the water surface) for the lower completion interval bridge plug measurement. These calculations include the effect of compressibility. Part of this difference is the uncertainty in accounting for the reference pressure of the PXDs, which is not known and was not recorded in the measurement process. The remainder of the difference is due to the other factors mentioned.

2.5 Flow in the Well Under Natural Gradient

Measurement of flow in the well under the natural gradient can be used in conjunction with other information collected to calculate transmissivity (T) values for the individual completion intervals. There are two types of analysis that can be developed, a steady-state analysis using the measurement of the head differences between the completion intervals, and a transient analysis using the pressure adjustment that occurred when the bridge plugs were set. An additional use of the flow measurements are calculation of the total amount of crossflow that had occurred between completion intervals prior to development. This information will be used in evaluation of the effectiveness of development for restoration of natural water quality. If crossflow is allowed to continue, the flow information will provide the basis for estimating future development/purging requirements for sampling of receiving intervals. Temperature logs run under nonpumping conditions also provide information on flow in the well, indicating locations of entry and exit of groundwater and direction of flow. The interpretation of the temperature logs is used in conjunction with the flow measurements, providing guidance for locating and interpreting discrete measurements.

2.5.1 Temperature Log

A temperature log was run under nonpumping conditions with the ChemTool 16 days after the constant-rate test. This log is shown in Figure 2-7 along with the postdevelopment thermal flow log measurements discussed in the next section. The temperature logs give an indication of the entry, direction, and exit of flow from the borehole, but do not provide any rate information. The temperature range observed in this well is small, which is consistent with the small vertical distance between completion intervals. The temperature log indicated downward flow from the upper interval to the lower interval, with fairly consistent inflow across the upper interval. The temperature increases more rapidly in the lower interval where the downward flow is injected into warmer formation. The formation temperature in the lower interval is apparently just over 80°F, based on the temperature log during pumping; see Figure 3-1. The interpretation of the temperature increase above the upper completion interval is unclear, perhaps representing residual heat from cement in the well construction.

2.5.2 Flow Measurements (Thermal Flowmeter)

Flow in the well under natural gradient (i.e., nonpumping, equilibrium conditions) was measured using the thermal flowmeter after recovery following the constant-rate test. Flow measurements from before and after well construction are tabulated in Table 2-2. There was downward flow in the borehole prior to completion, and apparently even greater downward flow from the upper completion interval to the lower interval after development (see Figure 2-7). This information is consistent with the temperature log.

2.5.3 Derived Hydraulic Properties

General estimates of the transmissivity of the completion intervals can be derived from information on the flow from and/or into the completion intervals and the hydraulic gradients associated with the flow. The estimate could be made using the empirical equation $T=2000Q/s_w$ (Driscoll, 1986), where Q is the flow rate in gpm and s_w is the drawdown in feet. Downward flow of 2.2 gallons per minute (gpm) was measured between the completion intervals. The calculated head difference between the completion intervals is 0.85 ft. The calculation yields a T value of 690 square feet per day (ft^2/d) for the upper interval; which results in a hydraulic conductivity (K) value of 6.2 feet per day (ft/d). These values have an uncertainty based on the head difference uncertainty (+/- 0.36 ft) and the flow measurement uncertainty (max +/- 0.44 gpm) of about +/- 62 percent. These values can be compared to the results from the pumping test and flow logging in Section 3.0.

Table 2-2
Thermal Flow Measurements

Prior to Well Construction		After the Constant-Rate Test		Well Construction
Depth (ft)	**Flow (gpm)**	**Depth (ft)**	**Flow (gpm)**	**Location**
845	0.000	910	0.000 +/- .000	Above upper completion interval
921	-0.540	930	-1.290 +/- .851	In upper completion interval
1,000	-0.456	990	-2.200 +/- .009	In upper completion interval
		1,210	-2.200 +/- .440	In lower completion interval
1,220	-0.744	1,225	-0.918 +/- .064	In lower completion interval
		1,230	-1.568 +/- 1.054	In lower completion interval
		1,240	-1.144 +/- .115	In lower completion interval
		1,245	-0.994 +/- .132	In lower completion interval
1,305	-0.566			Below lower completion interval

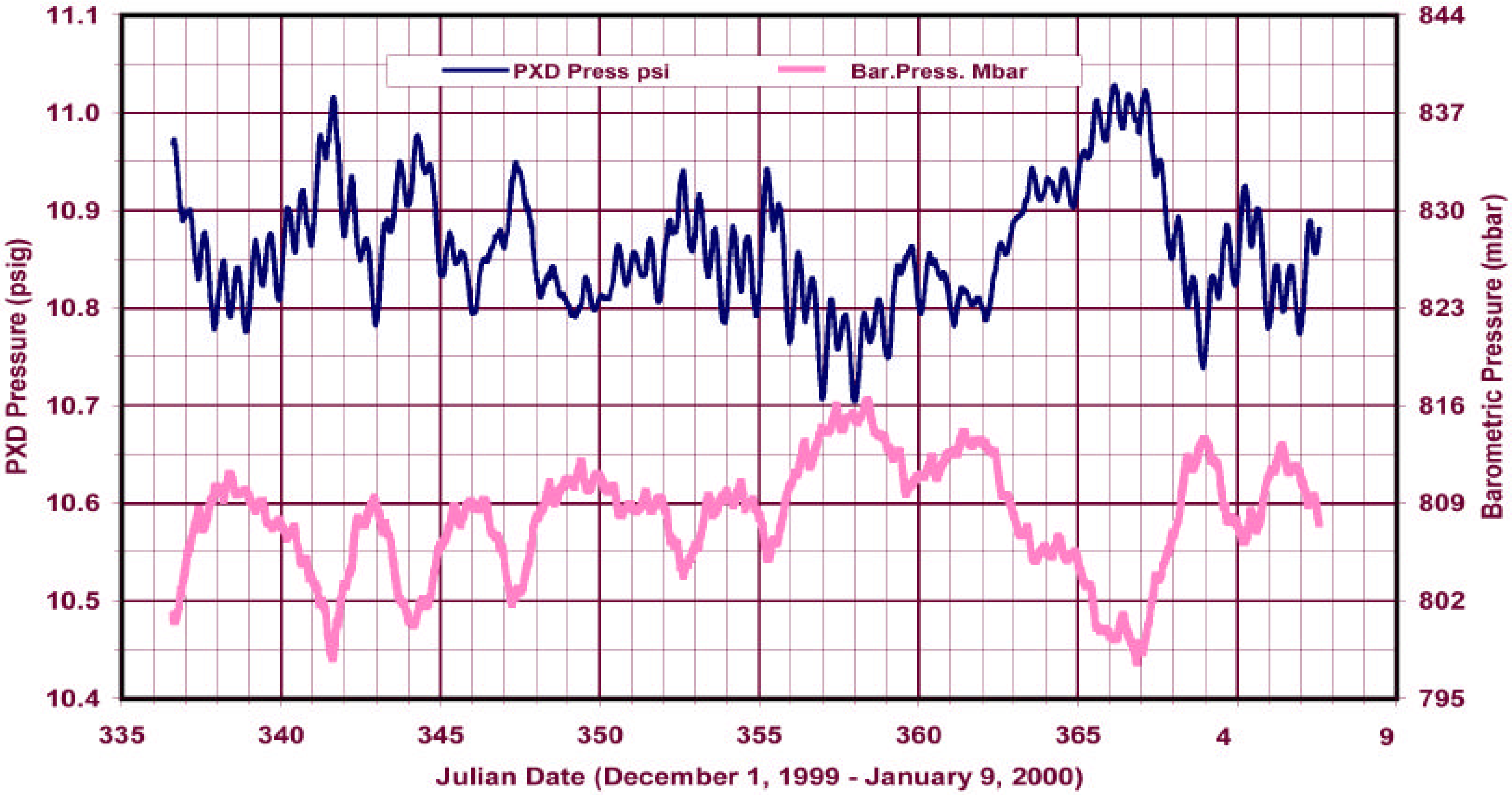
+ Indicates upward flow
- Indicates downward flow
gpm - Gallons per minute

While these estimates are less specific and accurate than pumping test information, they can provide estimates of T values where better information is not available. This applies to wells when pumping tests are not run, and to the deeper completion intervals when there was no production during the pumping tests.

2.6 Pressure Equilibration Following Setting of Bridge Plugs

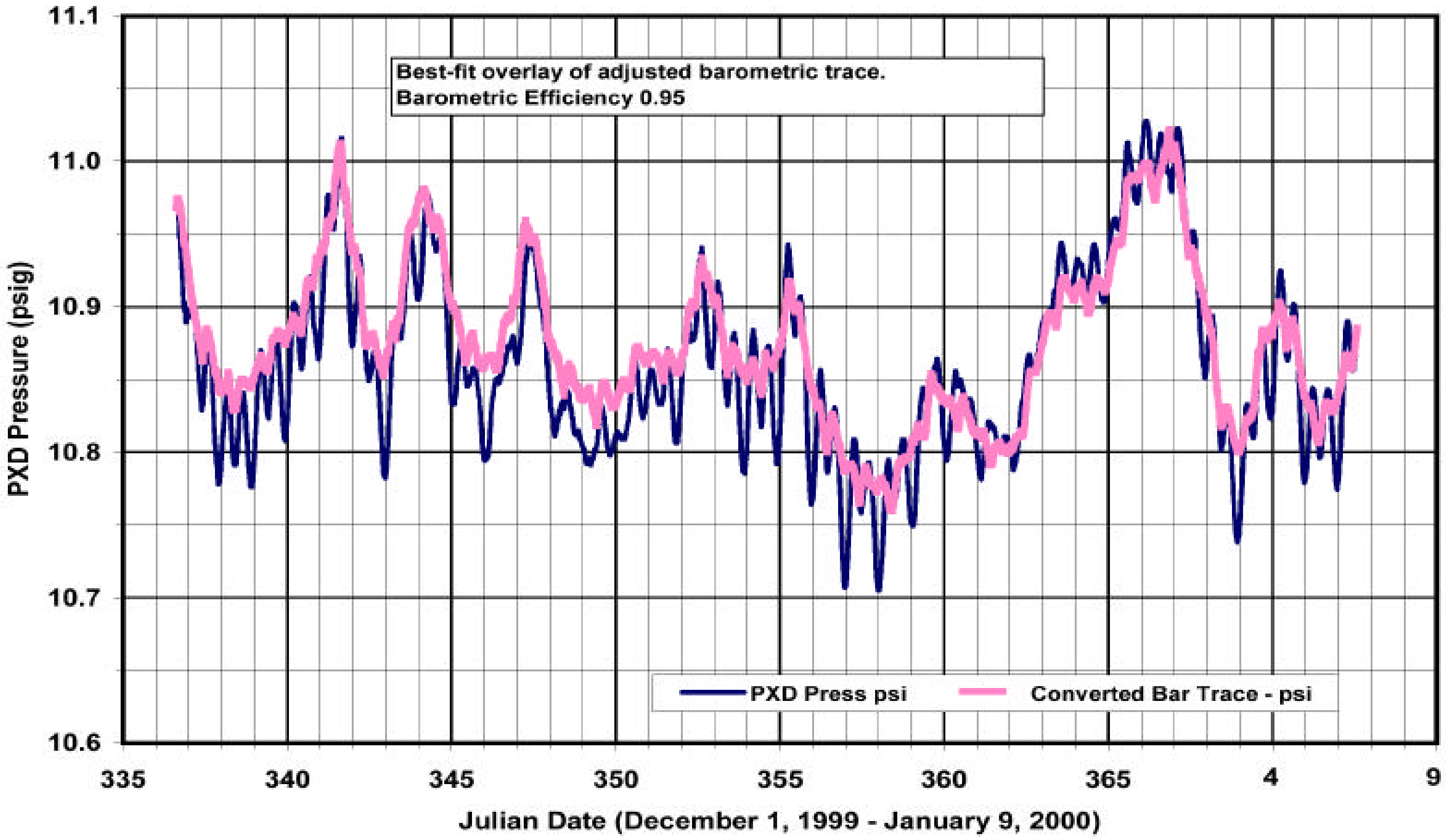
The pressure equilibration records for each completion interval following setting the bridge plugs also have the potential for providing information on the transmissivity of the completion interval formation. For the upper completion interval, the recovery record could be analyzed if it could be captured with sufficient early-time data to define the recovery curve accurately. However, necessary early-time data is usually lost before water level measurements can be made and the PXD can be installed for recording. This is true for Well ER-EC-7 data.

Analysis of the pressure equilibration data for the lower completion intervals can be conducted using a pressure fall-off model following cessation of injection (Earlougher, 1977). The record for the lower completion interval is shown in Figure A.3-3, Appendix A. The data was found to be somewhat difficult to interpret because the trends of the changes in pressure are obscured by effects of the resolution of the measurement equipment. The resolution effect of the instrumentation produces bands in the data, and two different resolution effects are evident, that of the pressure sensor and that of the temperature correction. As discussed in Section 2.3, the head in the lower interval increased during equilibration, indicating that some other, undetermined effect also occurred when the bridge plug was set. The equilibration record cannot be used for the transient analysis proposed in this section until the record can be corrected to account for this other effect.



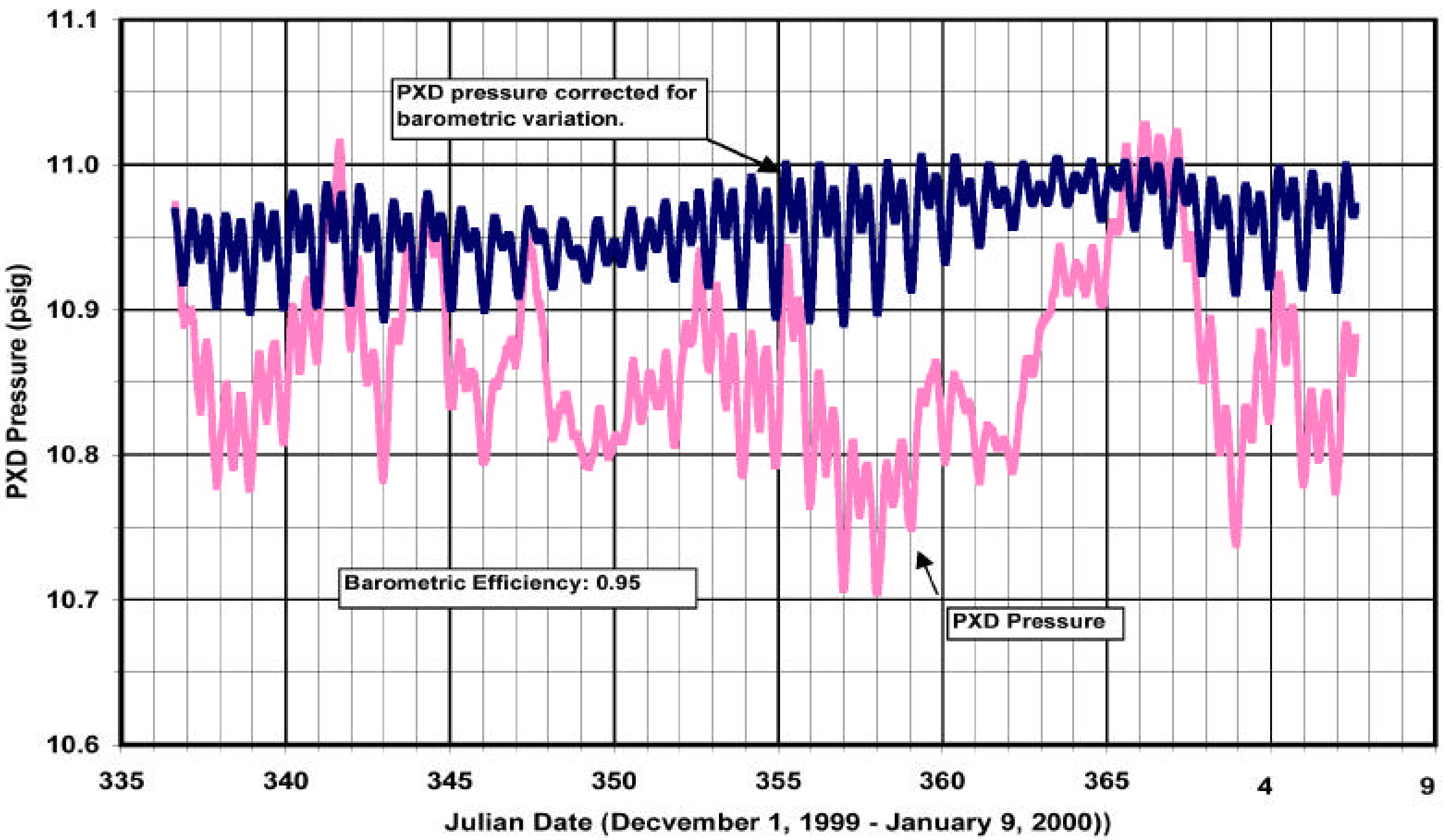
psig - Pounds per square inch gauge
mbar - Millibars
PXD - Pressure transducer

Figure 2-1
Long-Term Water Level Monitoring Record



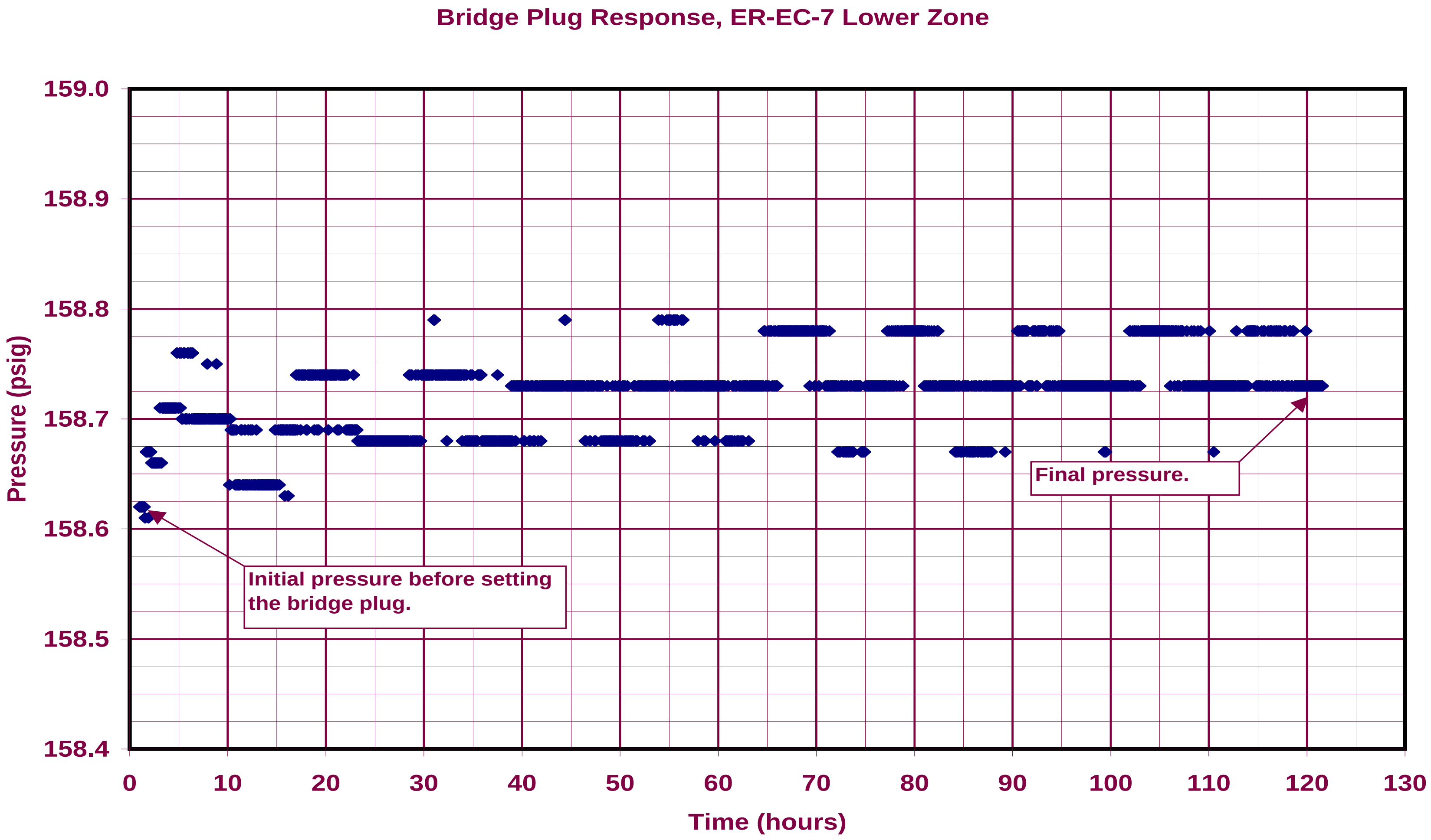
psig - Pounds per square inch gauge
mbar - Millibars
PXD - Pressure transducer

Figure 2-2
Barometric Efficiency Overlay



psig - Pounds per square inch gauge
mbar - Millibars
PXD - Pressure transducer

Figure 2-3
Barometric-Corrected Monitoring Record

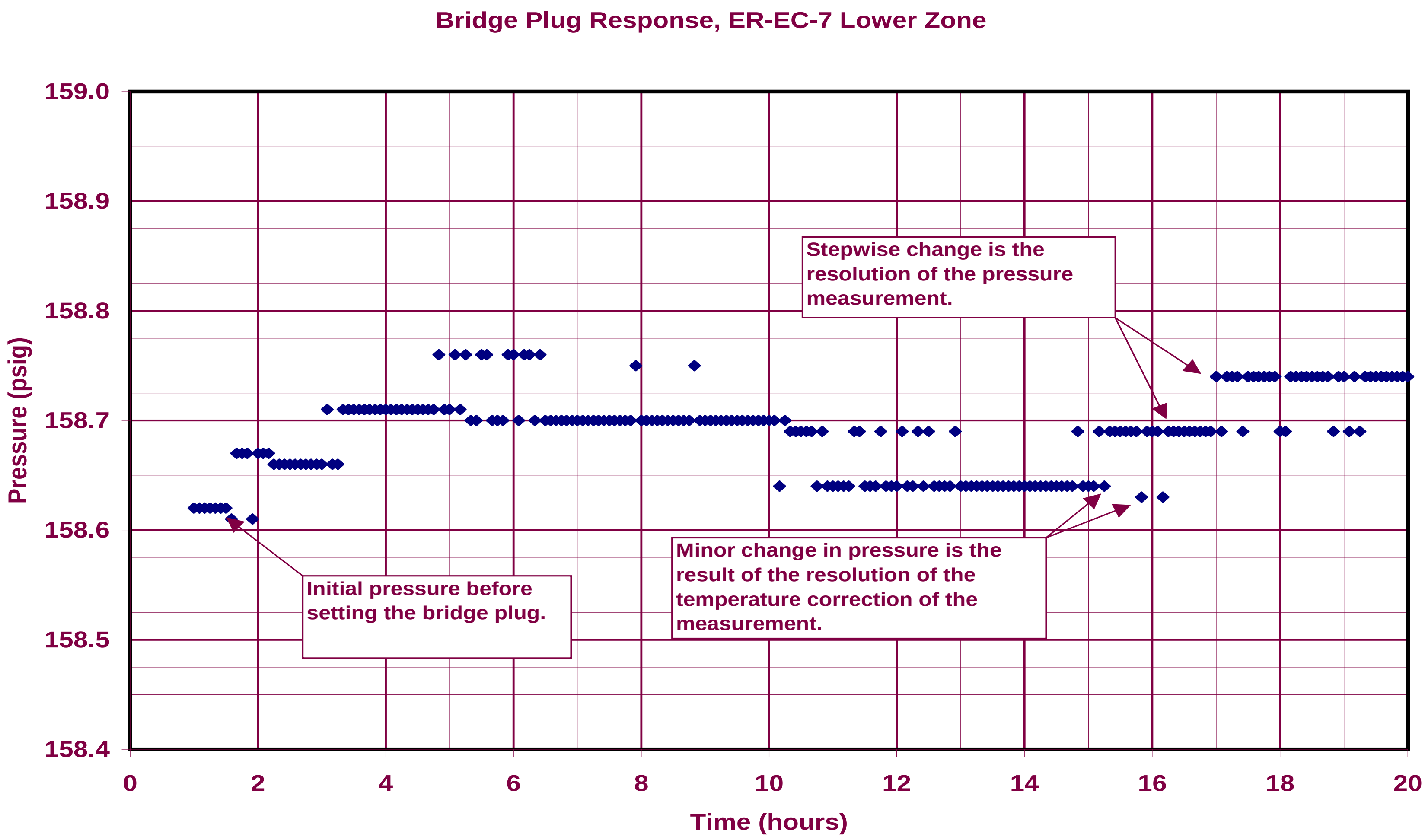


Initial pressure before setting the bridge plug.

Final pressure.

psig - Pounds per square inch gauge

Figure 2-4
Lower Completion Interval Pressure Equilibration Record



psig - Pounds per square inch gauge

Figure 2-5
Early-Time Lower Completion Interval Pressure Equilibration Record

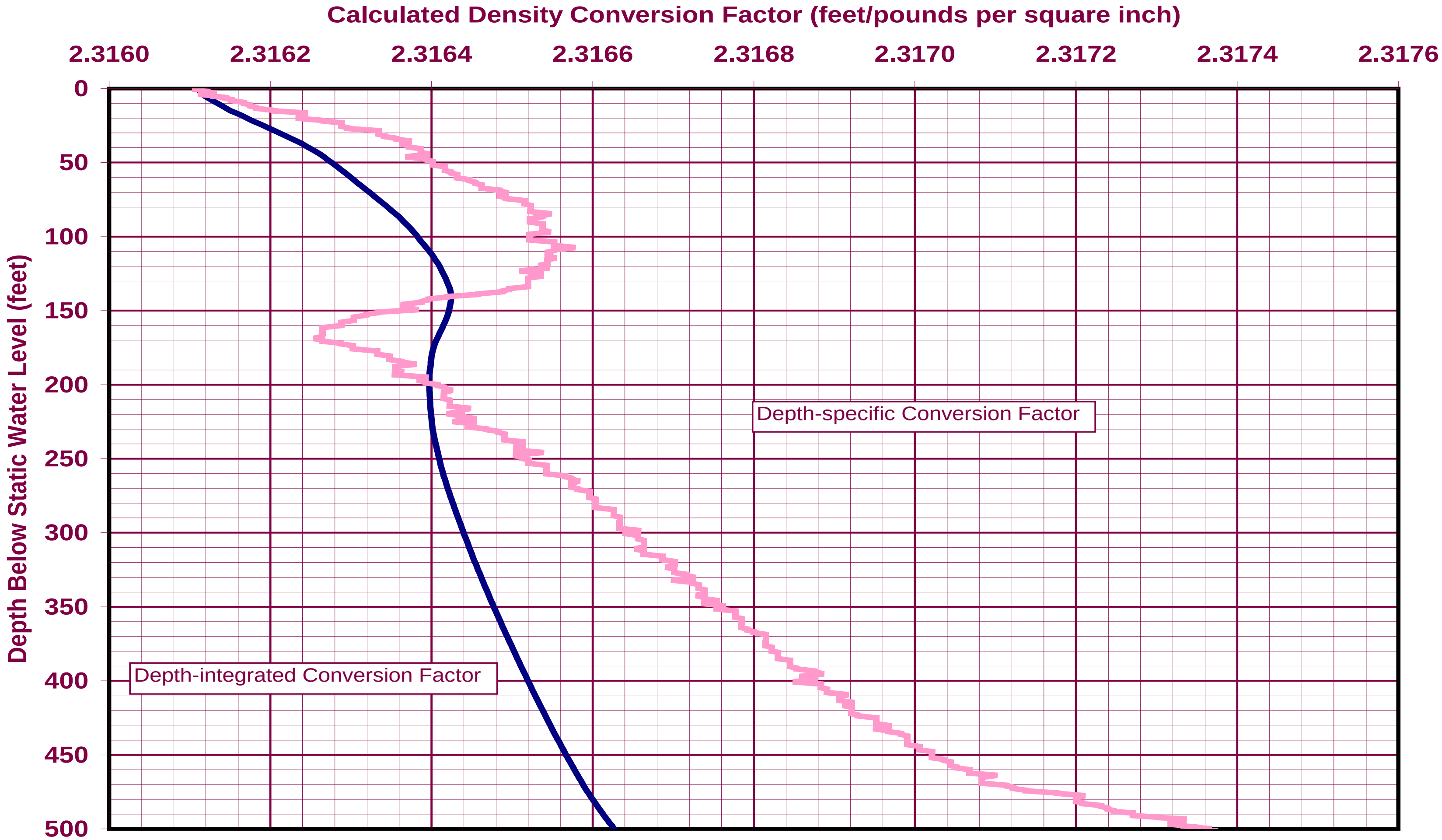


Figure 2-6
Temperature-Dependent Density Variation

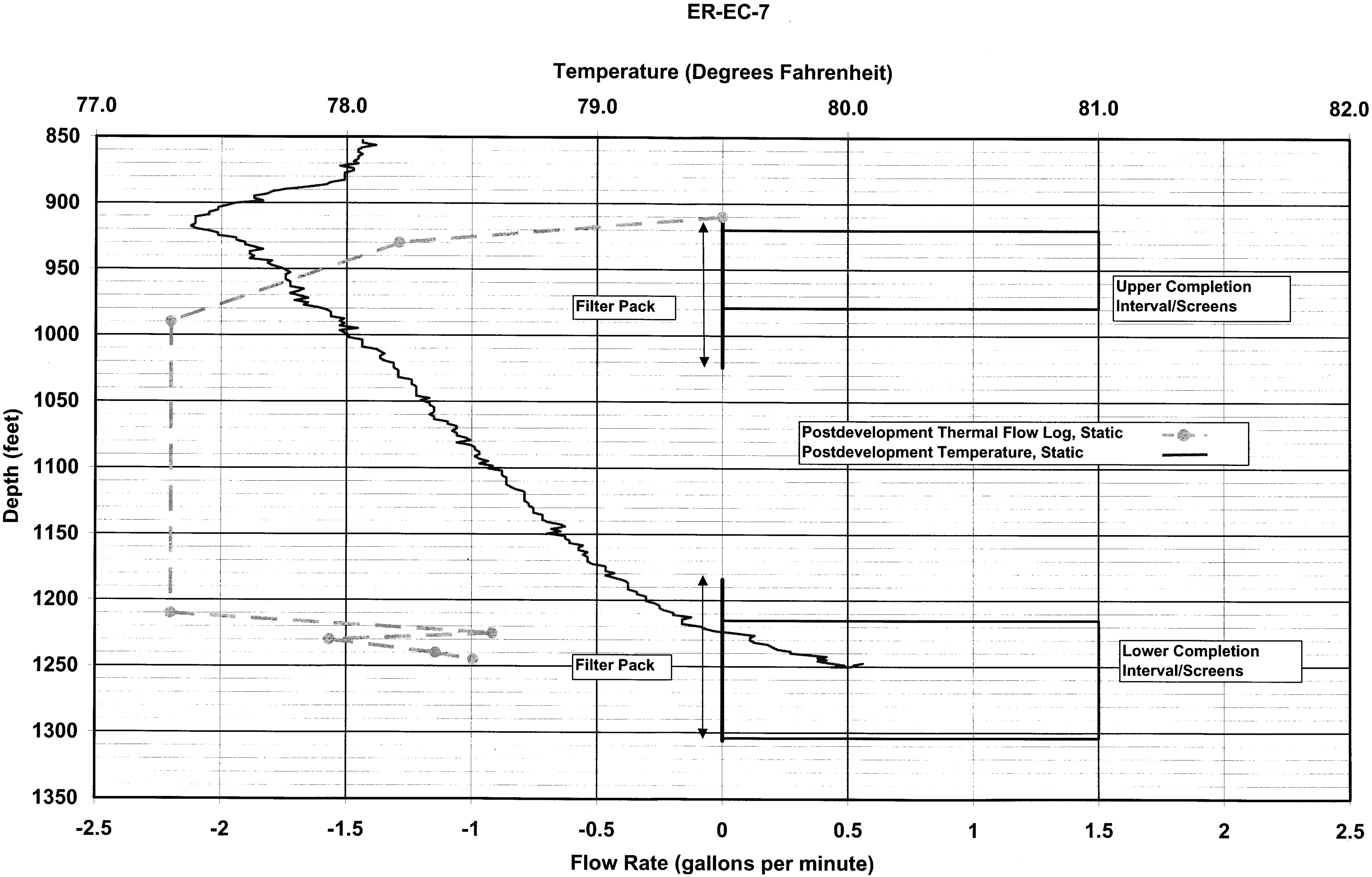


Figure 2-7
Nonpumping Temperature and Flow Logs

3.0 *Pumping Well Hydraulics*

The hydraulic testing of the well has been analyzed to provide both the transmissivity of the well and hydraulic conductivity of sections of the formation in the completion intervals. The hydraulic conductivity analysis is based on the flow logging that was conducted during pumping and a detailed analysis of the well losses.

3.1 *Measured Discrete Production*

One of the significant features of the WPM-OV testing program was the flow logging during pumping to identify the source(s) and distribution of water production in the well. This information will be used in interpreting the well hydraulics and water chemistry. These wells penetrate deeply through a variety of different formations and lithologies and have multiple completions, often in very different materials. Hydraulic testing and composite sampling provides information that is not specific to the differences in completion intervals, and interpretation of the data must often assume that the results pertain in general to all of the completion intervals.

Flow logging in conjunction with the testing and sampling allows the interpretation to be made specific to the origin of the produced water and the specific response of each completion interval, or even part of a completion interval. For example, as discussed later in this section, the flowmeter results show that the production was very different between the two completion intervals, even after accounting for the different lengths of the completion intervals. Consequently, the derived hydraulic conductivity is substantially greater for the one interval than the other; whereas, without the flow logging, all of the exposed formation would have been assigned one average value. The groundwater chemistry analyses can also be assigned more specifically to the depth and formation from which the samples actually came.

Figure 3-1 presents a composite picture of temperature and flow logs for both the static situation and while pumping. The static situation was characterized at the end of testing prior to installation of the sampling pump. The pumping case was characterized at the end of development and is presented with log ec7mov1 for a nominal pumping rate of 65gpm (actual 66 gpm); but all of the logs show very similar results. Figure 3-2 shows both of the completion intervals and an example of the flow log for each of the three pumping rates that were used. These figures include depth, lithology, hole diameter, and well construction. Flow log ec7mov1 is presented for 66 gpm, ec7mov5 for 122 gpm, and ec7mov7 for 178 gpm.

Flow logging run trolling upward produced bad results in this well. This has been attributed to an interference with the flowmeter resulting from the smaller interior diameter of the FG completion casing used in this well than the stainless steel casing used in the other WPM-OV wells. This smaller diameter was at the lower limit required to allow the flowmeter centralizer to open fully. Trolling in the upward direction is believed to have caused some compression of the flowmeter centralizer, interfering with the flowmeter impeller. Consequently, all flow logging was run in the downward direction, which appeared to allow the tool to function in the blank casing.

The flowmeter logs within the upper screen indicate anomalous loss of flow within the screen interval. The flowmeter logs show relatively steady flow in the blank casing below and above the completion interval, and a pattern of decreased flow within the upper completion interval with a sudden increase at the top of the interval. Above the interval, the flow rate increases to a value consistent with the surface flowmeter. These flow profiles probably indicate that some fraction of the flow in the casing is exiting the well casing in the lower part of the screen and reentering in the upper part of the screen. This could occur if such a flow configuration results in lower overall flow losses. The flowmeter may cause a local flow loss around it due to reduction of the flow cross section area, resulting in this situation. Consequently, only the measurements in the blank casing are used. The impact of this situation on interpretation of the flowmeter measurements is discussed in a later section.

3.1.1 Temperature Logs

The difference in the temperature logs between the static and pumping case indicates several things about flow in the well. During pumping at 178 gpm, the temperature is higher from the lower interval upwards, and does not decline significantly until the upper part of the upper completion interval. At the top of the upper interval, the temperature is still substantially higher than in the nonpumping case. This indicates both the production from the lower interval in general, and the proportionally greater contribution from the lower interval than the upper interval. Also, the inflow from the upper interval appears to be in the upper half of the interval, which is not evident in the flowmeter log. This log also shows an increase in temperature just above the upper interval, although here it is much more limited. It is not clear what this indicates.

3.1.2 Impeller Flow Log Interpretation

During constant-rate pumping, the amount of flow in the well as a function of depth was recorded using a borehole flowmeter. The flowmeter is a spinner device provided by Desert Research Institute (DRI), and was used in both a trolling and stationary mode. A total of 12 logging runs were made at different logging speeds and different pumping rates. In addition, a series of stationary measurements were taken while the well was pumping and the meter held stationary at one depth. A summary of these different logging runs is presented in Table 3-1. The listed pumping rates have been updated based on tabulation of the flowmeter records to more accurately reflect the actual average pumping rates.

Table 3-1
Summary of Impeller Flow Logs

Run Number	Direction of Run	Line Speed (fpm)	Pumping Rate (gpm)	Run Start/Finish (ft bgs)
ec7mov1	DOWN	20	66	866.8 - 1,261.2
ec7mov3	DOWN	60	66	865.8 - 1.227.8
ec7mov5	DOWN	20	122	866.2 - 1,232.2
ec7mov6	DOWN	60	122	865.8 - 1,233.2
ec7mov7	DOWN	20	178	865.8 - 1,227.8
ec7mov8	DOWN	60	178	866.2 - 1,227.8
ec7stat1	Stationary	0	66	910
ec7stat2	Stationary	0	66	1,000
ec7stat3	Stationary	0	122	1,000
ec7stat4	Stationary	0	122	910
ec7stat5	Stationary	0	178	1,000
ec7stat6	Stationary	0	178	910

The flow logs provide a measure of the water production as a function of depth. This information, along with an estimate of the drawdown in each interval, can be used to calculate the hydraulic conductivity of each segment. This section describes the analysis of the flowmeter measurements in preparation for calculation of interval-specific hydraulic conductivity in Section 3.5.4.

The flowmeter impeller spins in response to water moving through the meter. The rate of revolution is related to water velocity and flow via an equation which accounts for pipe diameter and the trolling speed of the flowmeter. The coefficients of the equation relating the impeller response to the discharge are determined via calibration. In theory, the meter could be calibrated in the laboratory using the same pipe as the well and no further calibration would be necessary. In reality, the flowmeter response is influenced by a large number of factors specific to an individual well including temperature, pumping rate variation, hole condition, and sediment load. Therefore, it is advantageous to perform a calibration in the well to use for interpretation. For Well ER-EC-7, the calibration of the flowmeter response is determined using flowmeter data collected above the uppermost screen but below the crossover to the nominal 5.5-inch pipe. In this section of the well, the amount of water flowing upward to the pump should equal the discharge at the land surface. The flowmeter response is calibrated against the measured surface discharge to provide the necessary coefficients to calculate the discharge at any depth in the well as a function of impeller response and logging speed.

3.1.3 Calibration of the Borehole Flowmeter in the Well

The borehole flowmeter measures the velocity of water movement via an impeller that spins in response to water moving past it. Typically, the flowmeter is calibrated in the laboratory under controlled conditions to establish a calibration between the impeller response and discharge. The calibration is specific to a certain size pipe and may be different if flow is moving upward or downward through the meter. Hufschmeid (1983) observed significant differences between the meter response to upward and downward flow and established separate calibration equations for those two conditions. Rehfeldt et al. (1989) also observed different flowmeter responses to upward and downward flow, but the differences were not significant enough to warrant separate calibration equations. However, this is not an issue for Well ER-EC-7 because all flow logging runs were conducted in the downward direction. Logging in the upward direction was attempted but was unsuccessful because the impeller’s expansion arms could not fully open within the fiberglass casing. Also, no data are available from laboratory calibration of the flowmeter used in this study documenting the meter response to flow in different directions.

The borehole flowmeter was calibrated in the well to define a calibration equation specific to the well. This is necessary because the meter response may vary from well to well due to: (1) slight changes in the condition of the bearings that support the impeller; (2) differences in the physical characteristics of the fluid (density and viscosity) in the well that may vary from well to well due to temperature, dissolved gasses, or suspended solids content; (3) variations in the roughness or diameter of the well pipe; (4) slight variations in the position of the flowmeter relative to the center line of the well; and (5) variations in water flow in the well and the trolling speed of the flowmeter, which may vary among logging runs and affect the flowmeter response. The calibration procedure and results are presented in this section.

3.1.3.1 Calibration Procedure

The flowmeter calibration procedure includes preparation of the calibration data and identification of the calibration equation and associated uncertainty.

The well is constructed with a 30-ft long blank section of pipe above the uppermost screen. The pump is located above the blank section; therefore, the flow rate in the upper blank section should be the same as the discharge from the well. For each of the pumping rate and line speed combinations, the flowmeter response is recorded at 0.2-ft intervals along the length of the well including the blank section above the uppermost screen. To avoid end effects, the data observed from a 15-ft interval centered between the ends of the blank section are used to determine the calibration.

Data Preparation

Preparation of the flowmeter calibration data includes the following steps:

- Import the data into a spreadsheet and sort by depth
- Adjust the flow log depths
- Identify the blank intervals
- Extract the data above the top screen for use in the calibration

The flowmeter data, provided in ASCII format as a function of depth, are imported to Excel™. Some of the logging runs are made top to bottom, while others are bottom to top. To maintain consistency, each file is sorted to portray the data from top to bottom.

Differences in depth reporting equipment leads to errors in reported depths for the logging runs. An effort is made to correct logging depths to match the official well construction diagrams. Typically, this is performed by differentiating the log profile to identify locations where flow rates are changing rapidly. Such changes correspond to changes in the internal diameter of the well such as at the crossover, or to the boundaries of inflow. For simplification purposes, it was assumed that boundaries of inflow are located at the ends of the screens, which may not be correct in every case. However, considering the analysis method used, the impact of this assumption on the results would be negligible.

The flowmeter depths recorded for Well ER-EC-7 were adjusted to ensure that the flowmeter response corresponded to the well construction log. The top and bottom of blank and screened intervals were identified in the flowmeter logs by plotting the rate of change of flow rate versus depth, and recording the locations where flow rate was changing. These depths were compared with the top and bottom of pipe sections in the construction log. Then, the depth of the center of each section was calculated and compared between the two logs. The depth correction to match the flowmeter and construction logs was determined from the average difference in the center depth of blank and screened sections.

Figure 3-3 shows the differential flow log of the well corresponding to flow log ec7mov8, from depths 866.2 ft to 1,227.8 ft. This depth interval contains the blank casing above the first screen but below the crossover. Each peak on the curve shown in Figure 3-3 represents a change in flowmeter response, which corresponds to a transition from one type of interval to another. For example, the transition from the larger casing to the nominal 5.5-inch casing is clearly visible at a depth of 887.6 ft. Likewise, the transitions from the upper blank casing to the upper screen and from the lower blank casing to the lower screen are also apparent at depths of 923.2 ft and 1,218.2 ft, respectively. However, the transition from the upper screen to the lower blank casing section is not apparent on this log. This process was performed for the top blank section and for the interval comprised of the upper screen and the lower blank casing section for each logging run. The depth of the midpoint for each of these intervals from the flow log was compared with the midpoint of the same interval from the construction diagram. A depth correction to match the flowmeter and construction logs was determined from the average differences in the center depth of the two intervals. The calculated depth correction was +2.6 ft. This process ensures that the appropriate depth intervals of the flow log are analyzed.

Following depth correction, a 15-ft long section of the borehole flow log data (impeller revolutions per second, line speed, and surface discharge) in the blank section above the uppermost screen were extracted from each of the six moving flow logging runs and from the two logging runs where the flowmeter was held stationary in the blank section while the well was pumped (stationary runs 1, 4, and 6).

Calibration Equation and Uncertainty

Identification of the calibration equation and associated uncertainty includes the following analyses:

1. Multiple linear regression to determine an equation to relate meter response to line speed and measured discharge
2. Estimation of uncertainty using the calibration equation to determine a lower detection limit for the flowmeter

A calibration equation was derived in two steps. The first step consisted of a multiple linear regression on the calibration dataset using the flowmeter response (revolutions/second [rev/sec]) as the dependent variable and the line speed (feet/minute [fpm]) and flow rate (gpm) as the independent variables. The second step consisted of expressing the flow rate as a function of the flowmeter response and the line speed by rearranging the equation used to regress the calibration data. The multiple linear regression approach in this work was chosen to provide a method by which the accuracy of the calibration could be quantified.

In this report, the equation used to regress the calibration data is of the form:

$$f = a + b_1 Q + b_2 L_s \tag{3-1}$$

where:

f = Impeller frequency of revolution (rev/sec)
Q = Flow rate (gpm)
L_s = Line speed (fpm)
a = Constant
b_1 and b_2 = Coefficients for the two independent variables

This equation is solved by multiple linear regression of the flow log calibration data. The use of equation (3-1) is advantageous in the multiple linear regression because Q and L_s are statistically independent which is desirable in regression analysis.

The equation expressing flow rate as a function of flowmeter response and line speed is then derived by rearranging equation (3-1) as follows:

$$Q = c + d_1 f + d_2 L_s \tag{3-2}$$

where:

$c = -a/b_1$
$d_1 = 1/b_1$
$d_2 = -b_2/b_1$

The primary advantage of the multiple regression approach is the ability to estimate the prediction error at any point in the response surface. For a given multiple regression on n data points where y is a variable that is dependent on k independent variables noted x_i, for i=1 to k, the confidence interval for a specific predicted value of y given specific values of the x_i may be calculated using the following equation (Hayter, 1998):

$$\left(\hat{y}\Big|_{x^*} - t_{\alpha/2,n-k-1}\,\mathrm{s.e.}\left(\hat{y}\Big|_{x^*} + \varepsilon\right),\ \hat{y}\Big|_{x^*} + t_{\alpha/2,n-k-1}\,\mathrm{s.e.}\left(\hat{y}\Big|_{x^*} + \varepsilon\right)\right) \tag{3-3}$$

where the standard error, $\mathrm{s.e.}\left(\hat{y}\Big|_{x^*} + \varepsilon\right)$, for the case of a single predicted value is given by:

$$\mathrm{s.e.}\left(\hat{y}\Big|_{x^*} + \varepsilon\right) = \hat{\sigma}\sqrt{1 + x^{*\prime}(X'X)^{-1}x^*} \tag{3-4}$$

and

σ = Root mean sum of errors between the predicted and measured flow values
X = Matrix of entries that include the number of data points, sums of variables, sums of squared variables, and sums of cross terms
x^* = Vector of independent variables with specific values 1, x_1^*, x_2^* where the confidence interval is to be estimated
$t_{\alpha/2,n-k-1}$ = Students' t-statistic at the α level of significance and n-k-1 degrees of freedom

n = Number of data points
k = Number of independent variables

The prediction of a specific value of y given specific values of the independent variables is more uncertain than the mean y calculated by the regression equation. The prediction uncertainty is a function of how well the regression equation fits the data (the root mean sum of errors), the distance of the specific independent variable values from their means, and the number of data points which influences the value of the t-statistic and the X matrix.

Although equation (3-2) is not solved directly by multiple linear regression, it may be used to calculate downhole flow rates (Q) for each pair of measured flowmeter response and line speed of the calibration dataset. The standard error associated with equation (3-2) may then be calculated using the corresponding root mean sum of errors. The confidence interval for each predicted downhole flow rate is then calculated using equation (3-3). The confidence interval is important because it may be used to represent the bounding error on a given flowmeter measurement.

3.1.3.2 Calibration Results

The calibration dataset consisted of 1,260 data points. Each data point consists of discrete measurements of line speed (fpm) and flow rates (gpm) (as discharge measurement recorded at the land surface), and a corresponding measurement of flowmeter response (rev/sec). Table 3-2 contains the values of the coefficients in equations (3-1) and (3-2), the regression model correlation coefficient, the sum of the squared errors, the number of observations, and the standard errors associated with the two equations.

In addition, Table 3-2 contains the 95 percent confidence intervals for flow rates calculated using specific pairs of flowmeter response and line speed. The 95 percent confidence interval was calculated for the measured range of flow to provide a measure of accuracy for the flow rates calculated using the calibration equation. As shown in Table 3-2, the confidence interval is less than 1.72 gpm and is insensitive to the magnitude of the flow rate within the range considered. No near-zero flow rates were measured in this well. Measured flow rates less than 1.72 gpm are considered statistically indistinguishable from zero.

An argument against the flowmeter calibration approach described above is the concern that discharge measured at the land surface at a time, t, may not represent the instantaneous conditions recorded downhole by the flowmeter at that same time. To evaluate this source of uncertainty, a second approach could be used to derive a flowmeter calibration equation using the flow-logging data. In this method, the calibration dataset consists of values of the surface discharge, the line speed, and the flowmeter response averaged over the length of the blank section, or over time in the case of the stationary measurements. The averaged-data approach is conceptually appealing because it eliminates the assumption of a direct link between a downhole response and surface discharge at the same instant

Table 3-2
Flowmeter Calibration Results Using all Data Collected Above the Top Screen at Well ER-EC-7

Equations 3-1 and 3-2 Solutions

	Equation 3-1	Equation 3-2
Constant	-0.0067	0.2650
First dependent variable	0.0253	39.5813
Second dependent variable	-0.0229	0.9073
Multiple R	0.9999	-
Sum of Squared Errors	0.6110	957.1968
Standard Error	0.0220	0.8726
Number of Observations	1260	1260

95 Percent Confidence Interval for Flow Rates near Zero based on Equation 3-2

Flow Logging Run	Impeller Rate (rev/sec)	Line Speed (fpm)	Confidence Interval[a] (gpm)
ec7mov1	0.598	-21.807	1.72
ec7mov3	2.713	-66.797	1.72
ec7mov5	2.736	-21.702	1.71
ec7mov6	3.571	-62.094	1.72
ec7mov7	3.785	-22.531	1.71
ec7mov8	4.684	-66.625	1.72
ec7mov1	2.221	-22.809	1.71
ec7mov3	3.188	-67.202	1.72
ec7mov5	3.596	-22.4	1.71
ec7mov6	4.486	-62.717	1.72
ec7mov7	5.014	-22.926	1.71
ec7mov8	6.022	-67.337	1.72

Note: Impeller rate and line speed values were taken from depths ranging between 900.4 and 1,251 ft below ground surface, corresponding to the maximum range of flow rates measured for this well (4 to 178 gpm approximately).

[a] Confidence interval is calculated using equation (3-3) and represents half of the full range of the uncertainty. This confidence interval was used to represent the error associated with low flow rate measurements.

in time. However, the approach has a major drawback, it greatly reduces the number of data points.

The averaged-data approach could not be used for Well ER-EC-7 because of the limited number of logging runs (8). After averaging along the section of blank casing used for flowmeter calibration, only 8 data points corresponding to each of the logging runs would remain for use in the multiple regression. This number is too small to yield reliable results. However, this method was used for Well ER-EC-1, the dataset was reduced to 14 sets of measurements which were used to derive a second calibration equation. The regression coefficients derived from the detailed and reduced datasets were nearly identical. The calculated flow rates using the coefficients from the two methods differed by less than 0.2 gpm over the entire range of values. The primary difference was that the confidence interval near the zero discharge prediction was narrower for the full dataset than when average values were used. Based on the case of Well ER-EC-1, it will be assumed that the time lag between the discharge measured at the land surface and the flow recorded by the flowmeter for Well ER-EC-7 has a negligible impact on the flowmeter calibration.

3.1.4 Calculation of Flow in the Well as a Function of Depth

Following calibration of the flowmeter, the flowmeter readings were converted to flow rates using the calibration equation (3-2) and the coefficients obtained using the full dataset (Table 3-2). For each moving flow log, each depth where a flowmeter response and line speed were recorded, the values were inserted into equation (3-2), with the coefficient values provided in Table 3-2, and the flow rate in the well at that depth was calculated. This generated the flow log values used for later analysis.

3.1.5 Resolution Effects of Well Construction

The physical arrangement of the screens and limited screen length within the completion interval defined by the filter pack results in several limitations for resolving the origin of inflow from the aquifer. The slots for each screen start at 2.5 ft from the end of the casing joints, leaving 5 ft of unslotted casing between 25 ft lengths of closely spaced slots. Also, the filter pack extends a substantial distance beyond the ends of the screen. The drawdown imposed by pumping is distributed in some manner throughout the filter pack and stresses the aquifer behind the blank casing. However, there is no way of accurately determining the distribution of inflow behind the blank casing. Some qualitative interpretation may be attempted to evaluate the increase in production at the edges of each screen on the flow logs and attribute some of that production to vertical flow from behind the blank casing, but this is very speculative. The hydraulics of vertical flow in the filter pack and end effects for the screens are undefined. The main impact of this situation is the uncertainty in determining the appropriate thickness of aquifer to use in calculations of hydraulic conductivity.

3.2 Well Losses

The drawdown observed in the well is comprised of aquifer drawdown and well losses resulting from the flow of water into the well and up to the pump. Aquifer drawdown can be observed directly in observation wells near a pumping well, but such wells were not available near Well ER-EC-7. An attempt has been made to break down the total drawdown into its components to better understand the hydraulics of water production and derive better estimates of aquifer properties.

3.2.1 Step-Drawdown Test

The final step-drawdown test conducted prior to flow logging was analyzed according to the method of Jacob (Driscoll, 1986) using the Hantush-Bierschenk methodology (Kruseman and de Ridder, 1990). The assumptions and conditions for applying this analysis are: (1) the aquifer is confined, seemingly infinite in extent, homogeneous, isotropic, and of uniform thickness; (2) the initial piezometric surface is horizontal; (3) the well is fully penetrating and the well receives water through horizontal flow; (4) the well is pumped step-wise at increasing rates; (5) flow to the well is unsteady; and (6) non-linear well losses are appreciable and vary according to Q^2. While the assumptions and conditions about the aquifer and flow in the aquifer are not perfectly satisfied, it is believed that they were sufficiently satisfied during the step-drawdown test to provide a reasonable result. The test was conducted according to the required protocol.

The left side of Table 3-3 shows the basic data derived from the step-drawdown test, and Figure 3-4 shows the resultant graph of that data with the equation for the trendline. The coefficients of the trendline are substituted in the equation for losses, in the form of $s_w = BQ_n + CQ_n^2$ where s_w is the total drawdown in the well, Q_n is the net production rate, B is the linear loss coefficient, and C is the nonlinear loss coefficient. Evaluating this equation at the average production rate for the flow logging of 122 gpm gives a nonlinear component of 5.95 ft, which is generally equated to turbulent losses in the well. The pumping rate values used in these computations have been rounded to the nearest whole gpm, based on the production rates recorded in the flow logs. There is about a 1 gpm discrepancy between the rates recorded with the logs and the independent record; however, the difference in computed losses due to the difference is not significant. The turbulent losses include flow losses from the aquifer into the wellbore (skin losses), entrance losses into the well casing through the screen slots, and flow losses up the casing to the pump. The linear component of the losses are generally considered to be the laminar losses of the flow in the aquifer. The predicted losses for all three flow logging pumping rates are also tabulated in Table 3-3. It is recognized that this simplified approach is not completely accurate, but it is expected to provide a reasonable estimate of the various losses. The results will be used to estimate the actual aquifer drawdown and this value was used to calculate hydraulic conductivity. This was particularly important for this well because the well losses are a large fraction of the total drawdown.

Table 3-3
Step-Drawdown Results and Application

Duration Days	Ave Pumping Rate - Q (gpm)	Drawdown s_w (ft)	s_w/Q	Flow Logging Pumping Rate (gpm)	Predicted s_w (ft)	Laminar Losses (ft)	Turbulent Losses (ft)
0.0806	65.58	3.83	0.058	66	4.06	2.32	1.74
0.0887	121.56	10.23	0.084	122	10.24	4.28	5.95
0.0881	175.89	18.78	0.107	178	18.92	6.25	12.67

3.2.2 Flow Losses

Flow losses inside the well casing were computed based on standard theory of flow in a pipe using the Darcy-Weisbach equation. Losses through the slotted sections were assigned friction factors double those of blank pipe (Roscoe Moss Company, 1990). Table 3-4 presents a tabulated profile of calculated friction losses showing the cumulative loss at various locations down the well from the pump intake. The flow rates attributed to each screen section of the well were the average of the inflows from the flow logs that were conducted at pumping rates of about 178 gpm, rounded to the nearest whole gpm. These losses are associated with the flow of water up the well, and are only affected by the flow rate at each point where the loss is tabulated. The flow rates at each point of tabulation for the

Table 3-4
Calculated Flow Losses

Location in Well	Flow at Location (gpm)			Cumulative Friction Loss Inside Casing (ft)			Incremental Flow Losses Into Casing Per Screen (ft)			Total Flow Losses at Center of Screen (ft)		
	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
Pump Intake	66.4	122.4	177.7									
Bottom of Pump Motor	66.4	122.4	177.7	0.042	0.125	0.242						
Btm of 7 5/8-in Casing - Top of Crossover	66.4	122.4	177.7	0.049	0.145	0.280						
Crossover	66.4	122.4	177.7	0.090	0.265	0.513						
Top of Screen 1	66.4	122.4	177.7	0.090	0.287	0.559	0.07	0.27	0.71	0.22	0.75	1.63
Bottom of Screen 1	57.2	104.3	149.5	0.219	0.670	1.294						
Top of Screen 2	57.2	104.3	149.5	0.447	1.331	2.545	1.11	4.00	8.75	1.62	5.50	11.63
Bottom of Screen 2	0	0	0	0.532	1.682	3.211						

Blank = Not applicable

well screens should have been fairly stable since the well had been pumping for some time and the drawdown did not increase substantially during the period of logging. For the best applicability of flow logging data, flow logging should take place only after sufficient continuous pumping at each rate to achieve relatively stable drawdown.

For all three flow logging pumping rates, the component of turbulent losses for flow into the well casing were calculated by subtracting the flow losses inside the casing from the total turbulent losses tabulated in Table 3-3. The turbulent losses for flow into the well casing were then apportioned according to the flow through each screen by the square of the velocity.

This analysis was done for the flow logging pumping rates for use in the flow logging analysis. However, the constant-rate test pumping rate was very close to the 178 gpm flow logging pumping rate, and the calculated losses would be very similar for the constant-rate test.

It is recognized that this approach to determining total well losses for a single well test is not perfectly accurate, but it is believed to provide a reasonable estimate of the losses. The results are used to estimate the aquifer drawdown, and that drawdown is used to calculate hydraulic conductivity for each of the screens. This was particularly significant for this well since the aquifer losses appear to be only about one third of the total drawdown. Without this correction, the derived hydraulic conductivities would be low by a factor of three.

3.3 Head Distribution Under Pumping

The column in Table 3-4 labeled Cumulative Friction Loss Inside Casing tabulates the loss of head down the well casing due to flow up the casing. These values can be subtracted from the total measured drawdown to calculate the head at each tabulation point down the casing. For example, during the last flow log run at 178 gpm, the drawdown in the well would have been approximately 19.0 ft. This estimate is based on the equation derived from the step-drawdown test. During flow logging, the PXD was removed to allow access downhole, and drawdown could not be measured directly. At this time, the drawdown in the casing at the top of the first screen would have been about 18.4 ft (19.0-0.56), and the drawdown at the top of the second screen would have been about 16.5 ft. The column labeled Total Flow Losses at Center of Screen provides the total calculated flow loss from the aquifer into the casing and up to the intake. Subtracting this value from the total drawdown gives the aquifer drawdown at the center of each screen. The average flow losses across the first screen would have been about 1.68 resulting in aquifer drawdown of about 17.3 ft opposite the first screen.

The purpose of these computations is to estimate the actual aquifer drawdown at each pumping rate for each screen. The flow loss values will be used in the flow logging analysis to calculate the hydraulic conductivity attributed to the production from each screen.

3.4 Constant-Rate Test Analysis

The constant-rate test provides data for determining the overall transmissivity of the well. The constant-rate test was analyzed using the AQTESOLV® program (HydroSOLVE, Inc., 1996-2002). The constant-rate tests provide data for determining the overall transmissivity of the well. Figure 3-5 shows a graph of the constant-rate test data. The features of the record are explained in Section A.3.4.2 of Appendix A. The first constant-rate test was interrupted by problems with the pumping system. The head in the well was allowed to recover, and a second test was begun. This test was terminated by failure of the pump. The intent had been to run the test for 10 days to ensure that dual-porosity effects would be observed; however, problems with the pumping system exhausted the schedule. The second constant-rate test was slightly cleaner that the first test and was used for the analysis. The oscillation of the drawdown records can be traced to low-level oscillation of the pumping rate, which appears to be on a daily cycle and is apparently related to temperature affects on the power system for the pump. The average pumping rate for the first test was 175.99 gpm, and the average rate for the second test was 175.96 gpm.

The Moench model for dual porosity (1984 [HydroSOLVE, Inc., 1996-2002]) in a fractured aquifer was used to simulate the aquifer response. This model is consistent with the known geology, and produces an equivalent or better solution fit. The assumptions and conditions for this model are: (1) the aquifer is confined, seemingly infinite in extent, homogeneous, isotropic, and of uniform thickness; (2) the initial piezometric surface is horizontal; (3) the well is fully penetrating and the well receives water through horizontal flow; (4) the well is pumped step-wise at increasing rates; (5) flow to the well is unsteady; (6) non-linear well losses are appreciable and vary according to Q^2; (7) water is released from storage instantaneously; and (8) the aquifer is fractured and acts as a dual-porosity system consisting of low conductivity primary porosity blocks and high conductivity secondary porosity fractures. While the assumptions and conditions about the aquifer and flow in the aquifer are not perfectly satisfied, it is believed that they were sufficiently satisfied during the step-drawdown test to provide a reasonable result. The assumption about the fracture nature of the formation is believed to be appropriate based on characterization of the formation during drilling.

This model has many parameters that interact and can produce a variety of solutions, especially without observation well data. In order to determine the most appropriate solution with respect to K (fracture hydraulic conductivity), values for K’ (matrix hydraulic conductivity) and Ss and Ss’ (fracture and matrix specific storage) were constrained as much as possible. Ranges of possible values for those parameters were determined based upon typical properties for the rock type. Specific storage values were based on typical porosity and compressibility values.

Figure 3-5 shows the type curve for a dual-porosity solution and the resultant parameter values using the extent of the filter pack (238 ft) for the producing section of the upper completion interval for aquifer thickness. This solution yields a K of 9.28 ft/day with an associated T of 2,209 ft^2/d. Figure 3-6 shows a solution using the combined length of the producing screens (139 ft) rather than of the filter pack for the aquifer thickness. This solution is very similar to the first solution, with a resultant K of 15.99 ft/day, yielding a T of 2,207 ft^2/d.

The difference in these two values for aquifer thickness represents the overall uncertainty in the length of formation producing water. Examination of the flow logs generally finds progressive increases in flow near the bottom and top of the slotted portion of the screens rather than sudden increases which might be expected as an indication of substantial production behind the blank casing. However, the flow distribution that would be observed across the screen if there was significant production coming vertically through the filter pack has not been characterized in any calibrated fashion. Flow losses in the filter pack have an effect on the applied distribution of drawdown to the formation. Very high localized production related to a fracture would result in a different situation from well-distributed production from porous media. The difference in the fracture hydraulic conductivities derived using the two different aquifer thicknesses will be used later in an analysis of the uncertainty in the derived hydraulic conductivities.

An interesting feature of the aquifer response can be seen on Figure 3-5 for both tests. After cessation of pumping, the head rapidly recovers to slightly above the initial starting head. The head then declines back to the starting head, allowing for the small-scale earth tide variations. This behavior does not agree with the model for recovery, and has been interpreted as an effect resulting from the change in the temperature profile in the well as a result of pumping. As the temperature of the water in the upper part of the well is replaced by hotter water from the deeper completion interval, the average density of the water in the well decreases. This results in a compensatory increase in the water level. This adjustment is self-compensating for the pressure measurement of the water level above the PXD, which is set shallow in the well. However, the adjustment in the water column below the PXD shows up as an increase in head at the PXD depth in the pressure record. In this well this effect is on the order of .1 to .2 ft and does not make a significant difference in the analysis. In order to refine the analysis, the dataset used for analysis was adjusted to remove this effect so that the recovery curve approached but did not exceed the starting head.

The analysis in Section 2.5.3 for the upper completion interval hydraulic conductivity produced a value of about 690 +/- 428 ft^2/d, which is of the same order of magnitude as values derived from the pumping test analysis.

3.5 Interval Transmissivities/Conductivities

The flowmeter data provides a detailed assessment of the sections of the completion intervals producing water for determining the average hydraulic conductivity. In addition, the flowmeter data provides measurements to attribute varying production to the different screens. This data provides the basis for determining differences in hydraulic conductivity across different sections of the producing interval. This analysis will be used later in modeling flow in that aquifer.

3.5.1 The Borehole Flowmeter Method - Concept and Governing Equations

The borehole flowmeter measures the flow rate inside a well as a function of depth. When measurements are taken during pumping of the well, valuable information is obtained for interpreting the amount of water production coming from each screened interval of the geologic formation being tested. The basic concept and theory for interpreting borehole flowmeter logs is presented in Molz et al. (1989). Their work is based primarily on the previous work of Hufschmeid (1983) and Rehfeldt et al. (1989), who present detailed descriptions of the theory and application of the method.

Conceptually, as a well is pumped, water enters the well along the screen length, and the amount of water flowing inside the well at any depth is a function of the water that has entered the well. In the typical case of a pump located above the well screen, the amount of water flowing in the well will vary from zero at the bottom of the well to the well production rate (Q) above the screened interval. The change in flow rate between any two depths in the well is the amount of water that has been produced from that interval of the well. If certain assumptions are made, this water production profile can be used to estimate the hydraulic conductivity of the aquifer as a function of depth.

After a period of time following the start of pumping, the flow to the well is assumed to be horizontal. Javandel and Witherspoon (1969) used a finite-element model to show that flow to a fully screened well in a confined layered aquifer eventually became horizontal and that the drawdown in each layer eventually follows the Theis solution. The work of Javandel and Witherspoon (1969) assumes a constant head boundary condition at the well which ignores the effects of head losses in the well, the screen, and the filter pack. Nonetheless, the assumption of horizontal flow is necessary to derive an analytical solution to calculate depth-dependent hydraulic conductivity from the flow in the well.

For each vertical interval in the well, the Cooper and Jacob (1946) equation is assumed to govern the relationship between flow into the well and the aquifer parameters such that:

$$T_i = \frac{Q_i}{4\pi s_i} 1\mathrm{n}\left[\frac{2.25 K_i b_i t}{r_w^2 S_i}\right] \tag{3-5}$$

where:

K_i = Hydraulic conductivity of the interval
b_i = Thickness of the interval
T_i = Transmissivity of the interval and is defined by the product $K_i * b_i$
s_i = Drawdown in the aquifer for the interval
Q_i = Amount of flow from the interval into the well as determined from the flowmeter measurements

S_i = Storage coefficient for the interval
t = Time since pumping started
r_w = Effective radius of the well

In this form, the equation is difficult to use because the layer storage coefficient is unknown. Kabala (1994) proposed a double flowmeter method to simultaneously estimate K_i and S_i, but later (Ruud and Kabala, 1996) suggested the double flowmeter method produces inaccurate storage values and should not be used. Hufschmeid (1983) and Rehfeldt et al. (1989) assumed that the layer storage coefficient could be defined as a portion of the full storage coefficient, weighted by the transmissivity of each layer.

$$S_i = S\frac{K_i b_i}{Kb} \tag{3-6}$$

where:

S = Storage coefficient of the entire aquifer
K = Average hydraulic conductivity of the aquifer
b = Total aquifer thickness

This assumption amounts to a statement that the hydraulic diffusivity (T/S) of the aquifer is constant with depth. Substituting equation (3-6) into equation (3-5) leads to the equation for calculating the interval transmissivity as presented in Hufschmeid (1983) and Rehfeldt et al. (1989):

$$T_i = \frac{Q_i}{4\pi s_i} \ln\left[\frac{2.25Kbt}{r_w^2 S}\right] \tag{3-7}$$

The terms within the natural logarithm of equation (3-7) are determined from the full well response and are not dependent on interval-specific values. Molz and Young (1993), Kabala (1994) and Ruud and Kabala (1996) question the constant hydraulic diffusivity assumption and suggest it is a source of significant interpretation errors. Molz et al. (1989) and Molz and Young (1993) suggest that one alternative approach is to simply rely on the work of Javandel and Witherspoon (1969), and define the interval transmissivity as a simple ratio of the interval flow such that:

$$K_i b_i = \frac{Q_i}{Q} Kb \tag{3-8}$$

Molz and Young (1993) and Molz et al. (1989) fail to recognize that equation (3-8) can be obtained by dividing equation (3-7) by the Cooper-Jacob equation for the full aquifer thickness if one assumes, as did Javandel and Witherspoon (1969), that the drawdown in the well (s) is the same as the layer drawdown, (s_i). Therefore, equation (3-8) is merely a special case of equation (3-7) where the well losses are assumed to be zero. Molz et al. (1989) and Molz and Young (1993) do provide a second alternative approach based on the assumption that the specific storage is constant in the aquifer such that:

$$S_i = S\frac{b_i}{b} \tag{3-9}$$

Substituting equation (3-9) into equation (3-5) leads to an equation for the interval transmissivity of the form:

$$T_i = \frac{Q_i}{4\pi s_i} \ln\left[\frac{2.25K_i bt}{r_w^2 S}\right] \tag{3-10}$$

The only difference between equations (3-7) and (3-10) is the replacement of K with K_i within the logarithmic term. It is not clear which, if either, storage assumption is correct. To account for uncertainty, hydraulic conductivities were calculated for each storage assumption using equation (3-8) [(a special case of equation (3-7) and equation (3-10)].

3.5.2 Calculation Process to Determine Interval Hydraulic Conductivity Values

The steps for calculating the hydraulic conductivity of selected intervals in the well are presented in this section. The process begins with the determination of the average discharge for each screened section of well and ends with the calculation of the interval hydraulic conductivity. The steps are:

1. Selection of specific intervals in the well for which interval hydraulic conductivity is to be calculated.

2. Calculation of the interval hydraulic conductivity which is comprised of three main steps: (1) determine the average discharge for each blank section of well, then determine the total flow contributed by each section of well as the difference of flow in the blank sections above and below; (2) calculate the transmissivity of each screened section using the flowmeter derived flow and the drawdown in each section, corrected for well losses; and (3) determine the uncertainty in hydraulic conductivity

values for each screen section resulting from uncertainty in drawdown and contributing thickness.

3.5.3 Selection of Depth Intervals to Calculate Hydraulic Conductivity

To determine the hydraulic conductivity of an interval, the interval must be defined by top and bottom depths so inflow to the well can be determined. Previous applications of the flowmeter method (Rehfeldt et al., 1989; Hufschmeid, 1983; and Molz et al., 1989) calculated hydraulic conductivity at small intervals within fully screened wells in unconfined aquifers. One criterion to determine the size of the interval is to assess the minimum interval necessary to ensure that a statistically significant amount of flow enters the well between one flowmeter measurement and the next. The confidence intervals determined from equation (3-2) suggest that the difference in discharge should be about 1.72 gpm to be statistically significant. A criterion such as this would produce a variable interval, depending on inflow, that might be as small as 0.2 ft or as large as 10 ft or more.

In partially penetrating wells, or irregularly screened wells such as ER-EC-7, the horizontal flow assumption may not hold. Cassiani and Kabala (1998) examined flow to a partially penetrating well in an anisotropic confined aquifer where wellbore storage and infinitesimal skin may be present. They showed that, in their example, the flux near the end of the well screen could be exaggerated more than several times compared with elsewhere along the screen. Previous work by Ruud and Kabala (1996, 1997b) also showed that the flux to partially penetrating wells in heterogeneous aquifers can be significantly nonuniform and is a function of the hydraulic conductivity contrast of the adjacent layers. Ruud and Kabala (1997a) also examined the flow to a well in a layered aquifer with a finite skin interval. For their examples, they showed that the horizontal flow assumption inherent in the flowmeter analysis was violated and led to incorrect estimates of interval hydraulic conductivity values. The errors associated with violation of the horizontal flow assumption increase as the layer size decreases (i.e., the smaller the measurement interval). Another factor that may lead to errors is the head loss associated with flow through the borehole flowmeter itself. Ruud et al. (1999) show that head loss caused by the flowmeter can force water to flow in the filter pack outside the well and can lead to errors in measured flow.

For the WPM-OV wells where alternating screen and blank sections are present, the errors in estimated K values may be substantial if the analysis interval is too small. To avoid the need to quantify the potential errors for the WPM-OV wells, the decision was made to interpret the flowmeter response for each screened interval that produced statistically measurable flow. As stated before, Well ER-EC-7 has two screened intervals. Each screened interval is composed of a slotted section of pipe with slots beginning about 2.5 ft from both ends. The lengths of the slotted portions of these intervals are about 54 and 84 ft, respectively. Both screened intervals of Well ER-EC-7 produced measurable flow (greater than 1.72 gpm). Hydraulic conductivity values averaged over these slotted intervals are expected to provide adequate vertical resolution for the CAU-scale and sub CAU-scale models.

3.5.4 Calculation of Hydraulic Conductivity of Each Interval

The transmissivity of each interval is calculated using equations (3-8) and (3-10) prior to determining the hydraulic conductivity. The data requirements and the procedure are described.

3.5.4.1 Data Requirements

For a given pumping rate (Q), Equations (3-8) and (3-10) require a number of parameters to calculate interval transmissivities. These parameters include the following:

- Interval flow rates (Q_i)
- Term $r_w^2 S$.
- Drawdowns (sw and s_i) at selected times (t)
- Formation transmissivity
- Interval transmissive thicknesses (b_i)

Descriptions of each of these parameters are provided in the following text.

Interval Flow Rates (Q_i)

The quantities of inflow from each screen may be calculated from the flow in the well measured in the blank sections of pipe above and below each screen. The average discharges within the blank sections of pipe were determined for the portions of pipe centered between the ends of the blank section. This corresponds to a length of 15 ft for the upper blank section and 30 ft for the lower blank section. Since there is no blank casing section below the lower screen of Well ER-EC-7, all flow passing through the lower blank casing section is attributed to the lower screened interval. The average discharge values are tabulated in Table 3-5 for the blank casing sections and in Table 3-6 for the screens numbered one through two, beginning with the uppermost intervals. As seen in Table 3-5 and Table 3-6, all flow rates observed in Well ER-EC-7 are statistically different from zero (greater than 1.72 gpm). Therefore, hydraulic conductivity will be calculated for both screens.

The Term $r_w^2 S$.

The product $r_w^2 S$ is required in equation (3-10) and may be estimated using the Cooper-Jacob equation and data from the constant-rate test.

Table 3-5
Average Flow Rates Through the Blank-Casing Sections During the Flow Logging Runs of Well ER-EC-7

Pumping Rate = 66 gpm			
	Logging Run		
Blank Number	**ec7mov1**	**ec7mov3**	**Average**
1	67.44	65.41	66.42
2	58.16	56.24	57.20
Pumping Rate = 122 gpm			
	Logging Run		
Blank Number	**ec7mov5**	**ec7mov6**	**Average**
1	123.26	121.59	122.42
2	105.13	103.47	104.30
Pumping Rate = 178 gpm			
	Logging Run		
Blank Number	**ec7mov7**	**ec7mov8**	**Average**
1	178.83	176.54	177.69
2	150.36	148.62	149.49

Table 3-6
Average Flow Rates Through the Screened Sections During the Flow Logging Runs of Well ER-EC-7

Pumping Rate = 66 gpm			
	Logging Run		
Screen Number	**ec7mov1**	**ec7mov3**	**Average**
1	9.28	9.17	9.22
2	58.16	56.24	57.20
Pumping Rate = 122 gpm			
	Logging Run		
Screen Number	**ec7mov5**	**ec7mov6**	**Average**
1	18.13	18.12	18.12
2	105.13	103.45	104.30
Pumping Rate = 178 gpm			
	Logging Run		
Screen Number	**ec7mov7**	**ec7mov8**	**Average**
1	28.47	27.93	28.20
2	150.36	148.62	149.49

The Cooper-Jacob (1946) equation for flow to a well can be rearranged to produce:

$$\frac{1}{r_w^2 S} = \frac{1}{2.25Tt} \exp\left[\frac{4\pi sT}{Q}\right]$$

(3-11)

where:

Q	=	Discharge from the well
T	=	Transmissivity
s	=	Drawdown in the aquifer at the effective radius of the well
S	=	Storage coefficient
t	=	Time the drawdown was measured

Using equation (3-11) and known values of Q and T, it is possible to determine an approximate value of the product $r_w^2 S$ for any given time t.

Formation and Interval Drawdowns (s and s_i)

The formation drawdown is the drawdown observed at a given time t since pumping began at a given pumping rate Q, adjusted for well flow losses. Well flow losses were calculated using an average of the "Total Flow Losses at Center of Screen" presented in Table 3-4 weighted by the intervals' flow rates (Table 3-7). These weighted average well flow losses were substracted from the total drawdown to obtain an estimate of the formation drawdown for each pumping rate.

To capture the range of uncertainty associated with drawdowns during the flow logging, two values of drawdown were used for each pumping rate to assess the uncertainty associated with drawdown. The drawdowns in the well corresponding to a pumping rate of 126 gpm were obtained from the time-drawdown data recorded during the constant-rate test. Drawdowns in the well for the other two pumping rates were estimated using the Cooper-Jacob (1946) equation applied to the whole well. The drawdowns were calculated for the time period between 0.2 and 0.4 day, after pumping began. This period approximately corresponds to the time period during which the flow logs were conducted. The formation drawdown was calculated by substrating the weighted average flow loss in the well (shown in Table 3-7) from the well drawdown values described above.

The individual screen's formation drawdown (s_i) at the effective radius of the well are calculated as the drawdown in the well corrected for friction, entrance, and skin losses. These losses have been estimated previously and were presented in Table 3-4 and Table 3-7 as "Total Flow Losses at Center of Screen."

Table 3-7
Calculation of Average Well Losses For Each Pumping Rate

Q= 66 gpm			
Screen	**(1) Flow Rate into Well (gpm)**	**(2) Total Flow Losses at Center of Screen (ft)**	**(1) X (2)**
Screen 1	9	0.22	1.98
Screen 2	57	1.62	92.34
Total Flow	66		
Weighted Average Flow Loss in the Well = 1.429 ft			
Q= 122 gpm			
Screen 1	18	0.75	13.5
Screen 2	104	5.5	572
Total Flow	122		
Weighted Average Flow Loss in the Well = 4.799 ft			
Q= 178 gpm			
Screen 1	26	1.63	42.38
Screen 2	150	11.63	1744.5
Total Flow	176		
Weighted Average Flow Loss in the Well = 0.153 ft			

Transmissivity of the Formation

The transmissivity of the formation is the well transmissivity as calculated from the constant-rate test adjusted for well flow losses. An estimate of the formation transmissivity was then derived by multiplying the transmissivity derived from the constant-rate pumping test (Q=176 gpm) by the ratio of the formation drawdown to the well drawdown at t =0.0881 day. The well drawdown @ 0.0881 day is 18.78 ft. As shown in Table 3-7, the average well flow losses at an approximate pumping rate of 178 gpm are equal to 10.126 ft. The estimated formation losses are, therefore, equal to 8.654 ft. As a result, the ratio of the formation drawdown to the well drawdown is equal to 0.46. As reported earlier, the transmissivity derived from the constant-rate pumping test is equal to 2,209 ft^2/d. The derived estimate of formation transmissivity is 4,794 ft^2/d.

Individual Interval's Transmissive Thickness (b$_i$)

The interval thickness is not precisely known because flow to the screen may be derived, in part, from behind the blank section of pipe above or below the screen. The minimum contributing thickness is assumed to be the length of screen (54.25 ft for the upper screen and 84.15 ft for the lower screen) and the maximum is assumed to be equal to the lengths of the filter packs (112 for the upper screen and 126 for the lower screen).

3.5.4.2 Procedure and Results

For equation (3-10), the interval transmissivity is determined using an iterative approach. Equation (3-10) is solved iteratively by estimating K_i, then solving for T_i, dividing by b_i, and then substituting back into the equation. After 10 to 18 iterations, a value of T_i is determined. The Term $r_w^2 S$ is calculated using the formation transmissivity and a pair of known time-drawdown pair.

The interval hydraulic conductivities from equations (3-8) and (3-10) are given in Table 3-8 for each of the logging runs. The hydraulic conductivity of each interval is the interval transmissivity from equations (3-8) and (3-10) divided by the interval thickness.

Table 3-8
Interval Hydraulic Conductivities Calculated From Flow Logging Data for Well ER-EC-7

Logging Run	Screen	Interval Thickness = Length of Screen				Interval Thickness = Length of Filter Pack			
		Interval Thickness (ft)	Hydraulic Conductivity (ft/d)			Interval Thickness (ft)	Hydraulic Conductivity (ft/d)		
			(Equation 3-10)		(Equation 3-8)		(Equation 3-10)		(Equation 3-8)
			$s_{t=0.2\,d}$[a]	$s_{t=0.4\,d}$[b]	-		$s_{t=0.2\,d}$	$s_{t=0.4\,d}$	-
ec7mov1	Screen 1	54.25	7.59	7.94	12.48	112	3.68	3.84	6.04
ec7mov3	Screen 1	54.25	7.58	7.95	12.46	112	3.67	3.85	6.04
ec7mov5	Screen 1	54.25	6.26	6.69	13.13	112	3.03	3.24	6.36
ec7mov6	Screen 1	54.25	6.28	6.70	13.15	112	3.04	3.24	6.37
ec7mov7	Screen 1	54.25	5.64	5.73	14.17	112	2.73	2.78	6.87
ec7mov8	Screen 1	54.25	5.52	5.61	13.90	112	2.67	2.72	6.74
ec7mov1	Screen 2	84.15	56.35	55.73	50.44	126	37.63	37.22	33.62
ec7mov3	Screen 2	84.15	56.26	55.80	50.35	126	37.57	37.26	33.66
ec7mov5	Screen 2	84.15	59.57	58.53	49.08	126	39.78	39.09	32.81
ec7mov6	Screen 2	84.15	58.67	57.65	48.40	126	39.18	38.50	32.35
ec7mov7	Screen 2	84.15	63.23	63.05	48.25	126	42.23	42.11	32.25
ec7mov8	Screen 2	84.15	62.45	62.28	47.70	126	41.71	41.59	31.89

[a] Drawdown in the well 0.2 days after pumping started
[b] Drawdown in the well 0.4 days after pumping started

3.5.5 Sources of Uncertainty

Uncertainty in the interval hydraulic conductivity values comes from primarily two sources: uncertainty in the model and uncertainty in parameters.

The model uncertainty is principally the result of violations of key model assumptions such as the applicability of the Cooper-Jacob equation describing horizontal flow to the well. As Ruud and Kabala (1997a and b), Cassiani and Kabala (1998), and Ruud et al. (1999) note, vertical flow may occur in the vicinity of the well due to heterogeneity, head losses, well skin effects, and partially penetrating screens. Each of these can lead to errors in the calculated interval hydraulic conductivity when using the horizontal flow assumption. Many of the errors due to small-scale vertical flow have been minimized in this work by integrating flowmeter responses over the length of each screened section. Other sources of model uncertainty include the assumed form of the interval storage coefficient. The impact of the latter assumptions are presented in Table 3-8.

The parameter uncertainty comes from uncertainty in the flow rate, the drawdown, and the parameters within the logarithm of equation (3-10). The flow rate determined from the flowmeter and line speed measurements is accurate to within about plus or minus 1.72 gpm. This means that flow uncertainty is a small factor for the lower interval which produced the most water, but could be a significant factor, up to perhaps 25 percent of the value for the upper screen. The drawdown in the aquifer is uncertain because it relies on corrections for well losses, both inside and outside the well. The well loss corrections are similar down the well, but the impact of the uncertainty will be larger for the upper screen which has a lower flow rate.

The parameters within the logarithmic term of equation (3-10) are another source of uncertainty. The time at which flowmeter measurements are taken relative to the total time of pumping will influence calculated hydraulic conductivity as will the estimate for the effective radius-storage coefficient product. As seen in equation (3-10), time is a parameter in this equation. If the time of measurement is long after pumping began, the change in drawdown and well hydraulic condition will be small both during the logging run and between logging runs. If one logging run is made too close to the start of pumping, it seems likely that parameters from that run could differ from later runs. Table 3-8 summarized the hydraulic conductivity for each interval for each logging run using a range of interval thickness and a range of drawdowns. As can be seen, for a given screen, the differences between logging runs is quite small, considering that the logging runs were made at different times after pumping began. Therefore, the time of measurement was not a significant source of error in the interpretation. This is consistent with the expectation that the effect of these parameters is not too large because the logarithm has the effect of moderating the impact.

Perhaps the single biggest source of uncertainty is the selection of the length of the contributing interval for each screen. As noted earlier, the thickness could vary between 54 and 126 ft. This uncertainty in the thickness of the transmissive interval produces an uncertainty in interval hydraulic conductivity that is about a factor of two for Well ER-EC-7.

In summary, the interval hydraulic conductivity values are uncertain, with greater uncertainty associated with the small hydraulic conductivity interval (upper screened interval). The interval hydraulic conductivity values are probably no more accurate than about a factor of 2 to 6. This range is quite good when compared with the range of hydraulic conductivity values presented in the regional groundwater model report (DOE/NV, 1997), where values of hydraulic conductivity for volcanic units ranged over more than seven orders of magnitude.

3.6 Comments on the Testing Program and the Well Design

The pumping test in this multiple-completion well worked fairly well, yielding results for both completion intervals. This is a different result from Wells ER-EC-1 and ER-EC-6, for which results were limited to the upper completion intervals. This is apparently the result of a combination of factors which allowed the hydraulics of the well operation to significantly affect both completion intervals. These factors include the greater hydraulic conductivity in the lower completion interval, the not-too-dissimilar hydraulic conductivities of the two intervals, and sufficient drawdown to observe responses above the noise level.

The smaller inside diameter of the fiberglass casing of this well was found to conflict with the specifications of the borehole flowmeter, resulting in problems and uncertainties in the flow logging results. The use of the flow logging results is based on judgement as to what information may be accurate, although the meter was operating in an improper condition.

The head adjustment data collected during the bridge plug head measurements were used to calculate hydraulic conductivities for both completion intervals that compare reasonably with the results from the flow log analysis. Perhaps some effort should be put into improving procedures used for this work to improve the results. And this methodology may be useful by itself to test wells that will not be tested with pumping test methodology.

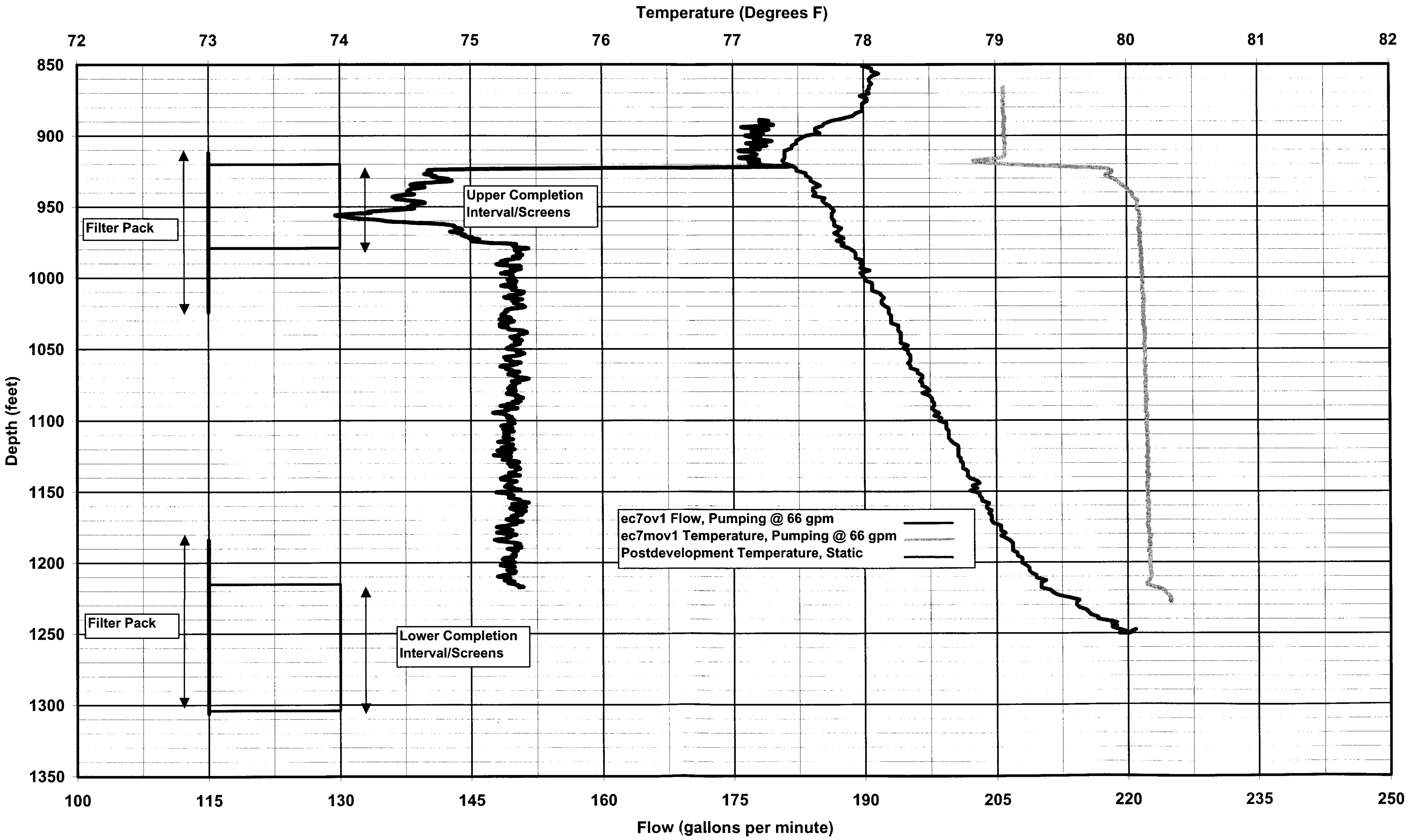


Figure 3-1
Pumping Temperature and Flow Logs

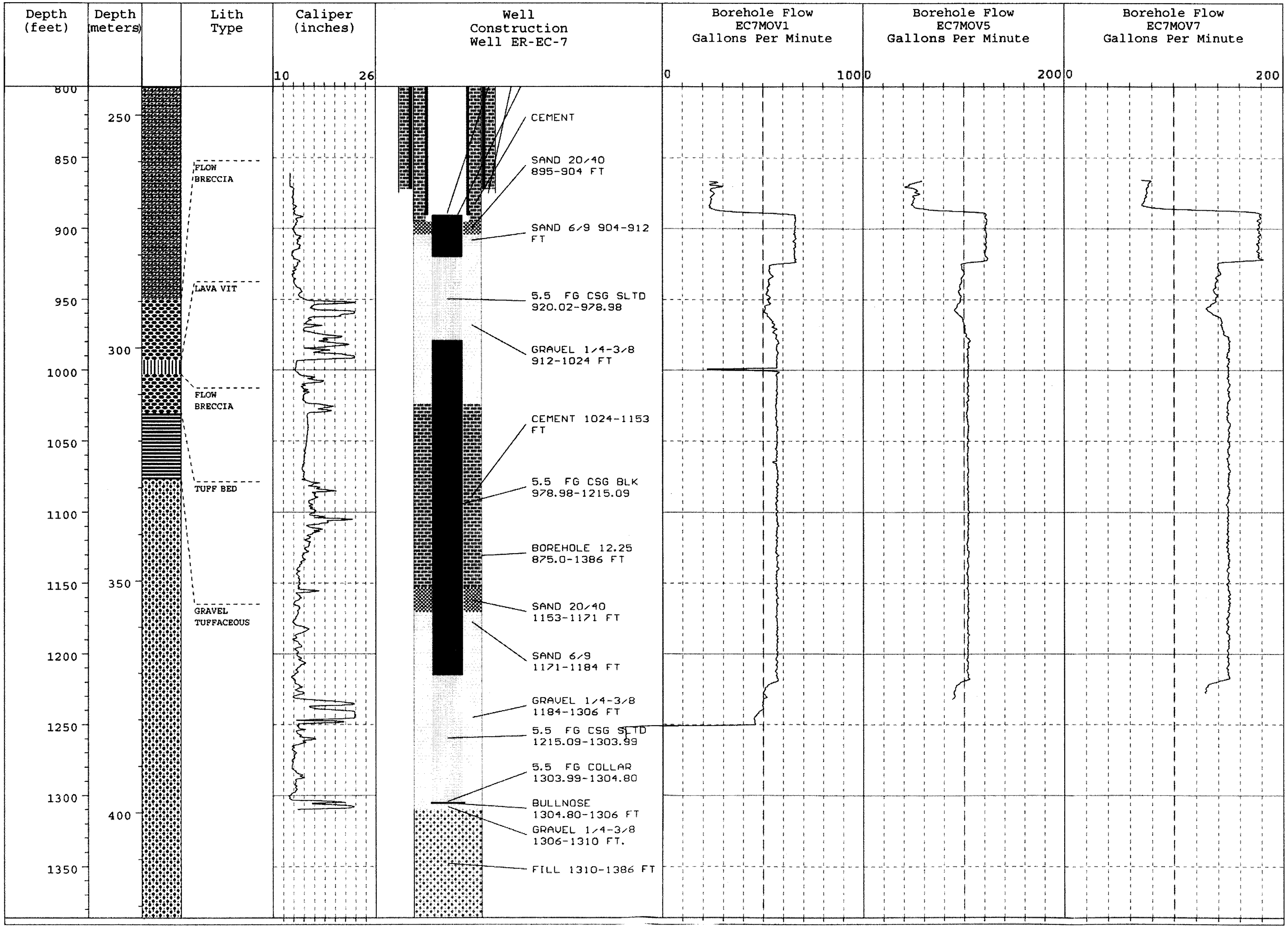


Figure 3-2
Geology and Well Construction in the Completion Interval

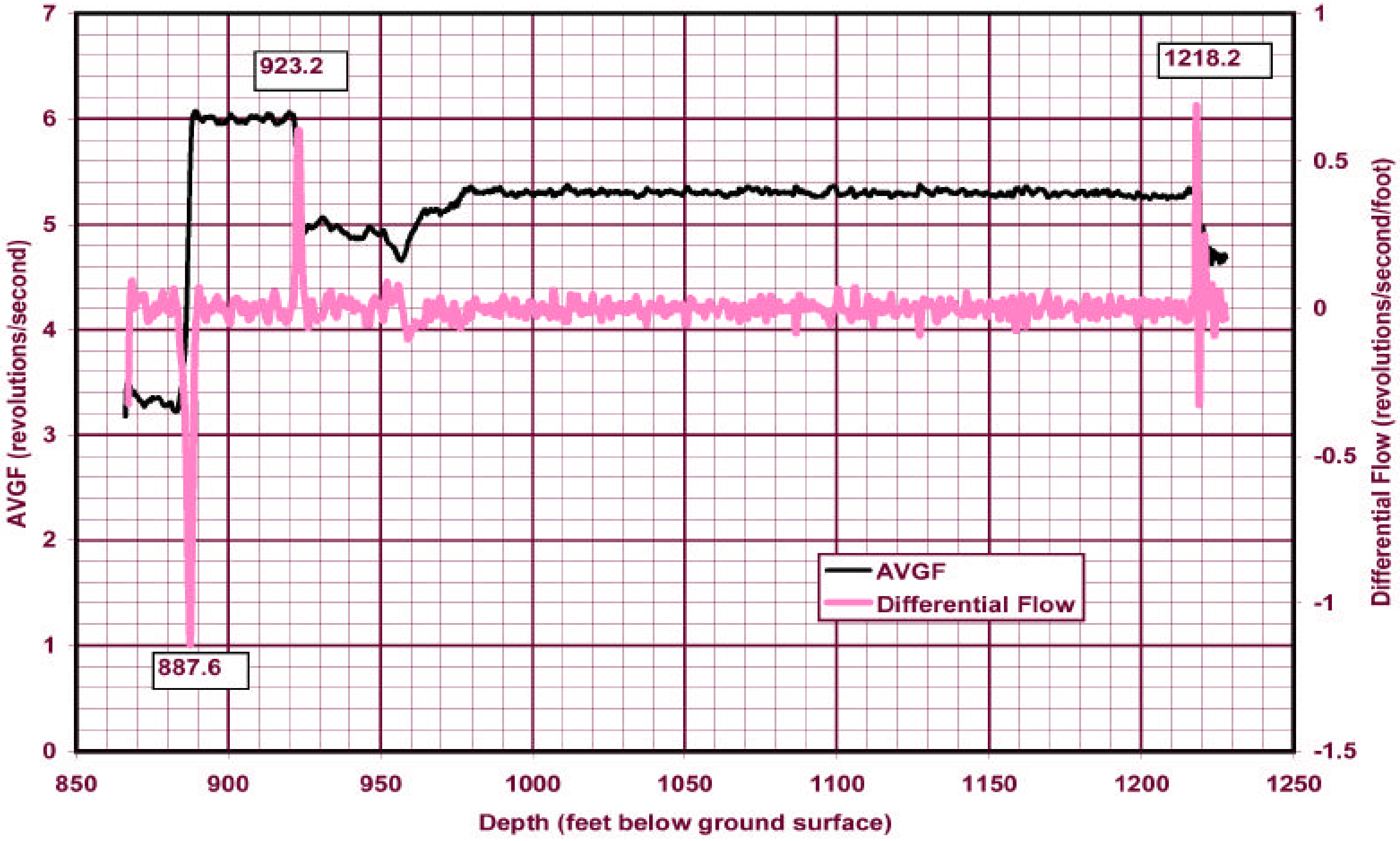


Figure 3-3
Example of Differential Flow Log Superposed on Flow Log (Flow Log ec7amov8)

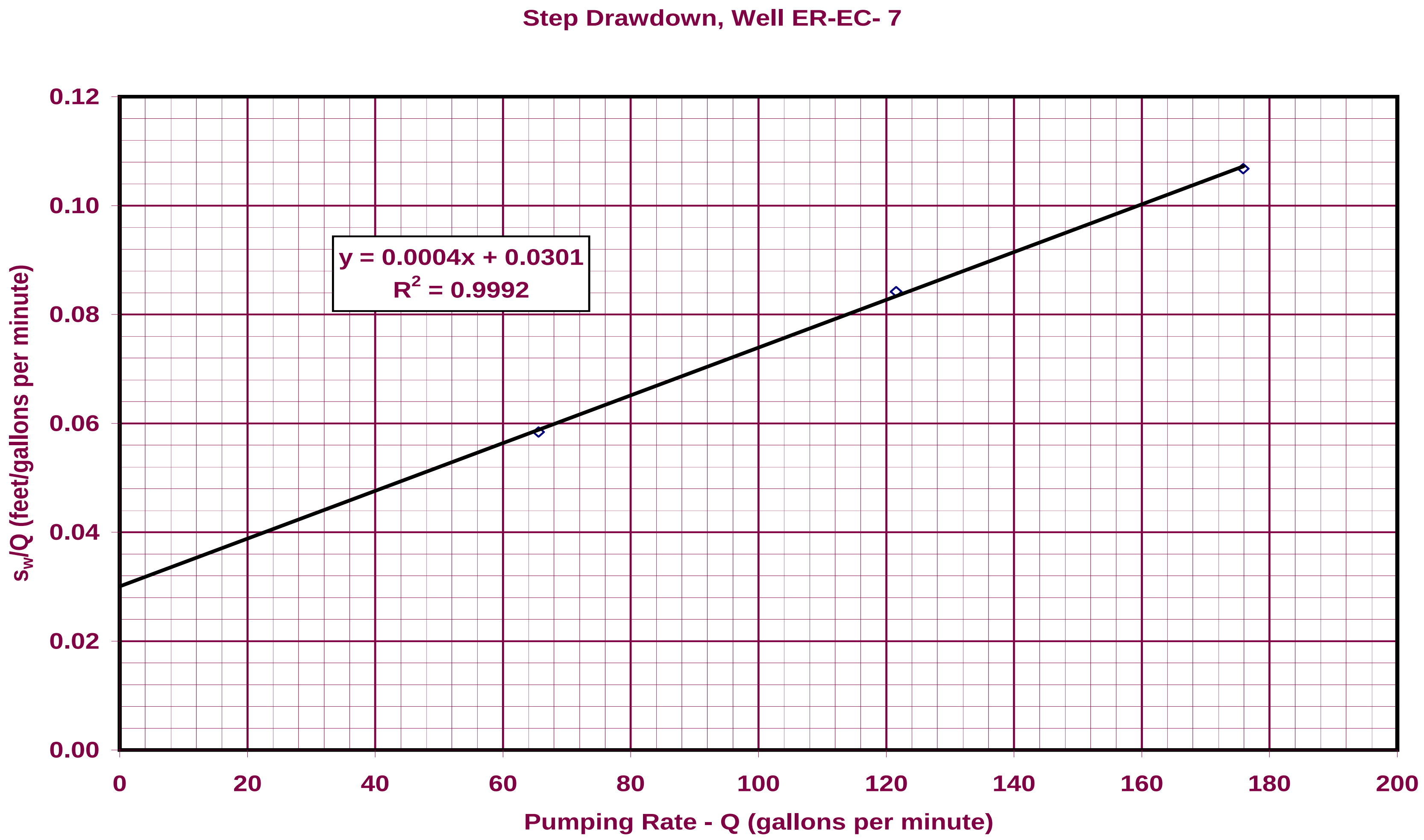


Figure 3-4
Step-Drawdown Analysis

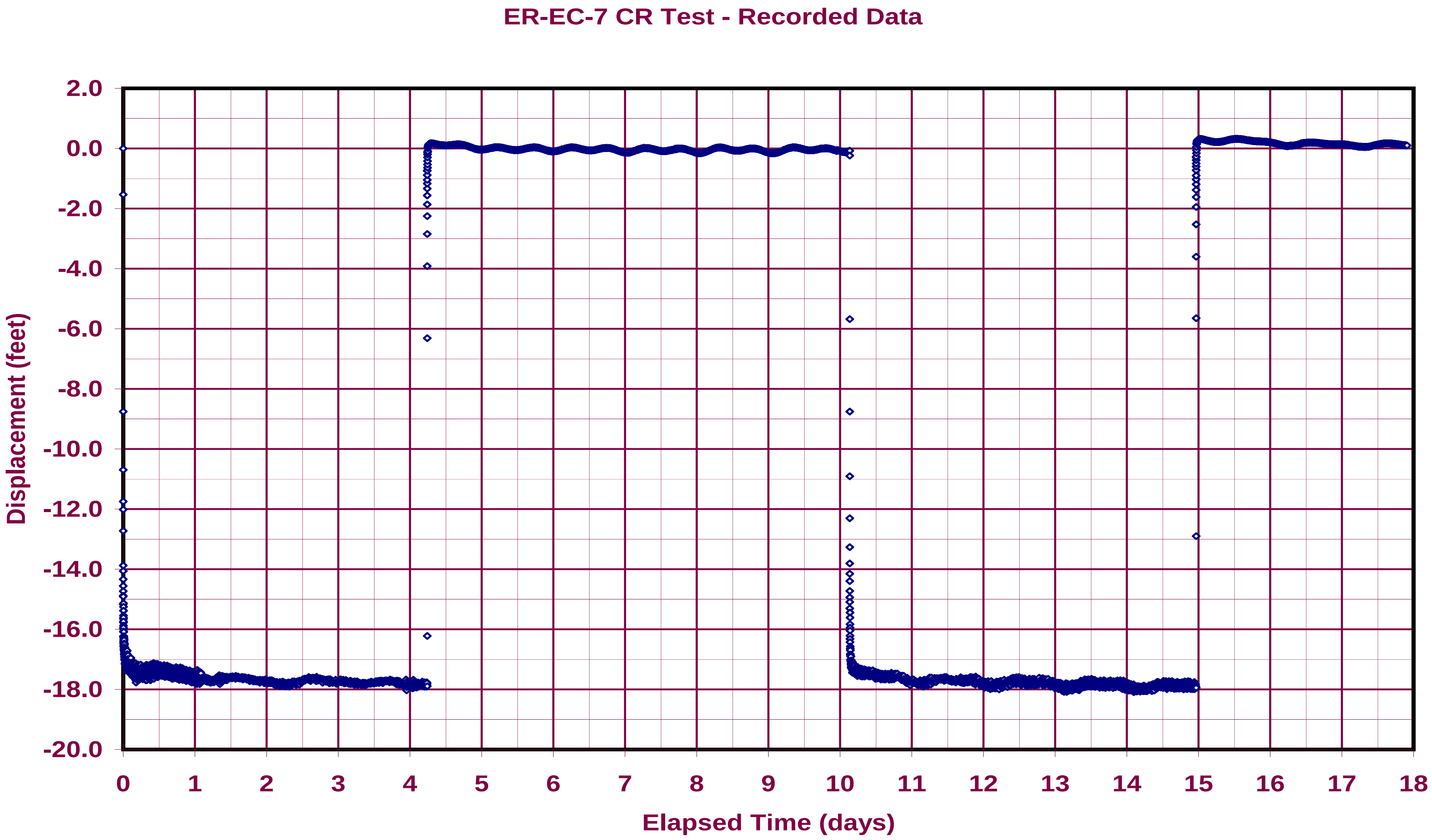
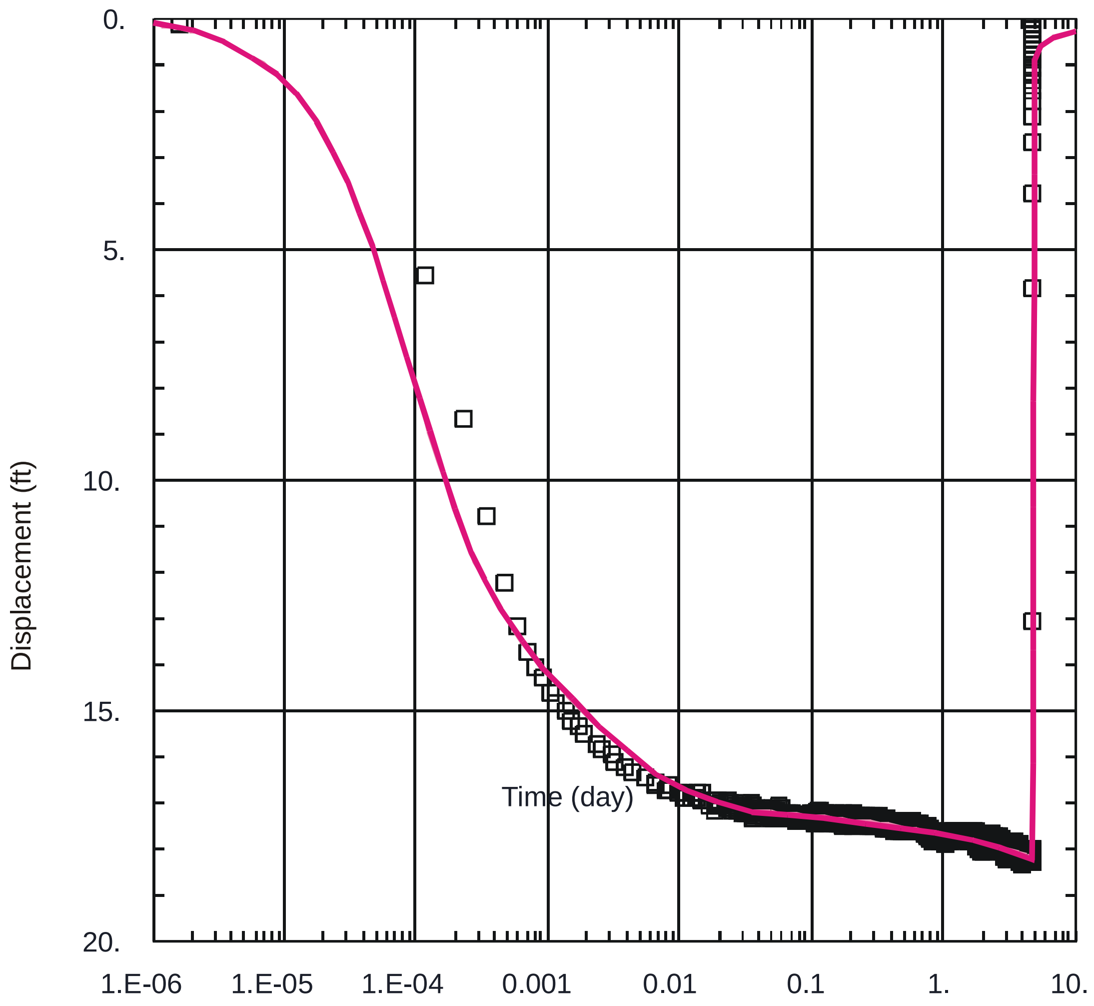


Figure 3-5
Constant-Rate Test Data



Well ER-EC-7

Constant-Rate Test
Production Rate 175.96 GPM
Aquifer Thickness 238 ft

Aquifer Model

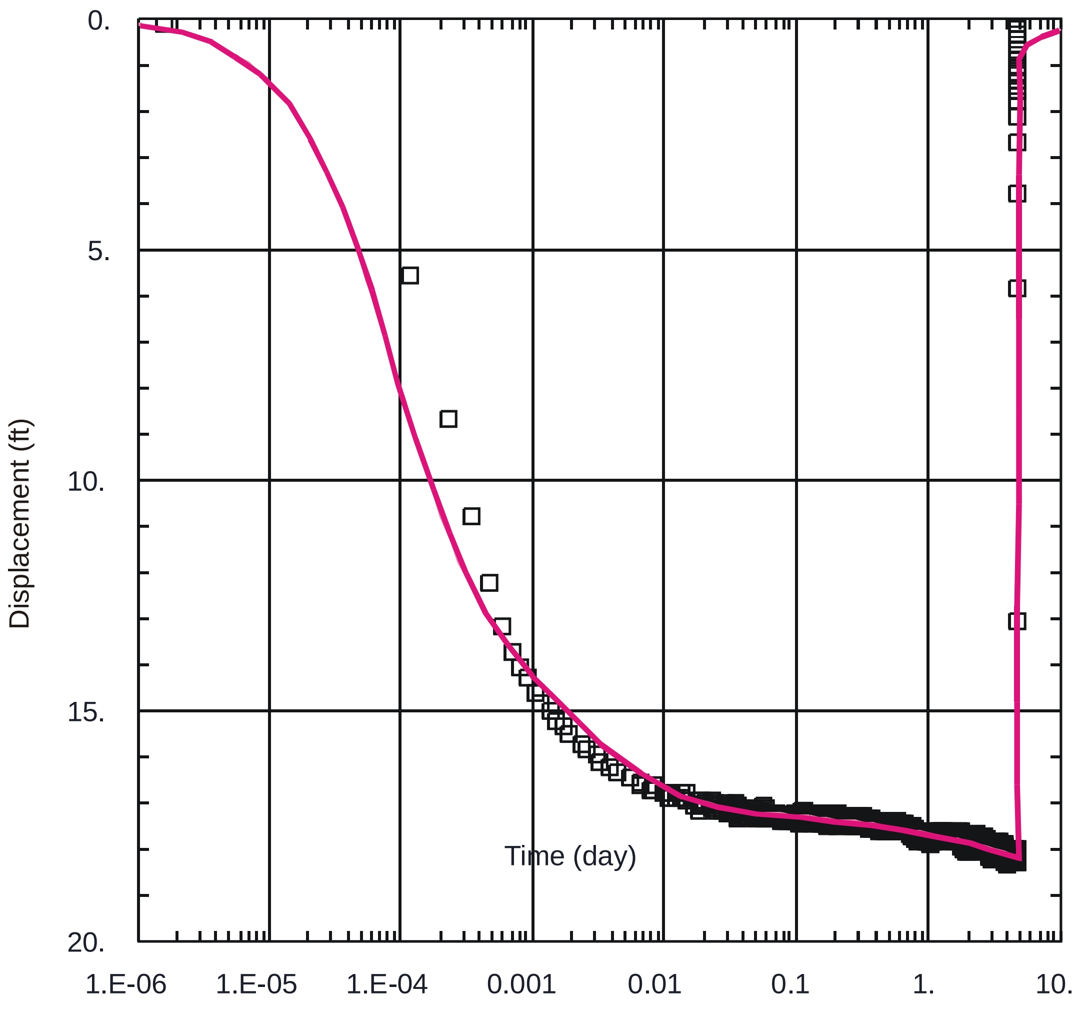
Dual-Porosity
Moench w/slab blocks

Parameters

K = 9.28 ft /day
Ss = 5.188E-07 ft^{-1}
K’ = 2.982E-05 ft /day
Ss’ = 0.0004504 ft^{-1}
Sw = 0.
Sf = 0.2971

K - Fracture Hydraulic Conductivity
Ss - Fracture Specific Storage
K’ - Matrix Hydraulic Conductivity
Ss’ - Matrix Specific Storage
Sw - Well Skin
Sf - Fracture Skin

Figure 3-6
Dual-Porosity Analysis of Second Constant-Rate Test - Filter Pack



Well ER-EC-7

Constant-Rate Test
Production Rate 175.96 GPM
Aquifer Thickness 138 ft

Aquifer Model

Dual-Porosity
Moench w/slab blocks

Parameters

K = 15.99 ft /day
Ss = 8.974E-07 ft^{-1}
K’ = 4.029E-05 ft /day
Ss’ = 0.00101 ft^{-1}
Sw = 0.
Sf = 0.2307

K - Fracture Hydraulic Conductivity
Ss - Fracture Specific Storage
K’ - Matrix Hydraulic Conductivity
Ss’ - Matrix Specific Storage
Sw - Well Skin
Sf - Fracture Skin

Figure 3-7
Dual-Porosity Analysis of Second Constant-Rate Test - Screens

4.0 Groundwater Chemistry

This section presents an evaluation of the analytical results for the groundwater characterization samples collected during well development and hydraulic testing activities at Well ER-EC-7. Both a discrete bailer and a well composite groundwater sample were collected at this site. The purpose of the discrete bailer sample was to target a particular depth interval for sampling under either static or pumping conditions, while the purpose of the composite sample was to obtain a sample that was as representative of as much of the open intervals as possible. The results from these two groundwater characterization samples were used to examine the overall groundwater chemistry of the well and to compare this groundwater chemistry to that of other wells in the area. The groundwater chemistry results were also evaluated to establish whether Well ER-EC-7 was sufficiently developed to restore natural groundwater quality in the formation around the well.

4.1 Discussion of Groundwater Chemistry Sampling Results

The groundwater chemistry of Well ER-EC-7 will be discussed in this section, and then compared to the groundwater chemistry of other nearby wells.

4.1.1 ER-EC-7 Groundwater Characterization Sample Results

On April 28, 2000, one discrete bailer sample (#EC-7-042800-3) was obtained from a depth of 1,200 ft below ground surface (bgs), just above the lower screened interval, at a pumping rate of approximately 176 gpm. The sample was obtained using a DRI logging truck and a discrete bailer (see Section A.2.10.1 of Appendix A). On June 5, 2000, a composite groundwater characterization sample (#EC-7-060500-1) was collected from the wellhead sampling port directly into sample bottles. A constant production rate of 44 gpm was maintained during the sampling event. At the time of composite sampling, approximately $3.6\text{x}10^6$ gallons of groundwater had been pumped from the well during development and testing activities (see Section A.2.10.2 of Appendix A). The results from these two samples have been tabulated and are presented in Table ATT.3-1, Table ATT.3-2, and Table ATT.3-3 in Attachment 3, Appendix A.

Inspection of the table reveals that both groundwater characterization samples have relatively similar analytical results. For example, it can be seen in the total and dissolved columns of the “Metals” section that both groundwater characterization samples have extremely similar silicon concentrations. The discrete bailer sample had estimated silicon concentrations of 20 milligrams per liter (mg/L), while the composite groundwater characterization sample had a silicon concentration of 21 mg/L. In addition, it can be seen from the "Metals" section of the table that sodium, calcium, and potassium are the predominate cations in both groundwater characterization samples with sodium having the highest concentration. The table also reveals in the "Inorganics" section that bicarbonate, sulfate, and chloride are the predominate anions in both groundwater characterization samples with bicarbonate having the highest concentration. Further examination of Table ATT.3-1, Attachment 3, Appendix A reveals that both groundwater characterization samples have a slightly basic pH with the composite groundwater sample having the highest estimated pH of 8.3. Both groundwater characterization samples also have relatively similar electrical conductivities. It can be seen in Table ATT.3-1, Attachment 3, Appendix A; however, that a significant number of the analytes were not detected at the given detection limits as indicated by the "U" qualifier. In addition, the table shows that for the discrete bailer sample almost all of the results in the "Metals" and "Inorganics" sections have been qualified with the "J" qualifier. The "J" qualifier was assigned to most analytes because there was no documentation that the samples' environmental temperatures were kept at the appropriate temperature.

Inspection of the "Age and Migration Parameters" section of the table for the composite groundwater sample reveals several interesting things. For example, the helium-3 (^{3}He)/^{4}He ratio in Well ER-EC-7 groundwater (R=1.18×10^{-6}) is less than the atmospheric ratio (R_a=1.38×10^{-6}), giving a R/R_a value of 0.86. According to Lawrence Livermore National Laboratory (LLNL) (2001), this value indicates a general lack of magmatic or tritium-derived ^{3}Helium (He) in the groundwater characterization sample. LLNL (2001) also states that the ^{4}He concentration in Well ER-EC-7 groundwater (7.45×10^{12} atoms per milliliter [atoms/mL]) is greater than the predicted recharge concentration. They state that at a recharge elevation of 2,000 meters (m) and a temperature of 10 degrees Celsius (^{o}C), the expected ^{4}He concentration in the groundwater is approximately 1.0×10^{12} atoms/mL. Higher ^{4}He concentrations reflect the *in situ* α-decay of naturally occurring radioactive elements in the host rock (LLNL, 2001). It can also be seen from the table that the carbon-14 (^{14}C) value of dissolved inorganic carbon (DIC) in Well ER-EC-7 groundwater is 36.5 percent modern, giving an uncorrected ^{14}C age of 8,325 years. LLNL (2001) also stated the δ^{13}C value suggests a partial equilibrium of the groundwater with carbonate minerals occurring along fractures in the volcanic aquifers. Finally, it was noted by LLNL (2001) that the chlorine-36 (^{36}Cl)/Cl value of 1.18×10^{-12} is elevated compared to other environmental samples from the Nevada Test Site region. However, they state that the lack of tritium in the sample indicates the ^{36}Cl is unrelated to weapons testing, and suggests the most likely source is natural neutron activation of ^{35}Cl due to the uranium-thorium series decay in the aquifer host rock (LLNL, 2001).

Table ATT.3-2, Attachment 3, Appendix A presents the results of the colloid analyses for Well ER-EC-7. The table shows that the discrete bailer characterization sample had a total colloid concentration that was approximately twice as large as the total colloid concentration for the composite groundwater characterization sample. Specifically, the table reveals that the discrete bailer sample had a total colloid concentration of 9.92×10^6 particles per milliliter (particles/mL) for particles in the size range of 50 to 1,000 nanometers (nm). The composite groundwater characterization sample, on the other hand, had a total colloid concentration of 4.59x10^6 particles/mL for colloids in the size range of 50 to 1,000 nm. It can also be seen in the table that the discrete bailer sample had greater colloid concentrations for each particle size range as well as for the total colloid concentration. Further inspection of the table reveals that the colloid concentrations decrease, in general, as the particle size range increases for both groundwater characterization samples.

While the two groundwater characterization samples have relatively similar analytical results, there are some notable differences that can be seen in Table ATT.3-1, Attachment 3, Appendix A. For example, one potential discrepancy between the two groundwater characterization samples can be seen in the oxidation-reduction sensitive parameters iron and manganese. It can be seen in the table that the concentrations of iron and manganese in the discrete bailer sample are significantly higher in the total analyses than in the dissolved analyses. This indicates that iron and manganese are predominantly present in the total phase rather than the dissolved phase. Further inspection of the table, however, reveals that the total and dissolved concentrations of iron and manganese in the composite groundwater sample are similar discounting the fact that the analytes were not detected at the given minimum detectable limit. This implies that the analytes in the composite groundwater sample are predominantly present in the dissolved phase. This discrepancy between the two samples may potentially be a result of the greater colloidal fraction present in the discrete bailer sample, or, maybe, an oxidation-reduction change in the groundwater sample between when the discrete bailer sample is collected and when it is filtered at the ground surface. Another notable difference between the two groundwater characterization samples can be seen in the sodium concentration of both samples. The discrete bailer sample had an estimated sodium concentration of 47 mg/L for the total analyses and 48 mg/L for the dissolved analyses. The composite groundwater sample, however, had sodium concentrations of 28 mg/L for the total analyses and 27 mg/L for the dissolved analyses. It can be seen from these results that the discrete bailer sample has sodium concentrations that are at least 1.5 times greater than the composite groundwater sample. The differences in the sodium concentrations between the two characterization samples may be an artifact of sampling, or they may represent an actual geochemical difference between the two groundwater samples.

In general, the geochemical compositions of the two groundwater characterization samples are typical for wells that penetrate volcanic rocks. These types of rocks tend to impart high concentrations of sodium and bicarbonate to groundwaters. Preliminary lithologic logs for the well indicated that the completion intervals for this well were completed in rhyolitic lavas and tuffaceous moat-filling gravels (DOE/NV, 2000).

4.1.2 Radionuclide Contaminants

Radiologic indicator parameters were not detected in the groundwater characterization samples from Well ER-EC-7.

4.1.3 Comparison of ER-EC-7 Groundwater Chemistry to Surrounding Wells

Table 4-1 presents groundwater chemistry data for Well ER-EC-7 and recently collected samples from wells in close proximity to Well ER-EC-7. Shown in the table are the analytical results for selected metals, anionic constituents, field measurements, and several radiological parameters. The data in this table were used to construct the trilinear diagram shown in Figure 4-1. Trilinear diagrams contain three different plots of major-ion chemistry and are used to show the relative concentrations of major ions in the groundwater. The triangular plots in Figure 4-1 show the relative concentrations of major cations and anions. The diamond-shaped plot in the center of the figure combines the information from the adjacent cation and anion triangles. The concentrations in all three plots are expressed in percent milliequivalents per liter and are used to illustrate various groundwater chemistry types, or hydrochemical facies, and the relationships that may exist between the types. Examination of the cation triangle reveals that the predominant cation type for Well ER-EC-7 and the surrounding wells can be classified as sodium (or potassium) type. It can be seen from the cation triangle; however, that the cation concentrations for Well ER-EC-7 have a greater concentration of calcium than most of the nearby wells. This is shown by Well ER-EC-7 groundwater compositions plotting farther to the left in the Na+K zone than any of the other nearby wells. In fact, the cation concentrations for the composite groundwater characterization sample almost fall out of the sodium type groundwater zone. Further inspection of Figure 4-1 and the anion triangle reveals that the predominant anion type for Well ER-EC-7 and the surrounding wells can be classified as bicarbonate type. The anion concentrations for all of the wells, however, tend to plot fairly close to each other as opposed to the cation concentrations that tended to plot along a straight line in the cation triangle. Regardless, Figure 4-1 shows that the groundwater chemistry for Well ER-EC-7 is relatively similar to surrounding wells at least in terms of the major ionic constituents even with the greater calcium concentrations.

The chemistry data in Table 4-1 were also used to construct Figure 4-2. The figure shows the stable oxygen and hydrogen isotope compositions of groundwater for Well ER-EC-7 and for selected sites within twelve and a half miles of ER-EC-7. Also plotted on Figure 4-2 are the weighted averages of precipitation for various sites on Buckboard Mesa, Pahute Mesa, Rainier Mesa, and Yucca Mountain based on data from Ingraham et al. (1990) and Milne et al. (1987). As can be seen from the figure, the precipitation data, as expected, lie along the local and global meteoric water lines of Ingraham et al. (1990) and Craig (1961), respectively. It can be seen from the figure, however, that there is substantial variability associated with the stable oxygen and hydrogen isotopes for Well ER-EC-7 and its nearby neighbors. In fact, the data for several of the nearby wells and Well ER-EC-7 plot within the same range as the precipitation data. This suggests that those wells are showing direct influence from atmospheric recharge. Other wells, however, plot isotopically lighter than the precipitation data, suggesting no influence of atmospheric recharge. One possible explanation for the isotopically lighter groundwater of these wells is that the recharge areas for the groundwater in those wells are located north of Pahute Mesa. Rose et al. (1998) report that the oxygen and hydrogen isotope composition of Pahute Mesa groundwater is similar to the composition of groundwater and alpine spring water

Table 4-1
Groundwater Chemistry Data for Well ER-EC-7 and Surrounding Sites

Analyte	ER-EC-7				Coffer's Ranch, Windmill Well	ER-30-1-1	ER-30-1-2	ER-OV-03c	Gexa Well #4	UE-18r	UE-25 WT #15	UE-25 WT #4	UE-25b #1 HTH	UE-29a #1 HTH	UE-29a #2 HTH	USW G-2	USW G-4	USW H-1 (HTH)	USW H-5	USW H-6 (HTH)	Water Pipe Butte
	(Bailer)		(Wellhead Composite)																		
	Total	Dissolved	Total	Dissolved																	
Metals (mg/L)																					
Aluminum	UJ 0.067	UJ 0.053	U 0.039	U 0.038	0.0009	< 0.0532	< 0.0532	0.0035		< 0.06				0.0026	0.0016						
Arsenic	J 0.0042	J 0.0056	B 0.0072	B 0.0047	0.00836	0.009	0.01	0.0153	0.014	< 0.1				0.00582	0.0022						
Barium	J 0.0067	J 0.0067	UJ 0.0047	UJ 0.0045	0.00161	B 0.0046	B 0.0046	0.00163	0.018	20				0.00205	0.00013	< 0.002					
Cadmium	UJ 0.005	UJ 0.005	U 0.005	U 0.005	0.000019	< 0.0024	< 0.0024	0.000024	< 0.01					0.000016	< 0.000016	< 0.001					
Calcium	J 23	J 22	20	20	19.3	5.64	5.32	14.4	11	21.5	12	10	18	14.7	11.1	7.7	13	9.9	1.9	4.7	
Chromium	J 0.006	UJ 0.0016	B 0.0013	B 0.0013	0.00013	B 0.0054	< 0.0041	0.00042	< 0.001					0.00139	0.00027	< 0.005					
Iron	J 0.74	UJ 0.066	U 0.048	U 0.036	0.1933	0.0964	0.209	0.0023	0.015	< 0.02				0.0046	0.0173	0.062					
Lead	UJ 0.003	UJ 0.003	UJ 0.003	UJ 0.003	0.000274	0.006	B 0.0013	0.000058	< 0.1	< 0.01				0.000008	0.00001	< 0.01					
Lithium	J 0.054	J 0.054	0.033	0.033	0.12	B 0.0647	B 0.0616	0.119		0.08	0.38	0.05	0.12	0.038	0.038	0.043	0.067	0.09	0.062	0.063	
Magnesium	J 1.5	J 1.5	1.6	1.7	0.21	0.555	0.502	0.4	0.34	0.92	1.7	0.8	0.72	2.17	1.39	0.47	0.2	1.5	0.01	0.07	
Manganese	J 0.012	J 0.0029	UJ 0.00053	UJ 0.00031	0.0082	0.0101	0.015	0.0005	0.01	< 0.03				0.0006	0.0049	0.042					
Potassium	J 2.5	J 2.6	2.9	2.9	0.91	0.938	1.235	1.19	3.1	3.49	4.6	5	2.8	4.02	2.88	5.3	2.1	1.8	2.1	1.4	
Selenium	UJ 0.005	UJ 0.005	U 0.005	U 0.005	0.00053	< 0.01	< 0.01	0.00049	< 0.001	< 0.01				0.00089	0.00049						
Silicon	J 20	J 20	21	21		11	11.3		48	21.6	53	57	51			51	45	49	48	49	
Silver	UJ 0.01	UJ 0.01	U 0.01	U 0.01	0.00002	< 0.0059	< 0.0059	0.00001	< 0.001					< 0.00001	< 0.00001	0.001					
Sodium	J 47	J 48	28	27	72.2	65.11	59.6	80	73	73.1	62	45	46	36.9	37.7	46	57	78	60	88	
Strontium	J 0.16	J 0.15	0.11	0.11	0.181	B 0.019	B 0.0193	0.0973	0.03384	0.08			0.047	0.0515	0.0299	0.0101	0.017	0.06	0.009	0.008	0.0345
Uranium	UJ 0.2	UJ 0.2	U 0.2	U 0.2	0.00586	< 0.106	< 0.106	0.00401	0.0039	0.0035			0.047	0.00132	0.00056	0.00118					0.000157
Mercury	UJ 0.0002	UJ 0.0002	UJ 0.0002	UJ 0.0002		< 0.0001	< 0.0001	0.0002	< 0.0001												
Inorganics (mg/L)																					
Chloride	J 7		4.7		7.6	6.75	6.71	17.5	14	6.9	12	8.2	7.5	7.7	7.9	6.5	5.9	10	6.1	7.4	
Fluoride	J 1.9		1.1		3.29	1.39	1.46	4.55	3	3		1.8	1.6	0.62	0.63	1	2.5	2.7	1.4	4.7	
Bromide	J 0.075		U 0.2		0.035	< 0.25	< 0.25	0.066						0.081	0.092	0.04					
Sulfate	J 22		14		31	13.2	12	44	44	23	16	22	21	16	15	15	19	44	16	32	
pH	J 8.1		J 8.3		8.43	8.79	8.93	8.39	7.9	8.05	7.5	7.27	7.7	8.01	8.3	7.5	7.7	7.5	7.8	8.3	
Total dissolved solids	J 220		160		194	186	200	218	263.4615	208			221.514	133	126	198.7					
Carbonate as CaCO3	UJ 5		U 10			18.1	20.1														
Bicarbonate as CaCO3	J 130		96		189	113	85	164	154	227	166	119	138	111	112	121	139	158	124	184	
Age and Migration Parameters (pCi/L) - unless otherwise noted																					
Carbon-13/12 (per mil)	N/A		-8		-3.4	-7.4	-8.2	-2.9		-1.4	-11.8	-12.7	-8.6	-9.93	-10.46	-11.8	-9.1	-11.4	-10.3	-7.1	-13.1
Carbon-14, Inorganic (pmc)	N/A		36.5		9.6	44.68	44.5	6.8		6.7 +/- 0.06	21.6	24.1	18.9	75.7	72.9	20.5	22	22.4	21.4	12.4	103.7
Carbon-14, Inorganic age (years)*	N/A		8,325		19350			22280					13400	2302	2612		12160				
Chlorine-36	N/A		2.03E-04							0.0001342											
Helium-3/4, measured value (ratio)	N/A		1.18E-06			9.77E-07	9.79E-07														
Helium-3/4, relative to air (ratio)	N/A		0.86		0.85	0.71	0.71	0.88		1.128 +/- 2				1.07	1.19						
Oxygen-18/16 (per mil)	N/A		-11.7 +/- 0.2		-14.2 +/- 0.2	-11.8	-11.9	-14.7 +/- 0.2		-14.7	-13.2	-12.75	-13.5	-12.6 +/- 0.2	-12.6 +/- 0.2	-13.33	-13.8	-14.2	-13.6	-14	-12
Strontium-87/86 (ratio)	N/A		0.709321 +/- 0.000017		0.70922	0.70829	0.70825	0.70924	0.70974	0.70909		0.71001		0.71096	0.71057	0.71058					0.71145
Uranium-234/238 (ratio)	N/A		0.000397			0.000135	0.000142														
Hydrogen-2/1 (per mil)	N/A		-94 +/- 1.0		-104 +/- 1	-89	-91	-109 +/- 1		-110	-97.5	-97.5	-99.5	-91 +/- 1	-91 +/- 1	-98.8	-103	-108	-101	-107	-91
Radiological Indicator Parameters-Level I (pCi/L)																					
Tritium	U -180 +/- 170		U 50 +/- 160		0.47 +/- 0.86	-220	-154			8 +/- 1.9	1.28	16	1.987552	43.43 +/- 2.5	38.91 +/- 2.28	< 1		< 20		3.2	
Gross Alpha	6.7 +/- 3.1		U 3.0 +/- 1.9					10.7													
Gross Beta	U 4.3 +/- 2.8		U 3.5 +/- 2.2					3.45													
Radiological Indicator Parameters-Level II (pCi/L)																					
Carbon-14	U -100 +/- 180		U -180 +/- 180																		
Strontium-90	N/A		U -0.23 +/- 0.32			0.31	0.29														
Plutonium-238	U 0.005 +/- 0.012		U 0.001 +/- 0.017			-0.01	0.006														
Plutonium-239	U 0 +/- 0.011		U -0.002 +/- 0.017				-0.001														
Iodine-129	N/A		U -0.46 +/- 0.67			0.106	0.149														
Technetium-99	N/A		U -0.5 +/- 1.5			1.4	1.51			< 5											

B = The result is less than the contract-required detection limit, but greater than the instrument detection limit.
J = The result is an estimated value.
N/A = Not Applicable for that sample
pmc = Percent modern carbon
U = Result not detected at the given minimum detectable limit or activity
mg/L = Milligrams per liter   pCi/L = Picocuries per liter
* = The carbon-14 age presented is not corrected for reactions along the flow path

in Central Nevada. An alternate explanation for the lighter isotopic signature is that the groundwater was recharged during cooler climatic conditions. Further inspection of the figure reveals that the isotopic signatures of some wells plot below the global and meteoric water lines. In general, data that fall below the meteoric water lines indicate that some form of secondary fractionation has occurred. The isotopic shift in the groundwater data for areas near Pahute Mesa has been ascribed to fractionation during evaporation of rainfall, sublimation of snowpack, or fractionation during infiltration (White and Chuma, 1987). Because the recent precipitation data plot along the meteoric water lines, it appears that fractionation during recent precipitation can be ruled out as causing the isotopic shift observed in the groundwater data. Therefore, the isotopic shift for Well ER-EC-7 groundwater can likely be attributed to either sublimation of snowpack or fractionation during infiltration of recent precipitation, or recharge under cooler condition either to the north or under past cooler climatic conditions.

Overall, several conclusions may be indicated by the groundwater chemistry of Well ER-EC-7. For example, it may be that the groundwater at this well has a significant contribution from recharge as evidenced by the stable isotope data. In addition, the higher proportion of calcium to the total cations in Well ER-EC-7 may indicate a lack of groundwater flow through zeolitized units, which would decrease calcium concentrations due to ion exchange. It could also be that the groundwater has not had sufficient time to completely equilibrate with the aquifer materials, which would allow for a greater amount ion exchange between sodium and calcium.

4.2 Restoration of Natural Groundwater Quality

A primary purpose for well development was to restore the natural groundwater quality of the completion intervals so that any future groundwater samples taken from the well would accurately represent the water quality of the producing formations. The formations exposed in each completion interval had potentially been affected by drilling and completion operations as well as crossflow from other completion intervals occurring under the natural head gradient. Various aspects of the restoration of the natural groundwater quality will be discussed in this section.

4.2.1 Evaluation of Well Development

Water quality monitoring of the well discharge was conducted during pumping to provide information on water chemistry and to indicate when natural groundwater conditions predominate in the pumping discharge. The values of certain geochemical parameters (e.g., pH, turbidity, dissolved oxygen) were expected to decline and stabilize as development progressed, indicating restoration of natural groundwater quality as opposed to water affected by drilling and completion activities. The results from the water quality monitoring were examined in a previous report (Appendix A), but the groundwater characterization samples can also help to address the effectiveness of well development. During drilling operations for Well ER-EC-7, the makeup water was tagged with a lithium bromide (LiBr) tracer to help determine such things as the water production during drilling. The makeup water was tagged with a LiBr concentration of approximately 10 mg/L to a little over 100 mg/L. The concentration was increased as water production increased to keep the concentration in the produced water at measurable levels. This relatively high concentration of lithium (Li^+) and bromide ions (Br^-) injected into the well bore also provides a means to further ascertain the effectiveness of the well development. If the groundwater characterization samples contained bromide concentrations of 20 mg/L after well development, it would suggest that the well might still not be completely developed. It can be seen in Table 4-1; however, that both groundwater characterization samples had extremely low bromide concentrations. The discrete bailer sample had an estimated bromide concentration of 0.075 mg/L, while the composite groundwater characterization sample had a bromide concentration less than 0.2 mg/L. It can also be seen from the table that the highest bromide concentration in the surroundings wells was less than 0.25 mg/L for Wells ER-30-1-1 and ER-30-1-2. These bromide concentrations are at least two orders of magnitude lower than the concentrations of bromide used during drilling and likely indicate that the well was sufficiently developed to restore groundwater quality close to its natural condition. This conclusion only pertains to the formations producing water during pumping.

4.2.2 Evaluation of Flow Between Completion Intervals

Well ER-EC-7 was drilled and completed in July and August 1999, with two discrete completion intervals. In order to determine flow in the well under ambient, static conditions, thermal flow logging was conducted. The results from the thermal flow logging indicated that groundwater flows under a natural vertical gradient from the upper completion interval to the lower completion interval (see Appendix A).

4.2.3 Source Formation(s) of Groundwater Samples

As discussed in Section 3.1, flow logging during pumping indicated that approximately 85 percent of the water produced during development and testing came from the lower completion interval (1,215 to 1,304 ft bgs). The contribution percentage from the upper completion interval ranged from 13.6 percent at a pumping rate of 65 gpm to 16.4 percent at a pumping rate of 176 gpm (see Appendix A). Consequently, the lower completion interval was the major source of groundwater for both characterization samples. The water quality results for the composite groundwater characterization can be attributed to both the tuffaceous moat-filling gravels and the rhyolite lava of the Beatty Wash Formation. In order to evaluate any difference in water quality between the two completion intervals, a discrete bailer sample was collected during pumping at a depth of 1,200 ft bgs, which corresponds to just above the lower completion interval. As a result, the water quality results for the discrete bailer sample can be attributed solely to the tuffaceous moat-filling gravels as indicated by preliminary lithologic logs (see Appendix A). Differences between the discrete sample and the characterization samples can be can be attributed to the water sourced from the upper completion interval.

4.3 Representativeness of Water Chemistry Results

The analytical results from the groundwater samples show no major geochemical differences between the discrete bailer sample and the composite groundwater sample. This can be interpreted to mean that the water quality in the upper completion interval did not differ significantly from the lower completion interval. Since the water in the composite groundwater characterization was mostly from the same source as the discrete characterization sample, a substantial difference in water quality would have to be present to show up as a identifiable difference.

There is little evidence of significant residual contamination from drilling, so it can be assumed that the discrete sample and composite characterization samples are fairly representative of formation waters. Also, the total amount produced from Well ER-EC-7 during development and testing was about 3.6 million gallons, of which about 85 percent, or 3.1 million gallons would have come from the lower completion interval. During the period between completion of the well and the start of development, about 0.8 million gallons may have flowed from the upper completion interval to the lower completion interval under the natural gradient, based on a rate of 2.2 gpm. Since the amount removed from the lower interval is about 3.5 times the amount that may have been injected, it can be reasonably expected that the water produced from the lower interval was fairly representative of the formation at that depth.

4.4 Use of ER-EC-7 for Future Monitoring

As discussed in this section, the flow logging indicates that approximately 85 percent of the produced water originates from the lower completion interval. The percentage varied from about from 13.6 percent at a pumping rate of 65 gpm to 16.4 percent at a pumping rate of 176 gpm. The permanent sampling pump installed after testing has a maximum capacity of about 44 gpm, and sampling conducted with this pump should produce water that primarily represents the water quality of the lower completion interval. However, samples would also include a contribution of less than 13.6 percent from the upper completion interval.

The direction of natural-gradient flow in the well is downwards, with a measured flow of 2.2 gpm from the upper completion interval to lower completion interval. Consequently, the upper completion interval should not become contaminated with any foreign water between pumping episodes. However, the lower interval will be flooded with water from the upper interval during the periods when the well is not being pumped; a bridge plug was not installed in this well to prevent crossflow. Substantial purging will be required to produce water from the lower interval that actually represents water quality in the lower interval.

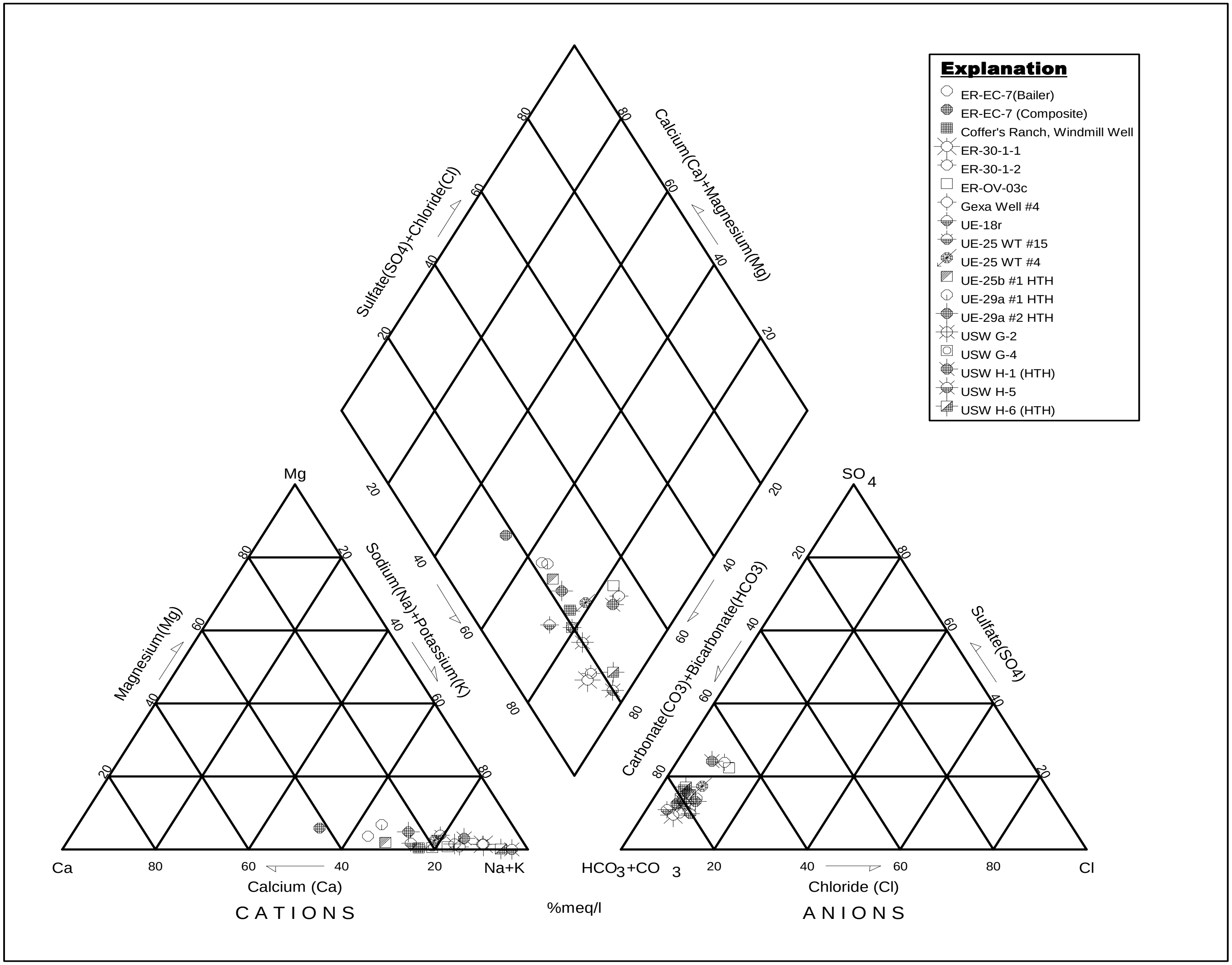


Figure 4-1
Piper Diagram Showing Relative Major Ion Percentages for Groundwater from Well ER-EC-7 and Surrounding Sites

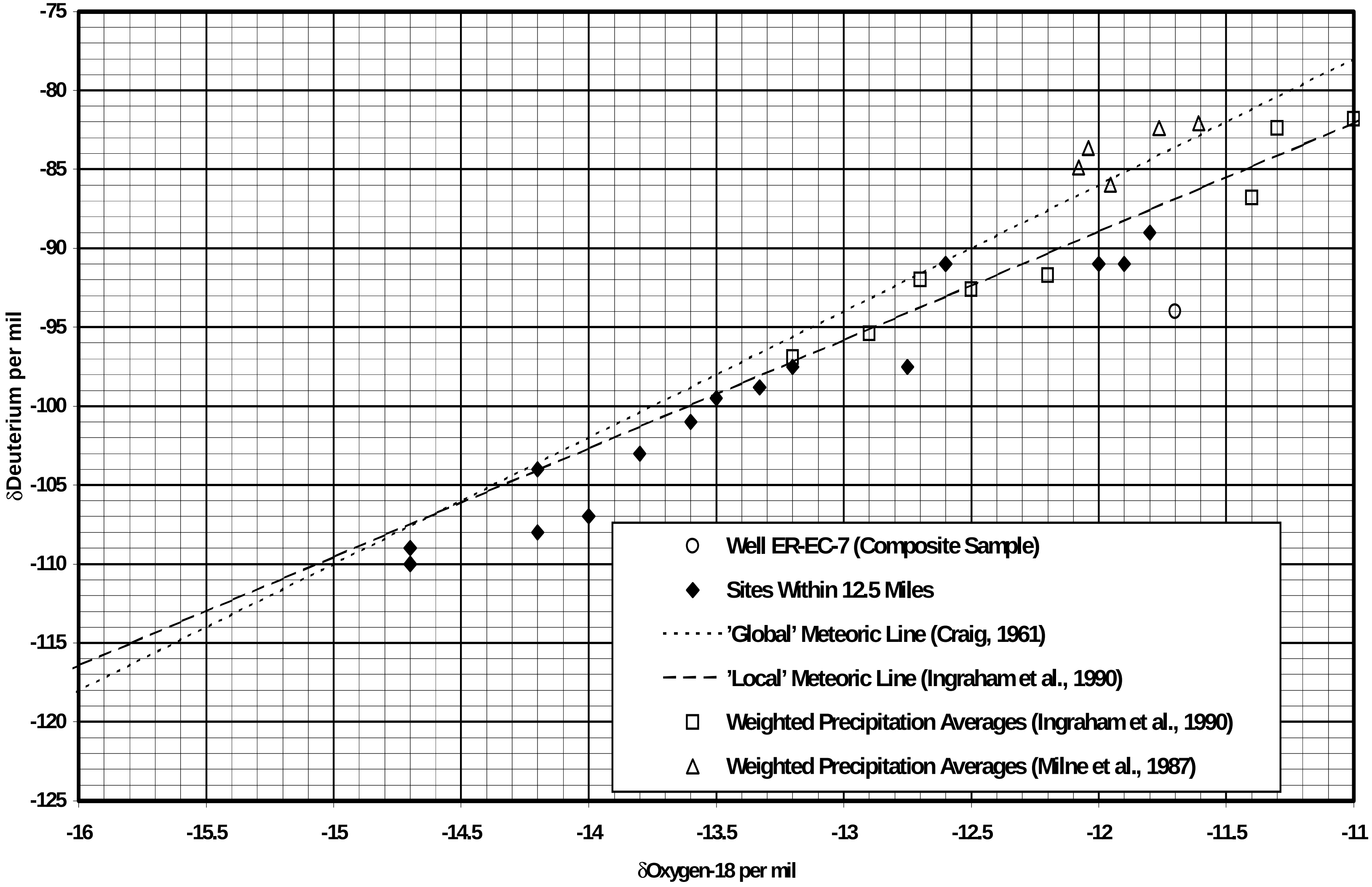


Figure 4-2
Stable Isotope Composition of Groundwater

5.0 References

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Appendix A

Western Pahute Mesa-Oasis Valley Well ER-EC-7 Data Report for Development and Hydraulic Testing

A.1.0 Introduction

Well ER-EC-7 is one of seven groundwater wells that were completed as part of FY 1999 activities for the DOE/NV UGTA Project. Figure A.1-1 shows the location of the WPM-OV wells. Hydraulic testing and groundwater sampling were conducted at Well ER-EC-7 to provide information on the hydraulic characteristics of HSUs and the chemistry of local groundwater. Well ER-EC-7 is constructed with two completion intervals, which are intervals of slotted casing with gravel-pack in the annulus. These intervals are isolated from each other by blank casing with a cement seal in the annular space. The completion intervals are separated by only 127 ft, but access different HSUs.

This document presents the data collected during well development and hydraulic testing for Well ER-EC-7 and the analytic results of groundwater samples taken during this testing.

The objectives of the development and testing program were:

1. Increase the hydraulic efficiency of the well.
2. Restore the natural groundwater quality in the completion intervals.
3. Determine the hydraulic parameters of the formations penetrated.
4. Collect discrete samples from discrete locations and/or specific completion intervals to characterize spatial variability in downhole chemistry.
5. Collect groundwater characterization samples to evaluate composite chemistry.

Well ER-EC-7 was the fourth of the WPM-OV wells to be developed and tested. Activities began February 4, 2000, and were completed by early June 2000. A variety of testing activities were conducted including discrete head measurements for each completion interval, flow logging under ambient conditions and during pumping, a constant-rate pumping test, water quality parameter monitoring, and groundwater sampling of individual producing intervals and of the composite discharge.

A.1.1 Well ER-EC-7 Specifications

The drilling and completion specifications of Well ER-EC-7 were obtained from a draft of the *Completion Report for Well ER-EC-7* (Townsend, 2000). This report also contains the lithologic and stratigraphic interpretation for this well. The schematic well construction is illustrated in various figures in this report showing logging information.

A.1.2 Development and Testing Plan

Well development consisted of producing water from the well to clean out sediment and drilling-induced fluid to restore the natural productivity and the natural water quality of the formation(s) in the completion intervals. The well was hydraulically stressed and surged to the extent possible to promote the removal of lodged and trapped sediment. Water production was accompanied by both hydraulic response and water quality assessments to evaluate the status of development.

The testing program was structured to develop a complete assessment of the hydrology and groundwater quality accessed by the well completion. The elements of the testing can be found in *Well Development and Hydraulic Testing Plan for Western Pahute Mesa - Oasis Valley Wells* (WDHTP) (IT, 1999d).

The testing activities included: (1) discrete head measurements for each completion interval using bridge plugs equipped with pressure transducers and dataloggers for the lower intervals and a wireline-set pressure transducer for the upper interval; (2) flow logging during pumping to determine the extent of the open formation actually producing water and locations of discrete production along the borehole; (3) flow logging under ambient head conditions to determine circulation in the well under the natural gradient; (4) a constant-rate pumping test to determine hydraulic parameters for the formation(s); (5) discrete downhole sampling both under ambient head conditions and during pumping to capture samples that can be determined to represent specific formations or portions of formations; and (6) a composite groundwater characterization sample of water produced during pumping after the maximum possible development.

A.1.3 Schedule

The generic schedule developed for the Well ER-EC-7 testing program was:

1. Measurements of interval-specific hydraulic heads, including monitoring of equilibration after installation of bridge plug (estimated 5 days)

2. Installation of well development and hydraulic testing equipment (estimated 2 days)

3. Well development and flow logging (estimated 7 days)

4. Water level recovery (estimated 5 days)
5. Constant-rate pumping test and discrete and groundwater characterization sampling (estimated 10 days)
6. Water level recovery (estimated 5 days)
7. Removal of downhole equipment and water level measurement (estimated 1 day)
8. Thermal flow logging and discrete sampling (estimated 2 days)
9. Installation of dedicated sampling pump and possible groundwater characterization sampling (estimated 4 days)

The history of the testing program at Well ER-EC-7 is shown in Table A.1-1. In general, the work proceeded according to the planned schedule, but the work was spread over a greater time period than the generic schedule in order to coordinate with other activities. There were several delays related to fitting the pumping system with a back-pressure valve, generator failure, and pump failure.

Table A.1-1
General Schedule of Work Performed at Well ER-EC-7

Activity	Start	Finish
Interval-specific head measurements (bridge plugs)	2/4/2000	2/9/2000
Site mobilization	3/30/2000	4/4/2000
Install access line and testing pump	4/4/2000	4/11/2000
Check pump functionality	4/12/2000	4/12/2000
Install back pressure valve and check pump functionality	4/20/2000	4/22/2000
Develop well and conduct step-drawdown testing	4/22/2000	4/28/2000
Pumping-condition flow logging (impeller flowmeter)	4/28/2000	4/28/2000
Discrete downhole sampling	4/28/2000	4/28/2000
Shutdown pump and monitor for recovery and pretest	5/2/2000	5/8/2000
Constant-rate test - first attempt ends with premature shutdown	5/8/2000	5/12/2000
Monitor recovery	5/12/2000	5/18/2000
Constant-rate test - second attempt ends with premature shutdown	5/1820/00	5/23/2000
Monitor recovery	5/23/2000	5/31/2000
Remove testing pump	5/31/2000	5/31/2000
Ambient-condition flow logging (thermal flowmeter)	6/1/2000	6/1/2000
Install sampling pump and test for functionality	6/2/2000	6/2/2000
Groundwater characterization sampling	6/5/2000	6/5/2000
Demobilize from site	6/5/2000	6/8/2000

A.1.4 Governing Documents

Several documents govern the field activities presented in this document. The document describing the overall plan is the WDHTP (IT, 1999d). The implementation of the testing plan is covered in *Field Instruction for Western Pahute Mesa - Oasis Valley Well Development and Hydraulic Testing Operations*, Rev. 0, December 1999 (IT, 1999b), as modified by Technical Change No. 1, dated December 22, 1999. This document calls out a variety of Detailed Operating Procedures (DOPs) (IT, 1999a) and Standard Quality Practices (SQPs) (IT, 2000) specifying how certain activities are to be conducted. The work was carried out under the *Site-Specific Health and Safety Plan for Development, Testing, and Sampling of Clean Wells, 1999* (IT, 1999c). Specifications for the handling and analyses of groundwater samples are listed in the *Underground Test Area Quality Assurance Project Plan*, Rev. 2 (DOE/NV, 1998).

A.1.5 Document Organization

This data report is organized in the following manner:

- Section A.1.0: Introduction
- Section A.2.0: Summary of Development and Testing. This chapter presents mostly raw data in the form of charts and graphs. Methodologies for data collection are described, as well as any problems that were encountered. Data is presented under the following topics: water level measurements, interval-specific head measurements, pump installation, well development, flow logging during pumping, constant-rate pumping test, water quality monitoring, groundwater sampling, thermal-flow logging, and ChemTool logging.
- Section A.3.0: Data Reduction and Review. This chapter further refines and reduces the data to present specific results that are derived from the program objectives. Information is presented on vertical gradients and borehole circulation, intervals of inflow into the well, the state of well development, reducing the data from the constant-rate test, changes in water quality parameters, and representativeness of groundwater samples.
- Section A.4.0: Environmental Compliance. This chapter records the results of the tritium and lead monitoring, fluid disposition and waste management.
- Section A.5.0: References.
- Attachment 1: Manufacturer Pump Specifications.
- Attachment 2: Water Quality Monitoring - Grab Sample Results. This appendix shows the field laboratory results for temperature, electrical conductivity (EC), pH, dissolved oxygen (DO), turbidity, and bromide in relation to date/time and gallons pumped.

- Attachment 3: Water Quality Analyses - Composite Characterization Sample and Discrete Samples.

- Attachment 4: Fluid Management Plan Waiver for WPM-OV Wells.

- Attachment 5: Electronic Data Files Readme.txt. This attachment contains the readme file text included with the electronic data files to explain the raw data files included on the accompanying compact disc (CD).

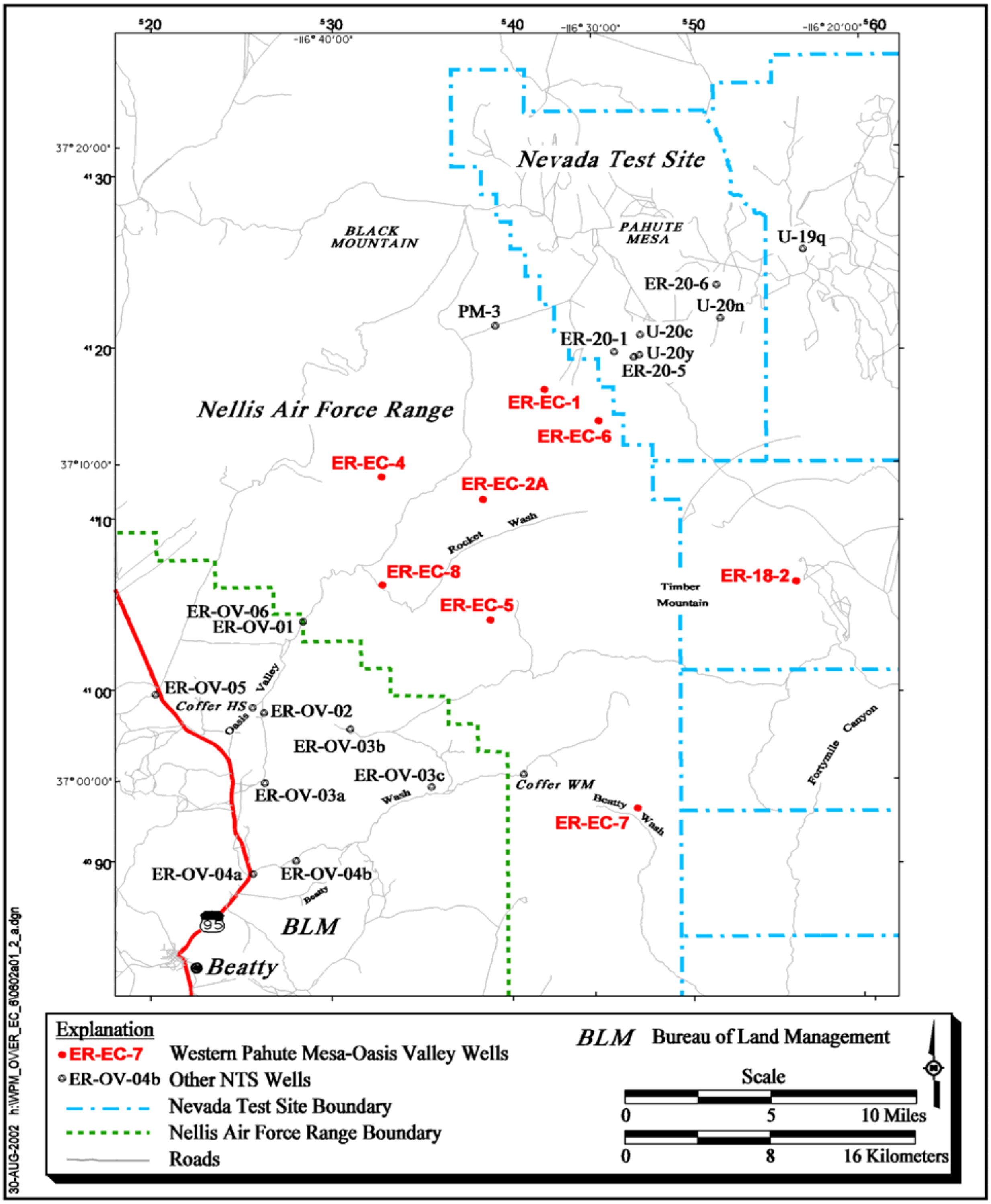


Figure A.1-1
Area Location Map

A.2.0 Summary of Development and Testing

This section presents details of the well development and testing activities, the associated data collection activities, and summaries and depictions of the unprocessed data that were collected. The detailed history of Well ER-EC-7 development and testing is shown in Table A.2-1.

A.2.1 Water Level Measurement Equipment

Following is a general description of the equipment used by IT Corporation, Las Vegas Office (ITLV) for measurements and monitoring during development and testing. Other equipment used for specific parts of the program are described in the appropriate section.

Depth-to-water measurements were made with a metric Solinst e-tape equipped with either a conductivity sensor or a float switch. The PXDs were Design Analysis Associates' Model H-310, which are vented. The vent line is housed in an integral cable of sufficient length to allow installation of the PXD to its maximum working depth below the water surface. The cable was crossed over to a wireline above the water surface. The PXDs employ a silicon strain gauge element, and include downhole electronics to process the voltage and temperature measurements. Data is transmitted uphole digitally to a Campbell Scientific CR10X datalogger located on the surface using SDI 12 protocol. The rated accuracy of the PXDs are 0.02 percent full scale (FS). Barometric pressure was measured with a Vaisala Model PTA 427A barometer housed with the datalogger. All equipment was in calibration.

A.2.1.1 Data Presentation

Most of the data were loaded into Excel® spreadsheets for processing and are presented with graphs directly from the spreadsheets. Due to the nature of the data and how the data were recorded in the datalogger program, certain conventions were used in presenting the data. Following are explanations of these conventions to aid in understanding the data presentations:

- The time scale for all monitoring is in Julian Days, as recorded by the datalogger. Julian Days are consecutively numbered days starting with January 1 for any year. This format maintains the correspondence of the presentation with the actual data, and presents time as a convenient continuous length scale for analytical purposes.

Table A.2-1
Detailed History of Development and Testing Activities

Date	Activities
11/24/1999	ITLV installs 0-15 psig PXD for predevelopment water level monitoring.
1/7/2000	ITLV removes PXD.
2/4/2000	Baker Hughes installs bridge plug/PXD at 1,120 ft bgs for lower interval head monitoring. ITLV installs 0-15 psig PXD for upper interval head monitoring.
2/9/2000	ITLV removes PXD. Baker Hughes removes bridge plug/PXD.
3/30/2000	Begin mobilization of equipment to site for hydraulic testing.
4/3/2000	USGS measures water level at 747.53 ft bgs.
4/4/2000	BN installs access line to depth of 861.31 ft bgs.
4/11/2000	BN installs pump; land bottom of motor at depth of 855.12 ft bgs, intake at 808.84 ft bgs, top of pump at 778.85 ft bgs.
4/12/2000	ITLV installs 0-30 psig PXD. Test function of pump. Shut down pump and discontinue development until back pressure and pressure relief valves are installed.
4/20/2000	BN installs the back-pressure valve and tests it. The ball-type back-pressure valve slowly closes when under pressure.
4/21/2000	BN installs gate valve and tests system. Pressure-relief valve leaks continuously.
4/22/2000	BN installs sheer pin type pressure relief valve. Begin development, pumping at 175 gpm. VSD shuts pump down and restarts it twice before it shuts the pump down at 23:32 for remainder of night.
4/23/2000	Conduct step-drawdown protocol and then continue pumping for development.
4/24/2000	Continue pumping, stopping pump periodically to surge the well.
4/25/2000	Conduct step-drawdown protocol.
4/26-28/2000	Continue development; surge the well by stopping the pump for short periods.
4/28/2000	ITLV removes PXD. DRI conducts flow logging at 65, 120, and 175 gpm. Collect discrete bailer sample at 1,200 ft bgs.
4/29/2000	DRI installs the check valve and the pump is run to fill the production tubing. The check valve leaks and allows water level to drop to approximately 400 ft bgs.
5/2/2000	DRI removes the check valve, cleans it, and then resets it. The valve is tested and it holds pressure.
5/3/2000	ITLV sets 0-30 psig PXD at 673 ft bgs for monitoring recovery and preconstant-rate test conditions.
5/3-8/2000	Monitor preconstant-rate test conditions.
5/820/00	Lower PXD to 680 ft bgs to accommodate expected drawdown. Start constant-rate test, pumping 175 gpm.
5/8-12/2000	Continue constant-rate test. VSD shuts pump down at 16:23 due to power problem.
5/12-18/2000	Monitor recovery. Service generators.
5/18/2000	Restart constant-rate test at 13:50, pumping 175 gpm.
5/18-23/2000	Continue constant-rate test. VSD shuts pump down on 5/23 due to power problem.
5/23-26/2000	Monitor recovery.
5/26/2000	Attempt to restart pump for characterization sampling is unsuccessful; error code indicates downhole short. Pump must be removed for troubleshooting. ITLV removes PXD.
5/30/2000	ITLV removes data collection equipment. DRI removes check valve. BN mobilizes rig to remove testing pump.
5/31/2000	BN removes access line and testing pump.
6/1/2000	DRI conducts thermal flow and ChemTool logging. BN sets up rig to install permanent sampling pump.
6/2/2000	BN installs sampling pump. Check function of pump.
6/5/2000	ITLV, DRI, and LLNL collect characterization samples using permanent sampling pump.
6/5-8/2000	Demobilize equipment from site.

BN - Bechtel Nevada
DRI - Desert Research Institute
ITLV - IT Corporation, Las Vegas Office
LLNL - Lawrence Livermore National Laboratory
in. - Inch(es)
PXD - Pressure transducer
USGS - U.S. Geological Survey

Hz - Cycles per second (hertz)
gpm - Gallons per minute
A - Amps
VSD - Variable speed drive
psig - Pounds per square inch gauge
ft bgs - Feet below ground surface

- The PXD data are presented as the pressure recorded by the datalogger so that it corresponds to the raw data in the data files. These data can be processed to various forms of head, with or without barometric correction. The required additional data to process the data into any required form are included in this report. Note that the data files contain a column in which the raw pressure measurement has been processed to a head measurement in terms of feet of water column above the PXD. The conversion was based on an approximate standard density for water, and was for field use in monitoring downhole conditions. In Section A.3.1, a well-specific value for the water density is derived and used for the processing of the drawdown response into head.

- Groundwater pressure measurements are reported as psig since the PXDs used for groundwater pressure monitoring were vented, not absolute. Pressure differences are reported as psi. Atmospheric pressure (i.e., barometric pressure) is reported as mbar; this is an absolute measurement.

- On graphs showing both PXD data and barometric data, the pressure scales for psi and mbar have been matched to show the changes in pressure proportionately. One psi is approximately equal to 69 mbar. For presentation convenience, the scales are not matched exactly, but are close enough so that the relative magnitude of the pressure changes is apparent. Complete electronic data files are included on an accompanying CD which allows the user to evaluate details of barometric changes and aquifer response, as desired.

- The data on water density in this report are presented in terms of the derived conversion factor for pressure in psi converted to vertical height of water column in feet. This is actually the inverse of weight density expressed in mixed units (feet-square inches/pound or feet/pounds per square inch). This is a convenient form for use in calculations. Later in the text, the derived densities are discussed in terms of specific gravity.

- Note that various derived values for parameters presented in this report may differ from values previously reported in morning reports. These differences are the result of improved calculations. Changes in measured parameter values are the result of corrections based on checking and confirming values from multiple sources.

- The production rates given in the text, shown in figures, and recorded in the data files are the flowmeter readings. During well development, 1 to 3 gpm was diverted to the Hydrolab® before production rate measurement by the flowmeter. The specific flow to the Hydrolab® at any particular time is not known exactly.

A.2.2 Predevelopment Water Level Monitoring

Following completion of Well ER-EC-7, the water level in this well was monitored with a PXD/datalogger for a period of approximately two months to establish the equilibrium composite head for this well. Figure A.2-1 shows the results of this monitoring. An electronic copy of this data record can be found on the CD as file EC-7-Water Level Monitoring.XLS.

A.2.3 Depth-to-Water Measurements

A series of depth-to-water measurements were made in Well ER-EC-7 as part of the various testing activities. Table A.2-2 presents all of the equilibrium, composite water level measurements made during the testing program. Measurements representing nonequilibrium or noncomposite water levels are presented in the appropriate section for the testing activity involved.

Table A.2-2
Equilibrium, Composite Depth-to-Water Measurements

Date	Time	Depth-to-Water bgs		Barometric Pressure (mbar)
		Feet	Meters	
11/24/1999	13:30	747.91	227.96	811.30
1/7/2000	13:42	747.68	227.89	807.34
4/12/2000	08:31	747.56	227.86	858.51
4/30/2000	12:10	747.59	227.87	859.20
5/3/2000	11:32	747.53	227.85	849.76
5/26/2000	09:12	747.49	227.84	850.00

bgs - Below ground surface
mbar - Millibars

A.2.4 Interval-Specific Head Measurements

The representative hydraulic heads of the individual completion intervals were measured to provide information on the vertical hydraulic gradients. This was accomplished by isolating the completion intervals from each other with bridge a plug and then measuring the pressure or head in each interval. The bridge plug contained a pressure transducer and datalogger to measure and record the pressure in the interval below the bridge plug. The head in the uppermost interval was monitored using a PXD installed on a wireline. After removal of the PXD, the corresponding water level was measured with an electrical tape (e-tape). The bridge plug remained downhole for five days to monitor the equilibration of the interval.

A.2.4.1 Bridge Plug Installation and Removal

The procedure for installing the bridge plug included:

1. Run gauge and basket to 1,200 ft bgs to verify that the bridge plug would fit through casing.
2. Measure the static water level to establish the reference head (head is assumed to be in equilibrium).
3. Run the bridge plug to set-depth minus 50 ft, and collect three or more pressure readings.
4. Lower bridge plug to set-depth plus 50 ft, and collect three or more pressure readings.
5. Raise bridge plug to set-depth, collect three or more pressure readings, then set bridge plug to isolate lower completion interval. Monitor head change in lower interval with internal pressure transducer/datalogger.
6. Measure water level in well to determine head change and establish a reference head elevation (treated as if stable; see discussion in Section A.3.1.1).
7. Install PXD in uppermost interval and monitor head change in uppermost interval.
8. After five days, measure water level in upper interval, then remove equipment and download dataloggers.

This procedure provides in-well calibration of pressure versus head (i.e., density which is a function of the temperature profile) for use in interpreting the equilibrated head for each isolated interval. No problems were encountered in this activity.

A.2.4.2 Pressure/Head Measurements

The bridge plug/PXD assembly was supplied and installed by Baker Hughes Corporation on their own wireline. The PXD was a Sunada Model STC8064A with a rated measurement accuracy of 0.1 percent FS. PXDs with various pressure ranges were used to suit the depth of installation. Information was collected by a built-in datalogger recording on a time interval of 5 minutes, following an initial 20-minute delay from the start of the datalogger. The datalogger time is in decimal hours. Since there was no data connection to the surface once the bridge plug was set, data could not be read or evaluated until the bridge plug was retrieved. The bridge plug/PXD was left downhole for five days, a length of time expected to be sufficient to determine the behavior of the intervals.

Table A.2-3 shows the interval-specific pressure and head measurements, including the calibration data. Graphs of the interval monitoring are included in Section A.3.0. Note that the corrected depths for the bridge plug are slightly different from the PXD set depths that had been specified and listed in the Morning Reports. The set depths were located according to the wireline odometer. Depth corrections were calculated later. However, there was no problem using the measurements collected at the actual locations once the location was verified. The depth corrections are discussed in Section A.3.1.1. The datalogger files for the pressure transducers can be found on the enclosed CD, labeled as follows: EC7gradient.xls (upper interval), and EREC7.xls (lower interval). A readme text file is included in Attachment 5, which explains how the data may be accessed.

Table A.2-3
Interval-Specific Head Measurements

Interval	Comment	Depth (ft bgs)	Depth (m bgs)	PXD Measurement (psig)
Upper	Final head	746.50	227.53	NA
Lower	Reference head - composite of both intervals	747.71	227.90	158.62
	Bridge Plug set depth minus 50 ft	1,068.25	325.60	137.07
	Bridge Plug set depth - post set	1,118.15	340.81	158.73
	Bridge Plug set depth plus 50 ft	1,168.15	356.05	180.14

ft bgs - Feet below ground surface
m bgs - Meters below ground surface
psig - Pounds per square inch gauge

A.2.5 Pump Installed for Development and Testing

A high-capacity pump was temporarily installed for well development and testing. This pump was later replaced with a lower capacity, dedicated pump for long-term sampling. The development and testing pump was the highest production-rate pump available that would physically fit into the well and still allow an access line along side. The access line was required to guide the flow logging and discrete sampling tools past the pump and into the completion intervals. The following sections discuss the details of pump installation and performance.

A.2.5.1 Pump Installation

The pump installed for development and testing was a Centrilift 86-FC6000 (387 Series) electric submersible consisting of two tandem pump units (#01F83215 and #01F83216) with 43 stages each, and a 130-horsepower motor (375 Series) (#21048009 and #21048010). Manufacturer's specifications for this pump are included in Attachment 1. Note that the pump units total 30.0 feet in length, with the intake at the bottom of the lower pump unit. A seal section separates the pump units from the motor, which is located at the bottom of the assembly. The pump was installed on 2 7/8-inch (in.) Hydril tubing. A model "R" seating nipple was placed just above the pump in the production tubing to allow future installation of a wireline-set check valve. The pump was operated without a check valve during development to allow the water in the production tubing to backflow into the well when the pump was shut down. This was intended to "surge" the well and aid in development. A check valve was installed prior to the constant-rate pumping test to prevent such backflow at the end of the test.

An Electro Speed 2250-VT Variable Speed Drive (VSD) was used to regulate the production of the pump. To maintain a constant production rate for testing, the transmitter of the Foxboro 1.5-in. magnetic flowmeter was connected to the VSD in a feedback loop to supply the VSD with continuous flow rate information. The VSD automatically adjusts the frequency of the power supplied to the pump to maintain a constant production rate. The flowmeter record shows that this worked very well and a constant production rate could be maintained as drawdown progressed.

In order to provide the required minimum pressure at the pump output, a back-pressure system was employed to maintain 325 psig surface pressure. This was required on Well ER-EC-7 because of the relatively shallow static water level and pump installation depth does not result in sufficient total dynamic head (TDH). The back pressure was provided by restricting flow with a valve placed at the top of the production string with a pressure relief valve. Since this was the first well in the WPM-OV series requiring the back-pressure system, several delays occurred as the equipment was perfected.

The pump was landed with the bottom of the motor at 855.12 ft bgs, which placed the pump intake at 808.84 ft bgs.

A.2.5.2 Pump Performance

Pump performance is illustrated by the records as shown in Table A.2-4. These production rates are in line with performance projections supplied by the manufacturer for this pump with similar pumping parameters. The data for April 12, 2000, indicates pump performance before the back-pressure system was installed. The later data shows performance with the correct back pressure. The pump performance was consistent throughout development and testing.

A.2.6 Development

There were two objectives for well development, the physical improvement of the condition of the well completion and restoration of the natural water quality. The early development activities were primarily designed to improve the physical condition of the well completion. This involved removing drilling fluid and loose sediment left from drilling and well construction to maximize the hydraulic efficiency of the well screen, gravel pack, and the borehole walls. These improvements promote efficient and effective operation of the well and accurate measurement of the hydrologic properties. The development phase was primarily

Table A.2-4
Pump Performance

Date	VSD Setting (Hz)	Production Rate (gpm)	Approximate Drawdown (ft)
4/12/2000	45	115.53	11.5
4/12/2000	50	140.33	15.4
4/12/2000	55	162.67	19.1
4/12/2000	60	182.26	22.7
4/22/2000	65	176.06	18.91
4/23/2000	51.9	65.5	3.21
4/23/2000	57.6	121.33	9.67
4/23/2000	65.4	175.72	18.42

Significant figures reported as recorded.
Back-pressure system installed at wellhead between April 12 and 22, 2000.

Hz - Hertz, cycles per second
gpm - Gallons per minute
ft - Feet

intended to accomplish hydraulic development in preparation for hydraulic testing.

Restoration of the natural water quality includes removal of all nonnative fluids introduced by the drilling and construction activities and reversal of any chemical changes that have occurred in the formation due to the presence of those fluids. This objective of development addresses the representativeness of water quality parameter measurements and chemical analyses of samples taken from the well. Another aspect of this objective was to remove nonnative water from completion intervals receiving water due to natural gradient flow from other intervals and reverse chemical changes that have occurred as a result. Since the well completion cross-connects intervals of different heads and hydraulic conductivities, such natural circulation was presumed to have been occurring since the well was drilled. Measurement of this circulation is addressed later under ambient flow logging with the thermal flowmeter. This issue would be important for determining the representativeness of discrete downhole samples that are intended to distinguish differences in water quality between completion intervals.

Restoration of natural groundwater quality is mostly a function of the total volume of water produced. Discrete sampling for groundwater characterization was scheduled at the end of the development stage, which provided the maximum development possible before downhole sampling without interfering with the constant-rate test. An evaluation of the status of development at the time of sampling is presented in Section A.3.5.

The history of the development phase for Well ER-EC-7 is shown in Table A.2-1. The generic plan allowed seven days for this phase, but additional time was required to sort out problems with the pumping system and to adjust the schedule to fit into the overall work scheme for UGTA field activities.

A.2.6.1 Methodology and Evaluation

The basic methodology for hydraulic development was to pump the well at the highest possible rates, and periodically surge the well by stopping the pump to allow backflow of the water in the pump column. The parameters of the pumping operations, production rates and drawdown responses, were recorded continuously by a datalogger from the production flowmeter and a downhole PXD. During flow logging and discrete-interval sampling, the PXD had to be removed to allow access for the flow logging tool and the discrete bailer. Barometric pressure was also recorded in conjunction with PXD records.

Monitoring during development included hydraulic performance data and a variety of general water quality parameters intended to evaluate both the effectiveness of the development activities and the status of development. These parameters included drawdown associated with different production rates to evaluate improvement in well efficiency, visual observation of sediment production and turbidity to evaluate removal of sediment, and water quality parameters (temperature, pH, EC, turbidity, DO, and bromide concentration [Br^-]) to evaluate restoration of natural water quality. With regard to the Br^- concentration, the drilling fluid was “tagged” with lithium bromide to have an initial concentration from approximately 10 mg/L to a little over 100 mg/L. The concentration was increased as water production increased to keep the concentration in the produced water at measurable levels. This methodology served to provide a measure of water production during drilling through reference to the dilution of the tracer, and later serves as a measure of development for evaluating the removal of residual drilling fluids from the formation.

A.2.6.2 Hydraulic Development Activities

A PXD was installed in the access tube of the well to monitor the hydraulic response of the well during pumping. The PXD range must be sufficient to accommodate the change in pressure corresponding to the amount of drawdown produced by pumping at the maximum rate. It is also advantageous to use a PXD with the minimum range necessary to maximize accuracy. A 0-30 psig PXD was installed for development. Information on this PXD installation and calibration is presented in Table A.2-5. This PXD was used to collect all the data during development until it was removed for flow logging.

The method of installing these PXDs does not provide a direct measurement of the total depth of the PXD. The uncertainty in the total measured depth is due to uncertainty in the hanging length of the PXD vent cable, which is difficult to measure accurately. Therefore, the installation depth is calculated from the depth-to-water and calibration measurements made during installation. The pressure reading of the PXD at the installation depth is multiplied by the water density conversion factor to give the depth below the static water level, which is then added to the measured depth-to-water level. The water density conversion factor is determined from the calibration measurements. Note that the Cal 1 PXD psig value was a measurement in air above the water surface, and is not used for the water density calculation.

Table A.2-5
PXD Installation Prior to Well Development

Design Analysis H-310 PXD SN 2266, 0-30 psig					
Install Date: 4/12/2000					
Calibration Date: 4/12/2000					
Static Water level depth 747.56 ft bgs (08:31, 4/12/2000)					
Stations	Cal 1	Cal 2	Cal 3	Cal 4	Cal 5
WRL/TOC[a] (ft)	590.00	602.00	614.00	626.00	638.00
PXD psig	- - -	0.4213	5.5461	10.6870	15.8330
Delta depth (ft): Cal5 - Cal2					36.00
Delta psi: Cal5 - Cal2					15.412
Density ft of water column/psi: delta depth/delta psi (in ft/psi)					2.336
Equivalent ft water: PXD psig (at Cal5) x density of water (ft/psi)					36.98
Calculated PXD installation depth: static water level + equiv. ft water					784.54

[a] Length of wireline (WRL) below top of casing (TOC): does not include the length of the PXD integral cable.

ft - Foot (feet)
bgs - Below ground surface
PXD - Pressure transducer
psi - Pounds per square inch
psig - Pounds per square inch guage

The total period spent on development was longer than planned due to working through problems with the pump, as described previously in Section A.2.5. The well was actually pumped for a total time of about five days prior to flow logging. During that time, development consisted of pumping at rates as great as possible, periodically stopping the pump to surge the well with the backflow from the production tubing. Step-drawdown protocol was used to generally assess well and pump performance. Water quality was monitored using both field laboratory grab sample testing and with an in-line Hydrolab® flow-through instrumentation cell with readings recorded by a datalogger.

A.2.6.2.1 Pumping Rates and Hydraulic Response

Figure A.2-2 shows the datalogger record of the pumping rate and hydraulic response during the development phase. Figure A.2-3 shows the datalogger record of the hydraulic response and barometric pressure. An electronic file of these data can be found on the attached CD with the file name EC-7_AQTEST_WD.XLS. The first day of the data record shows the initial testing of the pump to determine the operating range of the pump (see Table A.2-4) and resultant drawdown. Pumping was then discontinued until the back-pressure system was installed and perfected. Development with surging and intensive pumping was begun on Julian Day 113 (April 22, 2000) and continued until April 28, 2000, when flow logs were run. Drawdown during pumping was on the order of 18 ft (at a maximum of 176 gpm). The barometric record shows that the barometric pressure was relatively constant during this period, and variations were not great enough to have significant expression in the PXD pressure. The stress that could be applied to the completions for development was limited by the maximum production rate of the pump.

Several factors should be kept in mind when scrutinizing the pumping and drawdown record from the development phase. First, the well was operated without a check valve. Consequently, a water column above the pump was not maintained after the pump was stopped. When the pump was restarted, sufficient water had to be pumped to fill the tubing and surface hose before production would register at the flowmeter. This produces a lag time of approximately 1.67 minutes between the start of a drawdown response and the start of the flowmeter readings. Also note the brief surge that registered with the flowmeter just after the pump was started. This is probably residual water from development remaining in a low spot of the surface hose that was pushed through the flowmeter by air compressed ahead of the rising water column.

Second, because there was little head on top of the pump at startup, the initial pumping rate was much higher than the rate when the final, stable TDH was reached. The pumping rate decreased as the TDH increased until the discharge system was filled and TDH stabilized. This phenomenon is illustrated in Figure A.2-4. Dividing the volume of the discharge system by the time lag for flowmeter readings to start gives a production rate much greater than the VSD setting would produce under stable pumping conditions. As a result of this situation, the initial drawdown (both the rate of drawdown and the magnitude) was much greater until the stable pumping rate was reached. The installation of a check valve for the constant-rate test avoids these irregularities by maintaining the water column above the pump so that the stable TDH is developed very quickly as the system is pressurized.

For development at ER-EC-7, the pump was normally started operating the VSD in Mode 1. In this mode the VSD is set to operate at a specific power frequency Hz. The calibration of Hz versus gpm through the pumping range is determined during the functionality test. After the system is pressurized and a stable pumping rate is established, the VSD is then switched to Mode 2 in which the VSD varies the Hz to maintain a specific gpm setting. Since the testing is run according to desired pumping rates, the objective is for consistency in the pumping rate between the two modes.

If the pump were to be turned on directly in Mode 2, the VSD would accelerate the pump until the flowmeter reading equals the pumping rate setting. However, since the feedback from the flowmeter is zero until the system is fully filled with water, the VSD would initially accelerate to the upper clamp setting, usually set at the maximum pumping rate. This would result in correspondingly high pumping rates and drawdown until the flowmeter returned accurate pumping rate information. The VSD would then de-accelerate the pump and to seek the gpm setting. This method of starting the pump was used previously, but was changed to the present approach because of the irregularity it introduced in the startup record. For the constant-rate test, the check valve that is installed to maintain the water column precludes most of this problem since the flowmeter starts to measure the pumping rate very quickly.

An additional irregularity in the starting pumping rate is introduced by the back-pressure system. Bechtel Nevada (BN) protocol for starting the pump requires that the back-pressure valve be initially open, and it is then closed to produce the required back pressure after the full flow is established. The additional back pressure causes a reduction in pumping rate, which is then compensated by the VSD in Mode 2.

A.2.6.2.2 Surging and Step-Drawdown Protocol

Figure A.2-2 and Figure A.2-3 show instances when the pump was stopped, although the step-drawdown protocol is difficult to discern in these figures.

Stopping the pump produced a small surging action in the well which can be seen in Figure A.2-5. This figure shows a representative instance of surging expanded to illustrate the detail. When the pump is stopped, the water in the production casing backflows through the pump into the well, raising the water level in the well. This is referred to as the “u-tube” effect. The water level in the well casing temporarily rises above the instantaneous head in the formation around the completion because the rate of backflow down the casing is faster than the rate the water is injected into the formation under the instantaneous head differential. This action produces a reverse head differential which “surges” the well. The reverse flow may simply speed the apparent recovery of the well or result in a rise above the equilibrium water level, followed by a decline to the equilibrium head. The surge rapidly dissipates, merging into the recovery curve. This effect was not substantial in this well. The “u-tube” effect resulted in a rise in the water level in the well of approximately 2 ft above the equilibrium water level.

These starting and stopping effects are much subdued for the constant-rate test because a check valve is installed to prevent backflow into the well and maintain the water column in the production tubing. The initial condition upon startup is then a high proportion of the operating TDH.

With the step-drawdown protocol the pump was run for a certain period of time at each of three progressively higher rates, 65, 121, and 176 gpm. Drawdowns at the end of each pumping period could then be compared to evaluate the well performance and any improvement in hydraulic efficiency since the last time the protocol was run. Figure A.2-6 and Figure A.2-7 show close-ups of two of the step-drawdown tests. The same pumping rates were used during flow logging. The performance of this well did not change appreciably during the development phase.

A.2.6.2.3 Other Observations

During development, visual observations were made of the water discharge, primarily whenever the pump was started, to monitor the amount of sediment produced. Logbook entries indicated that there was initial reddish brown turbidity in the water for less than a minute each time the pump was started, after which the water cleared.

A.2.7 Flow Logging During Pumping

Downhole flow logging was conducted after the development phase. Data on the proportional inflow of water from different completion intervals would be used for tuning the production rate used for constant-rate test, and later in understanding the hydraulic and analytical data. It was expected that the two completion intervals would not respond uniformly to pumping due to the influence of vertical hydraulic gradients, differences in the hydraulic conductivity of the geologic units, and flow losses along the completion. The flow logging directly measured the amount and location of incremental water production downhole.

A.2.7.1 Methodology

The information on water production from each completion interval was collected at different pumping rates to evaluate the linearity of effects for use in later interpretation. The same approximate pumping rates were used for flow logging as were used during step-drawdown protocol (65, 121, and 176 gpm) so that results could be directly compared with previous observations.

Flow logging was conducted by the DRI on April 28, 2000. A complete program of flow logging was run, including both stationary measurements and trolling logs. A temperature log was also recorded in combination with the flow logging to help in identifying production patterns and specific production locations. Trolling log runs were initially conducted at three line speeds, 20, 40, and 60 feet per minute (fpm), with 20 and 60 in a downward direction, and 40 fpm in the upward direction. The upward runs have been discounted because, in the upward runs, pressure on the bowspring centralizer started to collapse the spinner, leading to inaccurate results. This problem is specific to this well because it was completed with fiberglass tubing with an internal diameter less than the stainless steel tubing used on the other wells.

A.2.7.1.1 Equipment and Calibration

The DRI flow-logging system consists of, from top to bottom (all Flexstak equipment): telemetry cartridge, a centralizer, a temperature tool, another centralizer, and a full-bore flowmeter. All logging tools and the data acquisition system are manufactured by Computalog. This tool string has a maximum diameter of 1 1/16-in., is temperature rated to 176°C, and pressure rated to

17,000 psi. The full-bore flowmeter has a minimum measurement of 5 fpm for a static tool, and a resolution of 0.1 percent.

The full-bore flowmeter has a collapsible impeller that opens to cover a much larger percentage of the casing cross section than a standard fixed-blade impeller. Centralizers are run in conjunction with the sensor tools to center the tool string in the wellbore. The temperature tool is run to provide temperature gradient and differential temperature information. In conjunction with information from the spinner tool, the temperature tool yields information useful in fluid flow analysis.

Calibration is completed by comparing the raw flowmeter readings of counts-per-second to known velocities. Low flow-rate calibration data are obtained from a DRI calibration facility which can produce 0 to 60 gpm flow through 5.5-in. casing. The flow logging tool calibration was also checked on site against the production flowmeter readings at the three pumping rates by measuring uphole velocities in the 5.5-in. casing above the uppermost screen. Line speeds are also calibrated while the pump was turned off.

A.2.7.1.2 Logging Methodology

Six trolling flow logs were run at two line speeds from approximately 60 ft above the top of the upper screened interval to approximately 15 ft below the top of the lower screened interval. The runs were typically from about 866 to 1,230 ft bgs. The DRI logging tool bottomed out at about 1,250 ft bgs and subsequent logging runs were stopped short of that depth to prevent damage to the tool. When the tool was pulled up after hitting bottom, it was covered with grease and mud. The logging runs were all made in the downward direction at line speeds of 20 fpm and 60 fpm. Each line speed was conducted at three pumping rates, 65, 121, and 176 gpm. In addition to the moving logs, stationary flow measurements (tool held motionless in the well) were taken above and below the upper screened interval at 910 and 1,000 ft bgs. Table A.2-6 lists the trolling flow logs that were run. Stationary measurements are listed in Table A.2-7.

Table A.2-6
Listing of Trolling Flow Logs

Run Number	Date of Run	Direction of Run	Run Speed (fpm)	Surface Discharge (gpm)	Run Start/Finish (ft bgs)
ec7mov1	4/28/2000	Down	20	65	866.8 - 1,261.2
ec7mov3	4/28/2000	Down	60	65	865.8 - 1,227.8
ec7mov5	4/28/2000	Down	20	121	866.2 - 1,232.2
ec7mov6	4/28/2000	Down	60	121	865.8 - 1,233.2
ec7mov7	4/28/2000	Down	20	176	865.8 - 1,227.8
ec7mov8	4/28/2000	Down	60	176	866.2 - 1,227.8

fpm - Feet per minute
gpm - Gallons per minute
ft bgs - Feet below ground surface

Table A.2-7
Listing of Stationary Flow Measurements

Location	Log Run	Pumping Rate (gpm)	Depth (ft bgs)	Average (gpm)
above upper screened interval	ec7stat1	65	910	65.9
below upper screened interval	ec7stat2		1,000	56.9
below upper screened interval	ec7stat3	121	1,000	103.9
above upper screened interval	ec7stat4		910	121.9
below upper screened interval	ec7stat5	176	1,000	148.3
above upper screened interval	ec7stat6		910	177.3

gpm - Gallons per minute
ft bgs - Feet below ground surface

A.2.7.2 Flow Logging Results

The results of the trolling flow logs are presented in Figures A.2-8 through A.2-13. Figure A.2-8 and Figure A.2-9 show flow logs for two trolling speeds (20 fpm and 60 fpm downwards) at a well production rate of 65 gpm. Figure A.2-10 and Figure A.2-11 depict flow logs for the same trolling speeds at a well production rate of 120 gpm. Figure A.2-12 and Figure A.2-13 depict flow logs for the same trolling speeds at a well production rate of 175 gpm. The logs run at 20 fpm downwards contain the least amount of noise and fluctuations. This configuration seemed to provide the most sensitivity with the least induced disturbance.

The flow logs indicate that the greater proportion of production in the well was derived from the lower completion interval (1,215 to 1,304 ft bgs). The logs also show an apparent loss of flow in the lower to middle section of the upper completion interval. The flow log again comes cumulative in the upper portion of the upper completion interval. The distribution of production will be tabulated and discussed in Section A.3.2.3.

The results from the stationary flow measurements indicate that approximately 85 percent of the flow originated from the lower completion interval. Increasing the production rate produced an increase in the contribution from the upper completion interval. The contribution percentage from the upper completion interval ranged from 13.6 percent at 65 gpm to 16.4 percent at 176 gpm.

A.2.8 Constant-Rate Test

A constant-rate pumping test was conducted following well development to collect hydraulic response data for determination of aquifer parameters. Prior to the test, the water level in the well was monitored to observe recovery to ambient head from development pumping and to establish baseline pretest conditions. Pumping for this test commenced on May 8, 2000, and continued for 4 days until May 12, 2000, when the VSD shut the pump down due to a power problem. The water level in the well was allowed to recover, and a new constant-rate test was begun May 18, 2000. This test was terminated on May 23, 2000, when the VSD again shut the pump down due to a downhole power fault. Head recovery was monitored for three days until May 26, 2000. Since repair of this problem required removal of the testing pump, the testing program was terminated except for characterization sampling. The composite characterization sampling had to be delayed until the sampling pump could be installed. This would also necessitate sampling at a much lower pumping rate (44 gpm) than the 175 gpm rate used during the constant-rate test. Pumping during the constant-rate test served to continue and complete the development process to restore natural water quality for sampling purposes. After removal of the testing pump, the permanent sampling pump was installed, and groundwater characterization sampling was completed with this pump.

A.2.8.1 Methodology

A continuous datalogger record was captured for barometric pressure and head pressure on the PXD in the well, extending from pretest monitoring through the recovery monitoring. During pumping, the discharge rate of produced water was also recorded continuously. The production rate of the pump was controlled using a feedback loop from the discharge flowmeter to ensure a consistent rate. In addition, water quality was monitored during the constant-rate test with field analyses of grab samples taken daily.

A pumping rate of 175 gpm was chosen for the test. This rate was near the maximum rate the pump could sustain. Based on experience during the early part of development, a PXD with a range of 0-15 psig was installed after flow logging for the pretest monitoring and constant-rate test. The 0-15 psig range provided an appropriate range of measurement for the maximum anticipated drawdown. Use of the lowest possible range maximizes the accuracy of the pressure measurements, which are proportional to the overall measurement range of the PXD.

The PXD was installed on May 3, 2000, at a calculated depth of 775.35 ft bgs based on the calibration performed when the PXD was installed. The PXD was subsequently lowered an additional 7 feet (based on wireline measurements), placing the PXD at 782.35 ft bgs. Table A.2-8 shows the PXD installation/ removal data for the PXD used for the constant-rate test. The removal calibration data was used in calculations because this data reflected the lowered PXD location. Note that the Cal 1 PXD psig value was a measurement in air above the water surface, and is not used for the water density calculation.

A.2.8.2 Hydraulic Data Collection

Figure A.2-14 shows the datalogger record for the constant-rate test pumping period in terms of the pumping rate and the hydraulic response to pumping. Figure A.2-15 shows the head record for both the pumping period and the recovery period as well as the barometric pressure record. These graphs illustrate the datasets and major features of the respective activities. Note that these graphs were made with only half the data (every other data point) due to limitations for data handling in the graphing program. Pumping started on May 8, 2000, and was terminated prematurely by the VSD on May 12, 2000, due to a power problem. The average pumping rate was 175.9 gpm. A second test begun on May 18, 2000, was also terminated prematurely by the VSD, also because of a power problem, on May 23, 2000. The average pumping rate for the second test was 175.0 gpm. It was judged that the data collected during the tests were sufficient for analysis, and no further testing was planned. The recovery period after the second test was abbreviated since full recovery occurred quickly.

Table A.2-8
PXD Installation for Constant-Rate Test

Design Analysis H-310 PXD SN 2262, 0-15 psig					
Install Date: 5/3/2000					
Removal/Calibration Date: 5/26/2000					
Static Water Level Depth 747.5 ft bgs (09:12, 5/26/2000)					
Stations	Cal 1	Cal 2	Cal 3	Cal 4	Cal 5
WRL/TOC[a] (ft)	646	655	664	673	680
PXD psig	- - -	1.2734	5.1263	8.995	12.003
Delta depth (ft): Cal5 - Cal2					25.00
Delta psi: Cal5 - Cal2					10.730
Density ft of water column/psi: delta depth / delta psi (in ft/psi)					2.330
Equivalent ft water: PXD psig (at Cal5) x density of water (ft/psi)					27.97
Calculated PXD installation depth: static water level + equiv. ft water					775.47

[a] Length of wireline (WRL) below top of casing (TOC); does not include the length of the PXD integral cable.

PXD - Pressure transducer
psi - Pounds per square inch
psig - Pounds per square inch guage
ft - Feet
bgs - Below ground surface

The data file for the constant-rate testing is EC-7_Aqtest_HT.xls on the accompanying CD. The data records are very clean with only a small amount of noise in the drawdown PXD record. Note that the barometric record has been scaled proportionate to the PXD record so that the fluctuations in both records are presented in proportion. The barometric record shows that the barometric pressure was fairly constant relative to the PXD pressure changes.

A.2.9 Water Quality Monitoring

Water quality monitoring of the well discharge was conducted during pumping to provide information on water chemistry and to indicate when natural groundwater conditions predominate in the pumping discharge. Certain parameters such as Br^- ion concentration, pH, EC, turbidity, and DO were expected to decline as development progressed indicating natural groundwater quality as opposed to water affected by drilling and completion activities. Also, parameter values should stabilize after prolonged pumping and development as natural groundwater permeates the well environment. Rebound of parameter values at the beginning of each cycle of pumping was expected to decline toward the values observed toward the end of the previous cycle as development progressed.

The standard parameters that were monitored during development and testing of Well ER-EC-7 included pH, EC, temperature, turbidity, DO, and Br^- ion. In addition, lead and tritium were sampled in compliance with the schedule in the Fluid Management Plan (including waivers) (DOE/NV, 1999). In-line monitoring data was collected continuously for all the standard parameters except bromide. Grab samples were obtained every two hours when possible and analyzed for all the water quality parameters.

Pumping for well development was officially begun on April 22, 2000, at about 16:30. In-line monitoring began at 17:00 with operation of a Hydrolab® H20 Multiprobe. The Hydrolab® fed directly to the datalogger where data could be continuously accessed via a portable laptop computer. Grab sample monitoring was actually initiated earlier on April 12 and 21, 2000, as the field laboratory was fully operational during functionality testing of the pump and pressure control system.

A.2.9.1 Grab Sample Monitoring

Grab samples were obtained from a sample port located on the wellhead assembly. For the development phase, beginning April 22, 2000, grab samples were collected and analyzed every two hours primarily during daylight hours until 08:00 on April 29, 2000. For the constant-rate pumping test, up to six grab samples were obtained daily on May 12 and from May 18 to 23, 2000. No grab samples were obtained from May 8 to May 11 except for lead and tritium samples.

Grab samples were analyzed using equipment and methodology contained in the DOP ITLV-UGTA-312, "Water Quality Monitoring"; DOP ITLV-UGTA-301, "Fluid Sample Collection"; and DOP ITLV-UGTA-101, "Monitoring and Documenting Well Site Activities." All instruments were calibrated according to DOP ITLV-UGTA-312 at the beginning of each 12-hour shift, and a calibration check was completed at the end of each shift. The following instruments were used to analyze grab samples:

- YSI 58 (DO)
- YSI 3500 Multimeter (for pH, EC and temperature)
- HF Scientific DRT-15C Turbimeter (turbidity)
- Orion 290A (bromide)
- HACH DR100 Colorimeter Kit (lead)

The complete results of grab sample monitoring have been compiled and are presented in Attachment 2. The results have been related to the pumping rate, the total discharge, and the phase of development or testing. Additionally, two graphs have been made showing water quality parameters versus total discharge in gallons. Figure A.2-16 shows EC, pH, and DO. Figure A.2-17 shows turbidity and Br^- concentration.

The grab sample temperature results remained fairly constant throughout development and hydraulic testing, averaging 29.0°C with a range of between 26.4 and 30.0°C. The temperature results are not depicted. Temperature differences can often fluctuate depending on ambient air temperature and the speed with which the temperature of the wellhead sample is measured. Figure A.2-16 shows that pH remained fairly constant throughout the monitoring, ranging between 7.4 and 8.2. EC was much lower than in previously tested WPM-OV wells, beginning at below 200 micromhos/cm (µmhos/cm), climbing steadily with pumping, and finally leveling off at approximately 315 µmhos/cm. DO showed an expected decline, starting well development from a high of 6.76 mg/L, and leveling off at about 3.4 mg/L.

In Figure A.2-17, turbidity was mostly below 0.5 nephelometric turbidity units (NTUs), with occasional peaks up to 4.0 NTUs. The bromide concentration generally fluctuated between 0.10 and 0.27 mg/L. There were no long-term trends in turbidity or Br^- which would indicate any continuing progress in development. The bromide concentrations in the produced water suggest persistence of drilling fluids in the formation at a low level. The results of lead and tritium monitoring is presented in Section A.4.0, Environmental Compliance.

A.2.9.2 In-Line Monitoring

In-line monitoring was conducted using a Hydrolab® H2O Multiprobe. The Campbell Scientific datalogger recorded data at various sampling intervals ranging from 5 seconds to 5 minutes. These intervals varied depending on changes in pressure and head. The parameters temperature, EC, and pH were recorded continuously when the pump was running between April 23 (15:40) and April 28, 2000 (01:50). In-line data were also recorded every two hours on a "Water Quality Data Form," for comparison with grab sample results. The Hydrolab® was calibrated and maintenance was performed at the beginning of operations and every three to four days thereafter according to DOP ITLV-UGTA-312. The Hydrolab® was taken off-line during the constant-rate test.

Two figures have been derived from the in-line monitoring data. Figure A.2-18 shows EC and pH related to total discharge in gallons. Figure A.2-19 depicts the temperature over the same period. The temperature record shows a fairly constant 29 to 30°C after some initial fluctuations. The EC record in Figure A.2-18 shows a gradual rise in EC from about 220 to about 300 µmhos/cm at the end of well development. This is very similar to the grab sample data depicted in Figure A.2-16. The pH record from in-line monitoring shows some drift in an upward direction, but after each calibration the pH ended up lower from 1.25 to

0.5. The record seems to indicate that the pH meter was not working properly, especially in light of the extreme fluctuations ranging from about 7.5 to 9.5. The in-line data have been saved and are contained in the Excel® file hydrolab.xls on the accompanying CD.

A.2.10 Groundwater Sample Collection

Two types of well samples were collected for characterization of the groundwater in Well ER-EC-7: a discrete bailer sample and a composite sample from the wellhead.

A.2.10.1 Downhole Discrete Sampling

The purpose of a discrete sample is to target a particular depth interval for sampling under either static or pumping conditions. Discrete sampling is optimally performed after the well has been determined to meet the following criteria: (1) the maximum possible development has occurred for the interval in which the samples will be collected, and (2) a pumping rate can be maintained that will ensure a representative sample of the interval. The discrete sampling interval was determined after initial well development and downhole flow and temperature logging.

On April 28, 2000, discrete samples were obtained from a depth of 1,200 ft bgs, just above the lower screened interval, at a pumping rate of approximately 176 gpm. The samples were collected using a DRI logging truck and discrete bailer. The bailer was decontaminated using the methodology in DOP ITLV-UGTA-500, “Small Sampling Equipment Decontamination,” and SQP ITLV-0405, “Sampling Equipment Decontamination.” An equipment rinsate sample was collected from the decontaminated bailer prior to collection of the discrete samples. The samples were processed according to the following procedures: DOP ITLV-UGTA-302, “Fluid Sample Collection”; SQP ITLV-0402, “Chain of Custody”; and SQP ITLV-0403, “Sample Handling, Packaging, and Shipping.” Samples were immediately stored with ice and transported to a secure refrigerated storage. Sample bottles were obtained for the following laboratories: Paragon, Los Alamos National Laboratory (LANL), University of Nevada, Las Vegas - Harry Reid Center (UNLV-HRC), LLNL and DRI.

The preliminary results of the discrete samples have been tabulated and are presented in Attachment 3. These results are very similar for most of the parameters compared to the results of the discrete groundwater characterization sample taken during drilling (before the well was completed). That sample was obtained from a depth of 952 ft bgs.

A.2.10.2 Groundwater Composite Sample

The purpose of this sample is to obtain a composite of as much of the well as possible. The composite groundwater characterization sample would normally have been collected at the end of the constant-rate pumping test from the sampling port at the wellhead. Since this sample is meant to represent a composite of the whole well, there are two criteria for the sample to be the most representative: (1) the sample should be obtained after pumping for the longest possible time, and (2) the pumping rate should be as great as possible in order for the component water production to include as many completion intervals as possible. However, the testing pump developed a fault before the groundwater characterization sample was collected and had to be removed. Consequently, the composite sample had to be collected with the lower rate sampling pump that was subsequently installed.

For the composite sample, a flow rate of 44 gpm was used since this was the maximum pumping rate that could be obtained from the sampling pump. Both stationary and trolling flow logging showed that as the production rate decreased the percentage of flow from the upper interval also decreased somewhat. From the results of the flow logging, the proportional composition of the discharge water at 65 gpm from the upper completion interval was between 12 and 14 percent. At 44 gpm it can be inferred that the percentage contribution is slightly less.

On June 5, 2000, beginning at 09:15, a composite characterization sample was collected from the wellhead sampling port directly into sample bottles. A field duplicate sample was obtained concurrently. A constant production rate of 44 gpm was maintained during the sampling event. At the time of sampling, approximately 3,600,000 gallons of groundwater had been pumped from the well during development and testing activities. The samples were processed according to the same procedures used for the discrete sampling. ITLV samples were immediately put on ice and transported to a secure refrigerated storage. Sample bottles were collected for the following laboratories: Paragon (ITLV), LANL (ITLV), LLNL, UNLC-HRC, and DRI.

The final, validated results of the June 5, 2000, composite sample have been tabulated and are presented in Attachment 3.

A.2.11 Thermal Flow Log and ChemTool Log

Thermal flow logging was conducted at the very end of the development and testing program to determine flow in the well under ambient, static conditions. The resulting flow information may differ from that of the thermal flow logging conducted in the open borehole before well completion because it is specific to the completion intervals, and reflects remediation of conditions imposed by drilling. The ChemTool provides a depth log of temperature, pH, and EC. The thermal flow and ChemTool logging was conducted on June 1, 2000, by DRI.

A.2.11.1 Methodology

The thermal flow log is a stationary log that can measure vertical flow rates at very low velocities (less then 2 gpm). The flow profile along the well completion is constructed from multiple stationary flow measurements. The ChemTool log is a trolling log that collects data on parameter variation with depth.

A.2.11.2 Results

The results of the ChemTool logging are presented in Figure A.2-20. The ChemTool log shows relatively constant EC from the top of the upper completion down to about 1,250 ft bgs at the middle of the lower completion. The EC averages less than 150 µmhos/cm below the top of the upper completion interval, rising up to about 200 µmhos/cm in the upper water column. The pH gradually declines from about 6.9 at 760 ft bgs to 6.5 at 1,240 ft bgs. Both EC and pH generally decline with increasing depth. The temperature log shows a slightly increasing gradient with no particular deflections. The thermal flow log data are presented in Table A.2-9.

Table A.2-9
Thermal Flow Log Results

Station Depth (ft)	Response (sec)	Flow Rate (gpm)	Velocity (fpm)
910	13.70 +/- 3.740	0.000 +/- .000	0.000 +/- .000 *
930	-1.31 +/- .864	-1.290 +/- .851	-1.401 +/- .924
990	-0.50 +/- .002	-2.200 +/- .009	-2.390 +/- .010
1210	-0.54 +/- .108	-2.200 +/- .440	-2.390 +/- .478
1225	-1.55 +/- .108	-0.918 +/- .064	-0.997 +/- 0.069
1230	-1.19 +/- .800	-1.568 +/-1.054	-1.704 +/-1.145
1240	-1.39 +/- .140	-1.144 +/- .115	-1.243 +/- .125
1245	-1.49 +/- .198	-0.994 +/- .132	-1.080 +/- .143

* - Measurement was below calibration limits: > 10 or < -11 seconds
ft - Feet
sec - Second
gpm - Gallons per minute
min - Minute

Internal diameter at all stations was 4.75 in.

Note: Positive values indicate upward flow; negative values indicate downward flow.

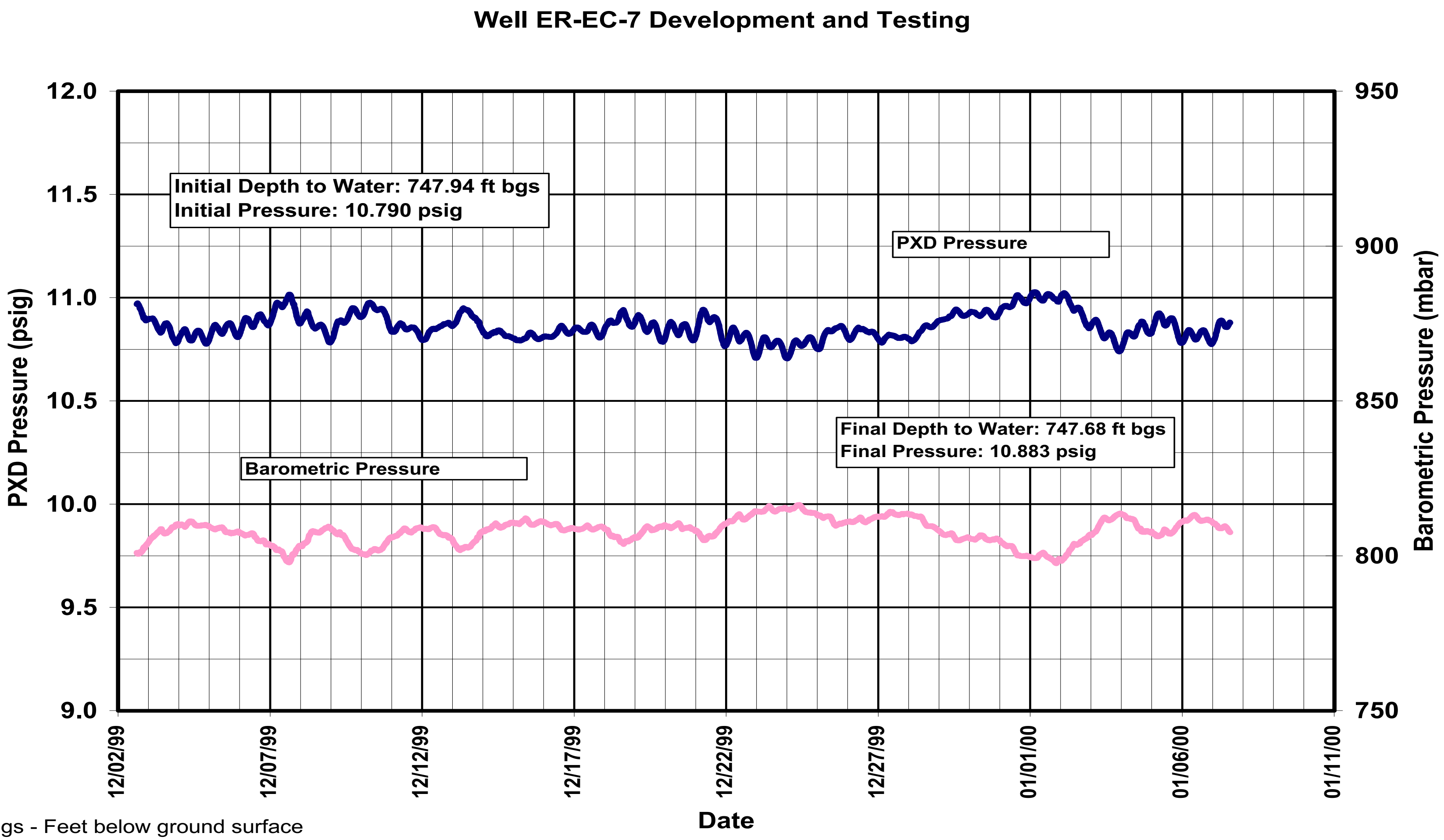
A.2.12 Sampling Pump Installation

On June 2, 2000, a sampling pump was installed in Well ER-EC-7 by BN with the assistance of the Electrical Submersible Pump (ESP) Systems representative. Manufacturer's specifications for this pump are included in Attachment 1. The pump assembly was placed using 2 7/8-in. outside diameter (od) stainless steel pipe. The bottom of the pump assembly was landed at 906.05 ft bgs. A 2.42 ft stickup makes the entire string a length of 908.47 ft. The pump intake is located at 886.05 ft bgs and the top of the pump assembly is at 880.05 ft bgs. The total length of the pump assembly is 26.0 ft, not including the crossover to the 2 7/8-in. pipe. Table A.2-10 summarizes the details of the pump assembly components. Figure A.2-21 depicts the final wellhead configuration.

The pump string was landed to a 1-in. landing plate at the wellhead. A VSD was wired to the pump. On June 2, 2000, a functionality test was conducted on the pump after appropriate wellhead plumbing was attached to the pump string. The discharge was routed to the unlined Sump #1. At about 14:52, the pump was started and discharge occurred at the surface approximately 4.5 minutes later. The pump was run for about 40 minutes at discharge rates of between 22.5 gpm (47 Hz and 18 amps) and 44 gpm (70 Hz and 31 amps). Approximately 1,000 gals were pumped during the functionality test. No problems were encountered.

Table A.2-10
Dedicated Sampling Pump Specifications for ER-EC-7

Pump Component	Type/Model	Serial Number	Other Information
ESP Pump	TD 800	2D8I15039	52 Stage
ESP Protector	TR3-STD	3B8I07993	- - -
ESP Motor	TR3-UT/13 THD	3B8I06466	40 hp, 740 V, 30 A

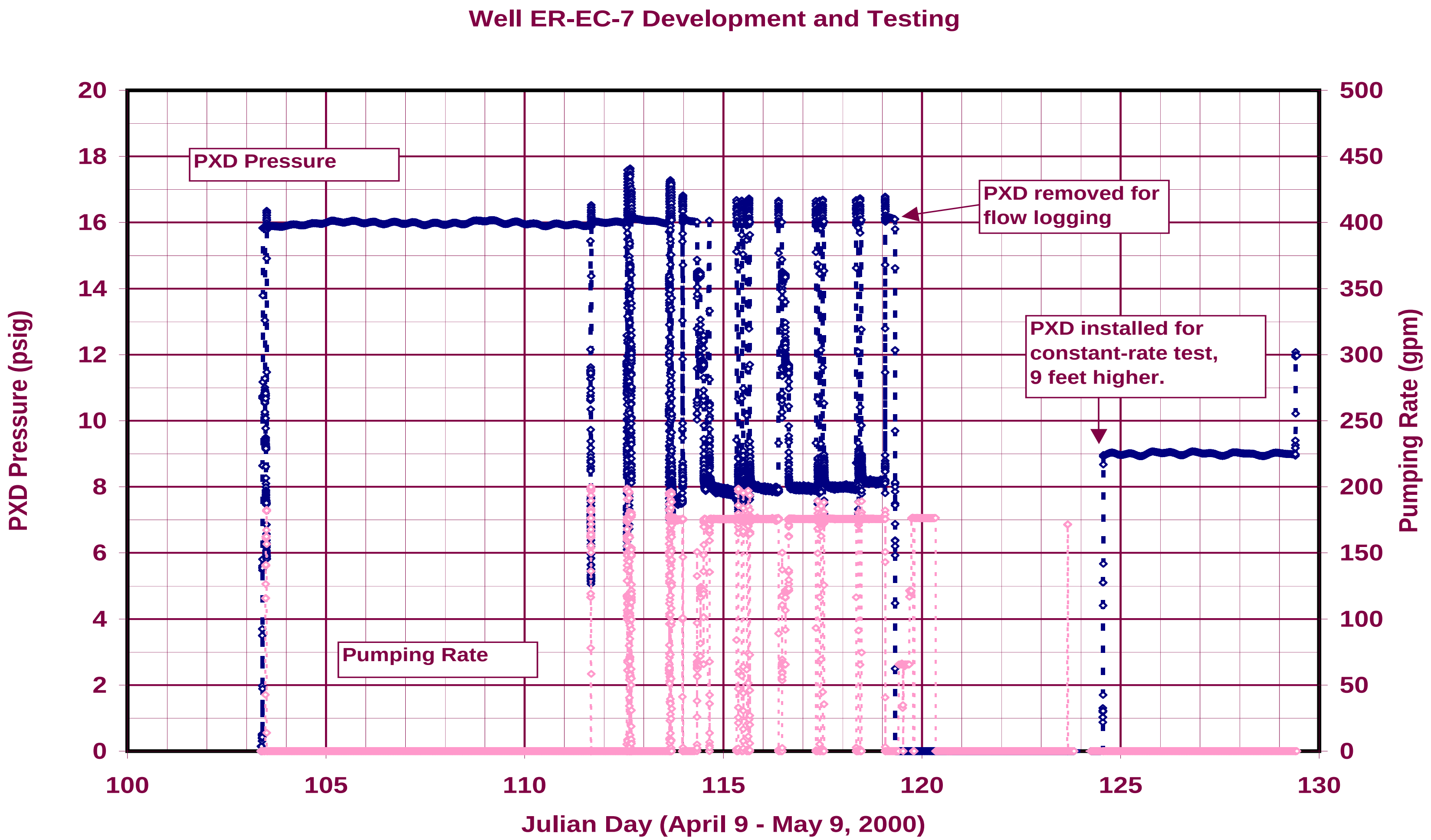


Initial Depth to Water: 747.94 ft bgs
Initial Pressure: 10.790 psig

Final Depth to Water: 747.68 ft bgs
Final Pressure: 10.883 psig

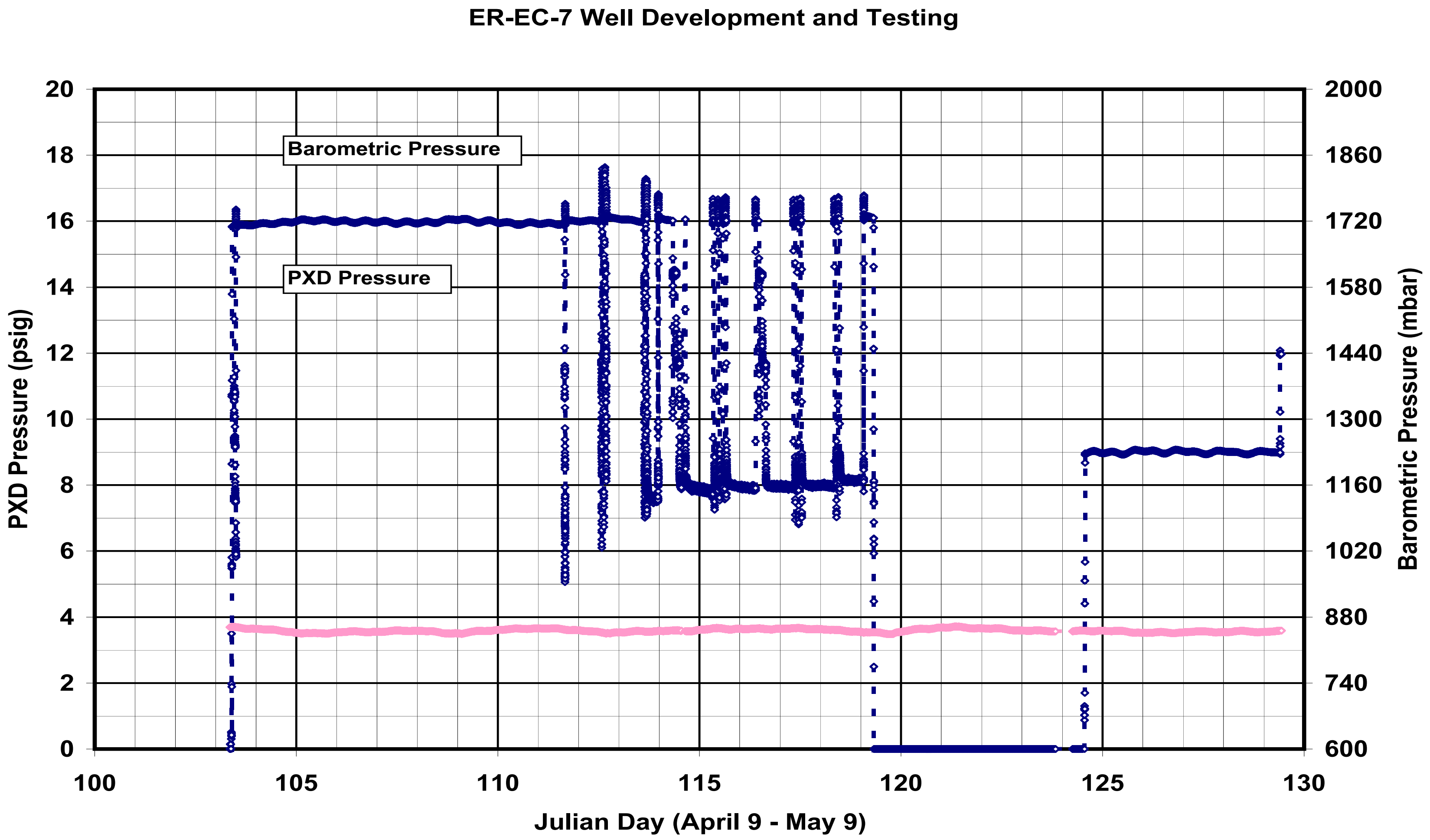
ft bgs - Feet below ground surface
mbar - Millibars
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.2-1
Predevelopment Water Level Monitoring



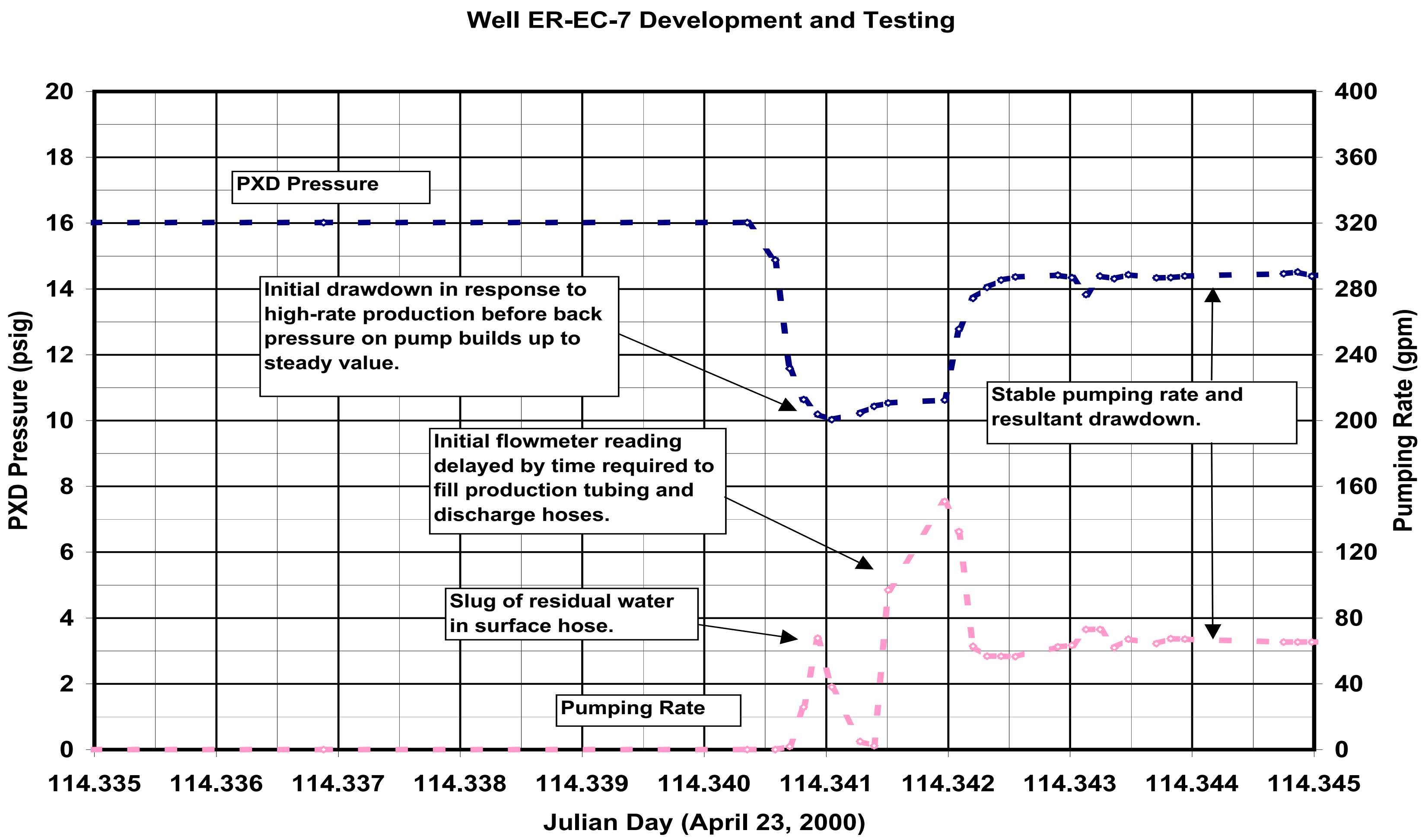
gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.2-2
Pumping Rate and Hydraulic Response During Development



mbar - Millibars
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.2-3
Hydraulic Response and Barometric Pressure During Development



Initial drawdown in response to high-rate production before back pressure on pump builds up to steady value.

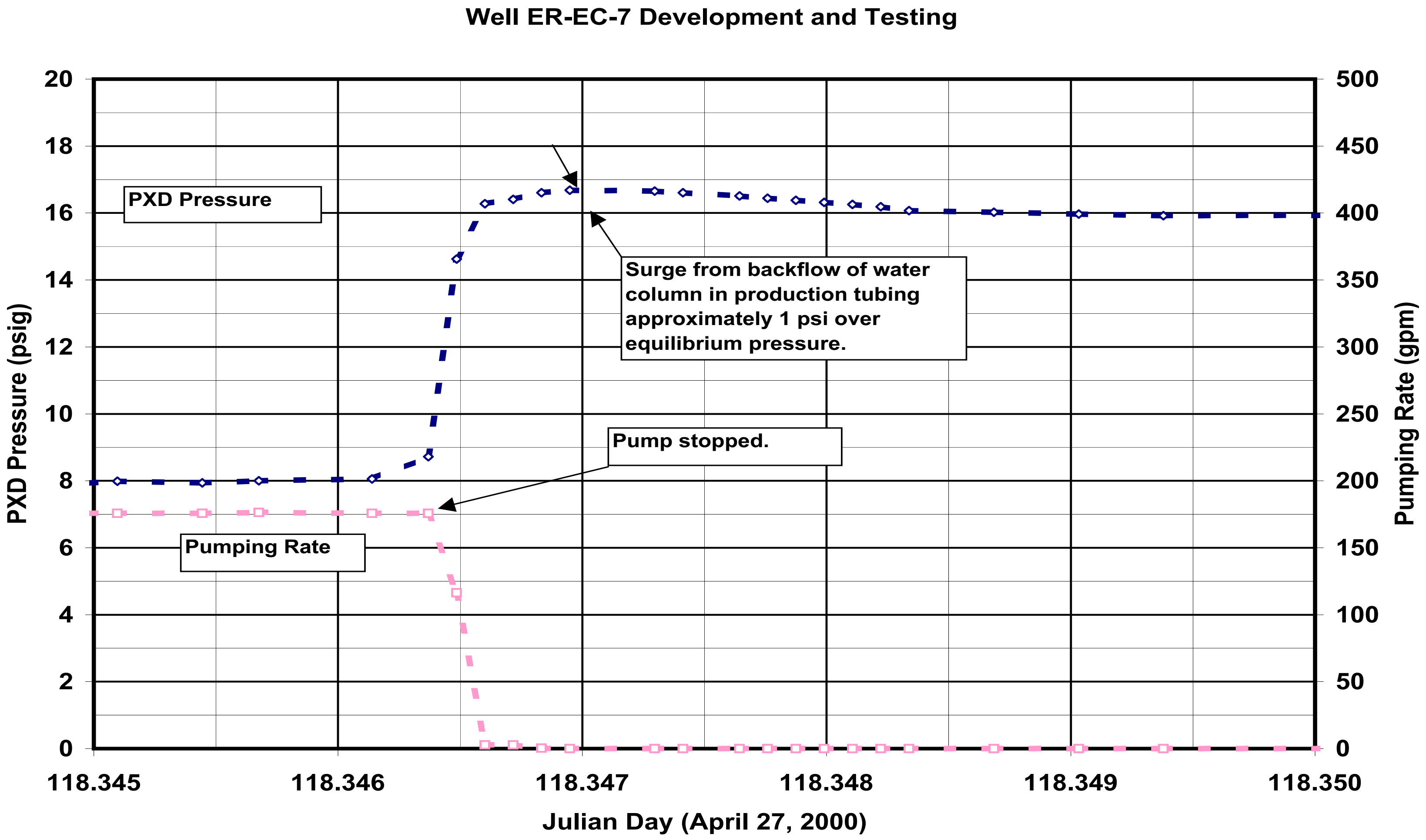
Initial flowmeter reading delayed by time required to fill production tubing and discharge hoses.

Slug of residual water in surface hose.

Stable pumping rate and resultant drawdown.

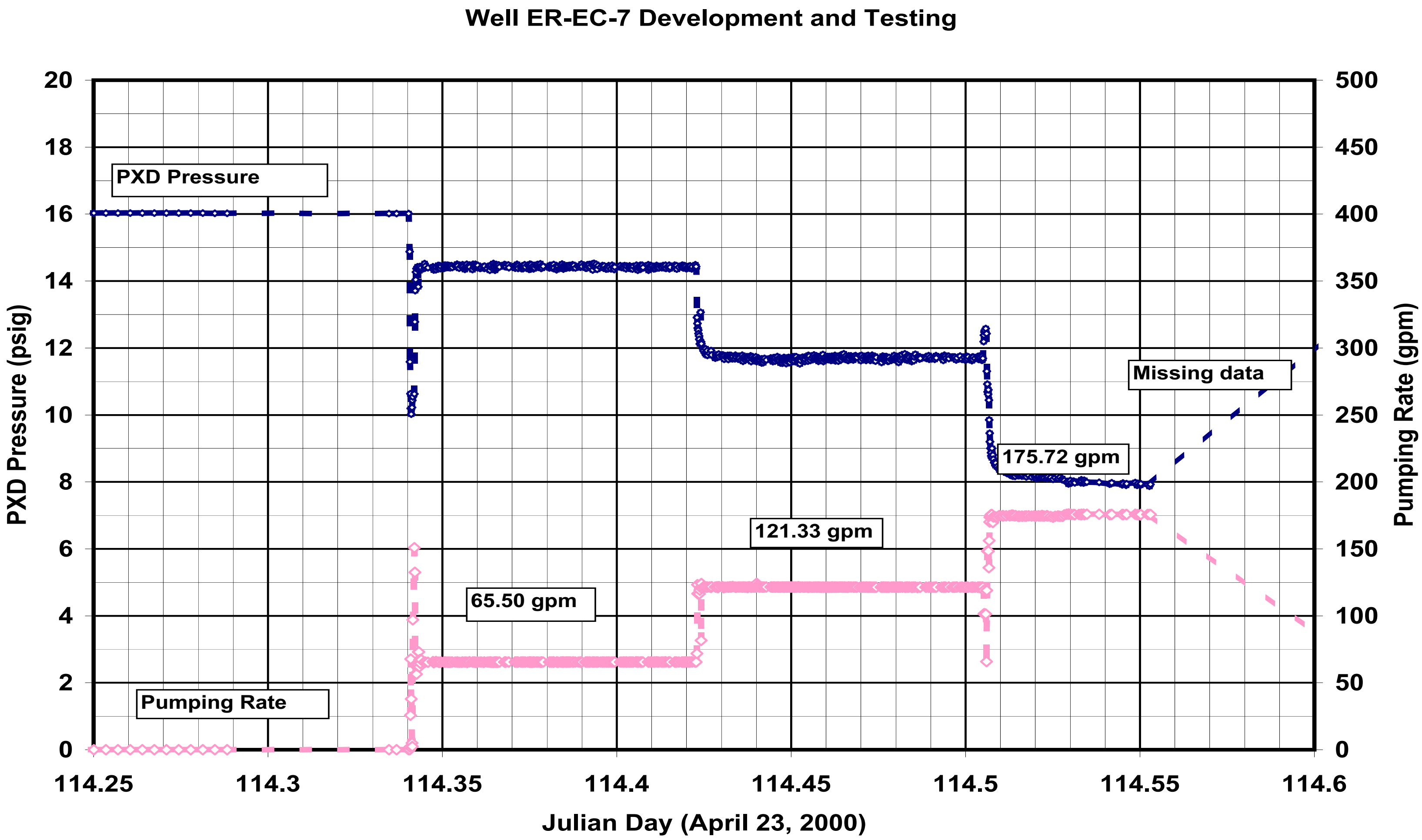
gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.2-4
Detail of Startup Effects



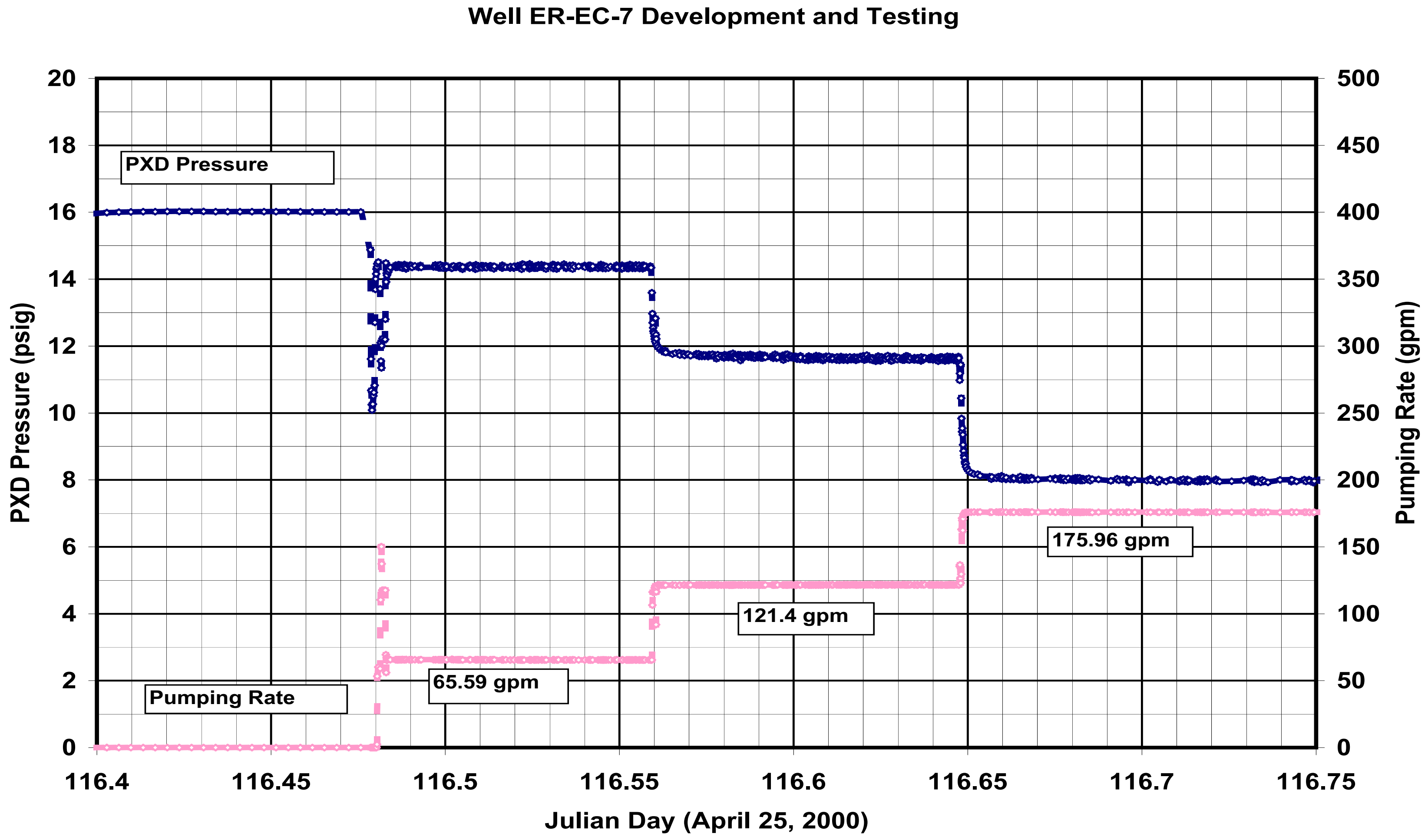
gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.2-5
Detail of Surging Action



gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.2-6
Detail of First Step-Drawdown



gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.2-7
Detail of Second Step-Drawdown

Well Name: ER-EC-7	Western Pahute Mesa - Oasis Valley Drilling Program		
Date: 4/28/00	Start Date: 4/28/00	Stop Date: 4/28/00	
Well Development and Hydraulic Testing		Proj No: 799416.00020200	
Log Run #: ec7mov1		Geol: J. Wurtz	
Logging Contractor: Desert Research Institute (DRI)		Logging Method: Stressed Full-bore Flowlog	
Flow logging at 20 feet per minute- Down		Surface Discharge: 65 gals/min	

FOR PRELIMINARY USE ONLY

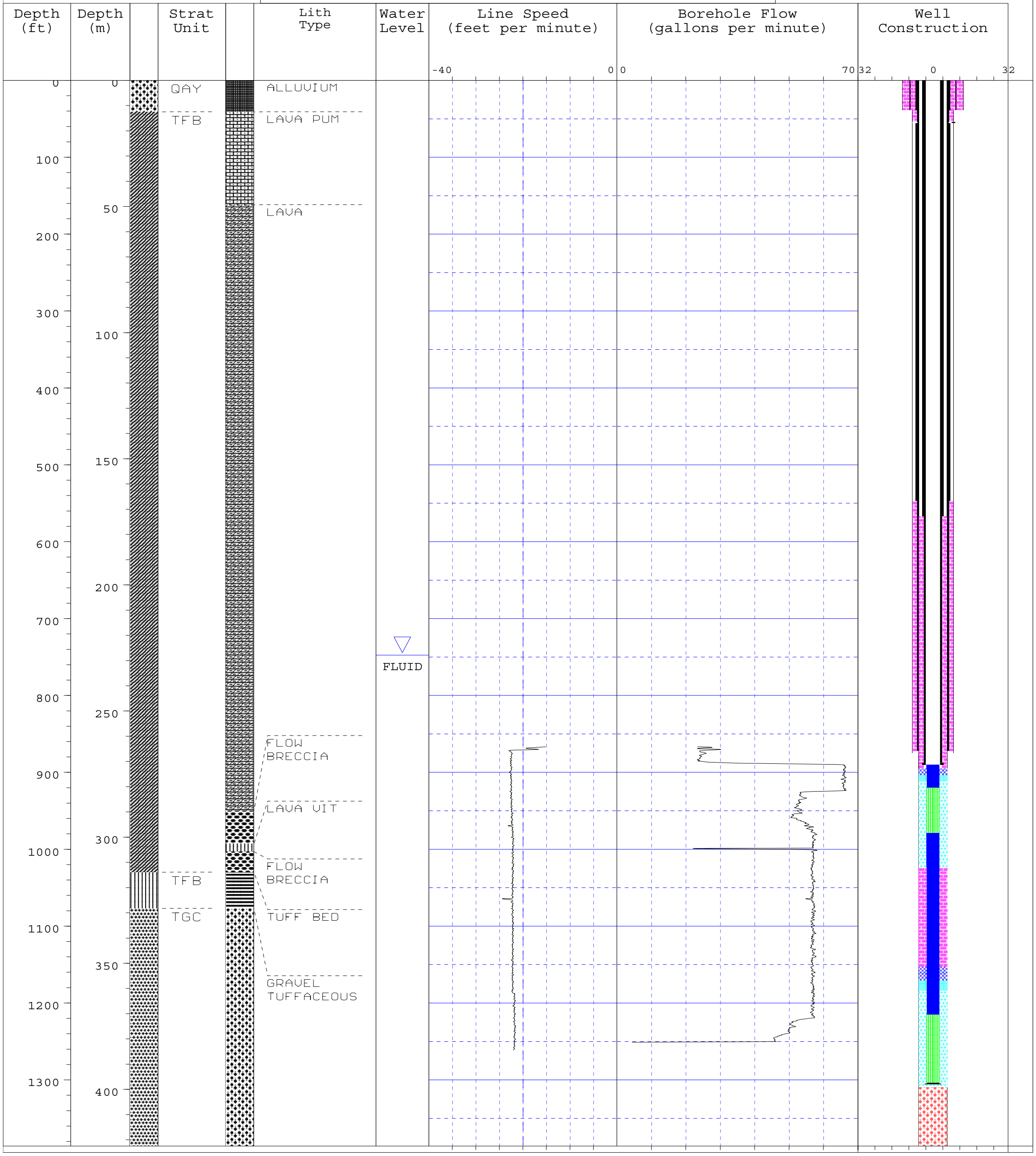
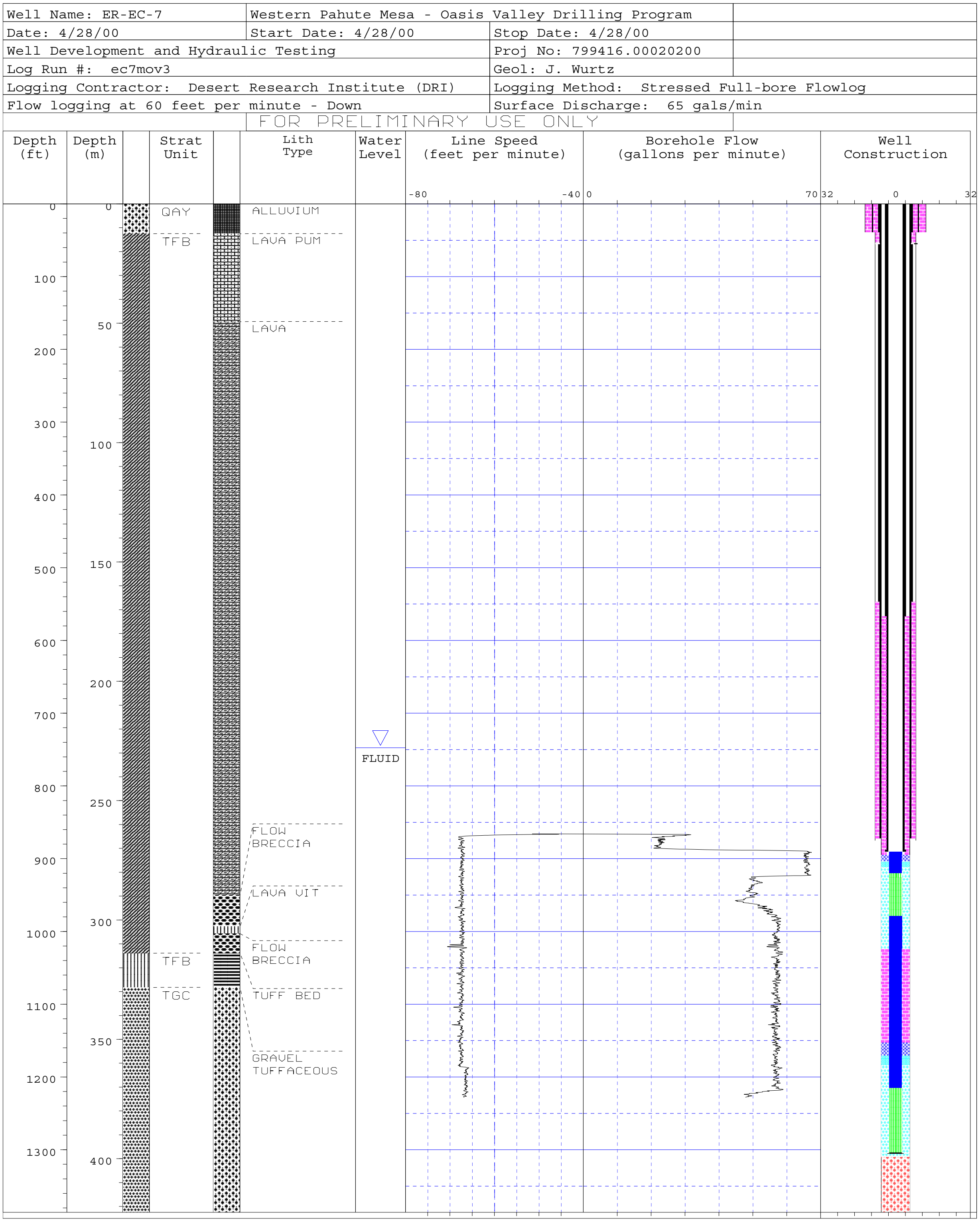


Figure A.2-8
Flow Log at 65 gpm Production Rate and 20 fpm Downward Trolling Rate



Well Name: ER-EC-7	Western Pahute Mesa - Oasis Valley Drilling Program		
Date: 4/28/00	Start Date: 4/28/00	Stop Date: 4/28/00	
Well Development and Hydraulic Testing		Proj No: 799416.00020200	
Log Run #: ec7mov3		Geol: J. Wurtz	
Logging Contractor: Desert Research Institute (DRI)		Logging Method: Stressed Full-bore Flowlog	
Flow logging at 60 feet per minute - Down		Surface Discharge: 65 gals/min	

FOR PRELIMINARY USE ONLY

Figure A.2-9
Flow Log at 65 gpm Production Rate and 60 fpm Downward Trolling Rate

Well Name: ER-EC-7	Western Pahute Mesa - Oasis Valley Drilling Program		
Date: 4/28/00	Start Date: 4/28/00	Stop Date: 4/28/00	
Well Development and Hydraulic Testing		Proj No: 799416.00020200	
Log Run #: ec7mov5		Geol: J. Wurtz	
Logging Contractor: Desert Research Institute (DRI)		Logging Method: Stressed Full-bore Flowlog	
Flow logging at 20 feet per minute - Down		Surface Discharge: 120 gals/min	

FOR PRELIMINARY USE ONLY

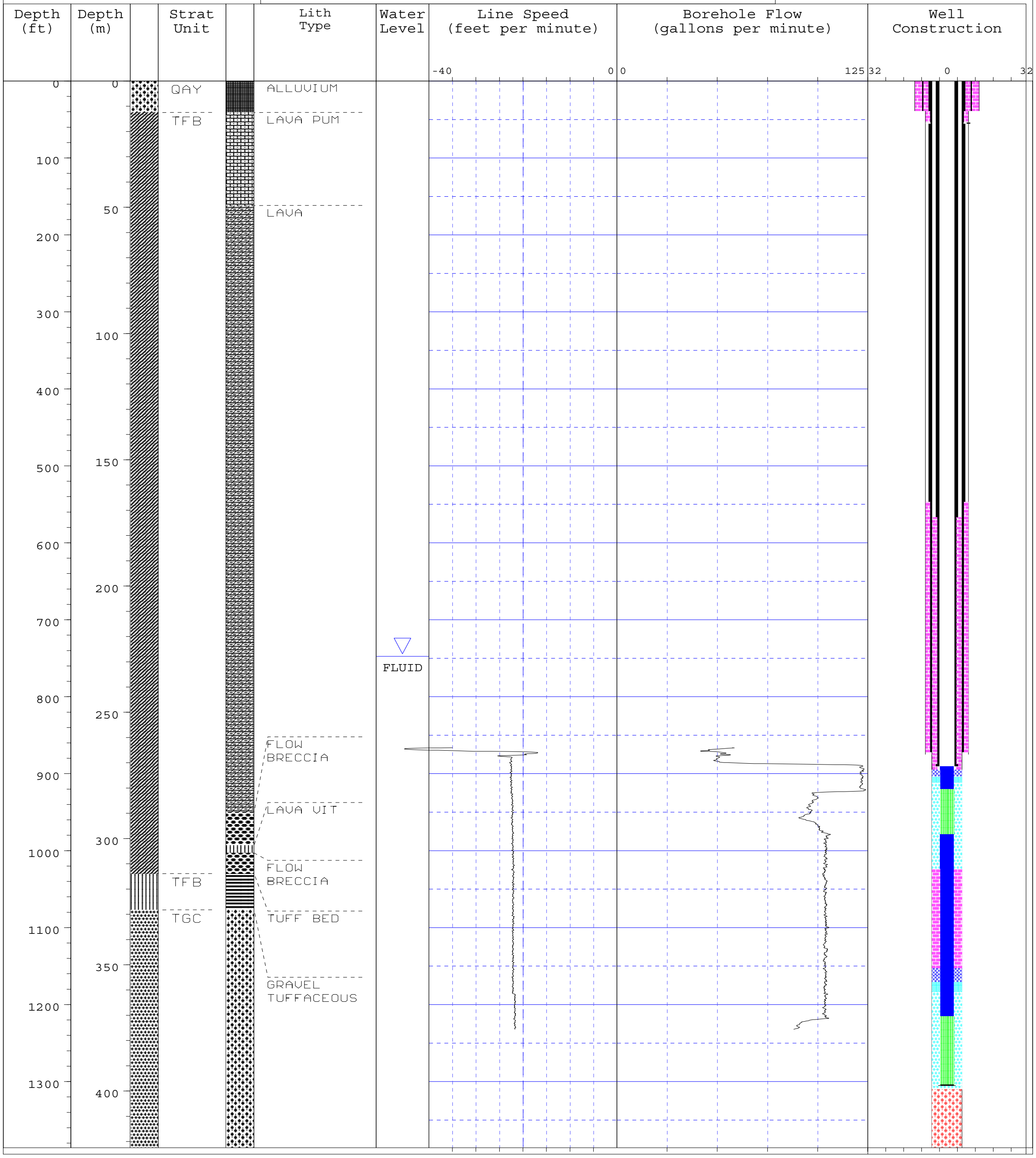


Figure A.2-10
Flow Log at 120 gpm Production Rate and 20 fpm Downward Trolling Rate

Well Name: ER-EC-7	Western Pahute Mesa - Oasis Valley Drilling Program		
Date: 4/28/00	Start Date: 4/28/00	Stop Date: 4/28/00	
Well Development and Hydraulic Testing		Proj No: 799416.00020200	
Log Run #: ec7mov6		Geol: J. Wurtz	
Logging Contractor: Desert Research Institute (DRI)		Logging Method: Stressed Full-bore Flowlog	
Flow logging at 60 feet per minute - Down		Surface Discharge: 120 gals/min	

FOR PRELIMINARY USE ONLY

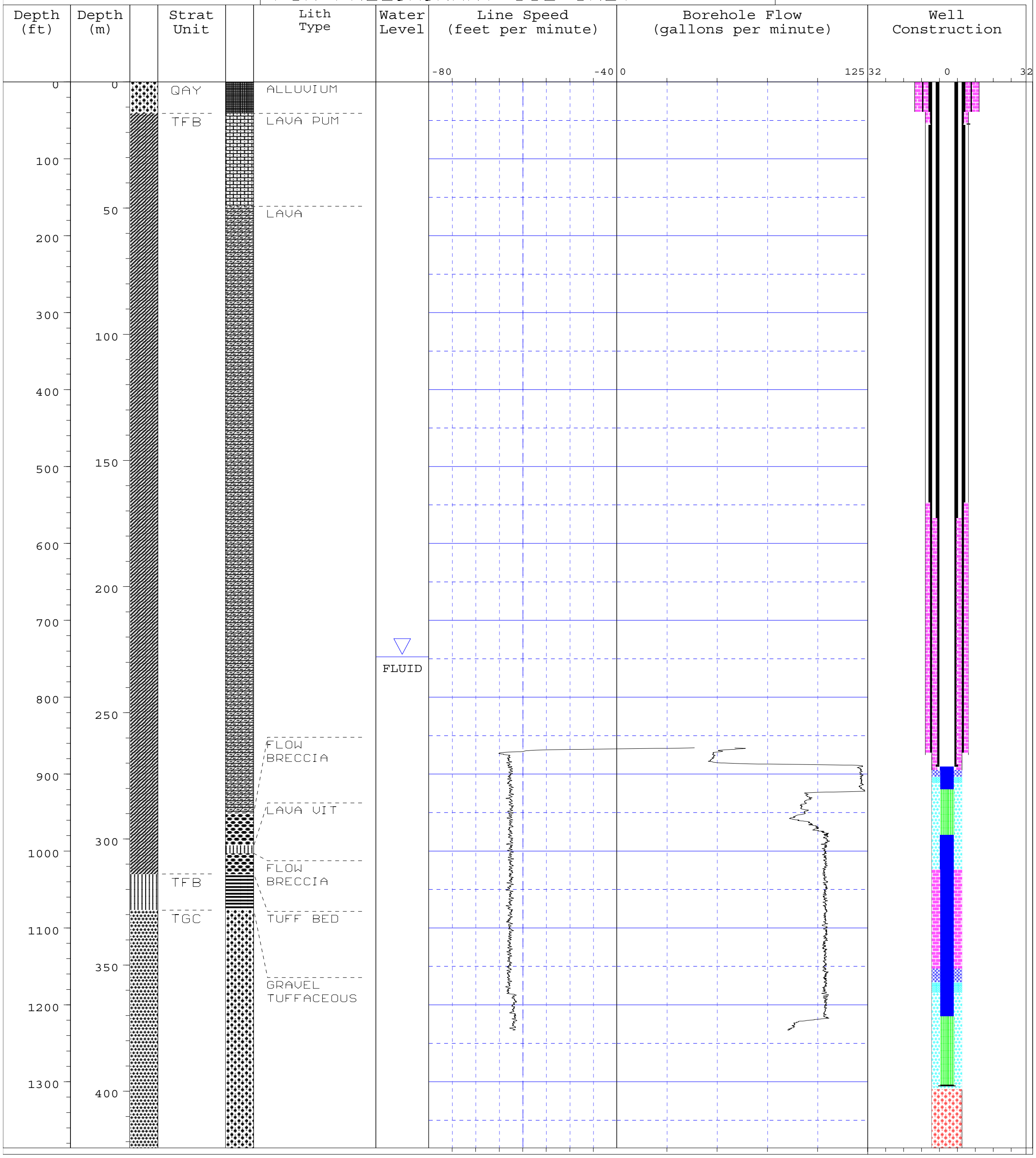
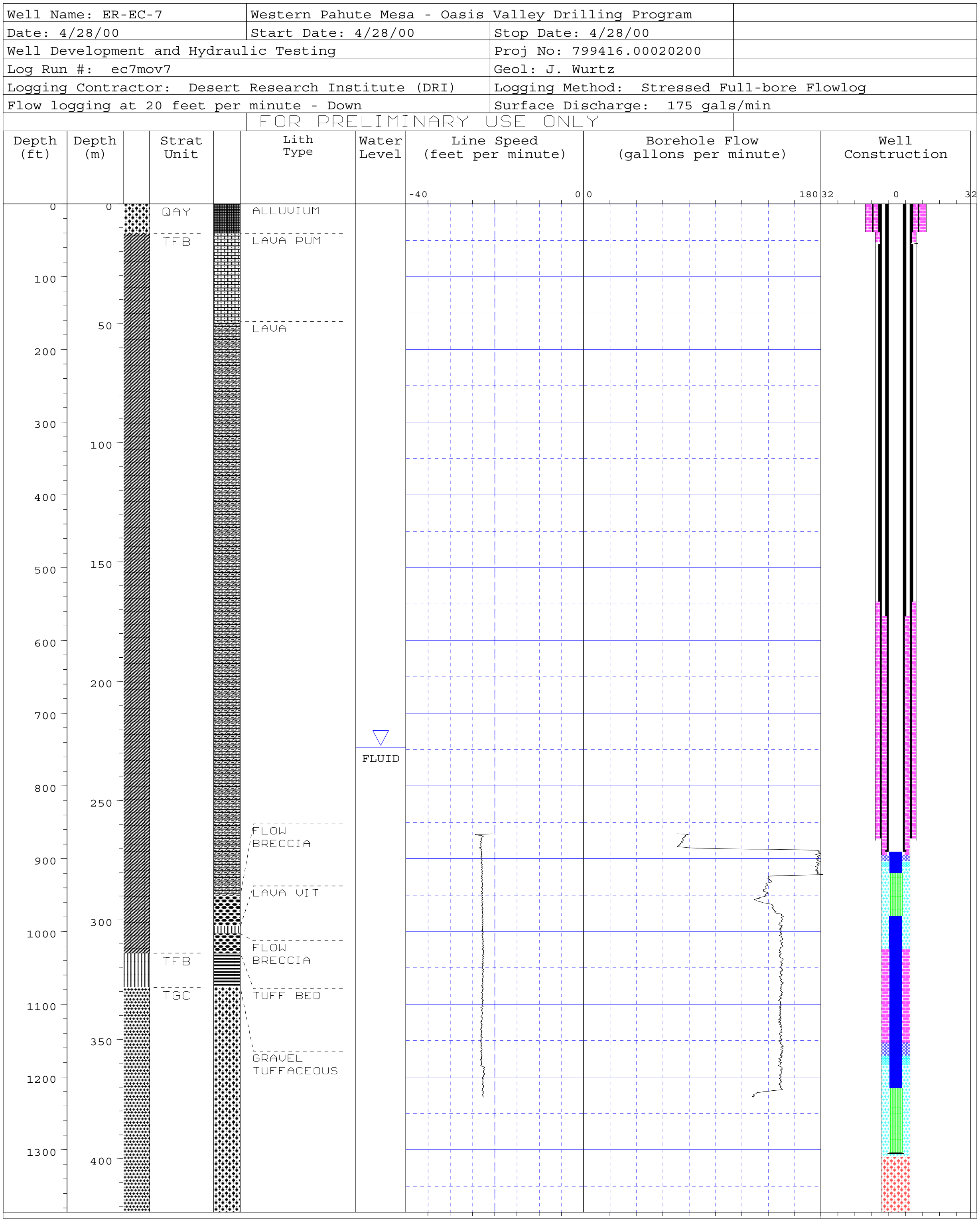


Figure A.2-11
Flow Log at 120 gpm Production Rate and 60 fpm Downward Trolling Rate



Well Name: ER-EC-7
Western Pahute Mesa - Oasis Valley Drilling Program
Date: 4/28/00
Start Date: 4/28/00
Stop Date: 4/28/00
Well Development and Hydraulic Testing
Proj No: 799416.00020200
Log Run #: ec7mov7
Geol: J. Wurtz
Logging Contractor: Desert Research Institute (DRI)
Logging Method: Stressed Full-bore Flowlog
Flow logging at 20 feet per minute - Down
Surface Discharge: 175 gals/min
FOR PRELIMINARY USE ONLY

Figure A.2-12
Flow Log at 175 gpm Production Rate and 20 fpm Downward Trolling Rate

Well Name: ER-EC-7	Western Pahute Mesa - Oasis Valley Drilling Program	
Date: 4/28/00	Start Date: 4/28/00	Stop Date: 4/28/00
Well Development and Hydraulic Testing		Proj No: 799416.00020200
Log Run #: ec7mov8		Geol: J. Wurtz
Logging Contractor: Desert Research Institute (DRI)		Logging Method: Stressed Full-bore Flowlog
Flow logging at 60 feet per minute - Down		Surface Discharge: 175 gals/min

FOR PRELIMINARY USE ONLY

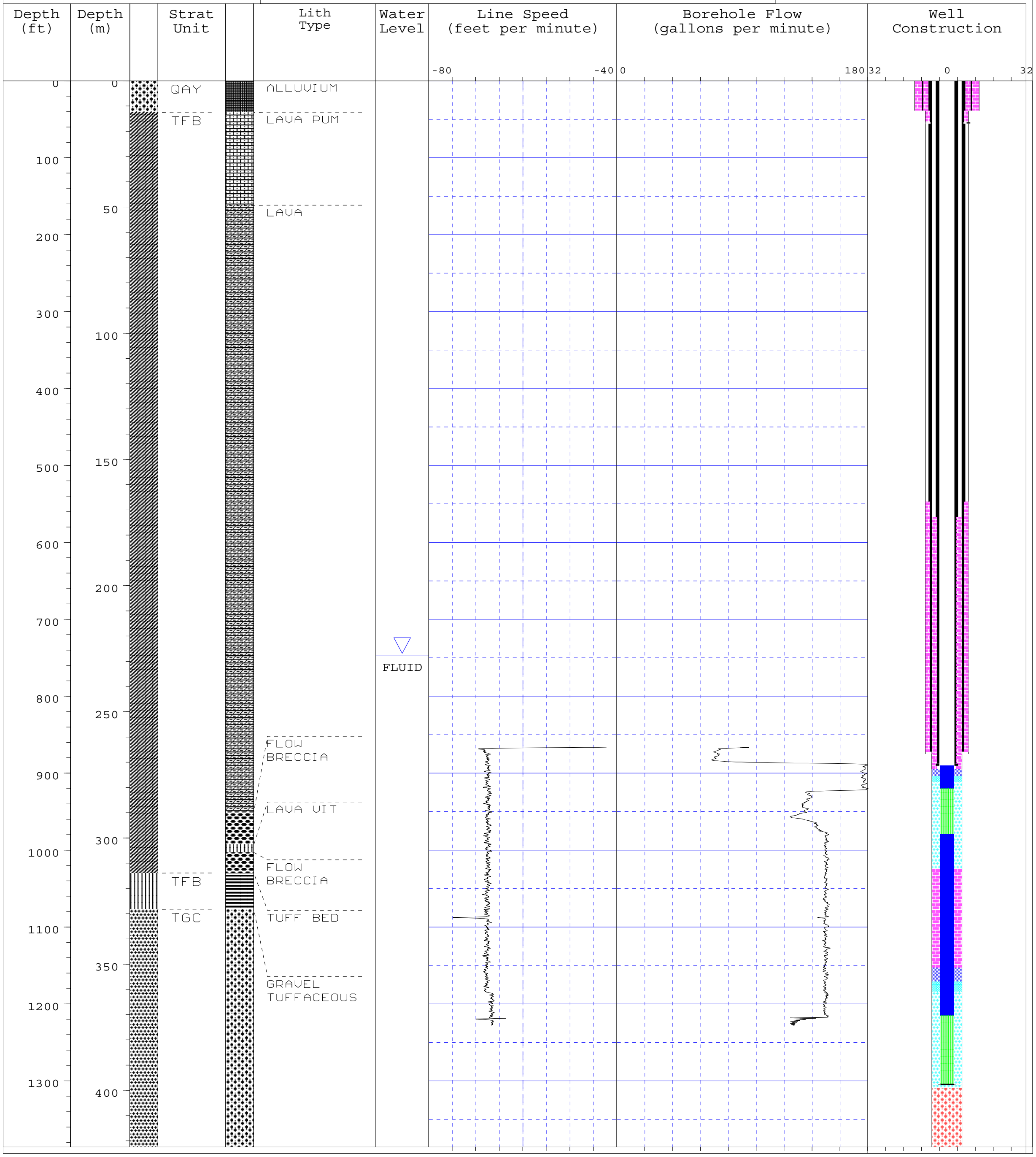
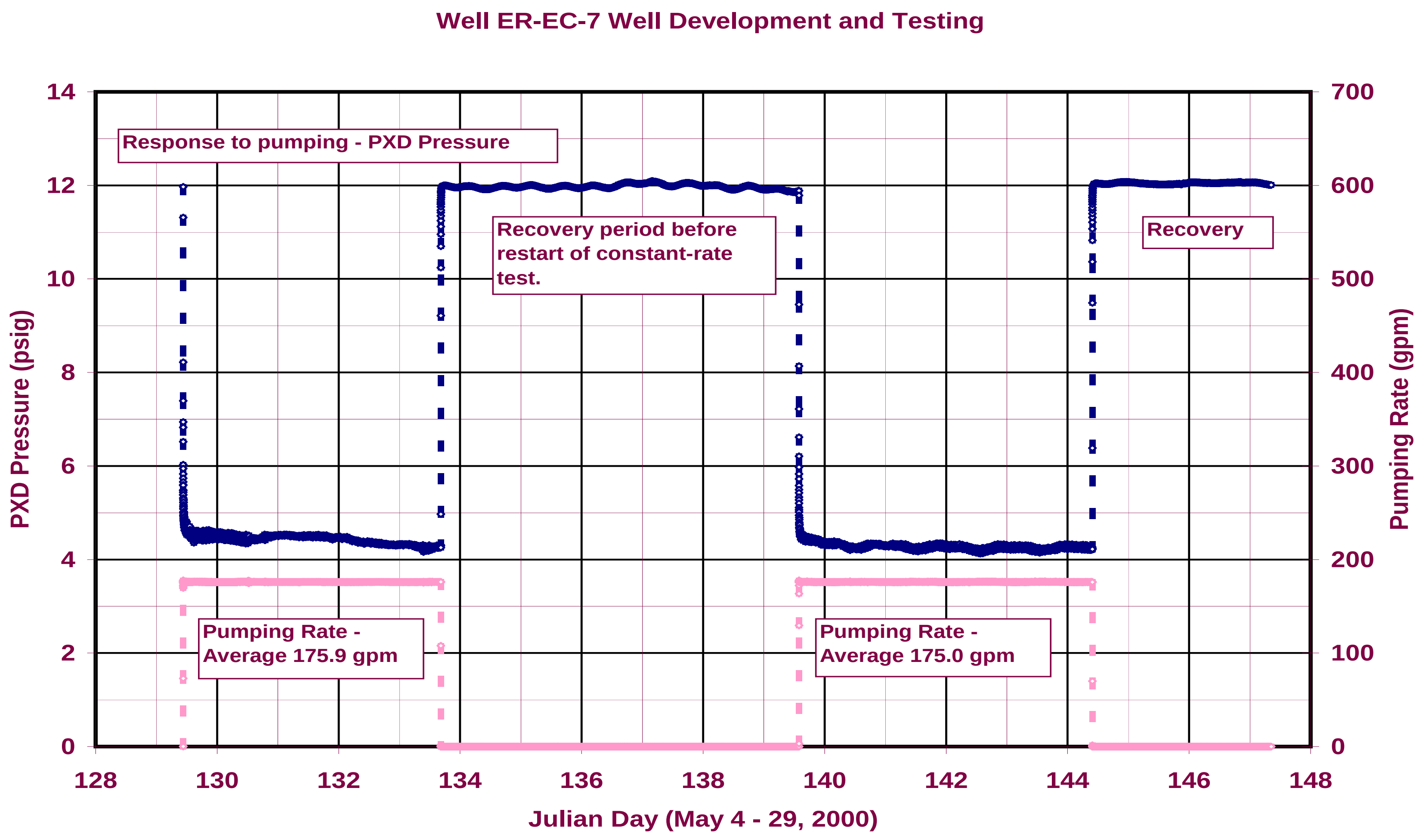
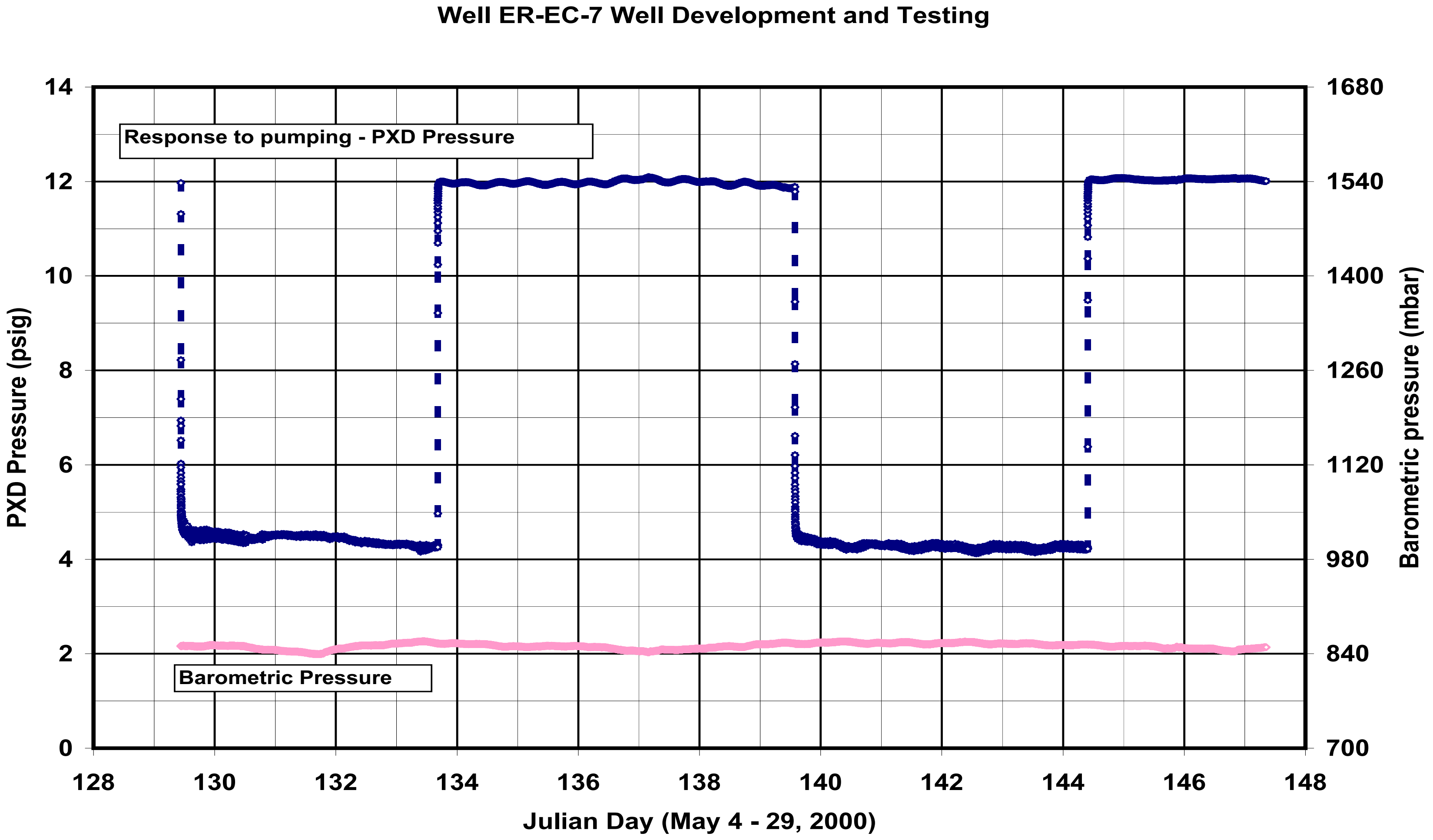


Figure A.2-13
Flow Log at 175 gpm Production Rate and 60 fpm Downward Trolling Rate



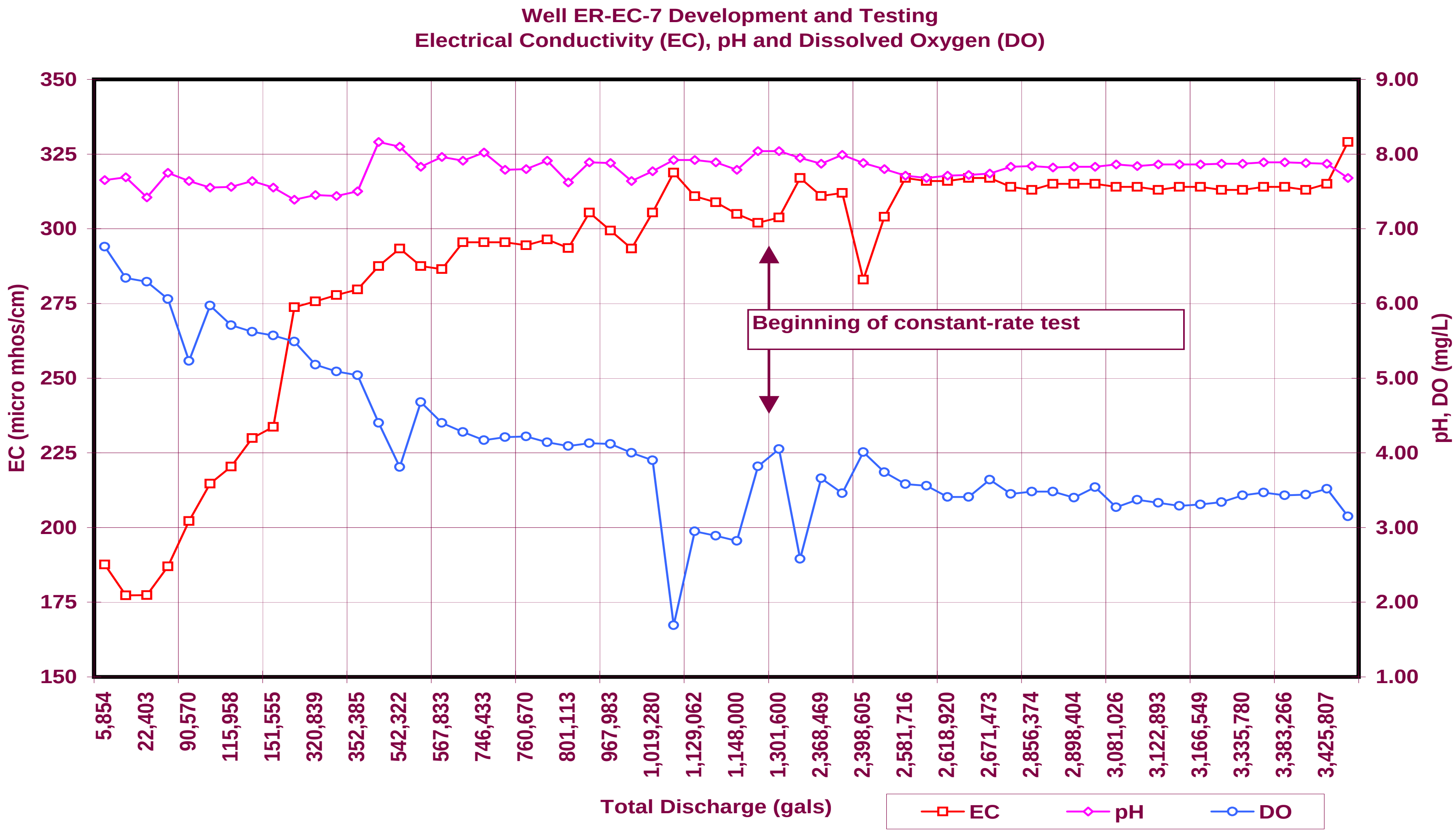
gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.2-14
Pumping Rate and Hydraulic Response During Constant-Rate Test



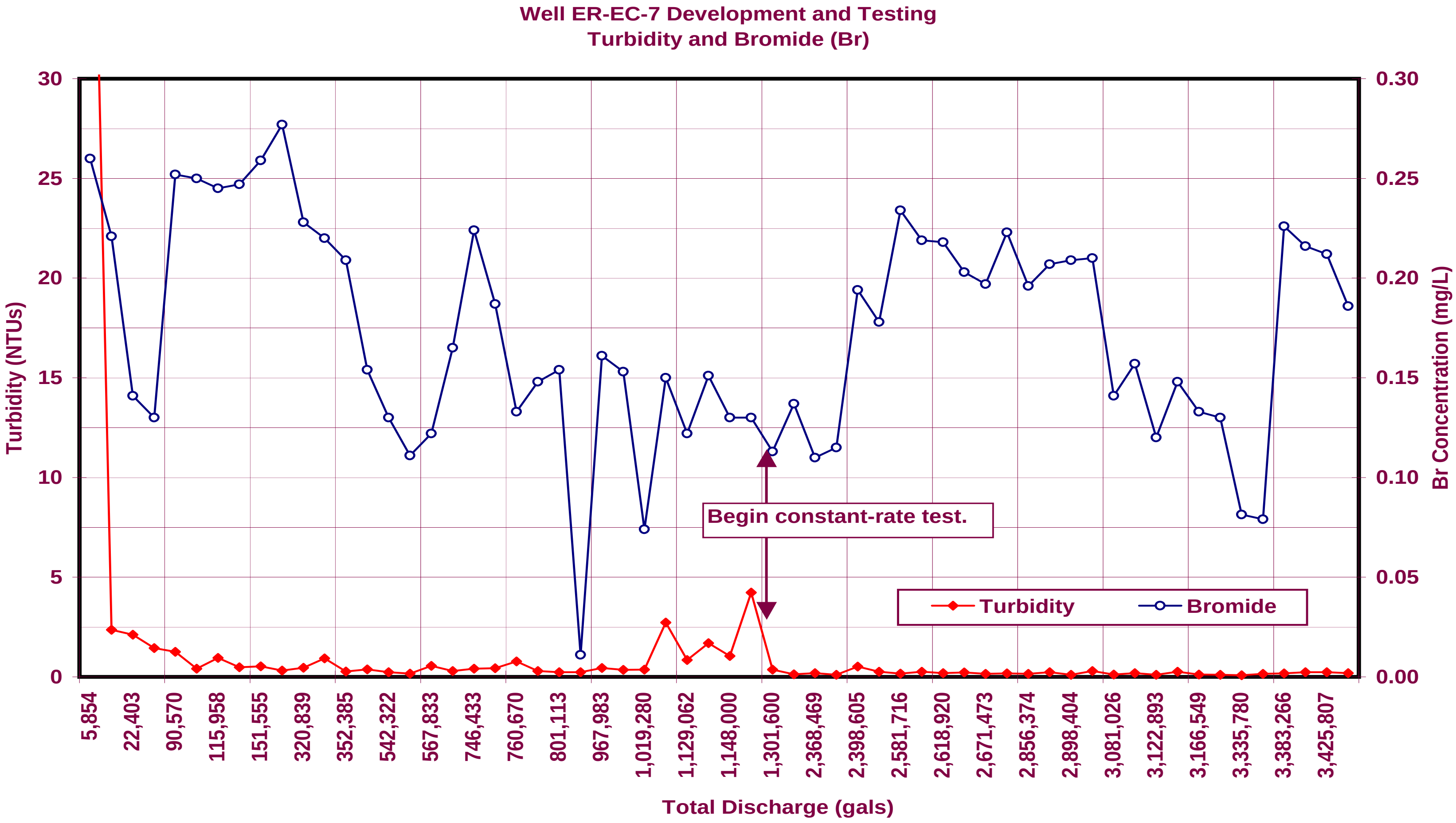
mbar - Millibars
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.2-15
Hydraulic Response and Barometric Pressure During Constant-Rate Test



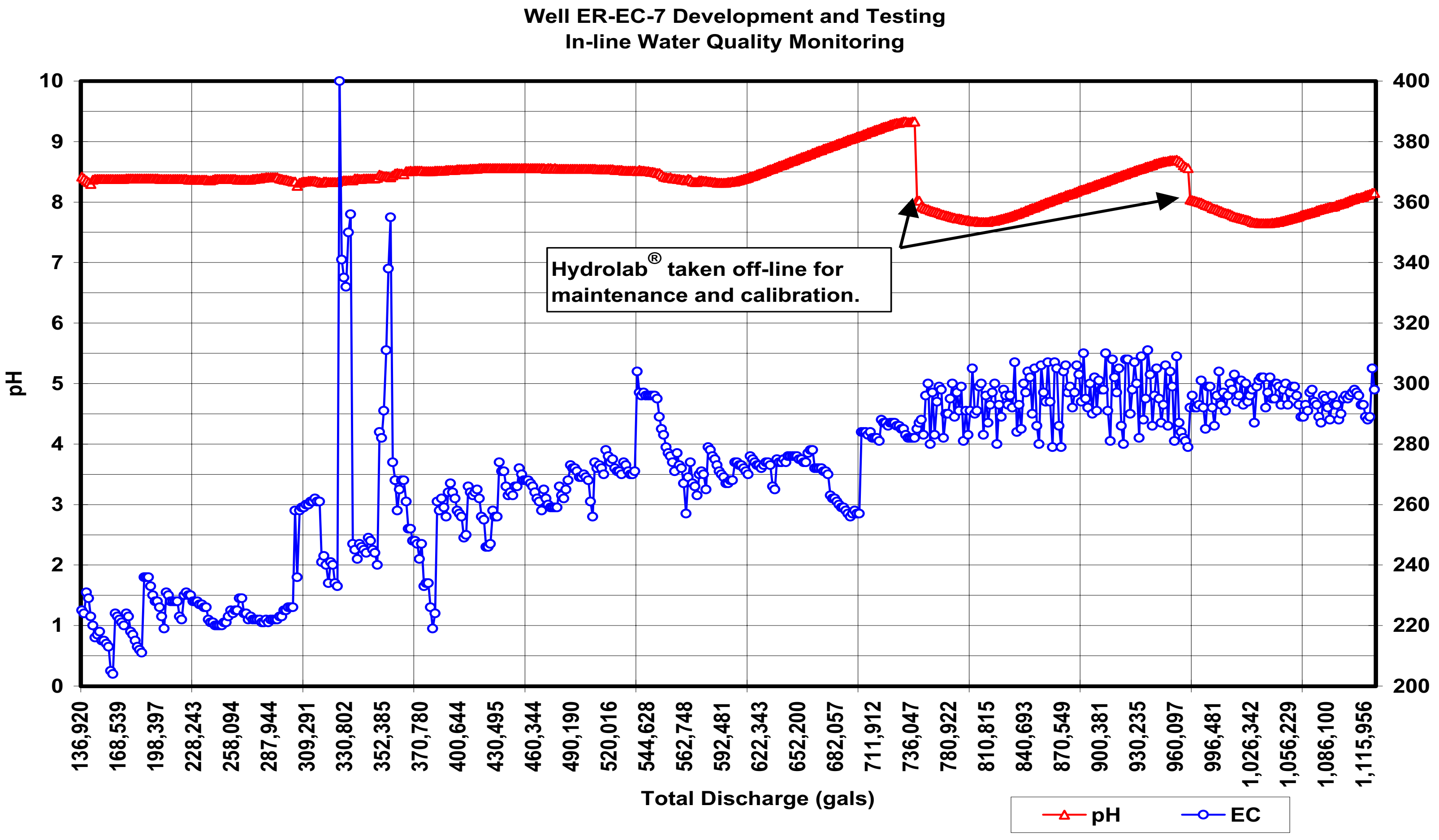
mg/L - Milligrams per liter
gals - Galllons
cm - Centimeter

Figure A.2-16
Grab Sample Monitoring for EC, pH, and DO



NTUs - Nephelometric turbidity units
mg/L - Milligrams per liter
gals - Gallons

Figure A.2-17
Grab Sample Monitoring for Bromide and Turbidity



Hydrolab® taken off-line for maintenance and calibration.

EC - Electrical Conductivity
gals - Gallons
cm - Centimeters

Figure A.2-18
In-Line Monitoring for EC and pH

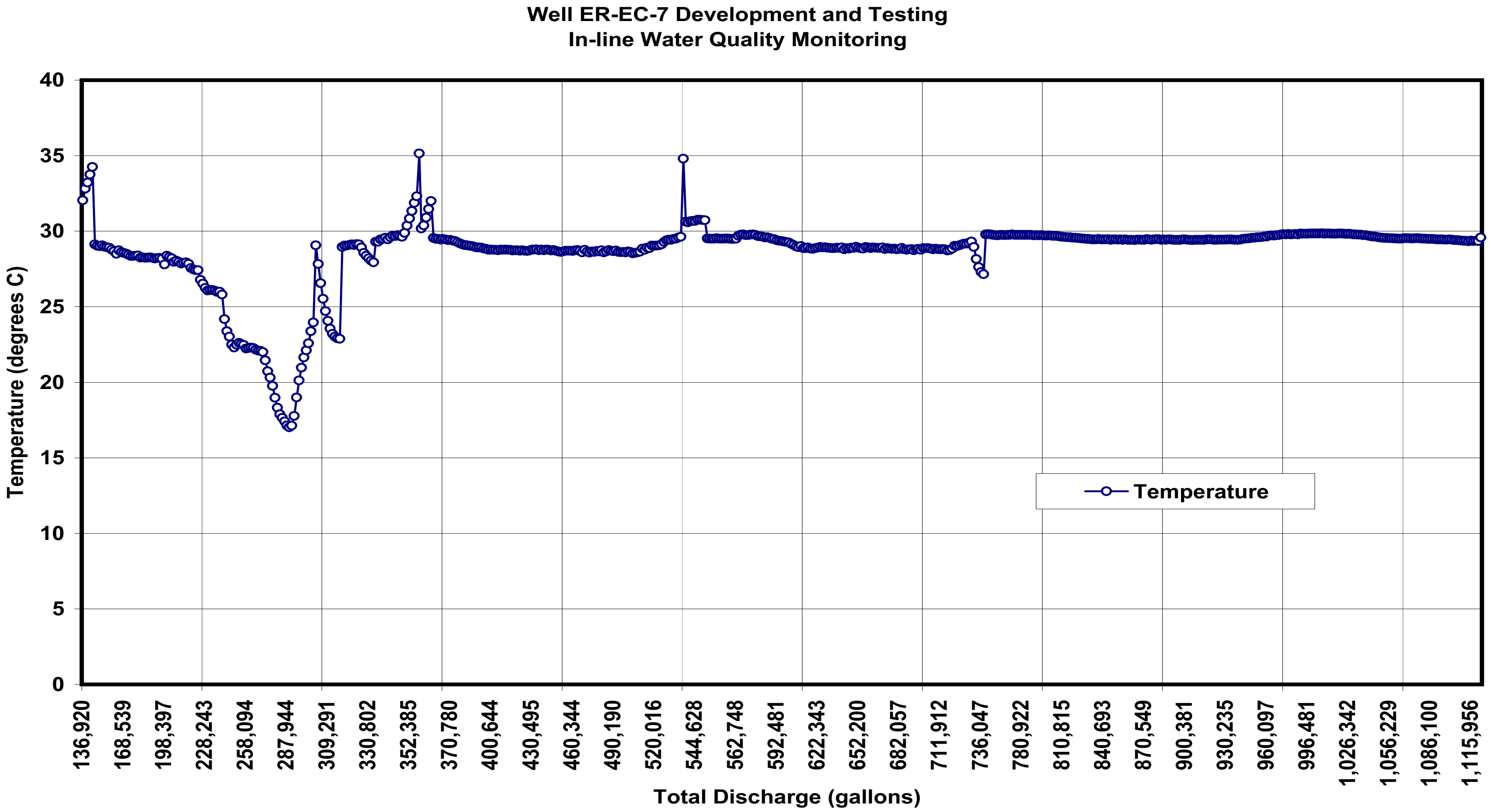


Figure A.2-19
In-Line Monitoring for Temperature

Well Name: ER-EC-7	Western Pahute Mesa - Oasis Valley Drilling Program		
Date: 6/01/2000	Start Date: 6/01/00	Stop Date: 6/01/00	
Environmental Contractor: IT/DOE		Proj No: 799416.00020200	
Logging Contractor: DRI		Geol: J. Wurtz	
Logging Method: ChemTool		Post Well Development Logging	
	FOR PRELIMINARY USE ONLY		

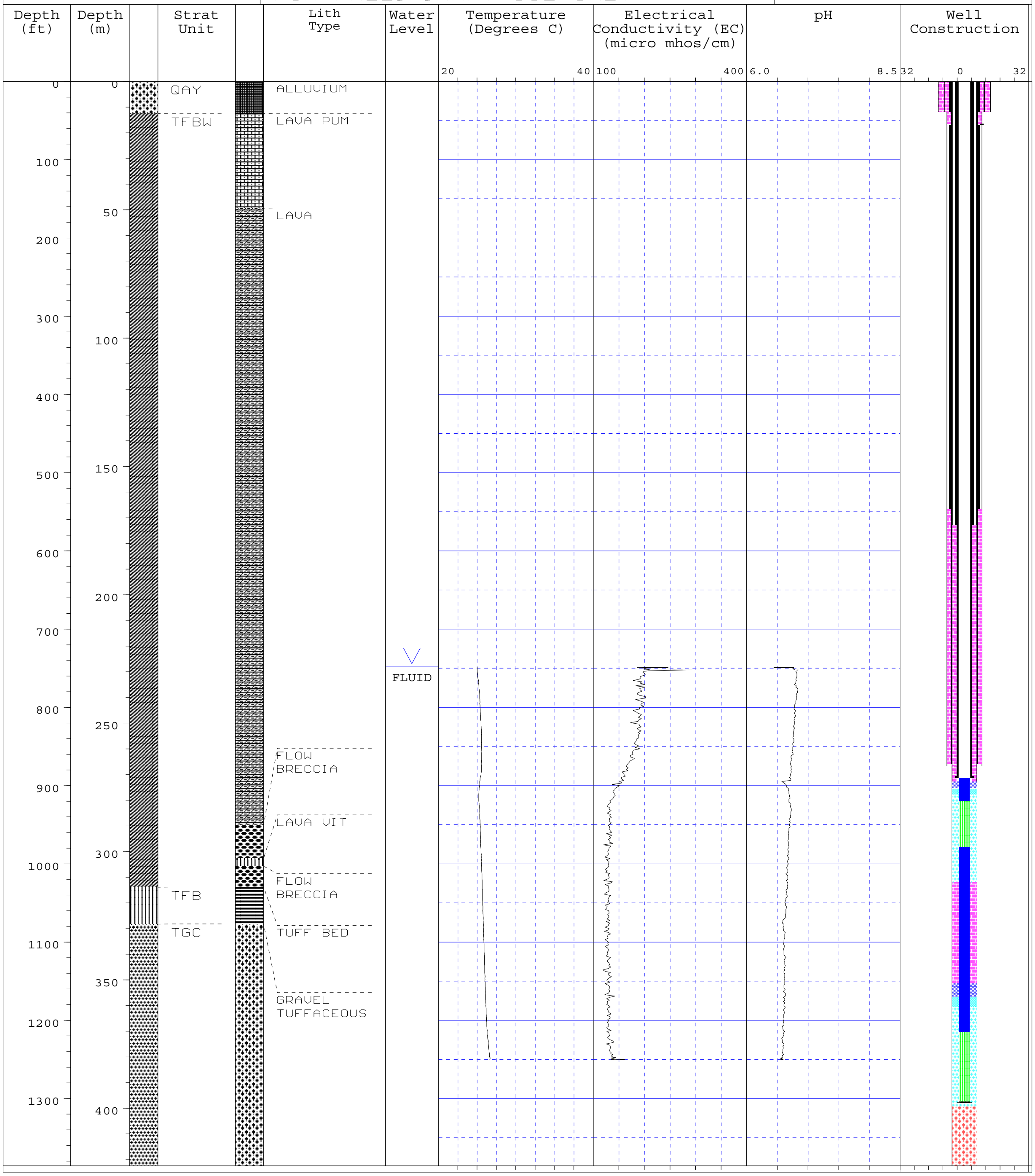


Figure A.2-20
ChemTool Log

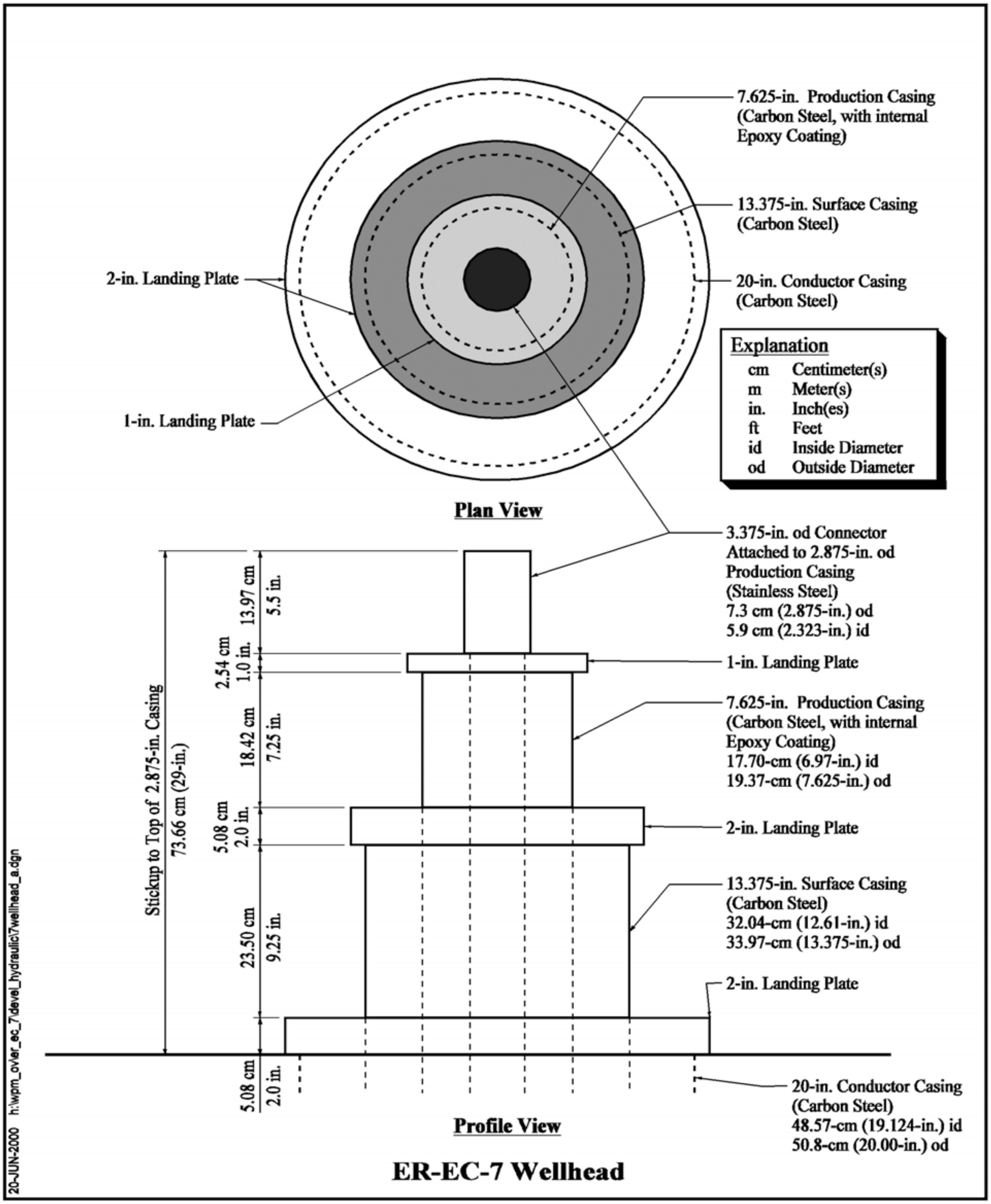


Figure A.2-21
Wellhead Completion Diagram After Sampling Pump Installation

A.3.0 Data Reduction and Review

This section presents basic reduction and processing of data collected during the Well ER-EC-7 development and testing program. Data review and preliminary examination of the results are offered, clarifications of details are provided, and points of interest are noted. Any data interpretations in this section are preliminary and subject to change in future data analysis tasks.

A.3.1 Vertical Gradient and Borehole Circulation

The ambient vertical gradient between completion intervals drives circulation of fluid in the wellbore. Bridge plug head measurements provide independent measurements of the head in each of the completion intervals, and the thermal flow logging provides a direct measure of the resultant flow. The equilibrium composite water level for the well is a transmissivity-weighted resultant head showing the effects of flow in the well.

A.3.1.1 Methodology

The head for the lower interval was calculated from the change in pressure of the interval measured after the interval was isolated with a bridge plug. The head was computed by multiplying the pressure for the interval by the composite density of the water in the well above the PXD, and adding that head to the elevation of the PXD. The composite density of the water in the well was computed by dividing the height of the water column above the PXD by the PXD pressure at the set depth measured before setting the bridge plug. Determining the composite density from the actual pressure of the water column was required to calibrate the head calculation to the water density. Because of the high values of pressure, the calculation of equivalent head was very sensitive to density, which is not specifically known or otherwise measured. This is discussed further in Section A.3.1.4. This method also renders the calculation insensitive to wireline measurement errors.

The height of the water column was determined from a water level measurement (denoted as the reference head) taken after the bridge plug was set. This measurement accommodated any composite head adjustment that occurred due to isolating the lower interval. While there is a chance that this water level may not have completely stabilized, it provides a better estimate of the height of the water column than the total well composite water level. The interval was left to equilibrate for five days before the bridge plug was removed. The PXD pressure was recorded at five-minute intervals during that time. The well-composite head and the head for the upper interval were determined with an e-tape measurement. The upper interval was monitored with a PXD set on a wireline.

A.3.1.2 Data Reduction

Figure A.3-1 shows the PXD monitoring record for the upper interval. Since the upper interval was open to atmospheric pressure in the well, the head was affected by barometric pressure changes during the monitoring period. The graph of the upper interval monitoring shows the PXD pressure record and the barometric record for that period, and also a pressure record corrected for barometric change. A preliminary barometric efficiency was derived for the upper interval using the later part of the record based on an interpretation that the later part of the PXD pressure record represents a stable water level. During the earlier part of the record, the PXD pressure record did not appear to respond to barometric pressure variation. This was interpreted to be the result of pressure changes counter to the response to barometric pressure variation. Table A.3-1 shows the calculation of the preliminary barometric efficiency.

Table A.3-1
Calculation of Upper Interval Barometric Efficiency

Time Julian Days	PXD Pressure (psi)	Barometric Pressure (mbar)
38.43063	9.2739	864.68
40.25354	9.3338	853.79
Barometric Excursion mbar		10.89
PXD Excursion psi		-0.0599
Barometric Efficiency psi/mbar		-0.0055
Barometric Efficiency %*		-37.93

* Conversion factor = 68.95 mbar/psi

psi - Pounds per square inch
mbar - Millibars
PXD - Pressure transducer

The calibration and monitoring records for the lower interval are illustrated in Figure A.3-2 and Figure A.3-3. These records indicate that the intervals equilibrated during the period of measurement. Note the steadiness in the pressure readings for the calibration data points, indicating the PXD temperatures were stable by the beginning of the record segments. No adjustment in pressure immediately following setting the bridge plugs is evident in Figure A.3-2. Figure A.3-3 shows that the interval pressure changed gradually over the entire monitoring period. These figures also show noise in the PXD readings in the form of random readings of a consistent amount both above and below a central value; the final value of the central values was used as the representative value. Table A.3-2 shows interval-specific head information for Well ER-EC-7 at the end of the monitoring period. The methodology for calculating the head for the lower interval depends upon the e-tape reference head measurement and the

Table A.3-2
ER-EC-7 Interval-Specific Heads

Measurement	Well Composite	Upper Interval	Lower Interval
Head - Depth[1] ft bgs	747.71	746.50	747.46
Determination Method	Direct Measurement Using e-tape	Direct Measurement Using e-tape	Calculated from Bridge Plug Data
Change in Head ft			+ 0.25
Composite Water Density Conversion Factor ft/psi	---	---	2.335
Equilibrium Pressure psig	---	---	158.73
Preset Pressure psig	---	---	158.62
Reference Head ft	---	---	747.71
PXD Set Depth ft	---	---	1,118.15
PXD Serial Number	---	---	21013
PXD Range psig	---	---	0-750

m - Meter(s)
psig - Pounds per square inch gauge
ft - Feet
PXD - Pressure transducer
bgs - Below ground surface
psi - Pounds per square inch

change in PXD pressure from before to after the bridge plug is set, and is insensitive to wireline errors for the PXD set depth. There has been no correction for friction losses due to gradient-driven circulation in the well.

The data indicate a downward hydraulic gradient; the final head of the lower interval was 0.96 ft less than the final head of the upper interval. The head of the upper interval rose 1.21 ft, and the head of the lower interval rose 0.25 ft. This difference in calculated head between intervals is less than the potential absolute measurement error. Quoted accuracy for the PXD is 0.1 percent of FS. Treating the nominal accuracy as measurement uncertainty, the potential uncertainty for the lower interval is +/- 0.75 psi. This uncertainty results in potential uncertainty in the head difference of +/- 0.75 psi (approximately 1.8 ft) between the upper and lower interval. In addition, there is also some unquantified uncertainty in the e-tape measurements. The composite static water level measurement was used as the reference head for the lower interval, while the upper interval head was determined by a separate, direct measurement. Since two different e-tape measurements are used to determine the lower interval head and the upper interval head, the measurement uncertainty affects the calculated head difference between the upper and lower intervals.

During the course of monitoring the heads in both the upper and the lower interval rose, indicating a general trend in the heads. However, the slight rise in head of the lower interval is uncertain. The record of PXD temperature shows that there was a long-term increase in temperature of almost 3°F over the equilibration period. The apparent increase in pressure may be a temperature equilibration effect resulting from the cessation of downward flow of cooler water after the bridge plug was set. The upper interval may be expected to show the greatest adjustment since it was apparently much less productive than the lower interval. This is discussed in Section A.3.2.3.

A.3.1.3 Correction of Bridge Plug Set Depths

As mentioned in Section A.2.4, the bridge plug set depths have been corrected from the originally specified set depths. Table A.3-3 shows the specified and the corrected depths. These corrections were supplied by BN Geophysics personnel, who oversaw these measurements. The bridge plug was located by measuring the depth with the wireline used to set the bridge plug. Correction was required for the calibration error of the wireline measurement. The calibration method used for operations at this well based the calibration error correction on calibration measurements made in a test well. The corrections based on this method are reported in Table A.3-3.

Table A.3-3
Bridge Plug Set Depth Corrections

Location	Specified Depth (ft bgs)	Specified Depth (m bgs)	Corrected Depth (ft bgs)	Corrected Depth (m bgs)
Lower Interval Calibration at +50 ft	1,170.00	356.62	1,168.15	356.05
Lower Interval Calibration at -50 ft	1,070.00	326.14	1,068.25	325.60
Lower Interval Set Depth	1,120.00	341.38	1,118.15	340.81

ft bgs - Feet below ground surface
m - Meters

The requirement for locating the bridge plug was primarily to place it in the blank casing between completion intervals. It was nominally to be located halfway between completion intervals, and in the middle of a length of casing between the casing joints. The actual set depths of the bridge plug, although somewhat different from the specified depth, fulfilled those requirements.

A.3.1.4 Composite Water Density

The calculated composite density conversion factors were 2.335 (0.989 in terms of specific gravity corrected for temperature) for the lower interval. The specific gravity values are based on calculations relative to values for standard temperature corrected weight density of water (Roberson and Crowe, 1975). These values seem reasonable considering they must accommodate effects of entrained gases, suspended solids, and dissolved solids. The values also compare well with the conversion factor values of 2.336, 2.323, and 2.330 ft of water column/psi (specific gravities of 0.989, 0.994, and 0.991, respectively) calculated from the PXD installations for monitoring drawdown.

A.3.1.5 Thermal Flow Logging

The thermal flow logging found downward flow increasing with depth in the upper completion interval, with about 2.2 gpm at the bottom of the upper completion interval. This flow was also observed in the upper part of the lower completion interval. The downward flow in the lower part of the lower completion interval decreased to approximately 1 gpm, and appeared to vary somewhat with depth. However, the apparent variation is within the uncertainty of the measurement. The variation may indicate some variation in hydraulic conductivity of the formation. In any case, the measured downward flow is in accordance with the measured vertical gradient. With time, this downward flow will reverse any restoration of distinct water quality for the formation in the lower completion interval that resulted from development.

A.3.2 Well Development

Well development actions did not appear to have a substantial effect on improving the hydraulic efficiency of the well after a small initial improvement. Very little sediment was produced, and there was very little apparent improvement in specific capacity (drawdown divided by production rate) of the well during development, as was seen in Figure A.2-2.

Two step-drawdown tests were conducted and the results are tabulated in Table A.3-4. These tests indicate slightly improved well productivity. The results also exhibit a decrease in specific capacity with increased pumping rate, which may be useful in assessing well losses.

A.3.2.1 Flow Logging During Pumping

The flow logging during pumping provided valuable information on the inflow of water to the well that was induced at the pumping rates used for development, testing, and sampling. This information will allow accurate analysis of the hydraulic response, perspective on the effectiveness of this type of well design for accessing the formations over large vertical distance, and representativeness of water samples taken.

A.3.2.2 Optimal Flow Logging

The optimal flow logging trolling speed and direction during pumping is thought to be the downrun at 20 fpm. This configuration maximizes sensitivity of the

Table A.3-4
Step-Drawdown Tests

Step	Datalogger Time (days)	PXD Pressure (psi)	Pumping Rate (gpm)	Duration of Step (days)	Change in Drawdown (psi)	Specific Capacity (gpm/feet of water)
Start Test #1	114.3406	14.881	0	- - -	- - -	- - -
End of First Step	114.4228	14.43	65.44	0.082176	-0.4510	62.11
End of Second Step	114.5049	11.689	121.38	0.082176	-2.7410	18.96
End of Third Step	114.5530	7.9232	175.71	0.048032	-3.7658	19.97
Start Test #2	116.4803	14.3020	0	- - -	- - -	- - -
End of First Step	116.5593	13.5940	65.50	0.079051	-0.7080	39.60
End of Second Step	116.6475	11.4780	121.52	0.088194	-2.1160	24.58
End of Third Step	116.7362	7.9271	175.82	0.088657	-3.5509	21.20

psi - Pounds per square inch
gpm - Gallons per minute

logging to actual flow and minimizes the effects of trolling on the flow in the well. The logs from this configuration would be preferred for interpretation. However, other configurations are also run to supplement the data. The theory behind this conclusion is explained below.

The rotational response of the impeller is a function of two components, expressed as:

$$R_t = R_{ls} + R_v$$

where:

R_t is the total rotation rate of the impeller at any depth

R_{ls} is the rotation rate of the impeller due to line speed

R_v is the rotation rate of the impeller due to vertical flow

The greater the line speed, the more R_{ls} contributes to the total response, thereby increasing error due to variable line speed, depth offset, and other related factors. Logs conducted at 20 fpm, which is well above the stall speed for the full-bore flowmeter, provides for relatively short logging runs (one to two hours), yet minimizes the contribution of R_{ls} and maximizes the response to R_v. Additional runs are conducted at other line speeds in order to address the stall speed of the full-bore flowmeter. Every spinner tool has a minimum velocity required to initiate impeller movement and a slightly slower velocity at which the impeller will stall. There may be instances in any borehole where flow may be in the same direction and magnitude relative to the direction and line speed of the flowmeter. The impeller would be located in flow moving past the tool at rates below the stall speed of the tool despite substantial flow occurring within the well. Logging at different line speeds in different directions under identical conditions shifts the depths within the borehole where this is occurring so that the flow occurring in all depths of the borehole can be logged.

A.3.2.3 Intervals of Inflow

Table A.3-5 contains a tabulation of water production distribution between the two completion intervals derived from the stressed flow logs (trolling). These percentages are slightly less than those derived from the stationary flow logs, but show the same shift to greater percentage production from the upper interval at higher pumping rates. This seems reasonable as the friction losses for flow in pipe increase with the square of the velocity. As the velocity increases with the flow rate, the additional distance of flow from the lower interval to the pump would result in proportionately greater losses. Note an unexpected feature of the flow logs; all of the flow logs presented in Section A.2.7.2, Figures A.2-8 through A.2-13, show an apparent reduction in borehole flow at the bottom of the upper interval. This would seem to indicate that some of the flow from the lower interval is leaving the completion string to flow through the gravel pack outside the screen. At the top of the upper interval, the flow suddenly increases to the total production rate. This may also indicate that some of the additional borehole flow from the upper interval is coming from the portion of the upper completion interval above the top of the screen.

Table A.3-5
Water Production Distribution

Total Production	Lower Interval Production	
gpm	**gpm**	**Percent of Total**
65	57	87.7
120	105	87.5
175	150	85.7

gpm - Gallons per minute

A.3.3 Constant-Rate Test

The drawdown and recovery data from the constant-rate pumping test have been processed to adjust for the influences of barometric pressure changes.

A.3.3.1 Barometric Efficiency

Barometric efficiency is a measure of the proportional response of the head (water level) in the well to a change in barometric pressure; when barometric pressure rises, the head will be depressed by some fractional amount. The response of the well to barometric changes was determined from the predevelopment water level monitoring record. This was the best record where there was a substantial barometric excursion with a clean response. The barometric efficiency derived in this section for the complete well as it was tested is different from the barometric efficiency that was derived earlier for just the upper interval. This appears justified because two distinct behaviors were evident, which seem to correlate to the upper interval versus both intervals combined. As the stressed flow logging showed, the lower interval was much more productive than the upper interval, and it seems reasonable that the response of the lower interval to barometric variation may be different.

Figure A.3-4 shows the segment of that monitoring which was used to calculate a preliminary barometric efficiency. Also shown is the same record with the effect of barometric variation removed using the calculated barometric efficiency. The resultant record shows a much more consistent water level with a gradual trend and small scale twice-daily variations that are probably earth tides.

Table A.3-6 shows the calculation using measurement values extracted from the data file (file EC-7-Water Level Monitoring.XLS on the CD). The barometric efficiency was used to apply a correction for barometric pressure variation that occurred during the constant-rate tests and recovery periods. The drawdown record was processed into the form of “change from starting pressure” at the beginning of pumping. The data points were then adjusted by - 0.01341 psi/mbar (-92.46 percent of the barometric change from the initial barometric pressure at the start of the drawdown data).

Table A.3-6
Calculation of Barometric Efficiency for the Constant-Rate Test

Time (Julian Days)	PXD Pressure (psi)	Barometric Pressure (mbar)
362.31955	10.822	812.70
1.86122	10.992	797.52
3.97233	10.742	813.66
Barometric Excursion mbar		-15.66
PXD Excursion psi		0.21
Barometric Efficiency psi/mbar		-0.01341
Barometric Efficiency %*		-92.46

* Conversion factor = 68.95 mbar/psi

psi - Pounds per square inch
mbar - Millibars
PXD - Pressure transducer

A.3.3.2 Drawdown Record

Figure A.3-5 shows the resultant record for the constant-rate test pumping and recovery periods. The pressure drawdown record was converted to equivalent change in groundwater head using a conversion value for pressure to water head derived from the head measurement and pressure data collected when the PXD was removed after testing. This information is presented in Table A.2-8. The calibration data collected during removal of the PXD after recording the test was used because it was deemed most representative. The correction for barometric variation did not have a great effect because the drawdown was proportionally large, but did remove some minor inflections in the drawdown curve, resulting in a more consistent response.

A.3.4 Water Quality

ChemTool logs were run at various stages of Well ER-EC-7 completion and development activities. Comparisons can be made between the water quality parameters of the well water before well completion and after well development. There are also differences between grab sample results and ChemTool logs.

A.3.4.1 Precompletion Versus Postdevelopment

The ChemTool log of downhole water quality parameters was run at the very end of the testing program, and gives another perspective on the effectiveness of the development and testing activities on water quality restoration. Figures A.3-6 through A.3-8 show the ChemTool logs that were run following drilling, but prior to well completion, side-by-side with the logs that were run following well development and testing. Figure A.3-6 shows temperature logs, Figure A.3-7 shows the pH logs, and Figure A.3-8 shows EC logs. Included on these figures are lithologic information and well completion details.

The temperature log pre and postdevelopment shows some difference. The postdevelopment log shows the temperature at the top of the upper completion a little over 2°C less than precompletion, with a slightly lower gradient downwards. There is also a substantial decrease in the temperature rise above the upper completion, which was presumably due to the heat of reaction of the cement around the surface casing just above the completion interval. The parameters pH and EC generally give an indication of water quality differences along the wellbore as well as the representativeness of the water within the well relative to formation water. Postdevelopment pH has declined substantially from the precompletion log values, especially in the upper completion interval. Again, this is probably due to removal of the effects of the cement around the bottom of the surface casing. The postdevelopment log shows the pH declines a small amount from the upper completion interval to the lower interval. The EC log also indicates significantly lower EC values postdevelopment. The lower values extend down the well from the upper completion interval to the lower completion interval.

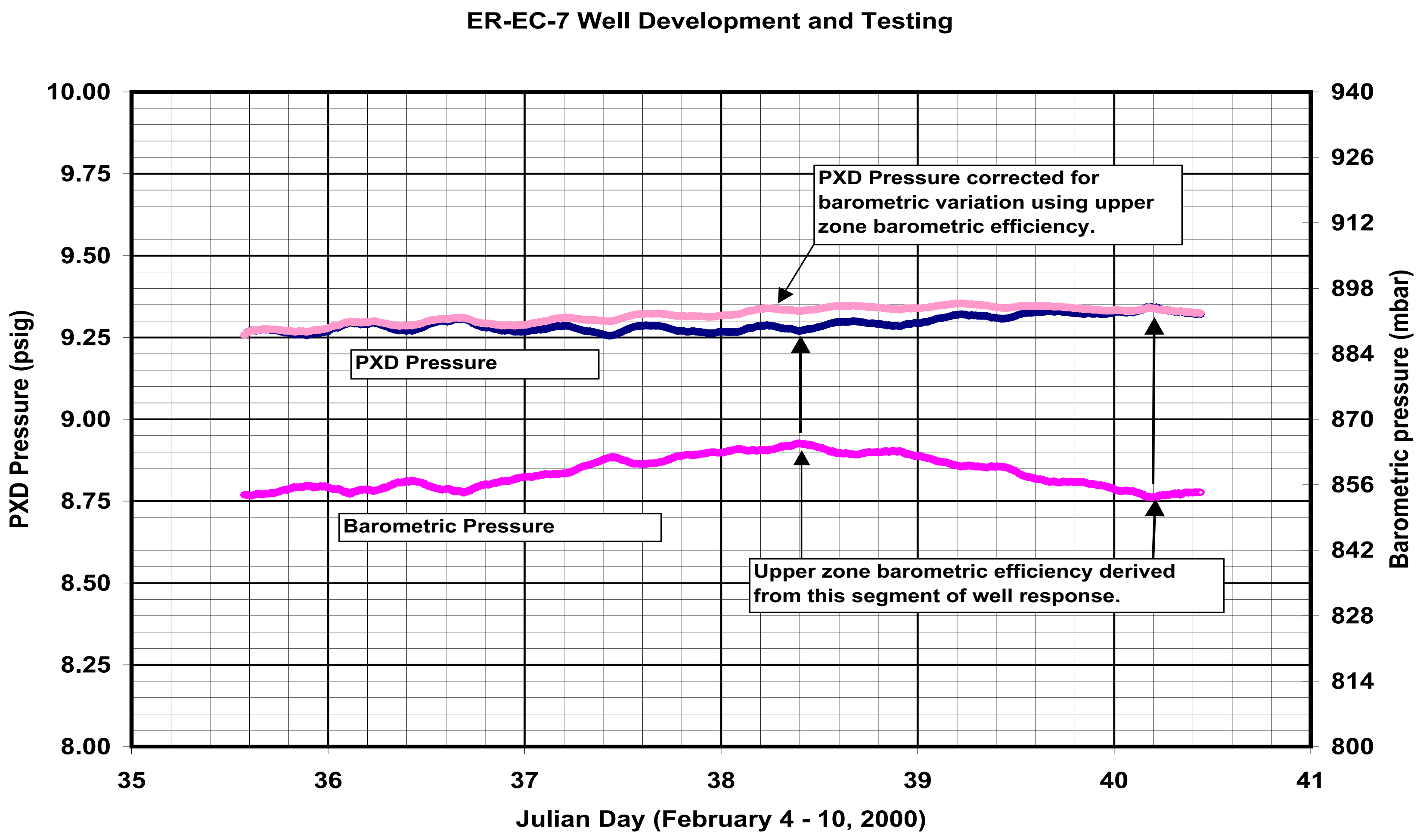
A.3.4.2 Grab Sample Results Versus ChemTool Logs

Water quality parameter values measured for grab samples taken from produced water are shown in Attachment 2 and in Figure A.2-16 and Figure A.2-17. The pH slightly increased during the course of pumping from around 7.5 to about 7.9 at the end of the constant-rate test. The pH values from the postdevelopment ChemTool (Figure A.3-7), on the other hand, ranged from 6.6 at 1,240 ft bgs to a high of around 6.8 at 760 ft bgs. There is a difference of about one standard unit between the two methods. The EC values from the grab samples gradually rose from around 200 µmhos/cm to a level of 315 µmhos/cm at the end of the constant-rate test. The EC values from the postdevelopment ChemTool (Figure A.3-8) were moderately lower, ranging from 130 µmhos/cm at a depth of 1,200 ft bgs to a high of around 200 µmhos/cm at 760 ft bgs. The discrepancy in the two measurements is about 100 µmhos/cm, the ChemTool results being lower than the grab samples. The temperature values from grab samples averaged 29°C. The postdevelopment ChemTool showed a gradual rise of 3°C with increased depth, ranging from 25°C to 28°C at 1,240 ft bgs. Since about 85 percent of the production originated from the lower completion interval, the 28°C water appears to be the greatest contributor. The temperature from the two methods correlate much better than the other two parameters. There are several possible reasons for the discrepancies. The conditions in the well are different during the two measurements; pumping versus ambient flow, and the depth origin of the water being measured changes somewhat depending upon this difference. Also there may be a calibration discrepancy since the two instruments are not calibrated with the same standards.

A.3.5 Representativeness of Hydraulic Data and Water Samples

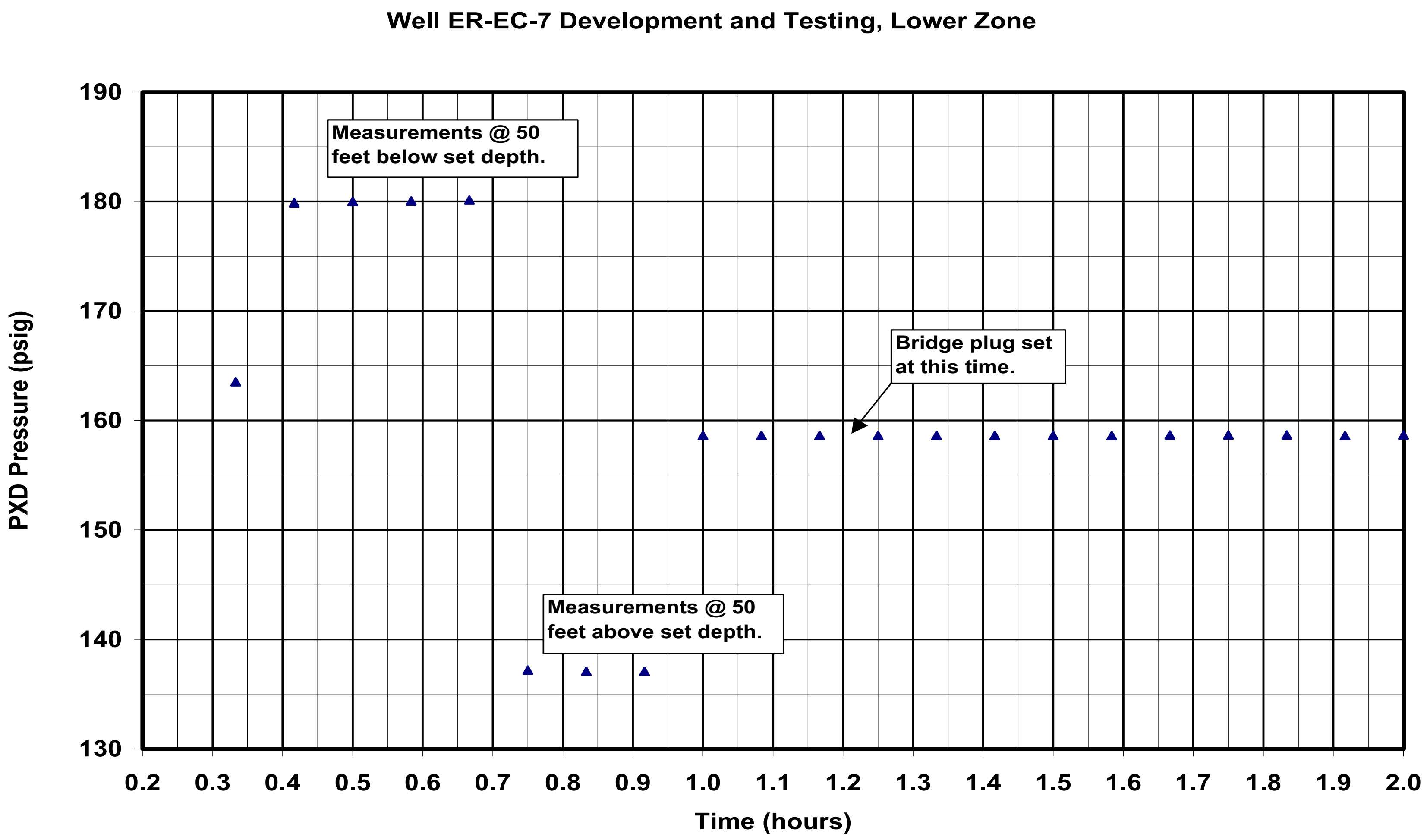
The flow logging has demonstrated that both completion intervals were affected by development and testing of Well ER-EC-7. The water quality, development, hydraulic testing, and composite sampling produced data applicable to both the completion intervals which must be interpreted proportionate to the effect on, and contribution from, each interval. The data collected should provide sufficient basis for attribution of the results.

The water quality information obtained from the well discharge during pumping at rates above gpm, both general parameters from grab samples and Hydrolab® results must be considered composites of the formation opposite both completion intervals. In the case of the composite groundwater characterization sample, the low pumping rate (44 gpm) leaves some uncertainty as to the percentages from each completion interval. However, based on the fact that there was little difference in the percentage contribution from each interval between the three pumping rates used in flow logging, it may reasonably be expected that a similar flow distribution is represented. In addition, the downhole, discrete sample should provide direct information on the lower interval water quality. Both completion intervals can probably be considered well developed. Since all natural flow in the well appears to be downward, the upper completion interval has not been continually receiving water from any source. Presumably the water quality in that interval was only affected by residual impacts of drilling and completion which has now been remediated. The water quality in that interval should be representative in the long term. The lower interval appears to have been receiving water from the upper interval since the well was drilled. This was probably remediated to a great extent by the end of the testing, but will revert over time as this interval continues to receive water from the upper interval.



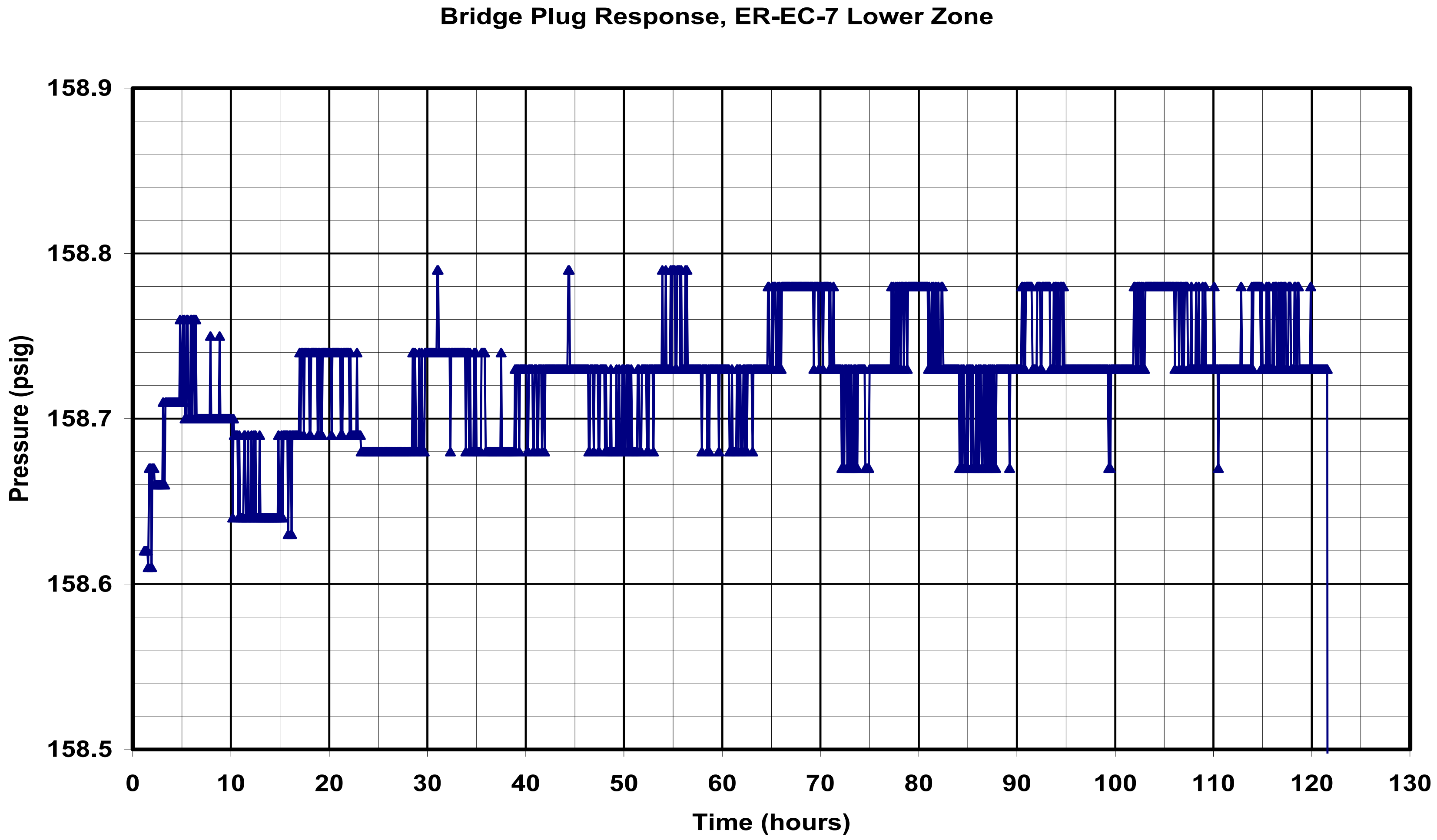
mbar - Millibars
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.3-1
PXD Equilibration Record for the Upper Interval



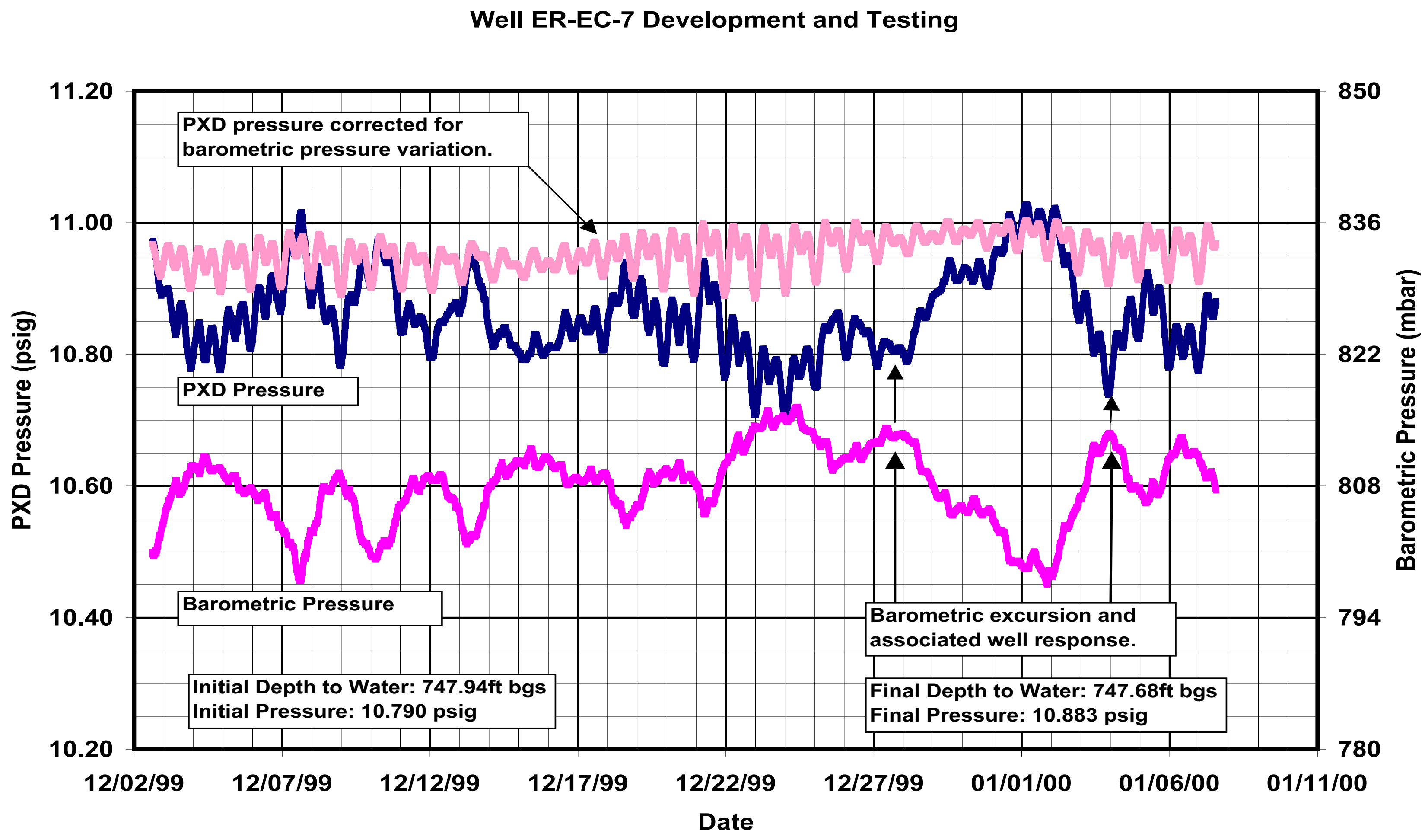
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.3-2
Lower Interval Calibration and Bridge Plug Set



PXD - Pressure transducer
psig - Pounds per square inch gauge

Figure A.3-3
Bridge Plug PXD Response for the Lower Interval



ft bgs - Feet below ground surface
mbar - Millibars
psig - Pounds per square inch gauge
PXD - Pressure transducer

Figure A.3-4
Barometric Excursion Used for Barometric Efficiency Calculation

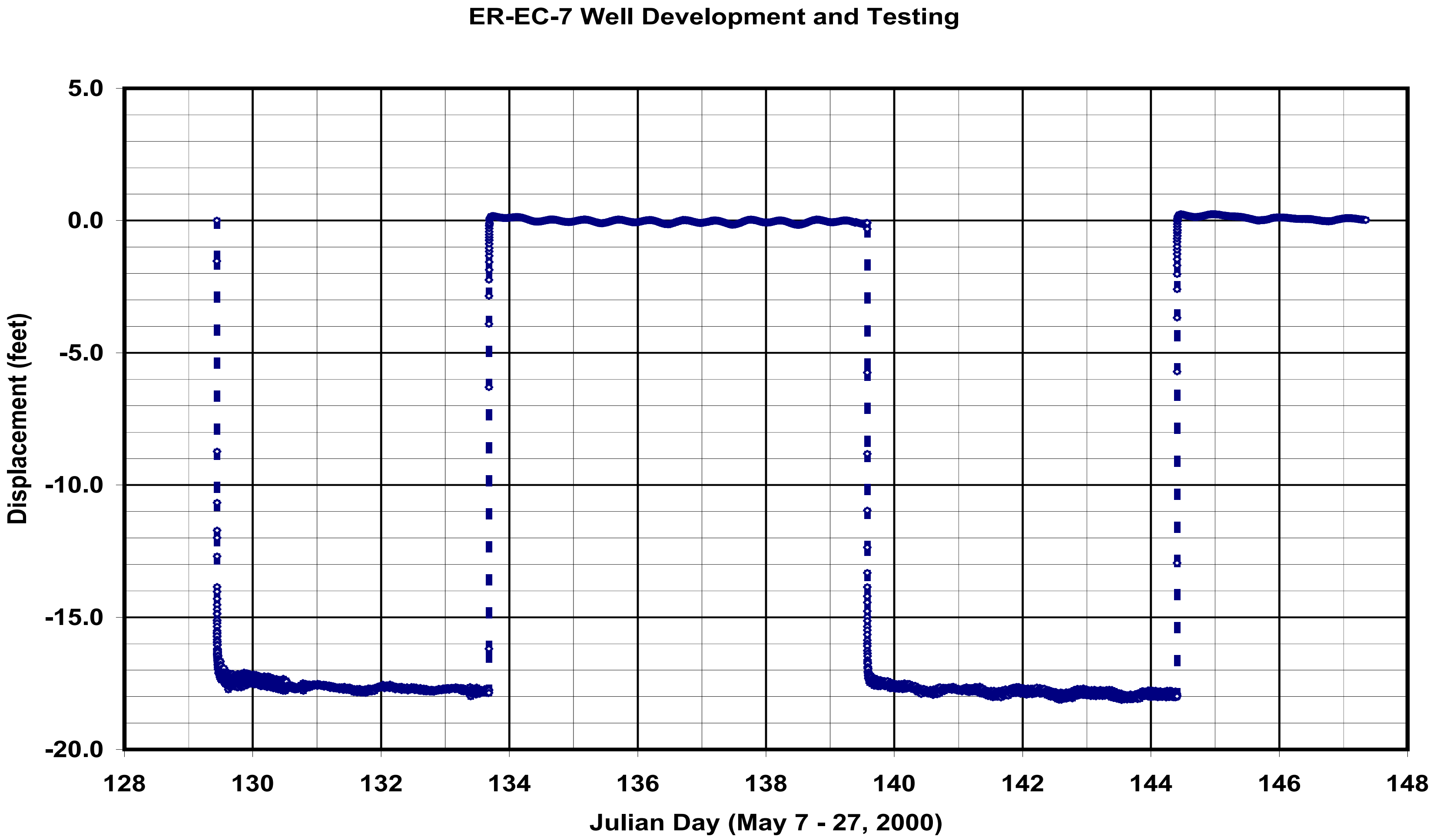


Figure A.3-5
Constant-Rate Pumping Test with Barometric Correction

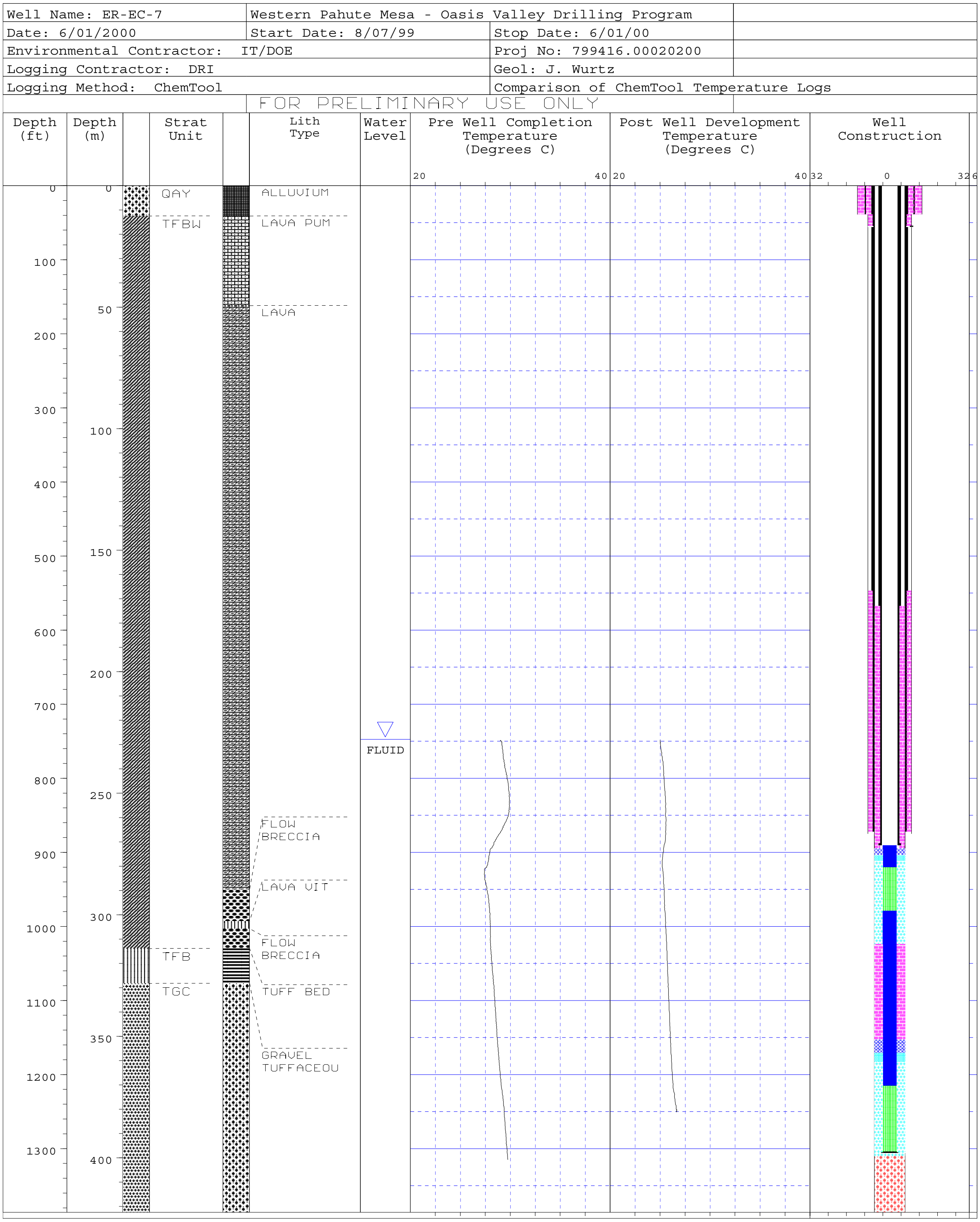
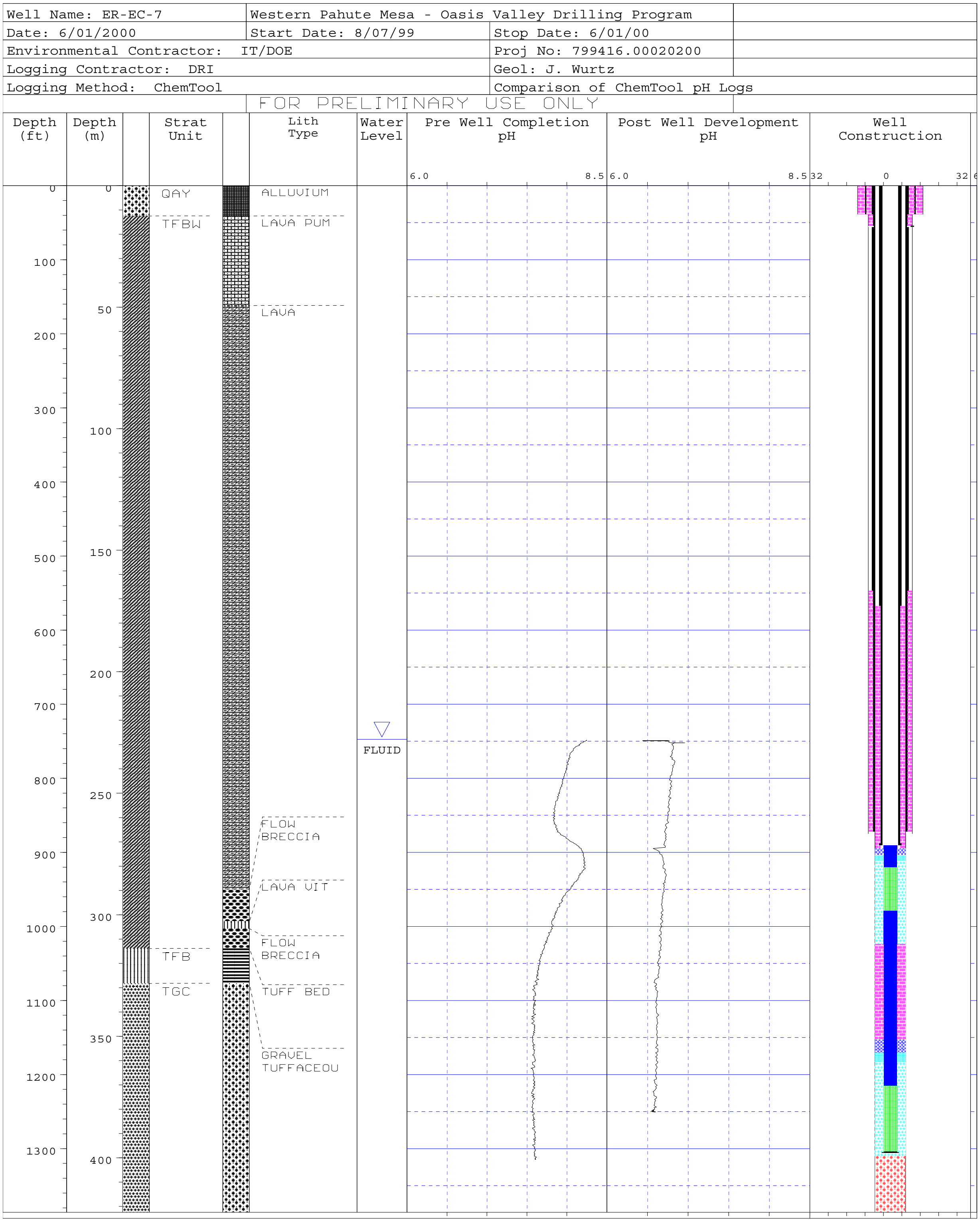


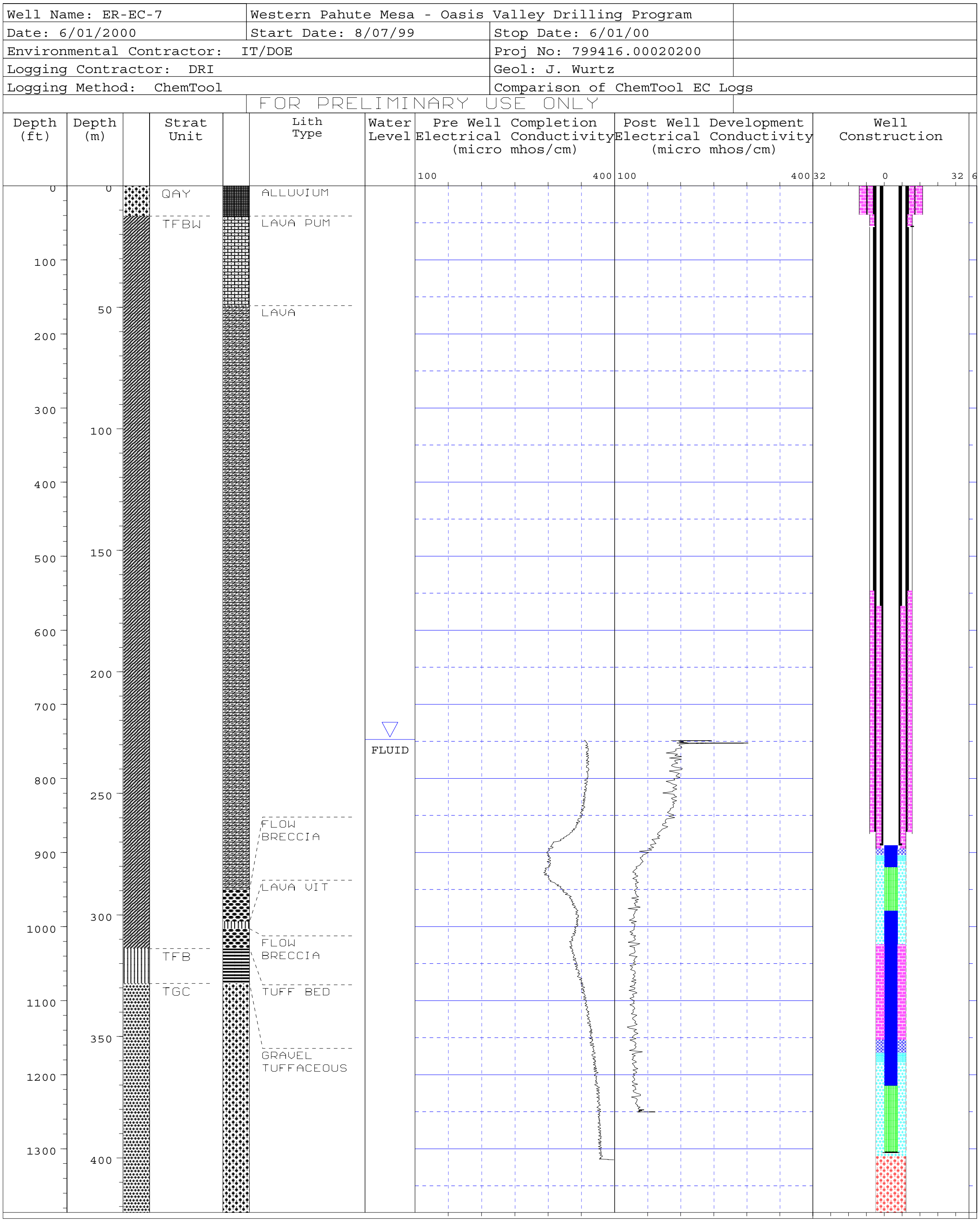
Figure A.3-6
Temperature Log Prior to Completion Versus Postdevelopment



Well Name: ER-EC-7	Western Pahute Mesa - Oasis Valley Drilling Program	
Date: 6/01/2000	Start Date: 8/07/99	Stop Date: 6/01/00
Environmental Contractor: IT/DOE		Proj No: 799416.00020200
Logging Contractor: DRI		Geol: J. Wurtz
Logging Method: ChemTool		Comparison of ChemTool pH Logs

FOR PRELIMINARY USE ONLY

Figure A.3-7
pH Log Prior to Completion Versus Postdevelopment



Well Name: ER-EC-7
Western Pahute Mesa - Oasis Valley Drilling Program
Date: 6/01/2000
Start Date: 8/07/99
Stop Date: 6/01/00
Environmental Contractor: IT/DOE
Proj No: 799416.00020200
Logging Contractor: DRI
Geol: J. Wurtz
Logging Method: ChemTool
Comparison of ChemTool EC Logs
FOR PRELIMINARY USE ONLY

Figure A.3-8
EC Log Prior to Completion Versus Postdevelopment

A.4.0 Environmental Compliance

A.4.1 Fluid Management

All fluids produced during well development and hydraulic testing activities were managed according to the *Fluid Management Plan for the Underground Test Area Subproject* (FMP) (DOE/NV, 1999) and associated state-approved waivers. In accordance with the FMP and the waivers, the fluids produced during drilling were monitored and tested for tritium and lead daily. Several samples of water were collected from the sumps and analyzed at a certified laboratory for total and dissolved metals, gross alpha/beta, and tritium. Based on this process knowledge, the DOE/NV requested a waiver for the disposal of fluids produced during well development/hydraulic testing for Wells ER-EC-1, ER-EC-4, ER-EC-5, ER-EC-6, ER-EC-7, ER-EC-8, and ER-18-2. The DOE/NV's proposal was to conduct activities at these well sites under far-field conditions with a reduced frequency of on-site monitoring. In October 1999, the Nevada Division of Environmental Protection (NDEP) granted DOE/NV a waiver to discharge fluids directly to the ground surface during well development (NDEP, 1999), testing, and sampling at the above wells. The waiver (provided in Attachment 4) was granted under the mandate that the following conditions were satisfied:

- The only fluids allowed to be discharged to the surface are waters from the wells.
- Fluids will be allowed to be discharged to the ground surface without prior notification to NDEP.
- Waters that are heavily laden with sediments need to be discharged to the unlined, noncontaminated basins to allow the sediments to settle out before being discharged to the land surface.
- One tritium and one lead sample from the fluid discharge will be collected every 24 hours for analysis.
- Additional sampling and testing for lead must be conducted at 1 hour and then within 8 to 12 hours after the initial pumping begins at each location. If the field testing results indicate nondetects for lead (less than 50 micrograms per liter [µg/L]), then the sampling may be conducted every 24 hours. If the field testing indicates detectable quantities less than 75 µg/L (5 times the *Nevada Drinking Water Standards* [NDWS]), then

sampling must occur every 12 hours until two consecutive nondetects occur. Sampling and testing may then resume on the 24-hour schedule.

- NDEP must be notified within 24 hours if any of the limits in the FMP are exceeded.

A.4.1.1 Water Production and Disposition

At Well ER-EC-7, all fluids from the well development and testing were discharged into unlined Sump #1. Sump #2 was also unlined, but was not used during development and testing activities. Sump #1 serves as an infiltration basin and has an overflow pipe approximately 7.8 ft from the bottom. Fluid reached the overflow pipe on April 24, 2000, and began discharging to the ground surface via a drainage ditch at the western corner of Sump #1. Discharge to the ground surface through the discharge pipe began after 348,200 gallons (gals) had been pumped into the sump.

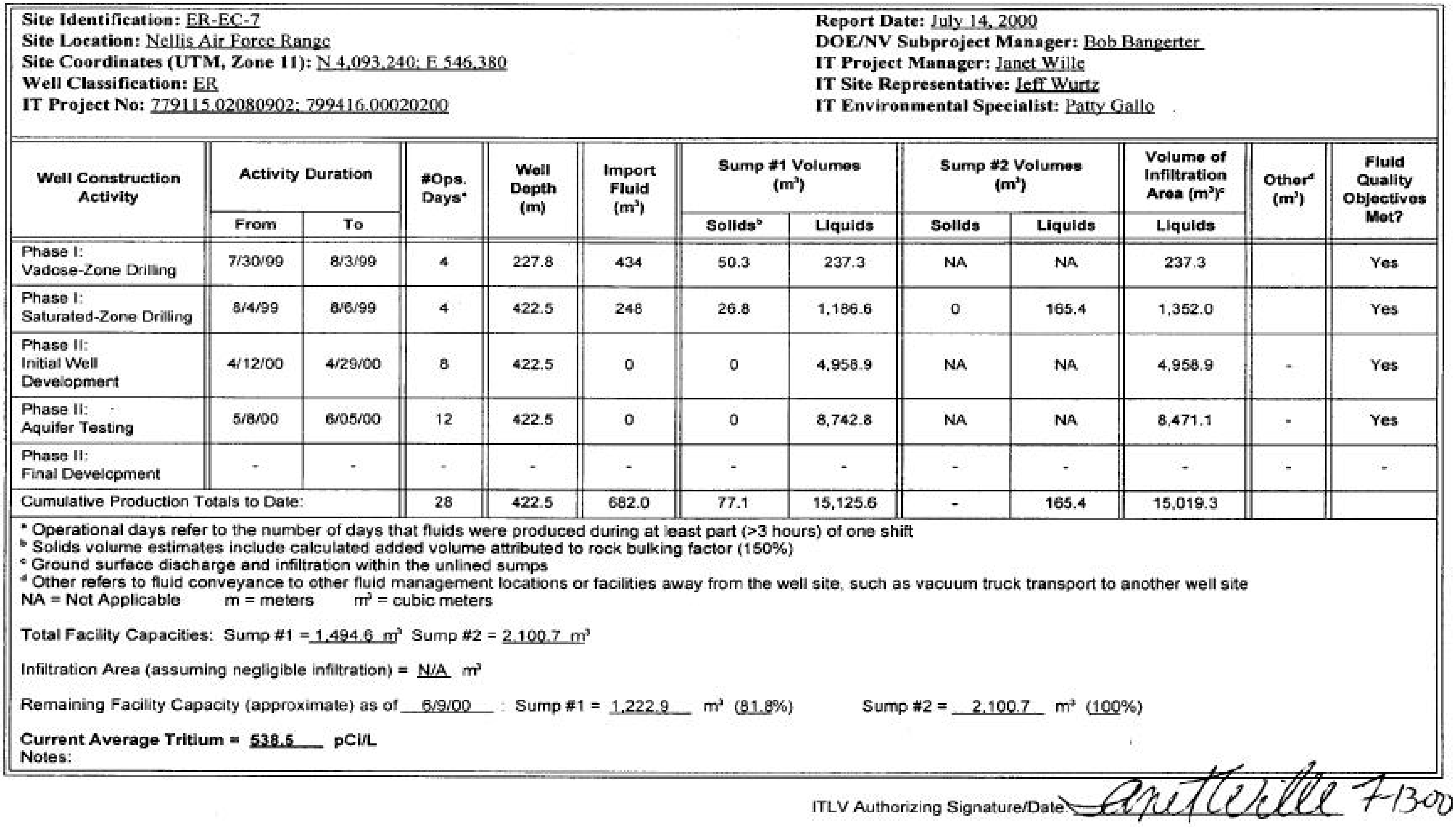
A total of approximately 3,620,000 gals of groundwater were pumped from Well ER-EC-7 during well development, hydraulic testing, and sampling activities. The total is composed of 1,310,150 gals during well development and 2,309,850 gals for the constant-rate pumping. Table A.4-1 contains the final Fluid Disposition Reporting Form.

A.4.1.2 Lead and Tritium Monitoring

Lead and tritium samples were collected daily according to the FMP and waivers. Lead analysis was conducted on site in the field laboratory using a HACH DR 100 Colorimeter according to DOP ITLV-UGTA-310, “Field Screening for Lead in Well Effluent.” A tritium sample was collected daily at the sample port of the wellhead. The sample was kept in locked storage until transported to the BN Site Monitoring Service at the Control Point in Area 6. The sample was analyzed using a liquid scintillation counter.

The NDWS were not exceeded at any time. The highest lead result was 2 µg/L and the highest tritium activity was 1,315.9 picocuries per liter (pCi/L). The average tritium activity was 538.5. The complete results of lead and tritium monitoring are presented in Table A.4-2.

Table A.4-1
Fluid Disposition Report Form



Site Identification: ER-EC-7
Site Location: Nellis Air Force Range
Site Coordinates (UTM, Zone 11): N 4,093,240; E 546,380
Well Classification: ER
IT Project No: 779115.02080902; 799416.00020200

Report Date: July 14, 2000
DOE/NV Subproject Manager: Bob Bangerter
IT Project Manager: Janet Wille
IT Site Representative: Jeff Wurtz
IT Environmental Specialist: Patty Gallo

Well Construction Activity	Activity Duration		#Ops. Days[a]	Well Depth (m)	Import Fluid (m^3)	Sump #1 Volumes (m^3)		Sump #2 Volumes (m^3)		Volume of Infiltration Area (m^3)[c]	Other[d] (m^3)	Fluid Quality Objectives Met?
	From	To				Solids[b]	Liquids	Solids	Liquids	Liquids		
Phase I: Vadose-Zone Drilling	7/30/99	8/3/99	4	227.8	434	50.3	237.3	NA	NA	237.3		Yes
Phase I: Saturated-Zone Drilling	8/4/99	8/6/99	4	422.5	248	26.8	1,186.6	0	165.4	1,352.0		Yes
Phase II: Initial Well Development	4/12/00	4/29/00	8	422.5	0	0	4,958.9	NA	NA	4,958.9	-	Yes
Phase II: Aquifer Testing	5/8/00	6/05/00	12	422.5	0	0	8,742.8	NA	NA	8,471.1	-	Yes
Phase II: Final Development	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			28	422.5	682.0	77.1	15,125.6	-	165.4	15,019.3		

[a] Operational days refer to the number of days that fluids were produced during at least part (>3 hours) of one shift
[b] Solids volume estimates include calculated added volume attributed to rock bulking factor (150%)
[c] Ground surface discharge and infiltration within the unlined sumps
[d] Other refers to fluid conveyance to other fluid management locations or facilities away from the well site, such as vacuum truck transport to another well site
NA = Not Applicable m = meters m^3 = cubic meters

Total Facility Capacities: Sump #1 = 1,494.6 m^3 Sump #2 = 2,100.7 m^3

Infiltration Area (assuming negligible infiltration) = N/A m^3

Remaining Facility Capacity (approximate) as of 6/9/00 : Sump #1 = 1,222.9 m^3 (81.8%) Sump #2 = 2,100.7 m^3 (100%)

Current Average Tritium = 538.5 pCi/L
Notes:

ITLV Authorizing Signature/Date: Janet Wille 7-13-00

Table A.4-2
Results of Tritium and Lead Monitoring at ER-EC-7

Sampling Date	Sample Number	Lead Results[1]	Tritium Results[2]
		µg/L	pCi/L[a]
04/12/2000	ER-EC-7-041200-1	1.0	1,315.9
04/21/2000	ER-EC-7-042100-1	1.0	648.3
04/22/2000	ER-EC-7-042200-1	2.0	1,172.9
04/23/2000	ER-EC-7-042300-1	1.0	719.0
04/24/2000	ER-EC-7-042400-1	1.0	379.6
04/25/2000	EC-7-042500-1	< 1.0	644.0
04/26/2000	EC-7-042600-1	<1.0	812.1
04/27/2000	EC-7-042700-1	<1.0	893.5
04/28/2000	EC-7-042800-1	<1.0	877.0
04/29/2000	EC-7-042900-1	1.5	694.2
05/08/2000	ER-EC-7-050800-1	1.5	1,143.5
05/09/2000	ER-EC-7-050900-1	<1.0	1,030.5
05/10/2000	ER-EC-7-051000-1	<1.0	394.2
05/11/2000	ER-EC-7-051100-1	1.0	40
05/12/2000	ER-EC-7-051200-1	< 1.0	0
05/18/2000	ER-EC-7-051800-1	< 1.0	0
05/19/2000	ER-EC-7-051900-1	1.0	248
05/20/2000	ER-EC-7-052000-1	<1.0	120
05/21/2000	ER-EC-7-052100-1	<1.0	0
05/22/2000	ER-EC-7-052200-1	< 1.0	176
05/23/2000	ER-EC-7-052300-1	< 1.0	0
Nevada Drinking Water Standards		15.0	20,000

1 - Lower detection limit 2 ppb.
2 - Lower detection limit 500 to 1,000 pCi/L, depending upon calibration.
[a] Analysis provided by Bechtel Nevada Site Monitoring Service at the CP in Area 6

µg/L - Micrograms per liter
pCi/L - Picocuries per liter

A.4.1.3 Fluid Management Plan Sampling

A fluid management sample was collected from the active unlined sump at the end of well development and testing activities to confirm on-site monitoring of well effluent. The sample was collected on June 5, 2000, and sent to Paragon. The FMP parameters of total and dissolved metals, gross alpha and beta, and tritium were requested for analysis. The laboratory results are presented in Table A.4-3 and compared to the NDWS.

Table A.4-3
Preliminary Analytical Results of Sump Fluid Management Plan Sample at Well ER-EC-7

Analyte	CRDL	Laboratory	NDWS	Results of Sump Composite Sample # EC-7-060500-4	
Metals (mg/L)					
				Total	**Dissolved**
Arsenic	0.01	Paragon	0.05	B0.0055	B 0.0049
Barium	0.2	Paragon	2.0	B 0.0054	B 0.0048
Cadmium	0.005	Paragon	0.005	U 0.005	U 0.005
Chromium	0.01	Paragon	0.1	B 0.001	B 0.00093
Lead	0.003	Paragon	0.015	U 0.003	U 0.003
Selenium	0.005	Paragon	0.05	U 0.005	U 0.005
Silver	0.01	Paragon	0.1	U 0.01	U 0.01
Mercury	0.0002	Paragon	0.002	U 0.0002	U 0.0002
Analyte	**MDC**	**Laboratory**		**Result**	**Error**
Radiological Indicator Parameters-Level I (pCi/L)					
Tritium	280, 270	Paragon	20,000	U 10	+/- 160
Gross Alpha	2.0, 3.6	Paragon	15	4.9	+/- 2.6
Gross Beta	2.4, 3.8	Paragon	50	2.6	+/- 2.3

U - Result not detected at the given minimum detectable limit or activity
B - Result less than the practical quantitation limit but greater than or equal to the instrument detection limit
CRDL - Contract-required detection limit per Table 5-1, UGTA QAPP (DOE/NV, 1998)
MDC - Minimum detectable concentration, sample-specific
NDWS - *Nevada Drinking Water Standards*
mg/L - Milligrams per liter
pCi/L - Picocuries per liter

A.4.2 Waste Management

Wastes generated during well development and testing activities were managed in accordance with the *Underground Test Area Subproject Waste Management Plan,* Revision 1 (DOE/NV, 1996); the *Waste Management Field Instructions for the Underground Test Area Subproject* (IT, 1997); SQP ITLV-0501, “Control of Hazardous Materials”; and SQP ITLV-0513, “Spill Management.” The following exceptions were added in the *Field Instructions for WPM-OV Well Development* *and Hydraulic Testing Operations* (IT, 1999b) because chemical and/or radiological contamination was not expected:

- Decontamination rinsate from laboratory and on-site equipment decontamination operations shall be disposed of with fluids in the on-site infiltration basin.
- All disposable sampling equipment and personal protective equipment shall be disposed of as sanitary waste and may be placed directly in on-site receptacles.

As a result of well development and testing activities, two types of waste were generated in addition to normal sanitary waste and decontamination water:

- Hydrocarbon: Two drums of hydrocarbon waste were produced containing oily/diesel-stained absorbant pads/debris and used pump oil.
- Hazardous Waste: Approximately 1/2 gallon of solid hazardous waste was generated from the installation of the bridge plugs/packer. This material consists of combustion by-products. This waste was removed from the site and consolidated with the bridge plug waste from other Nevada Test Site WPM-OV well sites. The waste was stored in a Satellite Accumulation Area at the ER-EC-6 well site. Monthly inspections of this area were conducted until the waste was transported off site for disposal.

All waste, hydrocarbon and hazardous, was disposed of by BN Waste Management after well development operations at the NTS were completed.

A.5.0 References

DOE/NV, see U.S. Department of Energy, Nevada Operations Office.

IT, see IT Corporation.

IT Corporation. 1997. *Waste Management Field Instructions for the Underground Test Area Subproject*, January. Las Vegas, NV.

IT Corporation. 1999a. *Detailed Operating Procedures Underground Test Area Operable Unit*, December. Las Vegas, NV.

IT Corporation. 1999b. *Field Instructions for Western Pahute Mesa* - *Oasis Valley Well Development and Hydraulic Testing Operations*, Rev. 0, December. Las Vegas, NV.

IT Corporation. 1999c. *Site-Specific Health and Safety Plan for Development, Testing, and Sampling of Clean Wells*, October. Las Vegas, NV.

IT Corporation. 1999d. *Well Development and Hydraulic Testing Plan for Western Pahute Mesa* - *Oasis Valley Wells*, Rev. 0, November. Las Vegas, NV.

IT Corporation. 2000. *ITLV Standard Quality Practices Manual*, Volumes 1 and 2, March. Las Vegas, NV.

NDEP, see Nevada Division of Environmental Protection.

Nevada Division of Environmental Protection. 1999. Letter from P. Liebendorfer (NDEP) to R. Wycoff (DOE/NV) granting a waiver from the FMP for WPM-OV wells and stipulating conditions for discharging fluids, 19 October. Carson City, NV.

Roberson, J.A., and C.T. Crowe. 1975. *Engineering Fluid Mechanics*. Boston, MA: Houghton Mifflin Company.

Townsend, M., Bechtel Nevada. 2000. Communication regarding completion and geology of Well ER-EC-7. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 1996. *Underground Test Area Subproject Waste Management Plan*, Rev. 1. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 1998. *Underground Test Area Quality Assurance Project Plan*, Rev. 2. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 1999. *Attachment 1 - Fluid Management Plan for the Underground Test Area Subproject* in "Underground Test Area Subproject Waste Management Plan," Rev. 1. Las Vegas, NV.

Attachment 1

Manufacturer's Pump Specifications

High-Capacity Testing Pump

RFO # 623 HIGH VOLUME ELECTRIC SUBMERSIBLE PUMP SYSTEMS
BECHTEL NEVADA CORPORATION
YUCCA MOUNTAIN PROJECT
NEVADA TEST SITE
TERRY FLETCHER

CENTRILIFT

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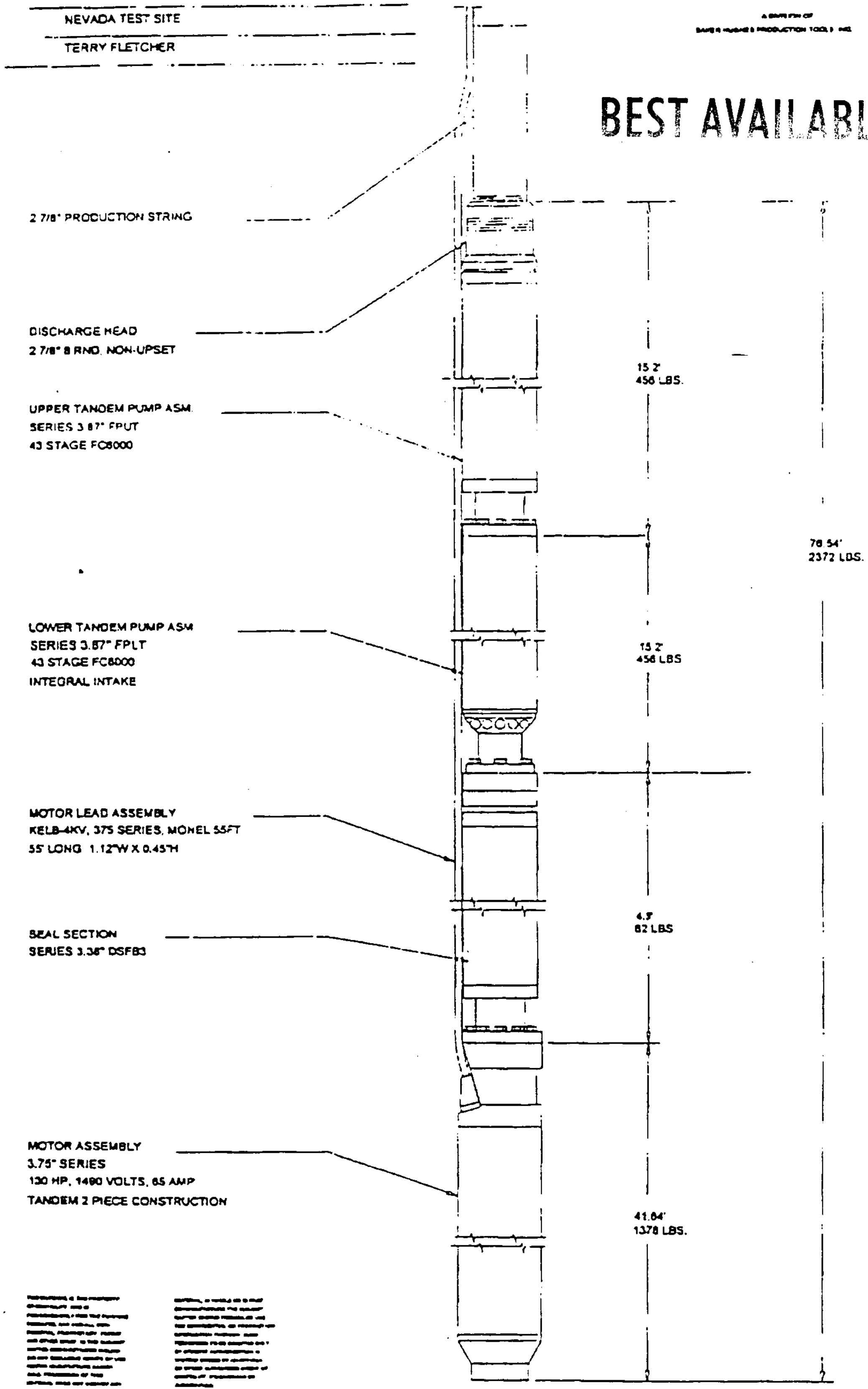
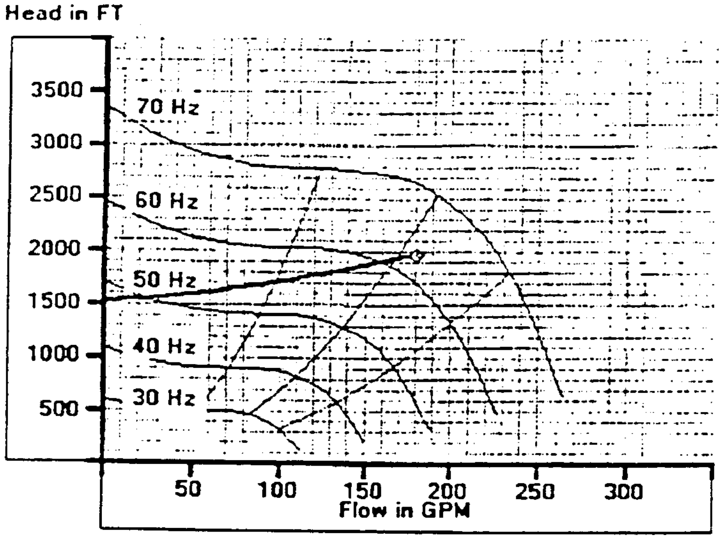
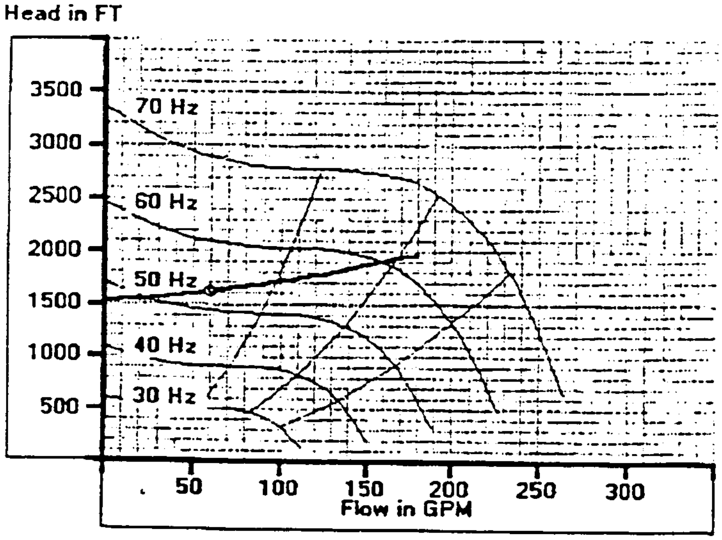


60-180 G.P.M. OPERATION
AT 500 FT PUMP SETTING DEPTH (600 PSI tubing pressure)





Frequency	Hz	50	55	60	65
Flow at Stock Tank	GPM	23.67	93	150	181
Pump Intake Pressure	psi	365	327	295	279
Total Dynamic Head	FT	1555	1702	1873	1980
Fluid speed by motor	ft/sec	0.284	1.115	1.804	2.166
Motor Load	%	34.19	56.27	78.79	93
Motor Amps	A	40.6	43.52	54.28	61.07
Pump RPM	rpm	2940	3224	3469	3719
Surface KVA	kVA	73.76	89.54	134	171

Centrilift - A Baker Hughes company
(714) 893-8511 (800) 755-8976 (714) 892-9945 FAX (714) 397-0941 MOBILE
5421 Argosy Drive Huntington Beach, CA. 92649
Terry Fletcher- Sales Engineer E- Mail: Terry.Fletcher@Centrilift.com

October 10,1999

Project: Nevada Test Site
Customer: Bechtel Nevada
Well: Various
Engineer: Mr. Ken Ortego

Pump: 86-FC6000 [400Series]
Seal: DSFB3 [338Series]
Motor: DMF 130 HP 1490V 65 A [375Series]
Cable: #4 CPNR 3kV ,980ft
Controller: VSD 2250-VT 260kVA/ 480V/ 313A

60-180 GPM @ 500' pump setting depth, 53.1-65 Hz. operation (600 PSI tubing)
Slim-line design to accomodate production logging tools *NOTE: Motor ratings at 60Hz
7-5/8" casing internally coated for a drift of 6.83" i.d. * Note: Set VSD to 64.9 Hz

Input Parameters:

Fluid Properties:
Oil Gravity = 20.0 °API
Water Cut = 100 %
SG water = 1.0 rel to H2O
SG gas = 0.8 rel to air
Sol GOR = 1.0 scf/STB
Prod GOR = 1.0 scf/STB
Bot Hole Temp = 120 °F
Surf Fluid Temp= 120 °F

Gas Impurities:
N2 = 0 %
H2S = 0 %
CO2 = 0 %

Bubble Point Pressure
Pb = 14.7psia

Inflow Performance:
Datum = 500ft
Perfs V. Depth = 2500ft
Datum Static P = 154psi
Test Flow = 6171BPD
Test Pressure = 64.94psi
PI = 63.05BPD/psi
IPR Method = Composite IPR

Target:
Pump Setting Depth (vertical) = 1000ft
Desired Flow = 6171BPD
Gas Sep Eff = 90%
Tbg Surf Press = 600psi
Csg Surf Press = 0psi

Casing & Tubing: Roughness = 0.0018 in

Casing ID (in) 6.969
Tubing ID (in) 2.441
Vertical Depth (ft) 3000
Measured Depth (ft) 3000

Correlations PVT:
Dead Visc: Beggs & Robinson
Saturated Visc: Beggs & Robinson
UnderSaturated: Vasquez & Beggs
Gas Visc: Lee

Oil Compress: Vasquez & Beggs
Formation Vol: Standings
Z factor: Hall & Yarborough
Bubble Point P: Standings

Correlations Multiphase:
Tubing Flow: Hagedorn & Brown
Casing Flow: Hagedorn & Brown

Centrilift - A Baker Hughes company
(714) 893-8511 (800) 755-8976 (714) 892-9945 FAX (714) 397-0941 MOBILE
5421 Argosy Drive Huntington Beach, CA. 92649
Terry Fletcher- Sales Engineer E- Mail: Terry.Fletcher@Centrilift.com

October 10,1999

Operating Parameters / Selection:

Design Point:

Desired flow (total) = 6171 BPD
% water = 100.0 %
% Gas into pump = 0.0 %bs /0.0 %

Frequency = 64.9 Hz
GOR into pump= 1.0 scf/STB
TDH = 1978 FT

Pump Selection:

	Intake	Discharge
Pressure	= 279 psi	1125 psi
Flowrate	= 6252 BPD	6237 BPD
Specific Gravity	= 0.987 rel-H2O	0.989 rel-H2O
Viscosity	= 0.516Cp	0.534Cp

Pump Selected:
86 stages Type: FC6000 [400 Series]
Shaft HP at 64.9 Hz = 125 (33 %)
Required motor shaft HP at 60.0 Hz = 120

60-180 GPM @ 500' pump setting depth, 53.1-65 Hz. operation (600 PSI tubing)

Seal Selection:

Well angle at set depth = 0Deg from vertical
No sand present
Pump uses floater-type stages
Motor/Seal Oil type = CL4
Seal Selected : DSFB3 [338 Series]
Options : None

Oil temperature at thrust chamber = 194°F
Chamber Cap Used (Top to Bot)=
19% 21%
Thrust bearing load =52 %
Shaft load = 70 %

Motor Selection:

Terminal Voltage =1574.8 V
Cable Current =60.9 A
Load acc to N.P. =92.3 %
Shaft Load =48.6 %

Fluid Speed =2.158ft/s
Internal Temp =161°F
Motor Selected: DMF 130 HP 1490V 65 A [375Series]
Options : None

Slim-line design to accomodate production logging tools *NOTE: Motor ratings at 60Hz

Cable Selection:

Surface Length = 50.0ft
Tubing Length = 980ft
MLE length = 20.0ft
Surface Temp = 75°F

Wellhead Voltage = 1609.4V
Wellhead kVA = 169.9kVA
Voltage Drop = 34.5V
Cond Temp (main) = 169°F
Temp Rating = 205°F

Surface Cable	Main Cable	MLE Cable
#2 CTTF 3kV 50.0ft	#4 CPNR 3kV 980ft	#6 MLE-KLHTLP 5kV 20.0ft

No comments

Controller Selection:

Input kVA = 134.7kVA
System kW = 129.0kW
Max Ctrl Current = 204.9A
Power Cost/kWH = 0.05$/kW
Total Power Cost = $4644/month

Voltage Input = 480V
Max Well Head Volts = 1609V
Max Frequency = 64.9Hz (7.40V/Hz)
Start Frequency = 10.0Hz
Step-up Trafo = 3.361 ratio
Selected: VSD 2250-V 260kVA/ 480V/ 313A

NEMA 3 design (outdoor use)

— End of Report —

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Terry Fletcher- Sales Engineer   E- Mail: Terry.Fletcher@Centrilift.com

October 10,1999

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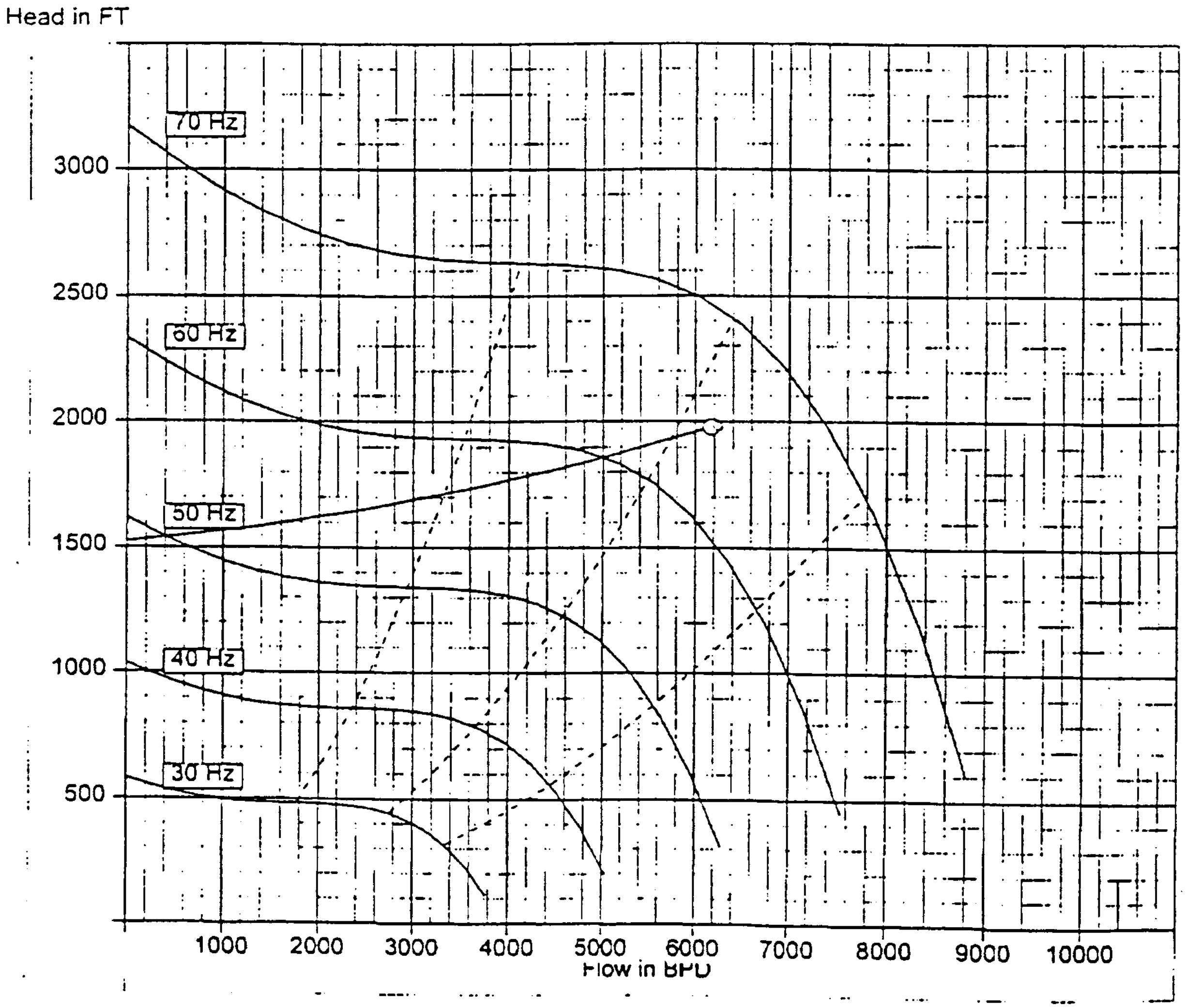
Controller: VSD 2250-VT 260kVA/ 480V/ 313A

60-180 GPM @ 500' pump setting depth, 53.1-65 Hz. operation (600 PSI tubing)
Slim-line design to accomodate production logging tools *NOTE: Motor ratings at 60Hz
7-5/8" casing internally coated for a drift of 6.83" i.d. * Note: Set VSD to 64.9 Hz

86-FC6000 Series: 400

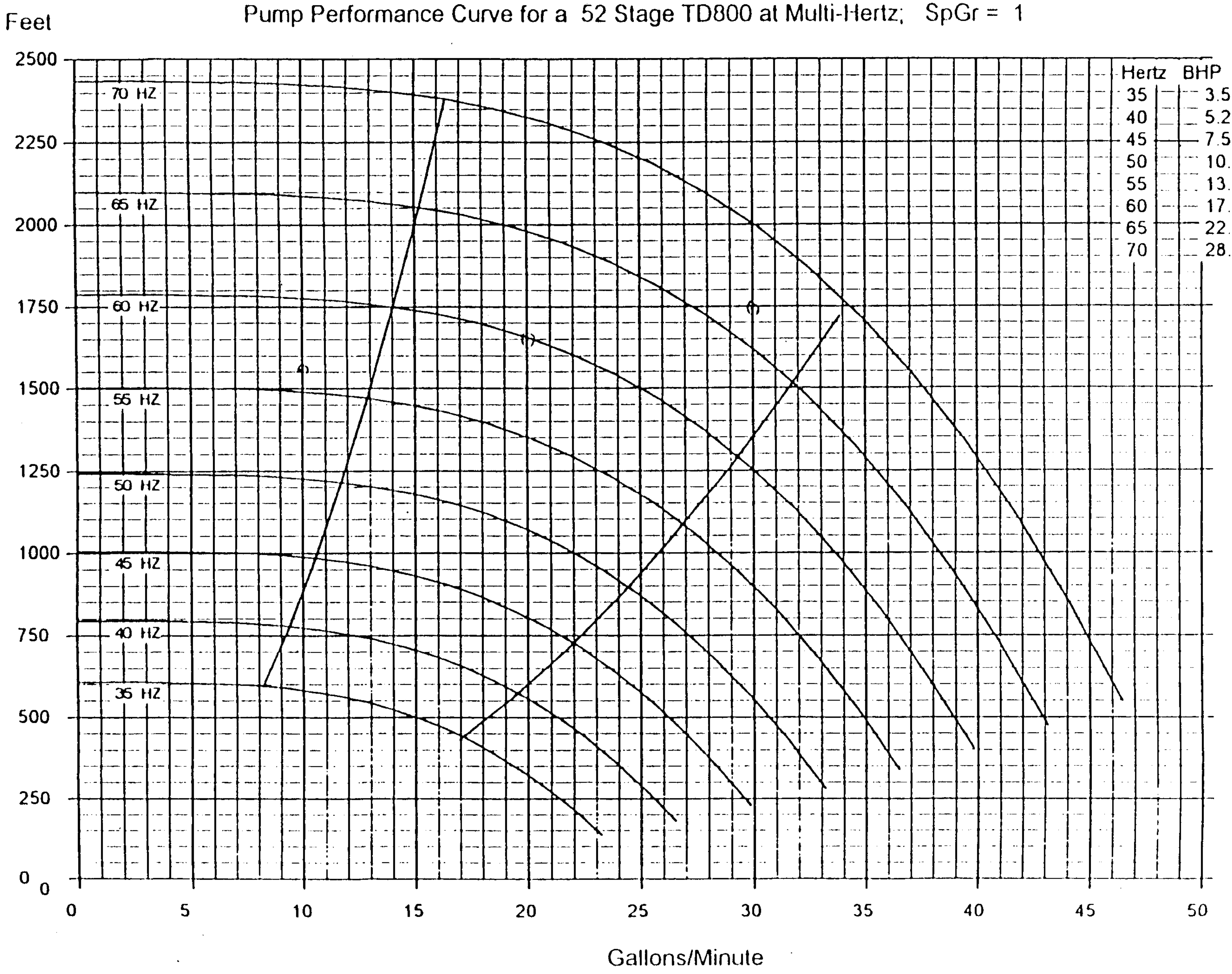


Dedicated Sampling Pump

Plot Program by Electric Submersible Pumps,Inc

4.00 ESP Pumps

Pump Performance Curve for a 52 Stage TD800 at Multi-Hertz; SpGr = 1



Hertz	BHP	NPHP
35	3.5	6
40	5.2	7.9
45	7.5	10
50	10.2	12.3
55	13.6	14.9
60	17.7	17.7
65	22.5	20.8
70	28.1	24.1

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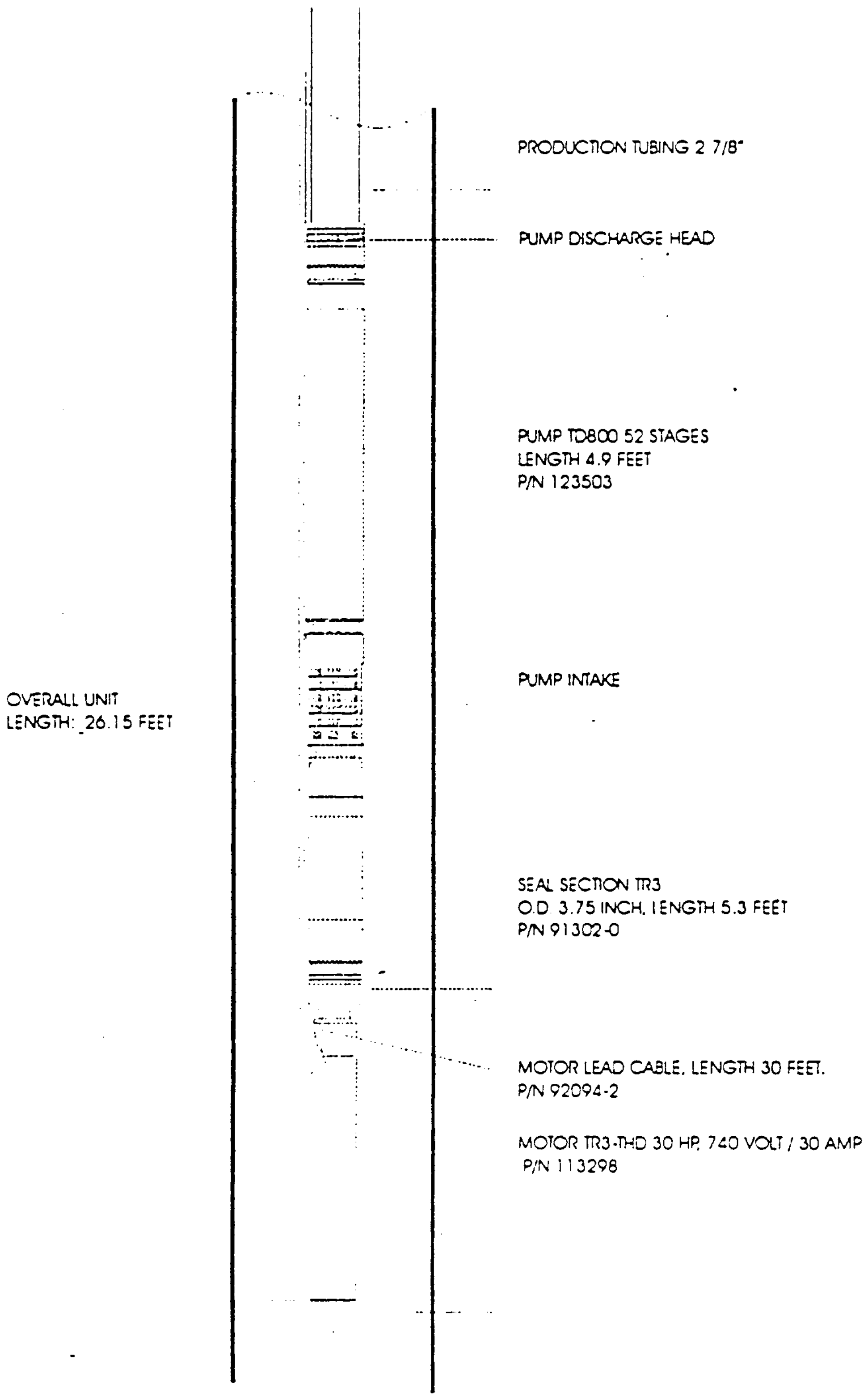
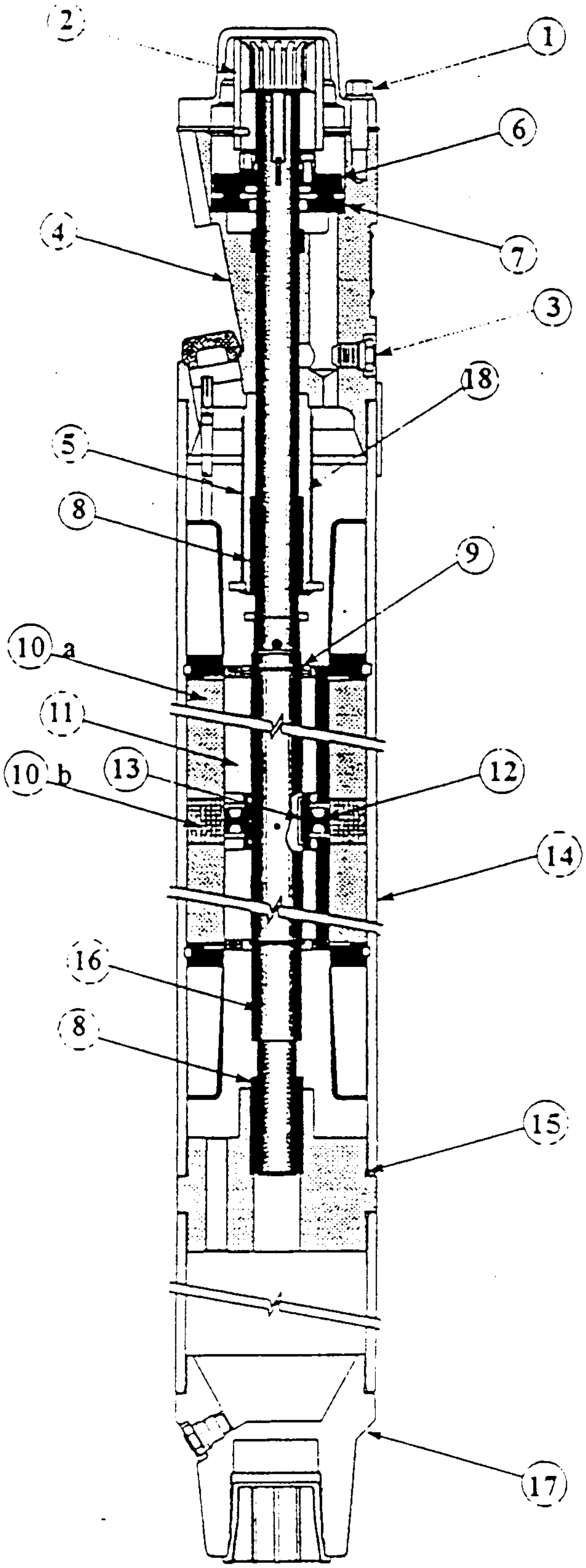
Bechtel Nevada
Las Vegas Nevada
Item Number 0002



MOTOR, SINGLE 30HP, 740 V 30A



PARTS LIST

ITEM	DESCRIPTION / MATERIAL
1	Unit Bolts Monel K500, UNS N05500
2	Coupling Steel 1042, ASTM 576
3	Vent Plugs Monel K500
4	Head Steel 1042, ASTM 576
5	Lead Guard Synthane
6	Thrust Runner Steel, C1117
7	Thrust Bearing Bronze, SAE 660 MP-481
8	Bushings Bronze 660
9	Snap Rings Beryllium Copper
10	Stator Laminations a)Steel b)Bronze,Silicon
11	Rotor Laminations Steel
12	Rotor Bearing Nitralloy
13	Rotor BearingSleeve Bronze 660
14	Stator Housing Steel 1026, ASTM A513
15	"O" Rings Viton
16	Shaft Steel 4130, ASTM A513, ASTM A519, UNS G41300
17	Base Steel 1042, ASTM 576
18	Guide Tube Steel 1020, ASTM A513,A519, UNS G10200

O.D. - 3.75 INCH
LENGTH - 13.3FEET
WEIGHT -495 LBS

QUALITY RUNS DEEP AT ESP

New Release
15 May 1997

ESP

Standard Seal

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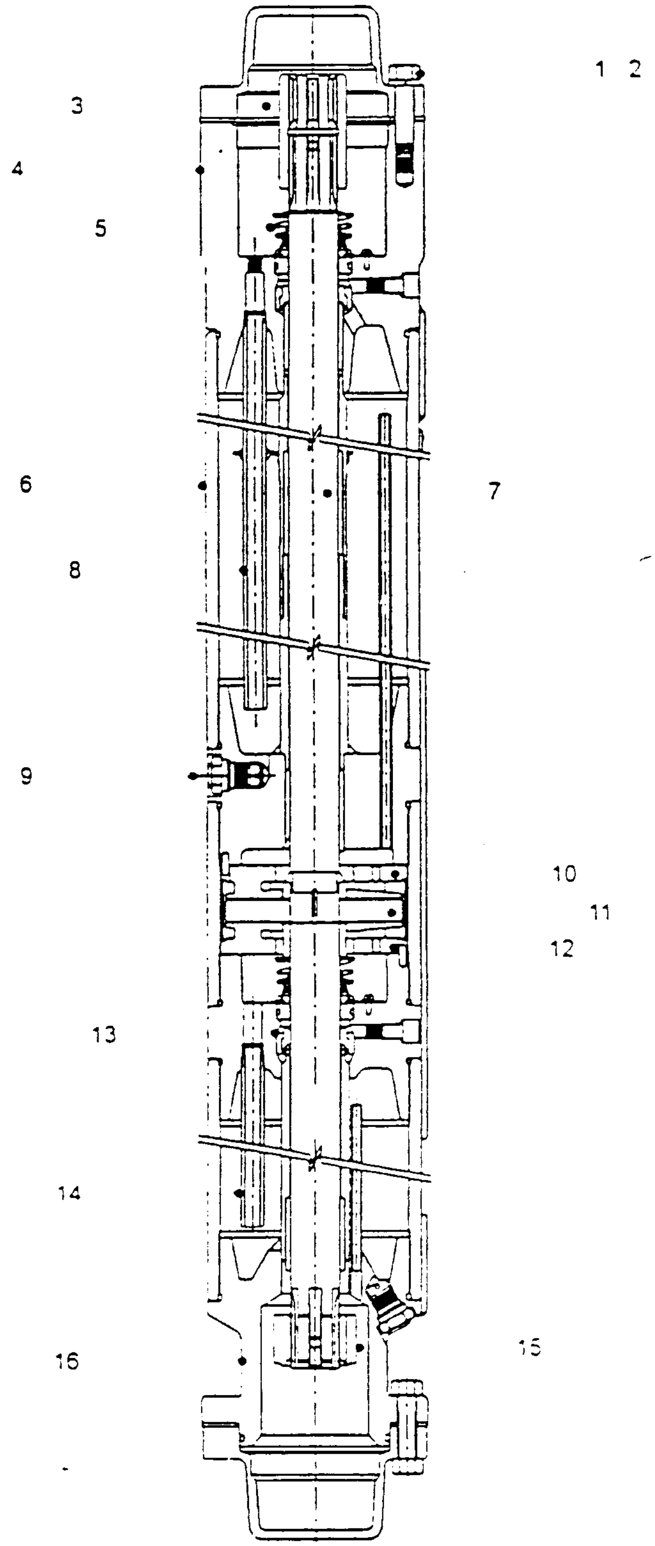
WOOD GROUP



PARTS LIST

ITEM	DESCRIPTION
1	Screw, Hex Head - Monel
2	Washer, Lock - Monel
3	Coupling - Monel
4	Head, Seal
5	Seal, Mechanical
6	Housing
7	Shaft
8	Breather Tube
9	Valve, Drain/Fill
10	Bearing, Up-Thrust
11	Runner, Thrust
12	Bearing, Down-Thrust
13	Water Shedder
14	Breather Tube
15	Coupling Adapter
16	Base

TYPE TR3
3.75 O.D.
5.3 FT.
Shaft Dia. 1"
Shaft Nitronic 50
Weight 125 lbs.

ESP

Standard Pump (Floater Stage Design)

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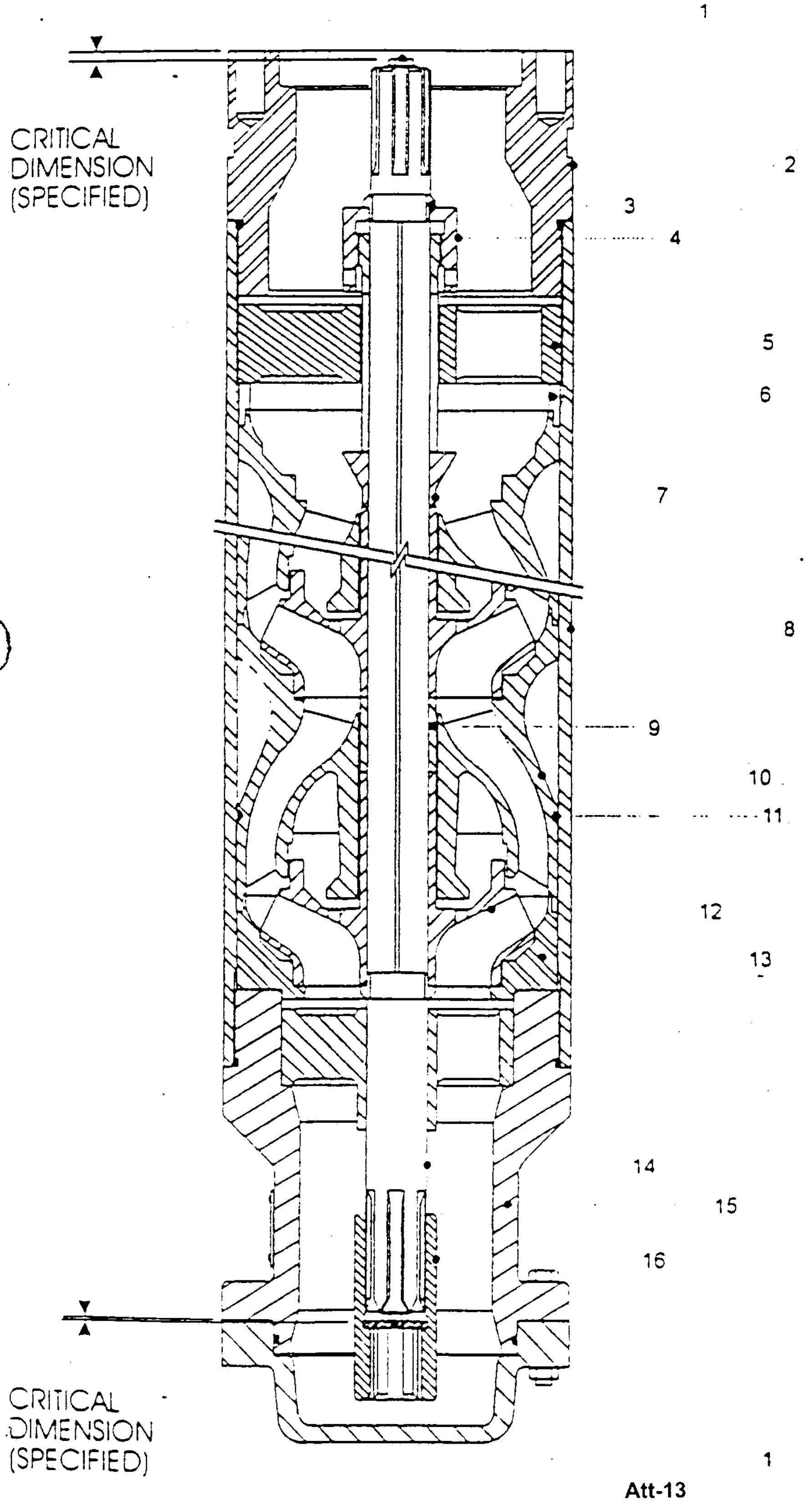
WG WOOD GROUP



PARTS LIST

ITEM	DESCRIPTION
1	Adj. Nuts & Shims
2	Head, TDM
3	Two Piece Ring
4	Compression Nut, Sleeve & Set Screw
5	Compression Bearing
6	Compression Tube
7	Fluid Director
8	Housing
9	Spacer - Impeller
10	Diffuser
11	O'Ring, Diffuser
12	Impeller
13	Lower Diffuser
14	Shaft
15	Base, TDM S/A
16	Coupling

TD800
51STAGE
3.87O.D.
4.9 FT
2 3/8 8RD DISCHARGE
BOLT ON INTAKE

Attachment 1

3.87 INTAKE

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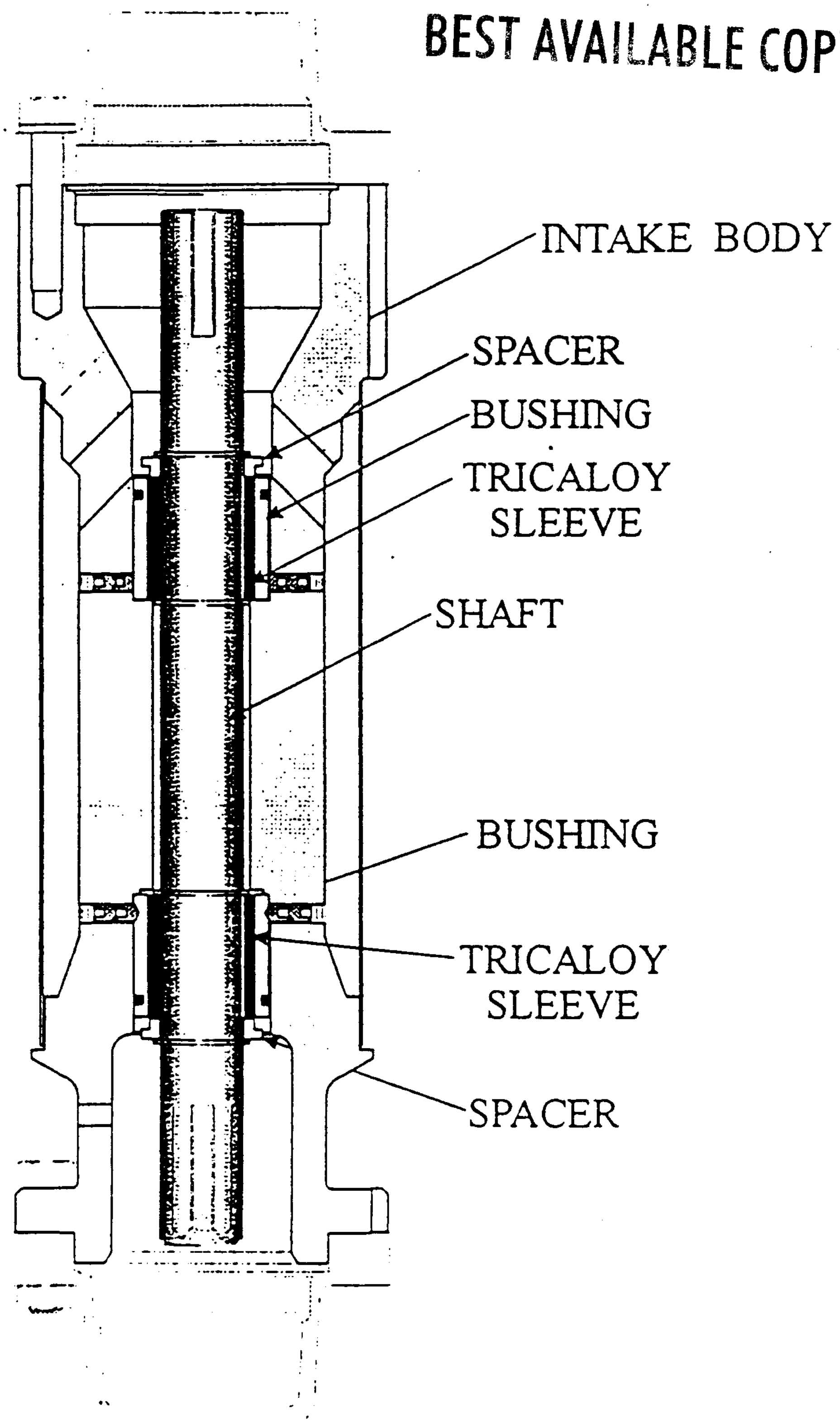
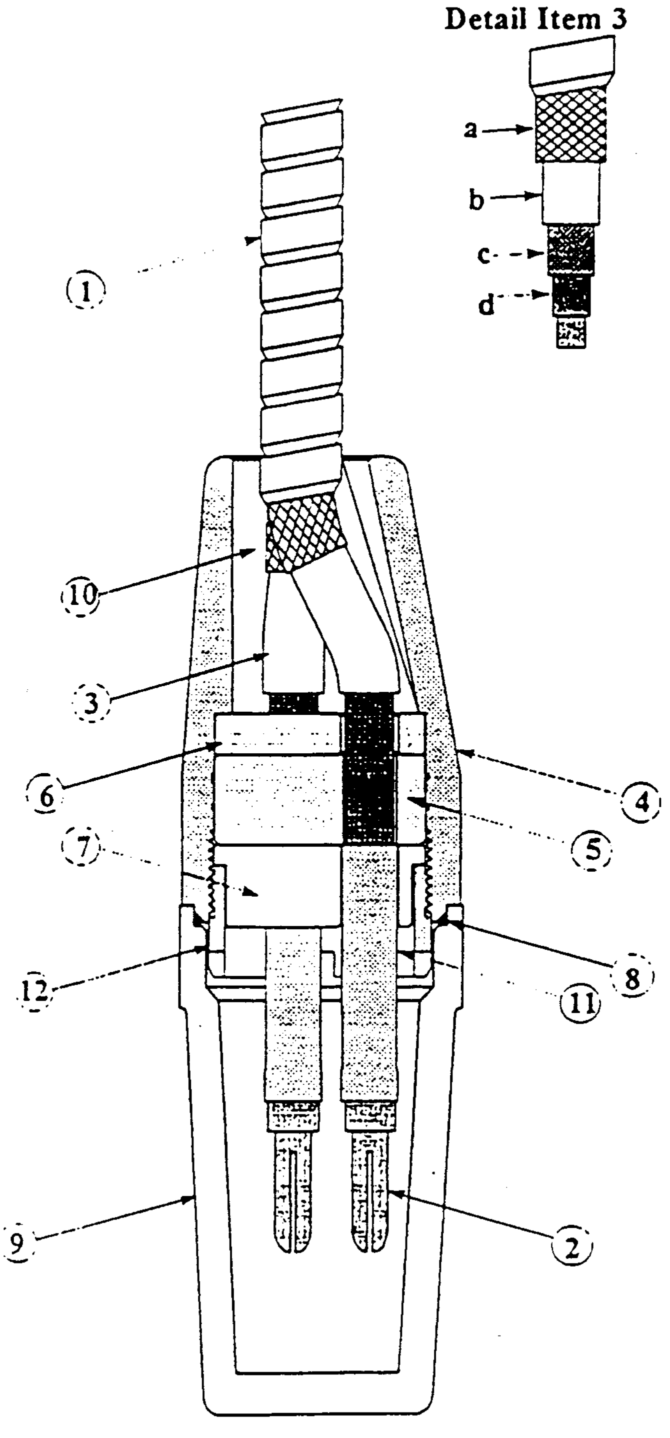


MLC, Tr3 KEOTB GALV.



PARTS LIST

ITEM	DESCRIPTION / MATERIAL
1	Cable, Flat KEOTB Cable w/ Galv Armor
2	Terminal Beryllium Copper MP1012
3	Insulated Conductor a) Nylon Braid b) Lead Sheath c) EPDM Insulation d) Kapton Tape
4	Pothead Casting Ni-Resist
5	Insulation Block High Dielectric Hypalon
6	Wall, Upper Epoxy Glass G10-11, MP1017-1018
7	Wall, Lower Aluminum 2014
8	O-Ring HSN 75 Duro
9	Shipping Cap Ni-Resist
10	Filler Epoxy, Thermoset
11	Tubing, Shrink Teflon FEP
12	Nut, Compression Steel 1042 ASTM 576

New Release
27 May 1997

Attachment 2

Water Quality Monitoring - Grab Sample Results

Table ATT.2-1
Water Quality Monitoring - Grab Sample Results for Well ER-EC-7

(Page 1 of 3)

Date	Time hr:min	Temperature ° C	EC µmhos/cm	pH SU	DO mg/L	Turbidity NTUs	Bromide mg/L	Pumping Rate gpm	Total Discharge gallons	Comments/Phase of Development or Testing
4/12/2000	12:00	- - -	187.6	7.65	6.76	50.10	0.260	182.1	5,854	Functionality test on pump; wait for pressure control valve
4/21/2000	14:08	26.4	177.3	7.69	6.34	2.36	0.221	7.6	12,765	Test new pressure regulator system
4/22/2000	17:09	27.5	177.4	7.42	6.29	2.12	0.141	176.6	22,403	Begin well devel. at 16:47
4/22/2000	18:04	27.7	187.0	7.75	6.06	1.44	0.130	176.7	32,899	
4/23/2000	8:36	27.9	202.2	7.64	5.23	1.26	0.252	65.4	90,570	Pump off midnight to 08:10, step drawdown - 1st step - 65 gpm
4/23/2000	10:37	27.8	214.7	7.55	5.97	0.41	0.250	121.5	100,060	Step drawdown - 2nd step - 120 gpm
4/23/2000	12:37	28.2	220.4	7.56	5.71	0.95	0.245	174.3	115,958	Step drawdown - 3rd step - 175 gpm
4/23/2000	14:36	28.5	229.9	7.64	5.62	0.48	0.247	175.7	122,864	
4/23/2000	17:03	28.5	233.7	7.55	5.57	0.53	0.259	175.6	151,555	
4/24/2000	8:03	- - -	273.7	7.39	5.49	0.32	0.277	84.1	309,291	Pump off between 8:00 and 9:00
4/24/2000	10:08	28.2	275.7	7.45	5.18	0.46	0.228	175.8	320,839	
4/24/2000	12:18	28.5	277.8	7.44	5.09	0.93	0.220	175.4	333,872	Pump off between 12:00 and 13:00
4/24/2000	14:05	28.7	279.7	7.50	5.04	0.27	0.209	61.8	352,385	
4/24/2000	16:30	28.9	279.7	7.53	4.82	0.58	- - -	175.8	361,966	Pump off between 15:30 and 16:00
4/25/2000	9:25	29.0	287.5	8.16	4.40	0.38	0.154	89.1	540,018	
4/25/2000	12:05	28.6	293.4	8.10	3.81	0.23	0.130	65.7	542,322	Step-drawdown testing
4/25/2000	13:57	28.8	287.5	7.83	4.68	0.17	0.111	121.5	551,421	Step-drawdown testing
4/25/2000	16:00	29.2	286.5	7.96	4.40	0.55	0.122	176.0	567,833	Step-drawdown testing
4/26/2000	7:55	28.3	295.5	7.91	4.28	0.29	0.165	175.9	735,592	
4/26/2000	10:05	29.0	295.5	8.02	4.17	0.41	0.224	175.6	746,433	
4/26/2000	11:45	29.4	295.5	7.79	4.21	0.44	0.187	175.8	754,251	
4/26/2000	13:15	29.3	294.5	7.80	4.22	0.77	0.133	175.8	760,670	

Table ATT.2-1
Water Quality Monitoring - Grab Sample Results for Well ER-EC-7
(Page 2 of 3)

Date	Time hr:min	Temperature ° C	EC μmhos/cm	pH SU	DO mg/L	Turbidity NTUs	Bromide mg/L	Pumping Rate gpm	Total Discharge gallons	Comments/Phase of Development or Testing
4/26/2000	15:00	29.4	296.4	7.91	4.14	0.29	0.148	176.0	779,134	
4/26/2000	17:03	28.9	293.5	7.62	4.09	0.24	0.154	175.9	801,113	
4/27/2000	8:15	28.2	305.4	7.89	4.13	0.23	0.011	175.7	960,946	
4/27/2000	10:13	28.5	299.4	7.88	4.12	0.45	0.161	175.6	967,983	
4/27/2000	12:25	28.7	293.4	7.64	4.00	0.35	0.153	175.8	981,511	
4/27/2000	16:00	28.5	305.4	7.77	3.90	0.36	0.074	175.8	1,019,280	
4/28/2000	10:05	27.2	318.8	7.92	1.69	2.73	0.150	65.5	1,123,318	DRI flow logging
4/28/2000	12:15	29.0	310.9	7.92	2.95	0.84	0.122	65.6	1,129,062	DRI flow logging
4/28/2000	14:15	29.0	308.9	7.89	2.89	1.69	0.151	65.5	1,141,342	DRI flow logging
4/28/2000	16:30	28.7	304.9	7.79	2.82	1.04	0.130	120 *	1,148,000	* DRI flow logging
4/28/2000	17:55	29.0	302.0	8.04	3.82	4.23	0.130	121.2	1,156,448	DRI flow logging
4/29/2000	8:00	27.9	303.8	8.04	4.05	0.36	0.113	176.0	1,301,600	End well devel.; install check valve
5/12/2000	13:00	29.7	317.0	7.95	2.58	0.13	0.137	176.1	2,347,200	Constant-rate pumping test started at 10:30 on 5/08/00
5/12/2000	14:15	29.5	311.0	7.87	3.66	0.19	0.110	176.1	2,368,469	
5/12/2000	16:20	29.2	312.0	7.99	3.46	0.10	0.115	176.0 *	2,380,000	Pump shut itself off; test ended prematurely at 16:23
5/18/2000	15:05	28.9	283.0	7.88	4.01	0.52	0.194	175.9	2,398,605	Restart constant-rate test at 13:50
5/18/2000	17:05	29.3	304.0	7.80	3.74	0.26	0.178	175.5	2,418,339	
5/19/2000	8:08	29.2	317.0	7.71	3.58	0.16	0.234	176.0	2,581,716	
5/19/2000	10:08	29.3	316.0	7.68	3.56	0.26	0.219	176.1	2,597,002	
5/19/2000	12:11	29.6	316.0	7.71	3.41	0.19	0.218	176.1	2,618,920	
5/19/2000	14:05	29.7	317.0	7.72	3.41	0.22	0.203	175.9	2,639,457	
5/19/2000	17:00	29.8	317.0	7.74	3.64	0.15	0.197	176.2	2,671,473	

Table ATT.2-1
Water Quality Monitoring - Grab Sample Results for Well ER-EC-7
(Page 3 of 3)

Date	Time hr:min	Temperature ° C	EC µmhos/cm	pH SU	DO mg/L	Turbidity NTUs	Bromide mg/L	Pumping Rate gpm	Total Discharge gallons	Comments/Phase of Development or Testing
5/20/2000	9:00	29.6	314.0	7.83	3.45	0.18	0.223	175.9	2,835,160	
5/20/2000	11:00	29.6	313.0	7.84	3.48	0.15	0.196	176.3	2,856,374	
5/20/2000	13:00	29.8	315.0	7.82	3.48	0.24	0.207	176.2	2,877,478	
5/20/2000	15:00	29.8	315.0	7.83	3.40	0.10	0.209	176.1	2,898,404	
5/20/2000	17:00	29.8	315.0	7.83	3.54	0.29	0.210	175.9	2,919,595	
5/21/2000	8:20	29.7	314.0	7.86	3.27	0.12	0.141	176.0	3,081,026	
5/21/2000	10:00	29.8	314.0	7.84	3.37	0.19	0.157	176.1	3,101,819	
5/21/2000	12:00	29.9	313.0	7.86	3.33	0.11	0.120	176.1	3,122,893	
5/21/2000	14:00	29.9	314.0	7.86	3.29	0.26	0.148	176.1	3,144,497	
5/21/2000	16:00	30.0	314.0	7.86	3.31	0.12	0.133	176.2	3,166,549	
5/21/2000	17:00	30.0	313.0	7.87	3.34	0.10	0.130	176.2	3,177,059	
5/22/2000	8:30	29.8	313.0	7.87	3.43	0.08	0.081	176.0	3,335,780	
5/22/2000	10:30	29.8	314.0	7.89	3.47	0.15	0.079	176.1	3,362,073	
5/22/2000	12:30	29.8	314.0	7.89	3.43	0.18	0.226	176.3	3,383,266	
5/22/2000	14:30	30.0	313.0	7.88	3.44	0.24	0.216	176.2	3,404,226	
05/22/2000	16:30	30.0	315.0	7.87	3.52	0.24	0.212	176.2	3,425,807	
05/23/2000	8:40	29.6	329.0	7.68	3.15	0.19	0.186	175.8	3,600,176	
05/23/2000	9:20								3,602,200	Pump shut down; end constant-rate test

DRI - Desert Research Institute
DO - Dissolved oxygen
EC - Electrical Conductivity
gpm - Gallons per minute

GW - Groundwater
hr:min - Hour: minute
in - Inch
mg/L - Milligrams per liter

NTUs - Nephelometric turbidity units
SU - Standard Units
µmhos/cm - Micromhos per centimeter

* - Value estimated, no field record

Attachment 3

Water Quality Analyses, Composite Characterization Sample and Discrete Samples

Table ATT.3-1
Analytical Results of Groundwater Characterization Samples at Well ER-EC-7
(Page 1 of 3)

Analyte	**Laboratory Detection Limit**[a]	**Laboratory**	**Results of Discrete Bailer Sample #EC-7-042800-3**		**Results of Wellhead Composite Sample #EC-7-060500-1**	
Metals (mg/L)						
			Total	Dissolved	Total	Dissolved
Aluminum	0.2	Paragon	UJ 0.067	UJ 0.053	U 0.039	U 0.038
Arsenic	0.01	Paragon	J 0.0042	J 0.0056	B 0.0072	B 0.0047
Barium	0.1	Paragon	J 0.0067	J 0.0067	UJ 0.0047	UJ 0.0045
Cadmium	0.005	Paragon	UJ 0.005	UJ 0.005	U 0.005	U 0.005
Calcium	1	Paragon	J 23	J 22	20	20
Chromium	0.01	Paragon	J 0.006	UJ 0.0016	B 0.0013	B 0.0013
Iron	0.1	Paragon	J 0.74	UJ 0.066	U 0.048	U 0.036
Lead	0.003	Paragon	UJ 0.003	UJ 0.003	UJ 0.003	UJ 0.003
Lithium	0.01	Paragon	J 0.054	J 0.054	0.033	0.033
Magnesium	1	Paragon	J 1.5	J 1.5	1.6	1.7
Manganese	0.01	Paragon	J 0.012	J 0.0029	UJ 0.00053	UJ 0.00031
Potassium	1	Paragon	J 2.5	J 2.6	2.9	2.9
Selenium	0.005	Paragon	UJ 0.005	UJ 0.005	U 0.005	U 0.005
Silicon	0.05	Paragon	J 20	J 20	21	21
Silver	0.01	Paragon	UJ 0.01	UJ 0.01	U 0.01	U 0.01
Sodium	1	Paragon	J 47	J 48	28	27
Strontium	0.01	Paragon	J 0.16	J 0.15	0.11	0.11
Uranium	0.2	Paragon	UJ 0.2	UJ 0.2	U 0.2	U 0.2
Mercury	0.0002	Paragon	UJ 0.0002	UJ 0.0002	UJ 0.0002	UJ 0.0002
Inorganics (mg/L) - unless otherwise noted						
Chloride	0.2	Paragon	J 7		4.7	
Fluoride	0.1	Paragon	J 1.9		1.1	
Bromide	0.2	Paragon	J 0.075		U 0.2	
Sulfate	1	Paragon	J 22		14	

Table ATT.3-1
Analytical Results of Groundwater Characterization Samples at Well ER-EC-7

(Page 2 of 3)

Analyte	**Laboratory Detection Limit**[a]	**Laboratory**	**Results of Discrete Bailer Sample #EC-7-042800-3**		**Results of Wellhead Composite Sample #EC-7-060500-1**	
pH (pH units)	0.1	Paragon	J 8.1		J 8.3	
Total Dissolved Solids	20	Paragon	J 220		160	
Electrical Conductivity (micromhos/cm)	1	Paragon	250		220	
Carbonate	5, 10	Paragon	UJ 5		U 10	
Bicarbonate	5, 10	Paragon	J 130		96	
Organics (mg/L)						
Total Organic Carbon	1	Paragon	J 0.42		U 1	
Redox Parameters (mg/L)						
Total Sulfide	5	Paragon	UJ 5		U 5	
Age and Migration Parameters (pCi/L) - unless otherwise noted						
Carbon-13/12 (per mil)	Not Provided	DRI	N/A		-8 +/- 0.2	
C-14, Inorganic (pmc)	Not Provided	LLNL	N/A		36.5	
C-14, Inorganic age (years)*	Not Provided	LLNL	N/A		8,325	
Chlorine-36	Not Provided	LLNL	N/A		2.03E-04	
Cl-36/Cl (ratio)	Not Provided	LLNL	N/A		1.18E-12	
He-4 (atoms/mL)	Not Provided	LLNL	N/A		7.45E+12	
He-3/4, measured value (ratio)	Not Provided	LLNL	N/A		1.18E-06	
He-3/4, relative to air (ratio)	Not Provided	LLNL	N/A		8.60E-01	
Oxygen-18/16 (per mil)	Not Provided	DRI	N/A		-11.7 +/- 0.2	
Strontium-87/86 (ratio)	Not Provided	LLNL	N/A		0.709321 +/- 0.000017	
Uranium-234/238 (ratio)	Not Provided	LLNL	N/A		0.000397	
H-2/1 (per mil)	Not Provided	DRI	N/A		-94 +/- 1.0	
Colloids	Not Provided	LANL	See Table 4-2			

Table ATT.3-1
Analytical Results of Groundwater Characterization Samples at Well ER-EC-7
(Page 3 of 3)

Analyte	Laboratory Detection Limit[a]	Laboratory	Results of Discrete Bailer Sample #EC-7-042800-3		Results of Wellhead Composite Sample #EC-7-060500-1	
Radiological Indicator Parameters-Level I (pCi/L)						
Gamma Spectroscopy	Sample-Specific	Paragon	All nuclides reported with a ’U’		All nuclides reported with a ’U’	
Tritium	300, 270	Paragon	U -180 +/- 170		U 50 +/- 160	
Gross Alpha	3.3, 2.6	Paragon	6.7 +/- 3.1		U 3.0 +/- 1.9	
Gross Beta	4.3, 3.5	Paragon	U 4.3 +/- 2.8		U 3.5 +/- 2.2	
Radiological Indicator Parameters-Level II (pCi/L)						
Carbon-14	300, 310	Paragon	U -100 +/- 180		U -180 +/- 180	
Strontium-90	0.57	Paragon	N/A		U -0.23 +/- 0.32	
Plutonium-238	0.027, 0.044	Paragon	U 0.005 +/- 0.012		U 0.001 +/- 0.017	
Plutonium-239	0.011, 0.033	Paragon	U 0 +/- 0.011		U -0.002 +/- 0.017	
Iodine-129	1.1	Paragon	N/A		U -0.46 +/- 0.67	
Technetium-99	2.6	Paragon	N/A		U -0.5 +/- 1.5	

a = If there is only one value present, that value is the detection limit for each analysis (or there was only one analysis).
U = Result not detected at the given minimum detectable limit or activity.
J = The result is an estimated value.
B = The result is less than the contract-required detection limit, but greater than the instrument detection limit.
N/A = Not applicable for that sample
mg/L = Milligrams per liter
µg/L = Micrograms per liter
pCi/L = Picocuries per liter
pmc = Percent modern carbon

* = The carbon-14 age presented is not corrected for reactions along the flow path.

Table ATT.3-2
Colloid Analyses for Well ER-EC-7

Analyte	Laboratory	Results of Discrete Bailer Sample #EC-7-042800-3	Results of Wellhead Composite Sample #EC-7-060500-1
Colloid Particle Size Range (in nanometer)		**Colloid Concentration (particles/mL)**	**Colloid Concentration (particles/mL)**
50 - 60	LANL	1.620E+06	8.314E+05
60 - 70	LANL	1.750E+06	8.164E+05
70 - 80	LANL	1.190E+06	6.861E+05
80 - 90	LANL	8.500E+05	5.409E+05
90 - 100	LANL	6.700E+05	3.606E+05
100 - 110	LANL	7.400E+05	2.855E+05
110 - 120	LANL	5.400E+05	2.504E+05
120 - 130	LANL	4.000E+05	1.753E+05
130 - 140	LANL	3.100E+05	9.016E+04
140 - 150	LANL	2.100E+05	1.102E+05
150 - 160	LANL	2.400E+05	7.512E+04
160 - 170	LANL	1.200E+05	8.514E+04
170 - 180	LANL	3.000E+05	6.010E+04
180 - 190	LANL	1.100E+05	4.508E+04
190 - 200	LANL	2.000E+05	4.508E+04
200 - 220	LANL	2.600E+05	3.006E+04
220 - 240	LANL	1.372E+05	3.566E+04
240 - 260	LANL	5.664E+04	1.992E+04
260 - 280	LANL	2.568E+04	9.960E+03
280 - 300	LANL	2.040E+04	7.200E+03
300 - 400	LANL	4.944E+04	1.356E+04
400 - 500	LANL	1.464E+04	3.960E+03
500 - 600	LANL	1.512E+04	4.560E+03
600 - 800	LANL	3.792E+04	5.880E+03
800 - 1000	LANL	1.128E+04	2.040E+03
>1000	LANL	3.912E+04	2.760E+03
Total Concentration, Particle Size Range, 50-1,000 nm	LANL	9.92E+06	4.59E+06

Table ATT.3-3
Trace Element Results for Groundwater Characterization Samples
(Page 1 of 2)

Analyte	Detection Limit	Laboratory	Qualifier	Results of Discrete Bailer Sample #EC-7-042800-3	Unit
Ag, Dissolved	0.16	UNLV-HRC	<	0.16	µg/L
Al, Dissolved	0.17	UNLV-HRC		6.04	µg/L
As, Dissolved	0.02	UNLV-HRC		5.08	µg/L
Au, Dissolved	0.030	UNLV-HRC	<	0.030	µg/L
Ba, Dissolved	0.006	UNLV-HRC		5.70	µg/L
Be, Dissolved	0.018	UNLV-HRC		0.021	µg/L
Bi, Dissolved	0.004	UNLV-HRC	<	0.004	µg/L
Cd, Dissolved	0.006	UNLV-HRC		0.029	µg/L
Co, Dissolved	0.006	UNLV-HRC		0.048	µg/L
Cr, Dissolved	0.012	UNLV-HRC		0.954	µg/L
Cs, Dissolved	0.003	UNLV-HRC		2.04	µg/L
Cu, Dissolved	0.011	UNLV-HRC		0.388	µg/L
Ga, Dissolved	6.3	UNLV-HRC		12	ng/L
Ge, Dissolved	0.006	UNLV-HRC		0.491	µg/L
Hf, Dissolved	0.015	UNLV-HRC	<	0.015	µgL/
In, Dissolved	0.004	UNLV-HRC	<	0.004	µg/L
Ir, Dissolved	8	UNLV-HRC	<	8	ng/L
Li, Dissolved	0.015	UNLV-HRC		58	µg/L
Mn, Dissolved	0.01	UNLV-HRC		0.718	µg/L
Mo, Dissolved	0.01	UNLV-HRC		2.30	µg/L
Nb, Dissolved	5.1	UNLV-HRC		27	ng/L
Ni, Dissolved	0.006	UNLV-HRC		0.394	µg/L
Pb, Dissolved	0.04	UNLV-HRC	<	0.04	µg/L
Pd, Dissolved	0.021	UNLV-HRC		0.025	µg/L
Pt, Dissolved	0.006	UNLV-HRC		0.007	µg/L
Rb, Dissolved	0.003	UNLV-HRC		5.35	µg/L
Re, Dissolved	0.004	UNLV-HRC		0.005	µg/L
Rh, Dissolved	0.004	UNLV-HRC	<	0.004	µg/L
Ru, Dissolved	0.005	UNLV-HRC	<	0.005	µg/L
Sb, Dissolved	0.004	UNLV-HRC		0.154	µg/L
Se, Dissolved	0.09	UNLV-HRC		0.48	µg/L

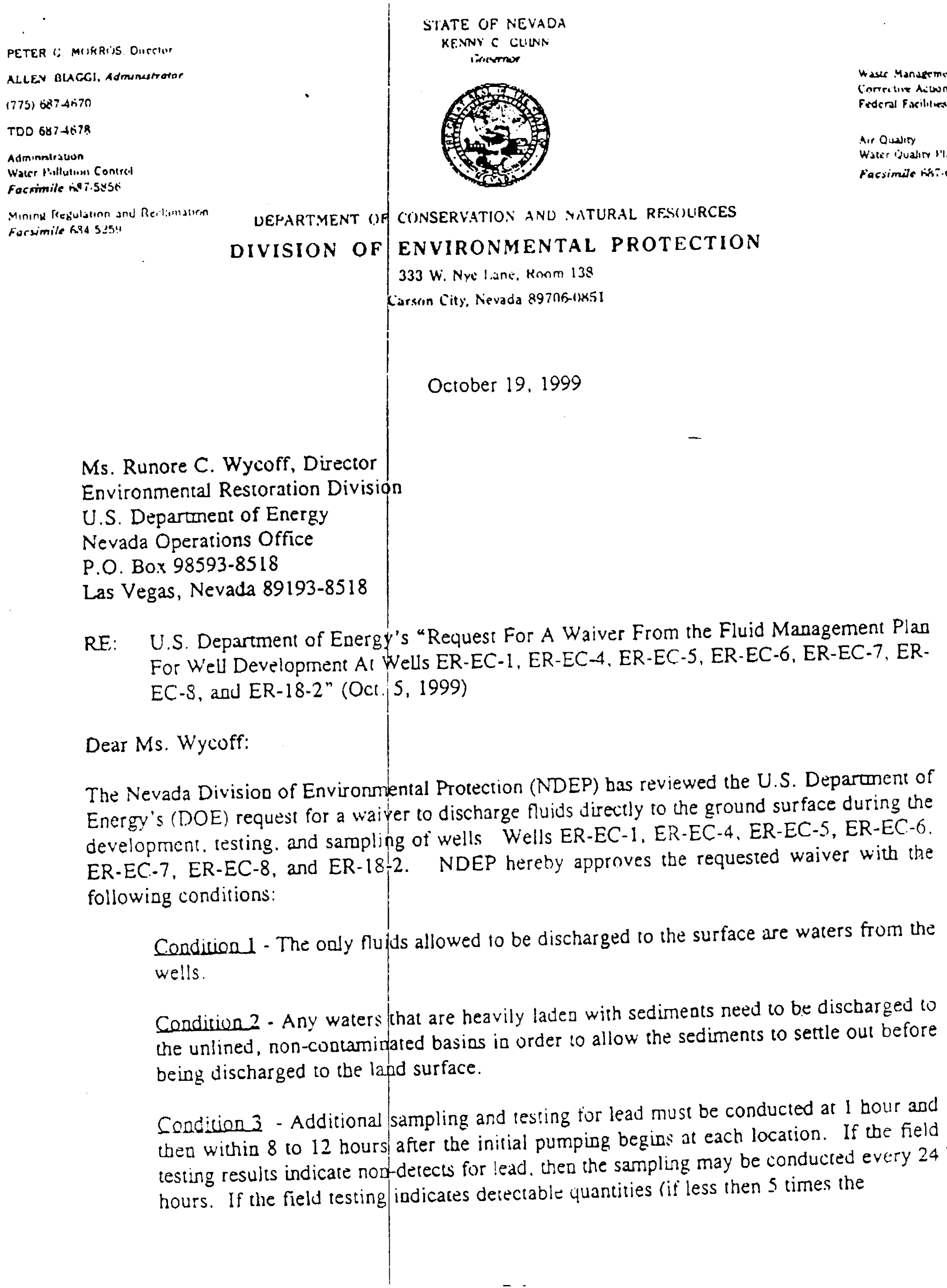
Table ATT.3-3
Trace Element Results for Groundwater Characterization Samples
(Page 2 of 2)

Analyte	Detection Limit	Laboratory	Qualifier	Results of Discrete Bailer Sample #EC-7-042800-3	Unit
Sn, Dissolved	0.004	UNLV-HRC		0.021	µg/L
Sr, Dissolved	0.01	UNLV-HRC		147	µg/L
Ta, Dissolved	0.009	UNLV-HRC		0.029	µg/L
Te, Dissolved	0.008	UNLV-HRC	<	0.008	µg/L
Ti, Dissolved	0.009	UNLV-HRC		0.394	µg/L
Tl, Dissolved	0.009	UNLV-HRC		0.063	µg/L
U, Dissolved	0.005	UNLV-HRC		3.13	µg/L
V, Dissolved	0.009	UNLV-HRC		3.20	µg/L
W, Dissolved	0.004	UNLV-HRC		0.44	µg/L
Zn, Dissolved	0.2	UNLV-HRC		4.22	µg/L
Zr, Dissolved	0.018	UNLV-HRC		0.019	µg/L

µg/L = Microgram per liter
ng/L = Nanogram per liter
< = Compound was analyzed for, but not detected above, the reported sample quantitation limit. The detection limit (quantitation limit) is reported in the results field.

Attachment 4

Fluid Management Plan Waiver for WPM-OV Wells



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ALLEN BIAGGI, *Administrator*
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TDD 687-4678
Administration
Water Pollution Control
Facsimile 687-5856
Mining Regulation and Reclamation
Facsimile 684-5259

STATE OF NEVADA
KENNY C. GUINN
Governor

Waste Management
Corrective Actions
Federal Facilities
Air Quality
Water Quality Planning
Facsimile 687-6396

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
333 W. Nye Lane, Room 138
Carson City, Nevada 89706-0851

October 19, 1999

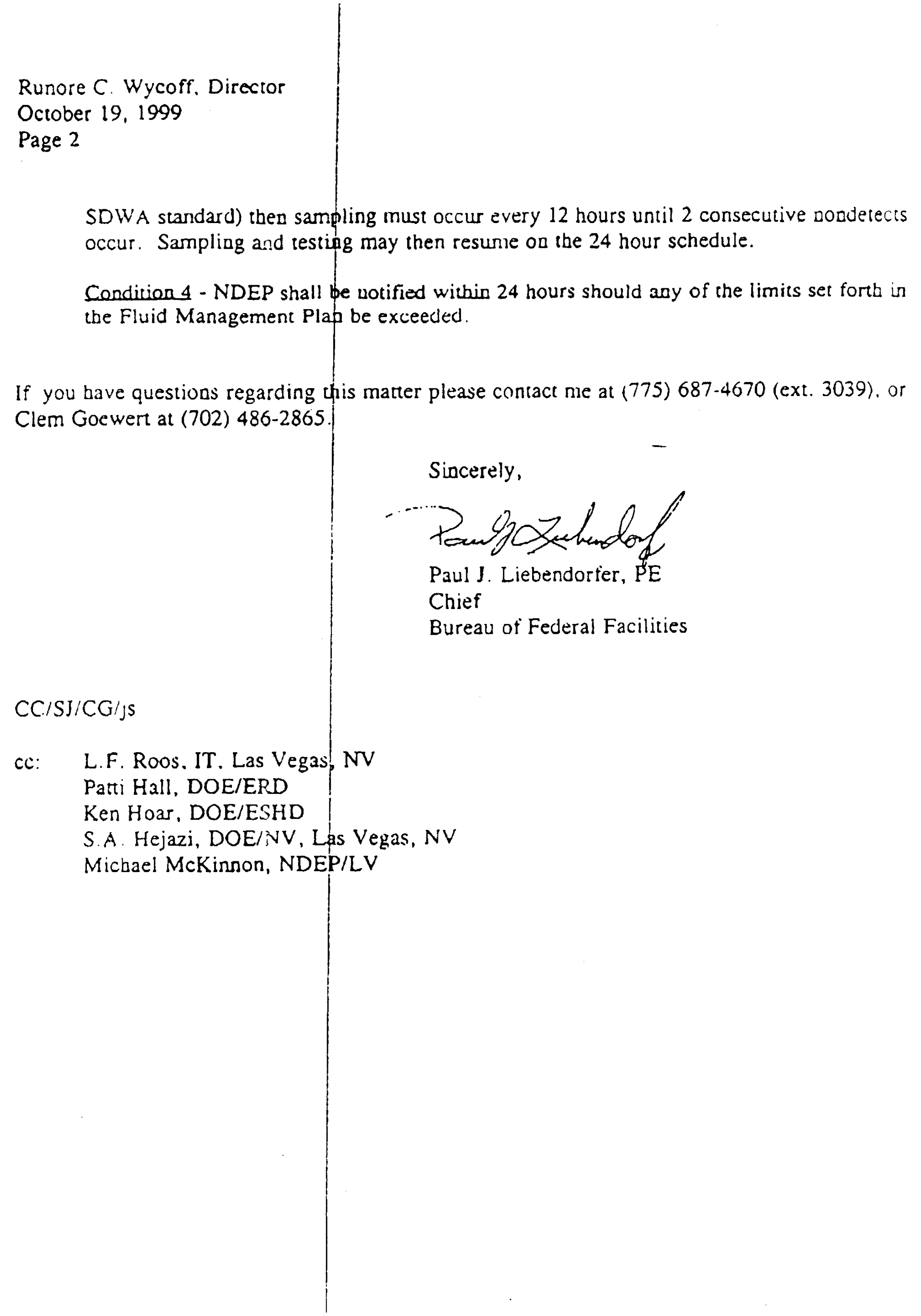
Ms. Runore C. Wycoff, Director
Environmental Restoration Division
U.S. Department of Energy
Nevada Operations Office
P.O. Box 98593-8518
Las Vegas, Nevada 89193-8518

RE: U.S. Department of Energy's "Request For A Waiver From the Fluid Management Plan For Well Development At Wells ER-EC-1, ER-EC-4, ER-EC-5, ER-EC-6, ER-EC-7, ER-EC-8, and ER-18-2" (Oct. 5, 1999)

Dear Ms. Wycoff:

The Nevada Division of Environmental Protection (NDEP) has reviewed the U.S. Department of Energy's (DOE) request for a waiver to discharge fluids directly to the ground surface during the development, testing, and sampling of wells Wells ER-EC-1, ER-EC-4, ER-EC-5, ER-EC-6, ER-EC-7, ER-EC-8, and ER-18-2. NDEP hereby approves the requested waiver with the following conditions:

> Condition 1 - The only fluids allowed to be discharged to the surface are waters from the wells.
>
> Condition 2 - Any waters that are heavily laden with sediments need to be discharged to the unlined, non-contaminated basins in order to allow the sediments to settle out before being discharged to the land surface.
>
> Condition 3 - Additional sampling and testing for lead must be conducted at 1 hour and then within 8 to 12 hours after the initial pumping begins at each location. If the field testing results indicate non-detects for lead, then the sampling may be conducted every 24 hours. If the field testing indicates detectable quantities (if less then 5 times the



Runore C. Wycoff, Director
October 19, 1999
Page 2

SDWA standard) then sampling must occur every 12 hours until 2 consecutive nondetects occur. Sampling and testing may then resume on the 24 hour schedule.

<u>Condition 4</u> - NDEP shall be notified within 24 hours should any of the limits set forth in the Fluid Management Plan be exceeded.

If you have questions regarding this matter please contact me at (775) 687-4670 (ext. 3039), or Clem Goewert at (702) 486-2865.

Sincerely,

Paul J. Liebendorfer, PE
Chief
Bureau of Federal Facilities

CC/SJ/CG/js

cc: L.F. Roos, IT, Las Vegas, NV
Patti Hall, DOE/ERD
Ken Hoar, DOE/ESHD
S.A. Hejazi, DOE/NV, Las Vegas, NV
Michael McKinnon, NDEP/LV

ERD (R)
ERD (RF)
EM (RF)
MGR (RF)

OCT 0 5 1999

Paul J. Liebendorfer, P.E., Chief
Department of Conservation and Natural Resources
Division of Environmental Protection
333 W. Nye Lane, Room 138
Carson City, NV 89706-0851

REQUEST FOR A FLUID MANAGEMENT PLAN WAIVER FOR WELL DEVELOPMENT AT WELLS: ER-EC-1, ER-EC-4, ER-EC-5, ER-EC-6, ER-EC-7, ER-EC-8, AND ER-18-2

The DOE Nevada Operations Office (DOE/NV) has completed drilling and well construction activities at seven wells as part of the Underground Test Area (UGTA) Pahute Mesa/Oasis Valley drilling program. Subsequent investigation activities planned for these wells include well development, hydraulic testing, and groundwater sampling. These activities will result in the production of substantial volumes of groundwater, which are subject to the conditions in the UGTA Fluid Management Plan (FMP) (July 1999). DOE/NV is requesting a waiver from the UGTA FMP (July 1999) to allow fluids produced during these activities to be discharged directly to the ground surface.

Enclosed for your information are the results for fluid management samples collected from the sumps and characterization samples collected by bailer from the boreholes upon completion of drilling activities. The enclosed data, coupled with the distance of the well locations from the nearest underground test, supports the premise that radiological and/or chemical contamination will not be encountered during subsequent investigation activities. Therefore, DOE/NV proposes to conduct activities at these well sites under far field conditions with a reduced frequency of on-site monitoring. The proposal includes the following elements:

- The on-site monitoring program will consist of collecting one tritium and one lead sample from the fluid discharge every 24 hours for analysis.
- Fluids will be allowed to discharge to ground surface without prior notification to the Nevada Division of Environmental Protection.
- All other conditions for far field wells, in the FMP, will be in effect.

This proposed strategy would be applicable only to well development, testing, and sampling activities at these well sites. These activities are scheduled to begin on October 18, 1999.

Paul J. Liebendorfer -2-

If you have any questions, please contact Robert M. Bangerter, of my staff, at (702) 295-7340.

Original Signed By:

Runore C. Wycoff

Runore C. Wycoff, Director
Environmental Restoration Division

ERD:RMB

cc w/encl:
M. D. McKinnon, NDEP, Las Vegas, NV

cc w/o encl:
S. R. Jaunarajs, NDEP, Carson City, NV
C. M. Case, NDEP, Carson City, NV
C. J. Goewert, NDEP, Las Vegas, NV
L. F. Roos, IT, Las Vegas, NV
K. A. Hoar, ESHD, DOE/NV, Las Vegas, NV
S. A. Hejazi, OCC, DOE/NV, Las Vegas, NV
P. L. Hall, EM, DOE/NV, Las Vegas, NV

Attachment 5

Electronic Data Files Readme.txt

ER-EC-7 Development and Testing Data Report:

This README file identifies the included data files. Included with this report are 20 files containing data that were collected electronically during the development and testing program for Well ER-EC-7. The .xls data files were originally collected in ASCII format by datalogger, and the data have been imported into Microsoft EXCEL 97 with minimal changes. Files 3, 4, and 5 contain two sheets, a RAW DATA sheet and a PROCESSED DATA sheet. The PROCESSED DATA sheet references the Raw Data sheet and performs basic processing on the data. Please consult the data report for more information on the data.

The files are:

1) EREC7L.xls
Bridge plug monitoring data for the lower interval.

2) EC7gradient.xls
Monitoring data for the upper interval during the bridge plug measurements.

3) EC-7_AQTEST_WD.xls
Complete monitoring record of development.

4) EC-7_AQTEST_HT.xls
Complete monitoring record of testing.

5) ER-EC-6 Water Level Monitoring.xls
Pre-development monitoring record.

6) EC7Hydrolab.xls
Hydrolab monitoring record.

7) DRIFileInfoGeneric.txt
DRI log head information.

8) ec7mov1.txt, ec7mov3.txt, and ec7mov5, ec7mov6, ecmov7, and ec7mov8.txt
DRI flow logs.

9) ec7stat1, ec7stat2, ec7stat3, ec7stat4, ec7stat5, and ec7stat6.txt
DRI static impeller tool flow measurements.

Distribution

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