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AQUIFER PUMPING TEST REPORT FOR THE BURN SITE GROUNDWATER AREA OF CONCERN

SANDIA NATIONAL LABORATORIES, NEW MEXICO ENVIRONMENTAL RESTORATION OPERATIONS

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United States Department of Energy
Sandia Field Office

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EXECUTIVE SUMMARY

The Aquifer Pumping Test Report for the Burn Site Groundwater (BSG) Area of Concern is being submitted by National Technology and Engineering Solutions of Sandia, LLC and the U.S. Department of Energy (DOE)/National Nuclear Security Administration to describe the results of the aquifer pumping test program and related field activities that were completed at the BSG Area of Concern.

This report summarizes the results of the field work and data analyses, and is being submitted to the New Mexico Environment Department (NMED) Hazardous Waste Bureau, as required by the April 14, 2016 letter, *Summary of Agreements and Proposed Milestones Pursuant to the Meeting of July 20, 2015,* (NMED April 2016). Specifically, the April 2016 letter required:

> "NMED and DOE/SNL [Sandia National Laboratories] will meet within 11 months after approval of the Aquifer Pump Test Work Plan to discuss the results of the test. An Aquifer Pump Test Report will be submitted to NMED within seven months after the meeting. The Aquifer Test Report [*sic*] will make recommendations with regard to the need for additional monitoring wells."

The field activities described in this report include:

- A pressure transducer network installed in monitoring wells across the study area as part of the long-term background groundwater elevation monitoring to evaluate natural background fluctuations in BSG monitoring wells. Barometric pressure data were recorded and subsequently used to filter out fluctuations in the groundwater elevation data due to changes in ambient pressure. The barometric efficiency (dimensionless) of each well was calculated, allowing mathematical analysis of the degree of hydraulic connection and confinement in the fractured-bedrock aquifer near each monitoring well.

- A step-drawdown test conducted using the Burn Site Well as the pumping well to determine a practical flow rate to use for the subsequent constant-rate test.

- A 24-hour constant-rate test conducted using the Burn Site Well as the pumping well to evaluate hydrogeologic conditions in the aquifer and identify hydraulic communication.

- Time interval sampling performed for nitrate analysis of discharge water from the pumping well.

The main conclusion from the interpretation of data described in this report include:

- There is significant compartmentalization of groundwater into distinct hydraulic domains, such that portions of the bedrock aquifer are unconfined and respond to precipitation infiltration, whereas other portions are semi-confined to confined. Some faults and fractures are sealed and act as barriers to groundwater flow.

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ACRONYMS AND ABBREVIATIONS

% Sat	Percent saturation
µmhos/cm	Micromhos per centimeter
ABCWUA	Albuquerque Bernalillo County Water Utility Authority
amsl	Above mean sea level
AOC	Area of Concern
APT	Aquifer Pumping Test
AR/COC	Analysis Request/Chain-of-Custody
bgs	Below ground surface
BSG	Burn Site Groundwater
°C	Degrees Celsius
CME	Corrective Measures Evaluation
DO	dissolved oxygen
DOE	US Department of Energy
DU	Duplicate
EM	Office of Environmental Management
EPA	U.S. Environmental Protection Agency
°F	Degrees Fahrenheit
FOP	Field Operating Procedure
ft	foot or feet
GEL	General Engineering Laboratories
gpm	gallons per minute
ID	Identifier
MCL	maximum contaminant level
MDL	method detection limit
mg/L	milligrams per liter
mV	Millivolt(s)
MW	Monitoring well
NAVD88	North American Vertical Datum of 1988
NC	Not contoured (used only on figures)
N.M.	Not measured (used in tables)
NMED	New Mexico Environment Department
NNSA	National Nuclear Security Administration
No.	Number
NPN	nitrate plus nitrite
NTU	Nephelometric turbidity units
ORP	oxidation-reduction potential
pH	Potential of hydrogen (negative logarithm of the hydrogen ion concentration)
POTW	Publicly Owned Treatment Works
PQL	Practical quantitation limit
PVC	Polyvinyl chloride
QC	quality control
SA	Sample
SC	specific conductivity
SFO	Sandia Field Office
SNL/NM	Sandia National Laboratories, New Mexico

1.0 INTRODUCTION

This section describes the weight-of-evidence process, site hydrogeology, study objectives, and scope of activities.

1.1 Weight-of-Evidence Process

Characterization activities have been conducted at the Burn Site Groundwater (BSG) Area of Concern (AOC) for over 25 years. The site is in the Corrective Measures Evaluation (CME) process. Table 1-1 summarizes the recent regulatory interactions for the BSG AOC with the more important items discussed below.

Sandia National Laboratories, New Mexico (SNL/NM) personnel had prepared an internal draft CME Report in the fall of 2013. Also in the fall of 2013, U.S. Department of Energy Office of Environmental Management (DOE/EM) initiated an Internal Remedy Review of the proposed corrective actions for nitrate in groundwater at the BSG AOC. The results of the Internal Remedy Review were documented in three DOE memorandums (DOE October 2013, November 2014, and May 2015). As documented in these memos, the Internal Remedy Review key points included:

1. The aquifer appears to be confined, which would preclude surficial contaminants from infiltrating to groundwater;

2. Nitrate contamination may be from either off-site sources or naturally occurring; and

3. A weight-of-evidence process was needed to determine if nitrate found in BSG monitoring wells was derived from DOE operations (i.e., SNL/NM testing activities).

In a January 2015 meeting with New Mexico Environment Department (NMED) Hazardous Waste Bureau, the NMED agreed to pause the CME process to allow the implementation of DOE's weight-of-evidence evaluation. At that meeting, the types of characterization activities were discussed, but the prioritization of these investigations was not finalized. The final Internal Remedy Review memorandum (DOE May 2015) identified the DOE's priority of weight-of-evidence activities that included the implementation of an aquifer pumping test. DOE National Nuclear Security Administration (NNSA) Sandia Field Office (SFO) further documented the scope and schedule of the weight-of-evidence investigations (DOE March 2016). The characterization milestones proposed by DOE/NNSA/SFO were subsequently accepted by NMED (NMED April 2016).

Table 1-1
Timeline of Recent Regulatory Interactions for the Burn Site Groundwater Area of Concern

Month	Year	Event	Reference
August	2013	DOE/NNSA/SFO submitted an Extension Request to the NMED for the Burn Site Groundwater CME Report.	DOE August 2013
October	2013	DOE/EM submitted the first Internal Remedy Review memo of the Burn Site Groundwater AOC to DOE/NNSA/SFO	DOE October 2013
January	2014	DOE/NNSA/SFO requested an extension to the delivery date of the Burn Site Groundwater CME Report to March 31, 2016.	DOE January 2014
June	2014	NMED approved the proposed extension request for the Burn Site Groundwater CME Report to March 31, 2016.	NMED June 2014
November	2014	DOE/EM submitted the second Internal Remedy Review memo of the Burn Site Groundwater AOC to DOE/NNSA/SFO.	DOE November 2014
May	2015	DOE/EM submitted the third Internal Remedy Review memo of the Burn Site Groundwater AOC to DOE/NNSA/SFO.	DOE May 2015
March	2016	DOE/NNSA/SFO proposed weight-of-evidence activities and schedule milestones for implementation of the studies.	DOE March 2016
April	2016	NMED approved the activities and milestones proposed by DOE/NNSA/SFO for the weight-of-evidence activities.	NMED April 2016
June	2016	DOE/NNSA/SFO and SNL/NM personnel submitted the Aquifer Pumping Test Work Plan.	SNL/NM June 2016
June	2016	NMED approved the Aquifer Pumping Test Work Plan.	NMED June 2016
March	2017	Field requirements of the Aquifer Pumping Test were completed.	This report
May	2017	Preliminary results of the pumping test were shared with NMED on May 10, 2017 at the NMED District 1 office.	This report
November	2017	DOE/NNSA/SFO request an extension for the submittal of recommendations for further characterization activities.	DOE November 2017

Notes:

AOC = Area of Concern.
CME = Corrective Measures Evaluation.
DOE = U.S. Department of Energy.
EM = Office of Environmental Management.
NMED = New Mexico Environment Department.
NNSA = National Nuclear Security Administration.
SFO = Sandia Field Office.
SNL/NM = Sandia National Laboratories, New Mexico.

In June 2016, DOE/NNSA/SFO and SNL/NM personnel submitted the Aquifer Pumping Test Work Plan (SNL/NM June 2016), and the Aquifer Pumping Test Work Plan was subsequently approved by NMED (NMED June 2016). The Aquifer Pumping Test Work Plan proposed that pumping would be performed at the Burn Site Well on the eastern side of the AOC, and all wells would be instrumented with transducers. The four major tasks identified in the Aquifer Pumping Test Work Plan included:

1. Long-term background groundwater elevation monitoring,
2. Step-drawdown test,
3. Constant-rate test, and
4. Interval sampling for nitrate in the water discharged from the pumping well.

The field work was conducted December 2016 through March 2017. The results of the pumping test and analysis were shared with the NMED in a technical presentation on May 10, 2017 at the NMED District 1 office. On November 8, 2017 DOE/NNSA/SFO submitted a Request for Extension for Recommendations to the NMED (DOE November 2017). This extension request proposed that a discussion of future characterization activities that were required by NMED (NMED April 2016) be deferred until June 8, 2018.

1.2 Hydrogeologic Setting

The following discussion of the hydrogeologic setting is summarized from the *Annual Groundwater Monitoring Report, Calendar Year 2016* (SNL/NM June 2017a). One unique feature of the BSG AOC, located in the Manzanita Mountains on Kirtland Air Force Base (Figure 1-1), is elevated concentrations of nitrate in a fractured bedrock aquifer. Table 1-2 lists the specifications for the BSG AOC groundwater monitoring well network. Nitrate has been detected in the BSG groundwater with a historical maximum concentration of 41.9 milligrams per liter (mg/L) in CYN-MW9. This concentration exceeds the U.S. Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) of 10 mg/L. Currently, the highest concentration of nitrate (35.5 mg/L) is found in CYN-MW13, approximately 3,400 feet west of the Burn Site Well.

Regionally, groundwater in the Manzanita Mountains flows toward the west from a groundwater divide located several miles east of the BSG AOC. Figure 1-2 presents the September 2016 potentiometric surface for the BSG monitoring well network.

The inferred horizontal groundwater gradient at BSG varies from approximately 0.08 to 0.18. This large gradient range is because the groundwater flow is controlled by a diverse pattern of bedrock fractures and brecciated fault zones (secondary porosity). The low permeability bedrock matrix likely has much less influence on flow. No information is available about vertical flow velocity within the fractured rocks. Vertical movement of groundwater within open fractures and the brecciated fault zones probably occurs as rapid, unsaturated to saturated flow.

Groundwater in the Manzanita Mountains predominantly occurs in fractured Precambrian metamorphic rocks (metavolcanics, quartzite, schists, phyllites, and granitic gneiss) (Table 1-2 and Figure 1-3). Some fractures in shallow bedrock are filled with chemical precipitates such as calcium carbonate, which effectively reduces permeability and may create a semiconfined unit above open fractures in bedrock. The BSG AOC is bisected by a north-south trending system of

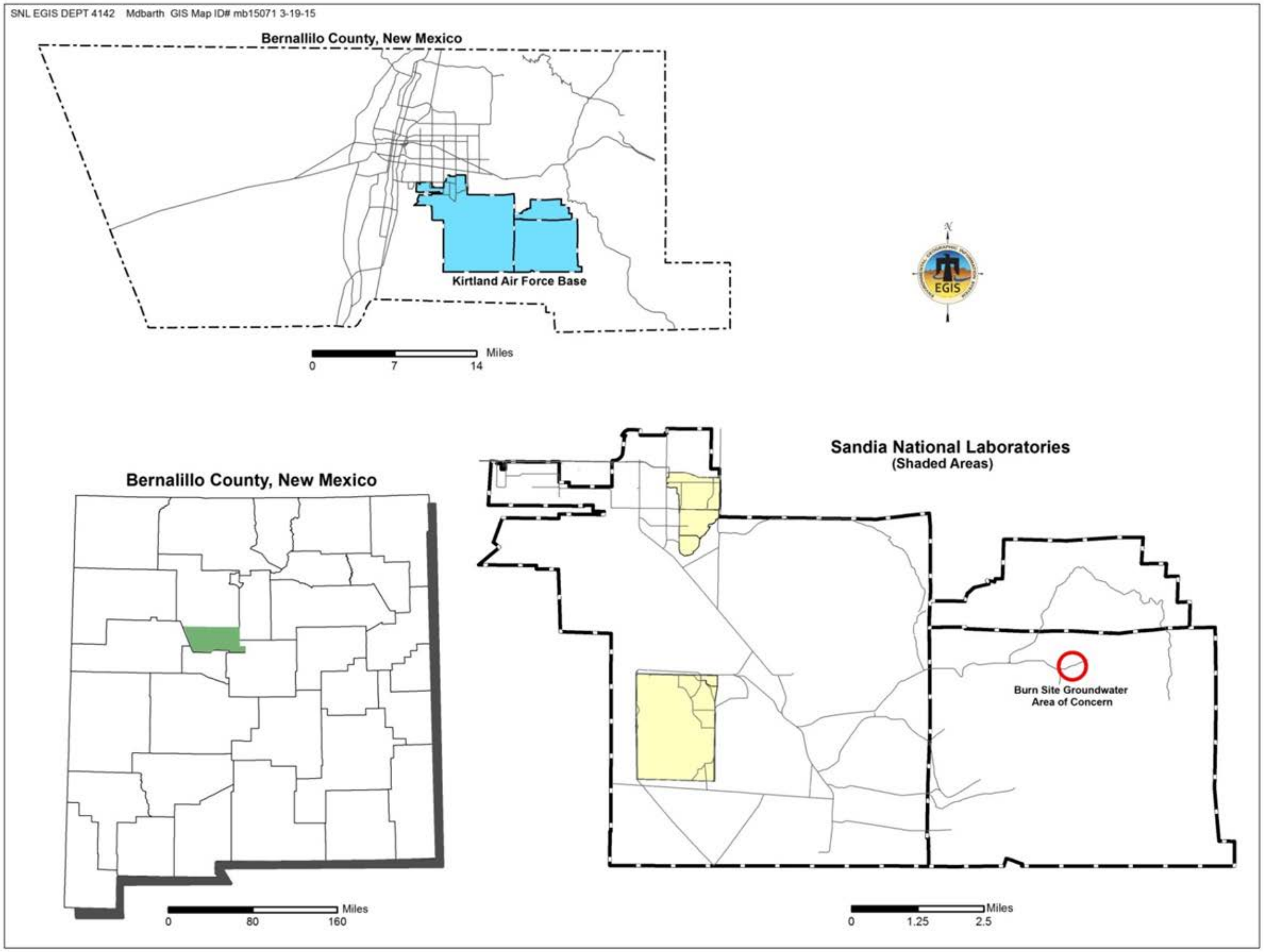

Figure 1-1
Location of the Burn Site Groundwater Area of Concern

Table 1-2
Monitoring Well Inventory for the Burn Site Groundwater Area of Concern

Well	Measuring Point (feet amsl)	Ground Surface (feet amsl)	Top of Screen (feet bgs)	Bottom of Screen (feet bgs)	Top of Screen (feet amsl)	Bottom of Screen (feet amsl)	Casing Total Depth (feet bgs)	PVC Casing, Inner Diameter (inches)	Lithology of Screened Interval	Installation Date
Burn Site Well[a]	6374.66	6372.97	231.0	341.0	6142.7	6032.7	341.0	4.0	Bedrock (schist and granite)	20-Feb-86
CYN-MW3	6313.26	6311.9	120.0	130.0	6191.9	6181.9	135.0	5.0	Bedrock (metamorphics)	18-Jun-99
CYN-MW4	6455.48	6454.7	260.0	280.0	6194.7	6174.7	290.0	5.0	Bedrock (quartzite)	18-Jun-99
CYN-MW6	6343.37	6340.5	141.5	161.3	6199.0	6179.2	161.7	5.0	Bedrock (metamorphics)	9-Dec-05
CYN-MW7	6216.35	6213.7	315.0	334.2	5898.7	5879.5	339.9	5.0	Bedrock (granitic gneiss)	6-Dec-05
CYN-MW8	6230.11	6227.8	338.5	358.3	5889.3	5869.5	363.4	5.0	Bedrock (granitic gneiss)	12-Jan-06
CYN-MW9	6360.67	6358.5	175.8	195.8	6182.7	6162.7	200.8	4.8	Bedrock (metamorphics)	27-Jul-10
CYN-MW10	6345.45	6342.8	150.4	170.4	6192.4	6172.4	175.4	4.8	Bedrock (metamorphics)	28-Jul-10
CYN-MW11	6374.41	6371.9	229.8	249.8	6142.1	6122.1	254.8	4.8	Bedrock (metamorphics)	29-Jul-10
CYN-MW12	6345.16	6342.9	252.5	272.5	6090.4	6070.4	277.5	4.8	Bedrock (metamorphics)	29-Jul-10
CYN-MW13	6237.79	6236.0	376.8	396.8	5859.2	5839.2	402.2	4.8	Bedrock (granitic gneiss)	5-Dec-12
CYN-MW14A	6315.85	6313.5	263.6	293.6	6049.9	6019.9	298.6	4.8	Bedrock (metamorphics)	4-Dec-14
CYN-MW15	6344.44	6342.3	160.0	190.0	6182.3	6152.3	195.0	4.8	Bedrock (metamorphics)	18-Nov-14

Notes:

[a]The Burn Site Well has not been used for groundwater production since 2003.
amsl = Above mean sea level, NAVD88.
bgs = Below ground surface.
CYN = Lurance Canyon.
MW = Monitoring well.
NAVD88 = North American Vertical Datum of 1988.
PVC = Polyvinyl chloride.

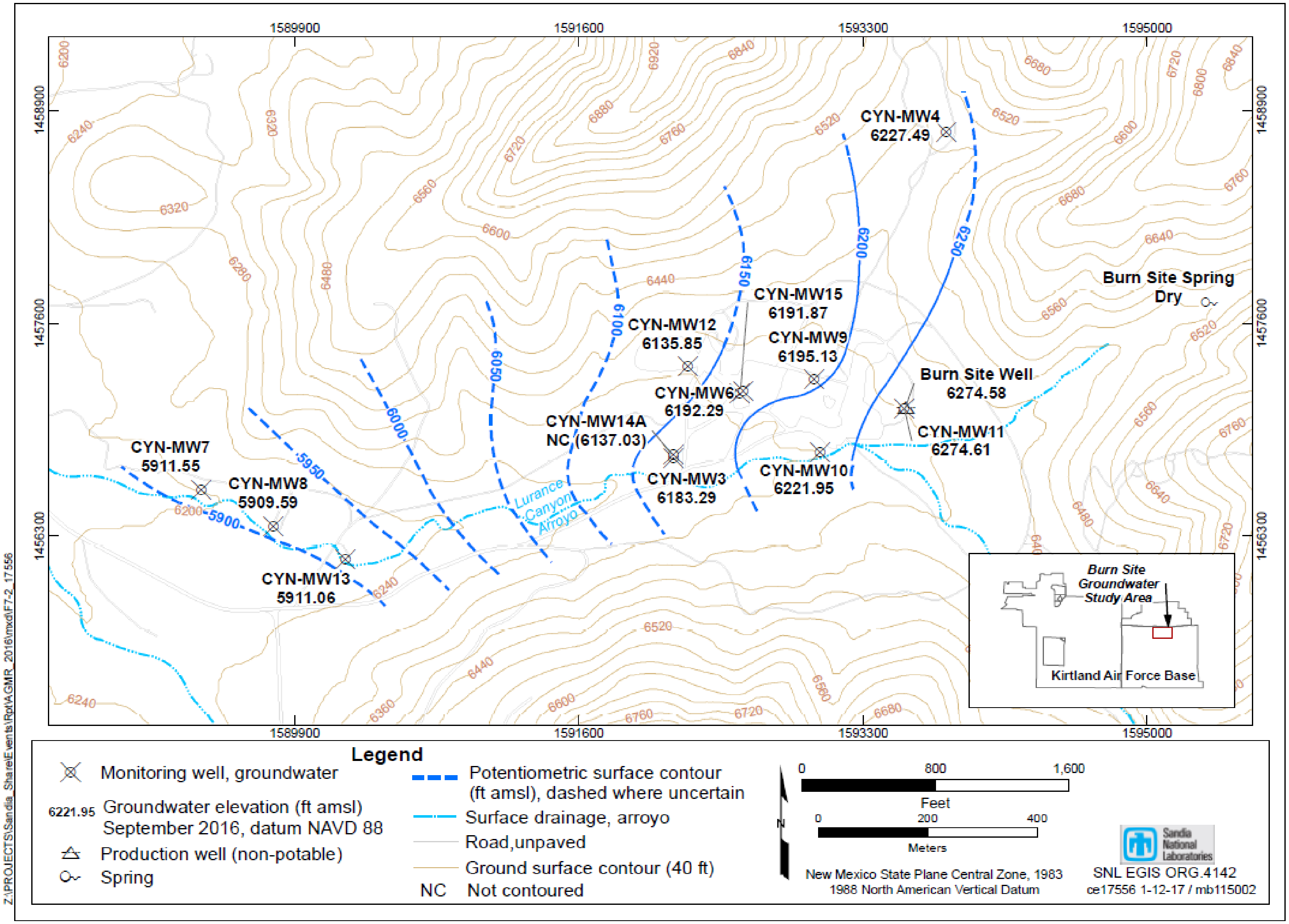

Figure 1-2
Localized Potentiometric Surface of the Burn Site Groundwater Area of Concern (September 2016)

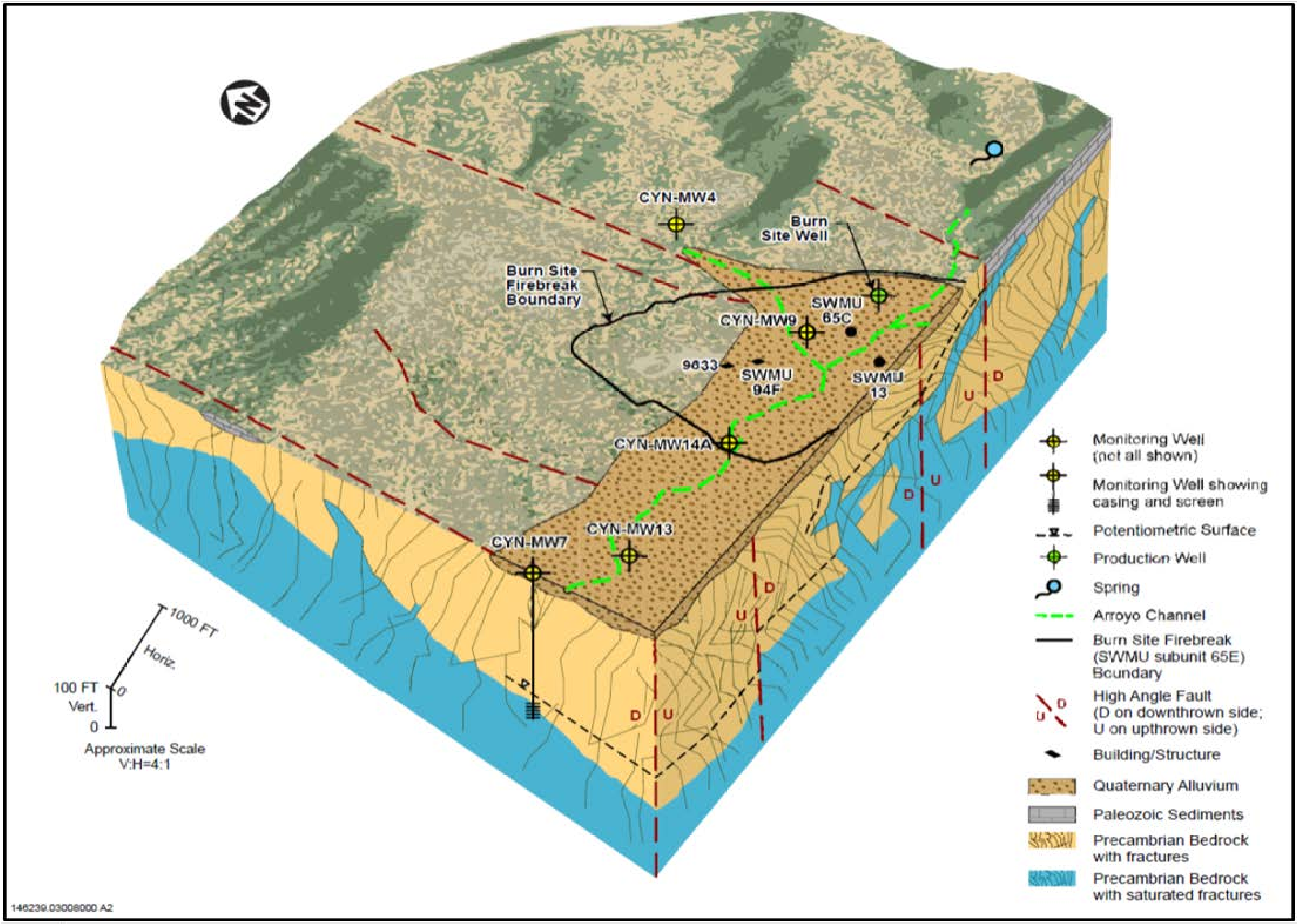

Figure 1-3
Site Conceptual Model of the Burn Site Groundwater Area of Concern

faults, consisting locally of several high-angle normal faults that are typically downthrown to the east. Faults (where exposed) are characterized by zones of crushing and brecciation. The site conceptual model showing the relationship of geologic and hydrologic features is shown in Figure 1-3. Based upon drilling activities, the depth to the uppermost water-bearing fracture zones has varied from approximately 124 to 379 feet below ground surface (bgs) across the monitoring well network. Initial water levels above the screened intervals have varied from approximately 5 to 153 feet due to semiconfined or confined conditions. As a standard practice, each monitoring well is screened across an individual fracture zone, which is interpreted to be at most a few feet thick for the BSG AOC. The depth to water in the well casings across the monitoring well network varies from approximately 108 to 326 feet bgs.

1.3 Study Objectives

The data collected during this aquifer pumping test program was used to determine the following hydrogeologic parameters and contaminant distribution for the fractured bedrock aquifer.

- **Degree of Hydraulic Confinement**—The rate at which the observation wells respond to a pumping well can qualitatively indicate if the aquifer is confined, semiconfined, or unconfined. In a fully confined aquifer, the pressure signal will reach the observation wells almost instantaneously. In an unconfined aquifer, the cone of depression caused by dewatering will take much longer to reach the observation wells. Barometric efficiency is also an indicator of the degree of confinement.

- **Hydraulic Communication**—The timing and magnitude of response in observation wells provide an indication of the fracture system configuration. Wells located along the predominant structural grain of the fracture system can be affected sooner and more significantly than wells located across the structural grain from the pumping well.

- **Recharge/Discharge Boundaries**—Recharge boundaries (the cone of depression intercepting more permeable materials) and discharge boundaries (less permeable, or the end of the fracture) can be detected during the analysis of the pumping test data.

- **Source of Nitrate**—Interval sampling of pumping test discharge water may help determine if nitrate in the groundwater is a localized or regional occurrence.

1.4 Scope of Activities

For corrective measures at the BSG AOC to be fully evaluated, hydraulic properties of the bedrock aquifer were assessed. The aquifer pumping test provided useful information relevant to evaluating a potential remedial measure and monitoring strategy. The aquifer pumping test was conducted in accordance with industry standard practices: the EPA's *Suggested Operating Procedures for Aquifer Pumping Tests* (EPA 1993); and SNL/NM Field Operating Procedure (FOP) 94-60, *Aquifer Pumping Test* (SNL/NM March 1995); and in accordance with the *Aquifer Pumping Test Work Plan* (SNL/NM June 2016). The field activities described in this report were completed in December 2016 through March 2017 (Table 1-3).

Table 1-3
Dates of Aquifer Pumping Test Activities at the Burn Site Groundwater Area of Concern

Task	Description	Start	Finish
Mobilize	Arranged for staffing, equipment, site access, training, etc.	01-Nov-2016	13-Mar-2017
Long-Term Background Groundwater Elevation Monitoring	Established background hydraulic conditions of the aquifer with the installation of transducer network and data review.	23-Dec-2016	23-Feb-2017
Step-Drawdown Test	Conducted step-drawdown test to determine optimum pumping rate.	14-Mar-2017	14-Mar-2017
Constant-Rate Test	Conducted constant-rate test.	16-Mar-2017	17-Mar-2017
Interval Sampling	Collected samples for laboratory analyses.	16-Mar-2017	17-Mar-2017
Data Analyses	Performed analyses on data collected in three phases of the aquifer pumping test.	20-Mar-2017	01-Sep-2017
Aquifer Pumping Test Report	Prepared field report including discussions of field activities and data analysis.	10-Apr-2017	10-Dec-2017[a]

Notes:

[a]Date required by New Mexico Environment Department (NMED April 2016).

An aquifer pumping test involves pumping water from a well at either a constant or variable-discharge rate while monitoring the water-level changes (drawdown) in the pumped well and observation wells. The drawdown, measured in response to the pumping, is used to determine the transmissivity and storage coefficient of the aquifer. After the pumping is discontinued, water-level recovery to the pre-pumping state was monitored.

The pumping test was performed in three phases:

1. **Long-Term Background Groundwater Elevation Monitoring**—Pressure transducers were installed in observation wells and the pumping well to record long-term background conditions of static water levels in the aquifer system, including evaluation of barometric influences.

2. **Step-Drawdown Test**—Performed to determine the optimal pumping rate for a longer-term constant-rate test.

3. **Constant-Rate Test**—Performed to evaluate hydrologic parameters of the aquifer near the pumped well, the degree of hydraulic communication with the observation wells, and to document changes of nitrate concentrations in discharge water from the Burn Site Well during pumping.

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2.0 LONG-TERM BACKGROUND GROUNDWATER ELEVATION MONITORING

This section describes the field setup, test procedures, and results of the long-term background groundwater elevation monitoring phase of the project. The objectives of the long-term background groundwater level monitoring were to:

- Identify trends in groundwater levels prior to conducting a hydraulic (pumping) test using the Burn Site Well.
- Estimate the barometric efficiency of each well, which is a general indicator of the degree of hydraulic confinement of an aquifer and isolation from vertical recharge.

2.1 Field Procedures

In the first phase of the field activities, water level transducers were installed in twelve monitoring wells and the Burn Site Well (Table 1-2). The pressure transducers were installed several months before the start of the step-drawdown and constant-rate tests (Table 1-3). Solinst Levelogger Edge transducers were tethered in each well casing and collected water level data at 60-minute intervals with an accuracy of 0.001 feet of water. The transducers were installed at 2 feet above the bottom of the screen in each well. The tethered transducers were removed from the well casing and placed in a data port to retrieve the water level data. The down loaded data produced a comma-separated values file for each well. Periodic measurements were manually collected with a water level meter to verify the data collected by the transducers. For the Burn Site Well and CYN-MW11, the transducers had signal cables connecting to the groundwater sampling truck for real-time data output to a laptop computer.

A Solinst Barologger barometer was installed in CYN-MW6 at a depth of 20 feet bgs and collected barometric readings (measured in feet of water equivalent) at 60-minute intervals to an accuracy of 0.001 feet of water. The local weather during the data collection period varied based on data from meteorological tower SC1, approximately 3 miles west of BSG. Temperatures fluctuated between -11.27 to 22.74 degrees Celsius (°C) (11.7 to 72.9 degrees Fahrenheit [°F]), with the coldest spell around January 7th and the warmest spell around February 10th. Barometric pressure recorded several storm events per month and barometric readings fluctuated between a minimum of 814.95 and maximum of 846.68 millibars. The Barologger data were compared to data recorded at meteorological tower SC1 and determined to be accurate. Precipitation during winter storms during the data collection event occurred on 16 days. In total, 1.55 inches of precipitation were recorded over the 2-month period. The minimum daily total was 0.01 inches and the maximum daily total was 0.43 inches. The largest storm event occurred from January 14 through 16 with 0.68 inches of precipitation recorded. The maximum wind gust recorded during the 2-month period was 63 miles per hour.

2.2 Data Analysis

The data collected during the long-term background groundwater level monitoring was used to calculate barometric efficiencies and perform trend analysis.

2.2.1 Barometric Efficiency

Barometric efficiency is a general indicator of the degree of hydraulic confinement of an aquifer and isolation from vertical recharge. The greater the response to atmospheric pressure fluctuations, the higher the degree of confinement (Landmeyer 1996). Barometric pressure rises result in water level drops in a confined aquifer. Unconfined aquifers generally do not respond to barometric pressure changes (Gonthier 2007).

The outputs of the pressure transducers and Barologger are in units of feet of water. These readings were normalized, with zero being the first groundwater level reading. The barometric data were inverted to allow easier correlation with barometric fluctuations (i.e., on the graph, a rise in barometric pressure would correspond with a rise in groundwater elevation).

Figure 2-1 shows an example of unfiltered groundwater elevation data (the data had not yet been filtered to remove barometric influence) using well CYN-MW4 data taken directly from the transducer. Figure 2-2 is a graph of normalized groundwater elevation and normalized/inverted barometric pressure. In this example, the barometric efficiency is calculated by comparing the magnitude of the groundwater elevation change to the barometric pressure change. A perfectly confined aquifer would have a barometric efficiency of 1. In the well CYN-MW4 example, the estimated barometric efficiency is approximately 0.6, meaning the change in water level in the well was 60 percent of the barometric fluctuation. This calculation could be repeated for each pair of barometric/elevation peaks (and subsequently averaged), but due to the volume of data collected, a more rigorous method was developed.

By multiplying the barometric pressure data by a specified efficiency, the resultant curve can be compared to the groundwater level data until a good match is achieved. Figure 2-3 adds a curve where the barometric pressure was attenuated by 0.6. This results in a good match between the modified barometric pressure and the groundwater elevation, and allows all the data collected from each well during background monitoring to be considered in the evaluation. This curve-matching method was employed on data from all wells in the long-term background groundwater elevation monitoring phase of the project.

Figure 2-4 shows the unfiltered and filtered groundwater elevation data for well CYN-MW4; the effects of barometric changes are removed in the filtered data.

As an independent verification, the slope method described in Gonthier (2007) was used for the well CYN-MW4 data. Figure 2-5 shows the normalized barometric pressure plotted against normalized groundwater elevation for each pair of data points. The barometric efficiency is given by the slope of a linear regression line. For well CYN-MW4, the barometric efficiency estimated using this method is 0.5997, comparable to that derived using the curve-matching method.

Figure 2-6 shows a comparison of the unfiltered and filtered data for all wells in the BSG long-term background groundwater elevation monitoring phase of the study.

Table 2-1 presents the estimated barometric efficiency of each well. Barometric efficiencies ranged from 0.60 in well CYN-MW4 (the most confined well) to 0.06 in well CYN-MW10 (a relatively shallow well that typically responds to infiltration of surface water from the Lurance Canyon Arroyo following significant precipitation).

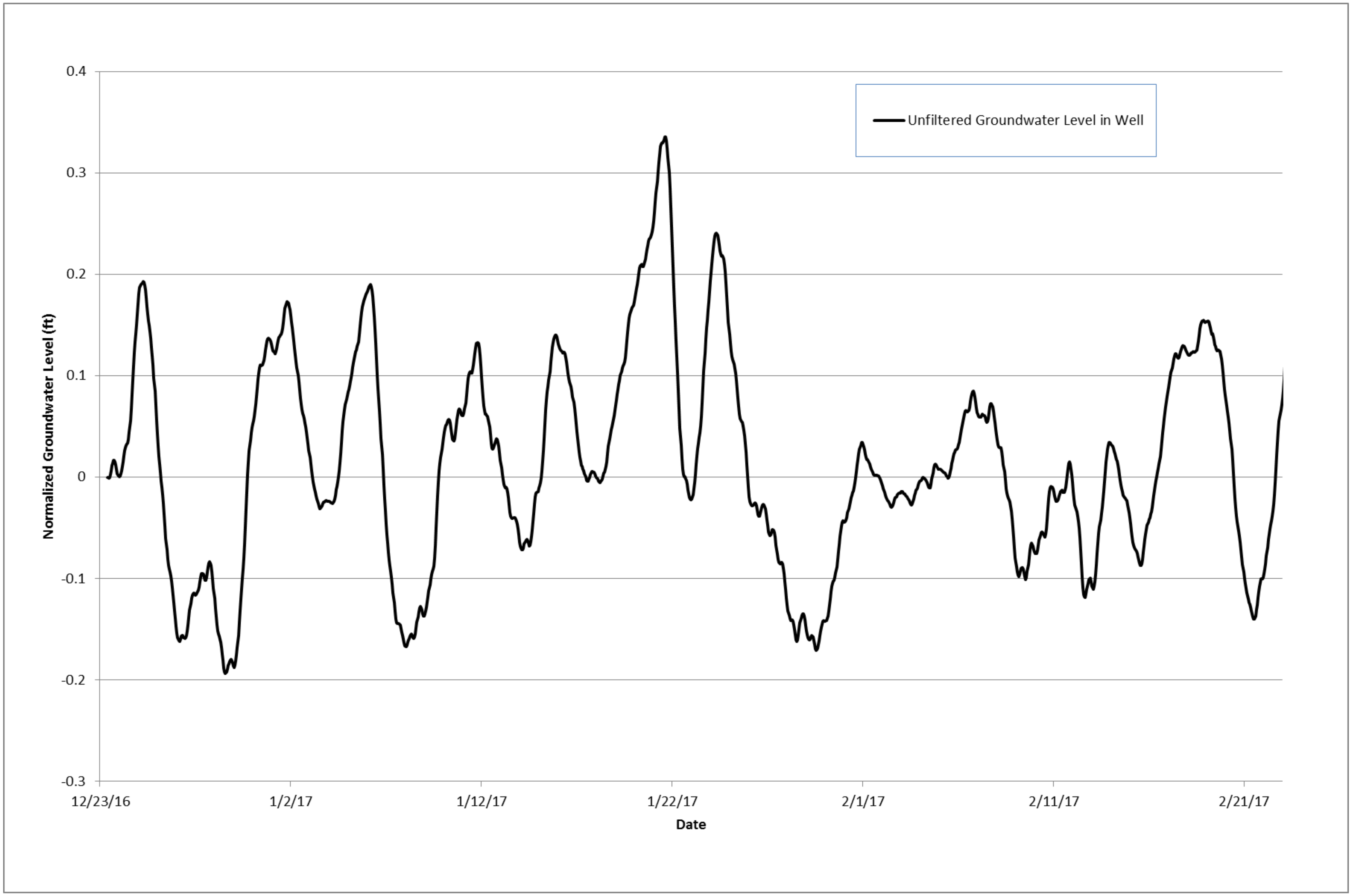

Figure 2-1
Unfiltered Groundwater Level in Well CYN-MW4

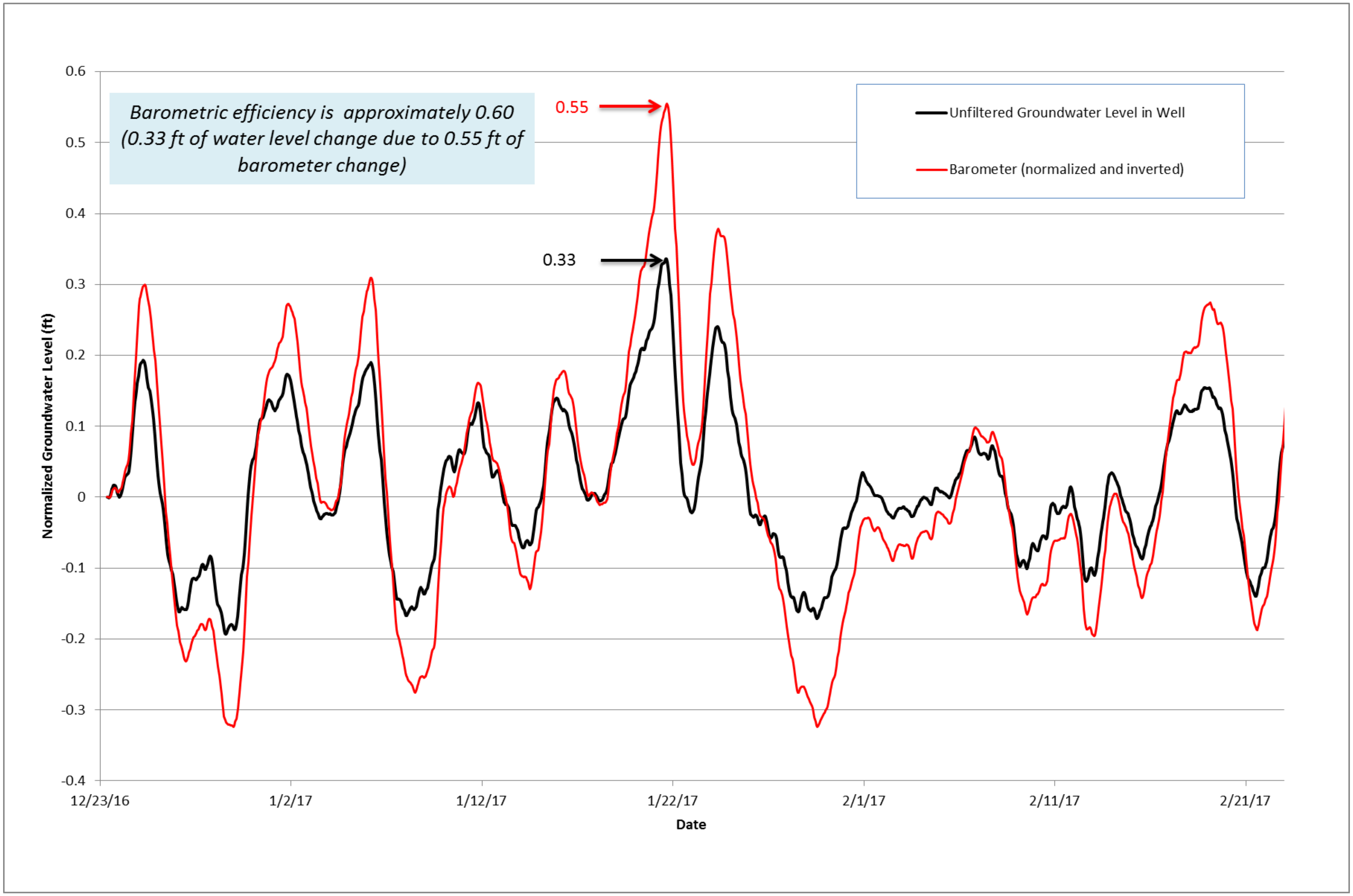

Figure 2-2
Groundwater Level and Barometric Pressure in Well CYN-MW4

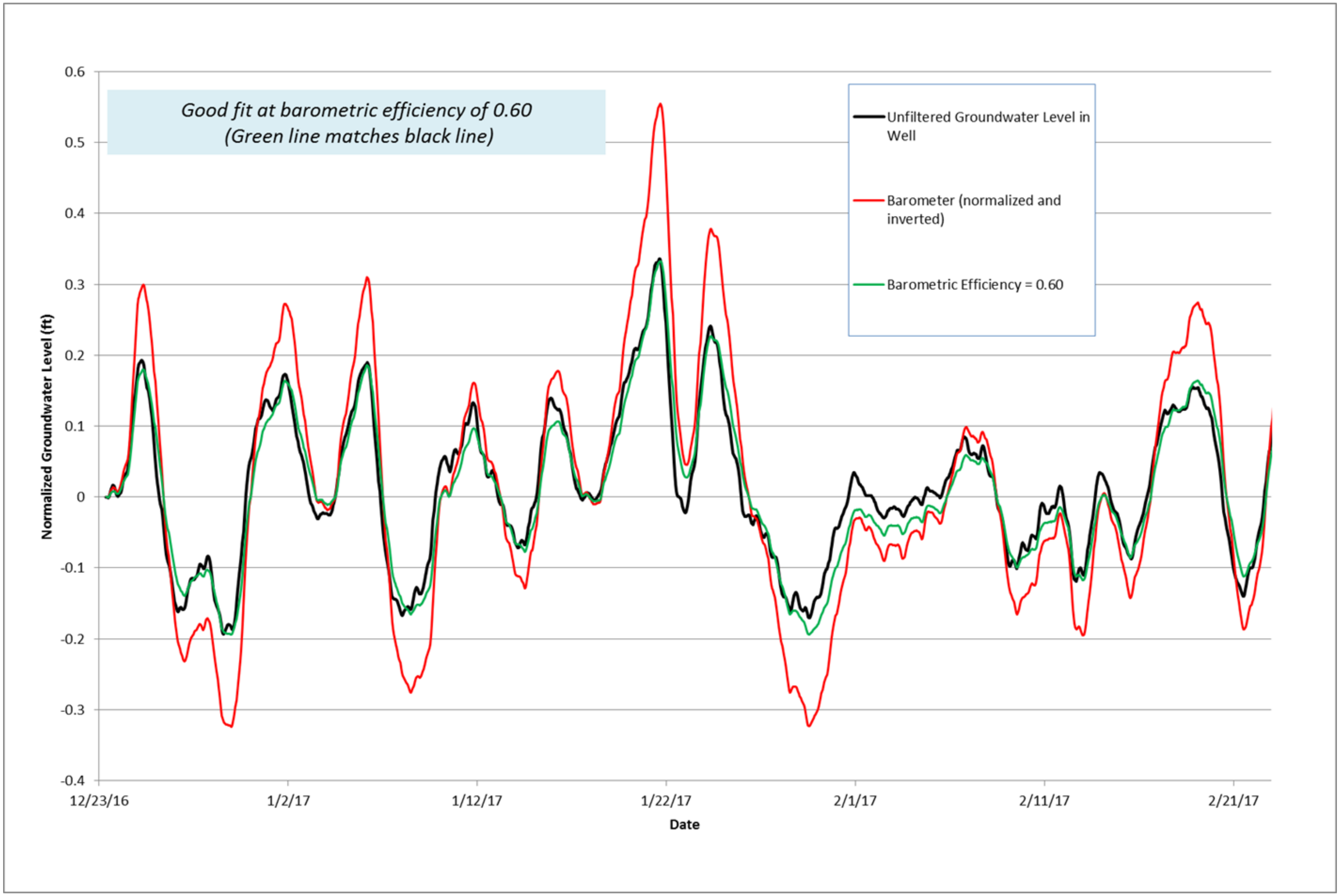

Figure 2-3
Barometric Efficiency in Well CYN-MW4

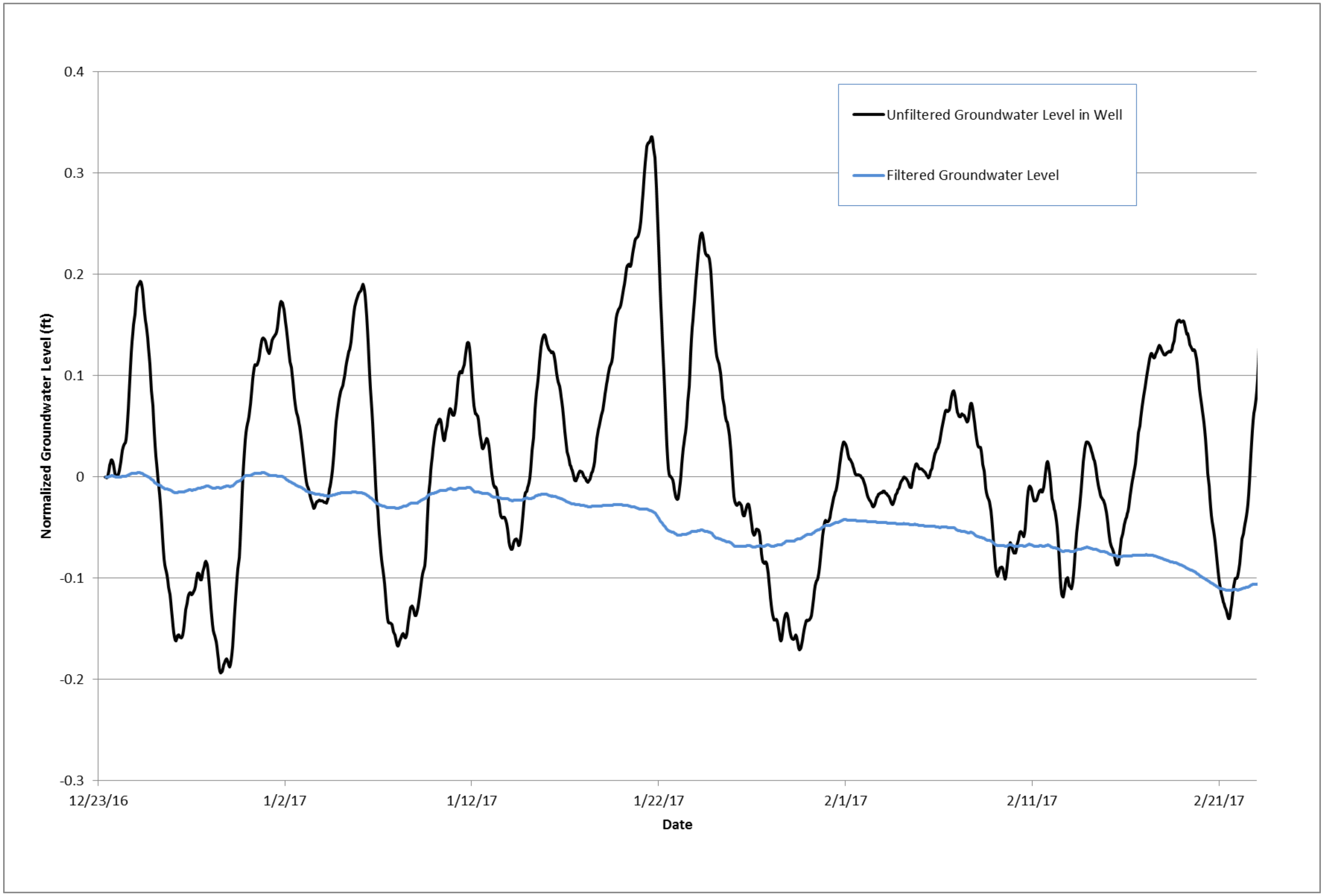

Figure 2-4
Unfiltered and Filtered Groundwater Levels in Well CYN-MW4

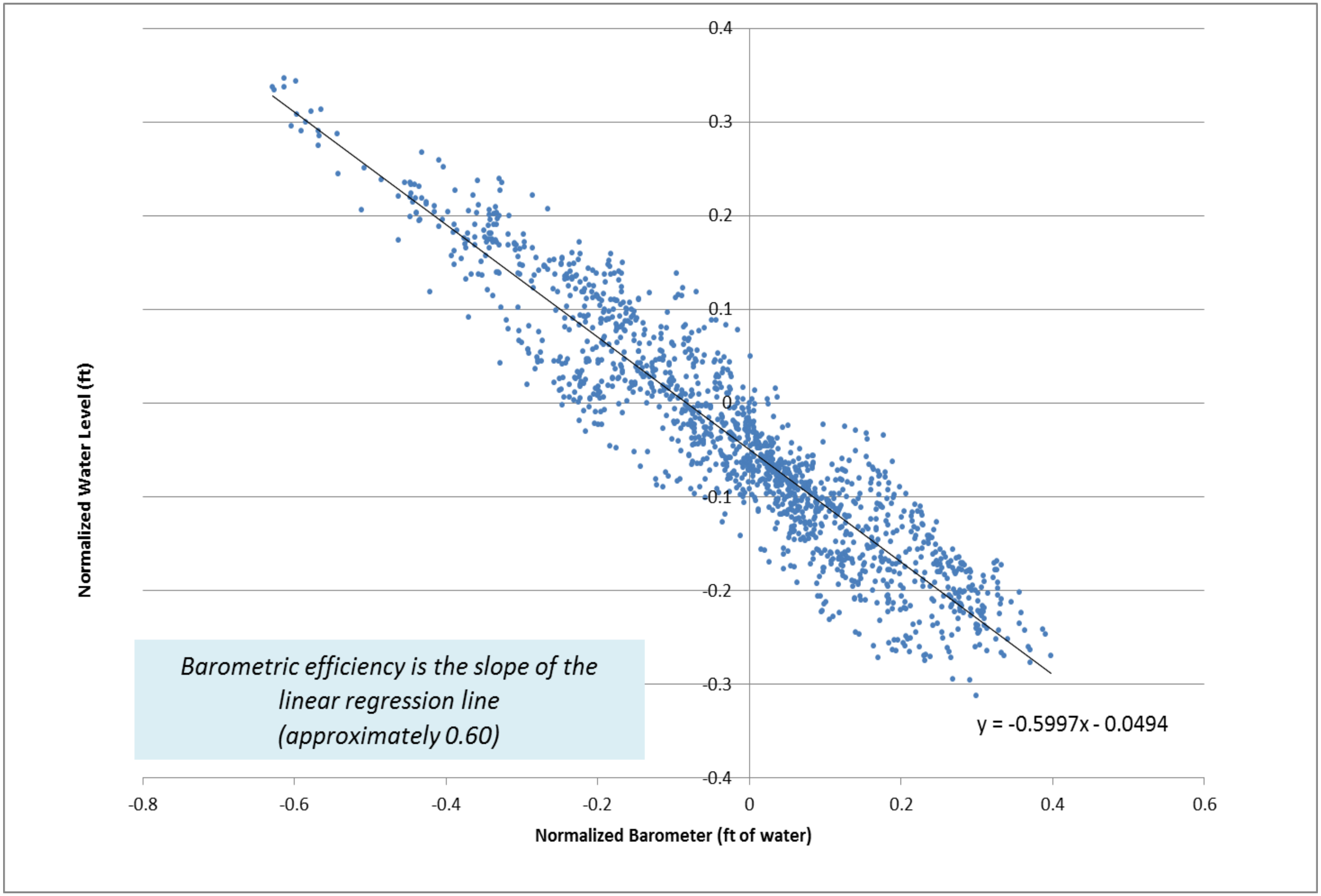

Figure 2-5
Slope Method for Determining Barometric Efficiency in Well CYN-MW4

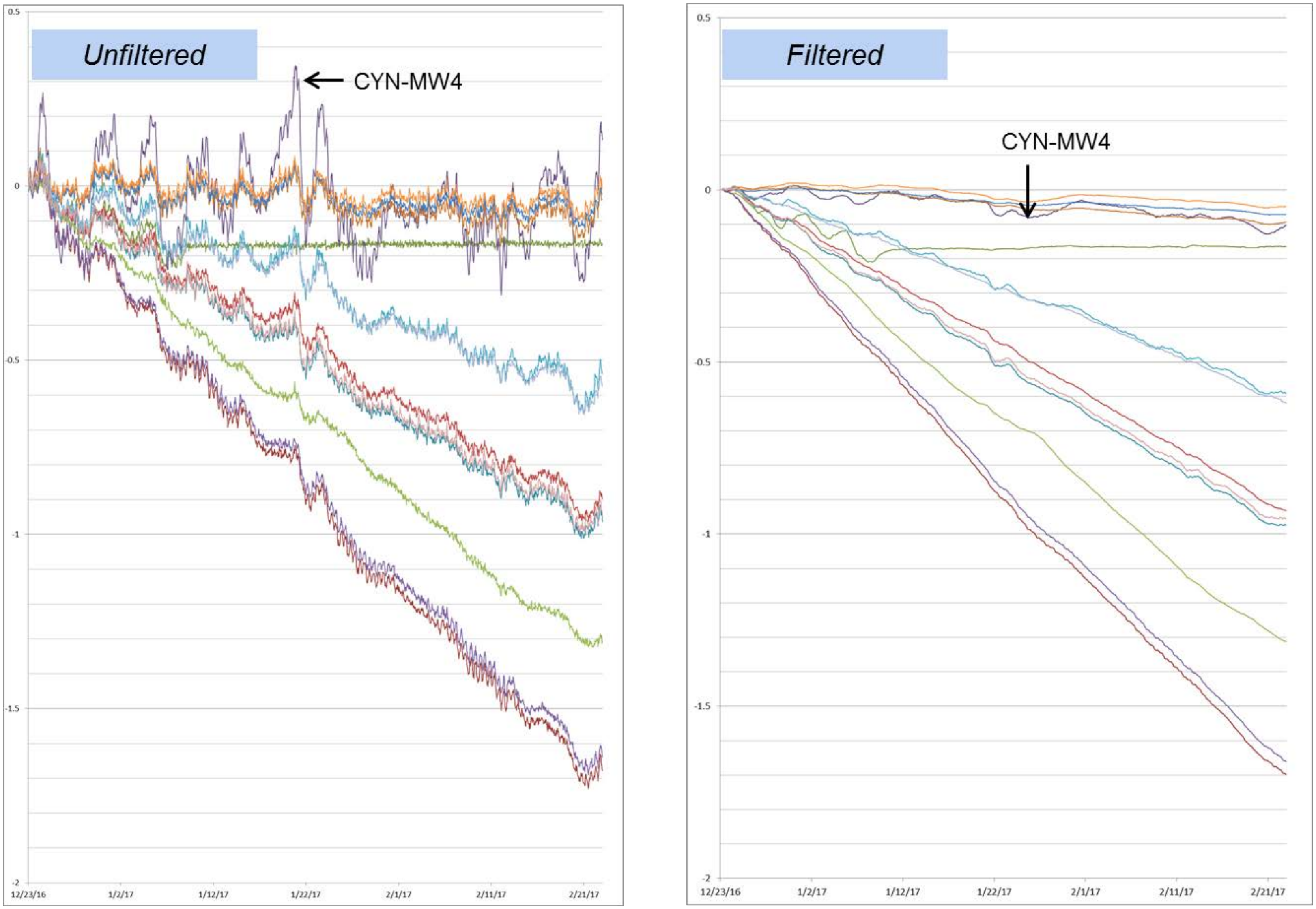

Figure 2-6
Comparison of Unfiltered and Barometrically Filtered Groundwater Levels in Burn Site Groundwater Wells
(well color coding described in Figure 2-7)

Table 2-1
Estimated Barometric Efficiency of Wells in the Burn Site Groundwater Area of Concern

Well	Barometric Efficiency	Comments
Burn Site Well	0.16	Semiconfined
CYN-MW3	-	Transducer daylighted during test, no usable data
CYN-MW4	0.60	Most confined
CYN-MW6	0.11	Semiconfined
CYN-MW7	0.13	Semiconfined
CYN-MW8	0.14	Semiconfined
CYN-MW9	0.13	Semiconfined
CYN-MW10	0.06	Least confined. Shallow well that responds to infiltration of precipitation.
CYN-MW11	0.15	Semiconfined
CYN-MW12	0.20	Semiconfined
CYN-MW13	0.16	Semiconfined
CYN-MW14A	0.16	Semiconfined
CYN-MW15	0.11	Semiconfined

Notes:

CYN = Lurance Canyon.
MW = Monitoring well.

2.2.2 Long-Term Trend Analysis

Over the two-month long-term background groundwater elevation monitoring period, groundwater levels declined in all BSG wells. The decline ranged from 0.05 feet to as much as 1.69 feet. As shown in Figure 2-7, the wells appear to represent six distinct groups (hydraulic domains) based on similarities in long-term water level trends. These domains are designated A through F, where Domain A has the smallest magnitude of water level decline over the monitoring period; and Domain F has the largest decline. Table 2-2 presents the groundwater level trend and barometric efficiency data for each domain. Although wells in a given domain have similar barometric efficiencies and water level trends, there does not appear to be a correlation between these two factors.

Figure 2-8 shows a map of the wells in the BSG long-term background groundwater monitoring study and shows the estimated barometric efficiency and water level trend of each well. Wells in a given domain are located in a relatively small area. For example, Domain A wells (CYN-MW7, CYN-MW8, and CYN-MW13) are all located in the downgradient portion of the BSG AOC nitrate plume; domain F wells (the Burn Site Well and CYN-MW11) are located approximately 12 feet apart.

The identification of distinctive hydraulic domains supports the conceptual site model of a compartmentalized bedrock aquifer system, with limited hydraulic communication between domains. This suggests that either:

1. the faults or fractures are capable of transmitting water, but are not laterally extensive (i.e., do not extend between domains), or
2. the faults/fractures have been mineralized and act as barriers to groundwater flow.

Section 6.0 discusses integration of hydraulic domains into the conceptual site model.

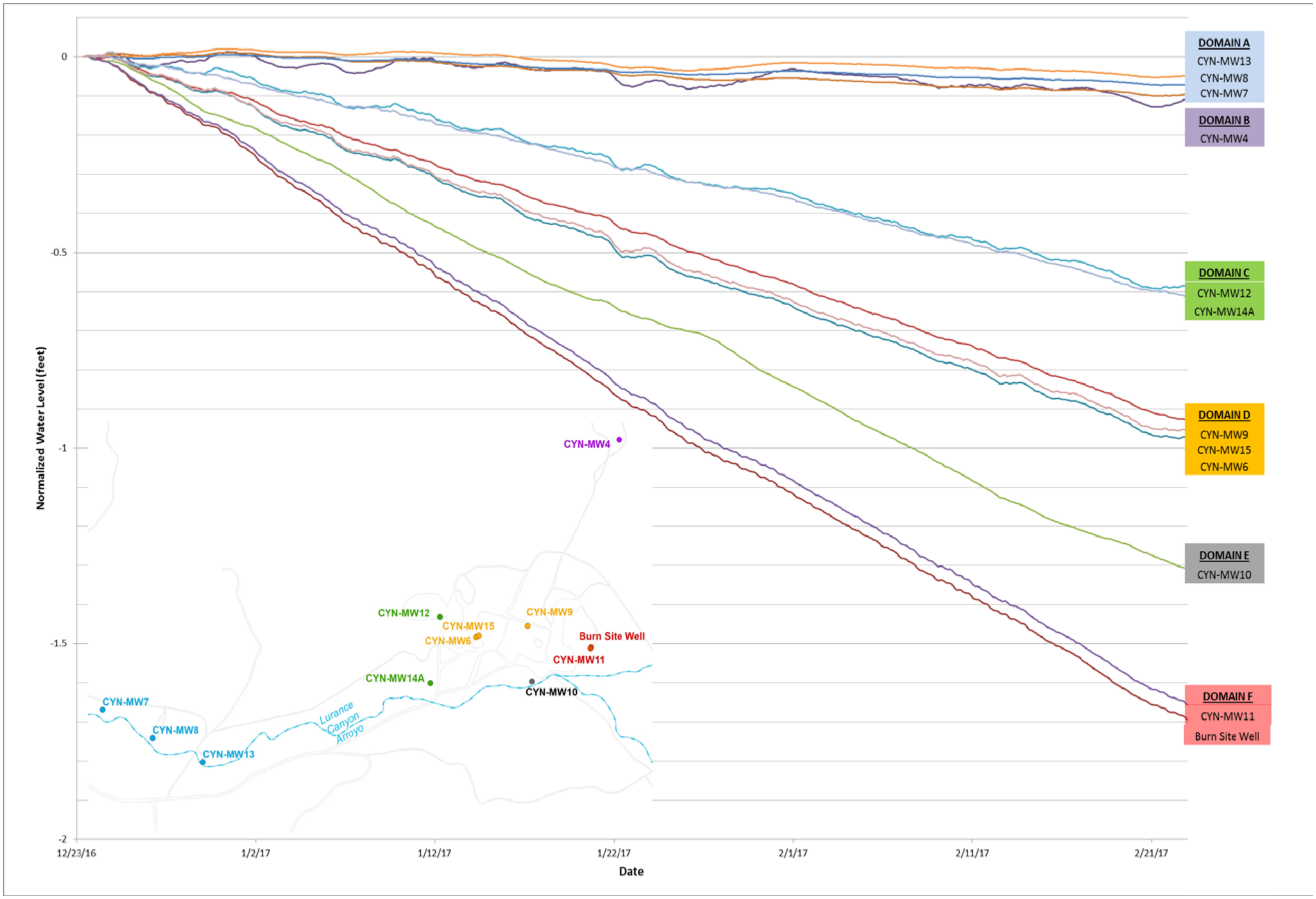

Figure 2-7
Groundwater Level Trends and Hydraulic Domains

Table 2-2
Hydraulic Domain Water Level Trends and Barometric Efficiencies

Hydraulic Domain	Well	Well Water Level Trend (feet)	Domain Average Water Level Trend (feet)	Well Barometric Efficiency	Domain Average Barometric Efficiency
A	CYN-MW7	-0.09	-0.07	0.13	0.14
	CYN-MW8	-0.07		0.14	
	CYN-MW13	-0.05		0.16	
B	CYN-MW4	-0.10	-0.10	0.60	0.60
C	CYN-MW12	-0.59	-0.60	0.20	0.18
	CYN-MW14A	-0.62		0.16	
D	CYN-MW6	-0.97	-0.95	0.11	0.12
	CYN-MW9	-0.93		0.13	
	CYN-MW15	-0.96		0.11	
E	CYN-MW10	-1.31	-1.31	0.06	0.06
F	Burn Site Well	-1.69	-1.68	0.16	0.13
	CYN-MW11	-1.66		0.15	

Notes:

The colors shown for each domain correspond to those shown on Figures 2-7 and 2-8.

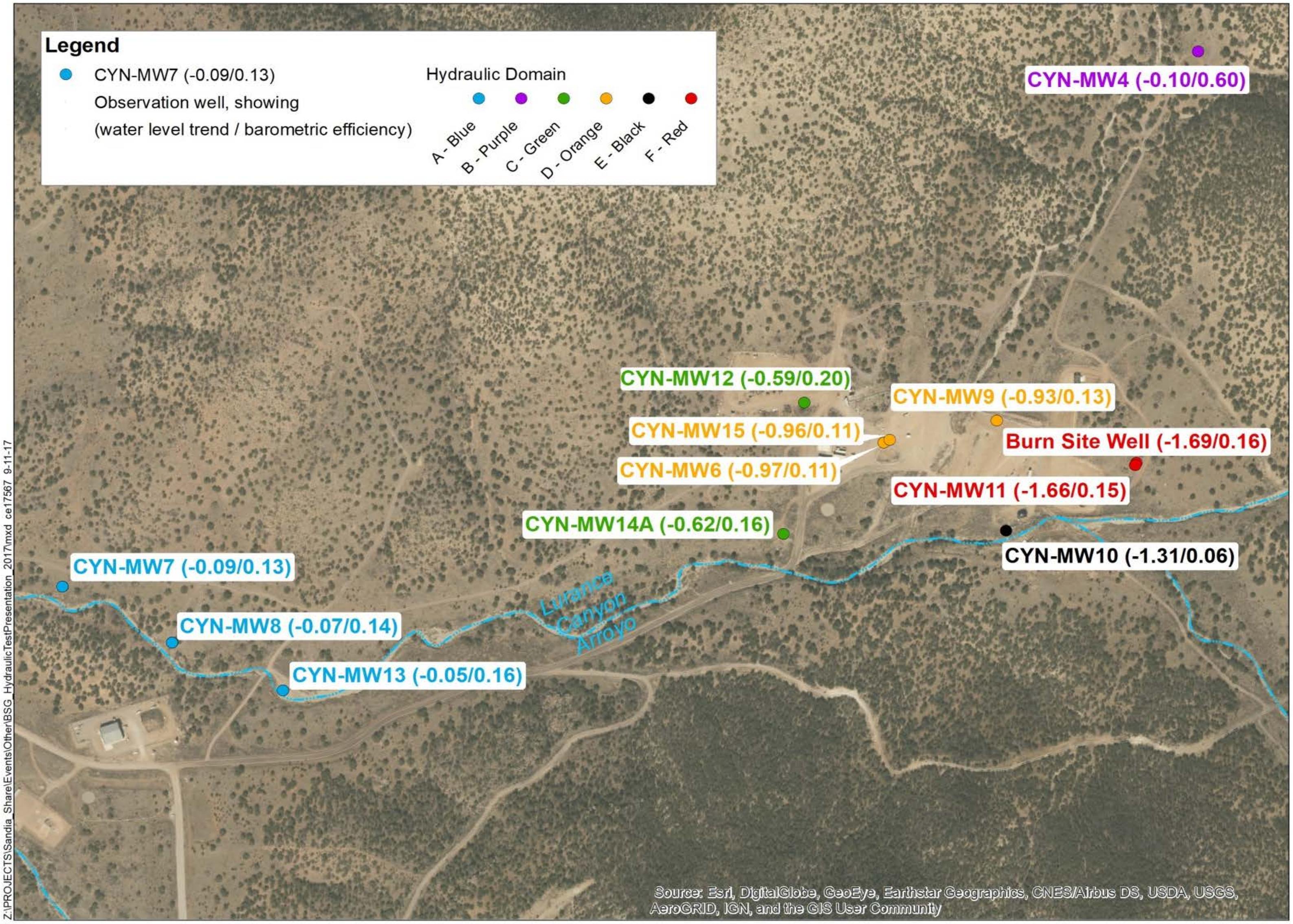

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Figure 2-8
Map of Barometric Efficiency and Hydraulic Domains

3.0 STEP-DRAWDOWN TEST

This section describes the field setup, test procedures, and results of the step-drawdown test. This test was conducted to determine the optimal flow rate to use for the subsequent constant-rate test, and consisted of three steps of increasing pumping rate at 5, 10, and 20 gallons per minute (gpm). Each step had a planned duration of approximately two hours, or until drawdown stabilized. The weather during the step-drawdown test was unseasonably warm with temperatures in the low 70s (°F). The temperatures ranged from 55°F at the start of the test to 72°F at the end of the test. There was no precipitation during the test as skies were sunny, and winds were mild to moderate from the west.

3.1 Field Activities

Water level measurement outputs from the transducers installed in the Burn Site Well and in CYN-MW11 could be viewed in real time, and recorded drawdown during both pumping and recovery. The transducer in the Burn Site Well was set at 318 feet bgs, and the transducer in CYN-MW11 was installed at 248 feet bgs. Both transducers were set to collect data at one-minute intervals. Real-time data viewing allowed for determining drawdown and preventing the pump from drawing air/overheating. The transducers in the observation wells were placed at the same depths as described above in the long-term background groundwater elevation monitoring and collected water level data at 10-minute intervals.

3.1.1 Field Setup at Burn Site Well

For the step-drawdown test, the pump installed in the Burn Site Well was a 4-inch Franklin Electric FPS 4400 stainless-steel submersible pump. The pump intake was set at 325 feet below top of casing with 92 feet of screen above the intake and 18 feet of screen below the intake. The discharge line was 1-inch steel pipe that was plumbed at the well head through a GPI Industrial Grade Electronic Digital Meter (totalizer), through two valves (in series) that controlled the pumping rate and flow, and through Tygon tubing for sample collection. In the sampling truck, the water was routed through Tygon tubing to a flow-through cell for measurement of field parameters, and the required samples could be collected from in-line sampling ports. Appendix A provides photographs of the field setup at the Burn Site Well.

The measured field parameters included turbidity, potential of hydrogen (negative logarithm of the hydrogen ion concentration [pH]), temperature, specific conductivity (SC), oxidation-reduction potential (ORP), and dissolved oxygen (DO). Groundwater temperature, SC, ORP, DO, and pH were measured with an YSI Model EXO1 water quality meter. Turbidity was measured with a HACH Model 2100Q turbidity meter. The water returning from the sampling truck rejoined the discharge pipe and was then passed through a 2-inch flat-laying hose to tanker trucks for transport and storage (Section 3.1.2 discusses waste management).

3.1.2 Waste Management of Produced Groundwater

The groundwater produced during the step-drawdown test was handled following Best Management Practices for collection, storage, and disposal of waste water. Due to historical concentrations of nitrate above the MCL in the Burn Site Well, the groundwater could not be discharged directly to the ground; therefore, SNL/NM developed and followed a waste management plan for handling the discharge water. SNL/NM personnel consulted with Albuquerque Bernalillo County Water Utility Authority (ABCWUA) personnel to handle and dispose of the produced water. Temporary tanks were used to contain the discharge water. After characterization sampling was complete, the groundwater was disposed through a connection on the ABCWUA Publicly Owned Treatment Works (POTW) sanitary sewer system.

The water was pumped directly from the Burn Site Well to 3,000-gallon tanker trucks and transported to a 20,000-gallon Baker Tank deployed at Building 9925. Multiple 3,000-gallon tanker trucks operated during the test to keep up with the uninterrupted flow of water produced from the Burn Site Well. To allow discharge to the POTW, the water was analyzed for a suite of analytes required by ABCWUA. After the analytical results were received, the ABCWUA allowed the water to be discharged to the POTW access point at Building 9925. The total volume of water produced during the step-drawdown test was 3,156 gallons.

3.2 Data Analysis

The optimal pumping rate for the subsequent constant-rate test was determined by reviewing the hydrograph of the step-drawdown test data (Figure 3-1). The discharge rate of Step 1 was 5 gpm, which produced approximately 31 feet of drawdown that stabilized after approximately 30 minutes. Step 2 began 120 minutes into the test and the discharge rate was increased to 10 gpm. This discharge rate produced an additional 41 feet of drawdown (compared to the end of Step 1), and stabilized after approximately 45 minutes. Step 3 began at 270 minutes into the test and the discharge rate was increased to 20 gpm. This discharge rate rapidly produced an additional 139 feet of drawdown and caused the water level to drop below the transducer (Figure 3-1). The pump was turned off at 326 minutes into the test and water levels recovered approximately 139 feet in just under 60 minutes. Specific capacity was calculated at 0.14 gpm per foot of drawdown for Step 1, and 0.13 gpm per foot of drawdown for Step 2. Specific capacity was not calculated for Step 3 because of the incomplete data set due to the water level dropping below the level of the transducer.

The data obtained in the step-drawdown test were used to select the 10 gpm discharge rate for the subsequent constant-rate test. A higher rate would run the risk of dropping the water level to below the transducer or pump intake as seen in the response to the 20 gpm discharge rate. The risk of over-pumping would also be increased if an impermeable boundary were to be encountered by the cone of depression during the 24-hour constant-rate test.

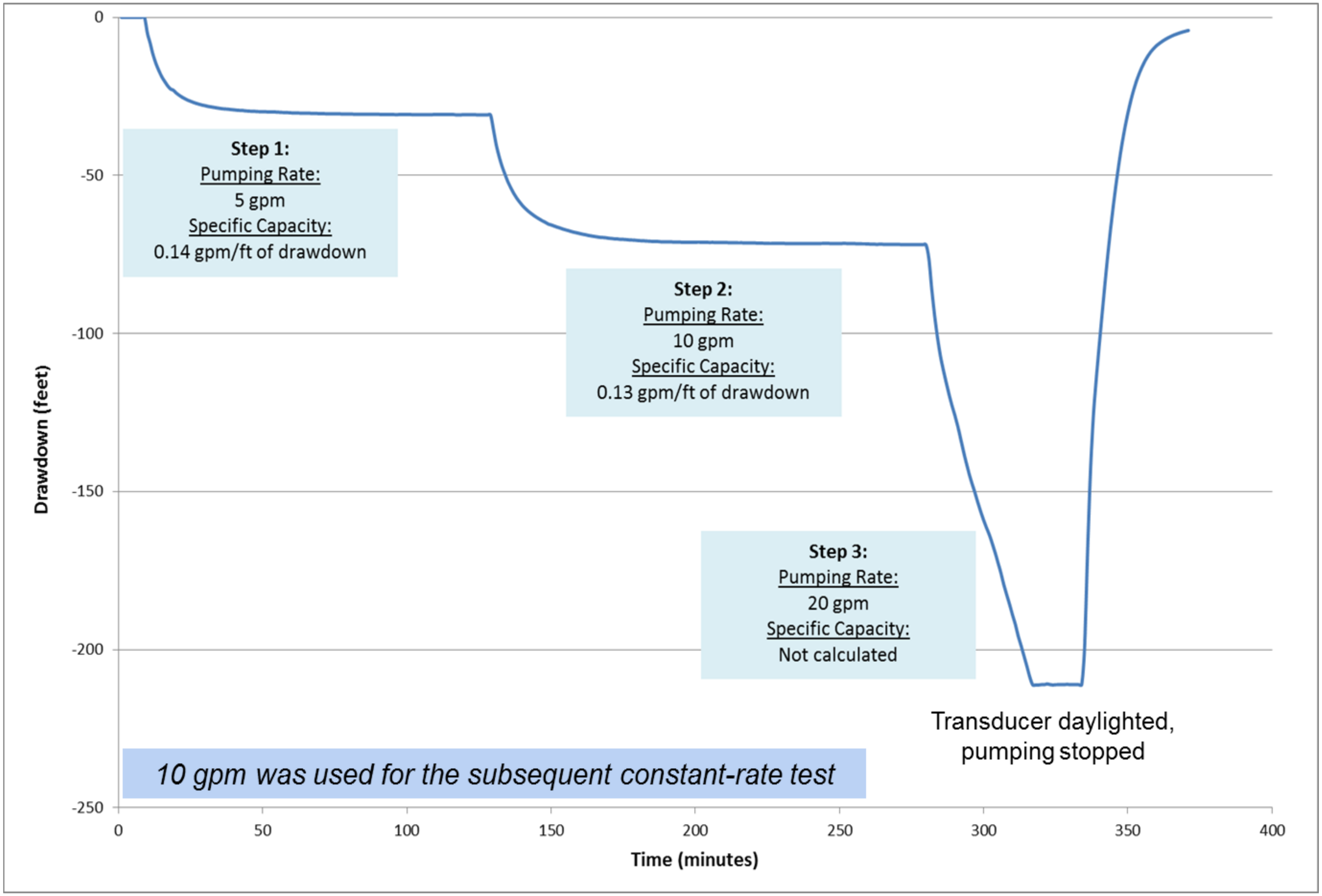

Figure 3-1
Burn Site Well Step-Drawdown Test Hydrograph

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4.0 CONSTANT-RATE TEST

This section describes the field setup, test details, and results of the constant-rate test. The aquifer was allowed to recover for 42 hours between the step-drawdown test and the constant-rate test. However, the data showed that most of the recovery occurred within the first two hours after the pumping stopped (Figure 3-1). The optimal flow rate of 10 gpm determined during the step-drawdown test was used to stress the aquifer for 24 hours. The weather during the constant-rate test was unseasonably warm with temperatures in the low 70s (°F) during the day and low 40s for the overnight portion of the test. The temperatures ranged from 43°F at pre-dawn hours of March 17th to 74°F in the late afternoon of March 16th. There was no precipitation during the test as skies were clear, and winds were light to moderate from the west.

4.1 Field Activities

Section 3.1 describes the field setup for the constant-rate test, and Section 3.1.2 describes how produced water was handled (i.e., pumped into 3,000-gallon tanker trucks and then transported to a 20,000-gallon Baker Tank at Building 9925). The total volume of water produced during the constant-rate test was 11,256 gallons for a grand total of 14,412 gallons stored, analyzed, and eventually disposed to the ABCWUA POTW.

The 24-hour constant-rate test was performed by pumping the Burn Site Well. After 24 hours, the pump was turned off and water level recovery was measured until static water levels were reached. All the BSG monitoring wells were used as observation wells during the constant-rate test. Figure 4-1 illustrates the location of the pumping and observation wells during the constant-rate test, and Table 4-1 provides distances from the pumping wells to the observation wells. Transducers recorded water levels at the same time intervals as the step-drawdown test data. Periodic manual water level measurements were recorded to verify the accuracy of the data obtained from transducers.

4.2 Data Analysis

The data collected during the constant-rate test was used to determine hydraulic responses in wells and calculate the distance to an impermeable boundary encountered by the cone of depression during the test.

4.2.1 Hydraulic Response to Pumping

As shown on Figure 4-2, the maximum drawdown in the Burn Site Well was approximately 73 feet. Approximately 9.5 feet of drawdown was measured in well CYN-MW11, located 12 feet from the Burn Site Well. However, no hydraulic response was detected in any of the other observation wells (Figure 4-3), in part due to the large distances (greater than 500 feet) between these observation wells and the pumped Burn Site Well. Figure 4-4 shows a more detailed view of observation wells in the area of the Burn Site Well; no response is discernable.

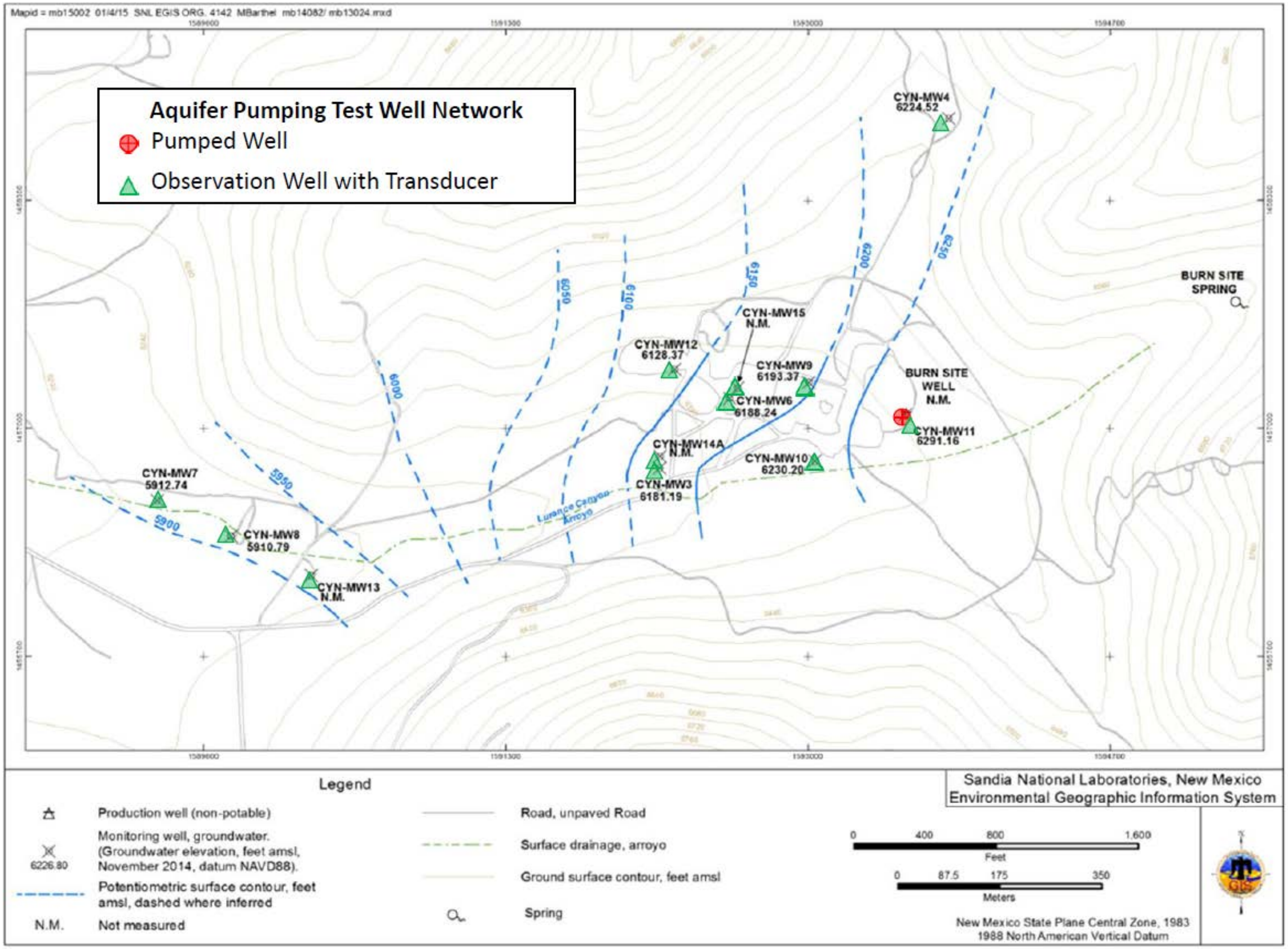

Figure 4-1
Burn Site Groundwater Aquifer Pumping Test Monitoring Well Network

Table 4-1
Summary of Aquifer Pumping Test Wells at the Burn Site Groundwater Area of Concern

Well	Screen Interval (feet bgs)	Horizontal Distance from Pumping Well - Burn Site Well (feet)	During Aquifer Pumping Test Well Used as:
Burn Site Well	231-341	0	Pumping Well
CYN-MW3	120-130	1,423	Observation Well
CYN-MW4	260-280	1,695	Observation Well
CYN-MW6	141-161	994	Observation Well, Barometer Location
CYN-MW7	315-334	4,240	Observation Well
CYN-MW8	338-358	3,857	Observation Well
CYN-MW9	176-196	575	Observation Well
CYN-MW10	150-170	581	Observation Well
CYN-MW11	230-250	12	Observation Well
CYN-MW12	252-272	1,328	Observation Well
CYN-MW13	377-397	3,474	Observation Well
CYN-MW14A	264-294	1,416	Observation Well
CYN-MW15	160-190	975	Observation Well

Notes:

bgs = Below ground surface.
CYN = Lurance Canyon.
MW = Monitoring well.

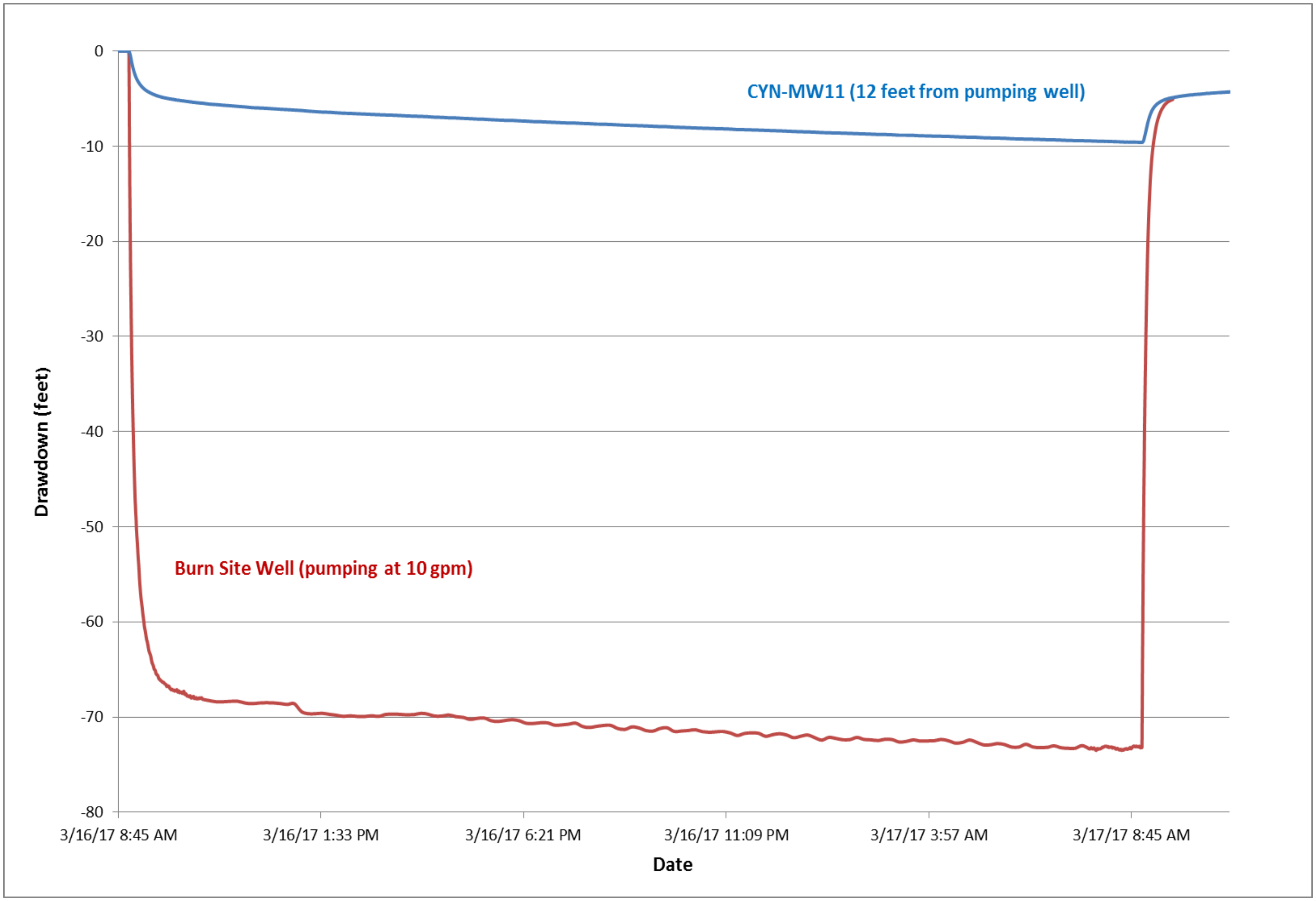

Figure 4-2
Constant-Rate Test Hydrographs for the Burn Site Well and Well CYN-MW11

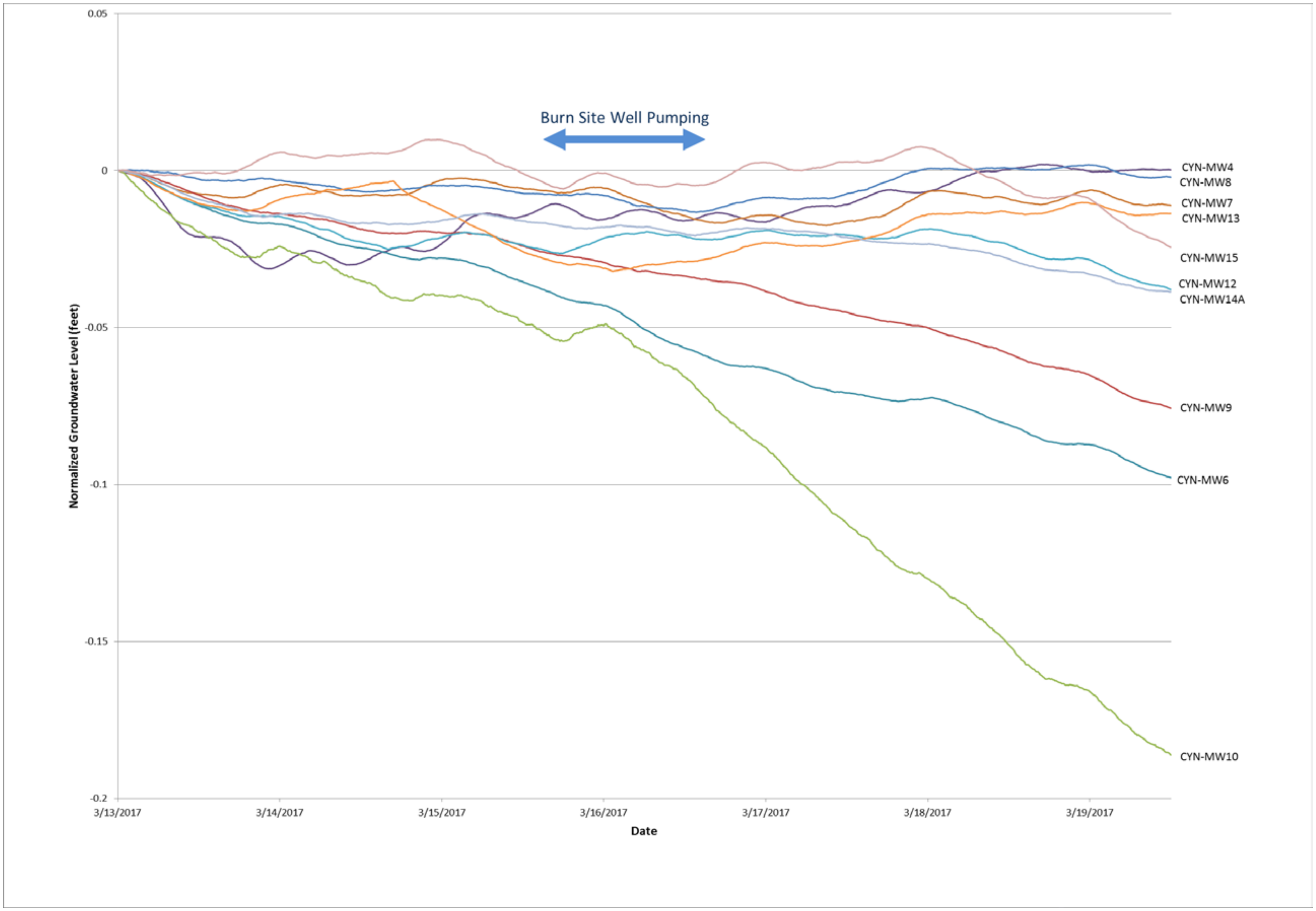

Figure 4-3
Constant-Rate Test Hydrographs for Observation Wells

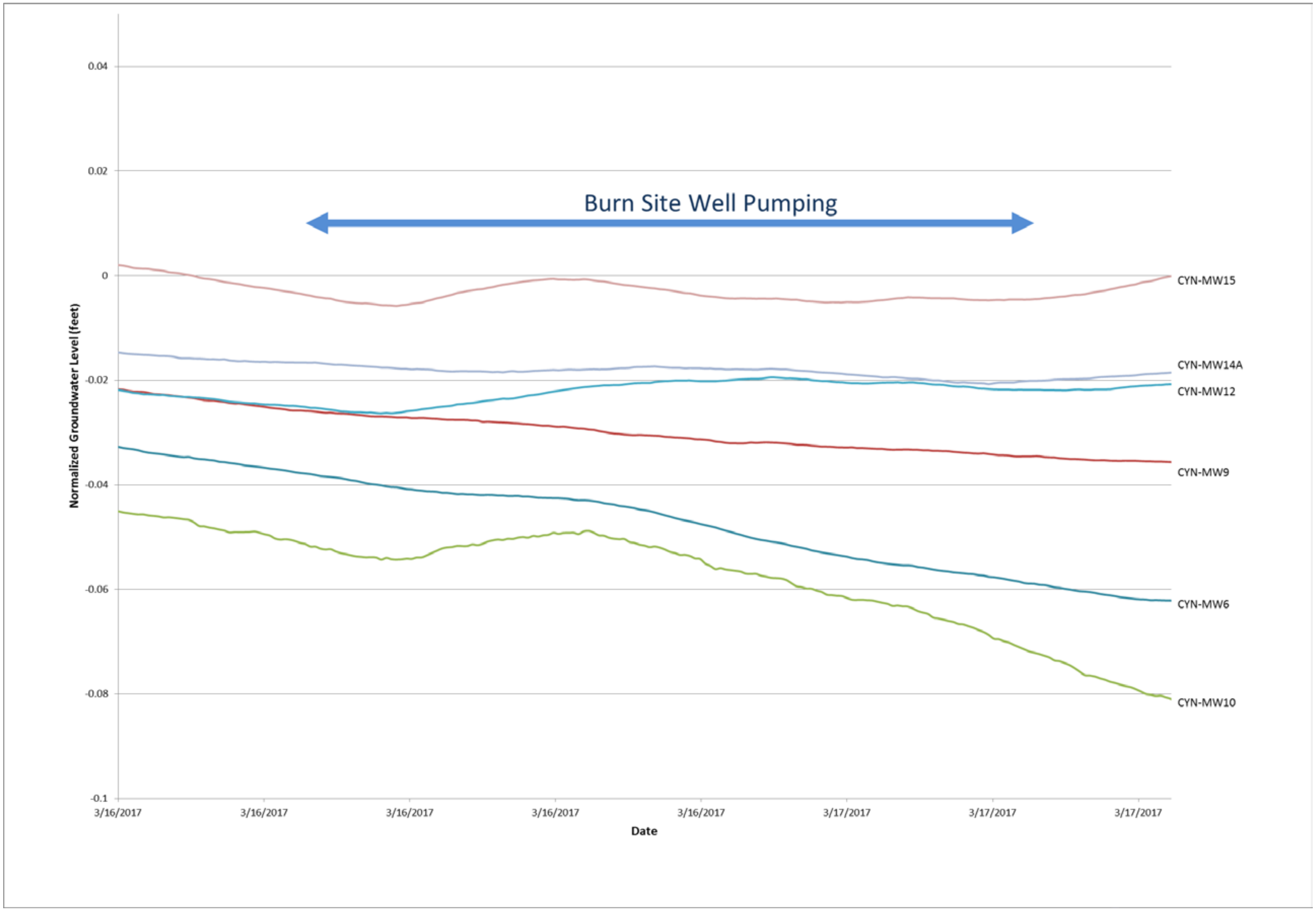

Figure 4-4
Constant-Rate Test Hydrographs for Selected Observation Wells (Detailed View)

These data show that Domain F (defined in Section 2 as being the area near the Burn Site Well and well CYN-MW11) is not in hydraulic communication with any of the other domains.

4.2.2 Distance to an Impermeable Boundary

Approximately 5 hours into the constant-rate test, the rate of drawdown in observation well CYN-MW11 increased, indicating that the cone of depression had likely reached an impermeable (or semi-permeable) flow boundary.

Using the methodology described in Todd (1980), the distance from the pumping well to the boundary was calculated. As shown on Figure 4-5, the lateral distance to the boundary is approximately 212 feet. This distance is consistent with the Burn Site Fault acting as a barrier to groundwater flow.

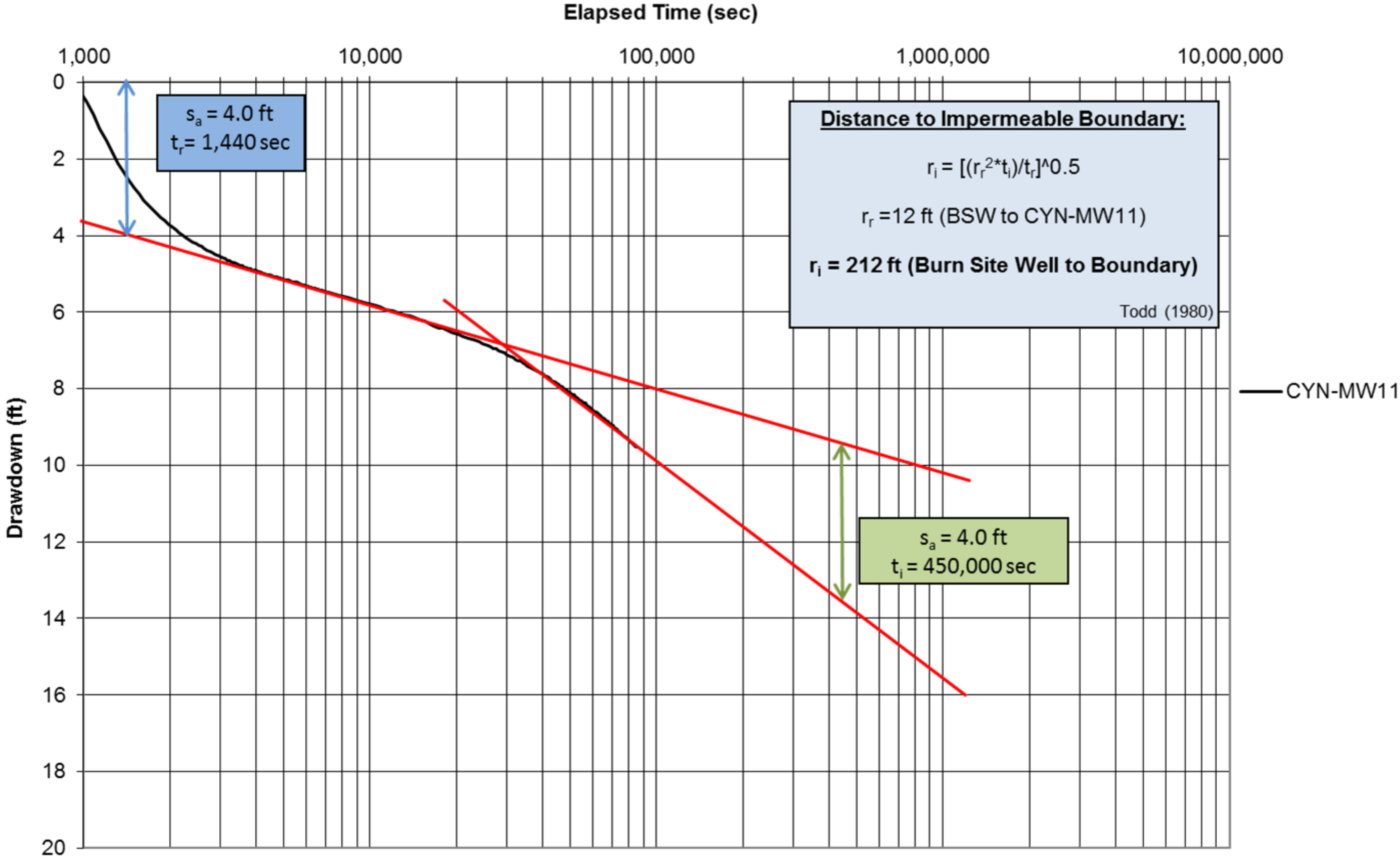

Figure 4-5
Distance to Impermeable Boundary Calculation

5.0 INTERVAL SAMPLING

To assess the extent of nitrate contamination and aid in determination of the source of nitrate, groundwater samples were collected periodically during the constant-rate test. This section describes the field setup, test details, and results of the interval sampling.

5.1 Field Activities

The sampling was conducted in conformance with applicable SNL/NM field operating procedures for groundwater sampling activities. Groundwater samples for nitrate plus nitrite (NPN) analysis were collected during the constant-rate test from the discharge pipe at approximately 1,200 gallon intervals for 10 samples total. Groundwater samples were submitted to GEL Laboratories LLC (GEL) for NPN analysis using Method EPA 353.2. Unfiltered samples were collected in 125-milliliter plastic containers, preserved with sulfuric acid, and analyzed during the 28-day holding time. Duplicate samples for NPN analysis were collected at the 5th and 10th intervals.

As required by the ABCWUA, samples for additional analytes were required for waste management purposes. The results of the waste characterization sample met acceptance criteria and the pumped groundwater was disposed to the POTW. The results of the waste characterization samples are not discussed further.

With some modifications, groundwater sampling was performed in accordance with FOP 05-01, “Groundwater Monitoring Well Sampling and Field Analytical Measurements” (SNL/NM January 2015), and SNL/NM Sample Management Office procedures and protocols. The most notable change to the requirements of the FOP is that standard sampling involves the use of low-flow sampling equipment. For the interval sampling, a high-flow submersible pump with a discharge rate of 10 gpm was used to obtain the samples. Field parameters were measured during sampling; however, field parameter stabilization was not required before collecting the sample.

Table 5-1 provides the sample identification, Analysis Request/Chain-of-Custody form number, and other pertinent sample information. The analytical report from GEL, including certificates of analyses, analytical methods, method detection limits (MDLs), practical quantitation limits, dates of analyses, and results of quality control (QC) analyses and data validation findings, have been submitted to the SNL/NM Customer Funded Record Center.

5.2 Data Analysis

Table 5-2 summarizes the NPN analytical results for the twelve samples (ten intervals, plus two duplicate samples) collected during the interval sampling. NPN was detected above the MDL of 0.425 mg/L in all samples, and above the EPA MCL of 10 mg/L in all but one of the samples. The two duplicate NPN analyses compared favorably with the environmental samples.

Table 5-1
Sample Details for the Nitrate plus Nitrite (NPN) Sampling During the Aquifer Pumping Test, March 2017

Well	Sample ID	AR/COC	Sample Date	Purge Volume (gallons)	Sample Time (hours)
Burn Site Well	BSG APT_SA1	617777	16-Mar-17	1,200	1105
	BSG APT_SA2	617778	16-Mar-17	2,400	1309
	BSG APT_SA3	617779	16-Mar-17	3,600	1601
	BSG APT_SA4	617780	16-Mar-17	5,400	1806
	BSG APT_SA5	617781	16-Mar-17	7,200	2107
	BSG APT_DU5	617781	16-Mar-17	7,200	2107
	BSG APT_SA6	617782	16-Mar-17	8,579	2327
	BSG APT_SA7	617783	17-Mar-17	9,600	0102
	BSG APT_SA8	617784	17-Mar-17	11,400	0402
	BSG APT_SA9	617785	17-Mar-17	12,600	0601
	BSG APT_SA10	617786	17-Mar-17	14,400	0858
	BSG APT_DU10	617786	17-Mar-17	14,400	0859

Notes:

APT = Aquifer Pumping Test.
AR/COC = Analysis Request/Chain-of-Custody.
BSG = Burn Site Groundwater.
DU = Duplicate.
ID = Identifier.
No. = Number.
SA = Sample.

Table 5-2
Summary of Nitrate plus Nitrite (NPN) Analytical Results During the Aquifer Pumping Test, March 2017

Sample ID	Analyte	Result [a] (mg/L)	MDL[b] (mg/L)	PQL[c] (mg/L)	MCL[d] (mg/L)	Laboratory Qualifier[e]	Validation Qualifier[f]	Sample No.	Analytical Method[g]
BSG APT_SA1 16-Mar-17	Nitrate plus nitrite	9.70	0.425	1.25	10.0			101962-001	EPA 353.2
BSG APT_SA2 16-Mar-17	Nitrate plus nitrite	**10.9**	0.425	1.25	10.0			101964-001	EPA 353.2
BSG APT_SA3 16-Mar-17	Nitrate plus nitrite	**12.0**	0.425	1.25	10.0			101965-001	EPA 353.2
BSG APT_SA4 16-Mar-17	Nitrate plus nitrite	**12.6**	0.425	1.25	10.0			101966-001	EPA 353.2
BSG APT_SA5 16-Mar-17	Nitrate plus nitrite	**13.2**	0.425	1.25	10.0			101970-001	EPA 353.2
BSG APT_DU5 (Duplicate) 16-Mar-17	Nitrate plus nitrite	**12.8**	0.425	1.25	10.0			101971-001	EPA 353.2
BSG APT_SA6 16-Mar-17	Nitrate plus nitrite	**13.2**	0.425	1.25	10.0			101968-001	EPA 353.2
BSG APT_SA7 17-Mar-17	Nitrate plus nitrite	**13.7**	0.425	1.25	10.0			101969-001	EPA 353.2
BSG APT_SA8 17-Mar-17	Nitrate plus nitrite	**13.5**	0.425	1.25	10.0			101972-001	EPA 353.2
BSG APT_SA9 17-Mar-17	Nitrate plus nitrite	**13.9**	0.425	1.25	10.0			101973-001	EPA 353.2
BSG APT_SA10 17-Mar-17	Nitrate plus nitrite	**13.8**	0.425	1.25	10.0			101974-001	EPA 353.2
BSG APT_DU10 (Duplicate) 17-Mar-17	Nitrate plus nitrite	**14.0**	0.425	1.25	10.0			101975-001	EPA 353.2

Notes:

[a]**Result**
Bold values exceed the established MCL.

[b]**MDL**
Method detection limit. The minimum concentration or activity that can be measured and reported with 99% confidence that the analyte is greater than zero; analyte is matrix specific.

[c]**PQL**
Practical quantitation limit. The lowest concentration of analytes in a sample that can be reliably determined within specified limits of precision and accuracy by that indicated method under routine laboratory operating conditions.

Table 5-2 (Concluded)
Summary of Nitrate plus Nitrite (NPN) Analytical Results During the Aquifer Pumping Test, March 2017

Notes (Continued):

[d]**MCL**
Maximum contaminant level. Established by the EPA Office of Water, National Primary Drinking Water Standards, (EPA May 2009).

[e]**Lab Qualifier**
Cell is blank, then all quality control samples met acceptance criteria with respect to submitted samples. Review conducted by the analytical laboratory.

[f]**Validation Qualifier**
Cell is blank, then all quality control samples met acceptance criteria with respect to submitted samples. Review conducted by SNL/NM contractor (third-party validation).

[g]**Analytical Method**
EPA, 1986 (and updates), "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," SW-846, 3rd ed.

APT = Aquifer Pumping Test.
BSG = Burn Site Groundwater.
DU = Duplicate.
EPA = U.S. Environmental Protection Agency.
mg/L = Milligrams per liter.
No. = Number.
SA = Sample.

The analytical data were reviewed and validated in accordance with Administrative Operating Procedure 00-03, “Data Validation Procedure for Chemical and Radiochemical Data,” Revision 5 (SNL/NM June 2017b). No problems were identified with the analytical data that resulted in qualification of the data as unusable. The data are acceptable, and reported QC measures are adequate. No nonconformances in the sampling field activities or field conditions from requirements in the Aquifer Pumping Test Work Plan (SNL/NM June 2016), were identified during the interval sampling task.

Section 3.1 describes field water quality measurements for turbidity, pH, temperature, SC, ORP, and DO were obtained from the well prior to collecting each interval groundwater sample. Table 5-3 summarizes the water quality values measured immediately before the groundwater samples were collected.

5.3 Discussion

After approximately 6,000 gallons had been pumped, NPN concentrations in the groundwater stabilized at approximately 13 to 14 mg/L and remained at that concentration until the end of the test (Figure 5-1 and Table 5-2). These concentrations are within the historical concentration range found in CYN-MW11 of approximately 10 to 18 mg/L (SNL/NM June 2017a). The data from the SC, pH, and DO field parameter measurements (Table 5-3) mimic the nitrate concentration trend of stabilizing at 6,000 gallons purged (at approximately 2100 hours). The nitrate concentration trend during this interval sampling may represent a nitrate plume centered on groundwater monitoring well CYN-MW9 575 feet west being pulled toward Burn Site Well and mixing with low-nitrate background to produce the 14 mg/L blend. Although a hydraulic response was not detected in CYN-MW9 during the constant-rate test, the eastern edge of the high-nitrate plume may have been pulled toward the Burn Site Well. The 110-foot long screen in the Burn Site Well makes a more definitive conclusion difficult.

Table 5-3
Field Water Quality Measurements[a] During the Aquifer Pumping Test, March 2017

Sample ID	Sample Time	Temperature (°C)	Specific Conductivity (µmhos/cm)	Oxidation-Reduction Potential (mV)	pH	Turbidity (NTU)	Dissolved Oxygen (% Sat)	Dissolved Oxygen (mg/L)
BSG APT_SA1	1105	15.76	921.9	-59.8	7.45	0.50	9.7	0.96
BSG APT_SA2	1309	19.32	1,005.4	-54.1	7.45	1.03	15.7	1.91
BSG APT_SA3	1601	19.15	1,042.6	-16.1	7.25	0.32	0.6	0.05
BSG APT_SA4	1806	18.88	1,040.0	-17.7	7.33	0.48	1.1	0.10
BSG APT_SA5	2107	18.26	1,028.4	-14.2	7.35	0.17	2.0	0.19
BSG APT_DU5	2107	18.26	1,028.4	-14.2	7.35	0.17	2.0	0.19
BSG APT_SA6	2327	18.02	1,022.8	-9.1	7.36	0.65	2.6	0.24
BSG APT_SA7	0102	17.82	1,016.4	-1.7	7.35	0.85	2.9	0.27
BSG APT_SA8	0402	17.84	1,015.3	4.2	7.35	0.17	3.6	0.34
BSG APT_SA9	0601	17.29	1,011.0	11.8	7.36	0.16	3.9	0.37
BSG APT_SA10	0858	18.04	1,016.5	18.6	7.36	0.19	3.8	0.36
BSG APT_DU10	0859	18.04	1,016.5	18.6	7.36	0.19	3.8	0.36

Notes:

[a]Field measurements obtained immediately before the groundwater sample was collected.
°C = Degrees Celsius.
% Sat = Percent saturation.
µmhos/cm = Micromhos per centimeter.
APT = Aquifer Pumping Test.
BSG = Burn Site Groundwater.
DU = Duplicate.
ID = Identifier.
mg/L = Milligrams per liter.
mV = Millivolt(s).
NTU = Nephelometric turbidity units.
pH = Potential of hydrogen (negative logarithm of the hydrogen ion concentration).
SA = Sample.

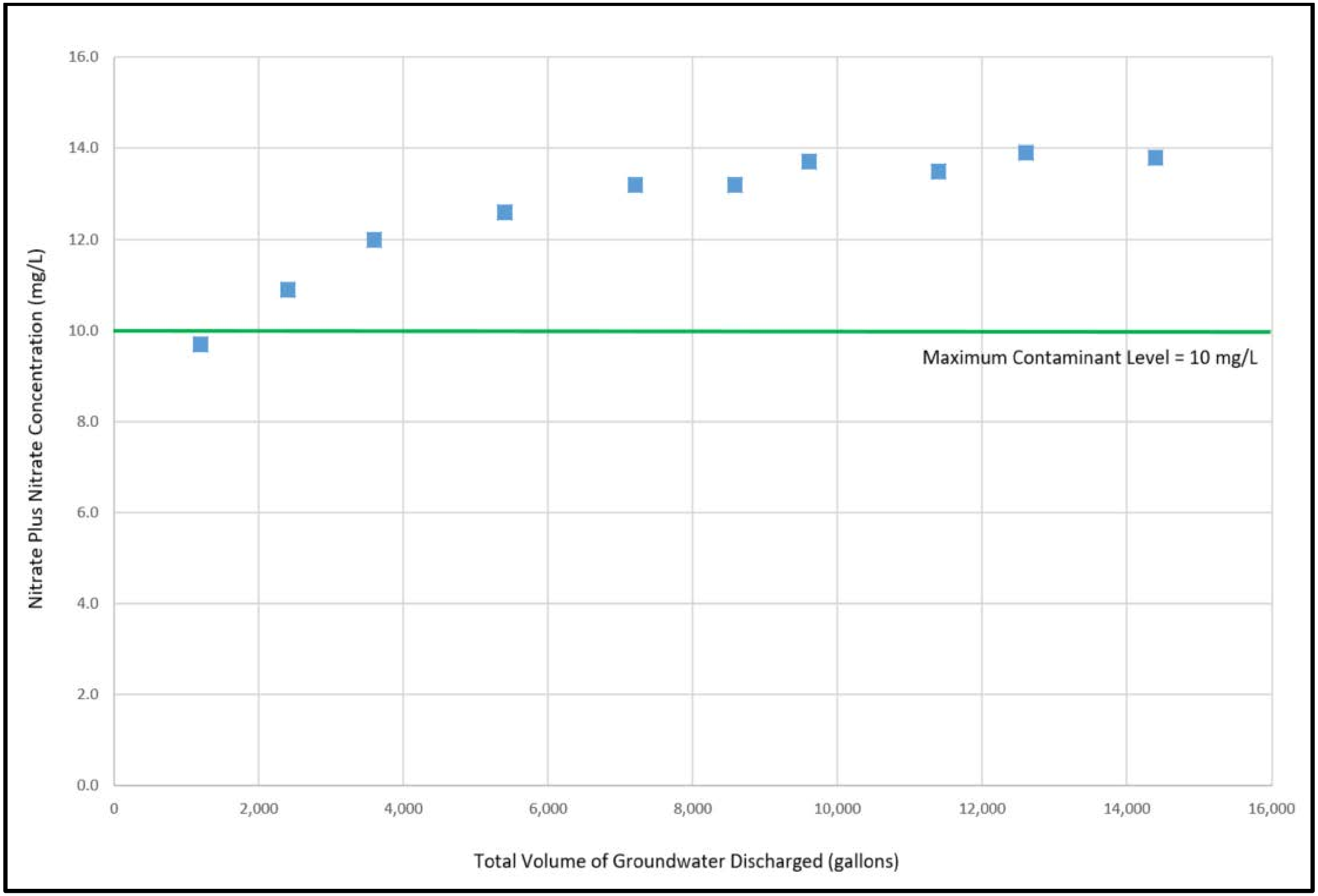

Figure 5-1
Nitrate plus Nitrite (NPN) Concentrations (mg/L) in Discharged Groundwater

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6.0 SUMMARY AND IMPLICATIONS FOR THE SITE CONCEPTUAL MODEL

The results of field studies described in this report can be summarized as follows:

- During the long-term background groundwater elevation monitoring, six hydraulic domains were identified that are characterized by background (before pumping) water level trends and their degree of confinement.

- Barometric efficiency ranged from 0.06 in unconfined well CYN-MW10 (historically this well responds quickly to precipitation infiltration) to 0.60 in upgradient confined well CYN-MW4. The barometric efficiency of the other wells was in the 0.11 to 0.20 range (semiconfined).

- The step-drawdown test determined that 10 gpm was the optimal rate for the 24-hour constant-rate test of the Burn Site Well.

- Hydraulic response was measured in nearby well CYN-MW11; however, no drawdown was detected in any of the other observation wells during the constant-rate test.

- Drawdown data during the constant-rate test suggest an impermeable flow boundary is located approximately 200 feet from the Burn Site Well; this boundary is most likely associated with the Burn Site Fault.

- There is evidence of significant compartmentalization of groundwater, as indicated by: 1) background water level trends, and 2) lack of response to pumping the Burn Site Well. Mineralized faults and fractures likely act as barriers to groundwater flow.

- During the interval sampling the concentration of nitrate stabilized at approximately 14 mg/L.

The results of the field studies described in this report supports the existing site conceptual model (SNL/NM June 2017a):

- Groundwater flows generally westward through bedrock fractures, and is controlled by the geologic framework, such as lithologic changes and structural features. For example, the site is bisected by several north-south faults (high angle down-to-the-east normal faults), and the exposed faults are zones of crushing and brecciation.

- Matrix permeability (primary porosity) of fractured bedrock is assumed to be low, and only small amounts of groundwater are produced from discontinuous water-bearing fracture zones (secondary porosity).

- Fractures filled with carbonate precipitates in the upper portion of bedrock may act as a semiconfined unit restricting vertical flow. However, in localized areas fractured bedrock is recharged by infiltration of precipitation mostly during summer thundershowers and sometimes by significant winter snowfall events. Connectivity of fractures across the AOC is variable.

- Recharge is restricted by high evapotranspiration rates for most of the year, low permeability of bedrock matrix, and discontinuity of fractures.

- Episodic accumulation of precipitation is a mechanism for recharging brecciated fault zones and non-cemented fractures in bedrock.

The results of the field studies described in this report are the final investigations associated with the weight-of-evidence process described above in Section 1.1 (DOE October 2013, November 2014, and May 2015). These field studies support the following statements regarding the weight-of-evidence:

- As shown by the barometric efficiency calculations, surface water is able to infiltrate fractured bedrock and interact with groundwater, especially in areas with unconfined conditions (as seen in monitoring well CYN-MW10).

- As shown by the interval sampling (Section 5.0), there does not appear to be a natural source of nitrate in the area surrounding or upgradient of the BSG AOC.

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APPENDIX A
Field Photos from the Aquifer Pumping Test at Burn Site Groundwater Area of Concern, March 2017

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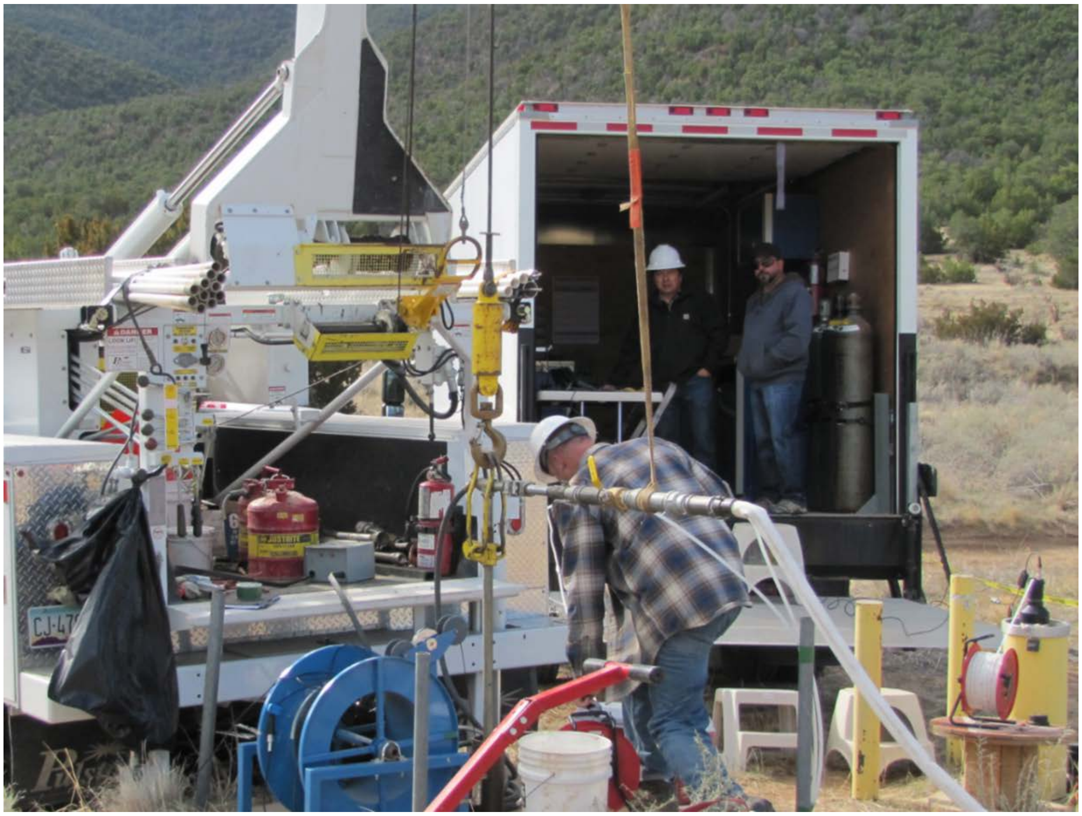
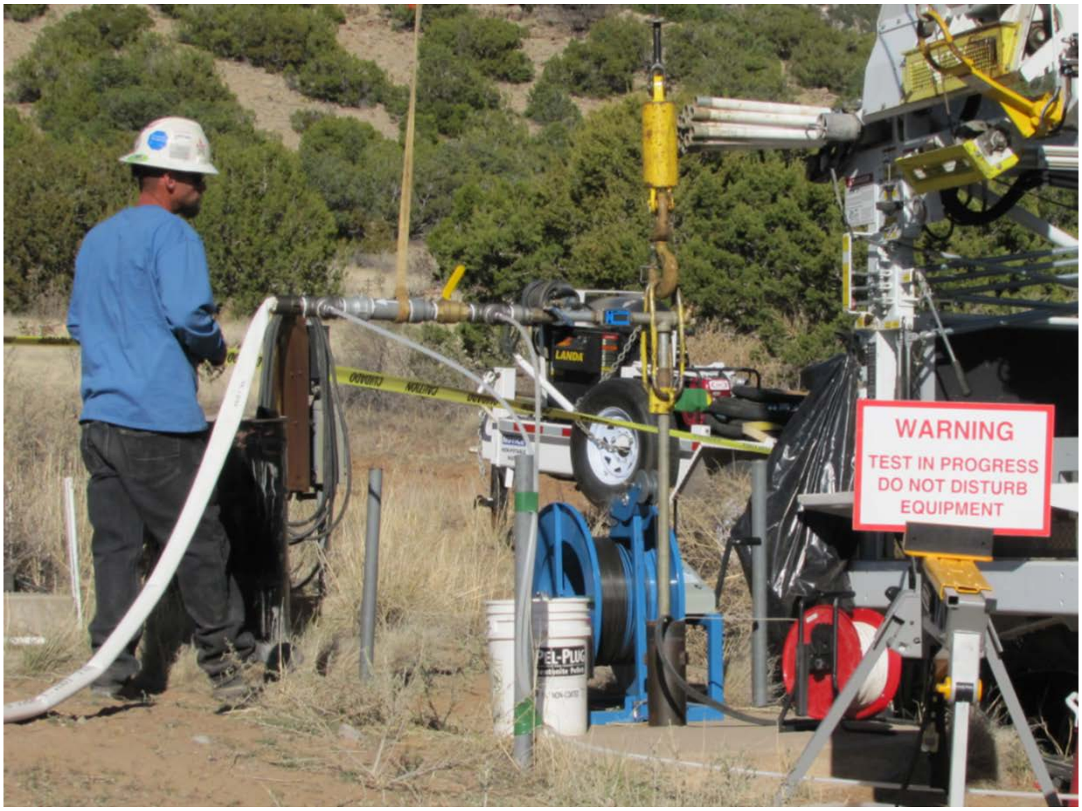
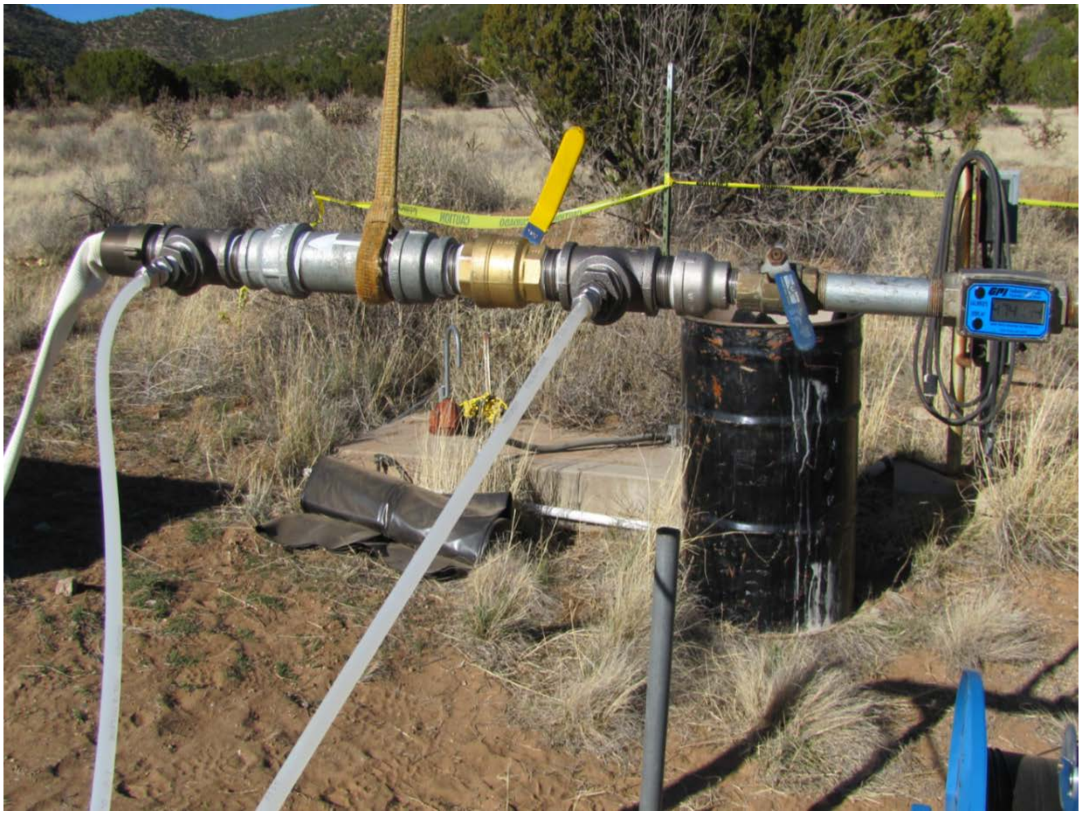
Field Photos from the Aquifer Pumping Test at Burn Site Groundwater Area of Concern, March 2017



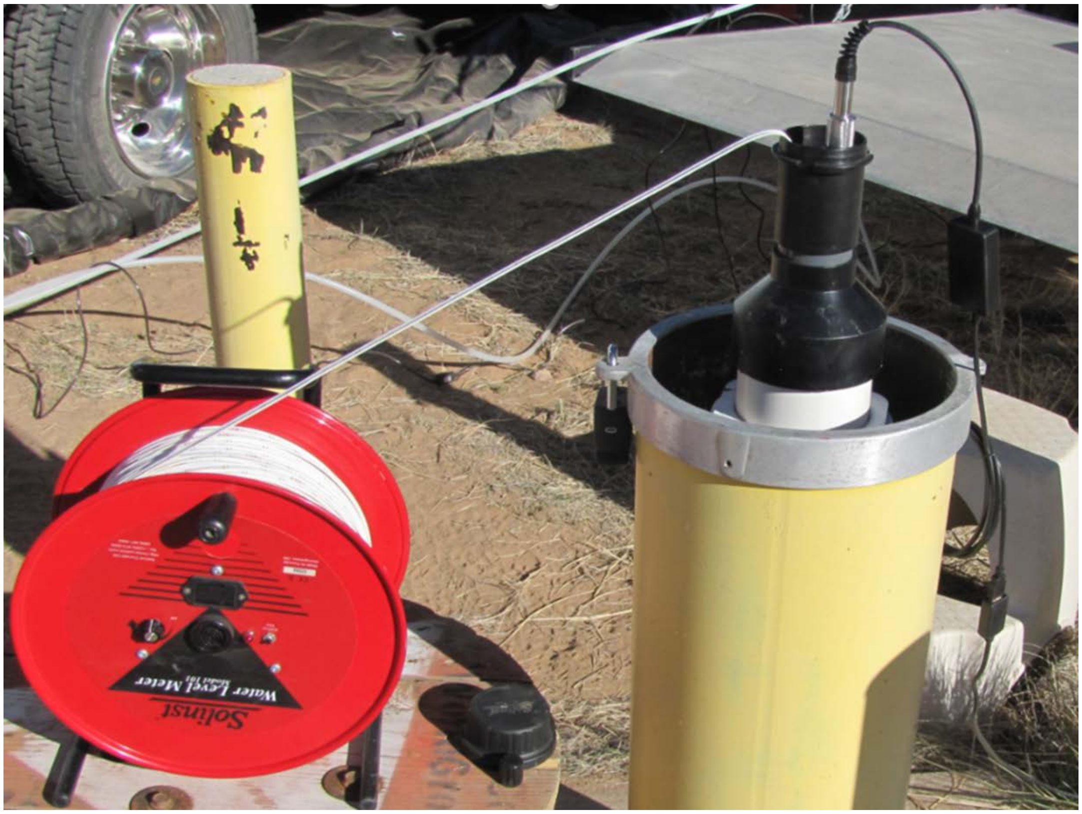
View to the Southeast. Pump Puller Rig (left) and Water Sampling Truck (right) set up over the Burn Site Well, and Monitoring Well CYN-MW11 with Water Level Sounder and Transducer (far right).



View to the North. Pump Puller Rig (right) and Discharge Line Setup in the Burn Site Well.



View to the North. Detail of Discharge Line Setup, from Right to Left: Totalizer, Main Valve, Tygon Tubing to Sampling Truck, Secondary Valve, Nylon Strap Fastened to Rig, Tygon Tubing Return from Sampling Truck, and Lay Flat Hose to Water Trucks.



View to the East. Detail of Monitoring Well CYN-MW11 with Water Level Sounder and Transducer.

View to the East. Detail of Laptop Computer Setup inside the Sampling Truck for Real-Time Viewing of Water Level Data from Burn Site Well and CYN-MW11 Transducers.

View to the West. System for Management of Groundwater Discharge, Lay Flat Hose from Burn Site Well (right), Splitter Valves/Hoses (Center), and 3,000-gallon Water Trucks (background).