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ENTERED

Received
JAN 31 2023
NMED Hazardous Waste Bureau

JAN 26 2023

Mr. Rick Shean
Chief, Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Bldg. 1
Santa Fe, New Mexico 87505

Subject: Submittal of the Burn Site Groundwater Area of Concern Current Conceptual Model and Corrective Measures Evaluation Report for Sandia National Laboratories, New Mexico, Environmental Protection Agency Identification Number NM5890110518

Dear Mr. Shean:

The Department of Energy, National Nuclear Security Administration, Sandia Field Office, and National Technology & Engineering Solutions of Sandia, LLC, submit the Subject document dated January 2023. This submittal presents, (1) an updated conceptual model of the Burn Site Groundwater Area of Concern that describes the geological and hydrogeological setting, the contaminant release sites, and the distribution of contaminants, and (2) the preferred remedial alternative for the contaminated groundwater. The dataset used for this report includes the analytical results from groundwater samples collected through December 2021.

This report meets the requirements under the Sandia National Laboratories Compliance Order on Consent (Consent Order) entered by NMED HWB, DOE/NNSA, and Sandia Corporation. The Consent Order, effective April 29, 2004, identifies the Burn Site Groundwater Area of Concern as an area of groundwater contamination requiring further characterization and corrective action.

If you should have any questions, please contact me at (505) 845-6036 or Dr. Adria Bodour of our staff at (505) 845-6930, or adria.bodour@nnsa.doe.gov.

Sincerely,

Daryl J. Hauck, Ph.D.
Manager

1 Enclosure:

1. Burn Site Groundwater Area of Concern Current Conceptual Model and Corrective Measures Evaluation Report (dated January 2023)

JAN 2 6 2023

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Burn Site Groundwater Area of Concern
Current Conceptual Model and Corrective Measures Evaluation Report, January 2023

CERTIFICATION STATEMENT

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

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Daryl J. Hauck, Ph.D., Manager
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Sandia National Laboratories, New Mexico
Environmental Restoration Operations

Burn Site Groundwater Area of Concern Current Conceptual Model and Corrective Measures Evaluation Report

January 2023

United States Department of Energy
Sandia Field Office

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

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ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
%	percent
µg/L	micrograms per liter
ABCWUA	Albuquerque Bernalillo County Water Utility Authority
AD	anno Domini
AGMR	Annual Groundwater Monitoring Report
AOC	Area of Concern
BH	borehole
BP	years before present
BCE	before common era
bgs	below ground surface
BSG	Burn Site Groundwater
BTEX	benzene, ethyl benzene, toluene, and xylene
CAC	Corrective Action Complete
CCM	Current Conceptual Model
CEARP	Comprehensive Environmental Assessment and Response Program
CME	Corrective Measures Evaluation
COC	Constituent of Concern
Consent Order	Compliance Order on Consent
CSM	Conceptual Site Model
CY	Calendar Year
CYN	Canyons (monitoring well designation only)
DAF	Dilution Attenuation Factor
DOE	U.S. Department of Energy
DRO	diesel range organics
DU	depleted uranium
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
FOP	Field Operating Procedure
ft	foot (feet)
ft/yr	foot (feet) per year
Ga	giga-annum (billions of years)
gpm	gallon(s) per minute
GRO	gasoline range organics
HE	high explosive(s)
HWB	Hazardous Waste Bureau
IMWP	Interim Measures Work Plan
IT	IT Corporation
JP-4	jet propellant, fuel grade 4
JP-8	jet propellant, fuel grade 8
KABQ	Albuquerque International Sunport (airport meteorological station)
KAFB	Kirtland Air Force Base
K	hydraulic conductivity
LAARC	Light Air-transport Accident Resistant Container
LC1	Lurance Canyon (SNL/NM meteorological station)
LCETS	Lurance Canyon Explosive Test Site
LLNL	Lawrence Livermore National Laboratory

ACRONYMS AND ABBREVIATIONS (Concluded)

M	million (dollars)
Ma	mega-annum (millions of years)
M&O	Management and Operating
MCL	Maximum Contaminant Level
MDL	method detection limit
meq/L	Milliequivalents per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	Monitored Natural Attenuation
mi^2	square mile(s)
MW	monitoring well (monitoring well designation only)
NFA	No Further Action
NMED	New Mexico Environment Department
NMOSE	New Mexico Office of the State Engineer
NNSA	National Nuclear Security Administration
NPN	nitrate plus nitrite, as nitrogen
NTESS	National Technology & Engineering Solutions of Sandia, LLC
OB	Oversight Bureau
P&A	plugging and abandonment
RCRA	Resource Conservation and Recovery Act
RDX	1,3,5-trinitro-1,3,5-triazinane
SC1	Schoolhouse (SNL/NM meteorological station)
SFG	Santa Fe Group
SMERF	Smoke Emissions Reduction Facility
SNL	Sandia National Laboratories
SNL/NM	Sandia National Laboratories, New Mexico
SSL	soil screening level(s)
SWHC	Site-Wide Hydrogeologic Characterization Project
SWMU	Solid Waste Management Unit
TA	Technical Area
TABS	Torch Activated Burn System
TKN	Total Kjeldahl nitrogen
TNT	trinitrotoluene
TPH	total petroleum hydrocarbons
USGS	U.S. Geological Survey
VA	Veterans Administration
VOC	volatile organic compound

EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) National Nuclear Security Administration (NNSA) and the Management and Operating (M&O) contractor for Sandia National Laboratories, National Technology & Engineering Solutions of Sandia, LLC (NTESS), hereinafter collectively referred to in this Executive Summary as DOE/NTESS, prepared this Burn Site Groundwater (BSG) Area of Concern (AOC) Current Conceptual Model (CCM) and Corrective Measures Evaluation (CME) Report, referred to as the CCM/CME Report, to meet requirements under the Sandia National Laboratories, New Mexico (SNL/NM) Compliance Order on Consent (Consent Order). The Consent Order became effective on April 29, 2004. The Consent Order identifies the BSG AOC as an area of groundwater contamination requiring further characterization and corrective action.

In June 2004, DOE/NNSA and the SNL/NM M&O contractor, Sandia Corporation (Sandia), hereinafter collectively referred to in this Executive Summary as DOE/Sandia, submitted a CCM and CME Work Plan to the New Mexico Environment Department (NMED). In February 2005, NMED responded that more characterization and Interim Measures were required. Several rounds of characterization activities occurred, and another CME Work Plan was submitted by DOE/Sandia in April 2008 and approved by the NMED in August 2011. Due to changing site conditions, additional monitoring wells were installed to delineate the nitrate groundwater plume. In May 2017, the name of the M&O contractor changed to NTESS and in November 2021, DOE/NTESS personnel proposed to the NMED that the existing monitoring well network was sufficient to characterize the extent of nitrate contamination and the NMED agreed to the preparation of this CCM/CME Report.

Conceptual Site Model

This CCM/CME Report includes an updated Conceptual Site Model of the BSG AOC and describes the geological and hydrogeological setting, the contaminant release sites, and the distribution and migration of contaminants in the subsurface. The dataset used for this CCM/CME Report includes analytical results from groundwater samples collected through December 2021.

Groundwater is found in a fractured bedrock aquifer system in the BSG AOC without saturated, unconsolidated deposits. Nitrate concentrations, as measured by a nitrate plus nitrite (NPN) analytical method, currently exceed the U.S. Environmental Protection Agency's (EPA) Maximum Contaminant Level (MCL) of 10 milligrams per liter (mg/L) in five monitoring wells located in two isolated plumes in the BSG AOC. In CY 2021, the highest NPN concentration detected in the BSG AOC was 39.8 mg/L in the eastern nitrate plume. The western nitrate plume had a maximum concentration of 30.2 mg/L. The lateral extents of the two nitrate plumes have been stable for the last several years. The nitrate plumes are at steady-state (stable) conditions. Historical groundwater analyses have demonstrated that nitrite concentrations are below method detection limits and are considered as non-contributory to the analytical results of NPN analyses. Therefore, NPN results are used directly to represent nitrate concentrations in this CCM/CME Report.

There is no current or anticipated use of groundwater from the fractured bedrock aquifer system in the vicinity of the BSG AOC. Groundwater in the BSG AOC is not used as a potable water supply, and the nearest human receptor is production well, operated by the Kirtland Air Force Base (KAFB) and referred to as KAFB-4, which is located approximately 9 miles northwest of the BSG AOC. However, the complex groundwater flow path from the BSG AOC to KAFB-4 may not be complete and would require groundwater to migrate through at least three zones of low hydraulic conductivity. Groundwater from the BSG AOC would have to migrate approximately 5 miles westward through bedrock fractures along Lurance Canyon, cross the Sandia and Tijeras Faults, and flow approximately 4 miles northwestward through unconsolidated alluvial fan sediments over several decades. Thus, there is no foreseeable risk to human or ecological receptors or a threat to beneficial use of nitrate-impacted groundwater.

There are no remaining active anthropogenic primary nitrate sources at the BSG AOC. Explosives testing and wastewater discharges involving ammonium nitrate slurry (the original sources of nitrate contamination) are no longer conducted. Such activities were last performed in 1975. The nitrate plumes are the result of past releases that have subsequently developed to their present size through dispersion and dilution.

Corrective Measures Evaluation

After a review of potential remedial technologies and discussions with NMED Hazardous Waste Bureau (HWB) personnel, three remedial alternatives were developed and evaluated in this CCM/CME Report:

- Alternative 1: Long-Term Monitoring
- Alternative 2: Monitored Natural Attenuation
- Alternative 3: Groundwater Extraction, Treatment, and Reinjection

Alternative 1: Long-Term Monitoring

DOE/NTESS would sample 14 monitoring wells completed in the BSG AOC fractured bedrock aquifer system annually. The sole analyte for the groundwater samples would be NPN.

DOE/NTESS would conduct five-year remedy performance reviews and would identify any required modifications or optimization measures for the remedy. This process would include a review of land use controls.

DOE/NTESS would implement and maintain land use controls to mitigate potential exposure to contaminated groundwater. Most of these controls are already in place, including maintaining existing site access controls.

The estimated timeframe for this alternative is 38 years (for costing purposes), assuming remedy implementation in 2026 following approval of the Corrective Measures Implementation (CMI) Plan.

The estimated total Present Value cost of the Long-Term Monitoring Alternative (in 2022 dollars) is $11.0 million (M).

Alternative 2: Monitored Natural Attenuation

DOE/NTESS would sample eight monitoring wells completed in the BSG AOC fractured bedrock aquifer system annually. The analytes for groundwater samples would include NPN and denitrification indicators (isotopes, dissolved gases, and total dissolved gases).

DOE/NTESS would conduct five-year remedy performance reviews and would identify any required modifications or optimization measures for the remedy. This process would include a review of land use controls.

DOE/NTESS would implement and maintain land use controls to mitigate potential exposure to contaminated groundwater. Most of these controls are already in place, including maintaining existing site access controls.

The estimated timeframe for this alternative is 38 years (for costing purposes), assuming remedy implementation in 2026 following approval of the CMI Plan.

The estimated total Prevent Value cost of the Monitored Natural Attenuation Alternative (in 2022 dollars) is $7.7M.

Alternative 3: Groundwater Extraction, Treatment, and Reinjection

The objective of Alternative 3 is to extract, treat, and reinject all BSG AOC groundwater with a nitrate concentration exceeding the EPA MCL within 20 years of initiating active remediation. This would be accomplished by installing multiple wells, nitrate treatment systems, and associated infrastructure (pipelines, powerlines, and communication cables). The Alternative would include installing a minimum of 12 extraction wells, 4 additional hydraulic-communication test wells, and 12 reinjection wells. Separate systems would be installed in the eastern and western nitrate plumes. These systems would create recirculation cells within the steady-state (stable) nitrate plumes. Water levels would be measured in 41 wells. Water samples would be collected from 20 wells.

DOE/NTESS estimates the total extraction rate for the two recirculation systems to be approximately 15 gallons per minute (gpm). Individual extraction well yields are estimated to be 1 to 1.25 gpm but are dependent on variability in hydraulic conductivity and fracture density.

DOE/NTESS would pump groundwater from the extraction wells and convey the water to two treatment facilities (one for each plume) via a network of double-contained piping. The extracted water would be treated with strong-base anion ion-exchange resin to reduce nitrate concentrations to below the 10 mg/L EPA MCL prior to discharge into reinjection wells. Spent ion-exchange resin would be regenerated offsite.

DOE/NTESS would conduct five-year remedy performance reviews and would identify any required modifications or optimization measures for the remedy. This process would include a review of land use controls.

DOE/NTESS would implement and maintain land use controls to mitigate potential exposure to contaminated groundwater. Most of these controls are already in place, including maintaining existing site access controls.

The estimated timeframe for this alternative is 31 years (for costing purposes), assuming remedy implementation in 2026 following approval of the CMI Plan.

The estimated total Present Value cost of Alternative 3 (in 2022 dollars) is $26.8M.

Table ES-1. Remedial Alternative Evaluation Summary for the BSG AOC

	Alternative 1: Long-Term Monitoring	**Alternative 2: Monitored Natural Attenuation**	**Alternative 3: Groundwater Extraction, Treatment, and Reinjection**
Threshold Criteria			
1. Protective of Human Health and the Environment	Protective. No potential exposure for human or ecological receptors at concentrations of concern.	Protective. No potential exposure for human or ecological receptors at concentrations of concern.	Protective. No potential exposure for human or ecological receptors at concentrations of concern.
2. Attain Media Cleanup Standard (EPA MCL)	Attained by dispersion and dilution.	Attained by dispersion, dilution, and possibly some degree of denitrification.	Attained by extracting and treating nitrate-contaminated groundwater exceeding the EPA MCL.
3. Control the Source of Releases	Original primary sources of nitrate (explosives testing and wastewater discharges involving ammonium nitrate slurry) already eliminated.	Original primary sources of nitrate (explosives testing and wastewater discharges involving ammonium nitrate slurry) already eliminated.	Original primary sources of nitrate (explosives testing and wastewater discharges involving ammonium nitrate slurry) already eliminated.
4. Comply with Standards for Management of Wastes	Would comply with all standards for the management of wastes.	Would comply with all standards for the management of wastes.	Would comply with all standards for the management of wastes.
Balancing Criteria			
1. Long-Term Reliability and Effectiveness	Proven reliability. Effectiveness relies on natural processes.	Proven reliability. Effectiveness relies on natural processes	Proven treatment technology for the remediation of nitrate-contaminated groundwater.
2. Reduction of Toxicity, Mobility, or Volume	Would not reduce toxicity, mobility, or volume of nitrate; however, anticipate achieving remedial objectives over time through dispersion and dilution.	Would possibly not reduce toxicity, mobility, or volume of nitrate; however, anticipate achieving remedial objectives over time through dispersion, dilution, and possibly some degree of denitrification.	Would not reduce the toxicity or mobility of nitrate. Volume of nitrate in groundwater reduced by transfer to ion-exchange resin.
3. Short-Term Effectiveness	Risk of worker exposure to contaminants during remedy implementation is manageable.	Risk of worker exposure to contaminants during remedy implementation is manageable.	Risk of worker exposure to contaminants during remedy implementation is manageable.
4. Feasibility	Feasible and easily implemented. The monitoring well network is in place. Water levels would be measured in 17 wells. Water samples would be collected from 14 wells. The estimated remedial timeframe is 38 years.	Feasible and easily implemented. The monitoring well network is in place. Water levels would be measured in 17 wells. Water samples would be collected from eight wells. The estimated remedial timeframe is 38 years.	Difficult due to the bedrock aquifer having low hydraulic conductivity that would require installing 12 extraction wells, 12 reinjection wells, 4 test wells, and over 1.1 miles of trenches, electric cables, and piping. Infrastructure and disruption to facility operations may prohibit implementation. Water levels would be measured in 41 wells. Water samples would be collected from 20 wells. The estimated remedial timeframe is 31 years.
5. Cost	Moderate. The total Present Value cost is $11.0M.	Low. The total Present Value cost is $7.7M.	High. The total Present Value cost is $26.8M.

NOTES:

AOC = Area of Concern.
BSG = Burn Site Groundwater.
EPA = U.S. Environmental Protection Agency.
M = Million (dollars).
MCL = Maximum Contaminant Level.

Evaluation of Alternatives 1 through 3

Section 7 evaluates the three remedial alternatives using the four threshold and five balancing evaluation criteria prescribed by Section VII.C.3 of the Consent Order. Table ES-1 summarizes the evaluation.

Preferred Remedy

The DOE/NTESS preferred remedy for nitrate in groundwater at the BSG AOC is the Long-Term Monitoring Alternative. It meets the threshold evaluation criteria, is readily implementable, and projected to meet the remedial objectives in a reasonable timeframe.

Long-Term Monitoring is the preferred remedy because:

1. There is no unacceptable risk to receptors or foreseeable groundwater beneficial use. There is no current or anticipated use of groundwater from the fractured bedrock aquifer system in the BSG AOC vicinity. The nearest receptor is production well KAFB-4, which is located approximately 9 miles from the BSG AOC. Thus, there is no foreseeable risk to human health or threat to beneficial use of groundwater.
2. There are no remaining active nitrate primary sources at the BSG AOC. Explosives testing and wastewater discharges involving ammonium nitrate slurry (the original sources of nitrate contamination) are no longer conducted. Such activities were last performed in 1975.
3. Nitrate concentrations in the two plumes are slightly decreasing to slightly increasing. Nitrate concentrations at the two plumes exceed the EPA MCL (10 mg/L). In October 2021, the maximum NPN concentration in the eastern nitrate plume was 39.8 mg/L; the maximum in the western nitrate plume was 30.2 mg/L. The two nitrate plumes are separated by monitoring wells with NPN concentrations less than the EPA MCL. The lateral extents of the two nitrate plumes have been stable for the last several years. The nitrate plumes are at steady-state (stable) conditions.
4. Land use controls can be maintained or implemented. DOE/NTESS expects to retain stewardship of the site for the foreseeable future. If land use changes were to occur at the BSG AOC, or transfer of the property from DOE/NTESS control were to occur, DOE/NTESS would reevaluate to ensure the protectiveness of the remedy.
5. The remedy is readily implementable. The monitoring well network is already in place.
6. Performance assurance measures were evaluated. A Contingency Plan would include measures to be implemented if the remedy does not proceed as anticipated.
7. DOE/NTESS would submit Progress Reports (Five-year Performance Monitoring Reports) to the NMED HWB.
8. DOE/NTESS would keep the public informed of the remedy progress by: (1) semiannual public meetings, (2) discussions in the Annual Groundwater Monitoring Reports, (3) the Five-year Performance Monitoring Reports, and (4) postings on internet websites.

9. The remedy is cost effective. The estimated total cost of the Long-Term Monitoring Alternative is $11.0M. The estimated total costs for the Monitored Natural Attenuation Alternative and the Groundwater Extraction, Treatment and Reinjection Alternative are $7.7M and $26.8M, respectively.
10. The remedy is fully protective of human health and the environment.

1. INTRODUCTION

Sandia National Laboratories (SNL) is a multimission laboratory which is presently managed and operated by National Technology & Engineering Solutions of Sandia, LLC (NTESS), a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's (DOE) National Nuclear Security Administration (NNSA). SNL/NM personnel conduct groundwater monitoring and site-specific investigations through Environmental Restoration (ER) Operations (formerly the ER Project) and the Long-Term Stewardship Program. The New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) provides regulatory oversight of SNL, New Mexico (SNL/NM) ER Operations, as well as implements and enforces regulations mandated by the Resource Conservation and Recovery Act (RCRA).

SNL/NM is located on Kirtland Air Force Base (KAFB), in Albuquerque, New Mexico (Figure 1-1). The Burn Site Groundwater (BSG) Area of Concern (AOC) is in the Manzanita Mountains in the eastern portion of KAFB and is not associated with any of the SNL/NM Technical Areas (TAs).

Groundwater monitoring has been conducted in the BSG AOC since 1996. The groundwater monitoring activities at the BSG AOC are not associated with a single Solid Waste Management Unit (SWMU) but have a broader scope for Burn Site groundwater as a whole. Prior to 2004, the investigation in the BSG AOC was known as the "Canyons Area" investigation and SNL/NM personnel voluntarily conducted groundwater characterization activities at the BSG AOC while remediating local SWMUs. In 2004, the Compliance Order on Consent (the Consent Order) became effective (NMED April 2004). The Consent Order referred to the study area as the "Burn Site" (as opposed to the "Canyons Area") and this terminology has been in use since 2004. The BSG AOC is shown as an ellipse in Figure 1-1, encompasses approximately 0.56 square miles (mi^2), and is defined by the extent of the groundwater monitoring well network.

The Consent Order identified the BSG AOC as an area of groundwater contamination requiring further characterization and corrective action. In response to the Consent Order, DOE/NNSA and SNL/NM personnel submitted the BSG Current Conceptual Model (CCM) and Corrective Measures Evaluation (CME) Work Plan to the NMED in June 2004 (SNL/NM June 2004a and 2004b). However, the NMED requested further characterization and did not approve the CME Work Plan (NMED February 2005).

The NMED identified the BSG AOC because nitrate had concentrations in groundwater that exceeded the respective U.S. Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL). Nitrate was specified as the constituent of concern (COC) because the fractured bedrock aquifer system contained nitrate concentrations that exceeded the EPA MCL. In addition to nitrate, the Consent Order (NMED April 2004) required investigation of petroleum fuel constituents in groundwater at the BSG AOC, stating "fuel constituents below state and EPA standards have also been detected in some wells."

1.1 BSG Background and Status of the CCM and CME Report

The Coyote Canyon Test Area is in the eastern portion of KAFB. The BSG AOC is in Lurance Canyon, one of three canyons that are located on the eastern edge of the Coyote Canyon Test Area within the Manzanita Mountains. Two other canyons, Madera Canyon and Sol se Mete Canyon, intersect Lurance Canyon to the west of the BSG AOC. These three canyons are the

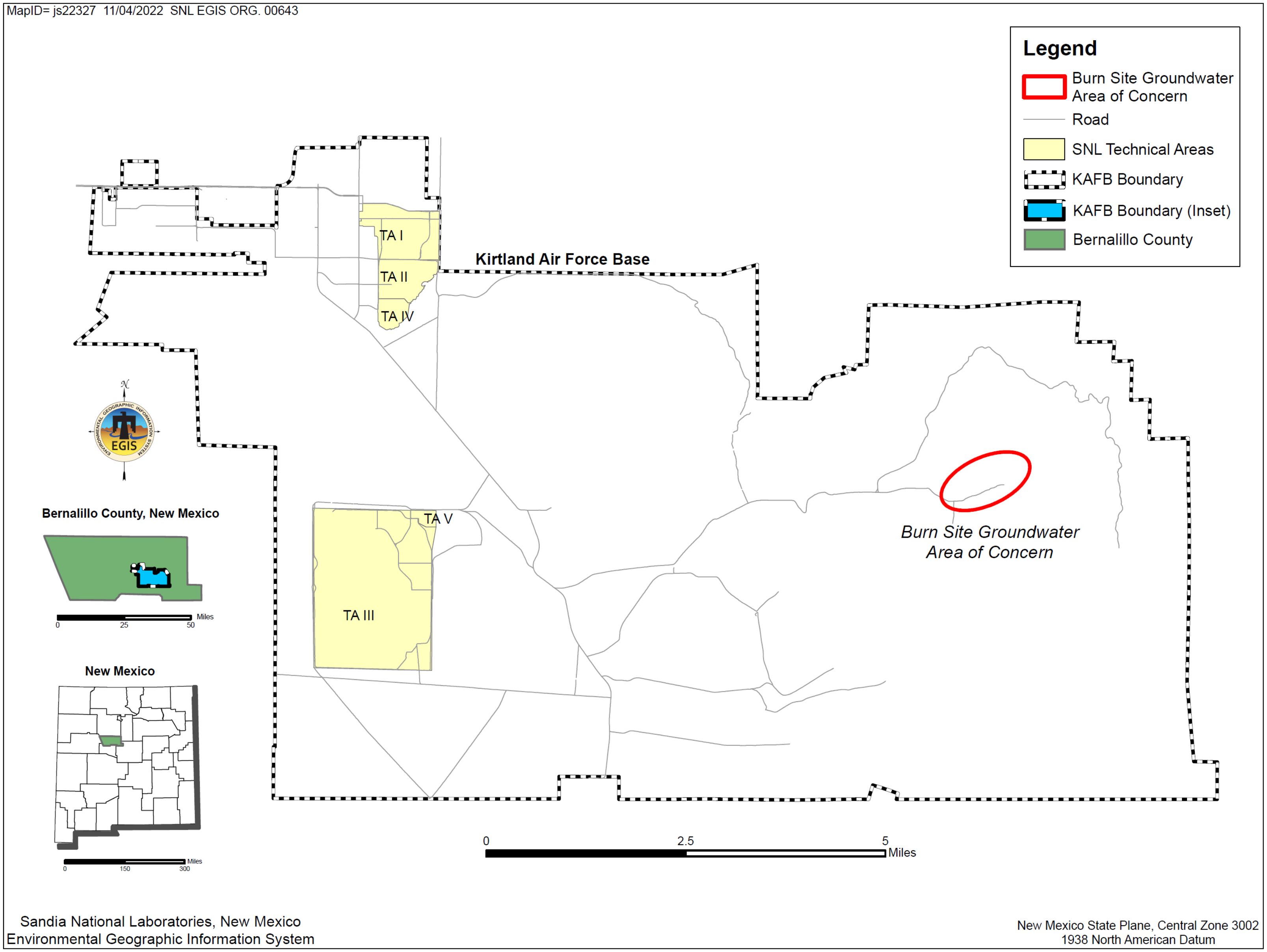


Figure 1-1. BSG AOC Location Southeast of Albuquerque

headwaters of Arroyo del Coyote, which is a tributary to Tijeras Arroyo. Testing activities at the Lurance Canyon Burn Testing Facility, near the center of the BSG AOC, began in 1967.

The BSG AOC is located just east of the margin of the Albuquerque Basin, and the terrain is characterized by large topographic relief, locally exceeding 500 feet (ft). Lurance Canyon, deeply incised into Paleozoic and Precambrian rocks, provides local westward drainage of ephemeral surface water flows to Arroyo del Coyote.

In past publications the study area boundary of the BSG AOC has been depicted as various shapes. The BSG AOC has a footprint substantially bigger than both the Lurance Canyon Burn Site Testing Facility and the footprint of the Burn Site SWMUs. After the installation of four groundwater monitoring wells in 2019, SNL/NM documents have used a standardized depiction of the BSG AOC for figures/maps. The current depiction of the BSG AOC ellipse shown in Figure 1-1 and Figure 1-2 is based on the following:

- The boundary shown in red is an elongated (~2:1) ellipse parallel to the Lurance Canyon Arroyo that encompasses all the existing groundwater monitoring and production wells with a 250-ft radius buffer around each well.
- The ellipse takes into consideration the area that has been impacted by SNL/NM operations and includes the local SWMUs that have been investigated, as well as the testing and support facilities associated with the Lurance Canyon Burn Site Testing Facility.
- The ellipse only covers a slight amount of the mountain sides and ridges to the north and south of the centerline of the arroyo as these areas have only been minimally impacted by SNL/NM operations.

Groundwater issues at the BSG AOC are primarily associated with two SWMUs. The Lurance Canyon Burn Site Testing Facility (SWMU 94) and the nearby/overlapping Lurance Canyon Explosive Test Site (LCETS; SWMU 65) have been used since 1967. Most of the operational activities involved testing the fire survivability of transportation containers, weapon components, simulated weapons, and satellite components. Historical operations included open detonation of high explosive (HE) compounds and ammonium-nitrate slurry along with the open burning of HE compounds, liquid propellants, and solid propellants. Most HE testing activities occurred between 1967 and 1975 and were completely phased out by the 1980s.

Burn testing began in the early 1970s and has continued to the present. Early burn testing was conducted in unlined pits excavated in native soil and alluvium. By 1975, portable steel burn pans were used for open burning, mostly using jet propellant, fuel grade 4 (JP-4). Several engineered structures, such as the Light Air-transport Accident Resistant Container (LAARC) Unit, were used at the facility. The structures mostly used JP-4 and occasionally used diesel fuel and gasoline to create the high temperatures associated with transportation accidents. In the mid-1990s, jet propellant, fuel grade 8 (JP-8) replaced JP-4 as the petroleum fuel used for burn tests. Most test structures have been dismantled. The Smoke Emissions Reduction Facility (SMERF) and the Large Open Burn Pool are the only remaining test structures. Portable burn pans up to 25 ft in diameter are still occasionally used.

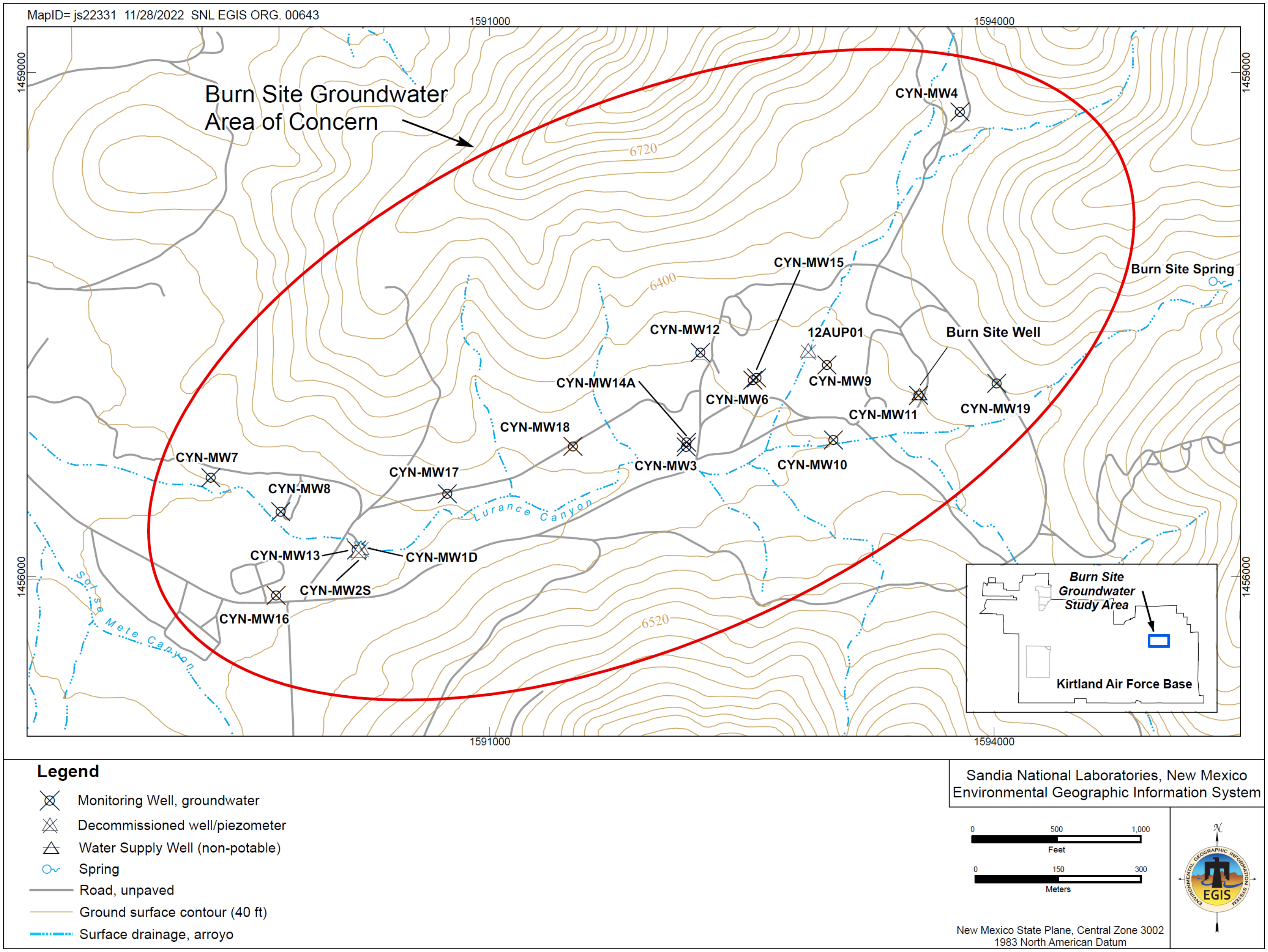


Figure 1-2. BSG AOC Well Network, including Active and Decommissioned Wells and Piezometers

Since the late 1990s, site-specific environmental investigations have been conducted at the SWMUs within the BSG AOC. These investigations included a review of background information/process knowledge, and as necessary, the implementation of characterization and remedial activities including soil sampling, and the excavation of contaminated soil and debris. No Further Action (NFA) proposals submitted since 1997 summarized findings for each SWMU.

To facilitate the timely regulatory review of the NFA proposals, the groundwater issues associated with the BSG AOC were decoupled from the individual SWMUs. By April 2005, the NMED had approved Corrective Action Complete (CAC), Without Controls status for each of the 21 SWMUs. Section 4 discusses the relevancy of specific SWMUs to potential groundwater impacts.

Groundwater samples collected during 1996 from the Burn Site Well (a non-potable production well used for fire suppression; Figure 1-2) contained elevated concentrations of nitrate with a maximum of 27 milligrams per liter (mg/L) detected in August 1996. Since the initial discovery of nitrate at the BSG AOC, numerous characterization activities have been conducted. The results of these characterization activities were summarized in the *Current Conceptual Model of Groundwater Flow and Contaminant Transport at Sandia National Laboratories/New Mexico Burn Site* (SNL/NM June 2004a) and subsequent update (SNL/NM April 2008a). A brief history of regulatory interactions and characterization activities is discussed below.

In 1997, the NMED HWB, DOE, and SNL/NM personnel agreed to investigate the source of the nitrate contamination. Later in 1997, monitoring wells CYN-MW1D and CYN-MW2S were installed downgradient of the Burn Site Well (Figure 1-2). Samples from monitoring well CYN-MW1D contained nitrate concentrations exceeding the EPA MCL. Two more monitoring wells, CYN-MW3 and CYN-MW4, were installed in 1999 to further characterize the study area.

In response to the Consent Order, the BSG AOC CME Work Plan was submitted to the NMED in June 2004 (SNL/NM June 2004b). The Work Plan was not approved and based on requirements stipulated by the NMED (NMED February 2005), the BSG Interim Measures Work Plan (IMWP) was submitted (SNL/NM May 2005) on May 30, 2005. As detailed in the IMWP, three monitoring wells (CYN-MW6, CYN-MW7, and CYN-MW8) were installed during December 2005 to January 2006. Quarterly sampling for eight quarters began for these three monitoring wells in March 2006 and was completed in December 2007. Samples from the two monitoring wells (CYN-MW7 and CYN-MW8) located downgradient of CYN-MW1D were analyzed for nitrate and other analytes. Groundwater samples from monitoring well CYN-MW6 (adjacent to SWMU 94F) were analyzed for nitrate, total petroleum hydrocarbons (TPH) as gasoline range organics (GRO) and diesel range organics (DRO), and other parameters.

Based on a letter received from the NMED (NMED April 2009), DOE/NNSA and SNL/NM personnel were required to further characterize the nature and extent of the perchlorate contamination at the BSG AOC. The BSG Characterization Work Plan (SNL/NM November 2009) was submitted and then conditionally approved by the NMED (NMED February 2010). In July 2010, the requirements of the BSG Characterization Work Plan were implemented and four groundwater monitoring wells (CYN-MW9, CYN-MW10, CYN-MW11, and CYN-MW12) were installed to determine the extent of groundwater contamination. These four monitoring wells were sampled for the first time in September 2010.

In February 2012, a work plan was submitted by DOE/NNSA and SNL/NM personnel to decommission three obsolete groundwater monitoring wells (12AUP01, CYN-MW1D, and CYN-MW2S); and install a replacement groundwater monitoring well, CYN-MW13 (SNL/NM February 2012). Monitoring wells 12AUP01 and CYN-MW2S were screened at the contact of unconsolidated coarse sand and gravel (alluvium) and the underlying bedrock. Although alluvium at this contact was dry during drilling, these wells were installed in anticipation of recharge occurring after rainfall events. However, these wells were consistently dry. Monitoring well CYN-MW1D was constructed with a nonstandard completion (low carbon steel screen and riser pipe), had very turbid water, and exhibited variable nitrate concentrations. A video log showed that monitoring well CYN-MW1D was heavily corroded. In April 2012, the NMED approved the work plan (NMED April 2012); the three monitoring wells (12AUP01, CYN-MW1D, and CYN-MW2S) were decommissioned in November 2012; and replacement monitoring well CYN-MW13 was installed in December 2012 near monitoring well CYN-MW1D.

In August 2013, DOE/NNSA and SNL/NM personnel submitted an Extension Request to the NMED for the BSG CME Report to March 31, 2013 (DOE August 2013). DOE/NNSA and SNL/NM personnel requested the extension for consideration of recently collected groundwater sample analytical results from replacement monitoring well CYN-MW13 that could impact the BSG CME Report.

In September 2013, a work plan for the installation of two groundwater monitoring wells was submitted (SNL/NM September 2013), and in June 2014 the work plan was approved by the NMED (NMED June 2014). The work plan discussed the need for installing two replacement monitoring wells (CYN-MW14 and CYN-MW15) because of declining groundwater levels. Monitoring well CYN-MW14 was planned to replace CYN-MW3, whereas monitoring well CYN-MW15 was planned to replace CYN-MW6. In December 2014, monitoring wells CYN-MW14A (note the ‘A’ suffix) and CYN-MW15 were installed (SNL/NM April 2015). The installation of a direct replacement for monitoring well CYN-MW3 was not possible because the shallow water-bearing fracture zone was not encountered. A deeper-than-planned well, CYN-MW14A, was installed near CYN-MW3. The replacement monitoring well, CYN-MW15, was installed as planned (at a similar to slightly deeper water-bearing fracture depth) near well CYN-MW6.

In October 2013, DOE Office of Environmental Management submitted the BSG AOC Internal Remedy Review memorandum to the DOE/NNSA Sandia Field Office (DOE October 2013). This memorandum stated that more characterization activities should be conducted at the BSG AOC before a CME could be prepared. The Internal Remedy Review recommended a weight of evidence approach to determine the source(s) of nitrate contamination.

In January 2019, a work plan for the installation of up to eight groundwater monitoring wells was submitted (SNL/NM January 2019), and in February 2019 the work plan was approved by the NMED (NMED February 2019). Based on NMED requirements (NMED June 2018), the work plan discussed the need for installing four monitoring wells (CYN-MW16, CYN-MW17, CYN-MW18, and CYN-MW19) to help define the extent of nitrate concentrations in groundwater and refine the potentiometric surface. Specifically, these monitoring wells were required to define the upgradient and downgradient extent of the elevated nitrate plus nitrite (NPN) concentrations and provide information on the 2,000-ft data gap between existing monitoring wells CYN-MW14A and CYN-MW13. Groundwater monitoring wells CYN-MW16, CYN-MW17, CYN-MW18, and CYN-MW19 were installed during 2019. The potential installation of up to four additional monitoring wells (SNL/NM January 2019) was evaluated after the July 2021 sampling event when eight quarters of water level and validated analytical sample data were available. DOE/NNSA and SNL/NM personnel proposed to the NMED that the existing monitoring well network was sufficient to characterize the extent of nitrate contamination (DOE November 2021) and the NMED agreed that the four additional monitoring wells were not required at this time (NMED December 2021).

The Consent Order (NMED April 2004) requires completion of a CME Report for the BSG AOC. The Consent Order stipulated that the DOE/NNSA and its Management and Operating (M&O) contractor for SNL/NM prepare a CCM to support a CME Report that would present remedial alternatives. The CCM objective is to provide NMED with sufficient information characterizing the hydrogeologic setting to allow DOE/NNSA and the M&O contractor for SNL/NM to proceed with preparing the CME Report. As determined in 2021 (DOE November 2021 and NMED December 2021), the groundwater monitoring well network at the BSG AOC is sufficient to propose a corrective action for the nitrate-impacted groundwater.

Appendix A provides a Historical Timeline for the BSG AOC, which lists various compliance plans, reports, and activities up through December 2021. SNL/NM's Annual Groundwater Monitoring Reports (AGMRs) routinely report ongoing groundwater monitoring activities. The Calendar Year (CY) 2021 report was submitted to the NMED in July 2022 (SNL/NM June 2022) and approved in October 2022 (NMED October 2022).

1.2 Objectives

This CCM/CME Report presents an updated Conceptual Site Model (CSM) of the BSG AOC that describes the geological and hydrogeological setting, the contaminant release sites, and the distribution and migration of contaminants in the subsurface. This CCM/CME Report also presents an evaluation of potential corrective measures to address nitrate-impacted groundwater. The dataset used for this CCM/CME Report includes the analytical results for groundwater samples collected through the end of December 2021. Subsequent sampling results will be presented in future AGMRs.

1.3 Organization

The Consent Order identified characterization requirements for satisfactorily evaluating the hydrogeologic setting for the BSG AOC and identified the required elements of the CME Report (NMED April 2004). This CCM/CME Report is organized into nine sections:

- Section 1.0: Introduction,
- Section 2.0: Regional Geology and Hydrogeology,
- Section 3.0: Geology and Hydrogeology of the BSG AOC,
- Section 4.0: Site History, Corrective Actions, and Potential Release Sites,
- Section 5.0: Groundwater Monitoring at the BSG AOC,
- Section 6.0: Conceptual Site Model,
- Section 7.0: Corrective Measures Evaluation,
- Section 8.0: Conclusions, and
- Section 9.0: References.

This CCM/CME Report also includes supporting information in the form of 12 appendices (Appendices A through L) and 3 attachments (Attachments 1 through 3). Table 1-1 summarizes the Consent Order requirements and lists the corresponding sections in this CCM/CME Report. This report for the BSG AOC follows the organization used in the NMED-approved *Revised Tijeras Arroyo Groundwater CCM/CME Report* (SNL/NM February 2018).

Table 1-1. Cross Walk of Consent Order (NMED April 2004) Requirements versus this CCM/CME Report

Site Characterization (CCM) Requirements from Section IV.C of the Consent Order	CCM/CME Report Sections
1. Nature, rate of transport, and extent of contamination	5.0 Groundwater Monitoring at the BSG AOC
2. Aquifer boundaries	3.3 Hydrogeologic Conditions at the BSG AOC
3. Depth to water, water levels, water table, potentiometric surface, and any seasonal variations	3.3 Hydrogeologic Conditions at the BSG AOC
4. Flow directions and velocities	3.3 Hydrogeologic Conditions at the BSG AOC
5. Geologic, hydrostratigraphic, and structural relationships	3.1 Geologic Setting of BSG AOC Vicinity
6. Water supply well pumping influences, seasonal pumping rates, and annual amounts of water withdrawn	3.4.4 Local Discharge and Production Wells
7. Saturated hydraulic conductivity, porosity, effective porosity, permeability, transmissivity, particle size, storage coefficients, and estimated fracture/secondary porosity	3.3 Hydrogeologic Conditions at the BSG AOC
8. Contaminant concentrations in soil, rock, sediment, and water (as appropriate)	5.2 Nature and Extent of Contamination
9. General water chemistry	3.5 Groundwater Geochemistry
CME Report Requirements from Section X.F of the Consent Order	**CCM/CME Report Sections**
I. Title Page and Signature Block	Title Page and Transmittal Letter
II. Executive Summary	Executive Summary
III. Table of Contents	Table of Contents
IV. Figures	Incorporated into applicable sections of text
V. Tables	Incorporated into applicable sections of text
VI. Introduction	1.0 Introduction
VII. Background Information	2.0 Regional Geology and Hydrogeology
VIII. Site Conditions	3.0 Geology and Hydrogeology of the BSG AOC 4.0 Site History, Corrective Actions, and Potential Release Sites 5.0 Groundwater Monitoring at the BSG AOC
IX. Potential Receptors	6.0 Conceptual Site Model
X. Regulatory Criteria	1.1 BSG Background and Status of the CCM and CME Report
XI. Identification of Corrective Measure Options	7.1 Remedial Technology Identification and Screening 7.2 Description of Remedial Alternatives
XII. Evaluation of Corrective Measure Options	7.3 Evaluation of Remedial Alternatives
XIII. Selection of Preferred Corrective Measure	7.4 Preferred Remedy
XIV. Design Criteria to Meet Cleanup Objectives	7.5 Remedial Alternative Design Criteria
XV. Schedule	7.6 Corrective Measures Implementation Plan
XVI. Appendices	Appendices A – L, and Attachments 1 – 3

NOTES:
AOC = Area of Concern.
BSG = Burn Site Groundwater.
CCM = Current Conceptual Model.
CME = Corrective Measures Evaluation.
Consent Order = Compliance Order on Consent.
NMED = New Mexico Environment Department.

2. REGIONAL GEOLOGY AND HYDROGEOLOGY

This section summarizes the regional geologic and hydrogeologic setting near the BSG AOC. Site-Wide Hydrogeologic Characterization Project (SWHC) reports describe the regional hydrology near SNL/NM (SNL/NM February 1998 and February 2001). Portions of the material presented below were obtained from the CY 2021 AGMR (SNL/NM June 2022), combined with a current understanding of the site-specific conditions.

2.1 Regional Geologic Setting

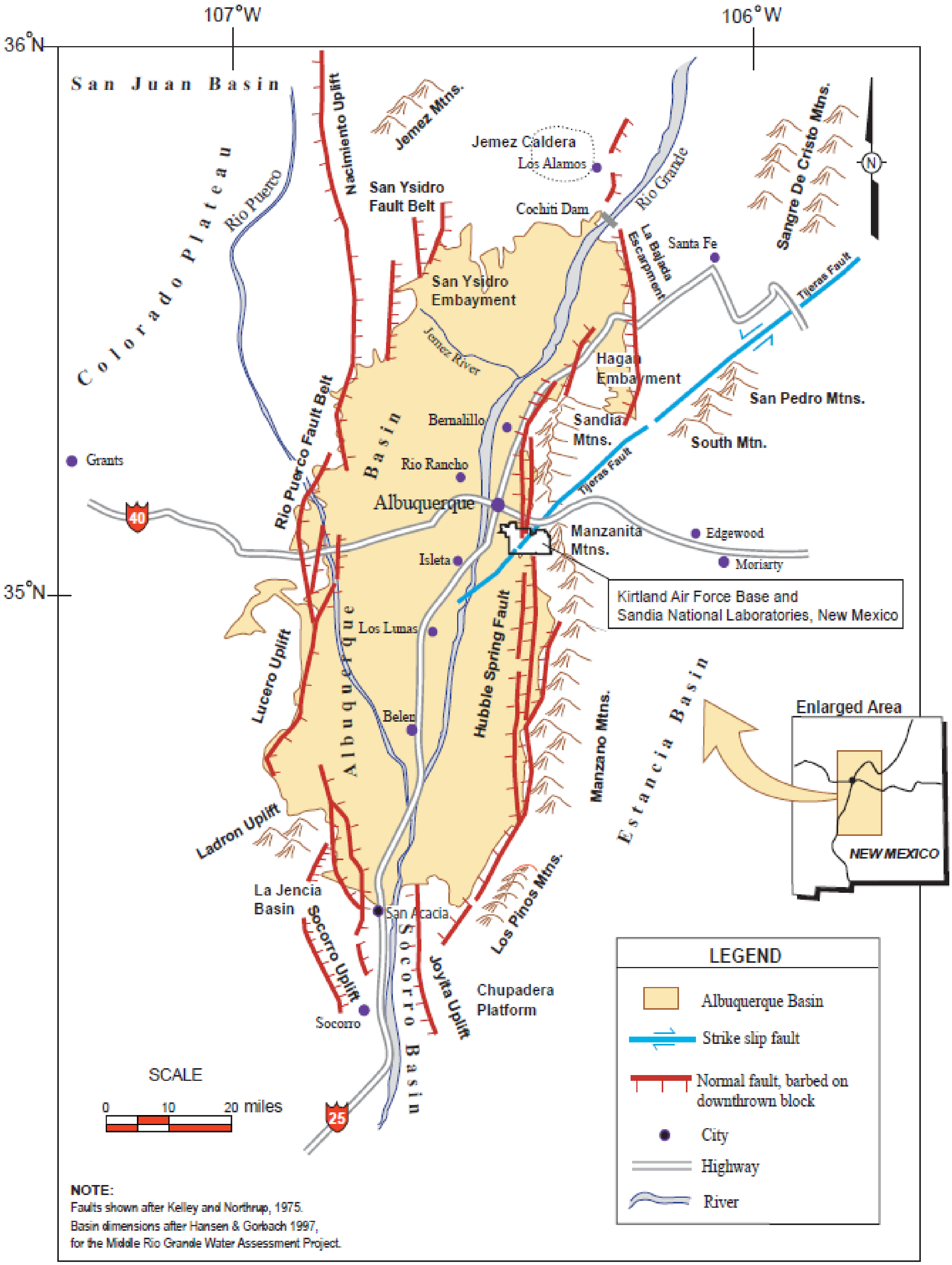
SNL/NM is located near the east-central edge of the Albuquerque Basin (SNL/NM June 2022). The Albuquerque Basin (also known as the Middle Rio Grande Basin) is one of a series of north-south–trending basins formed during the extension of the Rio Grande Rift. The basin is approximately 70 miles long and up to 40 miles wide near the center of the basin (~3,000 mi^2), and the City of Albuquerque and KAFB rely heavily on this basin's groundwater as their principal water supply. Rift formation began in the late Oligocene and continued into the early Pleistocene, with the primary period of extension occurring between 30- and 5-million years ago. Tectonic activity, which began uplifting the Sandia, Manzanita, and Manzano Mountains, was most prevalent from about 15- to 5-million years ago (Thorn et al. 1993). The rift today extends from central Colorado to northern Mexico. The vertical displacement between the rock units exposed at the top of Sandia Crest, and the equivalent units located at the bottom of the Albuquerque Basin, is more than 3 miles.

Figure 2-1 shows the structural boundaries of the Albuquerque Basin are as follows:

- Colorado Plateau on the west,
- Nacimiento uplift and the Jemez Mountains to the north,
- La Bajada Escarpment to the northeast,
- Sandia, Manzanita, Manzano, and Los Pinos Mountains to the east,
- Joyita and Socorro uplifts to the south, and the
- Ladron and Lucero uplifts to the southwest.

As the Rio Grande Rift continued to expand, the Albuquerque Basin subsided. The Ancestral Rio Grande meandered across the valley formed by the subsidence and deposited sediments in broad stream channels and floodplains. The basin also filled with aeolian deposits and alluvial materials shed from surrounding uplifts (Hawley and Haase 1992). This sequence of sediments is called the Santa Fe Group (SFG). The thickness of the SFG is up to 16,400 ft at the deepest part of the basin (Lozinsky 1994). The entire sequence consists of unconsolidated sediments, which thin toward the edge of the basin and are truncated by normal faults at the basin-bounding uplifts (Hawley January 2016).

Units overlying the SFG include Pliocene Ortiz gravel and Rio Grande fluvial deposits interbedded with Tertiary and Quaternary basaltic and pyroclastic materials. Based on recent geophysical models, the Albuquerque Basin has been further divided into three, 2 to 4 miles deep, interconnected structural depressions from north to south: Santo Domingo, Calabacillas, and Belen sub-basins. KAFB lies near the intersection of the Calabacillas and Belen sub-basins along a broad, northwest elongate structural high called the Mountainview prong that separates the two sub-basins (Grauch and Connell 2013). These tectonic/sedimentation features contribute greatly to the complex structural setting described below.



NOTE:
Faults shown after Kelley and Northrup, 1975.
Basin dimensions after Hansen & Gorbach 1997, for the Middle Rio Grande Water Assessment Project.

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Figure 2-1. Principal Geologic Features of the Albuquerque Basin

Figure 2-2 shows the four primary faults on the east side of KAFB are: (1) the Sandia Fault, (2) the buried West Sandia Fault with no surface expression, (3) the Hubbell Spring Fault (West, Central, and East fault segments), and (4) the Tijeras Fault.

The primary structural boundary between the Sandia/Manzanita Mountains and the Albuquerque Basin is the Sandia Fault. The Hubbell Spring Fault extends northward from Socorro County and terminates on KAFB near the Tijeras Fault. The Sandia Fault and the Hubbell Spring Fault are north-south-trending, down-to-the-west, *en echelon* normal faults bounding the east margin of the Albuquerque Basin.

The Tijeras Fault is an ancient strike-slip fault that developed in the Precambrian or early Paleozoic (approximately 600-million years ago) Periods and reactivated in association with the Laramide Orogeny during the Cretaceous Period (Kelley 1954). The fault also demonstrates Quaternary movement at locations 20 to 30 miles northeast of KAFB (Kelson et al. 1999, and SNL/NM February 1998). This fault has been traced as far north as Madrid, New Mexico, and continues into the Sangre de Cristo Mountains as the Cañoncito Fault. Preferential erosion along the fault formed Tijeras Canyon, which divides the Sandia and Manzanita Mountains. The fault trends southwest from Tijeras Canyon, intersects the northeast boundary of KAFB, and crosses KAFB east and south of Manzano Base. Manzano Base occupies an uplift of four peaks defined by the Tijeras Fault on the east side and the Sandia Fault on the west side. The Sandia, Hubbell Spring, and Tijeras Faults converge near the southeast end of TA-III. This complicated system of faults, defining the east edge of the basin, is referred to collectively as the Tijeras Fault Complex.

2.2 Regional Hydrogeologic Setting

Figure 2-3 shows the three distinct hydrogeologic regions for the KAFB area: (1) the Albuquerque Basin, (2) the Tijeras Fault Complex, and (3) the Foothills and Canyons Area. The Tijeras Fault Complex is a transitional zone between the Regional Aquifer of the Albuquerque Basin and the fractured bedrock aquifer system in the Foothills and Canyons Area. The BSG AOC lies solely within the fractured bedrock aquifer system east of the fault system in the Foothills and Canyons Area. The aquifer is characterized by fracture flow in Paleozoic and Precambrian lithologies. The Albuquerque Basin and the Tijeras Fault Complex hydrologic regions are downgradient and have little bearing on the BSG AOC, therefore, are only briefly discussed in this CCM/CME Report.

East of the Tijeras Fault Complex, a thin layer of alluvium covers Pennsylvanian and Precambrian bedrock, which has been fractured due to multiple stages of regional deformation. The depth-to-groundwater ranges from about 45 to 360 ft below ground surface (bgs). Groundwater occurs in the fractured bedrock on the east side of KAFB and well yields are relatively low. Groundwater generally flows westward from the canyons toward the Tijeras Fault Complex and eventually into the Albuquerque Basin. The groundwater gradient is relatively steep across the Tijeras Fault Complex, which suggests that westward groundwater flow into the Albuquerque Basin is restricted.

Downgradient of the BSG AOC, groundwater flows within the sediments of the Albuquerque Basin where the hydraulic gradient of the Regional Aquifer is relatively low. The historical direction of regional groundwater flow within the basin was westward from the mountains toward the Rio Grande. However, groundwater pumping at KAFB, Veterans Administration (VA), and Albuquerque Bernalillo County Water Utility Authority (ABCWUA) production wells, located near the northern boundary of KAFB, have created a broad trough in the potentiometric surface 7 to 8 miles west of the BSG AOC along the western boundary of KAFB.

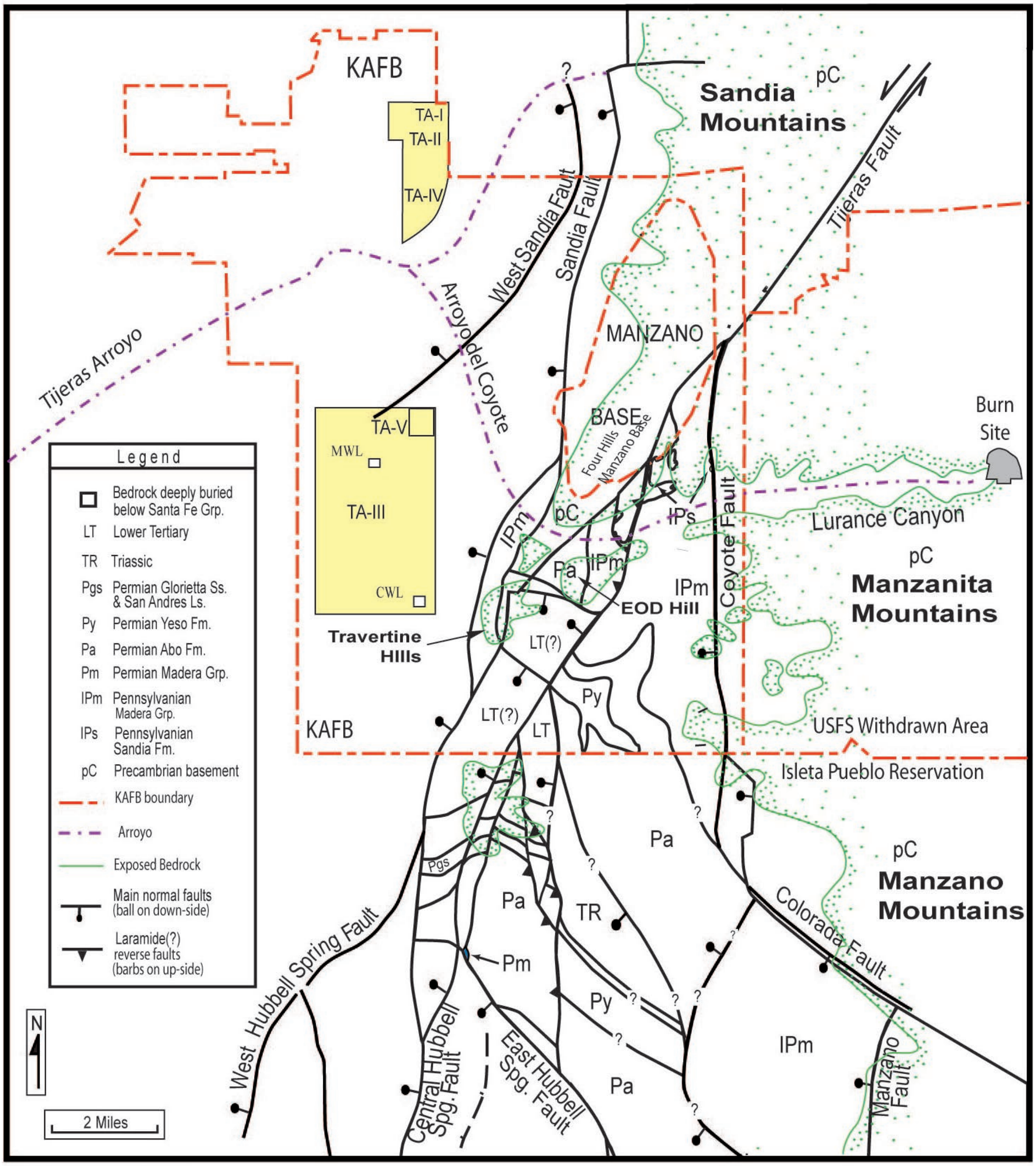

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Figure 2-2. Generalized Geology near SNL/NM and KAFB (Van Hart 2003)

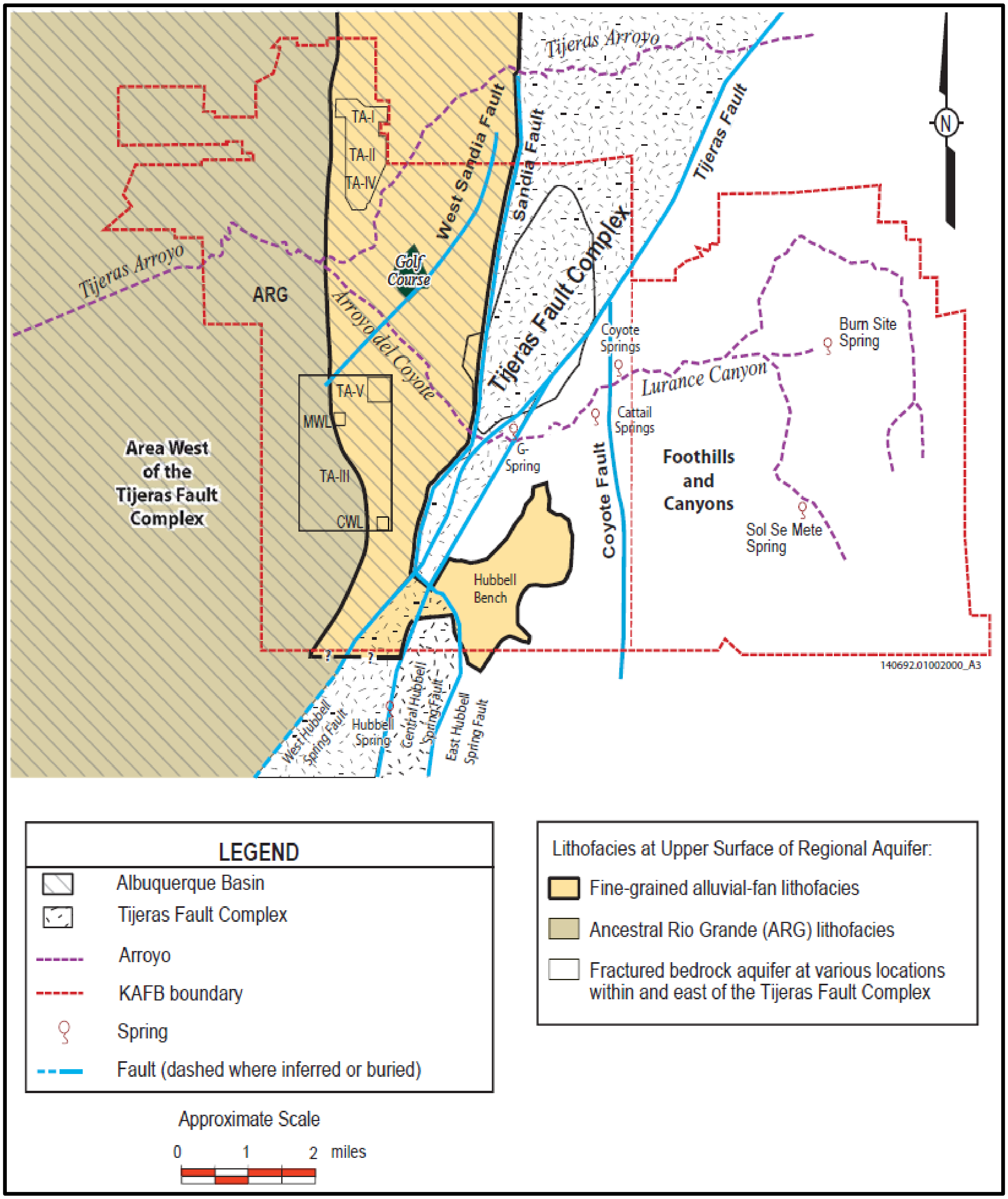


Figure 2-3. Hydrogeologically Distinct Regions near KAFB (SNL/NM June 2022)

2.3 Regional Stratigraphic and Structural Framework

The BSG AOC is in Lurance Canyon, within the Manzanita Mountains east of the Albuquerque Basin of the Rio Grande Rift. The geologic and hydrologic conditions of the Manzanita Mountains form the regional context of local groundwater flow and contaminant migration at the BSG AOC.

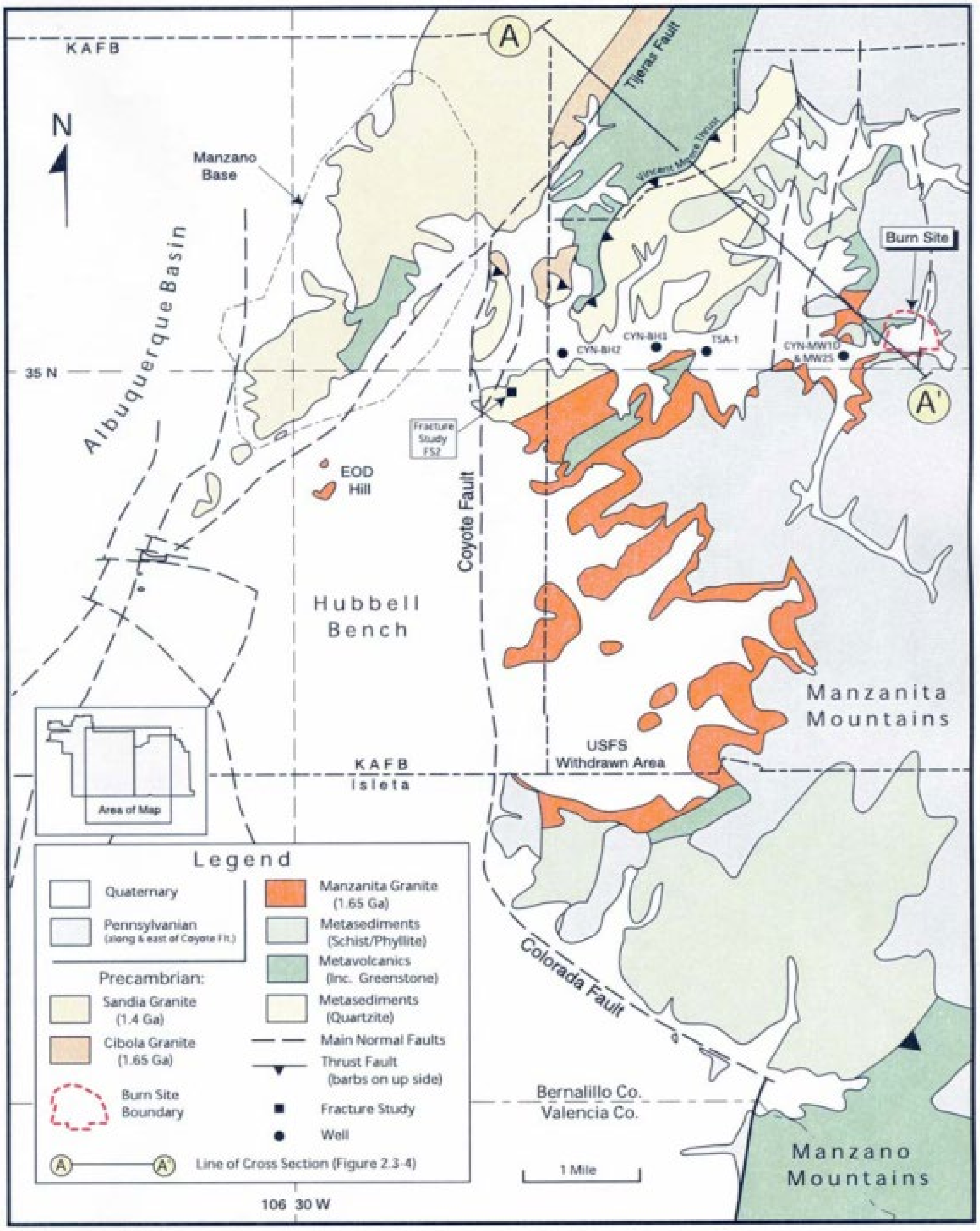
The Manzanita Mountains include a complex sequence of uplifted Precambrian metamorphic and granitic rocks (Figure 2-4) that were subjected to significant deformation throughout geologic history. These rocks are capped by Paleozoic sandstones, shales, and limestones of the Sandia Formation and Madera Formation. The following discussion of the geologic history of the Manzanita Mountains is derived from the description presented in the "*Groundwater Investigation Canyons Test Area, Operable Unit 1333 Burn Site, Lurance Canyon*" (SNL/NM November 2001) and utilizes the Precambrian tectonic model presented by Brown et al. (1999). The detailed discussion of site geology presented in the SNL/NM November 2001 report is included as Attachment 1.

A sequence of sedimentary and volcanic rocks was deposited approximately 1.7 giga-annum (Ga) in the region around what is now north-central New Mexico. These rocks subsequently were deformed through northwest compression and overthrust. This compression was followed by continued deformation and regional metamorphism. The Manzanita Pluton was intruded 1.65 Ga. This magmatic intrusion was accompanied by continuing deformation. Approximately 1.4 Ga, a renewal of the northwest thrust resulted in activation of shear zones and emplacement of the Sandia granitic pluton to the north. Deformation from compression and intrusion fractured the metamorphic rocks and developed sets of north-trending normal faults subsidiary to thrust and shear zones. Subsequent uplift and erosion over the next billion years resulted in a beveled surface of low elevation.

Approximately 300 mega-annum (Ma), regional subsidence resulted in transgression of Pennsylvanian seas and deposition of a sedimentary sequence of sandstones, shales, and limestones. The region was uplifted approximately 40 Ma during the northeast-directed Laramide compressive event. Approximately 26 Ma, east-west continental tensional forces initiated opening of the Rio Grande Rift across New Mexico. The rift was delineated by a series of basins, including the Albuquerque Basin. Continued basin development was accompanied by deposition of a thick sequence of unconsolidated alluvial deposits to the west of the BSG AOC. Continental tensional forces also lowered the erosional base for flanking uplands, permitting cliff retreat to the east across the Hubbell Bench resulting in the present-day geomorphic architecture of the Manzanita Mountains.

2.4 Regional Hydrology

Groundwater in the western Manzanita Mountains largely occurs in the fractured Precambrian metamorphic and intrusive rocks and in fractured Pennsylvanian sedimentary rocks. Precambrian rocks include metavolcanics, quartzite, metasediments, and the Manzanita Granite. Pennsylvanian sedimentary rocks consist of the Sandia Formation and Madera Formation. Groundwater in these rocks moves primarily as flow through fractures. The permeability of these fractured rocks characteristically is low and well yields are small.



From SNL/NM November 2001; modified from Karlstrom et al. (1994), and Myers and McKay (1970).

Figure 2-4. Regional Geology of the BSG AOC

The fractured rocks of the Manzanita Mountains are recharged by infiltration of precipitation, largely occurring in summer thundershowers and, to a lesser degree, from limited winter snowfall on the higher elevations. Recharge is restricted by high evapotranspiration rates (losses to the atmosphere by evaporation and plant transpiration) and low permeability of the metamorphic rocks.

Groundwater in the western Manzanita Mountains moves generally to the west (Figure 2-5) from a groundwater flow divide located east of the BSG AOC (SNL/NM November 2001). On the eastern side of that divide, groundwater discharges to the east into the neighboring Estancia Basin. Westward groundwater flow across the BSG AOC discharges primarily as direct underflow to the unconsolidated basin-fill deposits of the Albuquerque Basin. Based on field observations, some discharge occurs at springs along the mountain front. Much of the flow that discharges from these springs is likely lost to the atmosphere through evapotranspiration. Some flow from the springs locally infiltrates nearby alluvial deposits.

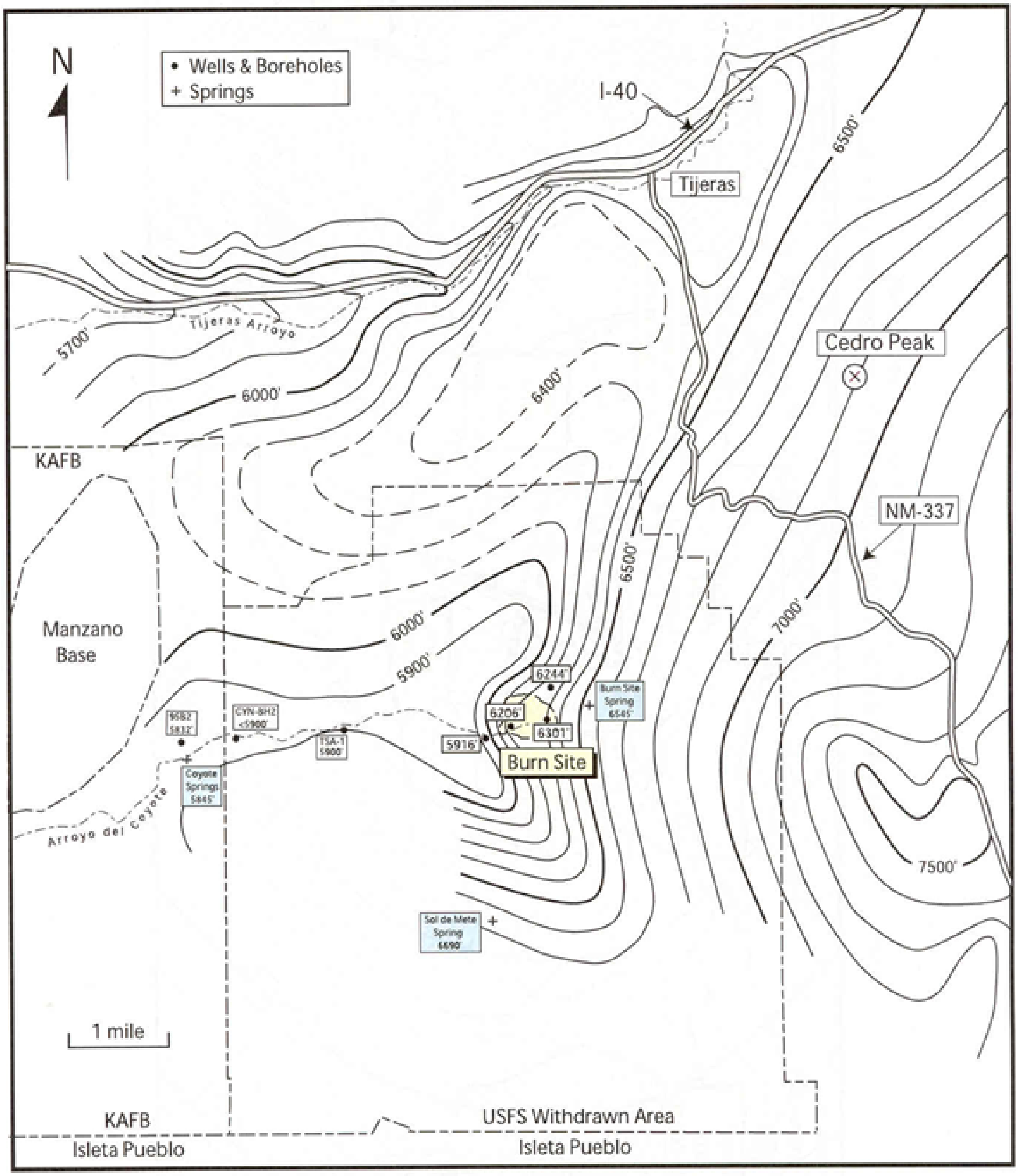
The regional potentiometric surface map (Figure 2-5) indicates that the generally westward flow direction locally may be modified by topographic features. Deeply incised canyons may provide local points of discharge through fault zones where the potentiometric surface intersects the canyon floor.

The Rio Grande, located approximately 15 miles west of the BSG AOC, is the major surface water (hydrologic) feature in central New Mexico. The Rio Grande originates in Colorado’s San Juan Mountains and terminates at the Gulf of Mexico, near Brownsville, Texas. The Rio Grande has a total length of 1,900 miles and is ranked as the fourth longest river system in the United States, but its meager and discontinuous flow in some stretches negates the river from being realistically ranked concerning discharge (U.S. Geological Survey [USGS] May 1990).

Surface water (except for a few springs) within the boundaries of KAFB is found only as ephemeral streams (arroyos) that flow for short periods due to runoff from thunderstorms. Occasionally, flow occurs after the spring melt of mountain snowpack. The primary surface water feature that drains the eastern foothills on KAFB is the Tijeras Arroyo. The BSG AOC lies within the Arroyo del Coyote drainage system that joins Tijeras Arroyo approximately 7 miles west of the BSG AOC (Figure 2-3). In the Manzanita Mountains headwaters to the east, the Arroyo del Coyote splits into three large canyons: Madera Canyon from the north, Sol se Mete Canyon from the south, and Lurance Canyon from the east. The BSG AOC is wholly within the Lurance Canyon drainage. Both Tijeras Arroyo and Arroyo del Coyote carry significant runoff after heavy thunderstorms that usually occur from June through September.

The Tijeras Arroyo, above the confluence with Arroyo del Coyote, drains about 80 mi^2, while Arroyo del Coyote drains about 39 mi^2 on KAFB (U.S. Army Corps of Engineers 1979). The total watershed for Tijeras Arroyo, which includes the Sandia and Manzanita Mountains and eastern portion of KAFB, is approximately 126 mi^2.

The Tijeras Arroyo/Arroyo del Coyote system is the most significant surface water drainage feature on KAFB and trends southwest across KAFB and eventually drains into the Rio Grande, approximately 3 miles west of KAFB. Surface water flows in the arroyo system several times per year because of significant thunderstorms. The average annual precipitation for the region, as measured at Albuquerque International Sunport, is 8.84 inches per year (30-year norm based on 1991 – 2020 data) (SNL/NM June 2022). During most rainfall events, rainfall quickly infiltrates into the soil and bedrock fractures in the study area. However, virtually all moisture subsequently undergoes evapotranspiration.



From SNL/NM November 2001, with northern and eastern parts adapted from Titus (1980).

Figure 2-5. Generalized Potentiometric Surface for the BSG AOC and Surrounding Region

Figure 2-6 shows several springs on KAFB associated with the uplifts in the Tijeras Fault Complex and Foothills and Canyons Hydrogeologic Area, including: (1) Coyote Springs, Cattail Spring, and G-Spring within Arroyo del Coyote, (2) Burn Site Spring in Lurance Canyon, and (3) Sol se Mete Spring within the Manzanita Mountains. Coyote Springs and Sol se Mete are perennial springs (continuously flowing), while the others are ephemeral. The wetland areas created by these springs, though very limited in extent, provide a unique ecological niche in an otherwise arid habitat.

2.5 Regional Recharge and Discharge

Regional recharge occurs from infiltration of stream flow from the Rio Grande and arroyos, from infiltration of areal precipitation, and from underflow originating from mountain front recharge. On KAFB, Tijeras Arroyo and Arroyo del Coyote provide limited recharge, as does mountain-front recharge. The amount of recharge occurring in the foothills and canyons is not well characterized. The estimated recharge for that portion of Tijeras Arroyo on KAFB is estimated to be up to 2.2 million cubic ft per year (ft/yr) (50-acre ft/yr). The best estimate for the groundwater recharge associated with Arroyo del Coyote is 0.4 million cubic ft/yr (9.2-acre ft/yr). Infiltration studies conducted by the SWHC Project (GRAM and Lettis December 1995) determined that recharge is negligible from areal precipitation due to the high rate of evapotranspiration (95 to 99 percent [%]) for most areas on KAFB, especially on alluvial fan slopes and other relatively flat areas.

Prior to development of water resources in the Albuquerque area, groundwater flow in the Albuquerque Basin was generally from the north to the south paralleling the Rio Grande (Bartolino and Cole 2002). Beneath KAFB, the predominant groundwater flow was westward prior to water resources development. As the Regional Aquifer was developed as a source for municipal and industrial water supplies, the natural groundwater flow directions were significantly altered toward production wells to the northeast. Regional discharge from the BSG AOC occurs as groundwater moves out of the fractured bedrock aquifer system into the Albuquerque Basin and then into downgradient basins in the Rio Grande Rift as underflow or through discharge to the Rio Grande.

Figure 2-6 shows the locations of production wells that pump groundwater from the Regional Aquifer west of the BSG AOC. In CY 2021, KAFB operated six production wells (KAFB-3, KAFB-4, KAFB-14, KAFB-15, KAFB-16, and KAFB-20) for potable water-supply purposes (SNL/NM June 2022). The nearest potable production well to the BGS AOC is KAFB-4 and it is approximately 9 miles from the AOC. By far the greatest volumes of groundwater produced in CY 2021 were from KAFB-3, KAFB-4 and KAFB-20. The VA operated production well VA-2 for potable water-supply purposes. The ABCWUA also operated production wells such as Ridgecrest 1 and Ridgecrest 2 near the northern edge of KAFB. The base-wide potentiometric surface map (referred to as “Plate 1”) in the CY 2021 AGMR (SNL/NM June 2022) also shows the effect of drawdown across the western portion of KAFB.

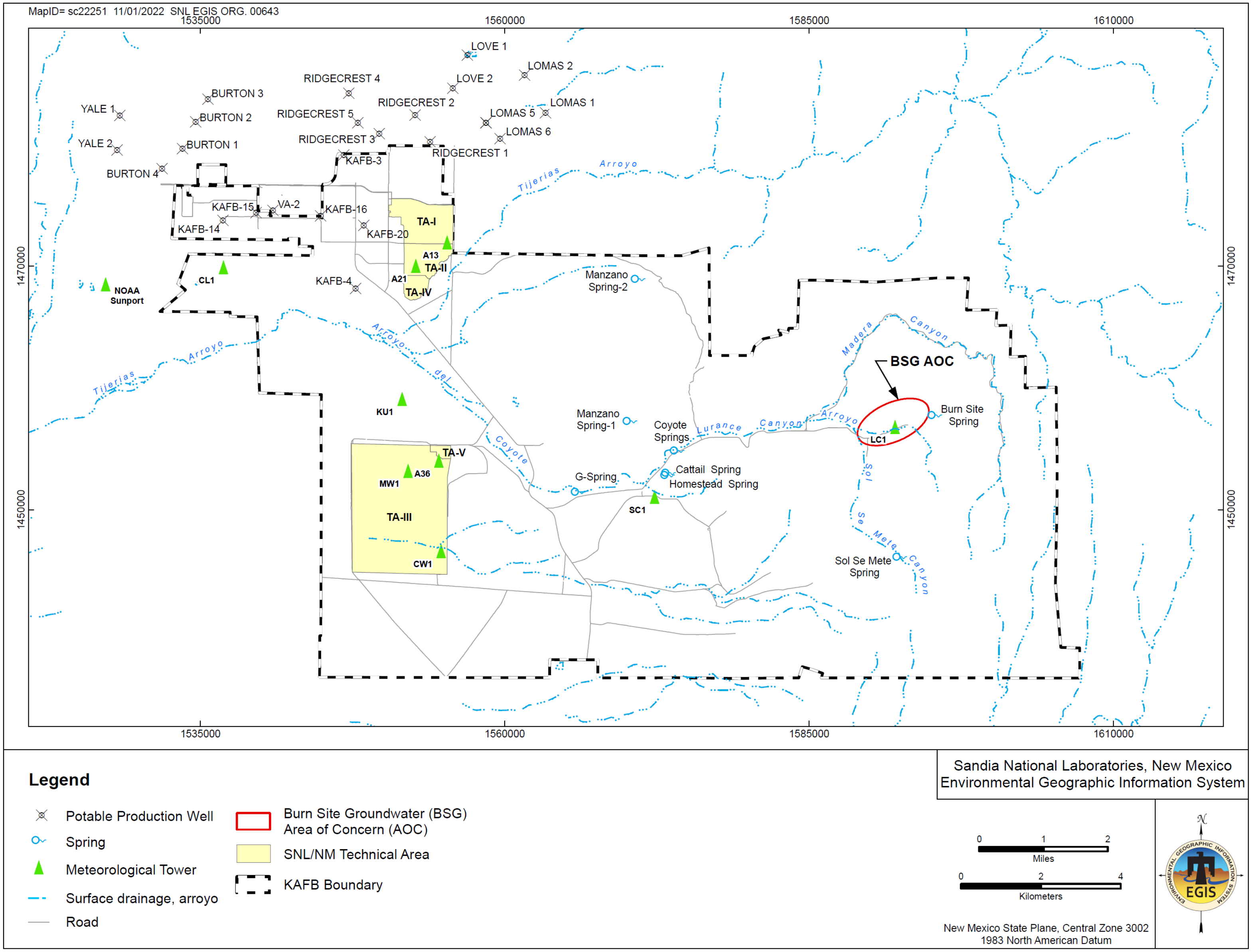


Figure 2-6. KAFB, VA, and ABCWUA Potable Production Wells and Springs Near and Downgradient of the BSG AOC

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3. GEOLOGY AND HYDROGEOLOGY OF THE BSG AOC

This section discusses the geologic setting, monitoring well network, hydrogeologic setting, geochemical setting, and other environmental factors for the BSG AOC.

3.1 Geologic Setting of BSG AOC Vicinity

The SWHC Project at SNL/NM provided the framework for the geologic and hydrogeologic interpretation of the BSG AOC (GRAM and Lettis December 1995 and SNL/NM February 1998). Hydrogeologic characteristics specific to the BSG AOC were presented in the 2001 report titled *Groundwater Investigation, Canyons Test Area, Operable Unit 1333, Burn Site, Lurance Canyon* (SNL/NM November 2001) and the 2008 *Current Conceptual Model of Groundwater Flow and Contaminant Transport at Sandia National Laboratories/New Mexico Burn Site* (SNL/NM April 2008a). The geologic information used to better define the site geology included geologic mapping of surficial and bedrock deposits, borehole geologic descriptions from cuttings and cores, and borehole video logs.

3.1.1 Structural Framework

The Precambrian geology is extremely complex and is documented in detail in the 2001 *Groundwater Investigation, Canyons Test Area, Operable Unit 1333, Burn Site, Lurance Canyon* (SNL/NM November 2001) which is provided as Attachment 1 of this CCM/CME Report. Since the Precambrian, a billion years of uplift and erosion resulted in a beveled surface of low elevation. Regional subsidence about 300 Ma allowed the Pennsylvanian seas to transgress over the low-relief Precambrian terrain and to deposit an epicontinental sedimentary sequence. The area was uplifted again during the northeast-directed Laramide compressive event at around 40 Ma.

By 26 Ma, regional tension was initiated by plate-tectonic effects propagating eastward from the western margin of the North American continent. The tension was accommodated in New Mexico by clockwise rotation of the Colorado Plateau away from the Stable Interior, the resultant opening of the Rio Grande Rift, and the lowering of erosional base level for the flanking uplands. Subsequent cliff retreat to the east across the Hubbell Bench resulted in the present architecture of the Manzanita Mountains. The geometry of the west-east rift-related foundering of the Precambrian basement and its Phanerozoic cover was in part influenced by the Precambrian and Laramide structural grains, but many north-south trending normal faults sliced across the grain of diverse rock suites at high angles.

3.1.2 Stratigraphic Framework

The Manzanita Mountains are underlain by a complex sequence of Precambrian igneous and metamorphic rocks, unconformably capped by Pennsylvanian-age sedimentary rocks, which in turn are unconformably overlain by Quaternary unconsolidated deposits. Fractured Precambrian rocks contain the groundwater at the BSG AOC, and these units are therefore the focus of this CCM/CME Report. Surface bedrock control is documented on the geologic map of the Tijeras Quadrangle (Karlstrom et al. 2000) with the BSG AOC located near the southeastern corner of the Tijeras Quadrangle. Geologic context south of the BSG AOC is provided by the geologic map of the Mount Washington Quadrangle (Chamberlin et al. 2002). The portion of the Tijeras Quadrangle is presented along with site features in Figure 3-1. The detailed lithologic descriptions of the mapping units in Figure 3-1 are provided in Appendix B and briefly described in this section.

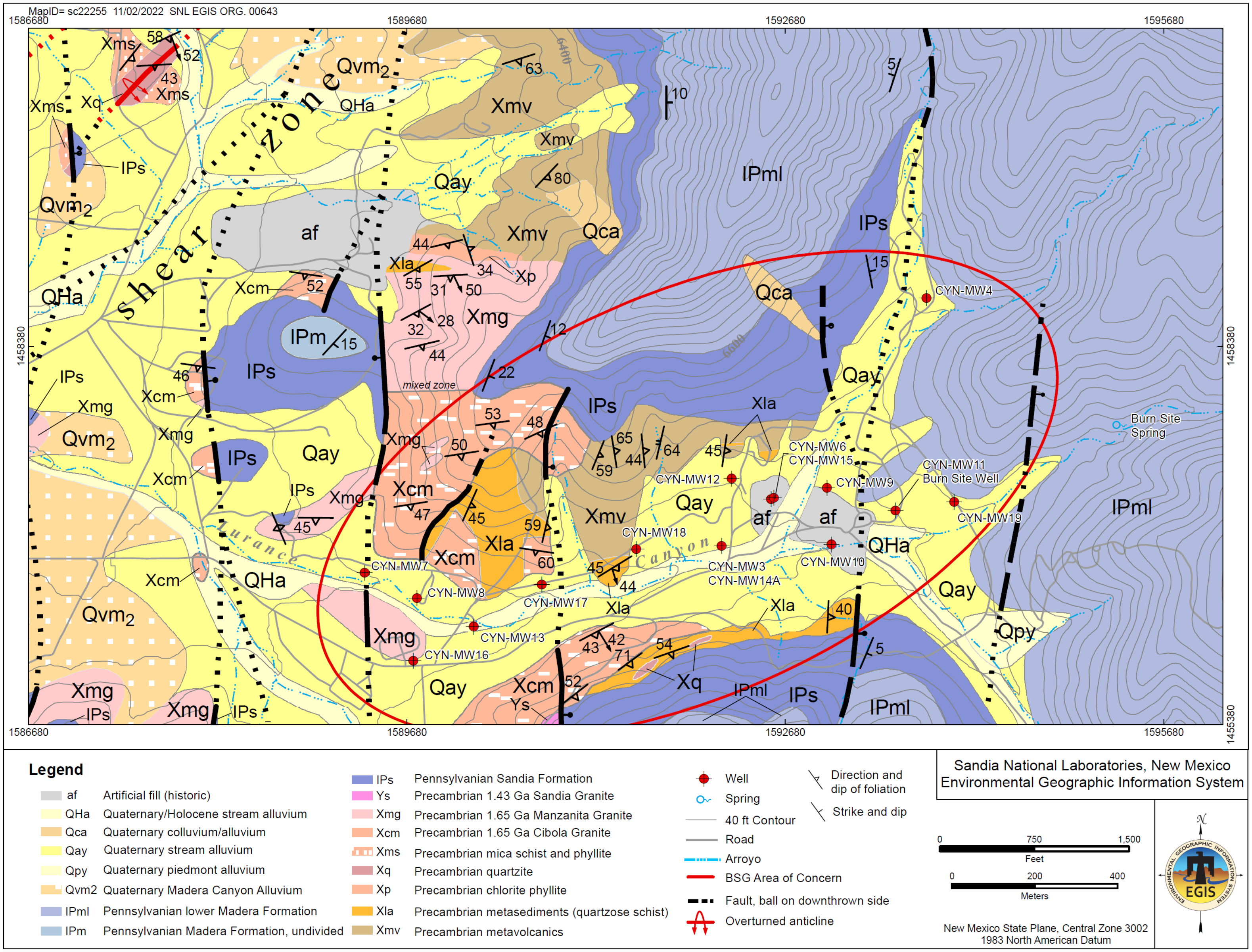


Figure 3-1. Geologic Map of the BSG AOC (from Karlstrom et al. 2000)

Subsurface geologic control was determined from data collected during installation of the monitoring well network and formed the basis of the east-west fence diagram presented as Figure 3-2. The detailed borehole lithologic descriptions of the monitoring wells are provided in Appendix C.

3.1.2.1 Unconsolidated Deposits

The detailed lithologic descriptions of the mapped unconsolidated deposits in the BSG AOC are provided in Appendix B. These deposits consist of thin Quaternary surficial sediments derived from wind (eolian) and mass-movement processes (colluvial/landslide). Also included are anthropogenic deposits which are found in areas disturbed by open pit aggregate mining or construction (Karlstrom et al. 2000).

Unconsolidated deposits unconformably overlie pre-Cenozoic rocks. Colluvium and alluvium consist of poorly consolidated, poorly sorted and stratified, fine- to coarse-grained, clast- and matrix-supported deposits derived from a variety of mass-movement hill slope processes, including debris flow, shallow slumping, and creep. Alluvium can be found in entrenched arroyos and streams originating in the Manzanita Mountains. Gravel clasts are typically angular to subangular, and composition reflects local provenance such as limestone, metarhyolite, granitic gneiss, and quartzite.

These unconsolidated deposits can range up to 50 ft thick in the central part of the Lurance Canyon Burn Site Test Facility, but the sediments thin quickly towards the canyon walls where they are bounded by exposures of bedrock. Considerable amounts of eolian material (well sorted fine-grained sand) are found along the active channel of Lurance Canyon Arroyo west of monitoring well CYN-MW10. Presumably these eolian sands were derived from wind events in the Albuquerque Basin to the west of the BSG AOC.

The artificial fill mapping unit consists of historically dumped fill and areas affected by human disturbances. This unit is mapped where disturbed lands are areally extensive or geologic contacts are obscured. The main portion of the Lurance Canyon Burn Site Testing Facility near monitoring wells CYN-MW9, CYN-MW10, and CYN-MW15 are mapped as artificial fill (Figure 3- 1).

Soils developed on unconsolidated deposits can locally range from weakly developed to exhibiting Stage I to Stage III carbonate morphology. Two soil types are present in the BSG AOC that have formed on unconsolidated deposits and bedrock outcrops (IT May 1994). Soils along the arroyo channel and on which the testing facility was constructed are classified as the Tesajo-Millett stony-sandy loams, which exhibit high runoff characteristics and an estimated permeability of 0.6 to 20.0 inches per hour. Soils on the surrounding steeper terrain are classified as the highly variable Rock outcrop - Orthids complex where limestone, sandstone, phyllite/schist, or granitic gneiss rocks are exposed. This soil exhibits high runoff characteristics and is believed to have low permeability (IT May 1994). Vegetation supported by these soil types is sparse and consists of club cholla, soapweed yucca, prickly pear cacti, and scattered bunch grasses such as black grama and hairy grama grass. The woodlands in higher elevations contain Colorado pinon and one-seed juniper (IT May 1994).

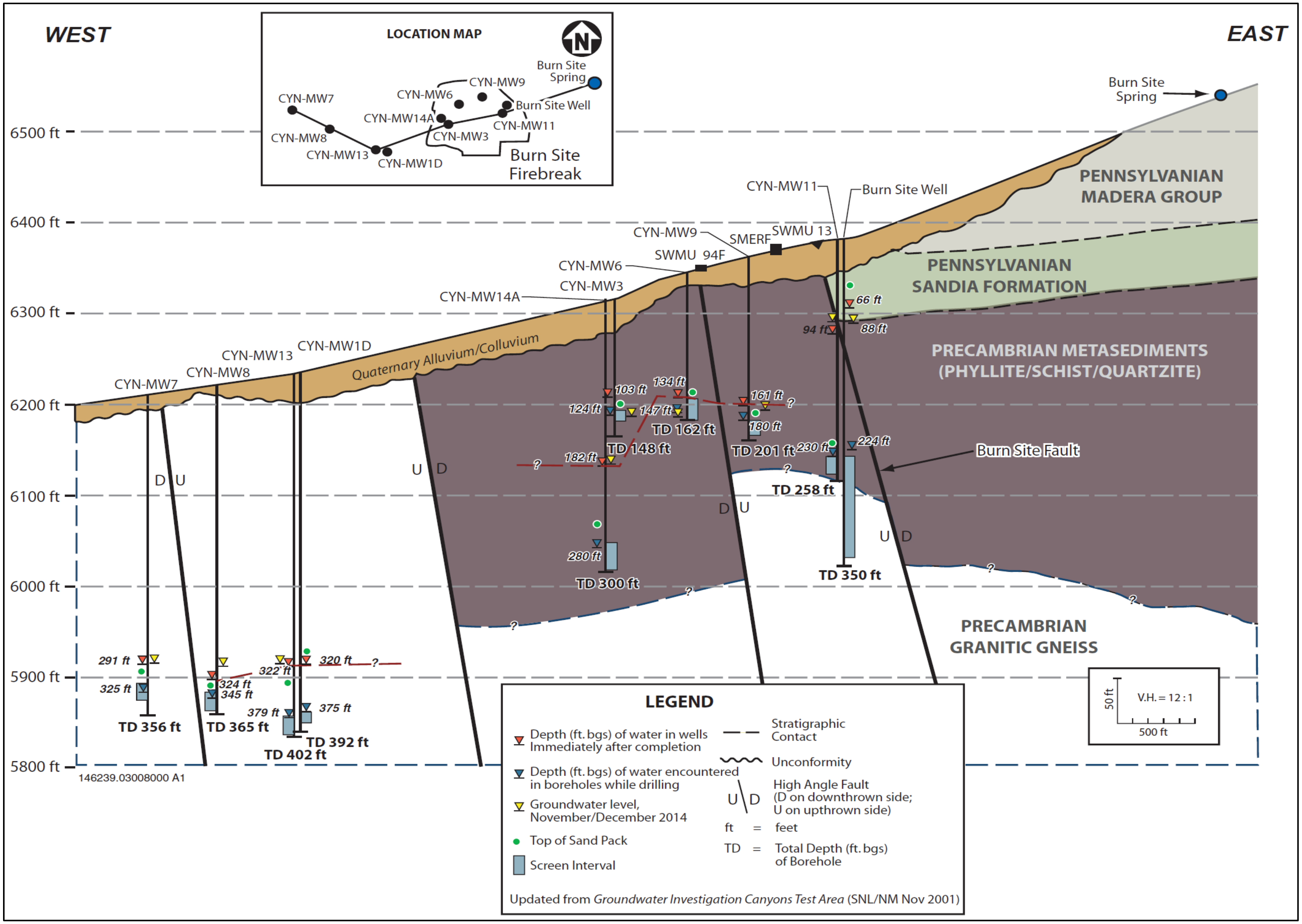


Figure 3-2. Fence Diagram through the BSG AOC

3.1.2.2 Paleozoic Rocks

The detailed lithologic descriptions of the mapped Paleozoic rocks in the BSG AOC are provided in Appendix B. The Paleozoic rocks exposed in the area are limited to Upper and Middle Pennsylvanian Madera and Sandia Formations. The Madera Formation is over 1,000 ft thick and in the BSG AOC consists of a sequence of often fossiliferous and massively bedded cliff-forming wavy laminated and cherty micritic gray limestone interbedded with shales. Shale is particularly abundant near the base of this member where it grades into the Sandia Formation (Karlstrom et al. 2000).

The Sandia Formation is approximately 170 ft thick and consists of a variety of lithologies including, in descending stratigraphic order: interbedded brown claystone and gray limestone, massive gray limestone, and a lower olive-brown to gray, subarkosic, fine- to coarse-grained sandstone. The contact with overlying Madera Formation is chosen at the base of the lowest thick, ledge-forming limestone. Limestone in the Sandia Formation is distinct from limestone in the overlying Madera Formation as they are typically thinner-bedded, clast-supported, greenish, and contain abundant siliciclastic material (Karlstrom et al. 2000). In the BSG AOC the lower contact is unconformable with Proterozoic crystalline rocks and the lower most sediments above the unconformity typically are comprised of a quartz-pebble conglomerate.

3.1.2.3 Precambrian Rocks

As proposed in the 2001 report titled *Groundwater Investigation, Canyons Test Area, Operable Unit 1333, Burn Site, Lurance Canyon* (SNL/NM November 2001; Attachment 1) there were multiple stages of Precambrian structural deformation that produced the mapped units exposed in the BSG AOC. At the beginning, a 1.7 Ga sequence of sedimentary and volcanic rocks was deformed via compression and overthrusting at about 1.65 Ga, followed by continued deformation and regional metamorphism. This was accompanied by magma intruding the deformational zone at a depth of some 4 to 9 miles bgs. Deformation intensified as intrusion of the pluton progressed and the surrounding country rocks were thermally softened. About 1.4 Ga, a second northwest-directed compressive event resulted in renewed thrusting and emplacement of the Sandia pluton to the north.

The multiple tectonic events have greatly deformed the northern and southern margins of the Manzanita pluton and the surrounding rock. The gross nature of the zone is that of a complex contact between the Manzanita granite and country rock and is characterized by masses of greenstone and metasediments (e.g., schist and phyllite) that are completely enveloped by the granite (Brown et al. 1999). In short, the Manzanita pluton and its enclosing rocks collectively constitute part of an exhumed mid-crustal, ductile mega-shear zone (SNL/NM November 2001).

The detailed lithologic descriptions of the mapped Precambrian rocks are provided in Appendix B. The Precambrian rocks exposed in the area are a diverse set of Paleoproterozoic igneous and metamorphic rocks that include:

- Manzanita granite — Strongly foliated, very coarse-grained biotite monzogranite (biotite is chloritized). Uranium-lead zircon date of 1,645 ±16 Ma.
- Medium-grained Cibola monzogranite — Equigranular, medium-grained, two-mica monzogranite; average grain size is 1-3 millimeters. Biotite-muscovite monzogranite with Uranium-lead dates of 1,632 ±45 Ma and 1,659 ±13 Ma.

- Mica schist, quartz-muscovite schist, and phyllite — Commonly rust red from hematitic staining, strongly crenulated and commonly crowded with boudinaged and folded stringers and lenses of vein quartz.
- Quartzite — Thick-bedded to massive and gray to milky-white quartz arenite with crossbedding and bedding defined by bands of iron oxides. Pelitic partings and interbeds contain aluminum silicates. 40Argon/39Argon date of 1,423 ±2 Ma.
- Chlorite-amphibole phyllite and schist — Metasedimentary and volcaniclastic rocks that grade from mafic metavolcanics to lithic arenites.
- Metamorphosed lithic arenite — Quartz schist, quartz-chlorite schist, and quartzite, interlayered with volcaniclastic schists; quartzite locally contains alumino-silicates.
- Mafic metavolcanic rocks — Heterogeneous unit consisting of massive to schistose metabasalt and metaandesite with subordinate chlorite phyllite and schist of volcaniclastic origin. Coarse dioritic units may locally intrude the volcanic rocks.

Of this suite of Precambrian lithologies the two most important to the groundwater investigation at the BSG AOC are the phyllite/schist and the granitic gneiss. The formal mapping unit designations were not used during the logging of boreholes (Appendix C). In general, the monitoring wells in the western portion of the BSG AOC are completed in the granitic gneiss and the monitoring wells in the eastern portion of the site are completed in the phyllite/schist. The dividing line between lithologies is the area between CYN-MW17 and CYN-MW18 (Figure 3-1). An exception to this rule is monitoring well CYN-MW4, which is completed in quartzite. A general description of the two major lithologies are described below.

The phyllite/schist is the water-bearing lithology for monitoring wells CYN-MW3, CYN-MW9, CYN-MW10, CYN-MW11, CYN-MW12, CYN-MW14A, CYN-MW15, CYN-MW18, and CYN-MW19. The color of the cuttings for this unit is highly variable and includes red, brown, purple, gray, green, and blue. Quite often there is a color change with depth. Near the surface the phyllite/schist is reddish purple and transitions to grayish green at depth, possibly due to more chlorite. Individual cuttings are mottled red, purple, gray, green, and brown, with some quartz stringers (or possibly quartzite) that are clear, white, pink, red, or brown. The larger cuttings are highly micaceous with a slatey cleavage, schistosity, fissile, fractured, greasy feel with a lustrous sheen. Some of the highly fractured intervals have brick-red fine-grained material (possibly fault gouge). Nearby outcrops (for example, immediately northwest of monitoring well CYN-MW15) show that this unit is highly fissile with well-developed near-vertical schistosity and anastomosing fractures. Of note, the phyllite/quartzite at CYN-MW18 was mineralized with oxide and sulfide minerals. The upper intervals at this location were pale red purple with a fair amount of limonite staining and cubic limonite pseudomorphs on some rock fragments, and with a trace of brassy sulfide minerals (possibly pyrite). With depth, the cuttings transitioned to grayish green and sulfide minerals (possibly galena, chalcopyrite, and pyrite) became more abundant.

The granitic gneiss is the water-bearing lithology for monitoring wells CYN-MW1D (decommissioned), CYN-MW7, CYN-MW8, CYN-MW13, CYN-MW16, and CYN-MW17. The color of the cuttings for this unit is uniform and includes moderate orange pink, pale reddish brown, and pale yellowish brown. In some fracture/void zones the cuttings contained some iron staining with pale red to moderate red staining (possibly indicating mineralized zones). Other times the cuttings contained a significant amount of white quartz or were chlorite rich. Nearby outcrops (for example, immediately west of monitoring well CYN-MW13) show that this unit is very well indurated and has minimal to moderate amounts of discontinuous fractures.

3.2 Monitoring Well Network

The DOE/NNSA and its M&O contractor for SNL/NM maintain a groundwater monitoring well network in the BSG AOC for studying the hydrogeologic setting and investigation groundwater contamination (Figure 3-3). In addition to the monitoring wells, the Burn Site Well is also located in the BSG AOC and is an inactive, non-potable, 4-inch diameter production well that had been used in the past to support operations at the Lurance Canyon Burn Site Testing Facility. No other production wells are located within the BSG AOC boundary and there are no other KAFB or private production or monitoring wells nearby, as the nearest downgradient potable production well is located approximately 9 miles from the site.

Table 3-1 summarizes the groundwater monitoring wells in the BSG AOC and Appendix D provides the well construction details. Seventeen wells are currently used for monitoring purposes, with 14 monitoring wells sampled on a regular basis. Appendix E contains the well completion diagrams for active and decommissioned (plugged and abandoned) monitoring wells and piezometers in the BSG AOC. Three SNL/NM monitoring wells and piezometers were decommissioned in November 2012. CYN-MW2S and 12AUP01 were alluvial-underflow monitoring wells/piezometers that never produced groundwater in sufficient quantities to collect samples. CYN-MW1D was a bedrock groundwater well that had construction issues and was replaced by CYN-MW13. The complete history of regulatory interactions associated with the planning and installation of the monitoring well network is provided in Section 1.1 and Appendix A.

The topographic relief across the BSG AOC is approximately 379 ft, as measured on the ground surface near the well pads. Ground surface elevations are lower on the floodplain of Lurance Canyon Arroyo on the western portion of the site and the highest ground surface elevations are in the eastern side of the BSG AOC (Figure 3-3).

3.3 Hydrogeologic Conditions at the BSG AOC

This section discusses hydrogeologic characteristics and properties of the fractured bedrock aquifer system in the BSG AOC.

3.3.1 Potentiometric Surface

Groundwater is limited to the fractured bedrock aquifer system; there is no saturation in the shallow, unconsolidated alluvial sediments in the BSG AOC. Figure 3-4 presents the most recent (October 2021) potentiometric surface for the BSG AOC monitoring well network, and Table 3-2 presents the data used to construct the potentiometric surface map. The general direction of groundwater flow beneath the BSG AOC is to the west, as inferred from the orientation of the potentiometric surface. With the addition of the four newest monitoring wells (CYN-MW16 through CYN-MW19), a more detailed interpretation of the potentiometric surface for the fractured bedrock aquifer system was possible. The interpretation of the potentiometric surface in the western part of the BSG AOC changed significantly between CY 2018 and CY 2019 based on the data from the newly installed monitoring wells. Most notably, the 6,000-ft potentiometric surface contour shifted eastward approximately 400 ft.

The CY 2021 potentiometric surface (Figure 3-4) depicts a steep groundwater gradient from easternmost monitoring well CYN-MW19 to well CYN-MW17, with nearly 456 ft of groundwater elevation difference over approximately 3,200 ft (0.6 miles), a gradient of 0.14. In contrast, the five westernmost monitoring wells (CYN-MW7, CYN-MW8, CYN-MW13, CYN-MW16, and CYN-MW17) spread along a down-canyon distance of approximately 1,400 ft and have groundwater elevations within a narrow range of approximately 2 ft, essentially a zero gradient.

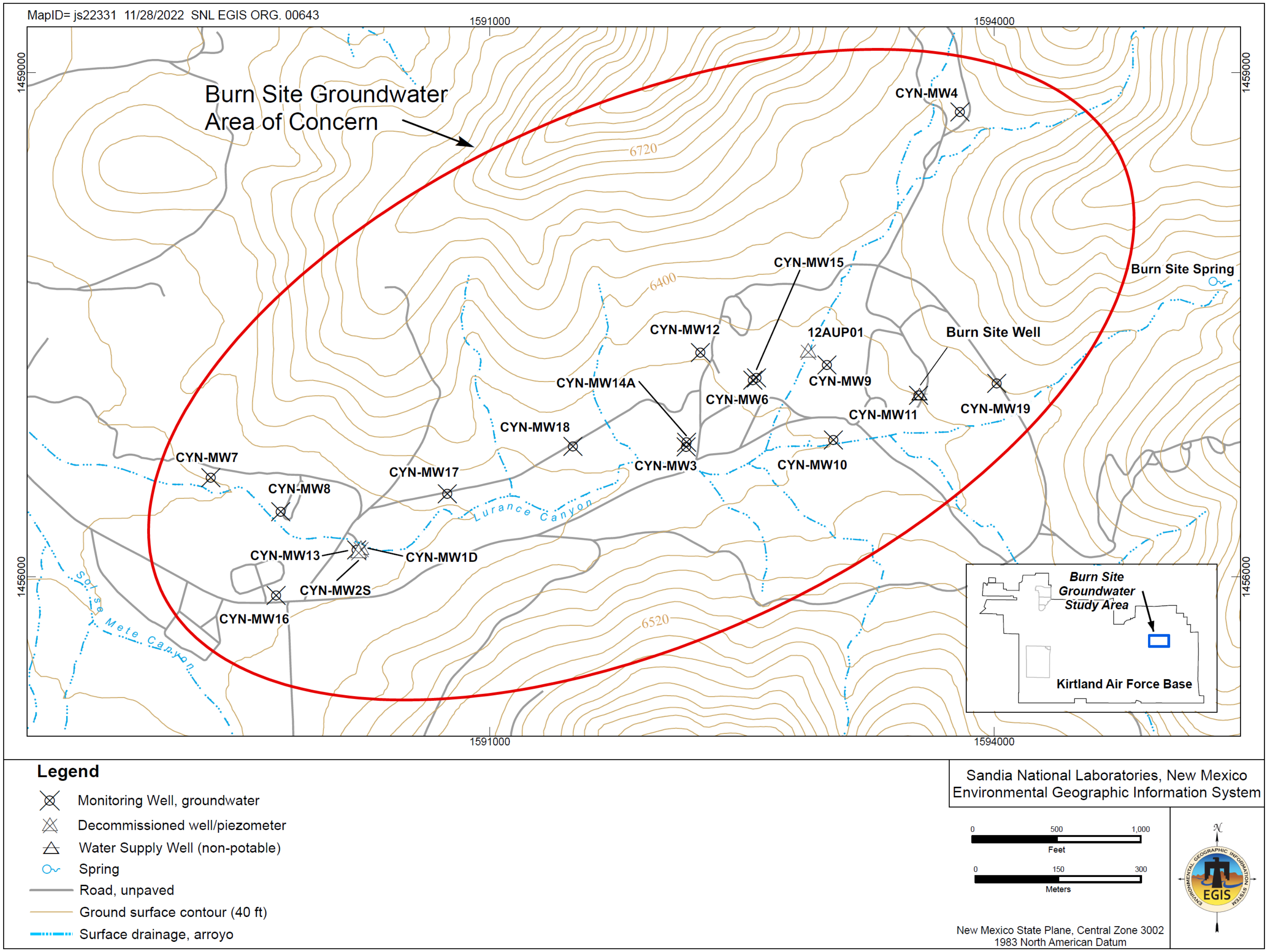


Figure 3-3. Active and Decommissioned Groundwater Monitoring and Production Wells in the BSG AOC

Table 3-1. Groundwater Monitoring and Production Wells at the BSG AOC

Well ID	Installation Year	WQ	WL	Comments
12AUP01	1996			Alluvial-underflow monitoring well, plugged and abandoned in November 2012
Burn Site Well	1986		✓	Non-potable bedrock production well, inactive since 2003
CYN-MW1D	1997			Bedrock groundwater well, plugged and abandoned in November 2012
CYN-MW2S	1997			Alluvial-underflow monitoring well, plugged and abandoned in November 2012
CYN-MW3	1999		✓	Bedrock groundwater well
CYN-MW4	1999	✓	✓	Bedrock groundwater well
CYN-MW6	2005		✓	Bedrock groundwater well
CYN-MW7	2005	✓	✓	Bedrock groundwater well
CYN-MW8	2006	✓	✓	Bedrock groundwater well
CYN-MW9	2010	✓	✓	Bedrock groundwater well
CYN-MW10	2010	✓	✓	Bedrock groundwater well
CYN-MW11	2010	✓	✓	Bedrock groundwater well
CYN-MW12	2010	✓	✓	Bedrock groundwater well
CYN-MW13	2012	✓	✓	Bedrock groundwater well, replaced CYN-MW1D
CYN-MW14A	2014	✓	✓	Bedrock groundwater well
CYN-MW15	2014	✓	✓	Bedrock groundwater well, replaced CYN-MW6
CYN-MW16	2019	✓	✓	Bedrock groundwater well
CYN-MW17	2019	✓	✓	Bedrock groundwater well
CYN-MW18	2019	✓	✓	Bedrock groundwater well
CYN-MW19	2019	✓	✓	Bedrock groundwater well
Total	----	14	17	

NOTES:

Check marks in the WQ and WL columns indicate WQ sampling and WL measurements were obtained in CY 2021.

AOC = Area of Concern.
BGS = Burn Site Groundwater.
CYN = Canyons (monitoring well designation only).
ID = Identifier.
MW = Monitoring well (monitoring well designation only).
WL = Water level.
WQ = Water quality.

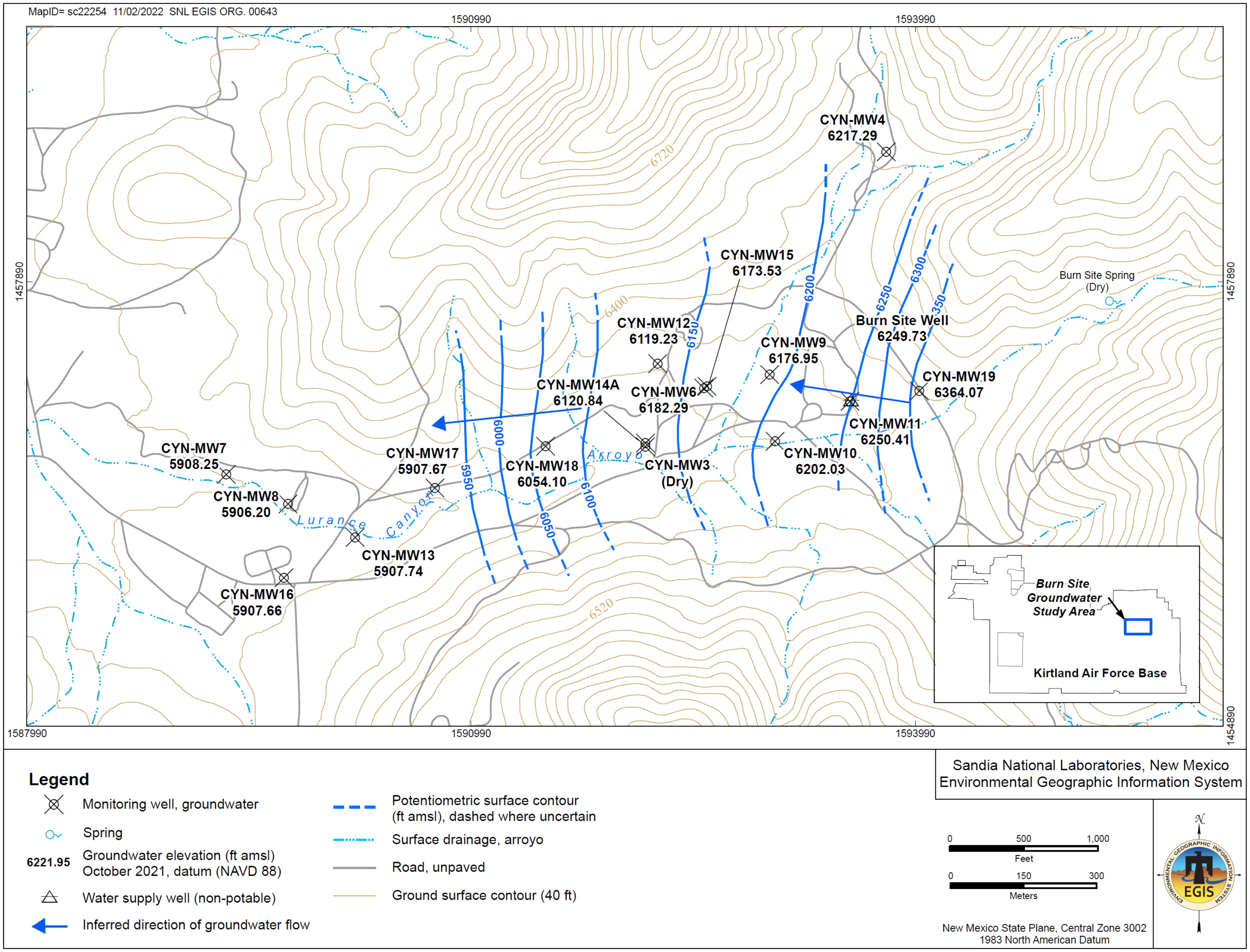


Figure 3-4. Localized Potentiometric Surface of the BSG AOC (October 2021)

Table 3-2. Groundwater Elevations Measured in October 2021 at Monitoring Wells Completed in the Fractured Bedrock Aquifer System at the BSG AOC

Well ID	Measuring Point (ft amsl) NAVD 88	Date Measured	Depth to Water (ft btoc)	Water Elevation (ft amsl)
Burn Site Well	6374.66	01-Oct-2021	124.93	6249.73
CYN-MW3	6313.26	01-Oct-2021	--	--
CYN-MW4	6455.48	01-Oct-2021	238.19	6217.29
CYN-MW6	6343.37	01-Oct-2021	161.08	6182.29
CYN-MW7	6216.35	01-Oct-2021	308.10	5908.25
CYN-MW8	6230.11	01-Oct-2021	323.91	5906.20
CYN-MW9	6360.67	01-Oct-2021	183.72	6176.95
CYN-MW10	6345.45	01-Oct-2021	143.42	6202.03
CYN-MW11	6374.41	01-Oct-2021	124.00	6250.41
CYN-MW12	6345.16	01-Oct-2021	225.93	6119.23
CYN-MW13	6237.79	01-Oct-2021	330.05	5907.74
CYN-MW14A	6315.85	01-Oct-2021	195.01	6120.84
CYN-MW15	6344.44	01-Oct-2021	170.91	6173.53
CYN-MW16	6249.60	01-Oct-2021	341.94	5907.66
CYN-MW17	6268.95	01-Oct-2021	361.28	5907.67
CYN-MW18	6304.02	01-Oct-2021	249.92	6054.10
CYN-MW19	6410.43	01-Oct-2021	46.36	6364.07

NOTES:

amsl = Above mean sea level.
AOC = Area of Concern.
BSG = Burn Site Groundwater.
btoc = Below top of casing.
CYN = Canyons (monitoring well designation only).
ft = Foot (feet).
ID = Identifier.
MW = Monitoring well (monitoring well designation only).
NAVD 88 = North American Vertical Datum of 1988.
-- = No data, monitoring well dry during this measurement period.

The gradient between CYN-MW17 and CYN-MW7 is less than 1 ft of groundwater elevation difference over 1,400 ft (0.27 miles), and although it is located further west (presumably the “downgradient” direction) the groundwater elevation at CYN-MW7 is slightly higher than that at CYN-MW17. Of the five western monitoring wells, CYN-MW8 has the lowest groundwater elevation and is therefore the most downgradient monitoring well at the BSG AOC.

The low gradient in the western portion of the BSG AOC may be related to (or controlled by) several high-angle faults that offset Precambrian and Paleozoic bedrock in the area west of CYN-MW18 (Karlstrom et. al. 2000). Another explanation for the flat groundwater gradient is that the area is possibly influenced by localized groundwater flow emanating from Sol se Mete Canyon, a large surface drainage south of the BSG AOC that merges with Lurance Canyon just west of monitoring wells CYN-MW7 and CYN-MW16 (Figure 2-6).

3.3.2 Groundwater Elevations Over Time

Water levels have been routinely monitored in BSG AOC monitoring wells since 1999. Figure 3-5 shows hydrographs (groundwater elevations versus time) for all the wells plotted on one diagram. Hydrographs for individual monitoring wells or groups of wells are provided in Appendix F. There are no active production wells in the area, as the nearest downgradient potable production well is located approximately 9 miles from the site. No substantial seasonal variations other than occasional extreme thunderstorms are evident in the water levels in the monitoring wells. The wide range of hydraulic gradients across the site and the lack of correlation of water

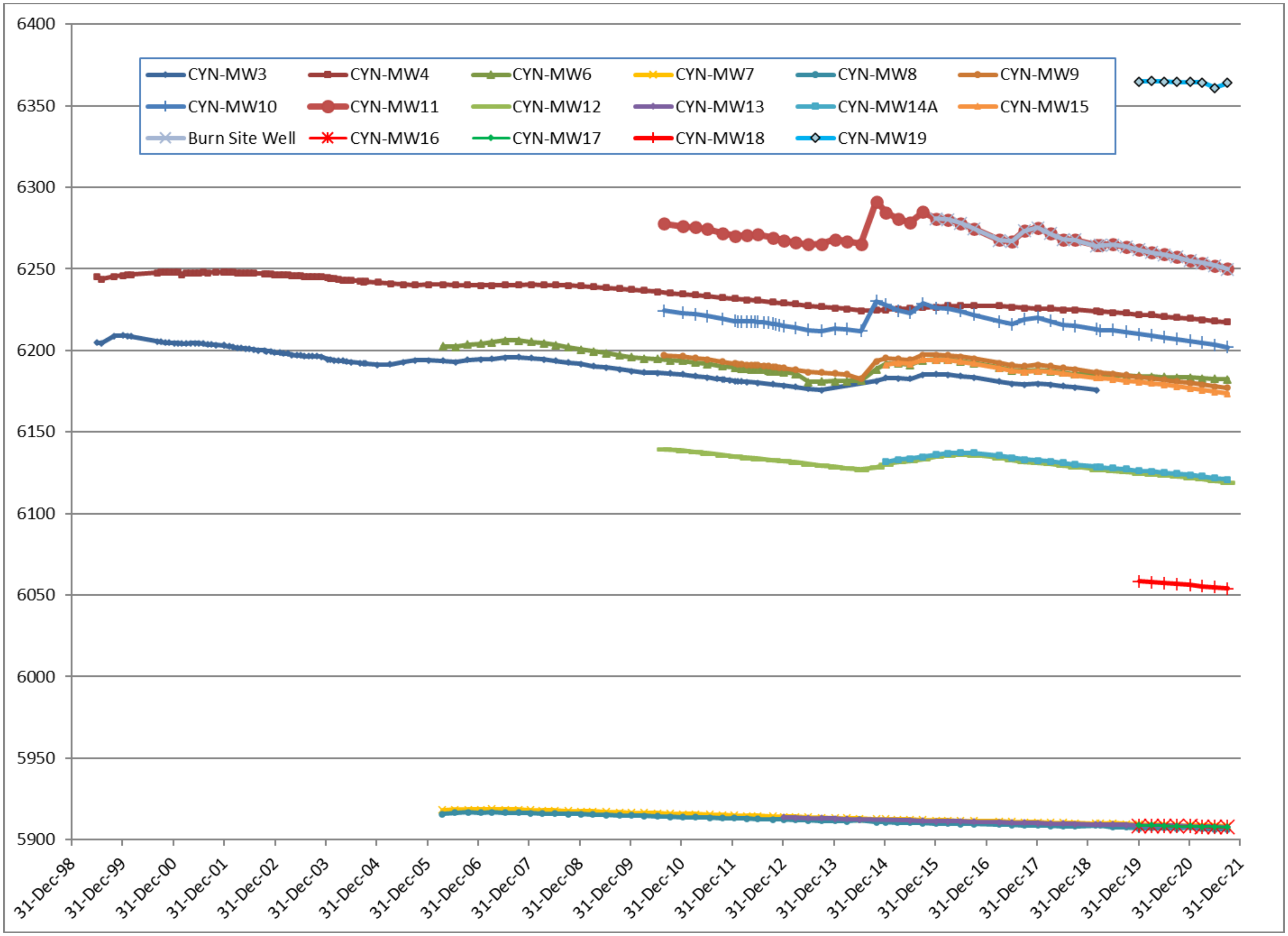


Figure 3-5. Hydrographs for Wells in the Fractured Bedrock Aquifer System at the BSG AOC

level fluctuations between groups of monitoring wells support the assessment that the BSG AOC low-permeability fractured bedrock aquifer system is poorly interconnected. Water level fluctuations may be a result of local heterogeneities in hydraulic properties related to the water-bearing fracture zones.

Figure 3-6 presents a geographic distribution of hydrographs for individual monitoring wells or groups of wells. The five monitoring wells in the lower (western) portion of the canyon (CYN-MW7, CYN-MW8, CYN-MW13, CYN-MW16, and CYN-MW17) exhibit little variability over time with a steady decline of approximately 0.75 ft/yr. The BSG AOC monitoring wells in the upper (eastern) portion of the canyon, most notably at monitoring wells CYN-MW6, CYN-MW9, CYN-MW10, CYN-MW11 (and Burn Site Well), and CYN-MW15, showed significant increases in water levels during a two-year interval starting in early 2014, apparently in response to intense thunderstorms in the 2013 and 2015 monsoon seasons. These five eastern monitoring wells, and most of the remaining BSG AOC monitoring wells, currently show declining groundwater elevations of 3 or more ft/yr (Figure 3-6 and Appendix F).

The hydrographs shown in Figures 3-5, 3-6, and Appendix F mimic the regional climate change trends that were recently documented in a report by the New Mexico Bureau of Geology and Mineral Resources (March 2022). The climate report concluded that the earth is warming in response to increasing atmospheric carbon dioxide, and this warming will result in greater aridity in many parts of the world, including New Mexico. In the southwestern United States, the primary observed and projected impacts include warmer temperatures, decreased water supply (partly driven by thinner snowpacks, increased evaporation/sublimation, and earlier spring melting), lower soil moisture levels, increased frequency and intensity of wildfires, and increased competition and demand for scarce water resources (New Mexico Bureau of Geology and Mineral Resources March 2022).

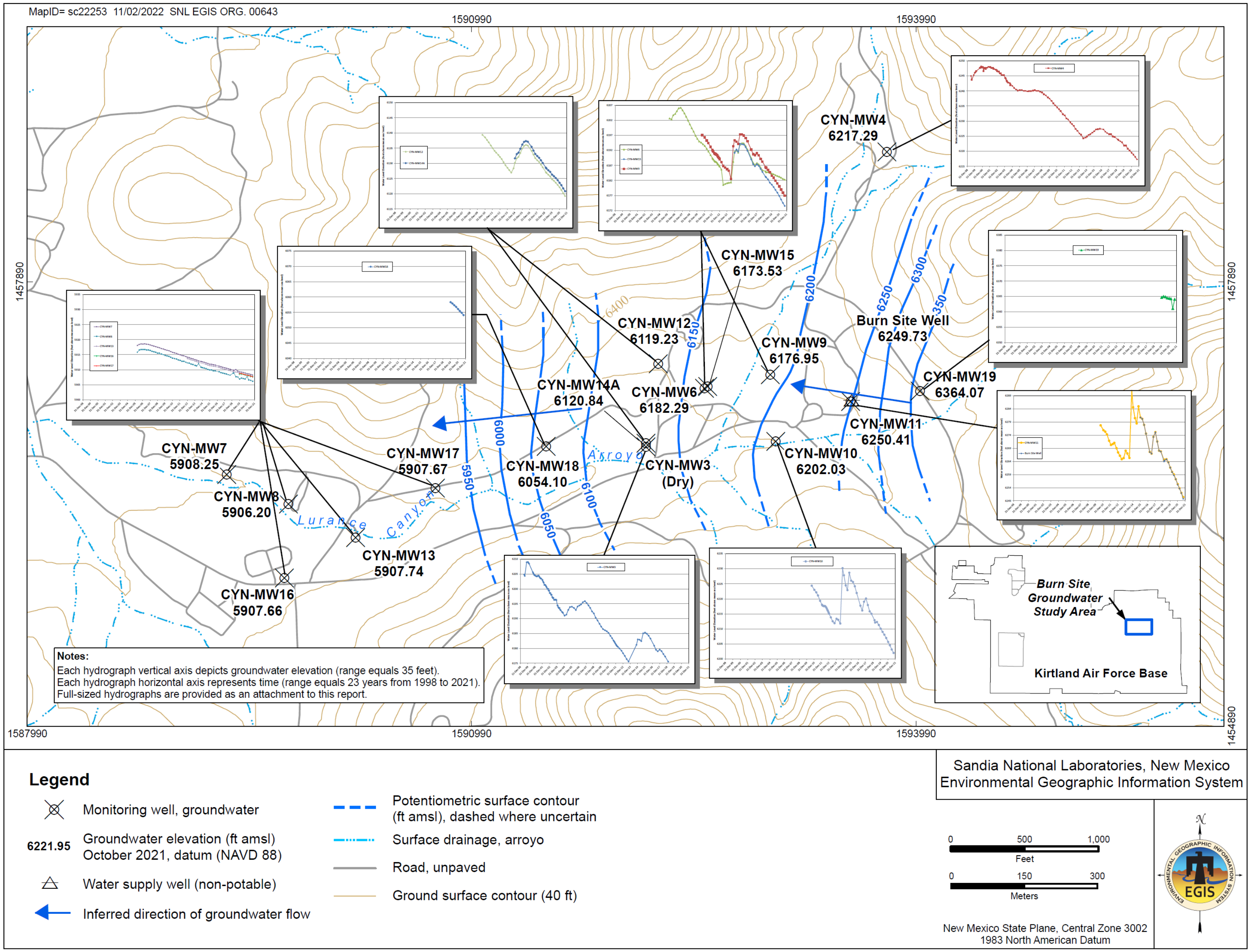
Two of the many findings of the 2022 report (New Mexico Bureau of Geology and Mineral Resources March 2022) that pertain to the BSG AOC include:

- The average temperature across New Mexico has risen by more than 2 degrees Fahrenheit (°F) from 1970 to 2020, in parallel with global temperatures.
- Annual precipitation across New Mexico shows no obvious long-term (1931 to 2020) trend, but interannual and decadal-scale swings are large. Decadal averages of precipitation values peaked in the 1980s and have since declined for the three subsequent decades. Four of the five lowest annual statewide precipitation values since 1931 have occurred since the turn of the 21st century.

Although erratic, the decreasing trend in statewide precipitation for the period of record for the BSG AOC monitoring well network (1999 to 2021) is the same downward trend seen in groundwater elevations, especially hydrographs for the monitoring wells on the western side of the BSG AOC (Appendix F).

3.3.3 Long-Term Transducer Study

As described in the *Aquifer Pumping Test Report* (SNL/NM December 2017) that was approved by the NMED (NMED January 2018), a pressure transducer network was installed in 12 monitoring wells across the study area as part of the long-term background groundwater elevation monitoring. This study was performed in 2016 and 2017 to evaluate natural background fluctuations in BSG AOC monitoring wells. Barometric pressure data were recorded and subsequently used to filter out fluctuations in the groundwater elevation data due to changes in



Notes:
Each hydrograph vertical axis depicts groundwater elevation (range equals 35 feet).
Each hydrograph horizontal axis represents time (range equals 23 years from 1998 to 2021).
Full-sized hydrographs are provided as an attachment to this report.

Figure 3-6. Geographic Distribution of Hydrographs for Wells in the Fractured Bedrock Aquifer System at the BSG AOC ambient atmospheric 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 system near each monitoring well. The full details of this investigation and analysis are provided in Section 2.0 of the *Aquifer Pumping Test Report* (SNL/NM December 2017). The *Aquifer Pumping Test Report* is provided as Attachment 2 and a summary of the long-term transducer study is discussed in the paragraphs below.

Water level transducers were installed in 12 monitoring wells and the Burn Site Well from December 2016 through February 2017 before the start of the aquifer pumping test that occurred on March 14, 2017. During transducer deployment, periodic measurements were manually collected with a water level meter to verify the data collected by the transducers. Meteorological data were also collected for the corresponding deployment interval from a nearby SNL-maintained tower. The data collected during the long-term background groundwater level monitoring were used to calculate barometric efficiencies and perform trend analysis. 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). Increases in barometric pressure result in water level declines in a confined aquifer. Unconfined aquifers generally do not respond to barometric pressure changes (Gonthier 2007).

Table 3-3 presents the estimated barometric efficiency calculated for each well. Barometric efficiencies ranged from 0.60 in monitoring well CYN-MW4 (the most confined well) to 0.06 in monitoring well CYN-MW10 (the least confined well). Well CYN-MW10 is a relatively shallow monitoring well that typically responds to infiltration of surface water from the Lurance Canyon Arroyo following significant precipitation events.

Table 3-3. Estimated Barometric Efficiency of Wells in the BSG AOC

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:
AOC = Area of Concern.
BSG = Burn Site Groundwater.
CYN = Canyons (monitoring well designation only).
MW = Monitoring well (monitoring well designation only).

The trend analysis shows that over the long-term background groundwater elevation monitoring period (63 days) groundwater levels declined in all BSG AOC monitoring wells. The groundwater elevation decline ranged from 0.05 ft to as much as 1.69 ft. As shown in Figure 3-7, the monitoring 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.

The identification of distinctive hydraulic domains supports the CSM of a compartmentalized fractured bedrock aquifer system that has limited hydraulic communication between six domains. This suggests that either: (1) the faults/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.

3.3.4 Aquifer Pumping Test

As described in the *Aquifer Pumping Test Report* (SNL/NM December 2017) that was approved by the NMED (NMED January 2018), an aquifer pumping test was conducted in March 2017 and involved pumping water from the Burn Site Well while monitoring the water-level changes (drawdown) in the pumped well and 12 observation wells. The drawdown, measured in response to the pumping, was used to determine the transmissivity and storage coefficient of the aquifer. The pumping test was performed in two parts:

1) Step-Drawdown Test performed to determine the optimal pumping rate for a longer-term constant-rate test.
2) Constant-Rate Test performed to evaluate hydrologic parameters of the aquifer near the Burn Site 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.

The full details of the pumping tests are provided in Sections 3.0 and 4.0 of the *Aquifer Pumping Test Report* provided as Attachment 2. A summary is discussed in the paragraphs below.

The step-drawdown 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 rates of 5, 10, and 20 gallons per minute (gpm). Each step had a planned duration of approximately two hours, or until drawdown stabilized in the pumping well.

Water level measurement outputs from the transducers installed in the Burn Site Well and in CYN-MW11 could be viewed in real time on a laptop computer, and recorded drawdown during both pumping and recovery. The transducer in the Burn Site Well was set at 318 ft bgs, and the transducer in CYN-MW11 was installed at 248 ft bgs. Both transducers were set to collect data at one-minute intervals. Real-time data viewing allowed for evaluating drawdown and preventing the submersible pump from drawing air/overheating. The transducers at the remaining observation wells collected water level data at 10-minute intervals.

The optimal pumping rate for the Burn Site Well for the subsequent constant-rate test was determined in the field by reviewing the hydrograph of the step-drawdown test data. The discharge rate of Step 1 was 5 gpm, which produced approximately 31 ft 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 ft of

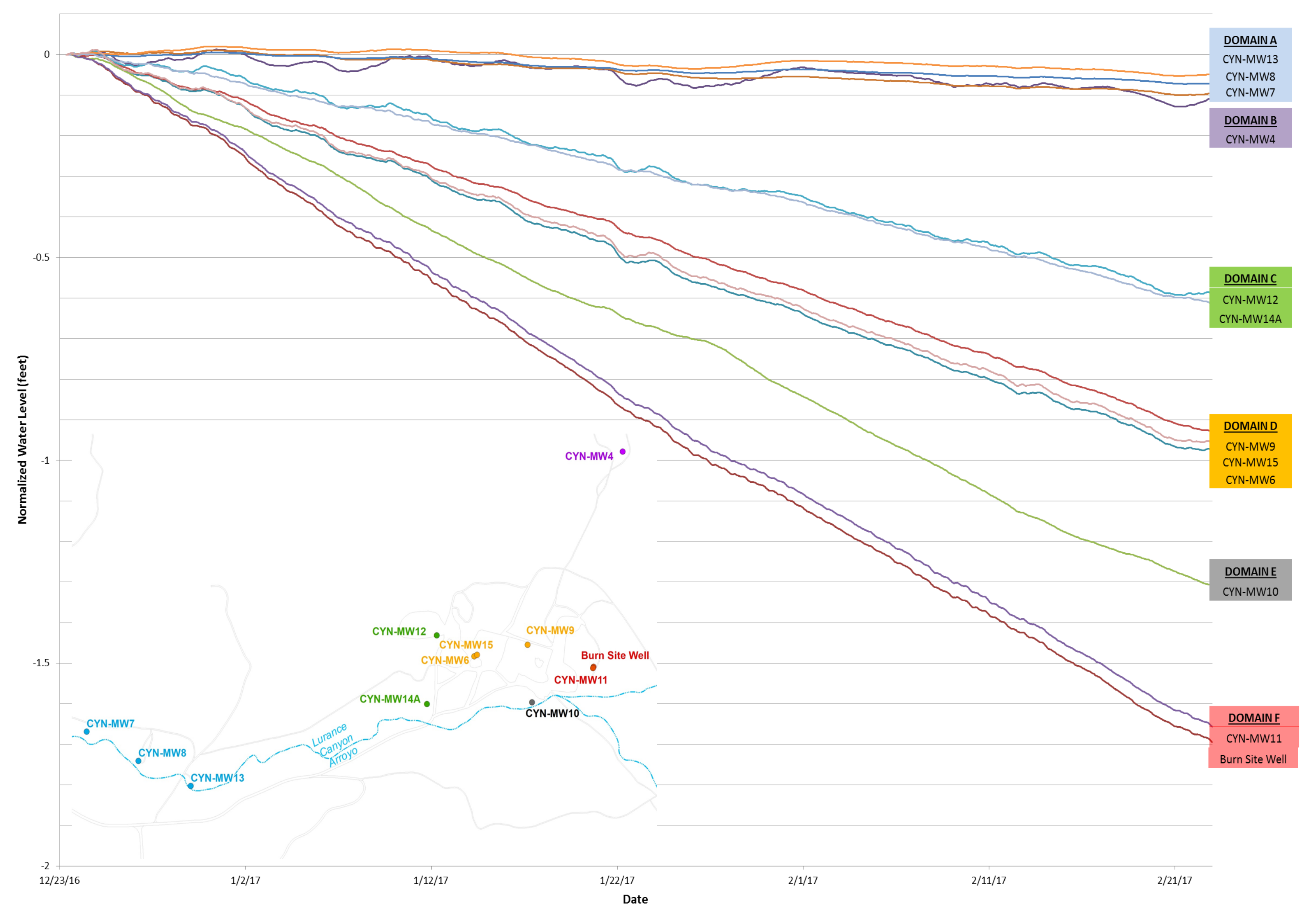


Figure 3-7. Groundwater Level Trends and Hydraulic Domains

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 ft of drawdown and caused the water level to drop below the transducer. The pump was turned off at 326 minutes into the test and water levels recovered approximately 139 ft in just under 60 minutes. Specific capacity was calculated at 0.14 gpm per ft of drawdown for Step 1, and 0.13 gpm per ft of drawdown for Step 2. Specific capacity was not calculated for Step 3 because of the insufficient dataset.

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 (318 ft bgs) or pump intake (323 ft bgs) 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.

The aquifer was allowed to recover for 42 hours between the step-drawdown test and the constant-rate test. The data showed that most of the recovery occurred within the first two hours after the pumping stopped. The optimal flow rate of 10 gpm was used to stress the aquifer for 24 hours. Meteorological data were also collected during the aquifer pumping test from a nearby SNL-maintained tower. 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.

The 24-hour constant-rate test was performed by pumping the Burn Site Well. The total volume of water produced during the constant-rate test was 11,256 gallons for a grand total of 14,412 gallons from both the step-drawdown test and the constant-rate test. The water produced was stored, analyzed, and disposed. After 24 hours, the pump was turned off and water level recovery was measured until static water levels were reached. All the BSG AOC monitoring wells were used as observation wells during the constant-rate test. Transducers recorded water levels at the same time intervals as the step-drawdown test data, and periodic manual water level measurements were recorded to verify the accuracy of the data obtained from transducers.

The data collected during the constant-rate test were used to determine hydraulic responses in the monitoring wells and calculate the distance to an impermeable boundary encountered by the cone of depression during the test. As shown on Figure 3-8, the maximum drawdown in the Burn Site Well was approximately 73 ft. Approximately 9.5 ft of drawdown was measured in observation well CYN-MW11, located 12 ft from the Burn Site Well. However, no hydraulic response was detected in any of the other 11 observation wells during pumping of the Burn Site Well (as shown by the blue arrow on Figure 3-9), in part due to the large distances (greater than 500 ft) between these observation wells and the pumped Burn Site Well. Figure 3-10 shows a more detailed view of the six observation wells closest to the Burn Site Well; no response is discernable other than the long-term downward trend seen before and after the pumping of the Burn Site Well. These data show that Burn Site Well and CYN-MW11 (defined in Section 3.3.3 as hydraulic Domain F) are not in hydraulic communication with any of the other 10 observation wells in other domains.

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 with a lateral distance to the boundary of

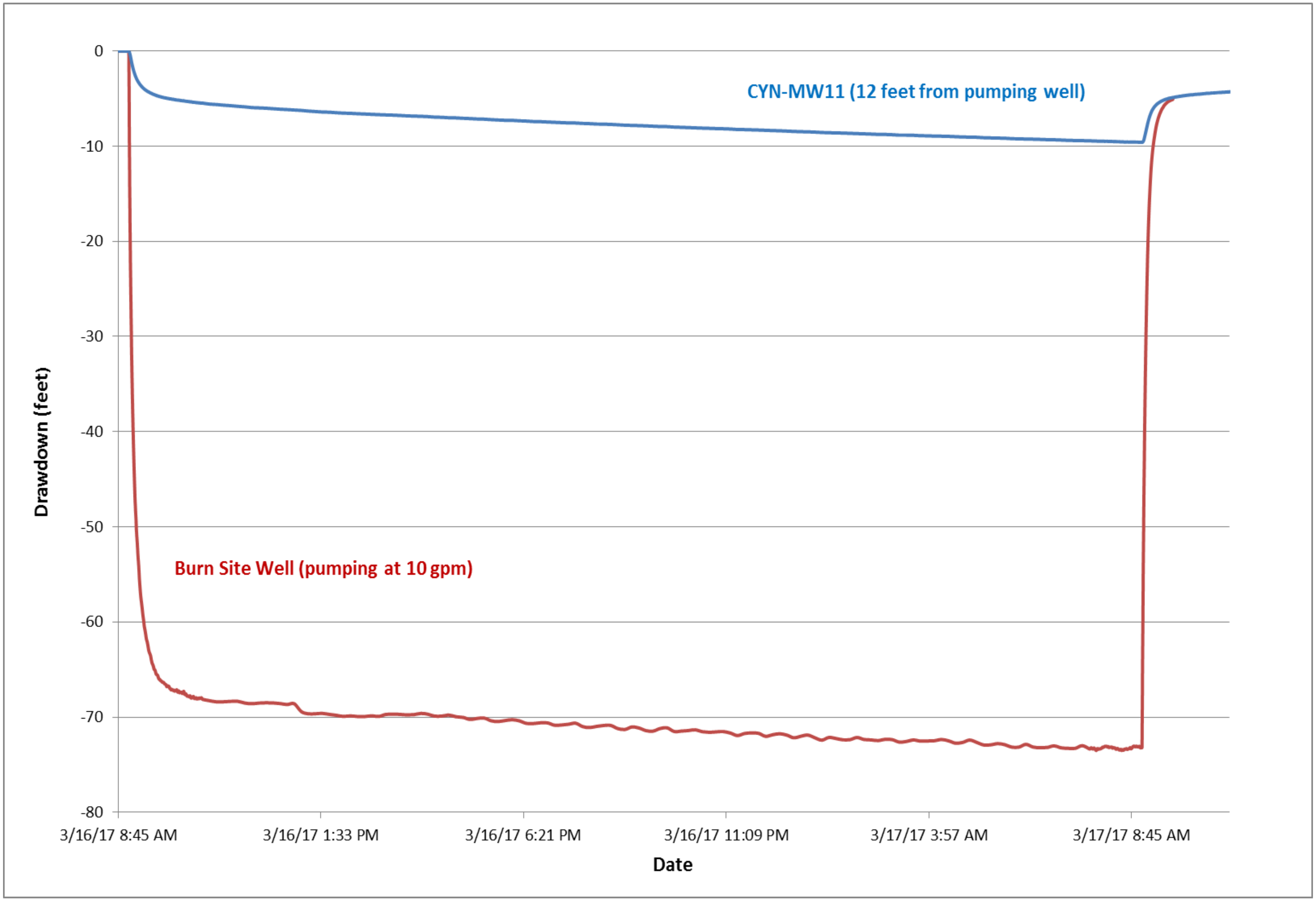


Figure 3-8. Constant-Rate Test Hydrographs for the Burn Site Well and Well CYN-MW11

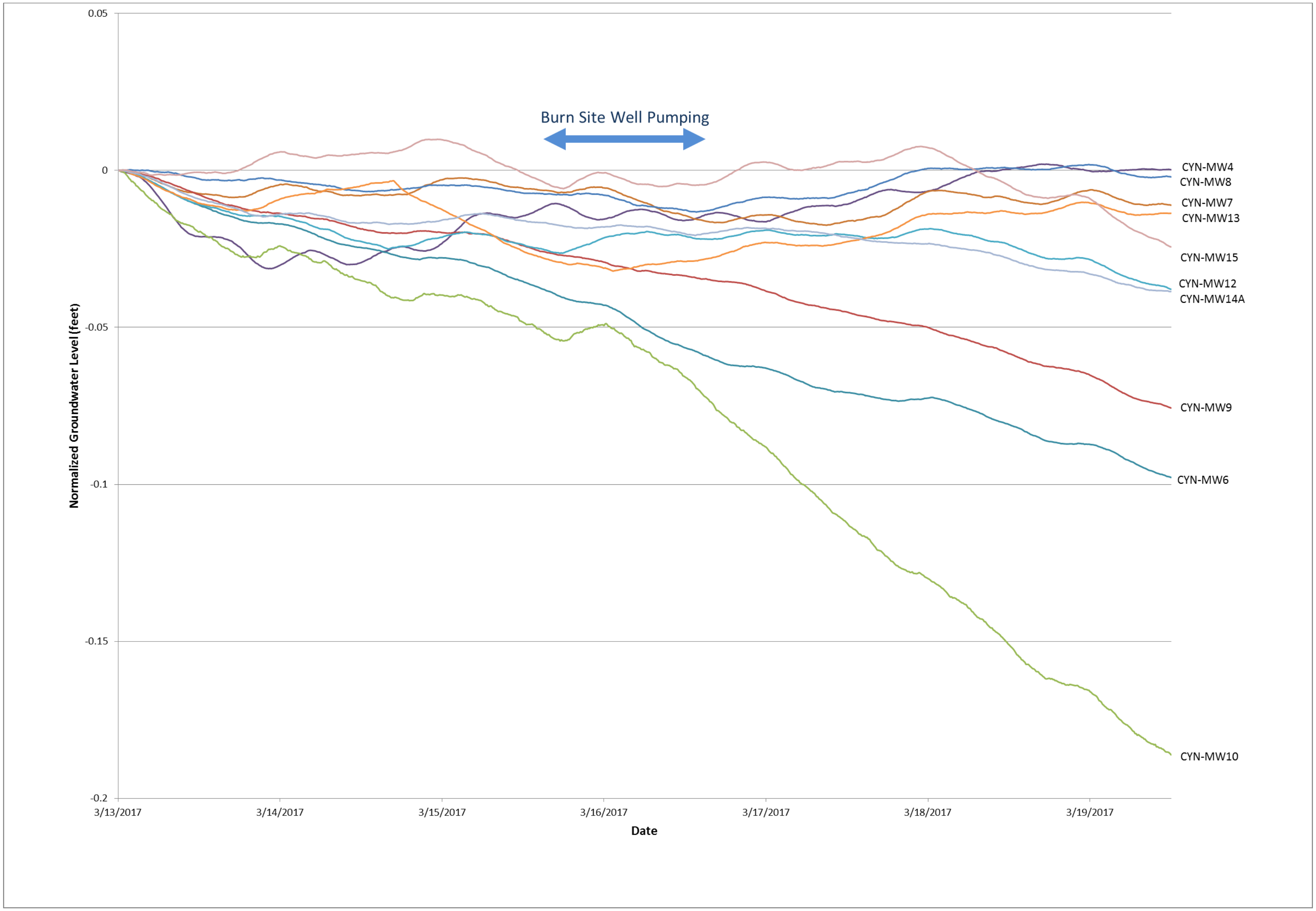


Figure 3-9. Constant-Rate Test Hydrographs for Observation Wells

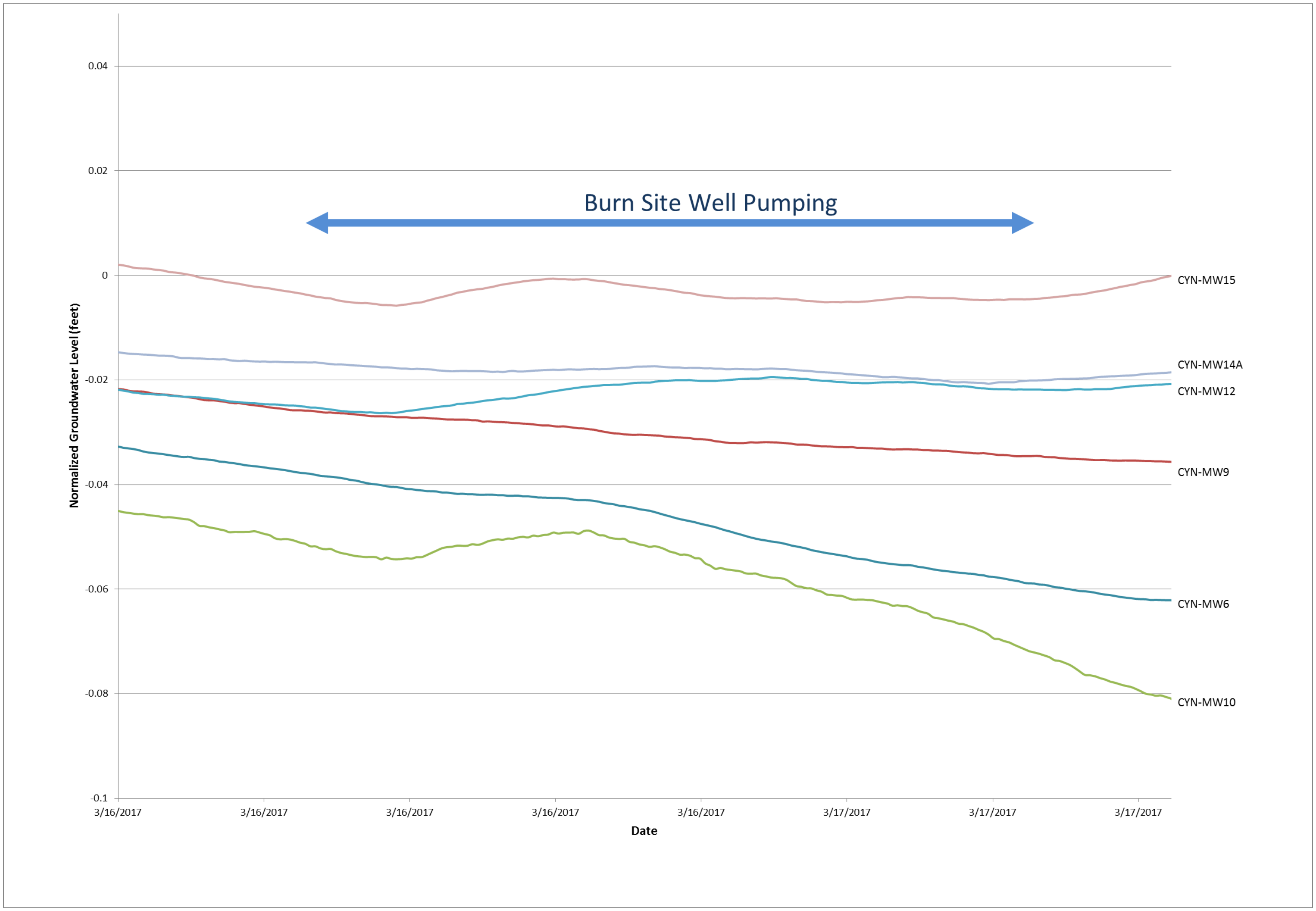


Figure 3-10. Constant-Rate Test Hydrographs for Selected Observation Wells (Detailed View)

approximately 212 ft. This distance is consistent with the previously mapped Burn Site Fault (west of the Burn Site Well; Figure 3-1) acting as a barrier to groundwater flow.

The results of aquifer pumping test field studies can be summarized as follows:

- 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 observation well CYN-MW11; however, no drawdown was detected in any of the other 11 observation wells during the constant-rate test.
- Drawdown data during the constant-rate test suggest an impermeable flow boundary is located approximately 212 ft from the Burn Site Well; this boundary is most likely associated with the Burn Site Fault located to the west.
- 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.

3.3.5 Hydraulic Conductivities Determined by Slug Tests

Over the last 18 years multiple slug test field programs have been conducted at groundwater monitoring wells at the BSG AOC. These slug tests were conducted to determine the hydraulic conductivity (K) of the fractured bedrock aquifer system in the study area. Slug tests induce stress on an aquifer by instantaneously injecting (slug in), or removing (slug out), a discrete volume of material into the well and measuring changes in the water level over time as the aquifer returns to equilibrium. Originally, slug tests were designed to insert or withdraw a specific volume of water. However, slug tests using an "artificial slug" (solid cylinder of known volume) are more commonly performed. All the active groundwater monitoring wells in the BSG AOC have been slug tested and the results of the analytical solutions for K are summarized in Table 3-4.

The slug tests were conducted by SNL/NM field team personnel. Over the years, the equipment used to conduct the slug tests has varied but usually included support vehicles for hauling equipment and the water-sampling truck that functioned as the platform for injecting and withdrawing the slug. The slug was raised and lowered by means of a large diameter (~4 ft) motorized spool with a graduated 0.25-inch stainless steel cable. The slug was a solid slug with known diameter, length, and volume. The Field Operating Procedure (FOP) 09-05 (SNL/NM March 2022, or earlier versions) was used for all slug test investigations. To document the reproducibility of the tests, the process was repeated such that the slug was injected (slug in) twice and withdrawn (slug out) twice producing four datasets for each monitoring well.

After collection of the slug test field data, analytical solutions were derived from the dataset. Data were imported into the AQTESOLV^{TM} Software (HydroSOLVE 2007) (or similar analytical software), and analytical solutions were generated using the Bouwer and Rice (1976) and Hvorslev (1951) methods to produce graphical solutions of hydraulic conductivity. The result of the analyses was the determination of the hydraulic conductivity for each of the tests, or eight conductivity values for each monitoring well (four datasets analyzed by two methods). The hydraulic conductivity values were then averaged for each monitoring well to produce the values listed in Table 3-4.

Table 3-4. Summary of Hydraulic Conductivity Values for Monitoring Wells in the BSG AOC

Well ID	Screened unit	Hydraulic Conductivity (K)				Reference
		(ft/min)	(ft/day)	(ft/year)	(cm/s)	
CYN-MW1D	granitic gneiss	~6.94E-04	~1	~3,65	~3.52E-04	SNL/NM June 2004a
CYN-MW4	quartzite	~3.47E-03	~5	~1,825	~1.76E-03	Inferred from SNL/NM April 2008a
CYN-MW7	granitic gneiss	1.50E-03	2.16	788	7.62E-04	Skelly et al. August 2015
CYN-MW8	granitic gneiss	9.98E-05	0.144	52	5.07E-05	Skelly et al. August 2015
CYN-MW9	phyllite	1.21E-03	1.75	638	6.17E-04	Skelly August 2011
CYN-MW10	phyllite	7.76E-04	1.12	408	3.94E-04	Skelly August 2011
CYN-MW11	phyllite	1.21E-03	1.74	636	6.15E-04	Skelly August 2011
CYN-MW12	phyllite	3.85E-04	0.55	202	1.47E-04	Skelly August 2011
CYN-MW13	granitic gneiss	6.65E-03	9.57	3,494	3.38E-03	Skelly et al. August 2015
CYN-MW14A	phyllite	9.21E-05	0.133	48	4.68E-05	Skelly et al. August 2015
CYN-MW15	phyllite	2.20E-03	3.17	1,158	1.12E-03	Skelly et al. August 2015
CYN-MW16	granitic gneiss	8.26E-03	11.19	4,344	4.20E-03	Skelly et al. May 2022
CYN-MW17	granitic gneiss	1.85E-02	26.6	9,711	9.39E-03	Skelly et al. May 2022
CYN-MW18	phyllite	5.87E-03	8.46	3,087	2.98E-03	Skelly et al. May 2022
CYN-MW19	phyllite	6.52E-02	93.90	34,274	3.31E-02	Skelly et al. May 2022
Average for all Wells		**7.71E-03**	**11.1**	**4,051**	**3.92E-03**	

NOTES:

AOC = Area or Concern.
BSG = Burn Site Groundwater.
cm/s = Centimeters per second.
CYN = Canyons (monitoring well designation only).
ft = Foot (feet).
ID = Identifier.
K = Hydraulic conductivity.
min = Minute.
MW = Monitoring well (monitoring well designation only).
SNL/NM = Sandia National Laboratories, New Mexico.

The range of hydraulic conductivities for the BSG AOC monitoring wells varied by several orders of magnitude from 9.98E-05 to 6.52E-02 ft per minute (0.144 to 93.90 ft per day; Table 3-4). It should be noted that the theory for slug test analyses were developed for use in unconsolidated deposits and as a result the analyses of fractured bedrock aquifer system slug tests may be of limited value. The hydraulic conductivity measured in fractured bedrock aquifer systems is overwhelmingly dominated by fracture flow. Water flowing through the matrix of crystalline bedrock is negligible. Therefore, the calculated conductivities are dependent on the diverse nature of the fractures intercepted in specific wells.

3.3.6 Other Hydraulic Properties

The capacity of these rocks to transmit water is described by the horizontal and vertical hydraulic conductivity. Although the horizontal hydraulic conductivities were determined through the slug test analysis described above, there is no way to determine the vertical hydraulic conductivity in the fractured bedrock aquifer system. The commonly accepted ratio of vertical to horizontal hydraulic conductivity of a layered heterogeneous sequence is approximately 1:100 (Freeze and Cherry 1979). However, this approximation is unlikely applicable to the fractured bedrock aquifer system in the BSG AOC.

As noted earlier in Section 3.3.1 the horizontal hydraulic gradients were estimated using the October 2021 potentiometric surface map. The horizontal gradient of the fractured bedrock aquifer system across the western 2/3 of the BSG AOC (from monitoring well CYN-MW19 to CYN-MW17) is 0.14 ft/ft. The horizontal gradient is much less steep to nearly flat in the five western-most monitoring wells (Figure 3-4).

The vertical gradient in the fractured bedrock aquifer system is upward, but a specific value could not be determined because there are no monitoring well clusters installed. Although unquantified, the upward vertical gradient was documented during well installation. At all monitoring well locations the first water-bearing zone was pressurized. During borehole drilling, after the first water bearing zone was encountered (as noted on the borehole lithology logs) the groundwater level rose within the dry borehole. Table 3-5 shows the vertical elevation rise for each borehole/well. The rise was calculated as the difference between the depth to water noted during drilling versus the depth to water after well development.

As noted above, no monitoring well clusters have been installed at the BSG AOC. However, two monitoring well pairs offer some insights. Well pair CYN-MW3 and CYN-MW14A are located approximately 25 ft apart, and monitoring well pair CYN-MW6 and CYN-MW15 are located approximately 26 ft apart. The deeper fracture encountered during the drilling of CYN-MW14A produced a greater head (99 ft) than the shallower fracture encountered at CYN-MW3 where the head was only 21 ft. Likewise, the deeper fracture encountered during the drilling of CYN-MW15 produced a greater head (22 ft) than the shallower fracture encountered at CYN-MW6 where the head was only 8 ft. Water levels at both monitoring well pairs demonstrate that deeper bedrock fractures have greater head potential with upward vertical gradients.

On average, the water level increased by 50 ft, with the range of water level differences shown as an increase of 8 ft (slightly over-pressurized) to an increase of 156 ft (greatly pressurized) (Table 3-5).

An interesting feature is that vertical heads in the eastern nitrate plume near monitoring wells CYN-MW6 and CYN-MW9 are low where most of the ammonium nitrate slurry was used (potential source areas are discussed in Section 4). That is to say, the higher nitrate concentrations/probable source areas occur where the upward vertical heads are minimal. It is likely that precipitation and wastewater more easily migrated into the fracture system at these locations with minimal vertical head.

Table 3-5. Vertical Groundwater Elevation Rise between Depth to First Water Noted During Drilling and Depth to Water after Well Development for Monitoring Wells Completed in the Fractured Bedrock Aquifer System at the BSG AOC

Well ID	Depth to First Water Noted During Drilling (ft bgs)	Depth to Water after Well Development (ft bgs)	Water Level Rise (ft)
Burn Site Well	222	65.74	156
CYN-MW1D	375	317.11	58
CYN-MW3	124	102.64	21
CYN-MW4	264	217.22	47
CYN-MW6	142	133.88	8
CYN-MW7	325	291.35	34
CYN-MW8	341	323.69	17
CYN-MW9	176	158.33	18
CYN-MW10	160	115.18	45
CYN-MW11	231	92.49	139
CYN-MW12	261	201.24	60
CYN-MW13	379	320.31	59
CYN-MW14A	280	180.65	99
CYN-MW15	174	151.51	22
CYN-MW16	390	336.40	54
CYN-MW17	377	355.42	22
CYN-MW18	270	240.09	30
CYN-MW19	55	41.07	14
Average	253	202	50

NOTES:
Calculated water level rise is reported to the nearest whole number.
AOC = Area or Concern.
BSG = Burn Site Groundwater.
bgs = Below ground surface.
CYN = Canyons (monitoring well designation only).
ft = Foot (feet).
ID = Identifier.
MW = Monitoring well (monitoring well designation only).

The capability of the fractured and faulted rocks to store water is described by the total and effective porosity. The total and effective porosity of the fractured bedrock aquifer system at the BSG AOC is not known. However, total and effective porosities of fractured metamorphic and igneous rocks typically are small, with a reasonable range of effective porosity from 10^{-2} to 10^{-5} (Freeze and Cherry 1979). The effective porosity of the fractured rocks at the BSG AOC most likely is toward the lower end of that range. The porosity values incorporated into the modeling used to support the remedial alternatives are discussed in Section 7.

3.4 Groundwater Recharge and Discharge

The subsections below discuss groundwater inflow and outflow from the fractured bedrock aquifer system.

3.4.1 Wastewater Disposal

Historical releases of wastewater are associated with several SWMUs, and Section 4 discusses these release sites in detail. Wastewater associated with explosives tests and burn tests was disposed at five SWMUs (13, 65C, 94D, 94E, and 94F) from 1969 to 1988. It is estimated that a total of 483,000 gallons of wastewater was disposed at these five SWMUs (see Section 4.2.2).

3.4.2 Precipitation

The climate of the Albuquerque Basin is semi-arid. Long-term average precipitation ranges from 8.84 inches per year (30-year norm based on 1991-2020 data) at Albuquerque International Sunport up to 35 inches per year at the crest of the Sandia Mountains located approximately 15 miles to the northeast. New Mexico receives most of its precipitation between July and September due to the development of the North American Monsoon. This precipitation comes in the form of brief, heavy rain. For CY 2021, the wettest month was July (SNL/NM June 2022).

In addition to the National Weather Service meteorological station "KABQ" at the Albuquerque International Sunport, precipitation data are available from four on-site rain gauges. Of these four on-site meteorological towers, two of them are relevant to the BSG AOC: (1) tower LC1 is in Lurance Canyon Burn Site Testing Facility and was established in 2019, therefore annual data prior to 2020 are not available, and (2) tower SC1 is near the Schoolhouse Well in the foothills of the Manzanita Mountains approximately 3 miles west of the BSG AOC and was established in 1994. The locations of these meteorological stations are shown on Figure 2-6.

Table 3-6 shows annual precipitation during CY 2021 at the three locations; CY 2020 data are also presented for comparison. The differences in precipitation totals from the three locations show the isolated nature of rain showers in the Albuquerque area. The 5.50 inches of precipitation measured at KABQ during CY 2021 is only slightly less than the corresponding period for the previous year (5.88 inches); but it is 3.34 inches below the 30-year (1991-2020) norm of 8.84 inches (SNL/NM June 2022).

Table 3-6. Precipitation Data for Kirtland Air Force Base, CY 2020 and CY 2021

Year	Meteorological Station		
	LC1	SC1	KABQ
2020	6.58	7.82	5.88
2021	9.73	8.58	5.50

NOTES:
Data are in inches of rainfall.
CY = Calendar Year.
KABQ = National Weather Service meteorological station at the Albuquerque International Sunport.
LC1 = SNL/NM meteorological station at the Lurance Canyon Burn Site Test Facility, installed in 2019.
SC1 = SNL/NM meteorological station in the foothills of the Manzanita Mountains.
SNL/NM = Sandia National Laboratories, New Mexico.

As previously mentioned, there are no long-term precipitation data available for tower LC1 in the BSG AOC. However, long-term precipitation data are available for tower SC1 and as expected shows values greater than KABQ (due to elevation differences). For the reporting period of 2011 through 2021 annual precipitation at SC1 ranged from 6.51 to 14.23 inches per year with an average of 10.10 inches per year (SNL/NM June 2022). With LC1 located further into the Manzanita Mountains at an elevation approximately 500 ft higher than SC1, it is likely that precipitation at the BSG AOC exceeds 10 inches per year. Previous estimates of the average annual precipitation in the Lurance Canyon drainage basin ranged between 12 and 16 inches depending on elevation (SNL/NM April 2008a).

3.4.3 Infiltration and Recharge

Lurance Canyon Arroyo trends across the center of the BSG AOC and directs sporadic, brief, ephemeral stream flows from mountainous catchments to the east towards Arroyo del Coyote, Tijeras Arroyo, and ultimately the Rio Grande. The uppermost extent of the active channel in

Lurance Canyon trends across the southern edge of the Lurance Canyon Burn Site Testing Facility. Near the center of the facility, two smaller tributaries branch off with one trending northward and the other southeastward. The surrounding terrain is steep and is generally sloped toward the combined drainage of Lurance Canyon.

Annual potential evapotranspiration in the Albuquerque area greatly exceeds annual precipitation. Because much of the rainfall in the Lurance Canyon drainage occurs during the hot summer months, losses to evapotranspiration are high. A small percentage may infiltrate into the exposed bedrock or into alluvial deposits in the canyon. In response to heavy rains a few times per year, the width of flowing water in the active channel of the Lurance Canyon Arroyo can be 10 to 20 ft. These flows are typically of brief duration. Much of the potential recharge flows beyond the BSG AOC boundary with the remainder returning to the atmosphere through evapotranspiration. Some water that infiltrates the arroyo channel may move past the root zone and provide some local recharge.

The north-trending brecciated fault zones crossing the BSG AOC and the Lurance Canyon drainage are considered to provide a permeable conduit between the land surface and the fractured water-bearing rocks at depth. These fault zones encompass a very small percentage of the drainage basin. Consequently, the amount of precipitation that falls directly on these fault zones is insignificant.

Streamflow occurs episodically in the Arroyo del Coyote channel in response to precipitation in the drainage basin. A USGS stream gaging station was operated during 1990-1995 on Arroyo del Coyote approximately seven miles downstream from the BSG AOC. This station monitored streamflow from a drainage area of about 35 mi^2, including the 2.8 mi^2 drainage area above the BSG AOC. A total discharge of 137 acre-ft of water occurred during July-September 1991, and 12 acre-ft of water occurred during May-September 1994. Except for several other short flows, the remainder of the period of record was characterized by no flow. No discharge records are available for Arroyo del Coyote after 1995 (SNL/NM April 2008a).

Based on the 6-year period of streamflow record on Arroyo del Coyote and on the distribution of rainfall at Meteorological Monitoring Station SC1 located in Arroyo del Coyote during 1995-2005, runoff in the BSG AOC region was sporadic and was associated with summer thundershowers (SNL/NM April 2008a). Periodic recharge to the alluvial sediments in Lurance Canyon is dependent on precipitation patterns in the 2.8 mi^2 drainage upstream from the BSG AOC.

There were two piezometers constructed in the BSG AOC to monitor moisture within the channel deposits at the contact with underlying Precambrian bedrock (Section 3.2). No water was detected in either piezometer until September 2, 2004. After a series of rain events, between 1 and 2 inches of water was measured in 12AUP-01. The water level remained constant through September 2004, but subsequent water level measurements showed no measurable water in 12AUP-01. It is likely that moisture is present in the vadose zone only after a series of significant rain events. Episodic accumulation of precipitation, as evidenced by the occurrence of water in the piezometer, may provide a mechanism for recharge through brecciated fault zones and uncemented fractures in the underlying bedrock (SNL/NM April 2008a).

Based on the limited streamflow information and piezometer data, streamflow at the BSG AOC sufficient to saturate alluvium and provide a source of recharge to brecciated fault zones is sporadic and infrequent. Also, those recharge events may saturate only the deepest parts of the alluvium and may not be observed elsewhere where alluvium is thinner. Infiltrating water from these stream flows temporarily saturates alluvial sediments adjacent to the arroyo. Much of the water retained as bank and channel bottom storage is probably returned to the atmosphere through evapotranspiration. If infiltrating water from a flow event or sequence of events is adequate to exceed evapotranspiration losses, water may move downward through the canyon alluvium and be available to enter brecciated fault zones in underlying bedrock.

3.4.4 Local Discharge and Production Wells

Based on regional potentiometric contours, groundwater flows west through fractured rocks of the western Manzanita Mountains from recharge areas in the mountain highlands to the east. Groundwater beneath the BSG AOC eventually discharges to basin-fill deposits of the Albuquerque basin to the west. Some discharge takes place at springs at the base of the Manzanita Mountains. No examples of local discharge, such as at production wells or springs, are located within the BSG AOC boundary. The upgradient Burn Site Spring is located to the east and several springs are located several miles to the west (Figure 2-6).

Groundwater discharges as spring flow at scattered mountain front locations. Several springs (Coyote Springs, Cattail Spring, Homestead Spring, and G-Spring) are located down slope and far to the west of the BSG AOC (Figure 2-6). Coyote Springs consists of a major perennial spring and secondary ephemeral spring located in the Arroyo del Coyote approximately 3 miles west of the BSG AOC and coincides with the Coyote Fault. The perennial and ephemeral springs exhibit differing geochemical signatures and water-level fluctuations (IT May 1994). The perennial spring discharges groundwater from bedrock, whereas the ephemeral spring discharges groundwater from alluvium. Farther down slope from Coyote Springs there are a pair of ephemeral springs: Cattail Spring and Homestead Spring. Farther west, G-Spring is ephemeral and located approximately 5 miles west of the BSG AOC (Figure 2-6). When flowing, each of these ephemeral springs are considered low flow with estimated discharge rates of less than a few gpm.

The Burn Site Spring is located about 2,500 ft east of the Burn Site Well and upslope (about 250 ft in elevation) at a limestone outcrop of Madera Formation (Figure 2-6). The spring is ephemeral and associated with bedding planes and/or fractures in the limestone. The stratigraphy surrounding the Burn Site Spring is dominated by the Pennsylvanian Madera Formation with a thin covering of Quaternary alluvium in the arroyo channel. The spring issues from a thinly bedded limestone unit at the base of a 10 to 15 ft high massively bedded limestone cliff and flows over another massive limestone bed that forms a slick-rock channel. Limestone bedding is nearly horizontal, striking east-west and dipping 5 degrees to the north.

The unnamed arroyo containing the Burn Site Spring contains sparse deposits of Quaternary stream alluvium in localized catchments. This alluvium is unconsolidated, light brown to gray, poorly sorted, monolithic sediments derived from weathered Madera Formation limestone (the only stratigraphic unit outcropping upstream of the spring). In this stretch of the canyon there are also some colluvial deposits, similar in lithology to the alluvium, especially on the south side of the unnamed arroyo.

Prior to the early 1940s, the Burn Site Spring was modified for livestock watering by constructing a 2-ft deep, open-top concrete cistern on the slick rock where the spring discharged. The north wall of the cistern is formed by a limestone cliff whereas the other three walls and top of the cistern are made of concrete. It is assumed that the bottom of the cistern is floored by the massive limestone bed that forms the slick-rock channel in the unnamed arroyo. A 1-inch diameter steel pipe connected the cistern to a concrete water trough that is located about 50 ft down slope. The pipe was broken prior to 2007, presumably by a storm event.

A field reconnaissance and sampling of the Burn Site Spring was conducted in October 2004 (SNL/NM January 2005). The immediate area surrounding the cistern was lush with hydrophilic plants such as reeds and grasses. A sporadic line of lush hydrophilic plants trended northward approximately 20 ft to the base of the small cliff indicating that some water was seeping from the base of the cliff toward the concrete cistern. The volume of the cistern was calculated to be approximately 40 gallons. After the cistern was bailed dry and allowed to recover, water samples were collected for NPN and general chemistry analyses. Water in the cistern recovered at a rate of approximately 0.2 gpm.

The Burn Site Spring has been inspected on an infrequent basis. In addition to the October 2004 inspection and sampling, the spring was inspected in March 2007 and August 2013. In March 2007, cistern was full of water and the overflowing water extended about 30 ft down the limestone slick rock. In August 2013, the cistern was nearly dry; approximately 0.5 inches of almost stagnant water was present in the base of the cistern and no water flowed out of the cistern.

No consumptive use of groundwater currently occurs in the vicinity of the BSG AOC. KAFB and other water providers operate production wells near and in the Albuquerque Basin to the west (Figure 2-6), but at distances too great to be impacted by groundwater from the BSG AOC. No potable production wells are located within three miles of the BSG AOC. The nearest active production wells are used for non-potable purposes (Table 3-7). The nearest production well used for potable purposes is well KAFB-4, which is located approximately 9 miles northwest of the Burn Site Well. The KAFB production wells are screened over a depth from approximately 500 to 2,000 ft bgs and extract groundwater from the Regional Aquifer in the upper and middle unit of the SFG. During CY 2021, KAFB pumped groundwater for consumptive use primarily from three production wells (KAFB-3, KAFB-4, and KAFB-20). Total production in CY 2021 was approximately 794 million gallons (SNL/NM June 2022).

Table 3-7. Construction Information for Serviceable Production Wells Located Nearest and Downgradient of the BSG AOC

Production Well	Distance (in miles) and Direction from BSG AOC	Use	Diameter (inches)	Screened Lithology
Burn Site Well	0	Non-potable. Occasional fire suppression usage from 1986 to 2003.	4	Bedrock (schist and granitic gneiss), screened 231 – 341 ft bgs.
KAFB-4	8.9 (northwest)	Potable, general water supply. Consistent usage from 1949 through 2021.	14	Basin fill. Screened 494 to 1,000 ft bgs.
KAFB-18 (Starfire Optical Range)	4.4 (southwest)	Non-potable, toilets and sinks.	5	Bedrock (granite), screened 160 - 200, and 240 - 320 ft bgs

NOTES:

KAFB-18 is also known as the Starfire Optical Range (SOR) well or the Optical Range Well.

AOC = Area of Concern.
BSG = Burn Site Groundwater.
ft bgs = Feet below ground surface.
KAFB = Kirtland Air Force Base.

KAFB supplies all the potable water used at SNL/NM and other DOE facilities on base except for bottled water at remote sites. A basewide water-distribution system of buried pipelines is permitted to and managed by KAFB. The system distributes potable water to SNL/NM TAs, Manzano Base, and Building 9925 in the Coyote Test Field. However, no pipelines extend east of Pennsylvania Street / Lovelace Road and along Lurance Canyon. Water trucks are used to haul water to the Lurance Canyon Burn Site Testing Facility and the Transportation Safeguards Academy. Also, a tanker truck is used for dust suppression by applying water on the gravel roads. The tanker truck is filled using potable water from the KAFB distribution system.

The nearest residences are located 2.9 miles east (upgradient) of the BSG AOC and several household/domestic use wells are located to the east of KAFB along New Mexico State Highway 337 (Bartolino et al. 2010).

In February 1986, the Burn Site Well (Figure 3-3) was installed as an onsite production well to supply fire-suppression water and fuel-pool water for testing operations. Water from this production well has not been used for dust suppression, sanitation, or drinking purposes. Water-bearing fractures were encountered from 230 to 350 ft bgs. The Burn Site Well is screened from 231 to 341 ft bgs across the water-bearing fractures. Immediately after drilling, the water level rose to 68 ft bgs (IT May 1994) which is 163 ft above the top of screen. According to the well record submitted to the New Mexico Office of the State Engineer (NMOSE) the sand pack extends from 50 to 341 ft bgs and the driller estimated a yield of 20 gpm (NMOSE April 1986). The Burn Site Well was used infrequently from 1986 to 2003. Production ceased in 2003 and the submersible pump was removed from the well in December 2014. The water was used for fire-suppression and in fuel pools. Records of the production values are limited. During February 1992 to February 1993, approximately 1,500 gallons of water was pumped. Water levels were not measured at the Burn Site Well during its operations because the well was not constructed with an access port or sounding tube.

3.5 Groundwater Geochemistry

This section discusses geochemical characteristics and properties of the fractured bedrock aquifer system in the BSG AOC.

3.5.1 Groundwater Isotopic Studies

Stable isotope, denitrification and groundwater age-dating studies were performed and reported for the BSG AOC by geochemists from Lawrence Livermore National Laboratory (LLNL). The final report from those studies (Madrid et al., 2016) combined and summarized results for two groundwater-sampling events in October 2012 and October/November 2015. The October 2012 event included samples from 19 wells at three separate AOCs (BSG, TA-V Groundwater, and Tijeras Arroyo Groundwater) that were analyzed by the Environmental Radiochemistry Laboratory at LLNL (Madrid et al. 2013) as part of a nitrate Monitored Natural Attenuation (MNA) evaluation. This sampling event included groundwater sampling at six BSG AOC monitoring wells. Each groundwater sample was analyzed using two specialized analytical methods: (1) age-dating, and (2) denitrification suites. In September 2015, a second phase of groundwater sampling took place at 10 BSG AOC monitoring wells with samples analyzed by the same two analytical methods. Five of the six monitoring wells sampled in 2012 were resampled in 2015.

Groundwater age dating was used to evaluate the degree to which groundwater at a particular monitoring well is derived from pre-modern and/or modern sources (i.e., during the last 50 years). More specifically, this analysis can be used to assess the timing and contribution of seasonal recharge to the groundwater beneath the BSG AOC relative to recent anthropogenic activities such as HE detonation and burning. Additionally, the data can be used to rule out the possibility that groundwater in some areas exhibits no evidence of recharge in modern times.

The analytical data from the denitrification suite was used to evaluate the presence and magnitude of *in situ* nitrate reduction by detecting the presence of excess dissolved nitrogen gas and any enrichment in the ^{15}N and ^{18}O of nitrate. Denitrification is a microbially facilitated process that reduces nitrate to molecular nitrogen (N_2) through a series of intermediate products. Denitrification typically occurs in oxygen-depleted, redox-negative groundwater systems. If present, the degree of denitrification in groundwater is expected to increase along a groundwater flow path as the residual nitrate concentrations decrease with the isotopic composition, enriched in the heavier ^{15}N and ^{18}O isotopes and depleted in the lighter ^{14}N and ^{16}O isotopes, relative to the original source nitrate. The ratio of the isotopic enrichment of nitrogen to oxygen is consistent across environmental settings, and has been empirically determined to be roughly 2:1 (Kendall 1998). As a result of denitrification, the concentration of dissolved N_2 gas also increases.

Data from both the 2012 and 2015 sampling events are presented in the 2016 report (Madrid et al. 2016), which is provided as Attachment 3. In Figure 3-11 nitrate concentration is plotted against δ^{15}N-NO_3 and each sample is symbolized by groundwater age. Excluding CYN-MW4, the trend indicates monitoring wells that sample modern groundwater also contain the highest nitrate concentrations. The range of ^{15}N-NO_3 is consistent with nitrate soil sources and exhibits little evidence of isotopic enrichment related to denitrification. Although CYN-MW4 contains fossil groundwater (greater than 50 years old, and possibly much older) that is slightly enriched in δ^{15}N-NO_3, it is located up-gradient of the Lurance Canyon Burn Site Testing Facility and appears to be hydraulically isolated from modern recharge.

The interpreted groundwater age for each monitoring well is plotted on the BSG AOC map in Figure 3-12. Based on these results, the conclusions of the groundwater denitrification and age dating study (Madrid et al. 2016) are:

- The highest NO_3 concentrations at the BSG AOC (CYN-MW6/15, CYN-MW9, CYN-MW10) exhibit the youngest ^{3}H/^{3}He groundwater ages and the lowest tritiogenic ^{3}He and radiogenic ^{4}He concentrations. These monitoring wells sample water that is predominantly to exclusively modern (less than 10 years).
- Groundwater samples from monitoring wells CYN-MW9, CYN-MW11, and CYN-MW12 that were collected in 2015 exhibited significant increases in the amount of tritium detected and changes in the oxygen and hydrogen isotope compositions when compared to the 2012 samples. CYN-MW11 and CYN-MW12 sampled predominantly fossil water with a detectable modern component in 2012. The 2015 tritium concentrations in these monitoring wells indicate a significant increase in the relative contribution from recent recharge. Recent or modern recharge is younger than the early 1950s when thermonuclear atmospheric testing took place and significant amounts of tritium (“bomb pulse tritium”) were released to the atmosphere.
- The spatial and temporal correlation between modern groundwater and elevated nitrate suggest a significant vertical pathway for recharge that is likely co-located with an elevated nitrate source. The nitrate source could be natural, anthropogenic, or mixed. Given the complex hydrogeologic setting, the recharge pathway could be associated with faults or fracture corridors that act as vertical conduits for recharge to the deep fractured bedrock aquifer system. It is also possible that the annular seal(s) in one or in one or more of the wells have degraded and may be acting as vertical conduits for deep recharge.

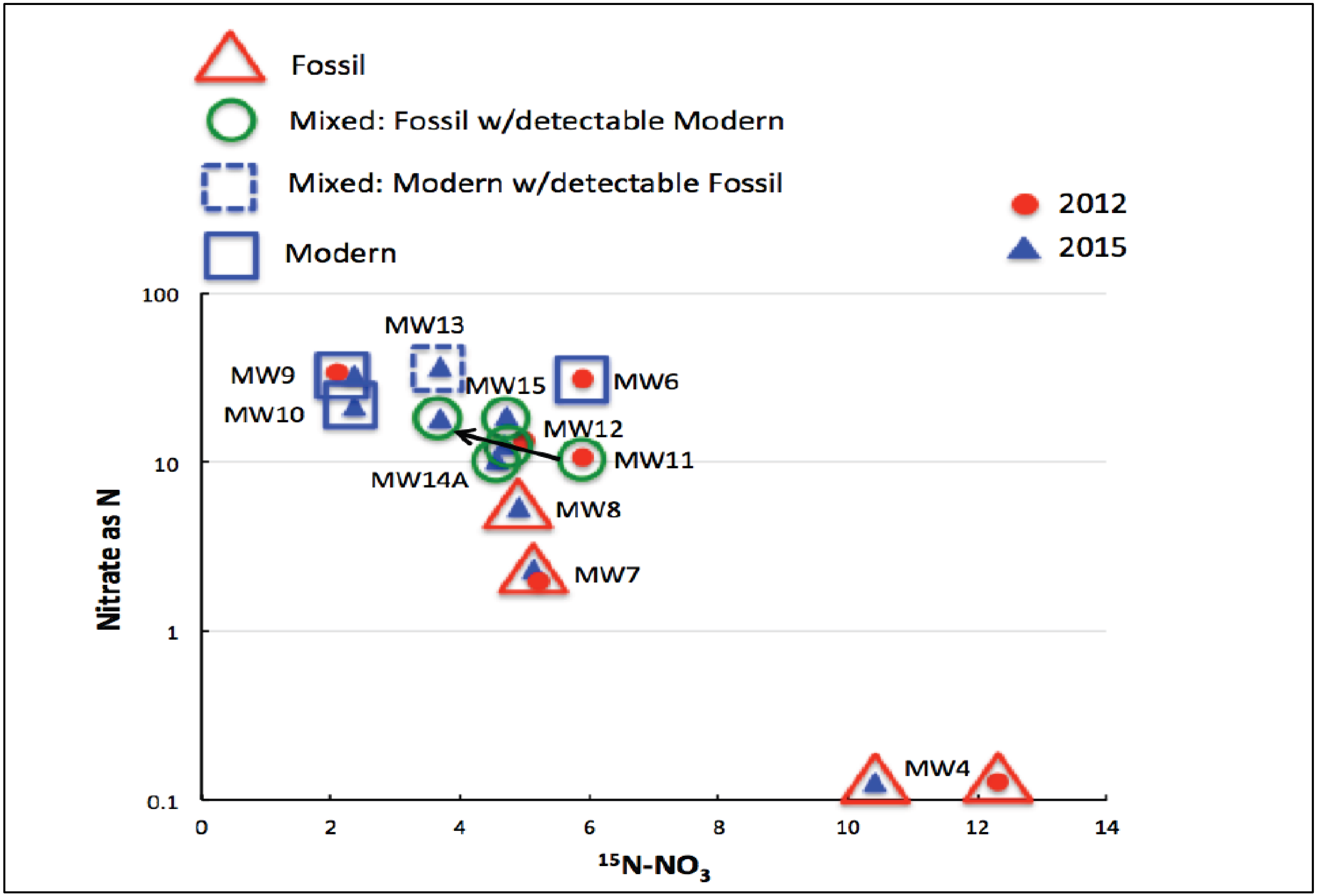


Figure 3-11. Plot of Nitrate (in mg/L, as N) Versus ^{15}N-NO$_3$ Annotated with Groundwater Ages for Samples Collected in 2012 and 2015 (Madrid et al. 2016)

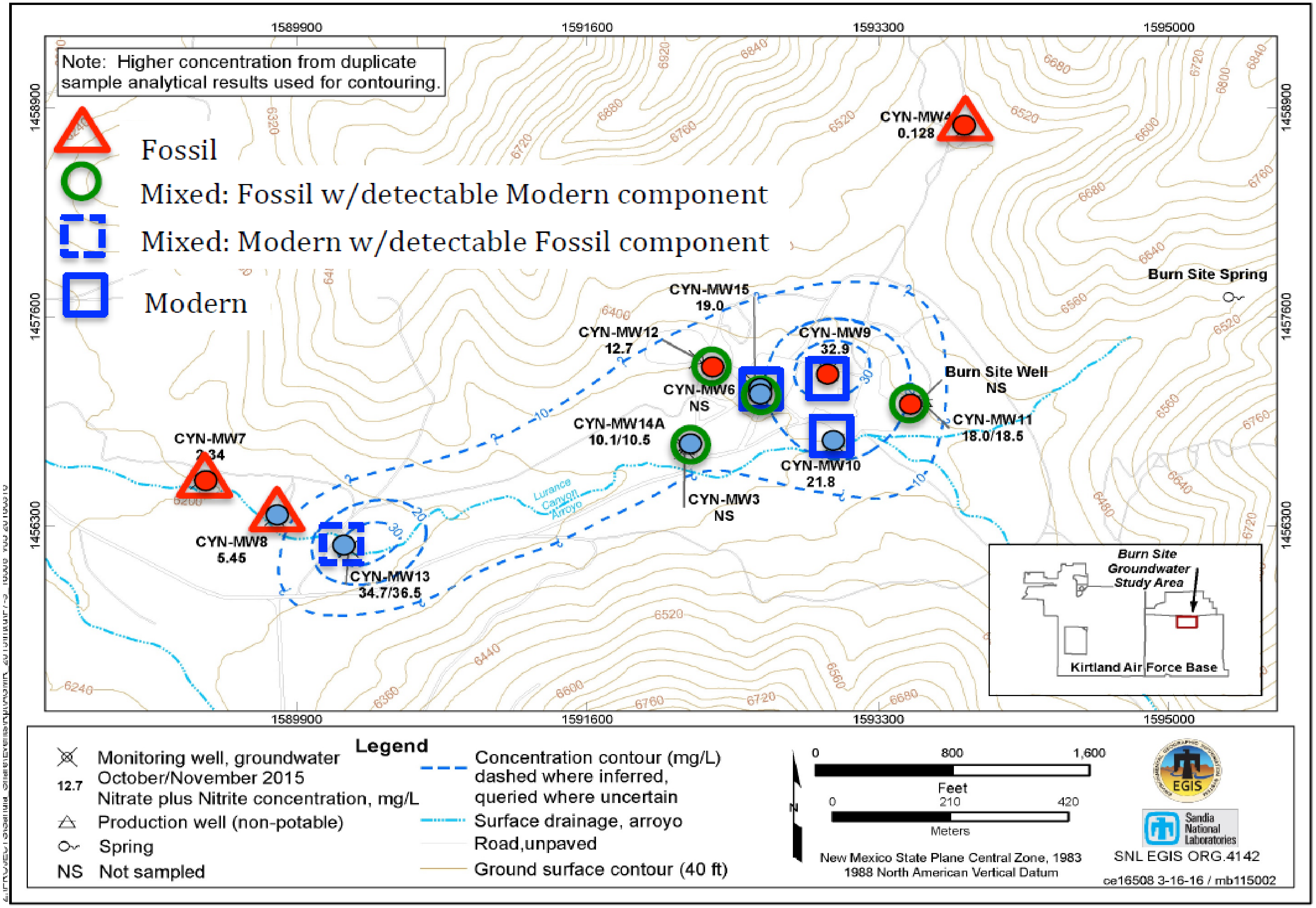


Figure 3-12. Summary Map Showing Groundwater Age on the 2015 Nitrate Distribution (Madrid et al. 2016)

- The lowest nitrate concentration wells (i.e., < 10 mg/L as N [the EPA MCL]), CYN-MW4, CYNMW7, and CYN-MW8, contain the most radiogenic ^{4}He. These wells sample very old fossil water and represent levels that are indicative of natural background nitrate levels under past climatic and environmental conditions, including water-rock interaction for at least several hundred years.
- The increased tritium concentrations in 2015, with respect to 2012, are evidence for recharge pathways at the BSG AOC that are active under present day conditions.
- The combined results of the denitrification suite (i.e., low to non-detectable excess N_2 and no significant enrichment in nitrate isotopic composition) are not supportive of any significant natural attenuation of groundwater nitrate in the BSG AOC monitoring wells.

In addition to the LLNL stable isotope, denitrification, and groundwater age dating studies, the NMED DOE Oversight Bureau (OB) performed similar and concurrent studies (Longmire and Armijo January 2017). During split sampling in October to November 2015, the NMED DOE OB collected and analyzed groundwater samples for NPN, ammonium-ammonia, Total Kjeldahl nitrogen (TKN), cations and anions, perchlorate, GRO compounds, DRO compounds, low-detection level tritium, and stable isotopes of hydrogen, nitrogen, and oxygen.

With findings similar to the results of the LLNL study, the NMED DOE OB report (Longmire and Armijo January 2017) found:

- The nitrogen isotope composition of the groundwater samples suggest that nitrification processes have taken place and that denitrification only occurs to a limited extent under aerobic conditions. Excess N_2 gas concentrations in groundwater were generally low to non-detect indicating that denitrification is not widely occurring.
- Downward vertical flow paths through the fractured and faulted vadose zone to the fractured bedrock aquifer system are collocated with a nitrogen source resulting in a nitrate plume.
- Activities of tritium are less than analytical detection and concentrations of NPN (as nitrogen) are less than 5 mg/L at background and noncontaminated, downgradient sampling stations.
- Non-detect activity of tritium in submodern groundwater confirms that recent recharge (post early 1950s) has not taken place outside of the source area.
- Groundwater with detectable activity of tritium have both mixed and/or modern ages, and recent recharge has taken place in the source area since the early 1950s. Sources of modern recharge water most likely include precipitation and water used for fire suppression.

3.5.2 Groundwater General Chemistry

The geochemistry discussion for groundwater samples collected from the BSG AOC monitoring wells is based on the interpretation of Piper and Stiff diagrams. The depiction of major ions is typically useful as a diagnostic tool for evaluating sources of groundwater recharge and groundwater flow patterns.

3.5.2.1 Piper Diagrams

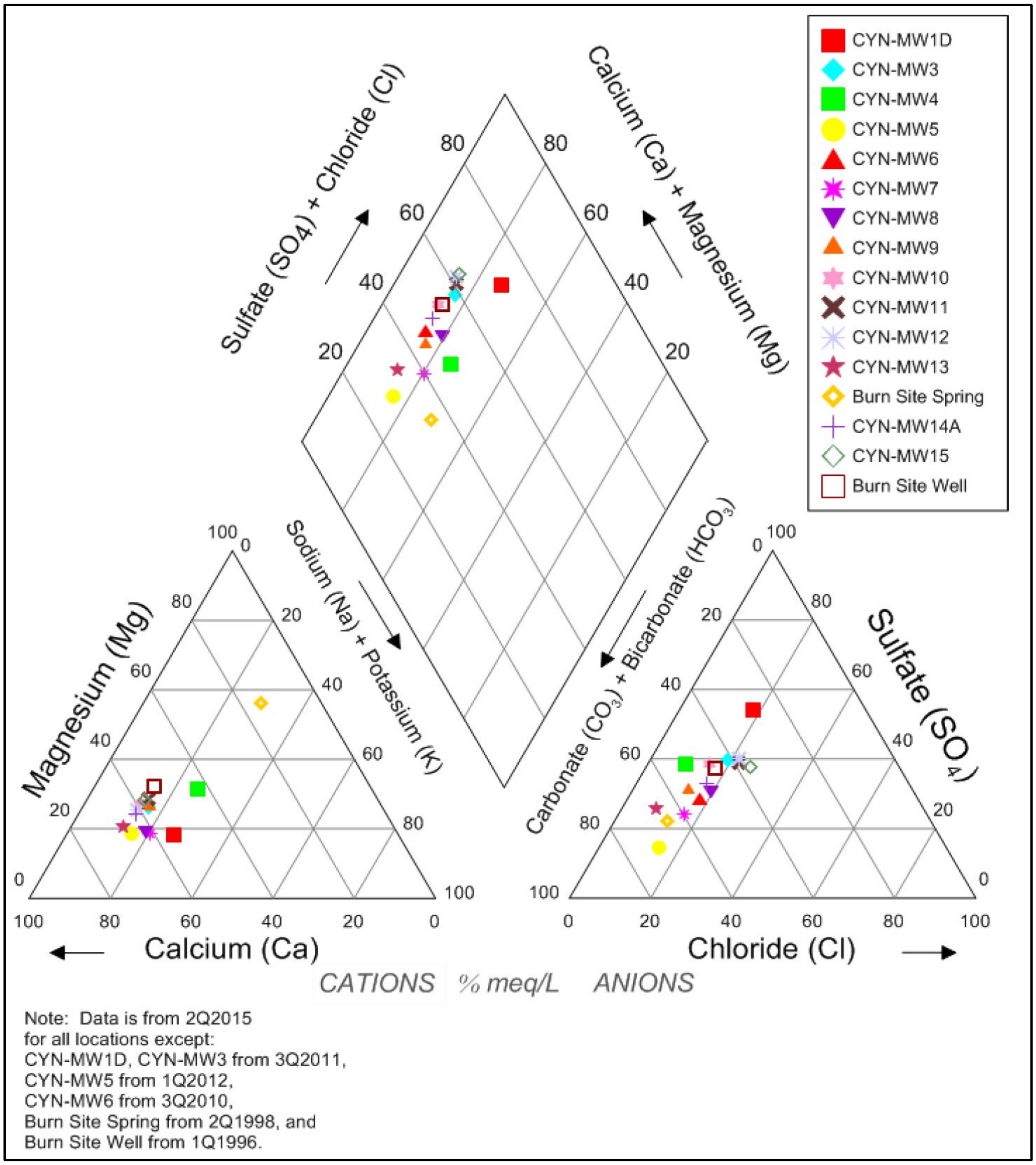
Figure 3-13 presents the Piper diagram depicting the geochemical data for select BSG AOC monitoring wells and the upgradient Burn Site Spring. Several interpretations can be gleaned from the Piper diagrams:

- Water samples exhibit a consistent groundwater chemistry that is classified as a calcium-bicarbonate type. Calcium is the dominant cation and bicarbonate is the dominant anion.
- There is only slight variability in geochemistry as shown in the plots; some variation was found for the Burn Site Spring (higher magnesium) and monitoring well CYN-MW1D (higher chloride). Well CYN-MW1D was replaced by well CYN-MW13.
- The tight grouping of the data points indicates that groundwater from all monitoring wells is chemically similar, and the water appears to have a single source.

3.5.2.2 Stiff Diagrams

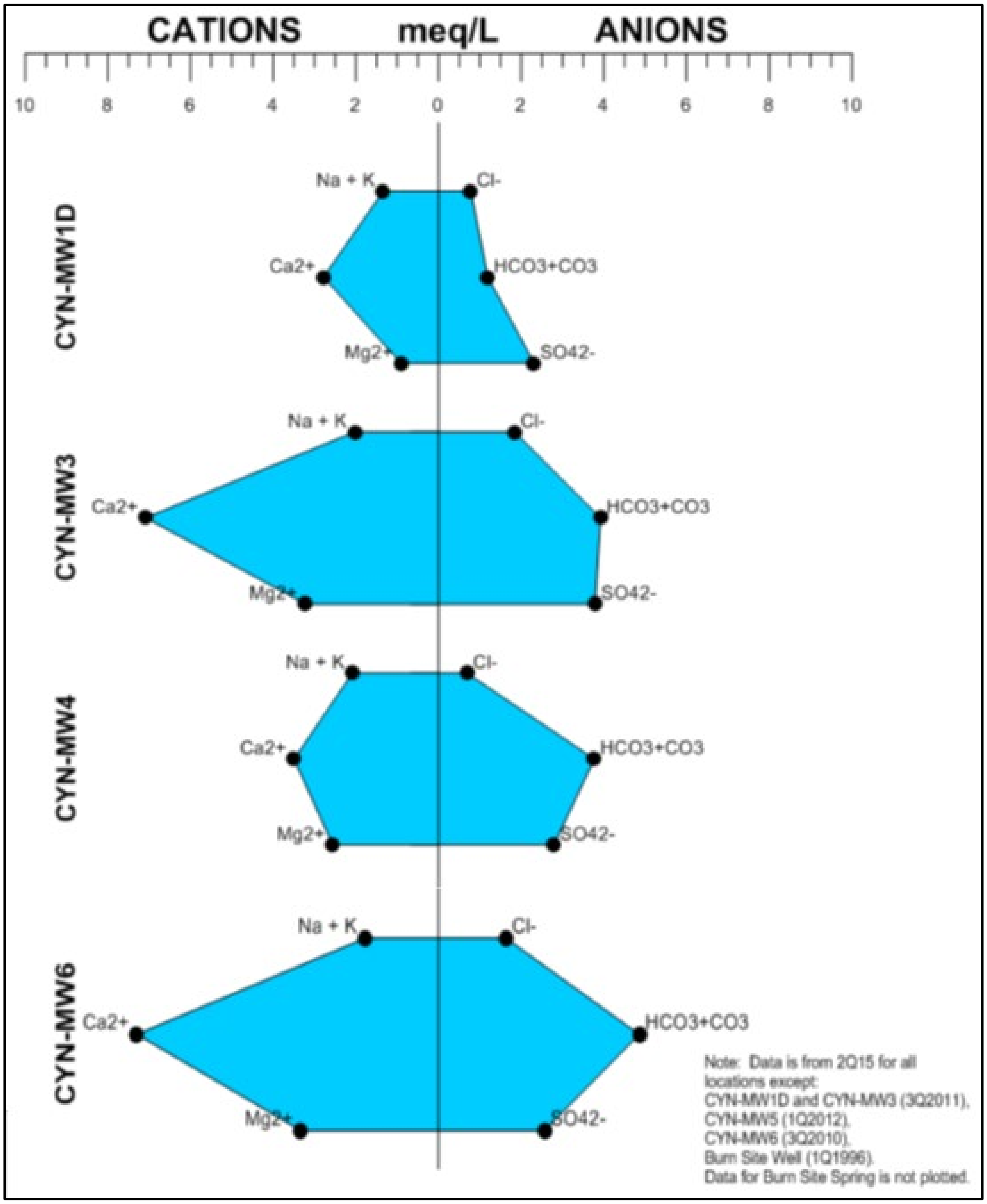
Figures 3-14 through 3-16 present Stiff diagrams for the BSG AOC monitoring wells. Several interpretations can be gleaned from the Stiff diagrams:

- Except for two wells (CYN-MW1D and CYN-MW4), the water from the monitoring wells has consistent ion concentrations, the dominant cation is calcium, and the dominant anions are bicarbonate and sulfate.
- The similarity of Stiff diagrams for water indicates that the groundwater from all monitoring wells is chemically similar and represent a single/broader source.
- The Stiff diagram for the decommissioned well CYN-MW1D (Figure 3-14) shows diminished concentrations of all cations and anions. Before decommissioning, this well had biofouling issues and an unusual well completion (carbon steel screen), both of which have locally affected the water chemistry.
- The Stiff diagram for monitoring well CYN-MW4 (Figure 3-14) shows reduced concentration of calcium on the cation side and more typical concentrations of anions. This is an upgradient monitoring well and may have a slightly different source of recharge or different residence time than the other monitoring wells.



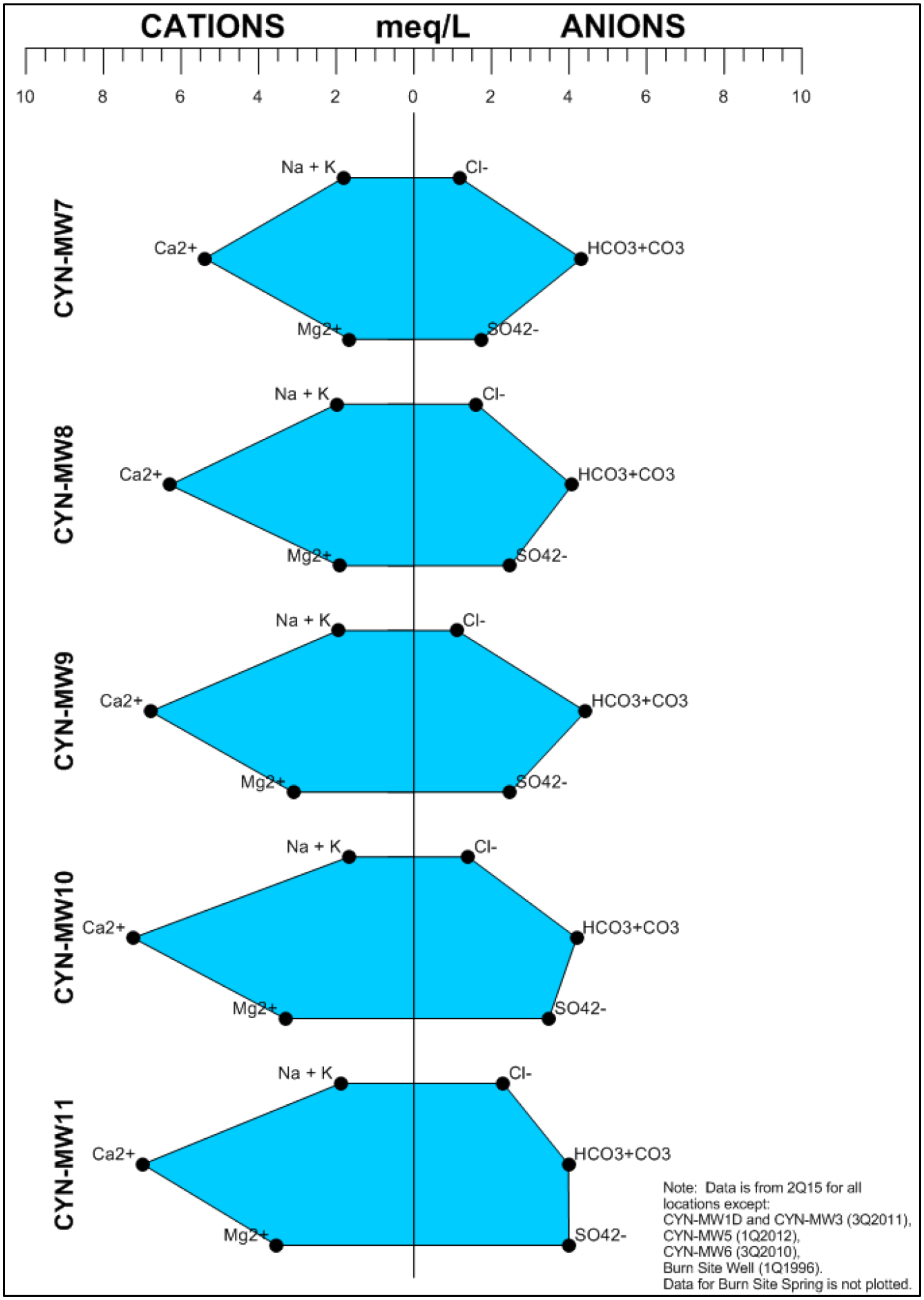
Note: Data is from 2Q2015
for all locations except:
CYN-MW1D, CYN-MW3 from 3Q2011,
CYN-MW5 from 1Q2012,
CYN-MW6 from 3Q2010,
Burn Site Spring from 2Q1998, and
Burn Site Well from 1Q1996.

Figure 3-13. Piper Diagrams for BSG AOC Monitoring Wells



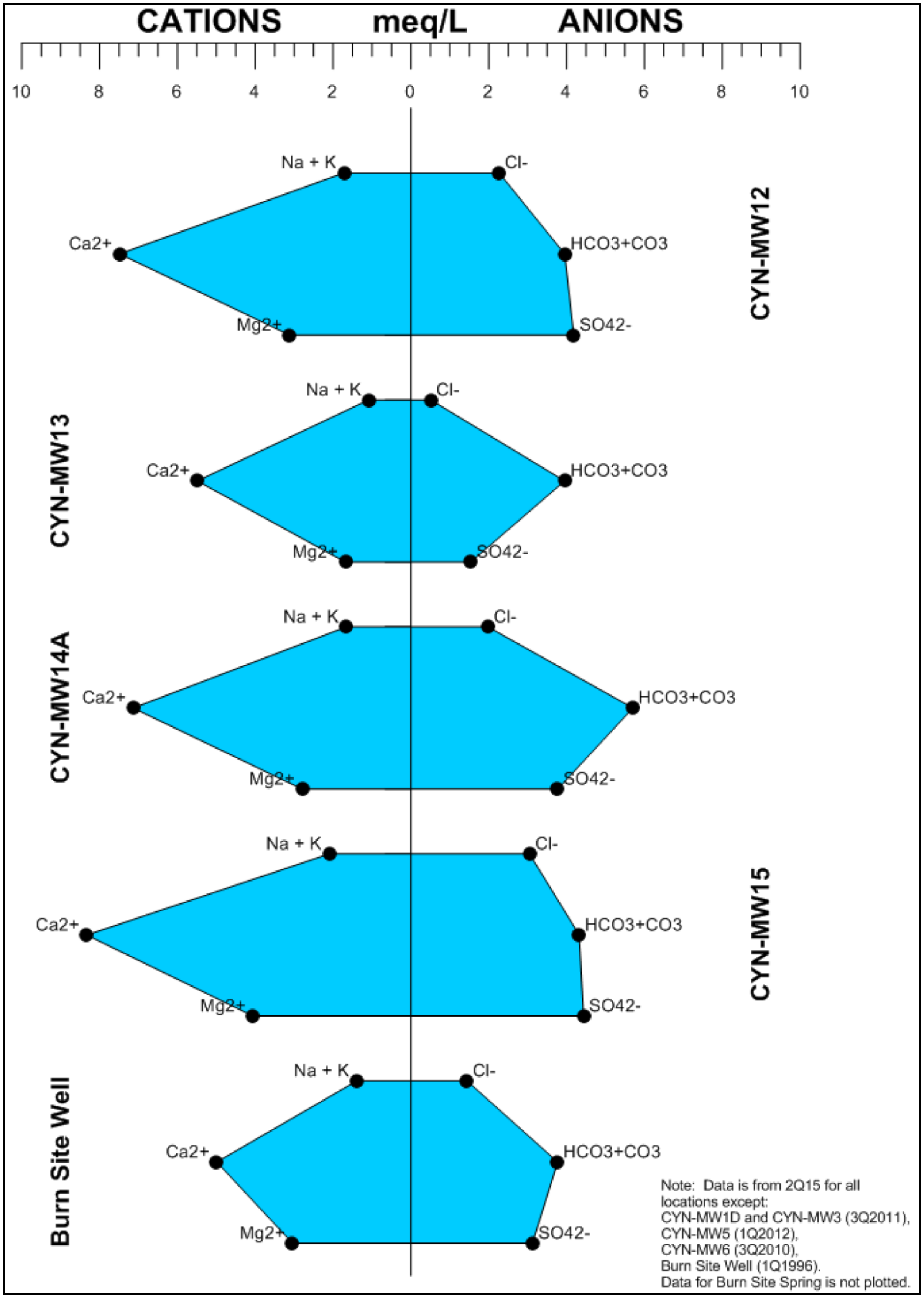
Note: Data is from 2Q15 for all
locations except:
CYN-MW1D and CYN-MW3 (3Q2011),
CYN-MW5 (1Q2012),
CYN-MW6 (3Q2010),
Burn Site Well (1Q1996).
Data for Burn Site Spring is not plotted.

Figure 3-14. Stiff Diagrams for BSG AOC Monitoring Wells (1 of 3)



Note: Data is from 2Q15 for all locations except:
CYN-MW1D and CYN-MW3 (3Q2011),
CYN-MW5 (1Q2012),
CYN-MW6 (3Q2010),
Burn Site Well (1Q1996).
Data for Burn Site Spring is not plotted.

Figure 3-15. Stiff Diagrams for BSG AOC Monitoring Wells (2 of 3)



Note: Data is from 2Q15 for all locations except:
CYN-MW1D and CYN-MW3 (3Q2011),
CYN-MW5 (1Q2012),
CYN-MW6 (3Q2010),
Burn Site Well (1Q1996).
Data for Burn Site Spring is not plotted.

Figure 3-16. Stiff Diagrams for BSG AOC Monitoring Wells (3 of 3)

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4. SITE HISTORY, CORRECTIVE ACTIONS, AND POTENTIAL RELEASE SITES

This section provides background information on the history of operational activities near the BSG AOC, a summary of the corrective actions conducted by DOE/NNSA and its M&O contractor for SNL/NM and a discussion of the potential nitrate-release sites. The water-type terminology used in this CCM/CME Report is as follows. Wastewater refers to water derived from activities such as research/testing operations. Septic water refers to sewage (sanitary waste) from restrooms and bathing showers. Stormwater consists of precipitation and ephemeral overland flow.

4.1 Pre-Operational History

The land use at BSG AOC has a long complex history from prehistoric through modern times. To investigate pre-modern land use, sixteen cultural resource investigations have been conducted within or near the BSG AOC either for: (1) specific ground-disturbing undertakings, (2) as part of long-term environmental stewardship, or (3) cultural resource identification programs. Some of the findings from the most recent cultural resource investigation conducted by Okun Consulting Solutions in the vicinity of the BSG AOC are summarized below (Okun Consulting Solutions November 2021).

The Paleoindian Period (11,500 to 7,500 years before present [BP]) represents the earliest human occupation in the New World. Clovis marks the first universally accepted and consistently dated human occupation in the Americas (11,500 to 10,800 BP). There is little evidence of Clovis remains in most of central New Mexico, however a Clovis point has been discovered on KAFB near a small marshland, and two slightly younger Folsom Period (10,800 to 9,500 BP) sites were documented on KAFB near the confluence of Arroyo del Coyote and Tijeras Canyon, west of the BSG AOC.

Early Archaic Period (5,500 to 3,500 years before common era [BCE]), Middle Archaic Period (3500 to 1500 BCE), and Late Archaic Period (1,500 BCE to anno Domini [AD] 400) sites have been documented at locations on low hills and ridges overlooking Coyote Canyon and at other sites in the eastern Albuquerque Basin. Close to the BSG AOC, one Late Archaic Period site in the foothills of the Manzanita Mountains has produced radiocarbon dates of 200 BCE to AD 30 from an informal structure. There are 188 Ancestral Pueblo Period (AD 400 to 1540) site components documented on lands managed by KAFB.

The Historic Period includes Early Spanish Colonial (1598 to 1680), Late Spanish Colonial (1680 to 1821), Mexican (1821 to 1848), U.S. Territorial (1848 to 1912), and Twentieth Century. The BSG AOC was not utilized by Euro-Americans until the 1800s, but the indigenous inhabitants of the region utilizing the BSG AOC were mostly Tiwa-speaking Puebloans of Sandia and Isleta in the Albuquerque Basin. The Manzanita Mountains were a boundary between the settled Pueblo and Hispanic villages of the Rio Grande Valley and the Great Plains, which were occupied primarily by nomadic Native American groups such as the Apache and Comanche.

By 1900, the area contained a few dispersed homesteads and ranches and was likely used to graze cattle and sheep, but it did not contain permanent settlements. Coal, copper, lead, and zinc mining developed in the nearby mountains. Fluorspar and iron ore were mined in the Manzanita Mountains from the 1920s to the 1940s, and sites near the BSG AOC contain associated mining features from this period (discussed below). During those times roads were constructed in the area to access mining sites and timber resources in the higher part of the mountains (Okun Consulting Solutions November 2021).

The history of KAFB originates in 1928 with the construction of the public Albuquerque Airport on the East Mesa. Renamed Oxnard Field in 1929, the airport was used until late 1939 when the vicinity of Oxnard Field was purchased by the federal government for use as an Army Air Depot Training Station, later to be known as Sandia Base (SNL/NM February 2018). In 1939, public airline service was moved approximately four miles to the west of Oxnard Field where the Albuquerque Municipal Airport was built. In 1943, the vicinity of the future Burn Site was withdrawn from the U.S. Forest Service and transferred to the U.S. Air Force. In July 1945, the "Z Division" of the Manhattan Engineers District, an extension of the original Los Alamos Laboratory, was established at Sandia Base in the area that would become known as TA-I. In 1949, the independent "Sandia Laboratory" was established. Using the set of municipal runways, the Albuquerque Army Air Base began operations in 1941. The air base was later dedicated as Kirtland Army Air Field and subsequently renamed as KAFB. The municipal airfield is now identified as the Albuquerque International Sunport and is situated at the northwest corner of KAFB. DOE/NNSA and SNL/NM personnel began testing activities at the remote Burn Site in 1967. KAFB is a federally controlled facility with restricted access. Land use development of the region around the BSG AOC is federally managed.

Findings from the most recent cultural resource investigation (Okun Consulting Solutions November 2021) show a wide variety of cultural findings from Archaic through Historic Periods. Examples of cultural findings include:

- Ancestral Pueblo lithic and ceramic scatter, including Socorro Black-on-white and Santa Fe Black-on-white.
- Dart-sized biface/projectile point.
- Lithic debitage (flakes and flake fragments).
- Grinding slick/bedrock metate features located on large siliceous boulders.
- One-handed bifacial sandstone mano.
- Rock shelter containing a masonry enclosing wall beneath a large granite boulder.
- Small rock hearth that contains visible charcoal in the center.
- Isolated rock alignment that could possibly be a hunting blind.
- Historical artifact dump possibly from 1940s or 1950s with 12 rotary-opened single-serving sanitary cans, two 12-ounce, all steel beverage cans (church-key opened), and one large machine part of unknown function.
- Fragments of thick plate metal that may be associated with military activity.
- Glass artifacts, including clear and sun-colored amethyst bottle shards.
- A historic/modern rock-lined hearth possibly from the 1960s.
- Rusted metal machinery part of unknown function.
- Concrete slab with milled wood, secondary dump of construction material.
- Several very modern fire rings.

One notable finding from the November 2021 survey is a small, twentieth century mining site containing a prospect pit and two associated features (similar to the SWMU 28 features described below). The prospect pit is partially infilled, but the site is generally in excellent condition. The prospect pit and associated tailings pile was part of a small mining district along Lurance and Sol se Mete canyons that included the Blackbird Mine and several other mines to the west that produced lead and fluorspar (and small amounts of gold and silver) in the 1920s and 1930s. There is no evidence that the prospect pit extends any significant distance horizontally into the bedrock, so it is unlikely that it was an adit. The prospect pit was excavated into sandstone bedrock that is highly mineralized and contains bands of schist or mica-like materials. The pit is now partially in-filled with rock rubble. The associated tailings pile is immediately to the south and contains cobbles and gravels of the same mineralized sandstone visible in the prospect pit. A small U-shaped masonry alignment of unknown function is located just west of the prospect pit and tailings pile and was probably constructed after the prospect pit was excavated (Okun Consulting Solutions November 2021).

Appendix G presents a series of seven air photos of the BSG AOC from 1951 through 2020. The current outline of the BSG AOC has been superimposed on the air photos as a point of reference. The time series shows evidence of land use changes over the approximately 70-year period from the use of simple wagon trails/jeep trails in the early 1950s to the construction of the well-developed Lurance Canyon Burn Site Testing Facility that occupies the site today. Land disturbances in the flat part of the canyon floor are visible in air photos as early as 1967 (Appendix G).

4.2 Operational History

In 1966, the canyon floor was graded for constructing the testing facilities and a fire-break road was graded along the perimeter of the site. Since then, the central portion of the site has been regraded numerous times as various structures have been built and dismantled. The unpaved ground surface across the facility currently slopes westward at approximately 8%.

The Lurance Canyon Burn Site Testing Facility and its LCETS have been used since 1967 to test the effects of impact, burning, and explosion. Historical operations included open detonation of HE. Most HE testing occurred between 1967 and 1975, and was completely phased out by the 1980s. Burn testing began in the early 1970s and has continued to the present. Early burn testing was conducted in unlined pits excavated in native soil. By 1975, portable burn pans were used for open burning using JP-4. The LAARC Unit was constructed in 1980 and other engineered burn units were constructed by 1983. These burn units used jet fuel, gasoline, and diesel as fuels for burn tests.

Over the past decade, the amount of testing at the Lurance Canyon Burn Site Testing Facility has significantly been reduced with a large proportion of burn tests being conducted at the Thermal Test Complex in TA-III. That being the case, there has been much less water used or discharged within the BSG AOC since 2005.

4.2.1 History of Open-Air HE Detonations

Testing operations at the LCETS were conducted from 1967 to 1993. Open-air HE detonations were conducted from 1967 to 1985 with most of the detonations occurring prior to 1975. At least 318 open-air detonations occurred from 1967 to 1993. The detonations were conducted at the Primary Detonation Area (SWMU 65B) and the Secondary Detonation Area (SWMU 65C; Figure 4-1).

The LCETS was originally designed with a 10,000-ft shrapnel-dispersion radius for creating an adequate safety buffer for detonating up to 10,000 pounds of HE materials per shot. The largest recorded detonation involved 15,000 pounds of ammonium nitrate. Only a few tests are known to have used such large amounts of HE materials. One such test used 8,100 pounds of ammonium-nitrate slurry (equivalent to 10,500 pounds of trinitrotoluene [TNT]) and radially dispersed shrapnel up to 800 ft. In 1977, the explosives-testing limit for the LCETS was reduced to 1,000 pounds of HE material per shot. The available records do not typically list the amount of HE materials used per test. However, it is known that the HE quantities varied from a few pounds up to 15,000

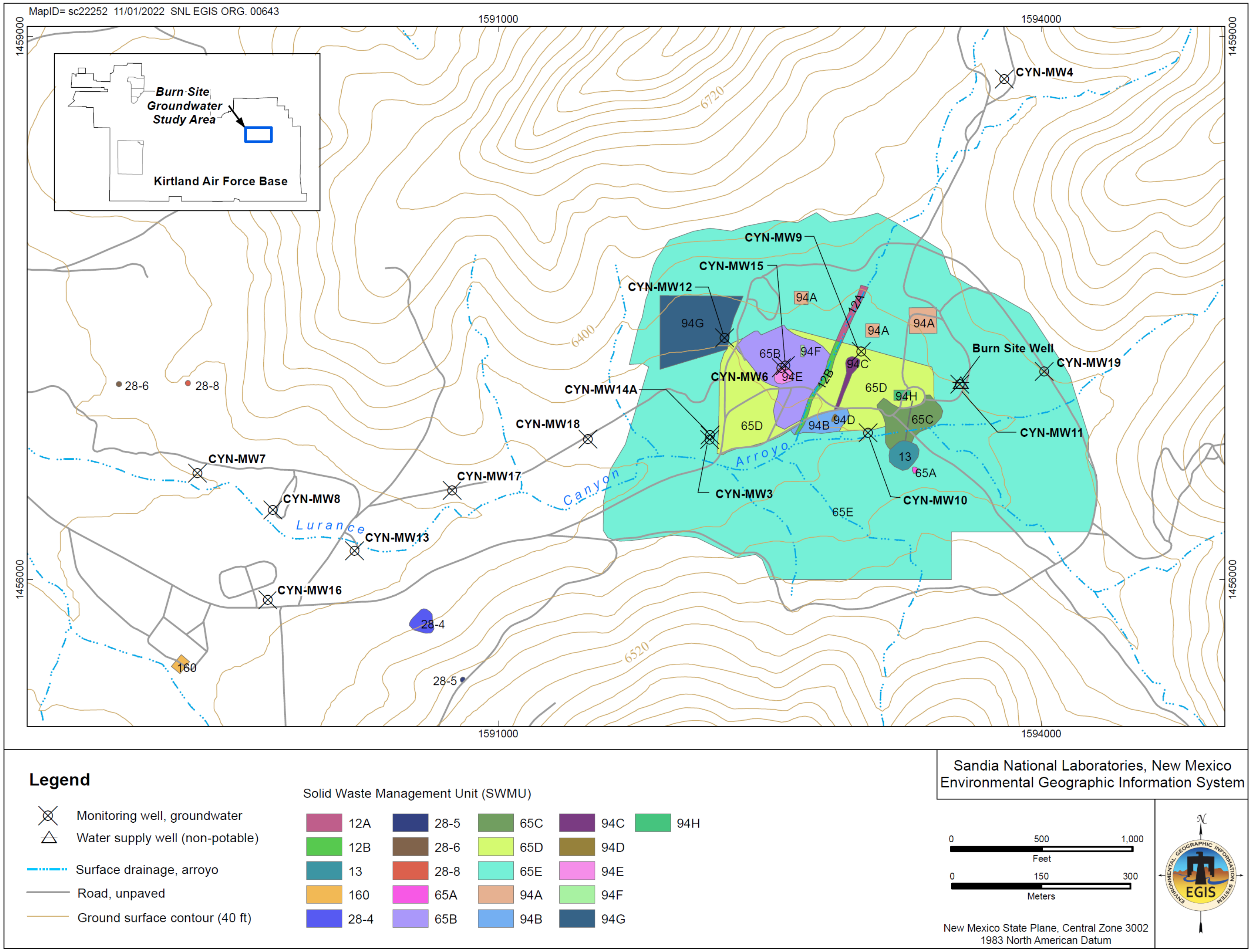

Figure 4-1. Solid Waste Management Units in the BSG AOC

pounds per shot. Depending upon the type of test and whether the HE went full order (was ignited and fully expended), the resulting testing debris could consist of burnt HE residue, HE particulates, and HE fragments. After some tests, pieces of unexpended HE were recovered for mass-balance calculations.

4.2.2 History of Burn Test Activities

Tests at the Lurance Canyon Burn Site Testing Facility are designed to produce simulations of transportation accidents involving various aircraft, vehicle, or rocket-launching scenarios. Flammable materials such as jet fuel produce the high temperatures potentially generated during an accident. Burn-test activities have primarily involved the fire-survivability testing of shipping containers, weapons components, ordnance, and satellite components.

The composition of test articles has included a variety of materials such as aluminum, steel, HE, wiring, and plastics. The test equipment, some of which is damaged or destroyed in the tests, can consist of thermocouples, wiring, insulation, and steel supports. Depleted uranium (DU) was used as a surrogate for some radioactive materials. As part of the environmental investigations, radiological surveys were conducted at all SWMU sub-units and the areas containing DU fragments and soil contamination were identified and remediated.

Lurance Canyon Burn Site Testing Facility began operations in 1975. Historically the tests had a much smaller environmental impact than the LCETS because burn tests had used enclosed testing structures and steel burn pans that did not involve the discharge of wastewaters to the ground surface. Most of burn tests have used petroleum fuels, however a small number of burn tests were conducted without the use of petroleum fuels. These tests used fuels such as wood, rocket propellant, and propane; such tests were conducted on the ground surface or using temporary fixtures. Other types of fuels were proposed, but apparently not used, for testing. These proposed fuels were sawdust, acetone, grease, chicken manure, cow manure, and explosives.

Water has served two crucial purposes for testing operations: (1) used in pool-fire tests, and (2) used for fire suppression in enclosed testing structures. A pool-fire test typically involved suspending a test item above a burning pool of petroleum fuel that floated on 1- to 2-ft column of water. The resulting test temperature was typically 1,700 to 1,800 °F. The average thickness of the fuel was 0.75 ft. For most of the tests, the fuel burned until totally consumed. Water/ethylene glycol coolant has also been sprayed inside enclosed testing structures to suppress and thus moderate the fire intensity. Non-potable water from the Burn Site Well was used from 1986 to 2003 for the sole purpose of supplying water for testing purposes (pool fire and fire suppression).

The duration of the burn test is controlled by using a specific amount of fuel. After the burn test was completed, salvageable materials such as metal supports were removed from the pit or burn pan and stored for possible future use. If not totally destroyed by the test, the device was typically transported to an off-site location for further study such as radiography. Metal slag was removed for disposal, but small residue particulates may have remained in the wastewater.

Table 4-1 lists the five SWMUs where wastewater was discharged to the ground surface and estimated volumes of wastewater. Following completion of a burn test at an excavated pit/impoundment, most of the wastewater infiltrated into the ground and a minor portion evaporated into the atmosphere. The pits were typically not cleaned up between tests and the number of pits and exact locations were not documented. The wastewater may have contained burnt HE residue, HE particulates, HE fragments, and dissolved fuel constituents.

Table 4-1. Volume of Wastewater Discharged to the Land Surface at SWMUS in the BSG AOC

SWMU	Site Name	Years of Use	Number of Tests	Volume of Wastewater Used per Test (gallons)	Total Volume of Wastewater Discharged per SWMU (gallons)
13	Oil Surface Impoundment	1984-1987	9	34,000	306,000
65C	Secondary Detonation Area	1969-1973	18	1,500	27,000
94D	Bomb Burner Discharge Pit	1982-1988	23	1,500	34,500
94E	Small Surface Impoundment	1978-1980	14	1,500	21,000
94F	LAARC Discharge Pit	1980-1987	63	1,500	94,500
				Total	**483,000**

NOTES:

The table does not list contained waters that evaporated or were hauled to and discharged at a permitted facility.

AOC = Area of Concern.
BSG = Burn Site Groundwater.
LAARC = Light Air-transport Accident Resistant Container.
SWMU = Solid Waste Management Unit.

Starting in 1975, some of the fuel-fire tests were also being conducted in portable steel burn pans or in enclosed structures. Wastewaters from these later tests were diverted to unlined impoundments in alluvium and allowed to infiltrate and evaporate. After 1979, all burn tests were conducted in steel burn pans, two concrete basins, or in enclosed structures. The burn pans were constructed of steel and occasionally moved to various locations across the facility. The burn pans and enclosed structures did not discharge wastewater directly to the ground surface. Following a pool-fire test, the remaining wastewater was pumped into a holding tank along with any residual fuel or combustion products. The fuel-pool water is recycled for approximately one year before disposal and replacement.

From 1980 to 1983, six enclosed burn test structures, such as the SMERF, were constructed and used until the late 1990s. During decommissioning activities in the late 1990s and early 2000s, obsolete structures such as the LAARC Unit, the Bomb Burner Unit, the Large Oil Burn Pool, the Small Oil Burn Pool, the Small Wind Shielded Unit, and the Conical Containment Unit were dismantled and removed from the facility. The environmental investigations associated with these structures were addressed in the CAC proposals for the SWMUs in the BSG AOC.

The Lurance Canyon Burn Site Testing Facility currently has a variety of trailers, transport-containers, small sheds, utility buildings, and other structures to support operations. Examples of support buildings and structures include:

- Trailers that contain offices, a conference room, and an instrumentation fabrication shop.
- Instrumentation trailer with computer equipment and data recorders.
- Transport containers and small sheds used for storing tools, electronic components, wiring, cable, plumbing fittings, fire hoses, water pumps, test equipment, and insulation.
- Transport container used as a break room and lunch area.

- Metal utility building for storage and assembly tasks.
- Bunker 9830 (an earthen covered concrete structure) for storage; was previously used as an observation bunker.
- Storage yard on the northwest side of the facility stores metal pipe, sheet metal, cinder blocks, and previously used test fixtures.

The office trailers (MO299) were not designed for continuous occupancy. The facility does not have a sewer or potable water system. Portable sanitary restrooms are serviced by a local contractor and the sewage is transported off-site by a septic service provider. Bottled water and a potable water holding tank are used for drinking. No septic tanks or Drain or Septic System sites are located at the facility; therefore, no septic water was released at the site.

A pair of aboveground non-potable water-storage tanks are currently located near the center of the facility. Each tank has a capacity of 30,000 gallons and is used for storing fire-suppression and pool-fire water. From 1986 to 2003, water was obtained from the Burn Site Well. Since 2003, the water has been obtained from a tanker truck or from the recycling of wastewaters from burn pans or enclosed structures.

4.3 SNL/NM Corrective Actions in the BSG AOC

The initial environmental investigations at SNL/NM were conducted under the Comprehensive Environmental Assessment and Response Program (CEARP) (DOE September 1987). DOE/NNSA and SNL/NM personnel built on the CEARP findings and conducted a wide range of activities to determine the nature and extent of contamination at identified SWMUs. Site characterization for the SWMUs has included the following activities:

- Acquisition of background information/process knowledge,
- Collection of soil samples,
- Excavation of debris-contaminated soils at multiple SWMUs,
- Installation and sampling of groundwater monitoring wells, and
- Conducting ongoing groundwater monitoring (sampling and measuring water levels).

The potential release sites for nitrate-impacted waters were evaluated in the BSG AOC through the investigation of 21 SWMUs located in or near the site (Figure 4-1 and Table 4-2). The naming convention for the SWMUs discussed below may appear to be internally inconsistent, but the titles used in Table 4-2 are those as defined in Table K-4 of the RCRA Permit (NMED January 2015). Table 4-2 shows that the NMED has approved CAC Without Controls status for each of the 21 SWMUs (NMED January 2015). After the NMED approves an NFA proposal, the site needs not be considered as an ongoing potential source of groundwater contamination (Moats November 2001). Therefore, none of SNL/NM SWMUs are suspected of being an ongoing source of groundwater contamination in accordance with NMED guidance. Groundwater at the BSG AOC is addressed separately from the SWMUs in accordance with the Consent Order (NMED April 2004).

Table 4-2. Corrective Action Complete Without Controls Approval Dates for SWMUs in or near the BSG AOC (NMED January 2015)

SWMU Number	SWMU Name	CAC Approval Date
12A	Open Arroyo Channel	09/2000
12B	Buried Debris in Graded Area	07/2000
13	LCBS Oil Surface Impoundment (Lurance Canyon Burn Site)	07/2000
28-4	Mine Shafts	12/1997
28-5	Mine Shafts	12/1997
28-6	Mine Shafts	12/1997
28-8	Mine Shafts	12/1997
65-A	Lurance Canyon Explosive Test Site: Small Debris Mound	09/2000
65-B	Lurance Canyon Explosive Test Site: Primary Detonation Area	09/2000
65-C	Lurance Canyon Explosive Test Site: Secondary Detonation Area	09/2000
65-D	Lurance Canyon Explosive Test Site: Near Field Dispersion Area	09/2000
65-E	Far Field Dispersion Area	07/2000
94-A	Aboveground Tanks, Lurance Canyon Burn Site	07/2000
94-B	Debris/Soil Mound Area	04/2005
94-C	Bomb Burner Area and Discharge Line	11/2001
94-D	Lurance Canyon Burn Site: Bomb Burner Discharge Pit	09/2000
94-E	Lurance Canyon Burn Site: Small Surface Impoundment	09/2000
94-F	LAARC Discharge Pit	04/2005
94-G	Scrap Yard, Lurance Canyon Burn Site	11/2001
94-H	Fuel Spill at Open Pool Test Area, Lurance Canyon Burn Site	04/2005
160	Bldg. 9832 Septic System	11/2001

NOTES:
AOC = Area of Concern.
BSG = Burn Site Groundwater.
CAC = Corrective Action Complete.
LAARC = Light Air-transport Accident Resistant Container.
LCBS = Lurance Canyon Burn Site (Test Facility).
NMED = New Mexico Environment Department.
SWMU = Solid Waste Management Unit.

Brief discussions of the SWMUs are provided below, and more extensive descriptions are provided in Site Summary Sheets in Appendix H. For the discussion of the SWMUs in this CCM/CME Report, the sites have been divided into the following categories:

- Sites related to historical minerals exploration and extraction.
- Sites related to explosives testing.
- Site related to burn testing.
- Miscellaneous sites.

4.3.1 Sites Related to Historical Minerals Exploration and Extraction

SWMUs 28-4, 28-5, 28-6, and 28-8 Mine Shafts

There are 10 mine shafts (SWMUs 28-1 to 28-10) where mining activity took place prior to the 1950s, four of which are in the vicinity of the BSG AOC. The mines included as SWMU 28 have long since been abandoned or were only rarely worked beyond some very limited prospecting. The individual mine locations vary considerably. Old mine features (including adits, shafts, and prospecting pits) are the remnants of mineral mining activities conducted in the early to mid-1900s. Fluorite was the most common mineral mined, but barite, galena, and other sulfide minerals also were apparently mined based on examination of tailings piles. These mines are not SWMUs due to their mining activities, but because speculation that these remnant sites may have been used to dispose of various wastes. According to CEARP interviews, various wastes may have been placed in the mines; however, no evidence to support these rumors exists. Based on follow-up interviews, at least one rumor regarding the disposal of explosives in a mine is false. The CEARP findings also state that no radiation levels were measured significantly above background radiation levels.

SWMU 28-4 (the Blackbird Mine) is located on the south side of Lurance Canyon approximately 500 ft southeast of monitoring well CYN-MW13 (Figure 4-1). This mine was operated by the American Fluorspar Company in the 1940s. At one time, the workings consisted of a shaft 49 ft deep, with a drift 87 ft long on the 42-ft level southeast of the shaft, and some stopes above the drift. The stopes were later extended to the surface and the shaft was deepened (Rothrock et al. 1946). The main part of this mine site is a shaft covered with broken wooden framing and nearby concrete pads and scrap lumber. There are two associated trenches that are 3 to 6 ft deep and 25 ft long. There is abundant timbering at the collar indicating that there was once a headframe over the shaft. An old truck frame mounted near the collar is all that remains of the hoisting winch.

The mine is along an approximately vertical fault that cuts the Precambrian rocks and the overlying Sandia Formation. It follows the west side of one of the diabase dikes within the Precambrian complex. Fluorspar was deposited along this fault in solid veins where there was little brecciated rock, and as interstitial fillings in the parts of the fault that contained coarse breccia. Some replacement of the rock also took place. This deposit was fractured, and in some places, brecciated by later faulting. The ore is a crystalline intergrowth of fluorite with minor percentages of quartz, galena, and barite. The fluorite for the most part is fine-grained, but relatively large crystals are scattered through it. Galena occurs in crystalline aggregates up to 1 inch in diameter, and as tiny, isolated crystals. Bladed crystals of barite are common along the margins of the ore bodies. Some quartz occurs with the fluorite (Rothrock et al. 1946).

SWMU 28-5 is located on the south side of Lurance Canyon approximately 900 ft southeast of monitoring well CYN-MW13 (Figure 4-1). The site is comprised of a small pile of tailings from a prospect pit, but no shaft or adit has been found nearby. Aside from the tailings pile there is no other evidence of mining or postmining activity.

SWMU 28-6 is located on the north side of Lurance Canyon approximately 650 ft northwest of monitoring well CYN-MW7 (Figure 4-1). The site is comprised of a single vertical shaft that is approximately 15 ft deep and 5 ft in diameter. A small collar of tailings material surrounds the shaft. This site is easily inspected from the surface and no evidence of postmining activity exists.

SWMU 28-8 is located on the north side of Lurance Canyon approximately 500 ft north of monitoring well CYN-MW7 (Figure 4-1). This site is in the immediate vicinity of SWMU 28-6 and is a very small depression/excavation. It is probably a prospecting pit abandoned prior to significant excavation. This feature is insignificant and shows no evidence of postmining activity.

4.3.2 Sites Related to Explosives Testing

SWMU 65 Lurance Canyon Explosive Test Site

SWMU 65 is identified by the Hazardous and Solid Waste Amendments module as the LCETS. The site is situated on the canyon-floor alluvium in the upper reaches of the Lurance Canyon drainage. Based on the location of the detonations and the types of tests conducted at SWMU 65, the site has been divided into five sub-units (A through E). The location of SWMU 65 is coincident with SWMUs 94, 12, and 13. SWMU 65 was used from the late 1960s to the early 1980s for general explosives tests. Due to the overlap in location and periods of testing at SWMUs 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in the descriptions of each SWMU. SWMU 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (nonpetroleum fuel fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. SWMU 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in SWMU 94.

Interviews with past SNL/NM personnel and historical aerial photographs have been used to reconstruct past operations at SWMU 65. Aerial photographs indicate that construction of SWMU 65 had begun by October 1967. It was established as an explosives test area designed with a 10,000-ft dispersion radius to provide a buffer for open detonations of up to 10,000 pounds of HE. The test site was in full operation by 1971 and several structures were visible. A 25- to 50-ft-wide firebreak road was constructed on the hillslopes around the site between 1967 and mid-1971 to protect the surrounding forested area from accidental fires caused by detonation of explosives or burn testing.

Bunker 9830, established in the late 1960s, is located in the northwest portion of SWMU 65. It was originally intended to house instrumentation trailers for site activities. The bunker was reported to be the control point for explosives tests, as well as a shelter for staff during burn tests involving explosive materials. The eastern half of Bunker 9830 was also used for burn tests on nuclear reactor control cables and fire suppressant tests.

All open detonation explosives tests were concluded by the early 1980s. The frequency of testing from 1968 to 1980 has been estimated at approximately 20 tests per year and were conducted within the primary and secondary detonation areas. In addition to open detonation explosives tests, fuel-fire burn tests of test units containing explosives were conducted at SWMU 65 using excavated pits from 1969 to 1979. Portable pans and engineered burn structures completely replaced burn pit tests by 1979. From the mid-1970s, a variety of nonpetroleum-fuel-fire burn tests were conducted. These tests included slow-heat detonations, TABS tests, rocket propellant burn tests, liquid oxygen torch tests, and wood crib fire tests.

SWMU 65A Lurance Canyon Explosive Test Site: Small Debris Mound

SWMU 65A covers an area of less than 0.1 acre on the southeast rim of the Oil Surface Impoundment (SWMU 13). This small mound contained soil, limestone blocks, and concrete rubble and may have been the location of a propagation test. Two interview records identified the small debris mound as a small concrete bunker covered with soil and two records speculated the propagation test took place there.

SWMU 65B Lurance Canyon Explosive Test Site: Primary Detonation Area

SWMU 65B covers approximately 3.3 acres of the western portion of SWMU 65. The site was the detonation area for general explosives tests, miscellaneous burn tests, slow-heat tests, and a TABS test. The boundaries of this sub-unit were defined by historical aerial photographs and interview records.

SWMU 65C Lurance Canyon Explosive Test Site: Secondary Detonation Area

SWMU 65C lies on approximately 1.3 acres north of the Oil Surface Impoundment. The boundaries of the site were defined by historical aerial photographs and test reports. The site was the burn pit area for the Cloudmaker tests, ammonium nitrate burn tests involving fuel-rod containers, liquid fuel fire, and solid rocket propellant burn tests on Pioneer capsules, and plutonium shipping container tests. The site was regraded since testing activities ceased in the early 1970s significantly altering the ground surface at this site. No evidence of the pits associated with past testing exists after regrading.

SWMU 65D Lurance Canyon Explosive Test Site: Near-field Dispersion Area

SWMU 65D lies on approximately 8.0 acres at a mean elevation of 6,325 ft. The site represents the nearest extent of the fragmentation area associated with open detonation tests. The fragmentation boundary was confirmed by the surface gamma radiation survey performed in 1994. Tests conducted at SWMU 65D included miscellaneous burn tests, cone tests, and slow-heat tests. The area is considered a near-field dispersion area for general explosives test activities conducted at SWMUs 65B and 65C. Because this site is the current work area for testing activities, the ground surface has been disturbed by ongoing grading activities.

SWMU 65E Far Field Dispersion Area

SWMU 65E lies on approximately 77 acres at a mean elevation of 6,365 ft. This site represents the farthest extent of the fragmentation area associated with the open detonation tests. The fragmentation boundary was confirmed by the surface gamma radiation survey performed in 1994. No documented tests were conducted at SWMU 65E, but the area is considered a far-field dispersion area for general explosives testing activities from SWMUs 65B and 65C.

4.3.3 Sites Related to Burn Testing

SWMU 13 Lurance Canyon Burn Site: Oil Surface Impoundment

SWMU 13 is identified as the Oil Surface Impoundment site and covers approximately 0.5 acres in the general area of SWMU 94. Historical investigations concluded this site was used to receive wastewater from fire survivability tests conducted on transport containers and on weapon and satellite components. Water containing residual jet fuel was discharged into an unlined impoundment and percolated into soil. SWMU 65A, a small dirt-covered bunker, is located on the southeast edge of the oil surface impoundment.

In 1983 a drain with discharge pipe was constructed from a concrete burn pool to a spillway located in the center of a 120-ft diameter, 25-ft deep earthen depression. Although not actively used, SWMU 13 is one of the two surviving wastewater discharge impoundments/pits at the Burn Site. The other wastewater discharge point is the Small Surface Impoundment (SWMU 94E, discussed below).

SWMU 94, Lurance Canyon Burn Site

SWMU 94 is located on the canyon floor alluvium. To facilitate site characterization, SWMU 94 has been subdivided into eight sub-units (A through H) that represent areas where hazardous constituents may have been released. As discussed above, the location of SWMU 94 coincides with SWMU 65. The site is currently used for testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components. Only a few of the permanent, engineered structures at the site are currently active.

SWMU 94A Aboveground Tanks, Lurance Canyon Burn Site

SWMU 94A includes the current and historical aboveground tank storage locations, including the current tanks located on the north side of the facility. These tank areas have been included due to documented and potential accidental releases of JP-4 fuel. SWMU 94A is comprised of three individual areas having a total surface area of 0.8 acres.

SWMU 94B Debris/Soil Mound Area

SWMU 94B comprises approximately 0.6 acres and was a debris/soil mound area located north of the Lurance Canyon Arroyo. This site is primarily the product of grading and soil redistribution during the evolution of the facility into the present configuration. It was established as a sub-unit because of the lack of definitive information about past activities that may have created the mounds and the presence of beta/gamma radiological anomalies. A small soil pile northeast of the site was determined to be waste from a JP-4/wastewater spill in 1992.

SWMU 94C Bomb Burner Area and Discharge Line

SWMU 94C occupies an area of 0.2 acres surrounding the Bomb Burner Unit and the Bomb Burner Unit trench. An underground corrugated culvert extended from the Bomb Burner Unit to a discharge pit (SWMU 94D) located between the access road and the arroyo. The Bomb Burner Unit itself has been decontaminated and decommissioned and is not included as a sub-unit. Release of potential COCs outside of the Bomb Burner Unit were characterized as part of SWMU 94C. Releases of potential COCs from the TABS Test location, portable pan tests, rocket propellant tests, slow-heat tests, and uncontained pool fires that occurred in the Bomb Burner Unit trench were also characterized.

SWMU 94D Lurance Canyon Burn Site: Bomb Burner Discharge Pit

SWMU 94D encompasses the area of the discharge pit at the point of entry from the discharge line. The discharge pit received all wastewater from operation of the Bomb Burner Unit. The site covers less than 0.1 acre.

SWMU 94E Lurance Canyon Burn Site: Small Surface Impoundment

SWMU 94E is located approximately 250 ft southeast of Bunker 9830. The impoundment was used for several fuel-fire burn tests and may have received wastewater from some portable pan burn tests. The impoundment also receives surface-water runoff from the graded area. The site occupies 0.2 acres.

SWMU 94F LAARC Discharge Pit

SWMU 94F comprises approximately 0.5 acre and was used to receive wastewater from suppression of test fires in the adjacent LAARC Unit. The LAARC Unit was used for 63 fire tests between 1980 and 1987. The LAARC discharge pit was unlined and the wastewater, which contained residual jet fuel, infiltrated into the underlying soil. SMWU 94F was established based upon the release of fuel components.

SWMU 94G Scrap Yard, Lurance Canyon Burn Site

SMWU 94G is located on 3.2 acres in the northwest portion of SWMU 94. Surplus test materials and equipment to support burn testing at the facility are stored there.

SWMU 94H Fuel Spill at Open Pool Test Area, Lurance Canyon Burn Site

SWMU 94H was discovered in August 2000 immediately west of the Large Open Burn Pool on approximately 0.1 acres. No details exist on the date of the release of JP-8 from underground piping that connected the aboveground tanks (SWMU 94A) to the burn pool. The piping has since been upgraded.

4.3.4 Miscellaneous Sites

SWMU 12 Burial Site/Open Dump (Lurance Canyon)

SWMU 12 is identified as a Burial Site/Open Dump that covers approximately 0.6 acres and includes the upper open arroyo channel as SWMU 12A, and the lower, buried portion of the arroyo channel as SWMU 12B. Based on a review of historical aerial photographs, the Burial Site/Open Dump was undeveloped prior to 1971. A 1975 historical aerial photograph indicates site grading activities had buried a small portion of the arroyo. In a 1983 historical aerial photograph, the central and southern portions of the arroyo channel, which bisects SWMU 65, had been filled. Based on this record, activity at SWMU 12B may have been associated with historical disposal of testing debris from SWMU 65 or construction activities associated with SWMU 94.

SWMU 12A Open Arroyo Channel

Prior to 1990, approximately 8 to 10 drums, wooden pallets, twisted metal, and concrete blocks were disposed in the open arroyo channel of SWMU 12A. In 1990, drums of waste washed into SMWU 12A from an unknown upstream location. SNL/NM Waste Management personnel removed and disposed of the drums. An upstream survey of the arroyo confirmed there were no additional drums present, only small amounts of concrete and wood debris.

This site extends from the approximate location of some concrete blocks and debris on the north, to the junction with the filled arroyo channel immediately north of the cable rack. SWMU 12A is approximately 300 ft long and 20 ft to 30 ft wide.

SWMU 12B Buried Debris in Graded Area

This site was the filled portion of the arroyo and based on historical aerial photos, was approximately 450 ft long and 20 ft to 30 ft wide. It extended south from the cable rack to a road just north of the historical drainage confluence with the main channel of Lurance Canyon Arroyo.

SWMU 160 Building 9832 Septic System

SWMU 160 included the seepage pit serving the HE wastewater system for Building 9832. Although it was named “Septic System”, there is no septic system associated with this site; therefore, no septic water was released at the site. Building 9832, the Vehicle Assembly Building, was constructed in 1968 for the preparation of explosive tests, involving explosive train assembly, propellant assemblies, parts degreasing, and painting of test assemblies. Wastewater from the assembly area cleanup, some of which may have contained HE, was discharged through a floor trough to a catch box and a seepage pit. A hand-washing sink, located inside the high bay on the east wall, empties into the trough just before it exits the building. The building has no toilet facilities or permanent water supply; water for washing was provided by a tanker truck to a holding tank located on the north side of the building.

4.4 Potential Release Sources for Nitrate

Nitrate in BSG AOC may be derived from both natural and anthropogenic sources. A comprehensive list of potential nitrate sources was prepared for the 2015 Independent Remedy Review (DOE May 2015) and is included as Appendix I. The more probable sources of nitrate in groundwater are discussed below.

The degradation of energetic materials can release nitrate to the environment. The energetic materials used at the facility have consisted of:

- Ammonium nitrate slurry,
- HE compounds (for example, TNT and 1,3,5-trinitro-1,3,5-triazinane [RDX]), and
- Gun (howitzer) propellants and solid rocket propellants such as nitrocellulose and potassium nitrate.

Ammonium nitrate slurries with compositions of 50% to 94% ammonium nitrate were used at SWMU 65C from 1967 to 1975. Five tests during this time period used at least 54,700 pounds of ammonium nitrate slurry. Some fraction of that slurry may have been spilled onto the ground surface or did not undergo complete deflagration during explosive tests. Water used to clean up the slurry, or precipitation/stormwater in contact with slurry-impacted soils, could have subsequently infiltrated to groundwater and resulted in nitrate contamination.

HE open-air detonations at SWMU sub-units 65B (Primary Detonation Area) and 65C (Secondary Detonation Area) dispersed some portion of HE materials across the Burn Site vicinity during 1967 to 1985. Visual surveys were conducted after each test and HE fragments were picked up. However, some HE fragments outside the graded areas may have been overlooked. Some of these materials degraded (weathered) leaving nitrate compounds on the ground surface and subsequent precipitation may have flushed nitrate to groundwater. A decades-long Los Alamos National Laboratory outdoor study (DuBois and Baytos May 1991) at a high altitude, forested setting similar to the BSG AOC showed that some explosives (TNT, etc.) degraded at an environmentally significant rate and could release nitrate. Plastic explosives (for example, RDX) degraded extremely slowly.

Wastewater was discharged from five SWMUs (13, 65C, 94D, 94E, and 94F) as part of burn tests (Table 4-1). HE residues produced from the burn tests were likely present in the wastewater that percolated beneath the earthen pits and other unlined impoundments prior to about 1979. Following completion of a burn test at a pit excavated in alluvium, most of the wastewater likely infiltrated into the ground and a minor portion evaporated into the atmosphere. The pits were typically not cleaned up between tests. The wastewater may have contained burnt HE residue, HE particulates, HE fragments, and dissolved fuel constituents. Records indicate that an estimated 483,000 gallons of wastewater was discharged to the alluvium via unlined pits and impoundments from 1969 through 1988. The estimated volume of wastewater discharge per site is listed in Table 4-1. Approximately 64% of the wastewater-discharge volume occurred at SWMU 13 from 1984 to 1987. This wastewater may have contained elevated concentrations of nitrate.

Nitrate-containing contaminants may have leached from buried testing debris. The leaching would have occurred prior to site remedial activities. Buried debris was removed at SWMU 12B in the early 2000s. Debris was also removed from scattered bunkers and surface mounds.

Enhanced leaching of naturally occurring geologic nitrate from alluvium due to dust-suppression water application and increased surface permeability for the infiltration of precipitation may have resulted from the grading of previously undisturbed land (approximately 16.35 acres) during construction of the facilities. Research at numerous locations in the desert Southwest has shown that significant amounts of natural nitrate can be released due to land-use changes (Walvoord et al. November 2003). A comprehensive discussion of geologic nitrate is provided in Section 6.2.

4.5 Other Characterization Activities

In addition to soil sampling completed for the characterization of individual SWMUs, additional nitrate characterization studies were completed in 2004 and 2010. The presence of nitrogen in water may be reported by analytical laboratories in various forms. Most commonly for BSG AOC investigations the analytical results are reported as NPN (as nitrogen), abbreviated as NPN. Historical groundwater analyses have demonstrated that nitrite concentrations are below method detection limits (MDLs) and are considered as non-contributory to the analytical results of NPN analyses. Therefore, NPN results are used directly to represent nitrate concentrations in this CCM/CME Report.

4.5.1 2004 Nitrate Characterization Studies

In 2004 a shallow to deep soil sampling program for nitrate and other constituents was completed in the BSG AOC (SNL/NM January 2005). The objectives for performing the 2004 characterization activities included:

- Determine if the background nitrate concentrations in soil and groundwater inside and outside the study area were similar by sampling of near-surface soil and spring water.

- Determine if there is a source of nitrate in the vadose zone above groundwater at the monitoring well locations with elevated nitrate concentrations by sampling soil every 5 ft from the surface to bedrock using a hollow-stem auger.

The sampling design was based upon data gaps documented in the CME Work Plan (SNL/NM June 2004b). The fieldwork consisted of three activities: spring water sampling, near-surface soil sampling, and deep soil borings (Figure 4-2). The water sampling was completed in August 2004, and the near-surface soil sampling and deep soil sampling was completed in October 2004. Background water samples were collected at the Burn Site Spring and analyzed for NPN, alkalinity, major anions, and field water quality parameters. Two spring-water environmental samples and a duplicate sample were collected. An initial sample was collected from the cistern prior to purging and analyzed for NPN, alkalinity, and major anions. An attempt was also made to collect a sample from the Burn Site Spring that has not been exposed to the atmosphere for any length of time. The field team bailed the spring dry and allowed the water level to recover and an environmental and duplicate sample were collected and analyzed for NPN.

Near-surface (0 to 0.5 ft and 1.5 to 2.0 ft) soil samples were collected at three locations (Figure 4-2), including a location near monitoring well CYN-MW4 and two locations on the canyon floor outside of the Lurance Canyon Burn Site Testing Facility boundary. Samples were collected to a depth of two ft deep using a hand auger and were analyzed for NPN, chloride, ammonia, TKN, and HE compounds. Six near-surface environmental soil samples were collected. The lithology of all the soils encountered during the sampling event was similar, consisting of dry to damp, pale yellow to dark yellowish brown, silty gravelly sands. The gravel clasts were predominantly limestone with occasional metamorphic lithologies.

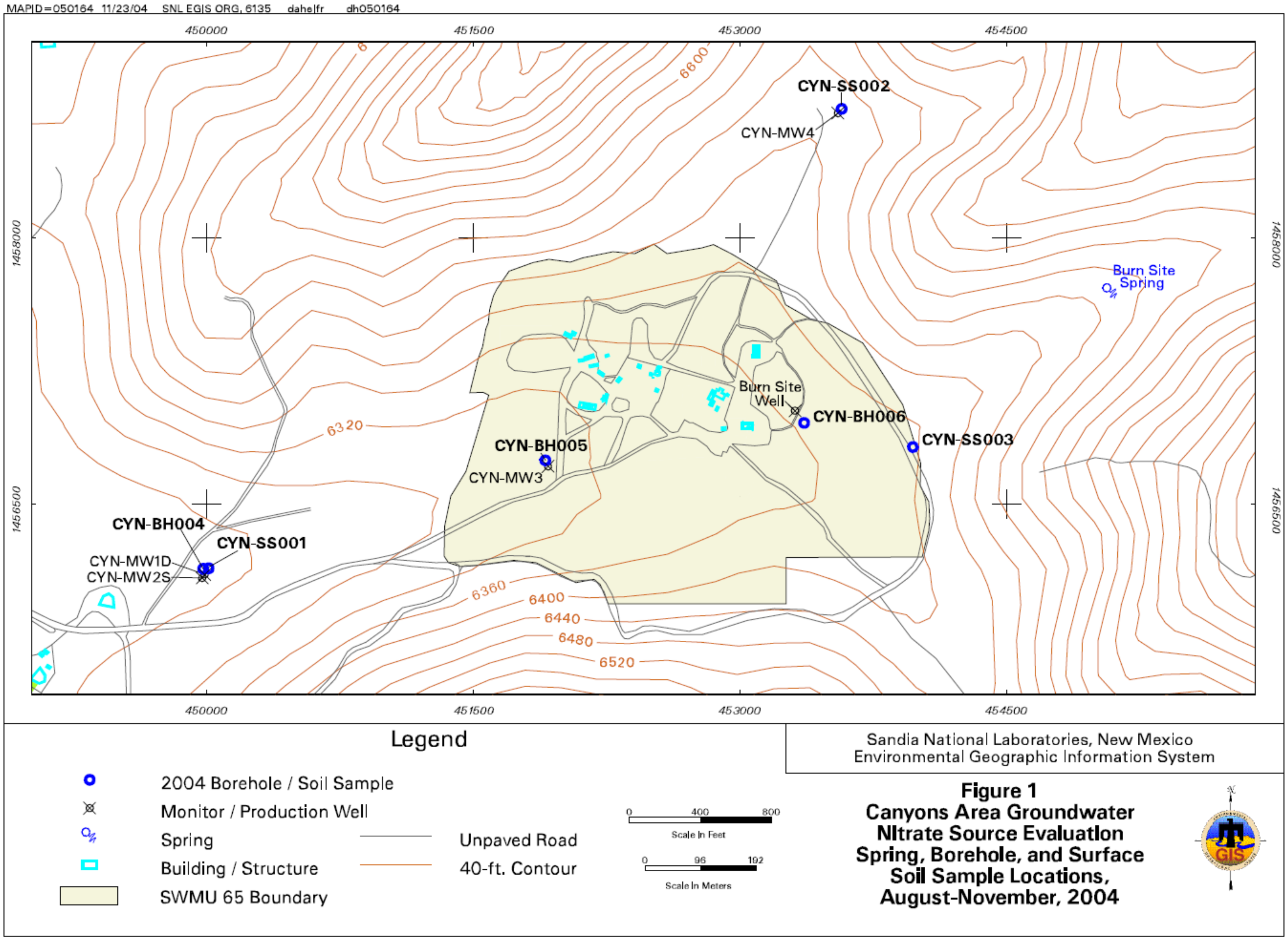

Figure 4-2. 2004 Soil and Spring Sample Locations (from SNL/NM January 2005)

Three deep soil borings were sampled near monitoring wells that show elevated nitrate concentrations. Deep soil borings (identified as “BH” on Figure 4-2) were drilled at locations near wells CYN-MW3, CYN-MW1D, and the Burn Site Well (Figure 4-2). These locations targeted the thickest section of alluvium, which was found to be up to 40 ft. A 2-ft drive sample was collected every 5 ft (3 to 5 ft, 8 to 10 ft, etc.) from the surface to bedrock (or to drill-bit refusal) using a hollow-stem auger.

The soil samples were analyzed for NPN, chloride, ammonia, and TKN. Fifteen deep-soil boring environmental soil samples and two duplicate soil samples were collected. Bedrock was encountered and was the sampled matrix at the 34 ft depth in BH-005. The bedrock consisted of Precambrian mica schist/phyllite with a strongly developed crenulation cleavage.

Water and soil samples were submitted to contract laboratories for analysis. The results of the laboratory analyses are summarized below, and the complete dataset is available in the original report (SNL/NM January 2005). For the water collected from the Burn Site Spring, the NPN analytical results ranged from 0.168 mg/L to a maximum concentration of 2.11 mg/L. This data indicates that there is no upgradient source of nitrate-impacted groundwater along this flow path toward the BSG AOC. For soil samples, the NPN analytical results ranged from non-detect (less than 0.070 milligrams per kilogram [mg/kg]) to a maximum concentration of 4.64 mg/kg found at the 10 ft depth in borehole CYN-BH005 (sample SWC-CYN-BH-005-010). All soil NPN concentrations detected were significantly less than the residential NMED soil screening levels (SSLs) (further discussed below).

4.5.2 2010 Nitrate Characterization Studies

In 2010 a shallow to deep soil sampling program for nitrate and other constituents was completed in the vicinity of the eastern nitrate plume. DOE/NNSA and SNL/NM personnel conducted soil sampling in the vicinity of monitoring wells CYN-MW6 and CYN-MW9 (Figure 4-3) to determine whether a continuing source of nitrate is present in the unconsolidated deposits. The boreholes at the soil sampling locations were drilled using a hollow-stem auger drilling rig following the procedures described in the NMED-approved Characterization Work Plan (SNL/NM November 2009).

The borehole drilling and sampling was completed during the week of July 5, 2010 and consisted of soil sampling at 10 borehole locations (BH001 through BH010) (SNL/NM January 2012). Borehole drilling and soil sampling occurred along two north-south lines (5 locations each) that straddle monitoring well CYN-MW6. Samples were collected from unconsolidated deposits (alluvium and colluvium) at 2 and 5 ft bgs and at approximate 5-ft intervals downward to the top of bedrock. The unconsolidated deposits were found to have a maximum thickness of 35 ft on the southern end of the two sampling lines. The unconsolidated deposits thin rapidly to the north into exposures of bedrock near the northernmost sampling locations.

Figure 4-3 shows the distribution of NPN concentrations in the soil samples collected in 2010. NPN was detected at all depths within each of the 10 boreholes. All the concentration results were assigned “J” or “J+” estimated values based on data validation findings. The maximum concentration (25.1J mg/kg) was detected at the 5-ft depth in BH003 adjacent to groundwater monitoring well CYN-MW6. Other locations with the higher concentrations include the 2-ft depth in BH004 (19.7J mg/kg) and the 10-ft depth in BH008 (13.8J mg/kg); these locations are adjacent to BH003. No systematic vertical distribution of the NPN concentrations is apparent and concentrations reported for other locations and depths are negligible. Although NPN was detected in every soil sample, the concentrations do not present a risk to human health or represent a significant source of nitrate that could further impact groundwater (SNL/NM January 2012).

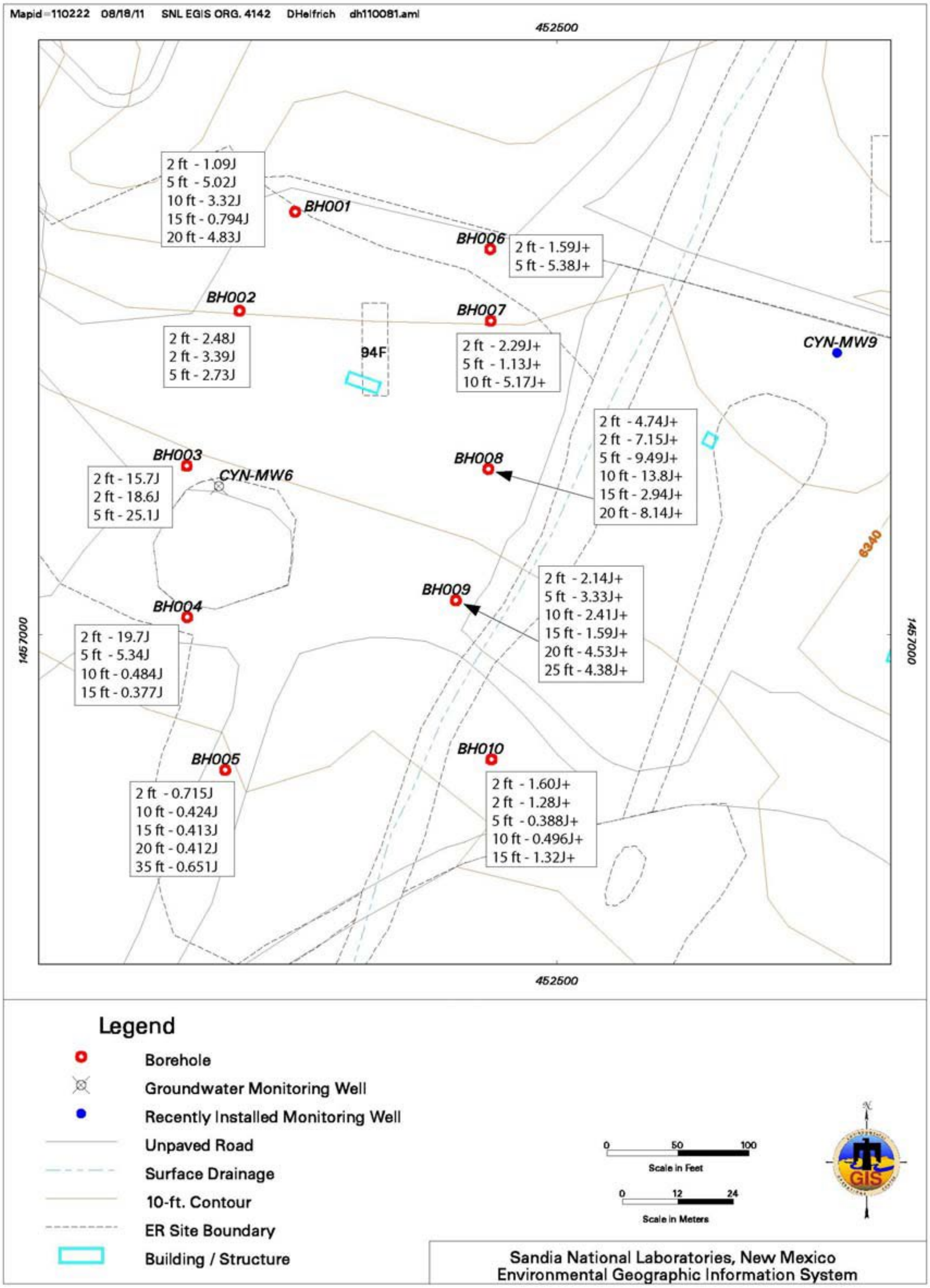

Figure 4-3. 2010 Soil Sample Locations and Analytical Results for NPN (in mg/L) (from SNL/NM January 2012)

To evaluate the NPN concentrations found in the soil samples, the analytical results were compared with the SSLs presented in state guidance documents current at the time (NMED August 2009). Of 42 samples analyzed, all NPN results indicated detectable concentrations, ranging from 0.377J to 25.1J mg/kg. The NPN concentrations are four orders of magnitude below the NMED SSL for residential soil (125,000 mg/kg), and less than one order of magnitude below the NMED SSL for the groundwater pathway with a Dilution Attenuation Factor (DAF) of 20 (335 mg/kg). Four of the results are within the range (slightly below to slightly above) of the NMED SSL for the groundwater pathway with a DAF of 1 (16.7 mg/kg). The groundwater pathway at the BSG AOC is best represented by the DAF of 20 (deep groundwater, semiconfined conditions due to filled fractures in the upper portion of the bedrock), and all NPN concentrations detected are significantly less than the NMED SSL of 335 mg/kg for the groundwater pathway.

Based on the results, the concentrations of these detected compounds did not justify a second phase of deep soil sampling. DOE/NNSA, SNL/NM, and NMED personnel met to discuss the Phase 1 soil sampling results and reached mutual agreement that based on the NPN results, a second phase of soil sampling was not required (Tso August 2010).

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5. GROUNDWATER MONITORING AT THE BSG AOC

Groundwater quality in the BSG AOC has been monitored since August 1996. The details of the monitoring well network were discussed in Section 3.2. Figure 5-1 shows the network of monitoring wells used for evaluating the groundwater potentiometric surface elevations and the distribution of nitrate and other constituents in the fractured bedrock aquifer system.

5.1 Nitrate

Nitrate is the only COC for the BSG AOC (NMED April 2004). The presence of nitrogen in water may be reported by analytical laboratories in various forms such as nitrate, nitrite, NPN (as nitrogen) (abbreviated as “NPN”), total nitrogen, or TKN. The EPA MCL for nitrate is 10 mg/L. The NMED has specified 4 mg/L as the maximum approved background value for nitrate at KAFB based upon calculations made by Moats and Winn (January 1995) (Dinwiddie September 1997). However, this value was not “reliably established” (Moats and Winn January 1995).

As discussed previously, historical groundwater analyses have demonstrated that nitrite concentrations are below MDLs and are considered as non-contributory to the analytical results of NPN analyses. Therefore, in this CCM/CME Report, NPN results are used directly to represent nitrate concentrations. The NPN analytical results discussed in this section were obtained from off-site certified laboratories that consistently use EPA Method 353.2 (or its equivalent).

As described in Section 4.5.1, a detailed field reconnaissance and sampling of the Burn Site Spring was conducted in October 2004 and three water samples were collected for NPN analysis. The NPN concentrations ranged from 0.168 to 0.211 mg/L (SNL/NM January 2005).

In CY 2021, DOE/NNSA and SNL/NM personnel sampled 14 monitoring wells at the BSG AOC during semiannual sampling events. Table 5-1 lists the maximum NPN concentrations for CY 2021 and shows that the NPN concentrations ranged from non-detect (ND, <0.50 mg/L) to 39.8 mg/L. For comparison, Table 5-1 also lists the historical maximum NPN concentrations for each monitoring well in the current network. The maximum historical concentration of NPN reported for any monitoring well is 49.6 mg/L, which was obtained from monitoring well CYN-MW9 in April 2020, this was also the well with the maximum NPN concentration in 2021. Screened intervals in Table 5-1 show that there is no correlation between NPN concentrations and depth to groundwater, i.e., high concentrations of NPN can be found in shallow or deep groundwater.

5.2 Nature and Extent of Nitrate Contamination

The October 2021 analytical results were used to generate Figure 5-2, which shows NPN concentrations in the BSG AOC fractured bedrock aquifer system. On Figure 5-2, the heavy blue lines depict the 10 mg/L, 20 mg/L, and 30 mg/L isoconcentration contours of NPN. Before the 2019 installation of the four newest groundwater monitoring wells (CYN-MW16 through CYN-MW19) the nitrate plume was depicted as one contiguous plume from CYN-MW9 to CYN-MW13. However, based on data from the monitoring wells installed in 2019, two distinct nitrate plumes exceeding the EPA MCL of 10 mg/L have now been identified: (1) an eastern nitrate plume centered around monitoring well CYN-MW9, and (2) a western nitrate plume centered around monitoring well CYN-MW13.

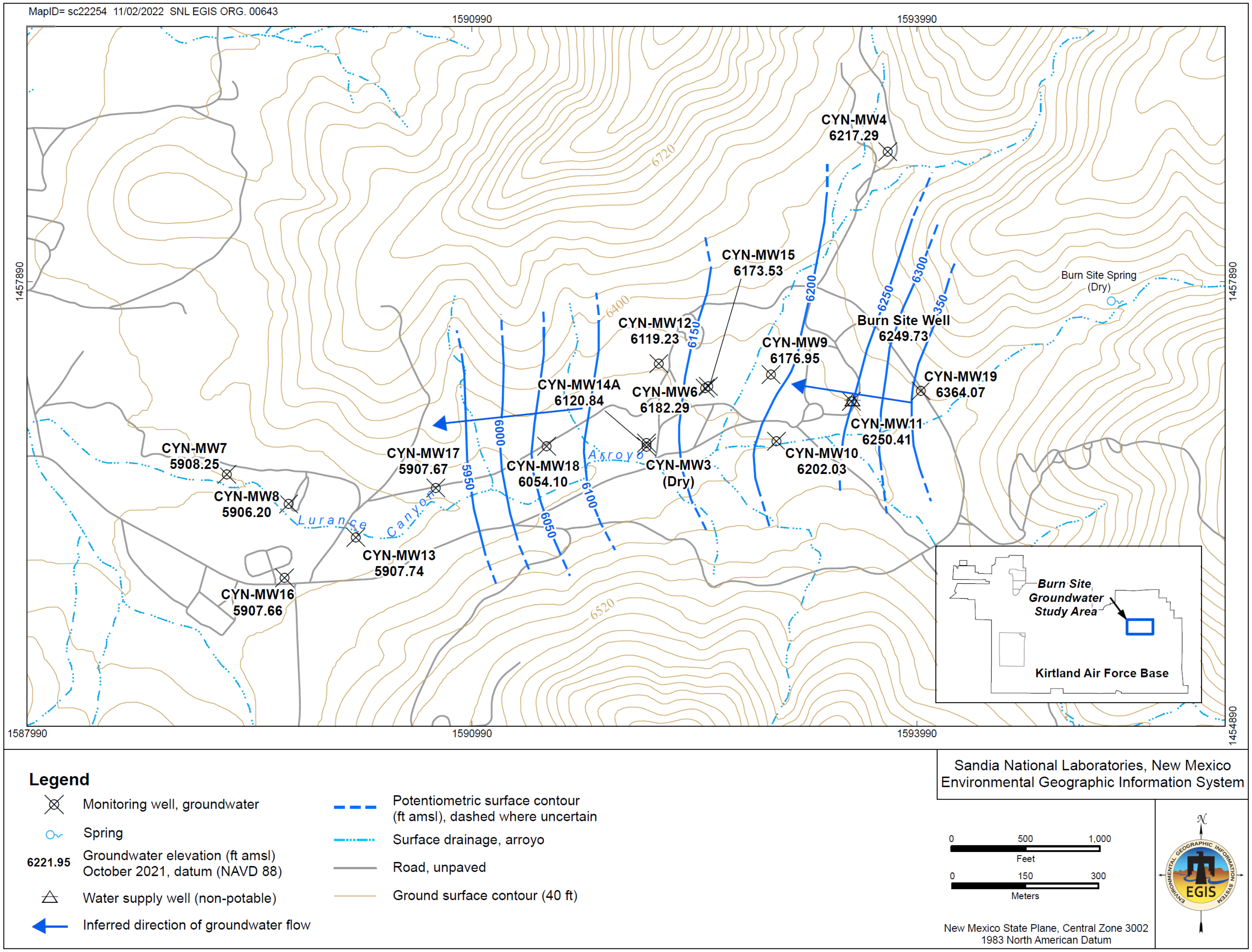

Figure 5-1. Monitoring Well Network in the BSG AOC as of December 2021

Table 5-1. Maximum NPN 2021 Concentrations and Maximum Historical Concentrations in the BSG AOC Monitoring Well Network

Monitoring Well	Maximum NPN Concentration in 2021 (mg/L)	Maximum Historical NPN Concentration at the Well (mg/L)	Screened Interval (ft bgs)
Eastern Nitrate Plume			
CYN-MW4	ND (<0.50)	3.94	260.0 – 280.0
CYN-MW9	**39.8**	**49.6**	175.8 – 195.8
CYN-MW10	7.63	**21.8**	150.4 – 170.4
CYN-MW11	9.25	**25.4**	229.8 – 249.8
CYN-MW12	**16.5**	**20.2**	252.5 – 272.5
CYN-MW14A	**14.6**	**15.7**	263.6 – 293.6
CYN-MW15	**20.6**	**29.8**	162.2 – 192.2
CYN-MW19	3.37	3.37	59.3 – 89.3
Western Nitrate Plume			
CYN-MW7	3.39	2.87	315.0 – 334.2
CYN-MW8	5.15	6.40	338.5 – 358.3
CYN-MW13	**30.6**	**40.0**	376.8 – 396.8
CYN-MW16	8.78	**11.7**	375.6 – 405.6
CYN-MW17	2.28	2.40	370.3 – 400.3
CYN-MW18	6.27	6.74	270.4 – 300.4

NOTES:

Bold value exceeds the EPA MCL for nitrate (10 mg/L).

Analytical method is EPA 353.2.

< = Less than.
AOC = Area of Concern.
bgs = Below ground surface.
BSG = Burn Site Groundwater.
CYN = Canyons (monitoring well designation only).
ft = Foot (feet).
EPA = U.S. Environmental Protection Agency.
MCL = Maximum Contaminant Level.
mg/L = Milligrams per liter.
MW = Monitoring well (monitoring well designation only).
ND = Non-detect; the analyte is absent or below the method detection limit.
NPN = Nitrate plus nitrite (as nitrogen).

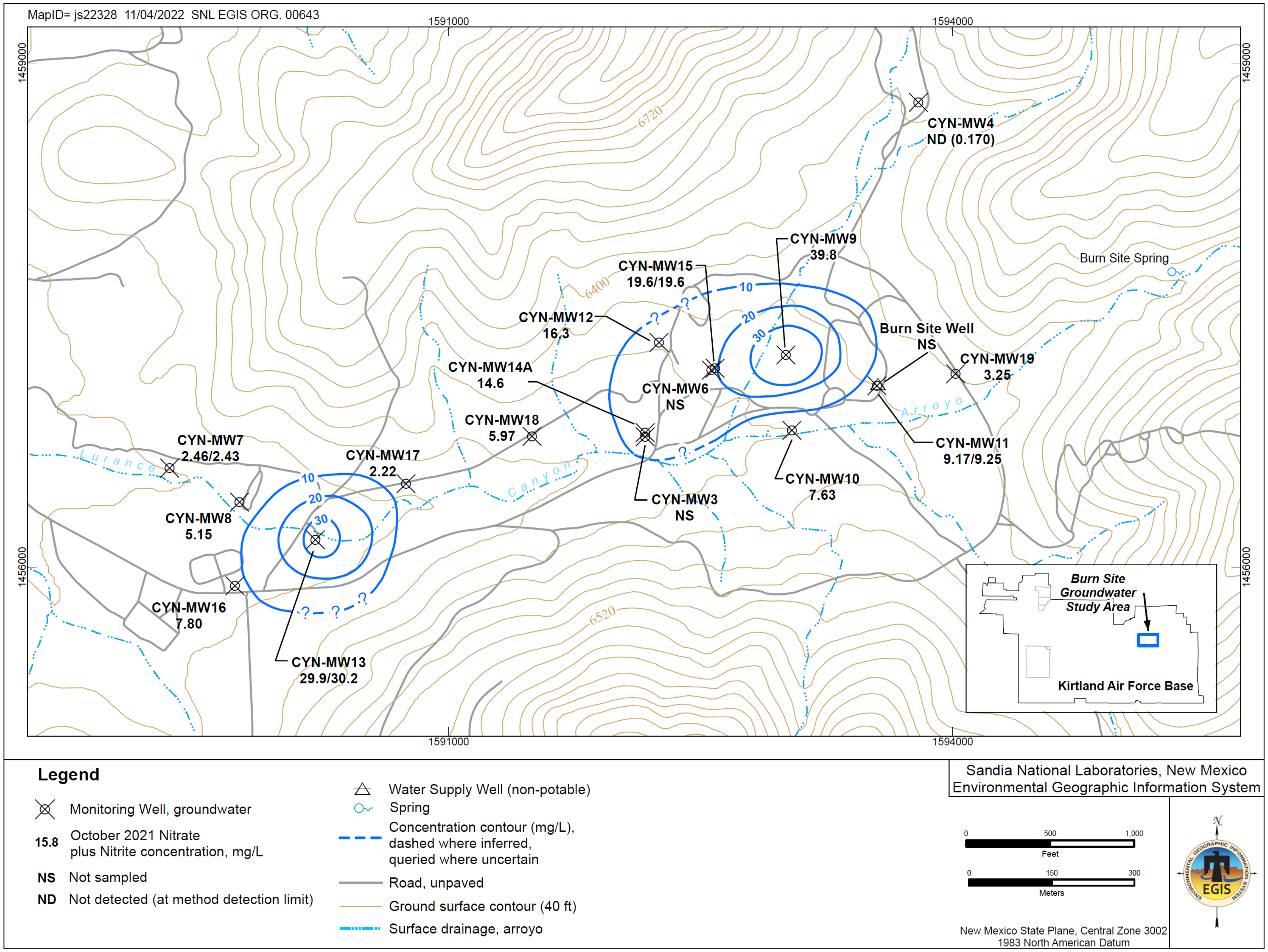

Figure 5-2. NPN Concentrations in Groundwater Samples Collected in October 2021 from BSG AOC Monitoring Wells

Except for the recent interpretation of the western edge of the eastern nitrate plume and the eastern edge of the western nitrate plume, the lateral dimensions of the two plumes appear to be stable. The plumes are at steady-state conditions. There are no ongoing releases of nitrate to groundwater, and the two plumes are the result of past releases that have subsequently developed to their present sizes through dispersion and dilution. NPN concentration trends are increasing in three wells in the interior of the eastern nitrate plume, with decreasing trends in all other wells. The lateral extent of nitrate (as delineated by the 10 mg/L MCL isoconcentration contour) is not expanding.

NPN concentrations below the EPA MCL in monitoring wells CYN-MW17 and CYN-MW18 demonstrate that the two nitrate plumes are not contiguous, and that the areal extent of NPN exceeding the EPA MCL is much smaller than previously interpreted. Concentrations in well CYN-MW18, located immediately downgradient of the eastern nitrate plume, are below the MCL and decreasing, indicating migration of nitrate is not occurring beyond the MCL isoconcentration contour.

The two stable nitrate plumes in the BSG AOC are the result of releases in separate areas. It is unlikely that the western nitrate plume was detached from the eastern nitrate plume and has migrated downgradient as a slug of groundwater contamination because the NPN concentrations between the two nitrate plumes at monitoring wells CYN-MW17 and CYN-MW18 are in the 2 to 6 mg/L range (Figure 5-2). The trend in NPN concentrations in these two monitoring wells have been consistent over the sampling timeframe (2019 to present), and these concentrations are consistent with background and indicate that nitrate-contaminated water did not migrate through these monitoring well locations.

It is also unlikely that there was ever one continuous nitrate plume that traveled through an unidentified preferential pathway past monitoring wells CYN-MW17 and CYN-MW18. The overall structural fabric in the fractured bedrock aquifer system is oriented north-south, and there is no east-west fault or fracture system that would provide a preferential pathway for a single nitrate plume to migrate across the 2,000-ft gap between CYN-MW14A to the east and CYN-MW13 to the west (Figure 5-2).

Explosive testing and wastewater discharges associated with ammonium nitrate slurry at SWMU 65 are the most likely cause of groundwater impacts. The eastern nitrate plume is the result of the usage or spillage of ammonium nitrate slurry near monitoring well CYN-MW9. During the many years of explosive testing at the BSG AOC, an estimated 54,700 pounds of slurry was used (Appendix I), and some fraction of that slurry may have been spilled onto the ground surface or did not undergo complete deflagration during explosive tests. Water used to clean up the slurry, or precipitation/stormwater in contact with slurry-impacted soils, subsequently infiltrated to groundwater and resulted in nitrate contamination.

The western nitrate plume is located near a wide portion of the arroyo channel near monitoring well CYN-MW13 where large volumes of recent-age sediments have been deposited. During large thunderstorms, slurry-contaminated soil was likely washed down the channel from the east (vicinity of SWMU 65) and deposited in the actively aggrading area near monitoring well CYN-MW13. For example, debris and gravel transported by a single September 2013 thunderstorm deposited 2 to 3 ft of alluvial sediment in this active channel area. A flash flood in July 2015 also covered the area surrounding CYN-MW13 with 3 ft of sand and gravel. Similar types of sediment transport from the testing area with downstream deposition has likely occurred periodically during the past several decades. Historically, the transported sediment presumably contained nitrate-contaminated soil from the explosive testing area (SWMU 65D) to the east and resulted in the groundwater impacts in the CYN-MW13 area (Figure 5-2). No explosive testing or disposal activities were conducted in this area that would have resulted in direct infiltration of nitrate.

NPN concentrations are currently below the EPA MCL in groundwater monitoring well CYN-MW16 that delineates the western (downgradient) extent of the western nitrate plume. NPN concentrations below the EPA MCL in groundwater monitoring well CYN-MW19 delineate the eastern extent of the eastern nitrate plume. In addition, NPN concentrations in CYN-MW10 continued to be below the EPA MCL during CY 2021, defining the southern boundary of the eastern nitrate plume. Therefore, the areal extent of nitrate contamination has been delineated by the current monitoring well network (Figure 5-2).

5.3 Time-Series Plots of NPN Concentrations in Groundwater

For a historical perspective, Figure 5–3 presents a time-series plot of normalized NPN concentrations in groundwater samples collected from BSG AOC monitoring wells since 1998. To construct the normalized plot the initial NPN concentration was set to zero and the differences were calculated for NPN concentrations from subsequent sampling events. The time-series plot (Figure 5–3) shows a strong variability (large swings in concentrations) that overwhelms the overall trends. However, many of the more recent data plot at or above the zero line and suggest that concentrations are mostly decreasing to stable over the last five years. The AGMRs provide complete analytical data results and discussions of historical NPN concentrations.

In CY 2021, NPN was the only analyte that exceeded EPA MCLs. NPN was detected at concentrations exceeding the EPA MCL of 10 mg/L in samples from five BSG AOC monitoring wells: CYN-MW9, CYN-MW12, CYN-MW13, CYN-MW14A, and CYN-MW15. Historically, groundwater samples from eight monitoring wells have exceeded the EPA MCL for nitrate (Table 5-1). Figures 5-4 through 5-11 show detailed time-series plots for NPN concentrations and water levels. Table 5-2 provides an evaluation of the trends for NPN concentrations and groundwater elevations for the eight monitoring wells that historically exceeded EPA MCLs.

Table 5-2. Evaluation of Trends for NPN Concentrations and Groundwater Elevations for Monitoring Wells that have Historically Exceeded the EPA MCL for Nitrate

Monitoring Well	Maximum NPN Concentration in 2021 (mg/L)	Historical Range of NPN Concentrations (mg/L)	5-Year Trend in NPN	5-Year Trend in Groundwater Elevation
Eastern Nitrate Plume				
CYN-MW9	39.8	29.1 to 49.6	Increasing	Declining
CYN-MW10	7.63	4.2 to 21.8	Decreasing	Declining
CYN-MW11	9.25	8.7 to 25.4	Decreasing	Declining
CYN-MW12	16.5	10.8 to 20.2	Stable	Declining
CYN-MW14A	14.6	10.1 to 15.7	Stable	Declining
CYN-MW15 [a]	20.6	18.6 to 39.4	Decreasing	Declining
Western Nitrate Plume				
CYN-MW13	30.6	29.9 to 40.0	Decreasing	Declining
CYN-MW16	8.78	7.20 to 11.7	Decreasing	Declining

NOTES:

[a] Includes data for replaced well CYN-MW6.

CYN	= Canyons (monitoring well designation only).
EPA	= U.S. Environmental Protection Agency.
MCL	= Maximum Contaminant Level.
mg/L	= Milligrams per liter.
MW	= Monitoring well (monitoring well designation only).
NPN	= Nitrate plus nitrite (as nitrogen).

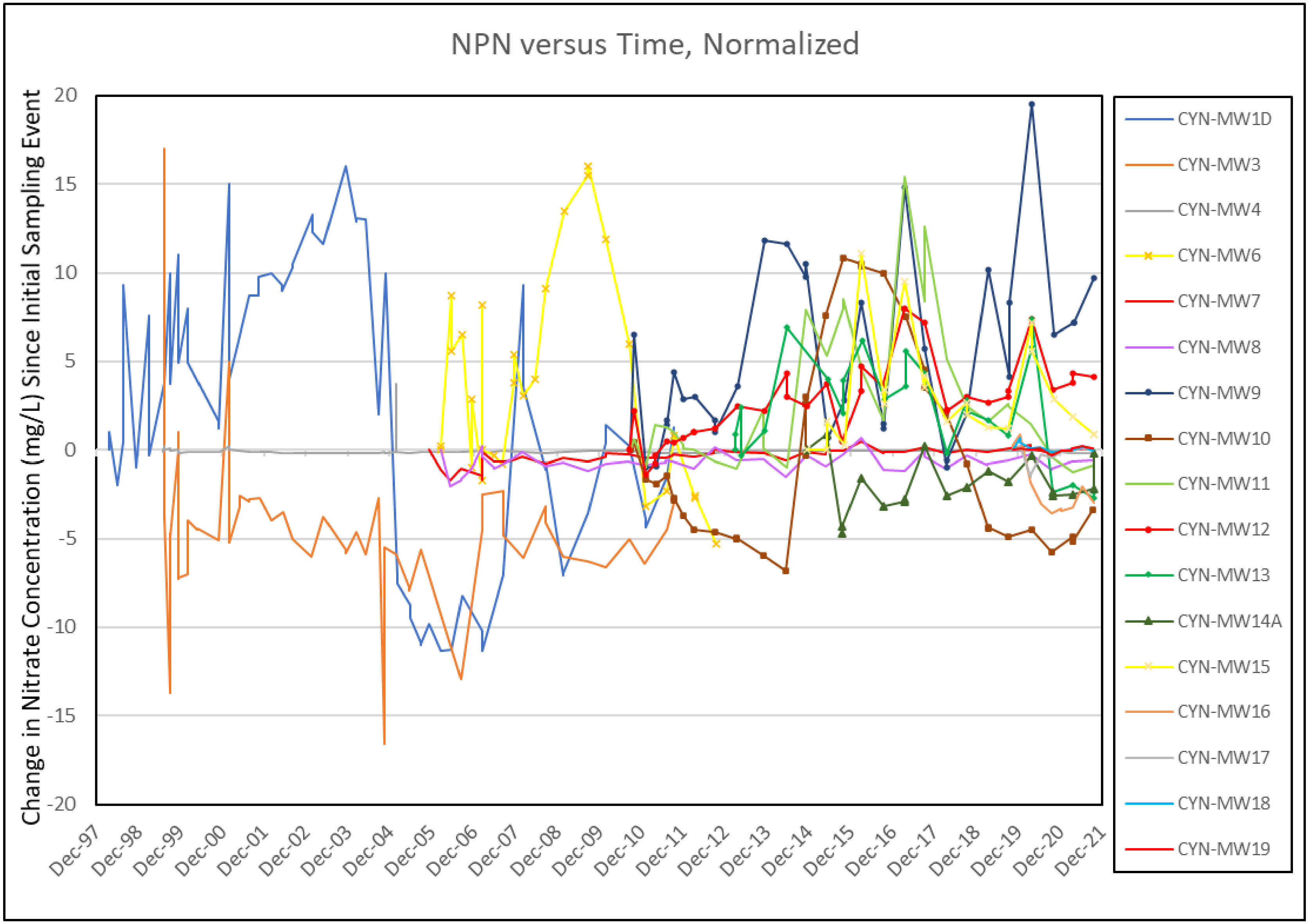

Figure 5-3. Time-Series Plot of Normalized NPN Concentrations in Groundwater Samples Collected from BSG AOC Monitoring Wells

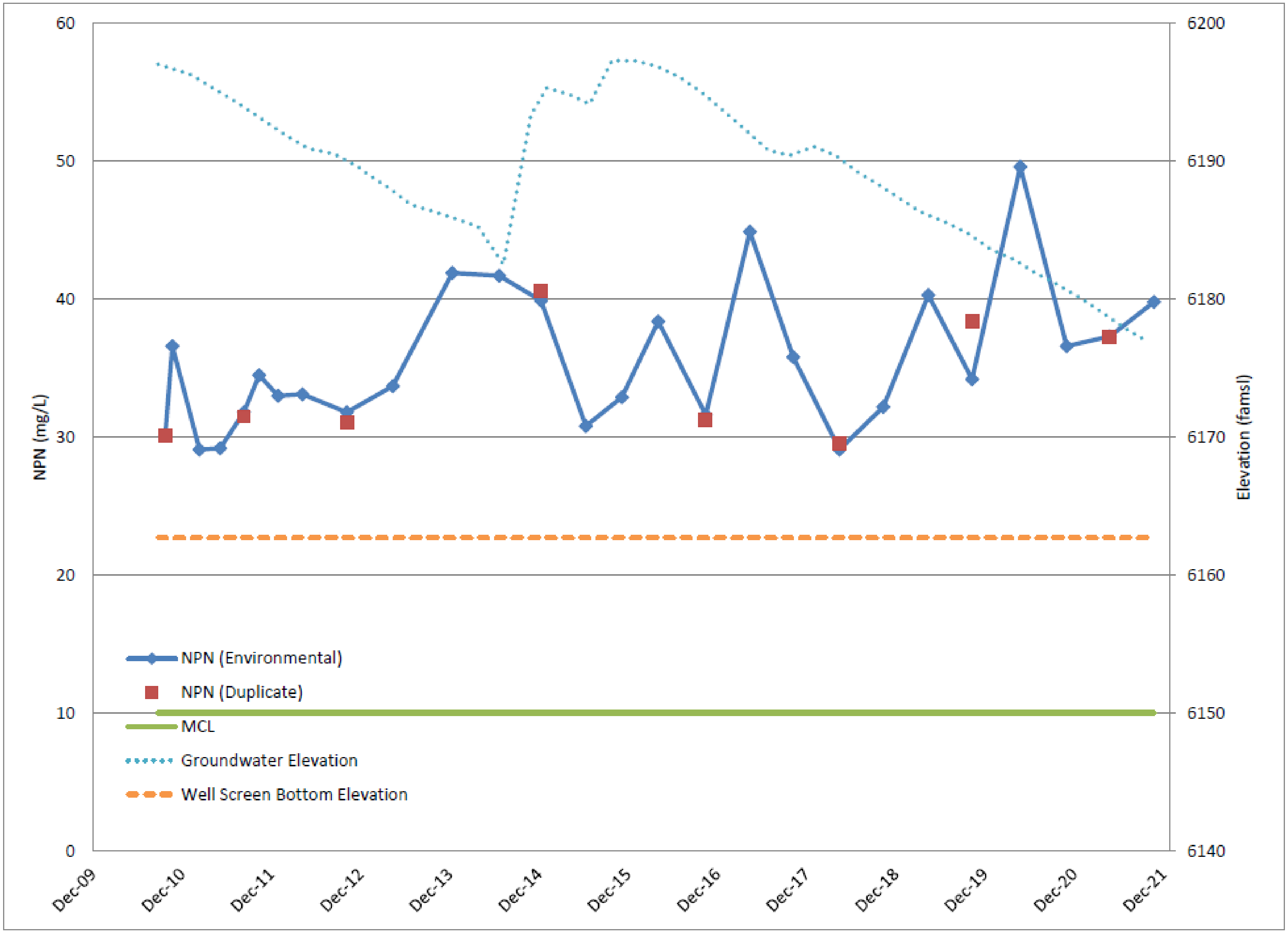

Figure 5-4. Time-Series Plot of NPN Concentrations in Groundwater Samples Collected from Monitoring Well CYN-MW9

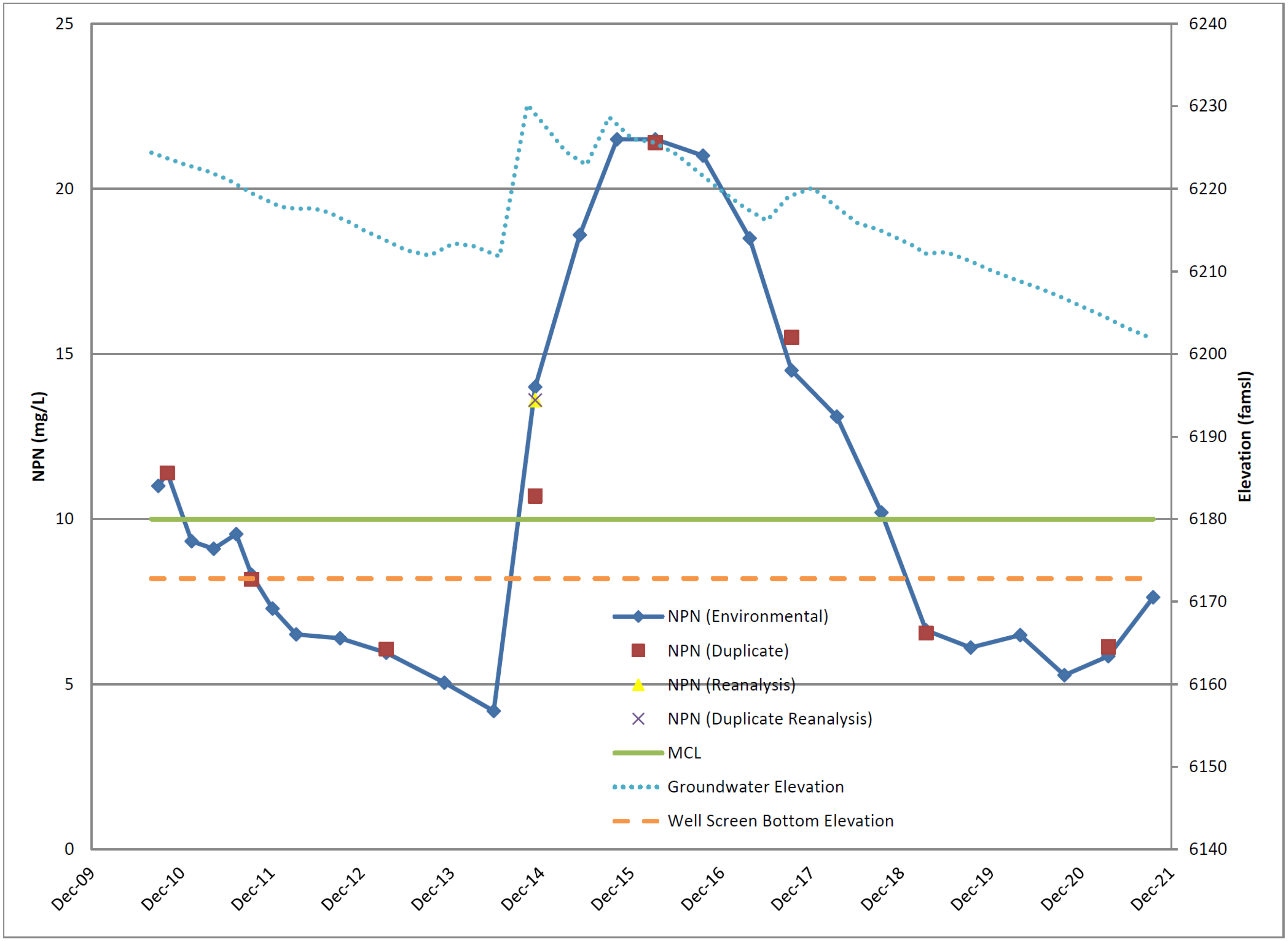

Figure 5-5. Time-Series Plot of NPN Concentrations in Groundwater Samples Collected from Monitoring Well CYN-MW10

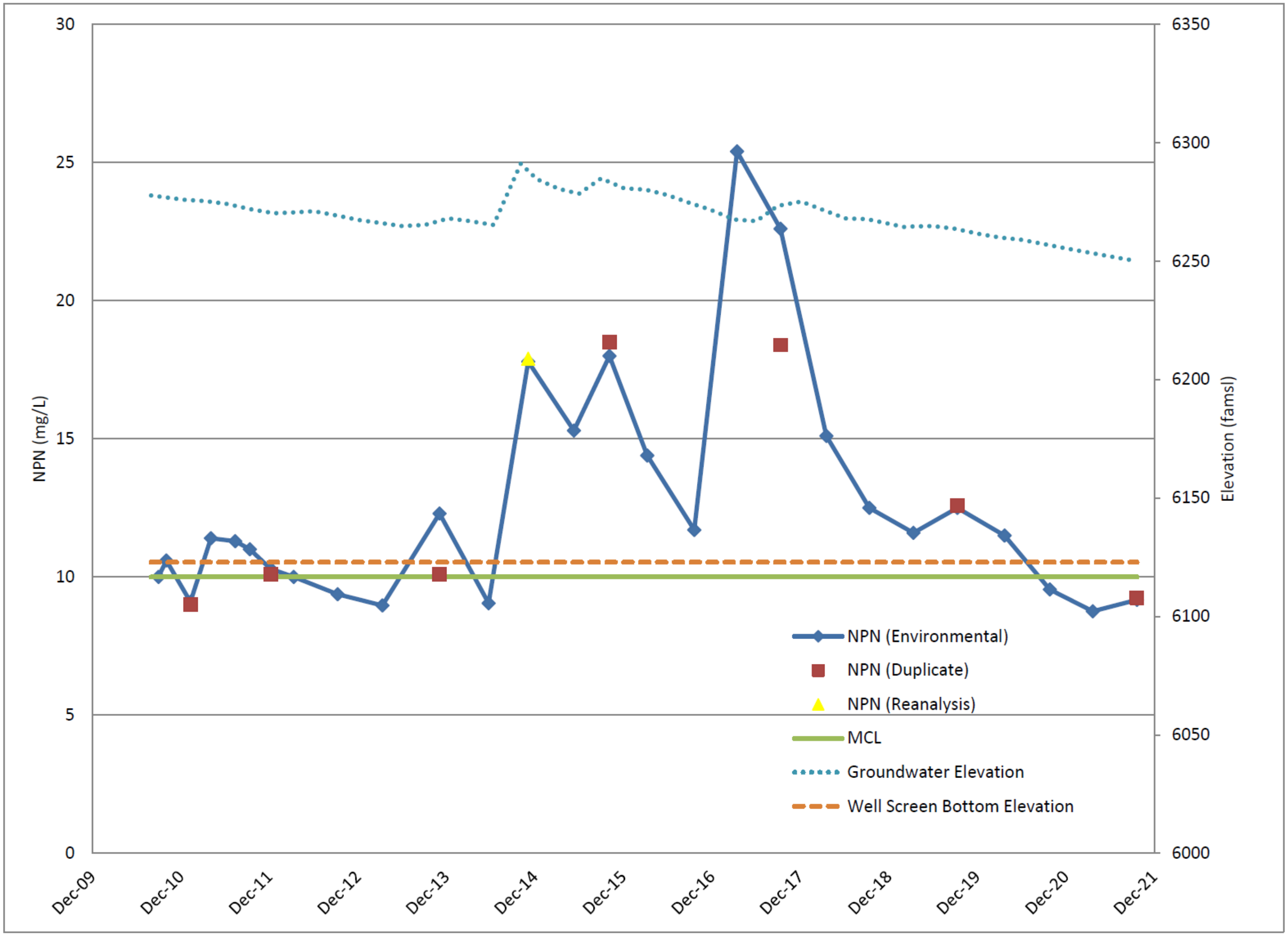

Figure 5-6. Time-Series Plot of NPN Concentrations in Groundwater Samples Collected from Monitoring Well CYN-MW11

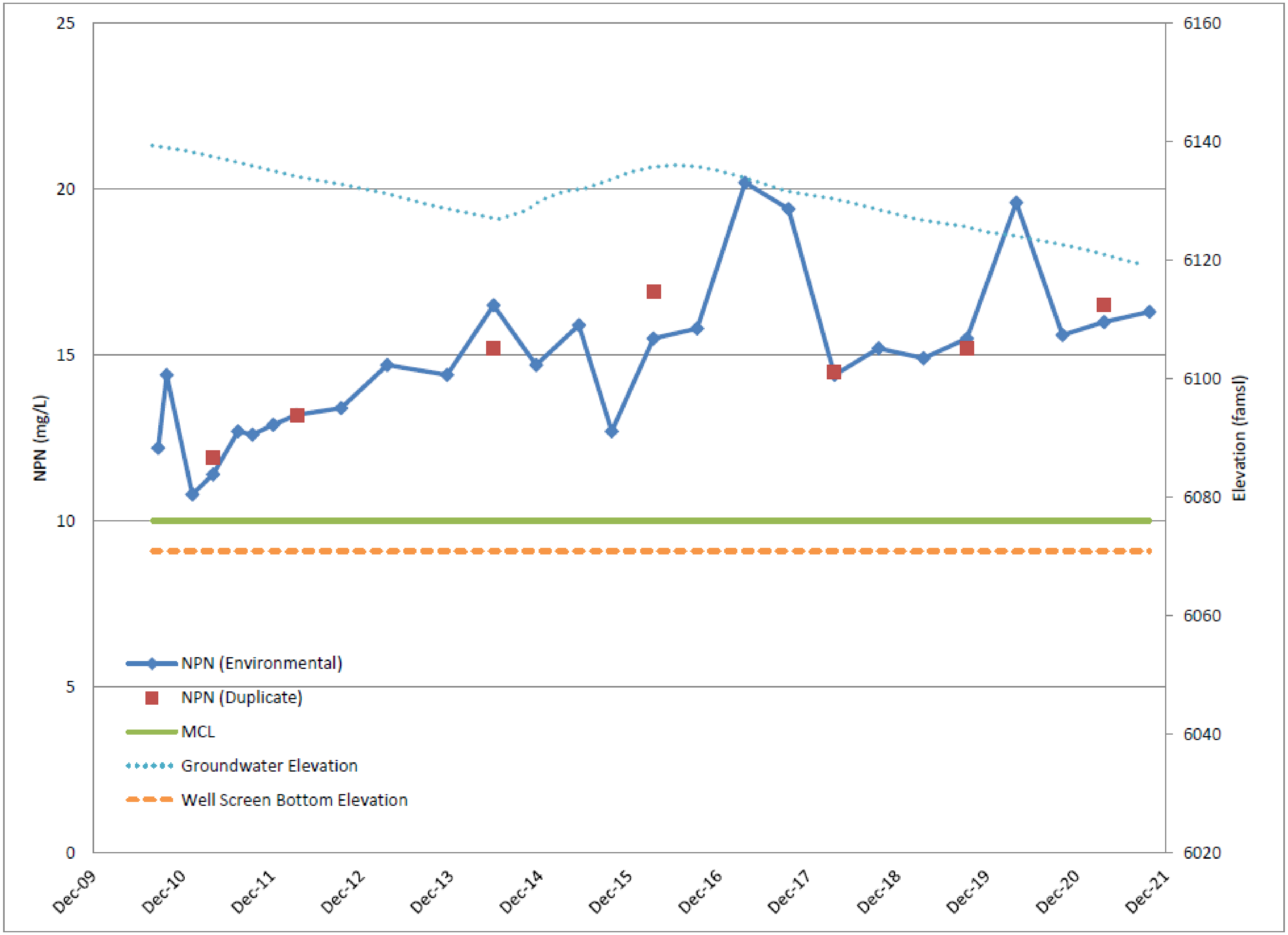

Figure 5-7. Time-Series Plot of NPN Concentrations in Groundwater Samples Collected from Monitoring Well CYN-MW12

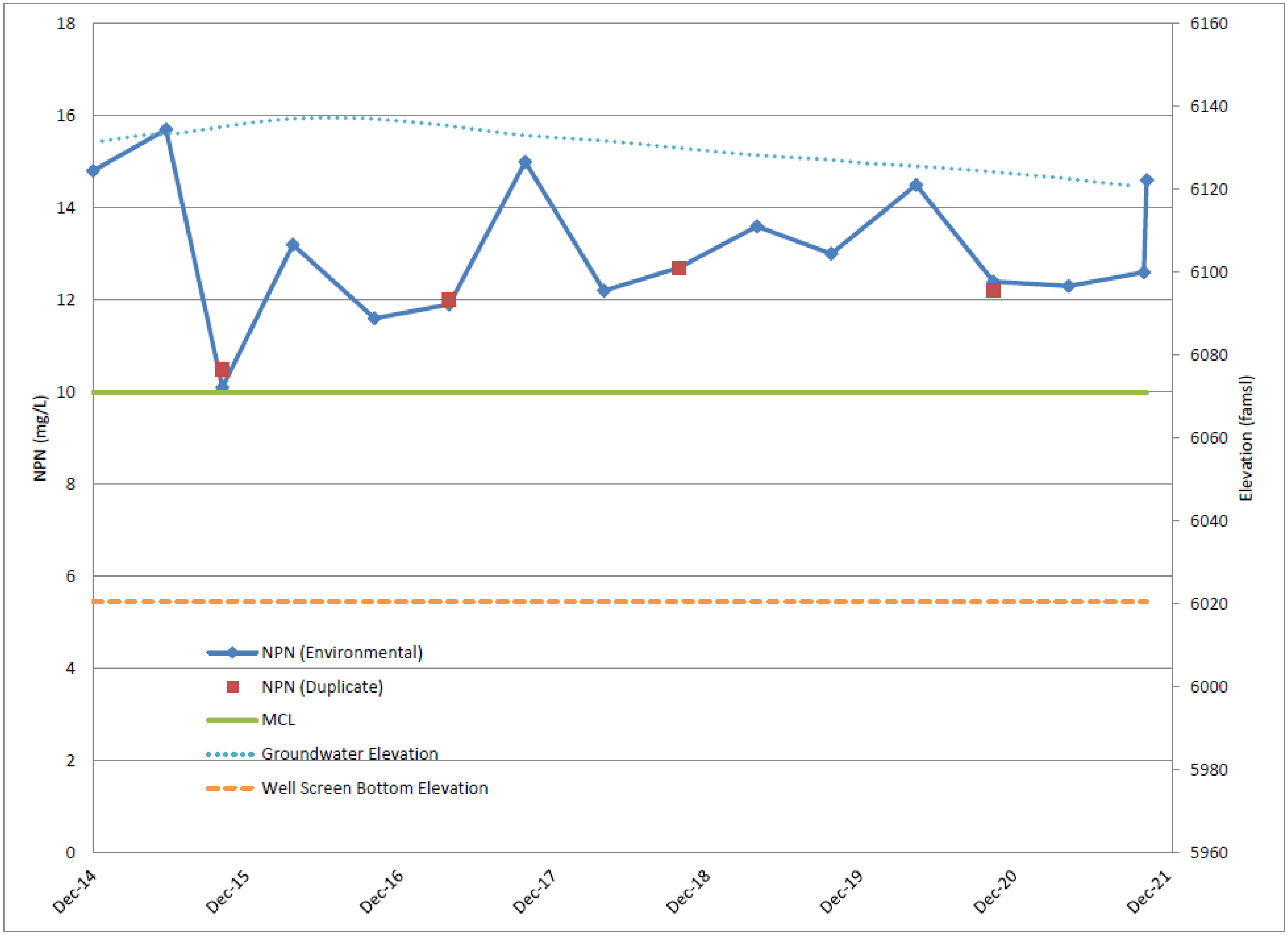

Figure 5-8. Time-Series Plot of NPN Concentrations in Groundwater Samples Collected from Monitoring Well CYN-MW14A

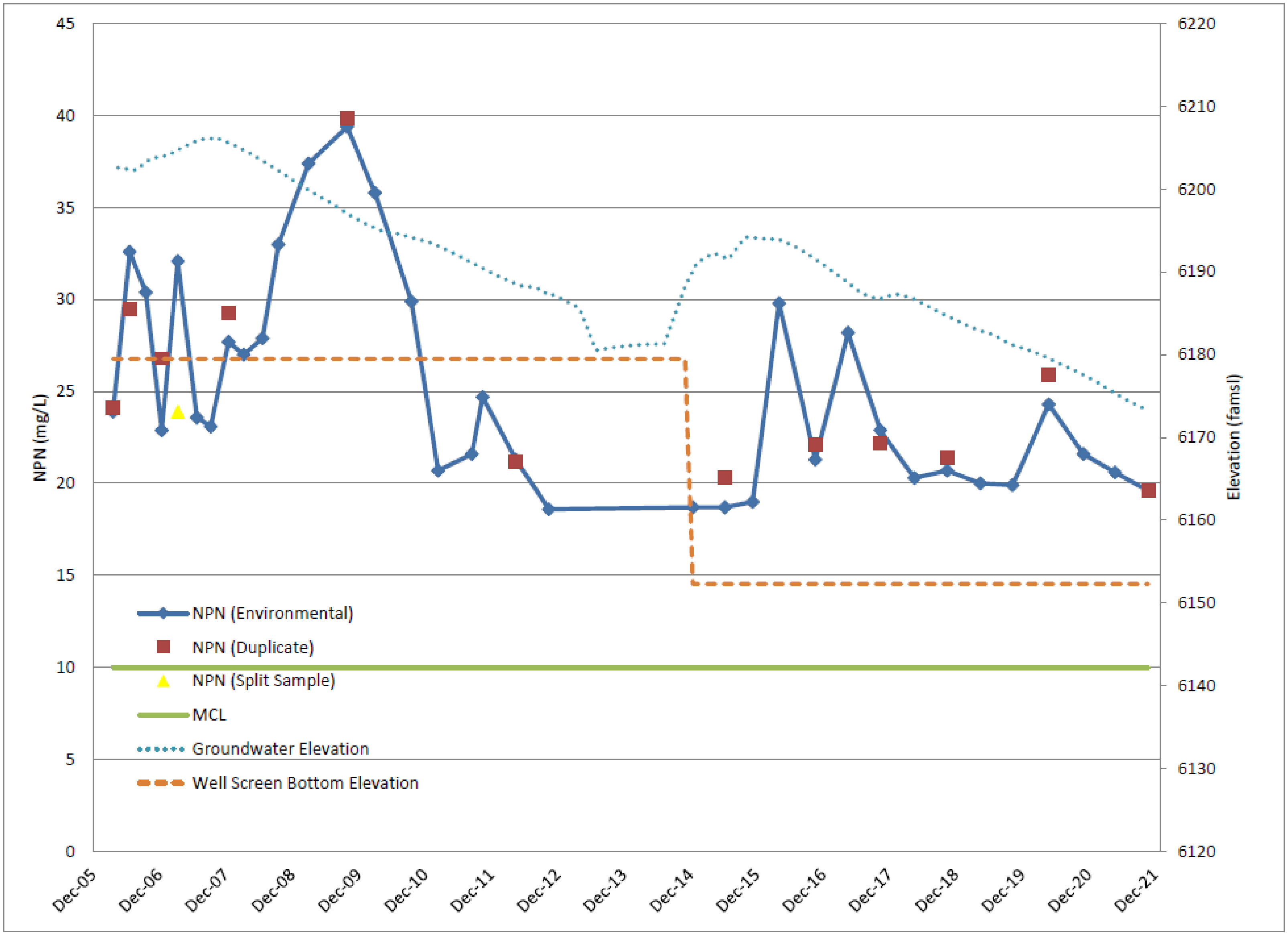

Figure 5-9. Time-Series Plot of NPN Concentrations in Groundwater Samples Collected from Monitoring Well CYN-MW15 (includes Historical CYN-MW6 Data)

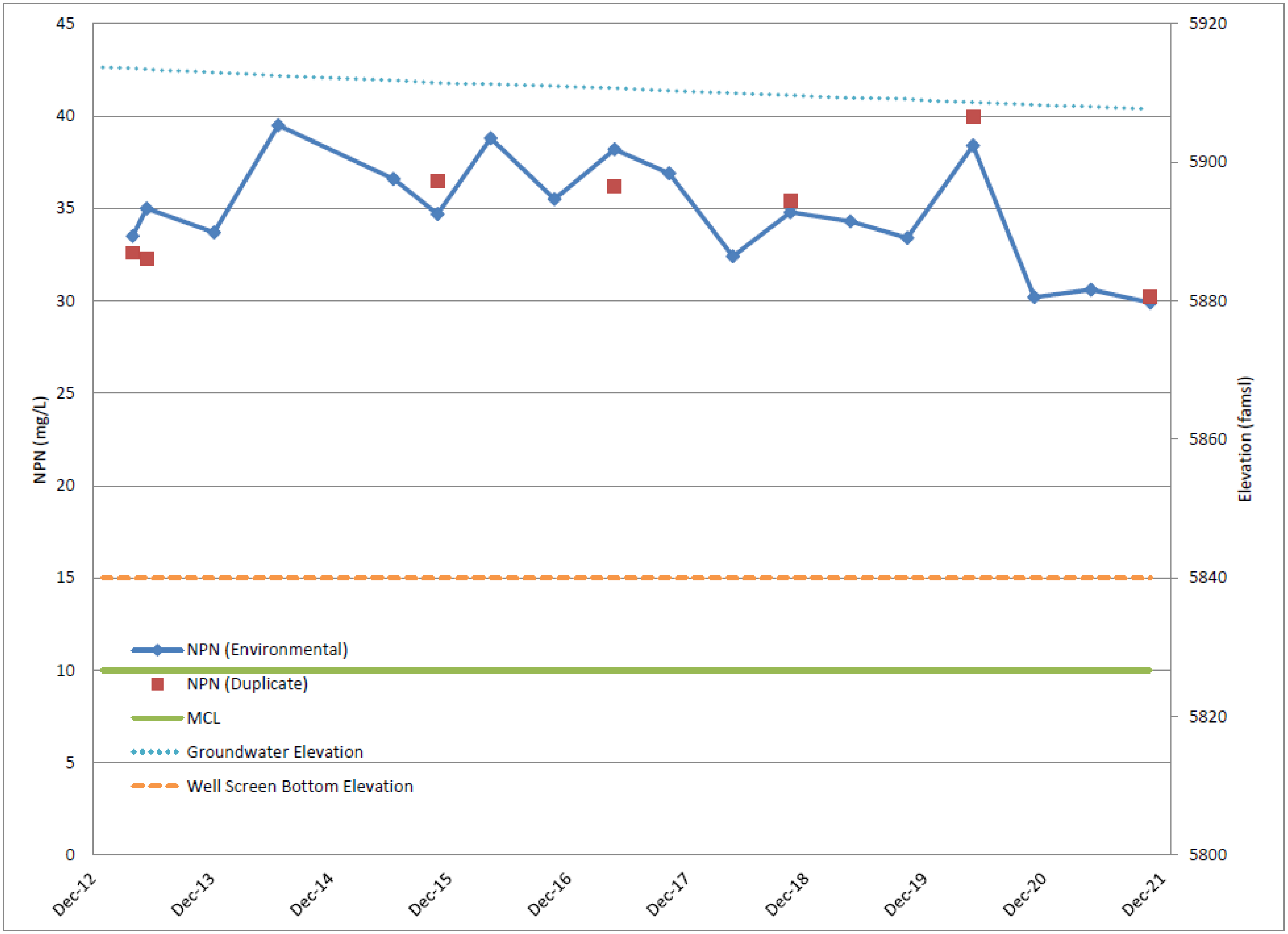

Figure 5-10. Time-Series Plot of NPN Concentrations in Groundwater Samples Collected from Monitoring Well CYN-MW13

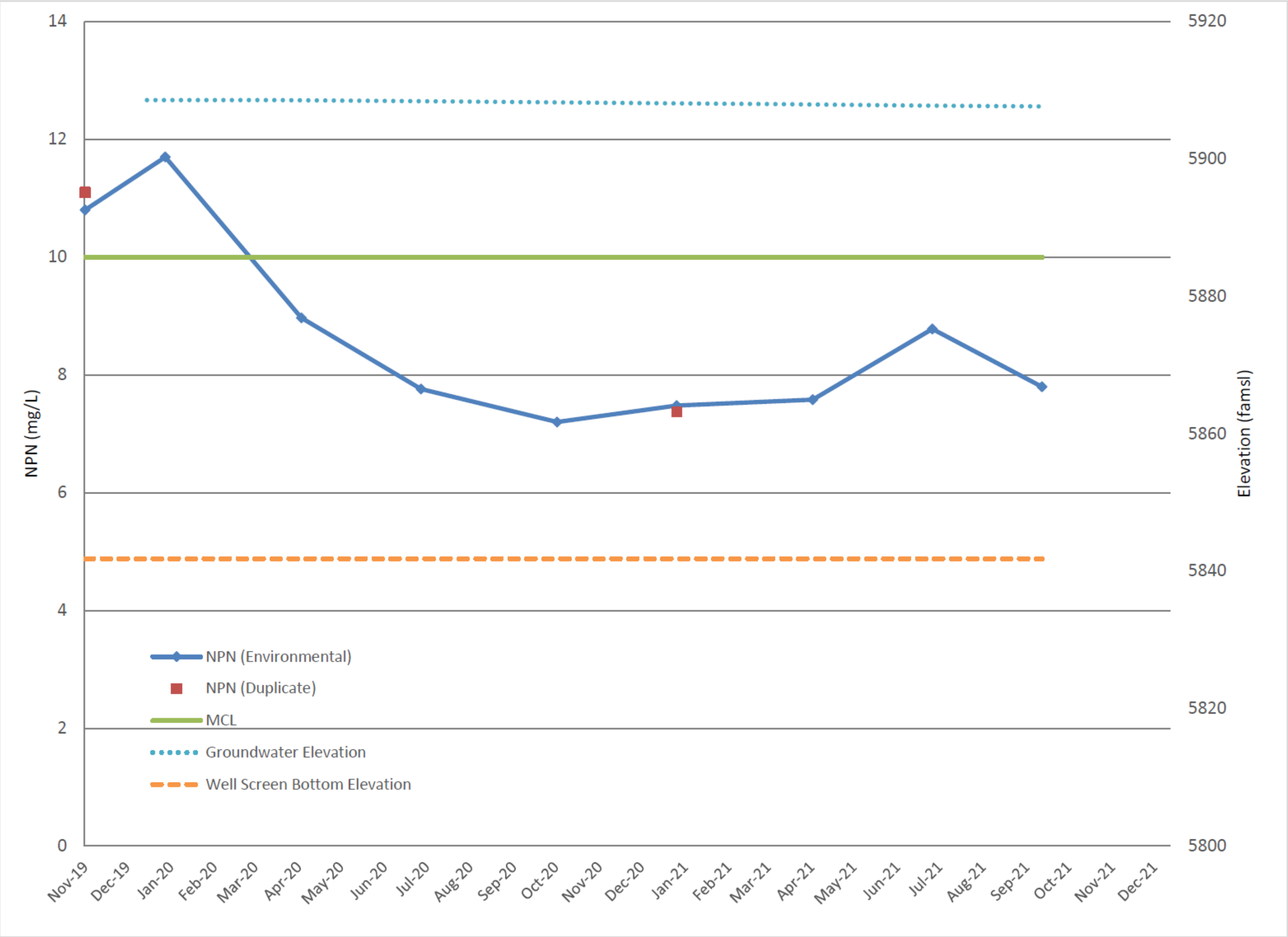

Figure 5-11. Time-Series Plot of NPN Concentrations in Groundwater Samples Collected from Monitoring Well CYN-MW16

Six monitoring wells (CYN-MW9, CYN-MW10, CYN-MW11, CYN-MW12, CYN-MW14A, and CYN-MW15) located at the eastern nitrate plume have historically exceeded the EPA MCL for nitrate (Table 5-2). Plots for the six monitoring wells are on Figures 5-4 through 5-9. Except for monitoring well CYN-MW9, all the monitoring wells in the eastern nitrate plume have decreasing or stable NPN trends for the last 5 years. Monitoring well CYN-MW9 exhibited slightly increasing NPN concentrations over the last 5 years and is the only monitoring well with concentration spikes increasing over time. This concentration trend in monitoring well CYN-MW9 may indicate a slight localized secondary source of nitrate in the vadose zone influenced by precipitation. Groundwater elevations at all six monitoring wells are declining.

Two monitoring wells (CYN-MW13 and CYN-MW16) located at the western nitrate plume have historically exceeded the EPA MCL for nitrate. As shown on Figures 5-10 and 5-11, NPN concentrations and groundwater elevations are decreasing at both monitoring wells.

5.4 Other Groundwater Analytes

In addition to NPN, groundwater from the BSG AOC monitoring well network has been sampled for a long list of analytes including alkalinity, anions, DRO, GRO, HE compounds, radionuclides, metals, perchlorate, and volatile organic compounds (VOCs). The analytical results for these parameters have been presented in AGMRs and other BSG AOC reports. Results indicate that no other analytes are potential COCs. To address regulatory requirements set forth in the Consent Order (NMED April 2004), discussions of the analytical results for fuel constituents and perchlorate are provided below.

5.4.1 Fuel Constituents

In addition to requirements in the Consent Order (NMED April 2004) to investigate nitrate, the NMED also required investigation of fuel constituents in groundwater at the BSG AOC, stating “fuel constituents below state and EPA standards have also been detected in some wells.” To meet this requirement, DOE/NNSA and SNL/NM personnel have been analyzing for fuel constituents in groundwater samples at BSG AOC monitoring wells since the late 1990s. Sampling was performed at active and now decommissioned monitoring wells. Depending on the age of the well, the number of analytical events (environmental samples and duplicate samples) ranges from 22 to 135 analytical sampling events per well. Since August of 1999, the analytical suite for groundwater monitoring has included TPH as DRO using EPA Method SW846 8015D and TPH as GRO using EPA Method SW846 8015A/B (EPA 1986).

The DRO/GRO analytical results have been presented in historical AGMRs. This extensive dataset shows that fuel constituents (DRO/GRO) are not present at levels of concern at the BSG AOC. There were more minor detections of fuel constituents (DRO/GRO) in the early years, but over time the number of detections and the concentrations of the detected DRO/GRO decreased. This trend could possibly be due to improved sampling procedures, improved analytical procedures, or lower detection limits over time.

As seen in the historical dataset, any DRO/GRO detected was at very low concentrations, on the order of 1 mg/L or less. The maximum DRO detection was 0.406 mg/L and the maximum GRO detection was 0.500 mg/L, both of which were detected in decommissioned monitoring well CYN-MW1D. As further evidence that fuel constituents have not impacted groundwater, the dataset shows that monitoring wells installed adjacent to SWMUs with known fuel-contaminated soils do not have detectable DRO/GRO in groundwater. For example, monitoring wells CYN-MW6 and CYN-MW15 were installed adjacent to (and downgradient of) SWMU 94F. During a Voluntary

Corrective Measure the TPH-contaminated soil at SWMU 94F was excavated down to bedrock and disposed offsite. However, the DRO/GRO concentrations from the nearby monitoring wells CYN-MW6 and CYN-MW15 have all been non-detect.

In addition to the DRO/GRO data, VOC data collected further supports the conclusion that fuel constituents are not a concern at the BSG AOC. Since August of 1999, the annual analytical suite for groundwater monitoring has included VOCs using EPA Method SW846 8260 (EPA 1986) for waste management characterization. The VOC analytical results have been presented in historical AGMRs. Based on this extensive dataset it is apparent that VOCs, and specifically fuel constituents such as benzene, ethyl benzene, toluene, and xylene (BTEX), are not present at levels of concern. There were several low concentration detections of BTEX at monitoring well CYN-MW1D in the early years but over time the number of detections and the concentrations of the detected BTEX decreased. This could possibly be due to incidental releases of fuel constituents during the 1997 construction of monitoring well CYN-MW1D (which dissipated over time), improved sampling procedures, improved analytical procedures, or lower detection limits.

As discussed above for DRO/GRO, the BTEX dataset also shows that monitoring wells located immediately adjacent to SWMUs with known fuel-contaminated soils (for example SWMU 94F) do not have detectable BTEX in groundwater. BTEX has never been detected in monitoring wells CYN-MW6 and CYN-MW15, which are located immediately downgradient of SWMU 94F. In summary, fuel constituents are not COCs at the BSG AOC.

5.4.2 Perchlorate

In addition to the requirements in the Consent Order (NMED April 2004) to investigate nitrate and fuel constituents, Section IV.B of the Consent Order stipulates that a select group of groundwater monitoring wells be sampled for perchlorate. For a given monitoring well, four consecutive non-detect results using the screening level/MDL of 4 micrograms per liter (µg/L) are considered by the NMED HWB as evidence of the absence of perchlorate, such that additional monitoring for perchlorate in that well is not required. If perchlorate is detected above the screening level/MDL in a specific monitoring well, perchlorate is considered a COC and monitoring will continue at that well at a frequency negotiated with the NMED (NMED April 2004).

During the implementation of this Consent Order requirement, it was determined that samples from monitoring well CYN-MW6 contained perchlorate above the 4 µg/L screening level/MDL with a maximum historical concentration of 8.93 µg/L. No other BSG AOC monitoring wells had perchlorate results above the screening level/MDL. Due to declining water levels, CYN-MW6 had insufficient water to allow sampling and replacement monitoring well CYN-MW15 was installed in December 2014.

In accordance with the requirements of Section VI.K.1.b of the Consent Order (NMED April 2004), a human health risk assessment was performed to evaluate the potential for adverse health effects from the concentrations of perchlorate detected in monitoring wells CYN-MW6/CYN-MW15 groundwater samples. The maximum perchlorate concentration in CYN-MW6 of 8.93 µg/L was used in the risk assessment. The calculated hazard quotient of 0.35 is less than the NMED HWB target level of a hazard index (the sum of all hazard quotients) of 1.0 (NMED June 2006, SNL/NM March 2008). For another point of comparison, NMED HWB risk assessment guidance lists a tap water standard of 13.8 µg/L for perchlorate (NMED February 2019); therefore, the historical maximum concentration detected is 64% of the NMED HWB tap water standard.

Since the 2014 installation of replacement monitoring well CYN-MW15, this well has been sampled for perchlorate during 13 events using EPA Method 314.0 (SNL/NM April 2021). As of November 2020, perchlorate was non-detect in 8 of 13 groundwater sampling events at CYN-MW15 (Figure 5–12). The November 2020 result represented four consecutive sampling events that perchlorate was non-detect at this monitoring well. Having met the requirements of the Consent Order (NMED April 2004), DOE/NNSA and SNL/NM personnel discontinued monitoring for perchlorate at monitoring well CYN-MW15 after the November 2020 sampling event (SNL/NM April 2021). No other BSG AOC monitoring wells ever had perchlorate detected above the 4 µg/L screening level/MDL. In summary, perchlorate is no longer considered a COC at the BSG AOC.

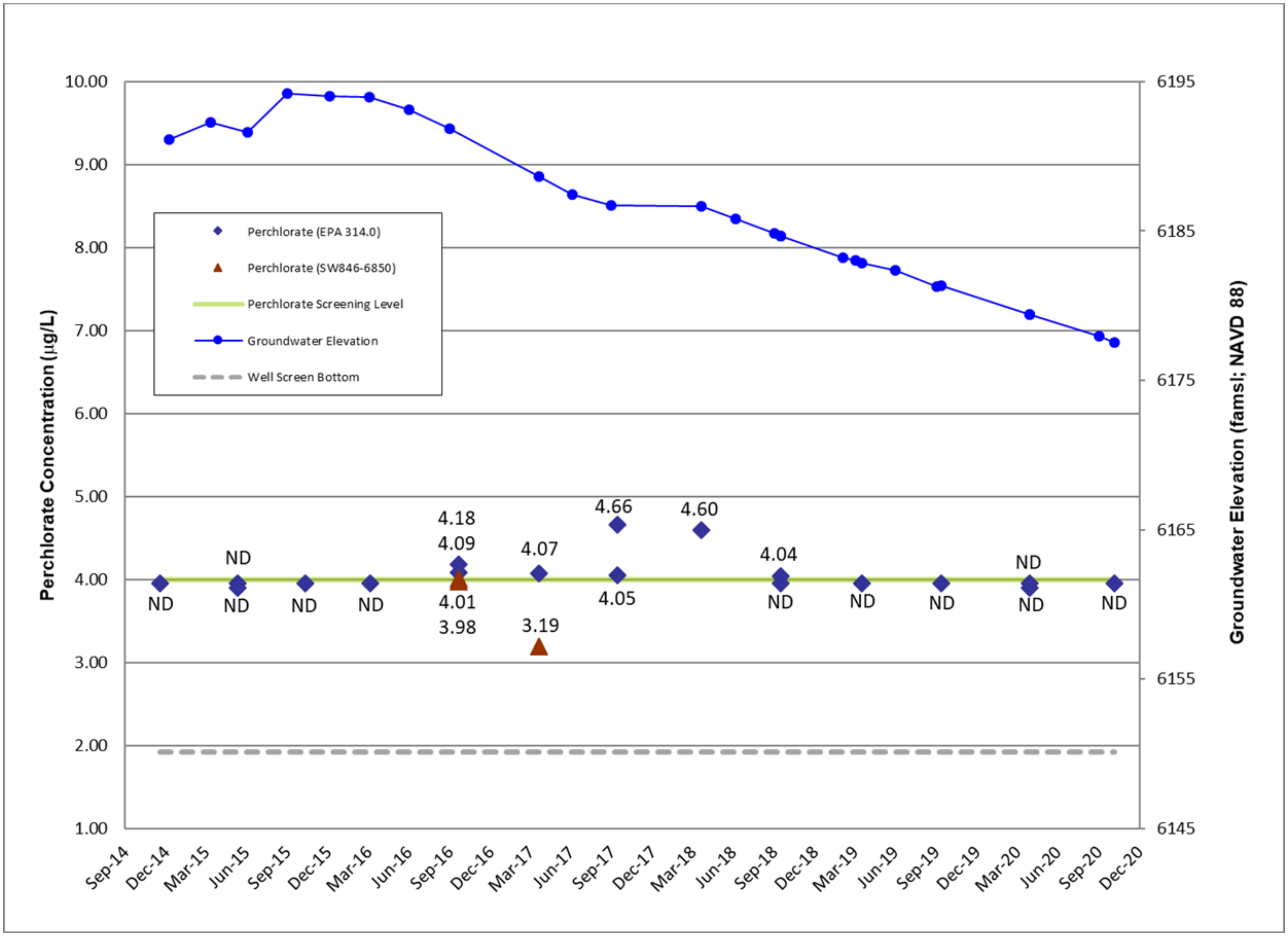

Figure 5–12. Groundwater Elevations and Perchlorate Concentrations Over Time in CYN-MW15

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6. CONCEPTUAL SITE MODEL

Groundwater flow and contaminant transport in the vicinity of the BSG AOC are controlled by stratigraphic, structural, and hydrogeological conditions. The CSM is discussed below and integrates data and interpretations from over 20 years of SNL/NM investigations in the study area. A visualization of the CSM is shown in Figure 6-1.

6.1 BSG Conceptual Site Model

The Manzanita Mountains are composed of a complex sequence of uplifted Precambrian metamorphic and granitic units that were subjected to several episodes of significant deformation. These units are capped by Paleozoic sandstones, shales, and limestones. Groundwater in the Manzanita Mountains predominantly occurs in fractured metamorphic and intrusive units that consist of metavolcanics, quartzite, metasediments (schists and phyllites), and the Manzanita Granite. Groundwater migrates through bedrock fractures in a generally westward direction.

The matrix permeability of the fractured bedrock units is low, and most groundwater is produced from discontinuous water-bearing fracture zones. Groundwater discharges to small ephemeral springs located at the base of the Manzanita Mountains approximately 3 miles west of the BSG AOC. Some groundwater may discharge as underflow to the Regional Aquifer in unconsolidated sedimentary deposits of the Albuquerque Basin after crossing the Tijeras Fault Zone.

The Precambrian metamorphic rocks (predominantly schists and phyllite) and the Precambrian intrusive rocks (predominantly granitic gneiss) are typically fractured as a result of the long and complex history of regional deformation. Drill core data, borehole video logging, and outcrop exposures indicate that some fractures in shallow bedrock are filled with chemical precipitates, such as calcium carbonate. The carbonate precipitation likely occurred when the water table was regionally elevated prior to the development of the Rio Grande. As chemical precipitates filled the fractures, permeability was effectively reduced, possibly creating a semiconfined unit above underlying bedrock with water-bearing open fractures.

The Burn Site is bisected by a north-south trending system of faults, consisting locally of several high angle normal and reverse faults that are mostly downfaulted to the east (Karlstrom et al. 2000). Faults (where exposed) are characterized by zones of crushing and brecciation. The Burn Site Fault trends north to south in the vicinity of the Burn Site Well and monitoring well CYN-MW4. Nearby outcrops indicate that the fault displacement is approximately 160 ft (SNL/NM June 2004a). Based upon water levels measured at the monitoring wells installed in 2019, current interpretations suggest that faults between CYN-MW17 and CYN-MW18 have a significant control upon the potentiometric surface.

The BSG AOC canyon floor consists of unconsolidated deposits over bedrock. These deposits are typically sand and gravel derived from erosion of upslope colluvium and bedrock, or eolian fine sand deposits derived from the basin to the west. These unconsolidated deposits range in thickness from 21 to 55 ft in boreholes drilled at the BSG AOC. The unconsolidated deposits pinch-out against nearby bedrock outcrops along the steep canyon slopes.

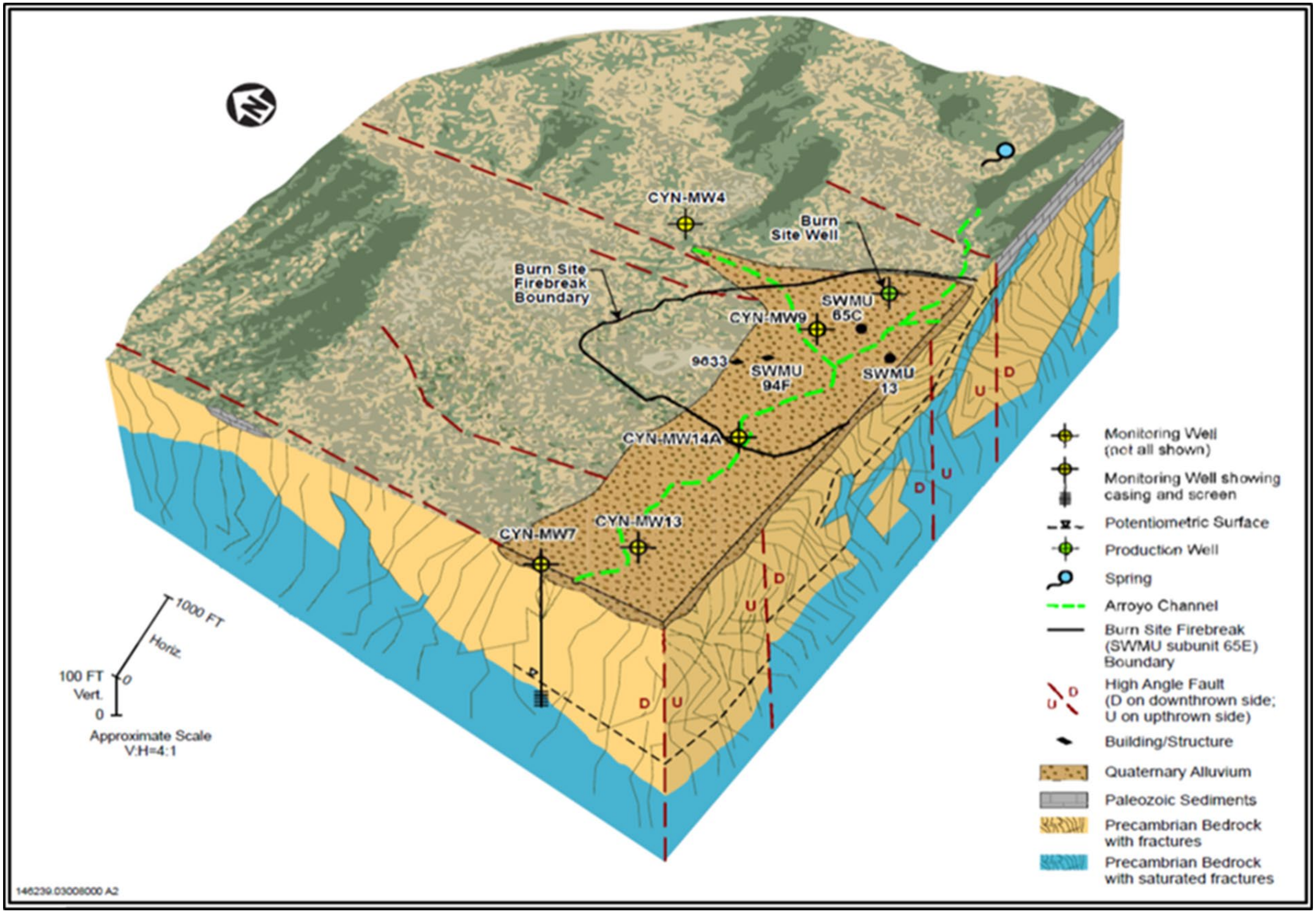

Figure 6-1. Conceptual Site Model for BSG AOC, View to Northeast, Not to Scale

The fractured rocks of the Manzanita Mountains are recharged by infiltration of precipitation, largely resulting from summer thundershowers and, to a lesser degree, winter snowfall on the higher elevations. Groundwater recharge is restricted by high evapotranspiration rates (losses to the atmosphere by evaporation and plant transpiration), the low permeability of the bedrock matrix, and the discontinuous nature of the bedrock fractures.

Ephemeral surface water flows occur in response to precipitation in the drainage basin. In 1997, two shallow monitoring wells/piezometers (CYN-MW2S and 12AUP01) were constructed in Lurance Canyon to monitor groundwater potentially occurring within the channel deposits at the contact with underlying Precambrian bedrock. No groundwater was present in either shallow monitoring well until September 2, 2004. After a series of rain events, 1-2 inches of water was measured in monitoring well 12AUP01. The water level remained constant for about one month. However, no water has been measured in monitoring well 12AUP01 since 2005 and no groundwater had ever been measured in monitoring well CYN-MW2S. Both wells were plugged and abandoned in 2012 (SNL/NM March 2013). It is likely that saturation in the alluvium only occurs after a series of heavy rain events. Episodic accumulation of precipitation may provide a mechanism for recharging the brecciated fault zones and non-cemented fractures in the underlying bedrock.

No production wells are located near the BSG AOC, except for the Burn Site Well that was only used for non-potable applications, such as for fire suppression in testing structures and for fuel pool tests. The well was last used in 2003. The submersible pump was removed from the Burn Site Well in December 2014 and has not been reinstalled. Water levels in the Paleozoic and Precambrian bedrock near the BSG AOC are not influenced by production well pumping from the basin fill deposits of the Albuquerque Basin (Regional Aquifer), which are located to the west of the Tijeras Fault Zone.

The variability of hydraulic gradients in the BSG AOCs indicates that localized controls are associated with brecciated fault zones in the low-permeability fractured bedrock. No information is available about horizontal and vertical flow velocity within the fractured bedrock. However, vertical movement of groundwater within the brecciated fault zones probably occurs as rapid, partially saturated to saturated flow.

Filled fractures within the upper portion of the metamorphic and intrusive rocks may act as a semiconfining unit restricting vertical flow. These concepts were corroborated by an aquifer pumping test conducted in March 2017 that showed 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 semiconfined to confined. Some faults and fractures are sealed and act as barriers to groundwater flow (SNL/NM December 2017).

Water levels have been routinely measured in monitoring wells since 1999. There are no active production wells within an eight (8) mile radius of the area and there are no regular seasonal variations in water levels in these monitoring wells. The wide range of hydraulic gradients and the lack of correlation between water level fluctuations in these monitoring wells support the assessment that the BSG AOC low-permeability fractured groundwater system is poorly interconnected. Water level fluctuations may be a result of local heterogeneities in hydraulic properties related to the water-bearing fracture zones.

Nitrate in the BSG AOC may be derived from both natural and anthropogenic sources. Potential natural sources include the weathering of rocks, atmospheric deposition, and the grading of soils and alluvium. Evaporation and transpiration of rainwater that has infiltrated canyon alluvial sediments might have increased nitrate concentrations. Evidence indicates that evaporation and transpiration may concentrate nitrate in sediments beneath ephemeral drainages in the vicinity of the Manzanita Mountains. This evidence includes nitrate concentrations that exceed the EPA MCL in groundwater beneath these drainages and a chloride to nitrate ratio in groundwater that is similar to that of rainfall (McQuillan and Space 1995). In more recent studies, the USGS has attributed naturally occurring accumulations of geologic nitrate in unconsolidated sediments along Tijeras Arroyo to a similar evaporation and transpiration mechanism (see Section 6.2 for further discussion).

Potential anthropogenic nitrate sources include the use of ammonium-nitrate slurry, wastewater discharges, and the degradation of HE compounds (Figure 6-2). DO/NNSA and SNL/NM personnel have conducted several soil sampling events in the BSG AOC to identify the source of nitrate; however, no conclusive source has been identified, most likely because chemical releases ceased decades ago and precipitation has leached the nitrate from the soil.

SWMU 65 is located in the center of the BSG AOC and contains open-air detonation areas where nitrate-based explosives were used. The detonations dispersed explosive compounds across the ground surface, and subsequent degradation (weathering) of these explosive compounds most likely released some nitrate. Testing at SWMU 94 also involved burn tests involving large volumes of ammonium-nitrate slurry, HE compounds (both nitrate-based and plastic explosives), and rocket propellants. Nitrate is highly soluble in water, and precipitation can enhance its migration to groundwater. In addition to nitrate, petroleum fuel products were detected in soil samples and potential impacts to groundwater were evaluated and found to be negligible.

In summary, the fractured bedrock aquifer system exhibits the following characteristics in the BSG AOC:

- Groundwater in the Manzanita Mountains predominantly occurs in fractured Precambrian metamorphic rocks.
- Groundwater flows generally westward through bedrock fractures, and is controlled by the geologic framework, such as lithologic variability and structural features. For example, the site is crossed by several north-south faults (high angle, down-to-the-east normal faults). Where exposed the faults exhibit crushing and brecciation.
- 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 principal control upon groundwater flow direction is topographic effects. Groundwater in the Manzanita Mountains flows toward the west from a groundwater divide/highpoint located approximately 4.5 miles to the east of the BSG AOC.
- The fractured bedrock aquifer system discharges into and merges with the Regional Aquifer approximately 3 to 5 miles to the west of the BSG AOC.

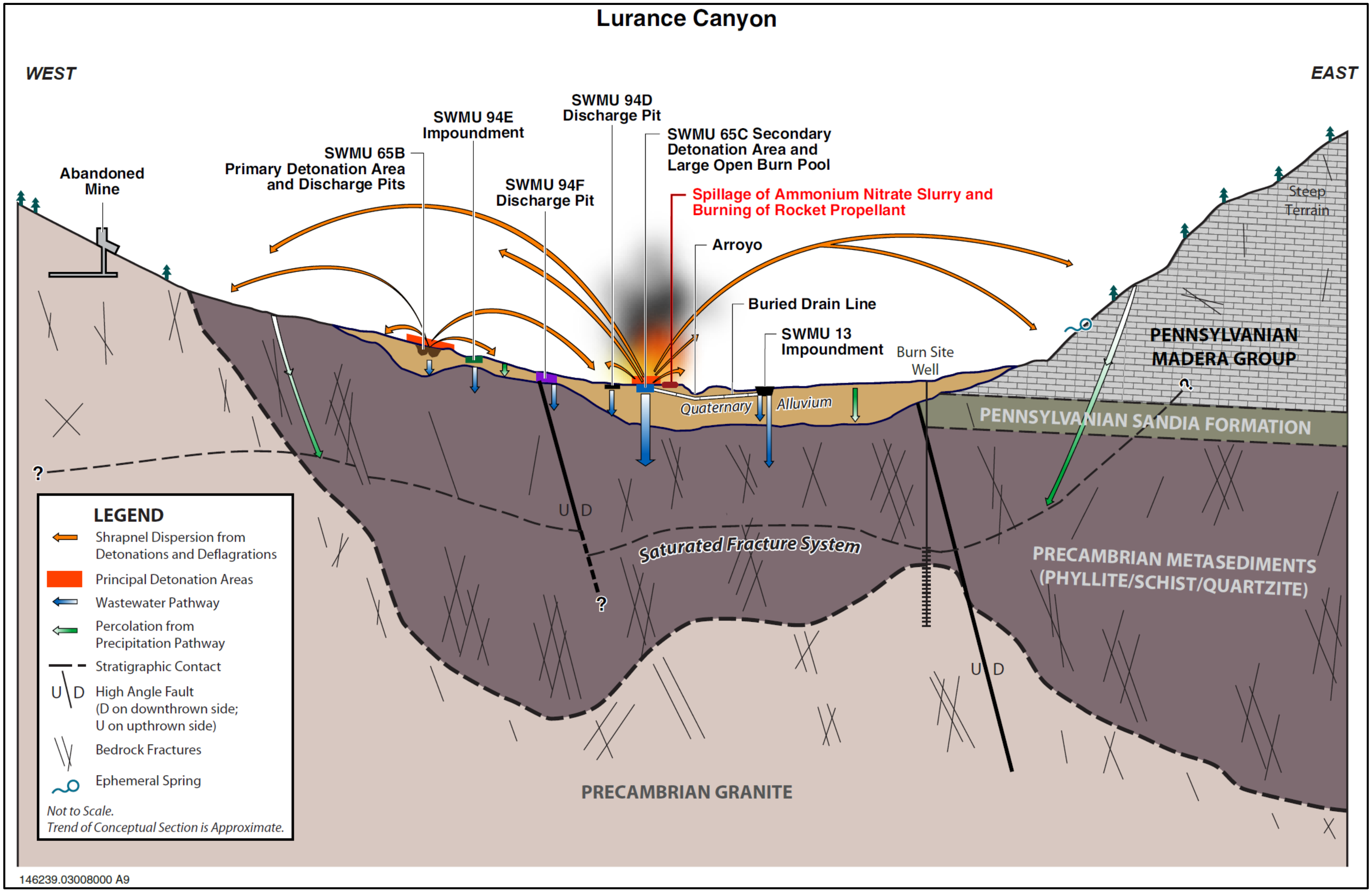

Figure 6-2. Potential Contaminant Release Mechanisms at the BSG AOC

- There is significant compartmentalization of groundwater into distinct hydraulic domains, such that most of the fractured bedrock aquifer is confined to semiconfined. 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.
- The depth to the uppermost water-bearing fracture zones varies from approximately 55 to 379 ft bgs. Initial water levels above the screened intervals (positive head) have varied from approximately 5 to 153 ft due to semiconfined or confined conditions.
- Alluvium along arroyo channels is predominantly unsaturated. Groundwater accumulates rarely in alluvium and only in response to significant precipitation events.
- The estimated horizontal groundwater gradient varies from approximately 0 to 0.14 ft/ft. This large gradient range is because the groundwater flow is controlled by a diverse pattern of bedrock fractures and brecciated fault zones (secondary porosity).
- No information is available about vertical flow velocity within the fractured bedrock. Vertical movement of groundwater within open fractures and the brecciated fault zones probably occurs as rapid, unsaturated to saturated flow.
- Groundwater is not used for potable purposes. Production (water-supply) wells do not affect the hydrogeologic regime.
- There are declining groundwater elevations for over 20 years, possibly related to persistent regional drought and global climate change.
- Matrix permeability (primary porosity) of the bedrock is assumed to be low. Meager amounts of groundwater are produced from the discontinuous water-bearing fracture zones (secondary porosity).
- Recharge of the fractured bedrock aquifer system is restricted by high evapotranspiration rates for most of the year, low permeability of bedrock matrix, and discontinuity of fractures. However, episodic accumulation of precipitation is a mechanism for recharging brecciated fault zones and non-cemented fractures in bedrock.
- Historical and ongoing recharge is by natural sources in the form of infiltration from direct precipitation and surface water flow in Lurance Canyon Arroyo.
- The occurrence of nitrate in groundwater at the BSG AOC is primarily the result of anthropogenic sources including the use of explosives with a possible contribution from natural sources.

6.2 Nitrate Occurrence in the Environment

Nitrate can leach from geologic deposits, especially sedimentary strata (Holloway et al. October 1998; Walvoord et al. November 2003). Holloway et al. (2001) coined the term “geologic nitrogen” to refer to nitrogen incorporated into the matrix of rock during diagenesis or through secondary alteration. Potential sources of elevated nitrate concentrations in surface water and groundwater in several states have been attributed to the dissolution of various rock types including sedimentary, igneous, and metamorphic units. As such, bedrock weathering is considered an important part of the terrestrial nitrogen cycle. Geologic nitrate associated with metasedimentary rocks, especially phyllite and schist, was found to be responsible for nitrate concentrations of up to 30 mg/L in stream-water samples collected along the Mokelumne River watershed of the Sierra Nevada (Holloway et al. 1998).

Recent USGS studies in the KAFB region have established that accumulation of naturally occurring nitrate in desert soil can be readily mobilized to groundwater when land-use changes occur, such as construction activities (Linhoff and Lunzer 2021; Linhoff 2022). These naturally occurring accumulations (subsoil nitrate reservoirs) are referred to as “geologic nitrate” or “geogenic nitrate.” Left undisturbed, nitrate from decayed vegetation can become concentrated by evapotranspiration in soil below the root zone during dry periods that last for decades or centuries (Walvoord et al. November 2003). However, land-use disturbances can alter surface and shallow soil such that precipitation can more readily infiltrate and subsequently flush nitrate downward to groundwater.

Disturbances of soil and natural storm-water channels occurred during construction activities at the Burn Site Testing Facility. These disturbances allowed the mobilization of geologic nitrate that had accumulated in the normally dry alluvium along the valley floor. The grading and construction activities began in 1966 and were primarily located where monitoring wells CYN-MW6 and CYN-MW9 were subsequently installed. Other disturbances included channelizing the north-south arroyo, constructing a small stormwater pond, grading storage yards, and building bunkers and roads. Excavation of several SWMUs by the ER Project Team also disturbed the ground surface. Using aerial photography analysis, the disturbed area at the Burn Site Testing Facility was estimated to be 14.5 acres (Sandlin June 2022).

Infiltration of precipitation or applied water at the disturbed area could cause the mobilization of geologic nitrate from the alluvium into the fractured bedrock aquifer by: (1) precipitation falling on the disturbed area, (2) stormwater flowing in the north-south arroyo, (3) stormwater accumulating in the retention pond, (4) dust suppression water applied to the ground surface, (5) water applied to moderate the fires in testing structures, with some fraction being discharged onto the ground surface, (6) applied water that leaked through plastic-lined earthen depressions prior the use of steel burn pans, and (7) applied water spilled during the filling of burn pans.

Naturally occurring nitrate at the BSG AOC could result from: (1) decaying vegetation, and/or (2) inherent in bedrock. Grasses and shrubs likely grew on thin soil profiles above the alluvium prior to SNL/NM activities at the site. Also, decayed vegetation in the surrounding watershed includes grasses and shrubs along the arroyos and forest duff (pine needles, leaves, fallen branches) on the steep canyon walls.

To summarize, natural geologic nitrate may: (1) become concentrated in shallow subsurface soil in desert soils due to evapotranspiration and subsequently mobilized to groundwater by infiltration of precipitation or applied water, (2) be derived from decaying vegetation and nitrate contained in bedrock, and (3) be mobilized to groundwater due to disturbances of surface and near-surface soils that occurred during construction activities or testing activities.

Nitrate is highly mobile in soil due to its high solubility in water and weak retention by soil particles (EPA October 2001). The primary mechanism for nitrate transport in the environment is movement of water containing dissolved nitrate through soil. Nitrate does not volatilize and is likely to remain dissolved in water until consumed by plants or other organisms. Nitrate degradation (denitrification) occurs most rapidly where anaerobic conditions are coupled with the presence of denitrifying bacteria and a suitable carbon source (EPA October 2001).

Nitrate occurs primarily in the dissolved phase and does not sorb onto sediments. Therefore, any locally derived nitrate more than the background concentration in groundwater was most likely transported by advection through the vadose zone with the wastewater discharges or surface water flow events. Infiltration of water can follow preferential pathways of saturated or partially saturated flow through the vadose zone. Because nitrate does not partition to the soil and is highly soluble, no secondary source of nitrate likely remains within the vadose zone except for extremely localized occurrences.

Contaminant transport mechanisms in groundwater include advection, dispersion, and diffusion. Dispersion is a process whereby a solute migrates in directions that are longitudinal and transverse to the advection of groundwater flow. The dispersion process dilutes contaminant concentrations in groundwater. Diffusion is a process whereby a concentration gradient can cause solute to migrate from zones of higher concentration to zones of lower concentration, regardless of groundwater flow direction. Studies of denitrification parameters and isotopic signatures conducted in 2013 and 2015 indicated that natural denitrification (such as biodegradation) in the fractured bedrock aquifer system at the BSG AOC was insignificant (Madrid et al. 2013; Madrid et al. 2016; Longmire and Armijo 2017).

In general, potential natural attenuation processes capable of reducing nitrate concentrations are biodegradation, dispersion, and dilution (EPA September 1998). The distribution and migration of nitrate compounds in the BSG AOC are most likely controlled by dilution and dispersion. There are no ongoing potential primary sources of anthropogenic nitrate, and the plumes are the result of past releases that have subsequently developed to their present size through dispersion and dilution.

6.3 Health Effects Associated with Nitrate

Elevated nitrate levels in drinking water are often caused in many communities due to groundwater contamination from animal waste run-off from dairies and feedlots, excessive use of fertilizers, or seepage of human sewage from septic systems (California Department of Health Services February 2000). Microorganisms in soil, water, and sewage can change the nitrate to nitrite. When ingested, nitrite causes hemoglobin in the blood to change to methemoglobin. This condition is known as methemoglobinemia and is a disorder characterized by the blood stream having a decreased ability to bind oxygen. Infants less than 4 months of age are most at risk of adverse health effects from over exposure to nitrates and nitrites through ingestion of formula diluted with nitrate-contaminated water (Agency for Toxic Substances and Disease Registry December 2015). In addition, the pregnant woman and her fetus might be more sensitive to toxicity from nitrite or nitrates. Decreased oxygen saturation in the blood stream can create cyanosis, which is typically recognized as a bluish tint in skin and fingertips. Healthy children and adults are more tolerant to elevated nitrate and nitrite levels in water. Tainted water can be effectively treated by using distillation or filtration techniques. Boiling is not effective because evaporation increases the nitrate/nitrite concentrations.

6.4 Potential Receptors of Groundwater Contamination

There are no potable production wells within the BSG AOC or located in the near downgradient vicinity. Much further west, production wells completed in the Regional Aquifer of the Albuquerque Basin are the only potential exposure points for elevated nitrate in groundwater to reach human receptors. The production wells are operated by KAFB, VA, and ABCWUA and located approximately 9 to 12 miles to the west-northwest of the BSG AOC. Another potential downgradient receptor for the nitrate plume is Coyote Springs, approximately 3 miles west of the BSG AOC. Numerical simulations (SNL/NM May 2005) predict nitrate concentrations in groundwater would decrease to below the EPA MCL at the Coyote Springs ecological receptor, and to below laboratory MDLs in the Regional Aquifer through dispersion and dilution as the nitrate-impacted groundwater moves into the more hydraulically conductive alluvial-fan and Ancestral Rio Grande deposits west of Coyote Springs. The numerical simulations also predict that groundwater travel times exceed 600 years from the BSG AOC to the ABCWUA, VA, and KAFB production well fields.

The BSG AOC is surrounded by wild lands with extensive habitat for wildlife. Nitrate- impacted groundwater ranges from 170 to 330 ft bgs. The only intermittent spring in the immediate area, the Burn Site Spring, is located upgradient and upslope of the testing facilities at a limestone outcrop. No flow has been observed at this spring since 2007. There are no wetlands at the site and the nearest downgradient wetlands occur at Coyote Springs over three miles west of the nitrate-impacted water at CYN-MW13. Historical data show that Coyote Springs has not been impacted by nitrate. The NPN concentration from the March 2021 sample from Coyote Springs was 0.248 mg/L (SNL/NM June 2022). Therefore, there are no significant ecological or biological receptors of concern to the nitrate-impacted groundwater in the BSG AOC.

6.5 Summary of the Conceptual Site Model

The CSM is summarized with these principal findings:

- Nitrate is the COC for groundwater being addressed within this CCM/CME.
- The elevated nitrate concentrations are primarily derived from past waste management practices during explosives testing and possibly some contribution from natural sources.
- Nitrate concentrations are not expected to significantly decrease as a result of natural groundwater transport mechanisms (advection, dispersion, and diffusion).
- Nitrate concentrations exceed the EPA MCL in two isolated steady-state (stable) nitrate plumes.
- No potable production wells are screened in nitrate-impacted groundwater.
- There is no threat to human health and the environment.

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7. CORRECTIVE MEASURES EVALUATION

The CME process consists of:

- Conducting remedial technology identification and screening (Section 7.1),
- Identifying and describing remedial alternatives (Section 7.2),
- Evaluating the remedial alternatives (Section 7.3),
- Selecting a preferred remedial alternative (Section 7.4),
- Developing remedial alternative design criteria (Section 7.5), and
- Presenting an outline and schedule for the Corrective Measures Implementation Plan (Section 7.6).

Remedial objectives can consist of media-specific or area-specific goals for protecting human health and the environment. They address COCs, media of concern, potential exposure pathways, and preliminary cleanup standards. While the Consent Order (NMED April 2004) only specifies contaminant concentrations, remedial objectives for protecting human receptors should also consider an exposure route, rather than contaminant concentrations alone, because protectiveness may be achieved by controlling or eliminating exposure as well as by reducing contaminant concentrations.

For the BSG AOC, four remedial objectives have been identified:

1. Preventing human ingestion or direct contact with groundwater containing nitrate above the EPA MCL,
2. Restoring groundwater containing nitrate to concentrations below the EPA MCL,
3. Implementing (or maintaining) land use controls at the BSG AOC, and
4. Preventing further releases of contaminants to the subsurface.

7.1 Remedial Technology Identification and Screening

The technology identification and screening process identifies potential remedial approaches to be considered for implementation in the BSG AOC. The following remedial technologies were initially considered to address elevated nitrate at the BSG AOC in the first CME Work Plan (SNL/NM June 2004b) and the second CME Work Plan (SNL/NM April 2008b):

- Groundwater monitoring.
- *In situ* bioremediation.
- MNA.
- Monolithic confinement.
- Permeable reactive barriers.
- Phytoremediation.
- Groundwater extraction and treatment.

The initial screening of technologies performed in the two CME Work Plans removed the following technologies from consideration:

- Monolithic confinement.
- Permeable reactive barriers.
- Phytoremediation.

These technologies were screened out because: (1) construction of deep mechanical structures in well-indurated metamorphic lithologies would be technically difficult, and/or (2) they are only applicable to relatively shallow groundwater conditions.

The remedial technologies that were retained in the CME Work Plans technology screening were:

- Groundwater monitoring (long-term monitoring).
- MNA.
- Groundwater extraction and treatment.
- *In situ* bioremediation.

The second CME Work Plan (SNL/NM April 2008b) was approved by the NMED HWB in August 2011 (NMED August 2011). Since then, a significant amount of information has been gathered at the BSG AOC. Several additional monitoring wells have been installed resulting in a more refined understanding of the concentrations and extent of nitrate and improving the CSM. Also, a 24-hour pump test showed extensive compartmentalization of the fractured bedrock aquifer system. Hydraulic conductivities are low at the BSG AOC where the two nitrate plumes are estimated to have a combined area of 41 acres. The recent treatability study conducted at the TA-V AOC evaluated the practicality of using *in situ* bioremediation to reduce nitrate concentrations where nitrate exceeded the EPA MCL in a 1.4-acre plume. Due to low hydraulic conductivities, the TA-V pilot test was not successful because the radius of influence surrounding the injection well was negligible. Using *in situ* bioremediation at the BSG AOC is considered unrealistic and is not carried forward as a viable technology.

Three remedial alternatives for nitrate in groundwater at the BSG AOC were identified during a May 2021 virtual meeting held by technical staff members from SNL/NM, DOE/NNSA, and the NMED HWB:

1. Long-Term Monitoring,
2. MNA, and
3. Groundwater Extraction, Treatment, and Reinjection.

The three remedial alternatives identified are carried forward and are summarized below. Section 7.2 describes the three remedial alternatives in greater detail. Section 7.3 evaluates the alternatives using the criteria specified in the Consent Order.

7.1.1 Long-Term Monitoring

Long-term monitoring consists of the continued evaluation of the concentrations and extent of nitrate throughout the duration of the remedy. This technology requires no removal, treatment, or storage of groundwater other than the minor volumes of purge water generated during monitoring well sampling.

Long-term monitoring is retained as a remedial technology for nitrate in the BSG AOC groundwater and is developed into Remedial Alternative 1 in Section 7.2.1.

7.1.2 Monitored Natural Attenuation

MNA relies on natural processes to decrease concentrations of contaminants in soil and groundwater. These processes may include denitrification (microbial destruction), advection, sorption, dispersion, dilution, and certain chemical reactions. The concentrations and extent of contaminants are monitored throughout the duration of the remedy. This technology requires no removal, treatment, or storage of groundwater other than the minor volumes of purge water generated during monitoring well sampling.

MNA is retained as a remedial technology for nitrate in the BSG AOC groundwater and is developed into Remedial Alternative 2 in Section 7.2.2.

7.1.3 Groundwater Extraction, Treatment, and Reinjection

Groundwater can be pumped to the ground surface and treated to remove contaminants. The remedial system can consist of extraction wells to remove contaminated groundwater for *ex situ* treatment and subsequent reinjection of the treated water into upgradient wells. The most common *ex situ* treatment technology used to remove nitrate from extracted groundwater is sorption onto ion-exchange resin.

Groundwater extraction, treatment, and reinjection is retained as a remedial technology for nitrate in the BSG AOC groundwater and is developed into Remedial Alternative 3 in Section 7.2.3.

7.2 Description of Remedial Alternatives

The following sections describe the scope, conceptual design, and estimated costs of each remedial alternative.

7.2.1 Alternative 1: Long-Term Monitoring

The objective of the Long-Term Monitoring Alternative is to measure the concentrations and extent of nitrate and prevent exposure.

Preparatory Activities

The preparatory activities include:

- Obtaining concurrence on the preferred remedy by the NMED HWB via a Decision for Final Remedy.

- Preparing a Corrective Measures Implementation Plan. This would include a schedule for remedy implementation.
- Preparing a Contingency Plan that identifies measures that would be taken if the remedy does not proceed as anticipated.
- Preparing a Land Use Controls Implementation Plan to define any institutional or engineered controls needed. A description of land use controls is presented in Appendix J.

Implementation

As shown in Table 7-1, water levels would be measured quarterly at 17 monitoring wells in the BSG AOC during remedy implementation. Fourteen monitoring wells would be sampled annually for nitrate. The number of monitoring wells to be measured and sampled are consistent with the current AGMR monitoring protocol (SNL/NM June 2022). Nitrate would be the sole analyte required for long-term monitoring of the fractured bedrock aquifer system. Additional analytes required for the disposal of purge water and equipment decontamination water to the sanitary sewer system would also function for surveillance monitoring purposes of the fractured bedrock aquifer system. Evaluation of the additional analytes would ensure that no new releases (considered unlikely) are overlooked. Figure 7-1 shows the monitoring well network for the BSG AOC during remedy implementation.

Remedy Performance Monitoring, Maintenance, and Closure

Performance Monitoring Reports (identified in the Consent Order as “Progress Reports”) would be prepared every five years. The reports would summarize the monitoring results for the five-year period and would identify any required modifications or optimization measures for the remedy. A review of land use controls would also be incorporated into this process.

Groundwater monitoring wells would be redeveloped and repaired as needed. The need for replacing a monitoring well where the water level has dropped below the bottom of the screen would be determined on a case-by-case basis, depending on the progress of the remedy, and would take into account the local nitrate concentrations and the need for water level data. Work Plans would be used for obtaining NMED HWB approval of proposed field tasks. Well Installation Work Plans would be submitted to the NMED HWB within one year of a well having a water level becoming unsuitable for sampling purposes.

The public would be kept informed of the progress of the remedy by: (1) semiannual public meetings, (2) discussions in the AGMRs, (3) Five-year Performance Monitoring Reports, and (4) postings on internet websites.

After this alternative is complete and verified, 14 monitoring wells would be plugged and abandoned. The three most downgradient monitoring wells (CYN-MW7, CYN-MW8, and CYN-MW16) would be retained as sentry wells and transferred to the SNL/NM Long-Term Stewardship program.

Table 7-1. Sampling and Water-Level Measurement Requirements for the Long-Term Monitoring Alternative

Well	Water Level Measurement	Groundwater Analysis, NPN	Well Status After Remedy Completion	NPN October 2021 (mg/L)
Burn Site Well	Q		P&A	NS
CYN-MW3	Q		P&A	Dry/NS
CYN-MW4	Q	A	P&A	<0.170
CYN-MW6	Q		P&A	NS
CYN-MW7	Q	A	Sentry Well	2.46
CYN-MW8	Q	A	Sentry Well	5.15
CYN-MW9	Q	A	P&A	**39.8**
CYN-MW10	Q	A	P&A	7.63
CYN-MW11	Q	A	P&A	9.25
CYN-MW12	Q	A	P&A	**16.3**
CYN-MW13	Q	A	P&A	**30.2**
CYN-MW14A	Q	A	P&A	**14.6**
CYN-MW15	Q	A	P&A	**19.6**
CYN-MW16	Q	A	Sentry Well	7.80
CYN-MW17	Q	A	P&A	2.22
CYN-MW18	Q	A	P&A	5.97
CYN-MW19	Q	A	P&A	3.25
Total	17	14		

NOTES:
Bold text denotes exceedance of the EPA MCL for nitrate (10 mg/L).
A = Annual.
CYN = Canyons (monitoring well designation only).
EPA = U.S. Environmental Protection Agency.
MCL = Maximum Contaminant Level.
mg/L = Milligrams per liter.
MW = Monitoring well (monitoring well designation only).
NPN = Nitrate plus nitrite (as nitrogen).
NS = Not sampled.
P&A = Plugging and abandonment.
Q = Quarterly.

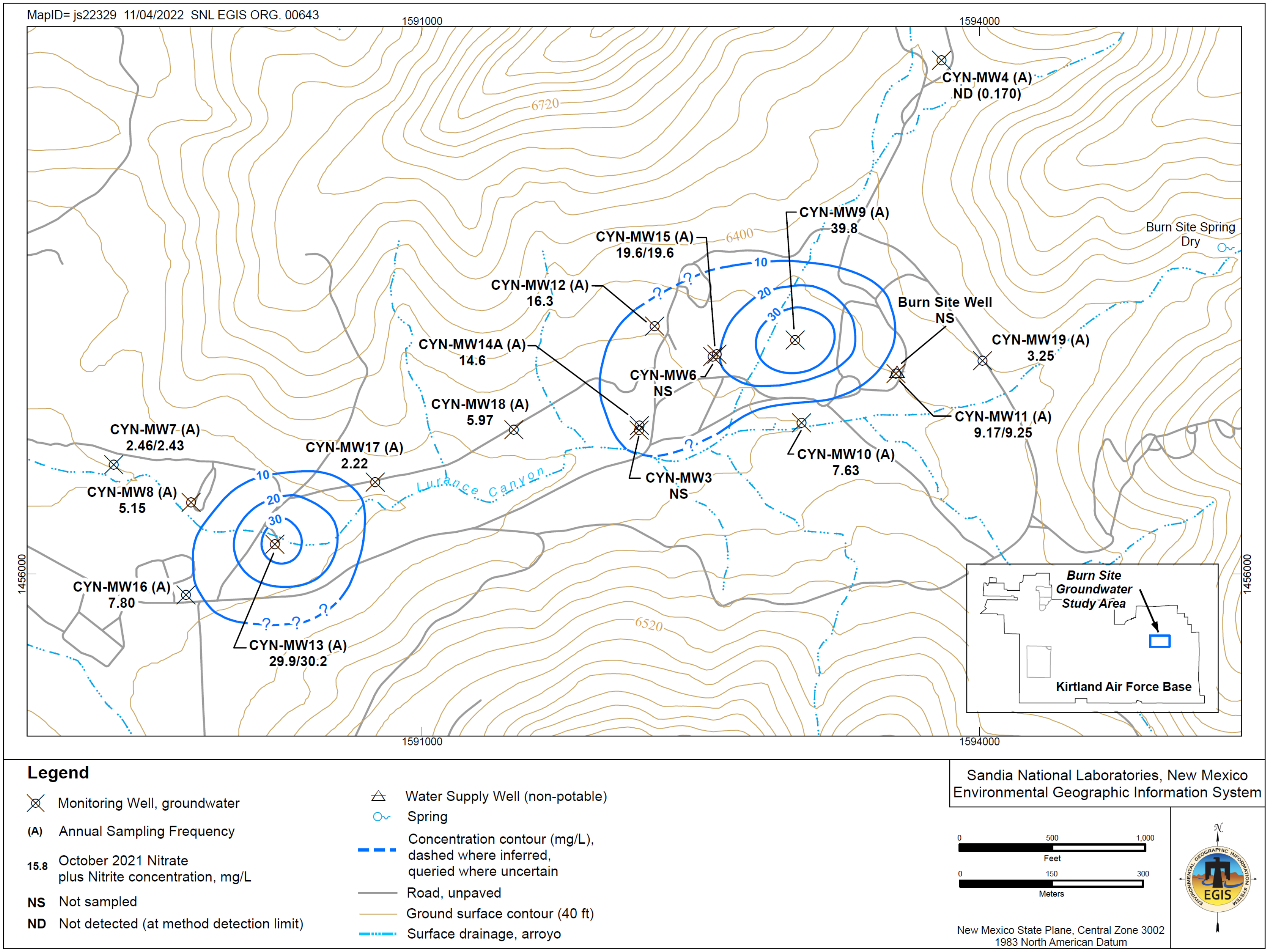

Figure 7-1. Conceptual Design for Alternative 1: Monitoring Wells for the Long-Term Monitoring Alternative

Land Use Controls

Land use controls to mitigate potential exposure to contaminated groundwater would be implemented and maintained. Most of these controls are already in place, including maintaining existing SNL/NM site access controls. Land use controls would be reviewed annually and modified, if necessary. The Corrective Measures Implementation Plan would include a Land Use Controls Implementation Plan that would be amended, if site conditions change.

Timeframe

Following NMED HWB issuance of the Decision for Final Remedy, the estimated total timeframe for Alternative 1 is 38 years. This includes:

- 1 year to prepare plans,
- 30 years of remedial sampling and water-level measurements,
- 2 years of post-remediation verification sampling and water-level measurements, and
- 5 years of final reporting efforts and plugging of monitoring wells.

Cost

The estimated total Present Value cost of the Long-Term Monitoring Alternative (in 2022 dollars) is $10,977,650. Task durations for the various tasks and their associated costs are presented in Appendix K. It is assumed that preparation of the Corrective Measures Implementation Plan, Conceptual Design, and Contingency Plan would begin in 2026 following NMED HWB issuance of the Decision for Final Remedy. Costs for field work (remedial sampling and depth to water measurement) would begin in 2027 following NMED HWB approval of the Corrective Measures Implementation Plan. Field work costs incurred before Corrective Measures Implementation Plan approval and after Corrective Measures Implementation Report approval are not presented in Appendix K.

7.2.2 Alternative 2: Monitored Natural Attenuation

The objective of the MNA Alternative is to measure the concentration and extent of nitrate and prevent exposure.

Preparatory Activities

The preparatory activities include:

- Obtaining concurrence on the preferred remedy by the NMED HWB via a Decision for Final Remedy.
- Preparing a Corrective Measures Implementation Plan. This would include a schedule for remedy implementation.
- Preparing a Contingency Plan that identifies measures that would be taken if the remedy does not proceed as anticipated.
- Preparing a Land Use Controls Implementation Plan to define any institutional or engineered controls needed. A description of land use controls is presented in Appendix J.

Implementation

As shown in Table 7-2, water levels would be measured quarterly at 17 monitoring wells in the BSG AOC during remedy implementation. The number of monitoring wells to be measured is consistent with the current AGMR monitoring protocol (SNL/NM June 2022). Eight monitoring wells would be sampled annually for nitrate and biennially (every two years) for the denitrification suite (isotopes, dissolved gases, and total dissolved carbon). These eight monitoring wells are the wells that have had historical detections of NPN above the EPA MCL. Additional analytes required for the disposal of purge water and equipment decontamination water to the sanitary sewer system would also function for surveillance monitoring purposes. Evaluation of the additional analytes would ensure that no new releases (considered unlikely) are overlooked. Figure 7-2 shows the monitoring well network for the BSG AOC during remedy implementation.

Remedy Performance Monitoring, Maintenance, and Closure

Performance Monitoring Reports (identified in the Consent Order as “Progress Reports”) would be prepared every five years. The reports would summarize the monitoring results for the five-year period and would identify any required modifications or optimization measures for the remedy. A review of land use controls would also be incorporated into this process.

Groundwater monitoring wells would be redeveloped and repaired as needed. The need for replacing a monitoring well where the water level has dropped below the bottom of the screen would be determined on a case-by-case basis, depending on the progress of the remedy, and would consider the local nitrate concentrations and the need for water level data. Work Plans would be used for obtaining NMED HWB approval of proposed field tasks. Well Installation Work Plans would be submitted to the NMED HWB within one year of a well having a water level becoming unsuitable for sampling purposes.

The public would be kept informed of the progress of the remedy by: (1) semiannual public meetings, (2) discussions in the AGMRs, (3) Five-year Performance Monitoring Reports, and (4) postings on internet websites.

After this alternative is complete and verified, 14 monitoring wells would be plugged and abandoned. Three downgradient monitoring wells (CYN-MW7, CYN-MW8, and CYN-MW16) would be retained as sentry wells and transferred to the SNL/NM Long-Term Stewardship program.

Land Use Controls

Land use controls to mitigate potential exposure to contaminated groundwater would be implemented and maintained. Most of these controls are already in place, including maintaining existing SNL/NM site access controls. Land use controls would be reviewed annually and modified if necessary. The Corrective Measures Implementation Plan would include a Land Use Controls Implementation Plan that would be amended if site conditions change.

Timeframe

Following NMED HWB issuance of the Decision for Final Remedy, the estimated total timeframe for Alternative 2 is 38 years. This includes:

- 1 year to prepare plans,
- 30 years of remedial sampling and water-level measurements,

Table 7-2. Sampling and Water-Level Measurement Requirements for the Monitored Natural Attenuation Alternative

Well	Water Level Measurement	Groundwater Analysis, NPN	Groundwater Analysis, Denitrification Suite	Well Status After Remedy Completion	NPN, mg/L, October 2021
Burn Site Well	Q			P&A	NS
CYN-MW3	Q			P&A	Dry/NS
CYN-MW4	Q			P&A	<0.170
CYN-MW6	Q			P&A	NS
CYN-MW7	Q	A	B	Sentry Well	2.46
CYN-MW8	Q	A	B	Sentry Well	5.15
CYN-MW9	Q	A	B	P&A	**39.8**
CYN-MW10	Q			P&A	7.63
CYN-MW11	Q			P&A	9.25
CYN-MW12	Q	A	B	P&A	**16.3**
CYN-MW13	Q	A	B	P&A	**30.2**
CYN-MW14A	Q	A	B	P&A	**14.6**
CYN-MW15	Q	A	B	P&A	**19.6**
CYN-MW16	Q	A	B	Sentry Well	7.80
CYN-MW17	Q			P&A	2.22
CYN-MW18	Q			P&A	5.97
CYN-MW19	Q			P&A	3.25
Total	17	8	8		

NOTES:

Bold text denotes exceedance of the EPA MCL for nitrate (10 mg/L).

A = Annual.
B = Biennial.
CYN = Canyons (monitoring well designation only).
EPA = U.S. Environmental Protection Agency.
MCL = Maximum contaminant Level.
mg/L = Milligrams per liter.
MW = Monitoring well (monitoring well designation only).
NPN = Nitrate plus nitrite (as nitrogen).
NS = Not sampled.
P&A = Plugging and abandonment.
Q = Quarterly.

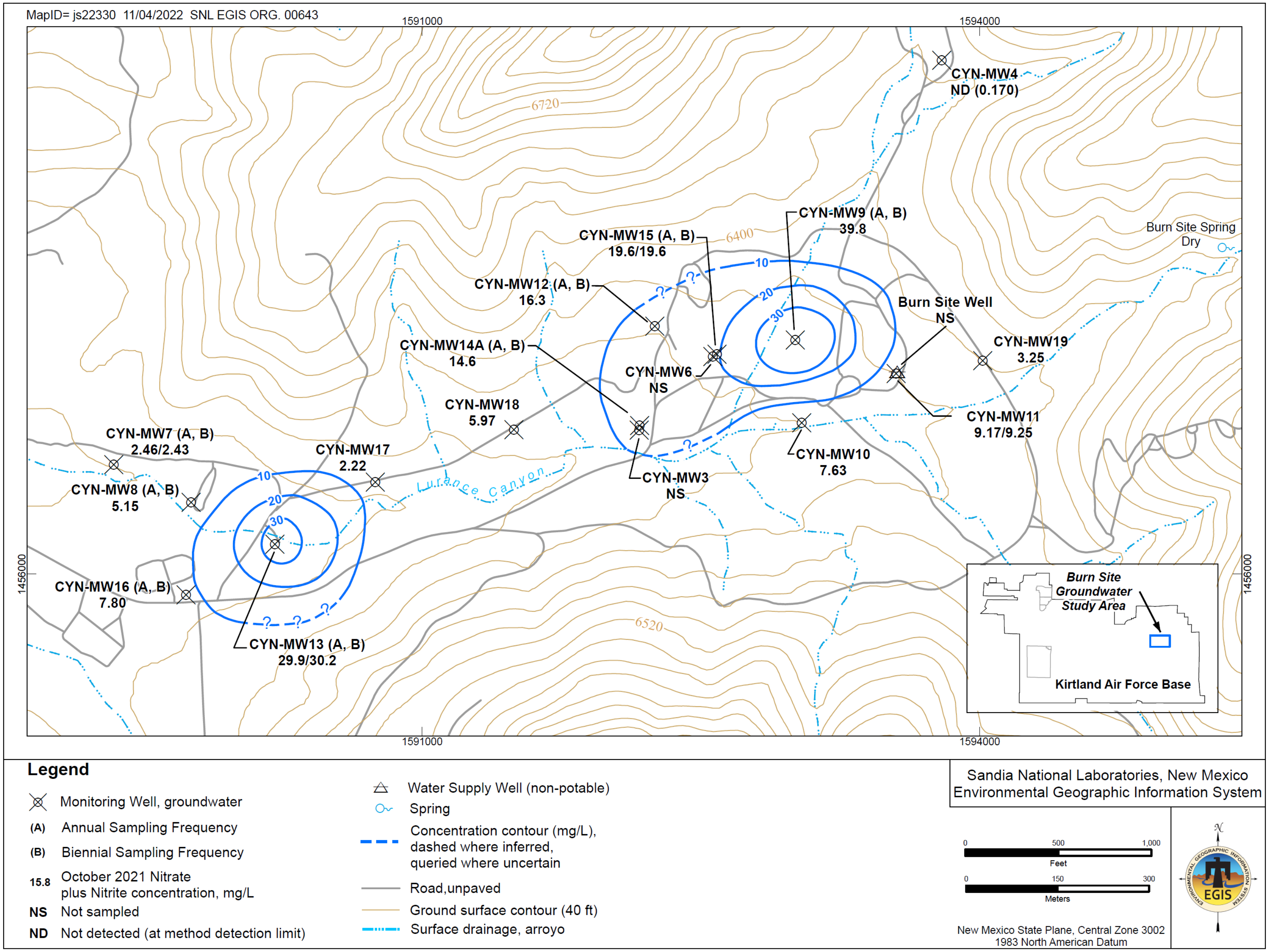

Figure 7-2. Conceptual Design for Alternative 2: Monitoring Wells for the Monitored Natural Attenuation Alternative

- 2 years of post-remediation verification sampling and water-level measurements, and
- 5 years of final reporting efforts and plugging and abandonment (P&A) of monitoring wells.

Cost

The estimated total Present Value cost of the MNA Alternative (in 2022 dollars) is $7,683,612. Task durations for the various tasks and their associated costs are presented in Appendix K. It is assumed that preparation of the Corrective Measures Implementation Plan, Conceptual Design, and Contingency Plan would begin in 2026 following NMED HWB issuance of the Decision for Final Remedy. Costs for field work (remedial sampling and depth to water measurement) would begin in 2027 following NMED HWB approval of the Corrective Measures Implementation Plan. Field work costs incurred before Corrective Measures Implementation Plan approval and after Corrective Measures Implementation Report approval are not presented in Appendix K.

7.2.3 Alternative 3: Groundwater Extraction, Treatment, and Reinjection

The objective of Alternative 3 is to remediate all BSG AOC groundwater with a nitrate concentration exceeding the EPA MCL. This would be accomplished by installing groundwater extraction wells, nitrate treatment systems, treated-water reinjection wells, hydraulic communication test wells, and constructing infrastructure (piping and electrical networks). Separate systems would be installed in the eastern and western nitrate plumes to create two groundwater recirculation cells.

Preparatory Activities

The preparatory activities include:

- Obtaining concurrence on the preferred remedy by the NMED HWB via a Decision for Final Remedy.
- Preparing a Corrective Measures Implementation Plan. This would include a schedule for remedy implementation, a Contingency Plan that identifies measures that would be taken if the remedy does not proceed as anticipated, and a Land Use Controls Implementation Plan to define any institutional or engineered controls needed. A description of land use controls is presented in Appendix J.
- Obtaining a permit from the NMED Ground Water Quality Bureau to allow discharge of treated water into reinjection wells.

Implementation

As shown in Table 7-3, water levels would be measured quarterly at 17 monitoring wells in the BSG AOC during remedy implementation. The number of monitoring wells to be measured is consistent with the current AGMR monitoring protocol (SNL/NM June 2022). Eight monitoring wells would be sampled annually for nitrate. These eight wells are the wells that have had historical detections of NPN above the EPA MCL. Groundwater samples would be collected quarterly from the 12 extraction wells. Additional analytes required for the disposal of purge water and equipment decontamination water to the sanitary sewer system would also function for surveillance monitoring purposes. Evaluation of the additional analytes would ensure that no new releases (considered unlikely) are overlooked.

Table 7-3. Sampling and Water Level Measurement Requirements for the Groundwater Extraction, Treatment, and Reinjection Alternative

Well	Water Level Measurement	Groundwater Analysis, NPN	Well Status After Remedy Completion	NPN October 2021 (mg/L)
Burn Site Well	Q		P&A	NS
CYN-MW3	Q		P&A	Dry/NS
CYN-MW4	Q		P&A	<0.170
CYN-MW6	Q		P&A	NS
CYN-MW7	Q	A	Sentry Well	2.46
CYN-MW8	Q	A	Sentry Well	5.15
CYN-MW9	Q	A	P&A	**39.8**
CYN-MW10	Q		P&A	7.63
CYN-MW11	Q		P&A	9.25
CYN-MW12	Q	A	P&A	**16.3**
CYN-MW13	Q	A	P&A	**30.2**
CYN-MW14A	Q	A	P&A	**14.6**
CYN-MW15	Q	A	P&A	**19.6**
CYN-MW16	Q	A	Sentry Well	7.80
CYN-MW17	Q		P&A	2.22
CYN-MW18	Q		P&A	5.97
CYN-MW19	Q		P&A	3.25
CYN-EXT-01 through CYN-EXT-12	Auto	Q	P&A	n.a.
CYN-REI-01 through CYN-REI-12	Auto		P&A	n.a.

NOTES:

Bold text denotes exceedance of the EPA MCL for nitrate (10 mg/L).

Sampling of monitoring wells within the two remediation areas and all extraction wells for nitrate as NPN would initially be quarterly and transitioned to semiannual sampling after two years.

Auto = Automatic data logging.
n.a. = Not applicable.
A = Annual.
CYN = Canyons (monitoring well designation only).
EPA = U.S. Environmental Protection Agency.
EXT = Extraction.
MCL = Maximum Contaminant Level.
mg/L = Milligrams per liter.
MW = Monitoring well (monitoring well designation only).
NPN = Nitrate plus nitrite (as nitrogen).
NS = Not sampled.
P&A = Plugging and abandonment.
REI = Reinjection.
Q = Quarterly.

Twelve groundwater extraction wells would be required to capture all groundwater in the two nitrate plumes in the BSG AOC with a nitrate concentration exceeding the EPA MCL. Six extraction wells would be located downgradient of each nitrate plume. Twelve reinjection wells for treated groundwater would be installed. Six reinjection wells would be located upgradient of each nitrate plume. This would create two recirculation cells within the fractured bedrock aquifer system to flush nitrate from the groundwater. The wells would be completed to approximately 250 ft bgs and intercept productive fractures in the fractured bedrock aquifer system. Prior to full remedy implementation, four hydraulic communication test wells (two wells for each nitrate plume) would be installed, and hydraulic communication evaluations performed to support the optimal locations of the extraction and reinjection wells.

Groundwater from the extraction wells would be conveyed to two treatment facilities (one for each nitrate plume) via a network of buried double-contained piping (approximately 0.6 miles in total length). The extracted water would be treated with strong base anion ion-exchange resin to reduce nitrate concentrations to below the 10 mg/L EPA MCL. The total length of the two treated-water conveyances to the reinjection wells would be approximately 0.5 miles. Spent ion-exchange resin would be regenerated offsite.

Groundwater travel times and flow paths for this alternative were simulated using the numerical models MODFLOW and MODPATH, with Groundwater Vistas pre/post processing (Environmental Simulations, Inc. 2022):

- The model domain included the entire BSG AOC and was comprised of approximately 20,000 finite difference cells.
- The model was calibrated to October 2021 groundwater elevations using constant-head boundary conditions under steady-state conditions.
- Hydraulic conductivity values obtained from slug and hydraulic tests were interpolated across the model domain using a kriging algorithm. Porosity was assigned a value of 0.015.
- Groundwater flow paths and velocities were predicted by inserting virtual particles into the reinjection wells and conducting MODPATH simulations.
- Individual extraction well yields were estimated to vary between 1 to 1.25 gpm but are dependent on lateral variability in hydraulic conductivity and saturated thickness.
- The total extraction rate is estimated to be approximately 7.5 gpm for each of the eastern and western recirculation cells (15 gpm total).
- For the eastern nitrate plume, the modeled time for one particle of water (one pore volume) to travel between the reinjection and extraction wells was 2,450 days (approximately 6.7 years). For the western nitrate plume, the predicted time was 600 days (approximately 1.6 years).
- Based upon the standard industry practice of using three pore volumes to flush contaminants such as nitrate that do not sorb to the rock matrix, the eastern nitrate plume would require approximately 20 years of active extraction and reinjection. For the western nitrate plume, approximately 5 years would be required.
- The extracted groundwater volumes for the eastern and western nitrate plumes are estimated to be 98,550,000 and 19,710,000 gallons, respectively. The total estimated volume is 118,260,000 gallons.

Figure 7-3 depicts the conceptual design for the BSG AOC. Figures 7-4 and 7-5 are enlargements for the eastern and western nitrate plumes, respectively. The three figures show the modeled flow paths within the two groundwater recirculation cells. Appendix L provides additional details on the conceptual design. The cost-estimating worksheets in Appendix K use assumed durations of active extraction/reinjection for the eastern nitrate plume and the western nitrate plume of 20 and 5 years, respectively.

Remedy Performance Monitoring, Maintenance, and Closure

Performance Monitoring Reports (identified in the Consent Order as “Progress Reports”) would be prepared every five years. The reports would summarize the monitoring results for the five-year period and would identify any required modifications or optimization measures for the remedy. A review of land use controls would also be incorporated into this process.

Groundwater monitoring wells would be redeveloped and repaired as needed. The need for replacing a monitoring well due to damage or declining water level would be determined on a case-by-case basis, depending on the progress of the remedy, and would consider the local nitrate concentrations and the need for water level data. Work Plans would be used for obtaining NMED HWB approval of proposed field tasks. Well Installation Work Plans would be submitted to NMED HWB within one year of a well having a water level becoming unsuitable for sampling purposes.

Sampling of monitoring wells within the two remediation areas and all extraction wells for nitrate as NPN would initially be quarterly and transitioned to semiannual sampling after two years. Electronic logging of water levels would be implemented in selected monitoring and extraction wells.

The groundwater treatment systems would be sampled at required points, (influent and effluent) of treatment prior to discharge in compliance with the discharge permit. For costing purposes, it is assumed that groundwater samples would be collected monthly at these points during system operation and analyzed for NPN. Purge water samples would also be analyzed for VOCs, metals, radionuclides, alkalinity, anions, and petroleum hydrocarbons.

Quarterly post-remediation verification monitoring would be performed for two years after the cleanup standard is reached to detect any rebound (increase) of nitrate concentrations in groundwater.

For waste management purposes, groundwater from each monitoring well would be sampled annually for constituents required under the sanitary sewer discharge permit that is currently used for purge water and equipment decontamination water disposal.

The public would be kept informed of the progress of the remedy by: (1) semiannual public meetings, (2) discussions in the AGMRs, (3) the Five-year Performance Monitoring Reports, and (4) postings on internet websites.

After remediation is complete and verified, all the extraction and injection wells and all but three of monitoring wells would be plugged and abandoned. These three monitoring wells (CYN-MW7, CYN-MW8, and CYN-MW16) would be categorized as sentry wells.

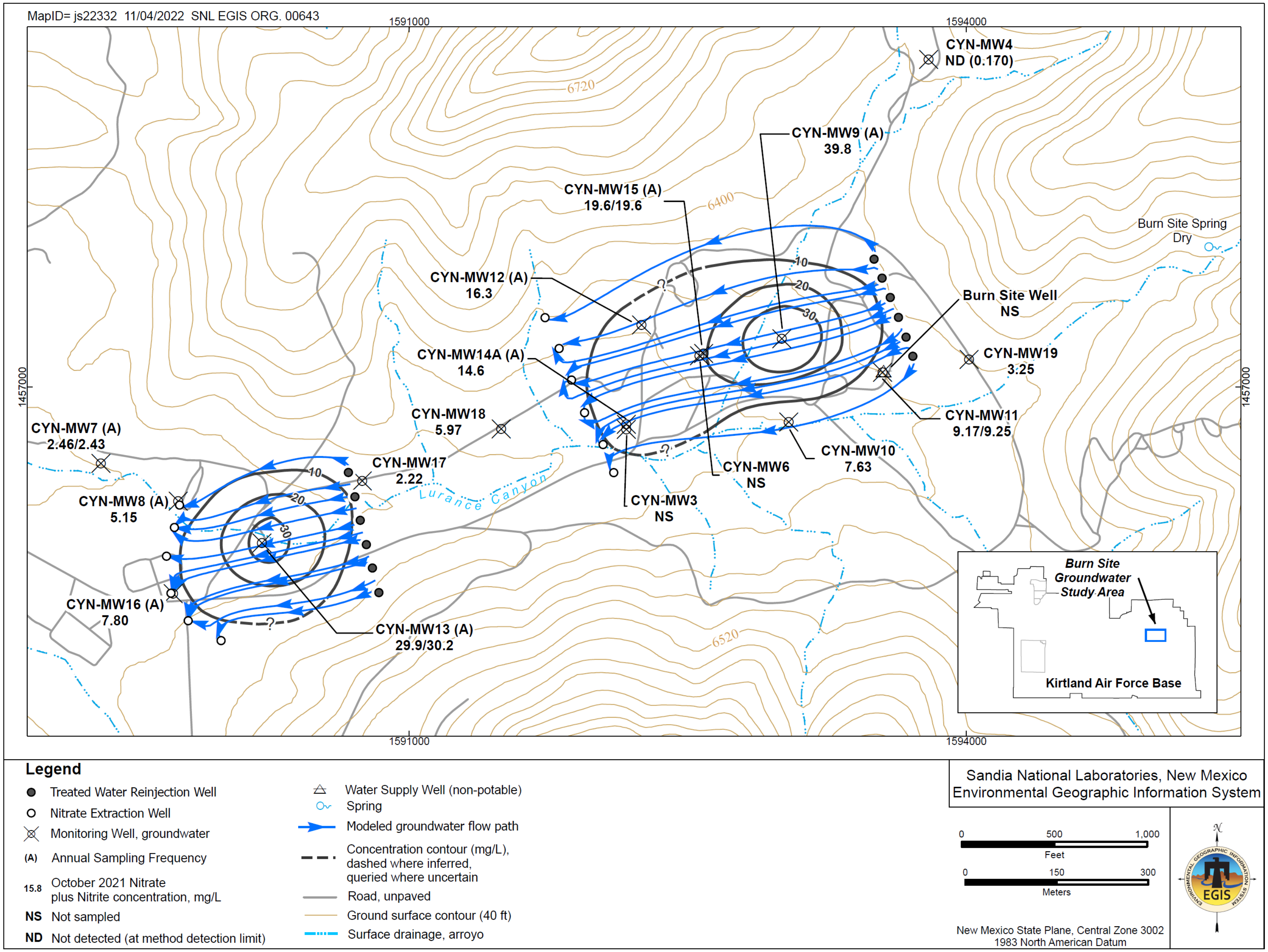

Figure 7-3. Conceptual Design for Alternative 3 (Groundwater Extraction, Treatment, and Reinjection) at the BSG AOC

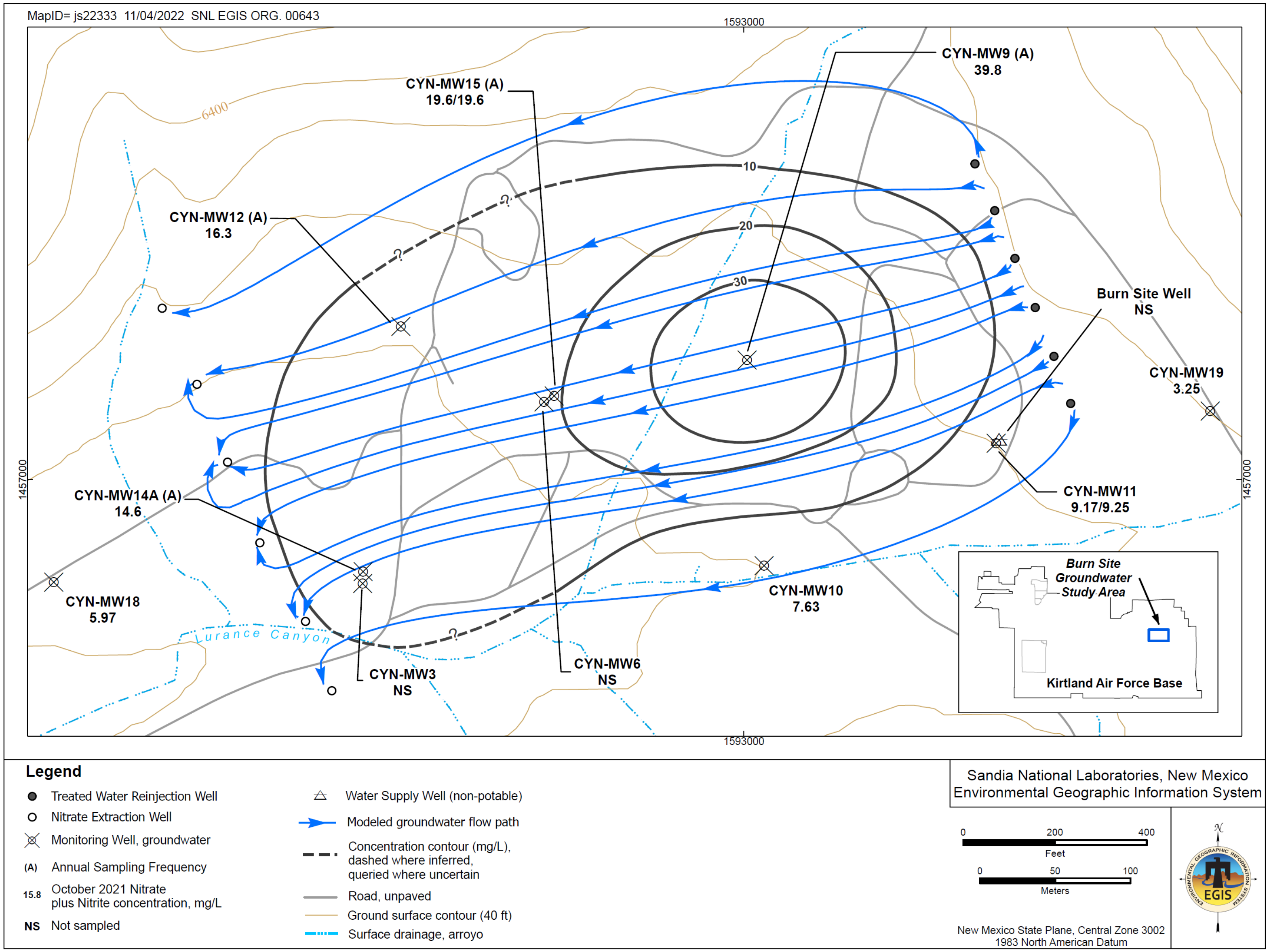

Figure 7-4. Conceptual Design for Alternative 3 (Groundwater Extraction, Treatment, and Reinjection) at the Eastern Nitrate Plume in the BSG AOC

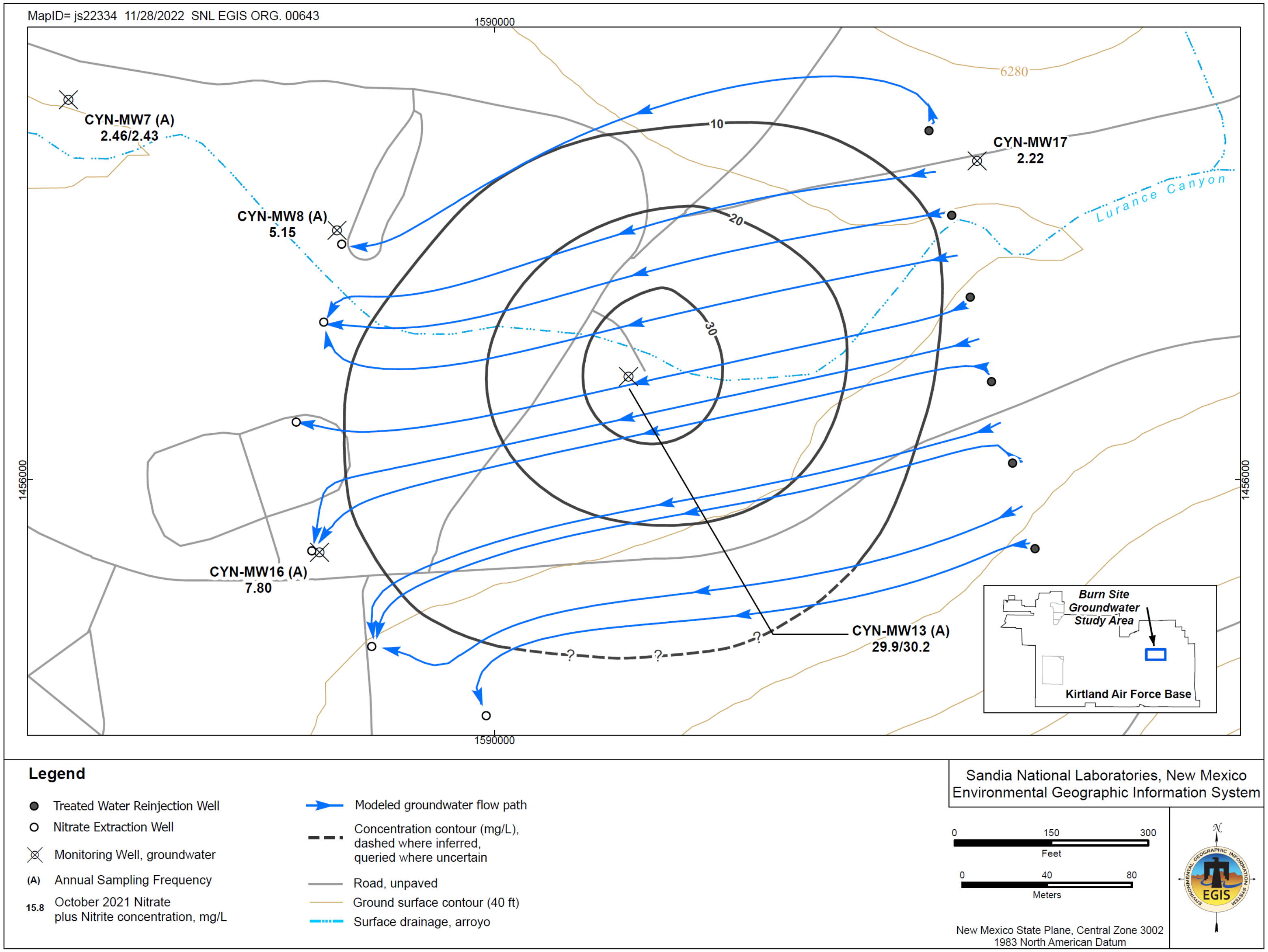

Figure 7-5. Conceptual Design for Alternative 3 (Groundwater Extraction, Treatment, and Reinjection) at the Western Nitrate Plume in the BSG AOC

Land Use Controls

Land use controls to mitigate potential exposure to contaminated groundwater would be implemented and maintained. Most of these controls are already in place, including maintaining existing SNL/NM site access controls. Land use controls would be reviewed annually and modified, if necessary. The Corrective Measures Implementation Plan would include a Land Use Controls Implementation Plan that would be amended, if site conditions change.

Timeframe

Following NMED HWB issuance of the Decision for Final Remedy, the estimated total timeframe for Alternative 3 is 31 years. This includes:

- 4 years to design the remedy, prepare plans, obtain permits, install hydraulic communication test, extraction, and reinjection wells, and construct the pipelines and treatment facilities,
- 20 years of active groundwater extraction, treatment, and reinjection, including remedial sampling and water-level measurements,
- 2 years of post-remediation verification sampling and water-level measurements, and
- 5 years of final reporting efforts, P&A of all but three wells, and removal of infrastructure.

Cost

The estimated total Present Value cost of the Groundwater Extraction, Treatment, and Reinjection Alternative (in 2022 dollars) is $26,793,676. Task durations for the various tasks and their associated costs are presented in Appendix K. It is assumed that preparation of the Corrective Measures Implementation Plan, Conceptual Design, and Contingency Plan begin in 2026 following NMED HWB issuance of the Decision for Final Remedy. Costs for field work begin in 2027 following NMED HWB approval of the Corrective Measures Implementation Plan. Field work costs incurred before Corrective Measures Implementation Plan approval and after Corrective Measures Implementation Report approval are not presented in Appendix K.

7.3 Evaluation of Remedial Alternatives

This CCM/CME Report evaluates the three remedial alternatives using the four threshold criteria and the five balancing evaluation criteria prescribed by Section VII.C.3 of the Consent Order. Table 7- 4 summarizes the evaluation.

Table 7-4. Evaluation Summary for the BSG AOC Remedial Alternatives

	Alternative 1: Long-Term Monitoring	Alternative 2: Monitored Natural Attenuation	Alternative 3: Groundwater Extraction, Treatment, and Reinjection
Threshold Criteria			
1. Protective of Human Health and the Environment	Protective. There is no potential for human or ecological receptors to be exposed to nitrate at concentrations of concern.	Protective. There is no potential for human or ecological receptors to be exposed to nitrate at concentrations of concern.	Protective. There is no potential for human or ecological receptors to be exposed to nitrate at concentrations of concern.
2. Attain Media Cleanup Standard	The alternative is expected to achieve remedial objectives over time by dispersion and dilution.	The alternative is expected to achieve remedial objectives over time by dispersion and dilution, and possibly some degree of denitrification.	The EPA MCL cleanup standard would be attained by extracting all nitrate-contaminated groundwater exceeding the EPA MCL.
3. Control the Source of Releases	The original SNL/NM primary source of nitrate contamination (explosives testing and wastewater discharges involving ammonium nitrate slurry) has been eliminated. Such activities have not occurred since 1975.	The original SNL/NM primary source of nitrate contamination (explosives testing and wastewater discharges involving ammonium nitrate slurry) has been eliminated. Such activities have not occurred since 1975.	The original SNL/NM primary source of nitrate contamination (explosives testing and wastewater discharges involving ammonium nitrate slurry) has been eliminated. Such activities have not occurred since 1975.
4. Comply with Standards for Management of Wastes	The alternative would comply with all standards for the management of wastes.	The alternative would comply with all standards for the management of wastes.	The alternative would comply with all standards for the management of wastes.
Balancing Criteria			
1. Long-Term Reliability and Effectiveness	Land use controls would be maintained during the course of the remedy. A Contingency Plan would be developed identifying measures to be taken if the remedy does not proceed as anticipated.	Land use controls would be maintained during the course of the remedy. A Contingency Plan would be developed identifying measures to be taken if the remedy does not proceed as anticipated.	Groundwater extraction coupled with ion-exchange resin treatment is a proven, effective technology for the remediation of nitrate-contaminated groundwater. Reinjection of treated groundwater would decrease the remediation timeframe by increasing groundwater velocities within the recirculation cells.
2. Reduction of Toxicity, Mobility, or Volume	Although Long-Term Monitoring would not reduce the toxicity, mobility, or volume of nitrate, there is no risk to human health or the environment, even if no degradation occurred. No hazardous byproducts would be produced during the remedy implementation. The mass of dissolved nitrate would decline proportionately to the decrease in nitrate concentrations thereby anticipate achieving remedial objectives over time through dispersion and dilution.	Although Monitored Natural Attenuation would not reduce the toxicity, mobility, or volume of nitrate, there is no risk to human health or the environment, even if no degradation occurred. No hazardous byproducts would be produced during the remedy implementation. The mass of dissolved nitrate would decline proportionately to the decrease in nitrate concentrations thereby anticipate achieving remedial objectives over time through dispersion, dilution and possibly some degree of denitrification.	Groundwater extraction and treatment would not reduce the toxicity of nitrate because the nitrate would be transferred to ion-exchange resin. The mobility of nitrate would not be reduced. The volume of nitrate in groundwater would be reduced by transferring it onto ion-exchange resin, which would be regenerated offsite.
3. Short-Term Effectiveness	No risks to human health or the environment have been identified for the BSG AOC stable nitrate plumes. There would be no risk of worker exposure to contaminants during remedy implementation that cannot be easily managed. No additional risks would be incurred.	No risks to human health or the environment have been identified for the BSG AOC stable nitrate plumes. There would be no risk of worker exposure to contaminants during remedy implementation that cannot be easily managed. No additional risks would be incurred.	No risks to human health or the environment have been identified for the BSG AOC stable nitrate plumes. There would be no risk of worker exposure to contaminants during remedy implementation that cannot be easily managed. No additional risks would be incurred.
4. Feasibility	Feasible and easily implemented. The monitoring network is in place. Water levels would be measured in 17 monitoring wells. Water samples would be collected from 14 monitoring wells. The estimated remedial timeframe is 38 years.	Feasible and easily implemented. The monitoring network is in place. Water levels would be measured in 17 monitoring wells. Water samples would be collected from eight monitoring wells. The estimated remedial timeframe is 38 years.	Difficult due to the bedrock aquifer having low hydraulic conductivity that would require the installation of 12 extraction wells, 12 reinjection wells, four hydraulic communication test wells, and approximately 1.1 miles of trenching to bury double-contained pipelines. The total volume of groundwater extracted to remediate the nitrate plume would be over 118 million gallons. The pre-existing infrastructure (buildings and underground utilities) and disruption to facility operations in the BSG AOC would complicate the logistics necessary for effective implementation of this alternative. Water levels would be measured in 41 wells. Water samples would be collected from 20 wells. The estimated remedial timeframe is 31 years. The estimated remedial timeframe is 31 years.
5. Cost	Moderate. The total Present Value cost is approximately $11.0M.	Low. The total Present Value cost is approximately $7.7M.	High. The total Present Value cost is approximately $26.8M.

NOTES:
AOC = Area of concern.
BSG = Burn Site Groundwater.
EPA = U.S. Environmental Protection Agency.
M = Million (dollars).
MCL = Maximum Contaminant Level.
SNL/NM = Sandia National Laboratories, New Mexico.

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7.3.1 Evaluation of Alternative 1: Long-Term Monitoring

Alternative 1 Threshold Criteria

Threshold Criterion 1: Be Protective of Human Health and the Environment

The Long-Term Monitoring Alternative would be protective of human health and the environment because:

- There is no current or projected use of groundwater near the BSG AOC.
- The nearest receptor production well is KAFB-4, located approximately 9 miles from the BSG AOC.
- There is no potential for formation of hazardous degradation products.
- There are no hazards associated with implementation, operation, and maintenance of the remedy that cannot be easily managed.

The Long-Term Monitoring Alternative passes Threshold Criterion 1.

Threshold Criterion 2: Attain Media Cleanup Standard or Alternative, Approved Risk-Based Cleanup Goals

The Long-Term Monitoring Alternative is expected to achieve remedial objectives over time by dispersion and dilution. The timeframe is uncertain and is assumed to be 38 years for costing purposes.

This timeframe is reasonable, considering regulators and facilities should take several factors into account when developing cleanup timeframe(s) for a given facility, where appropriate (EPA 1996):

- Potential risks from exposures to contamination: There is no current or potential for exposure to nitrate at a concentration exceeding the EPA MCL.
- Current and reasonably expected future land and water use(s): The BSG AOC is expected to remain under DOE/NNSA and SNL/NM personnel control for the foreseeable future, and site use is not anticipated to change. There is no current or projected use of groundwater.
- Type, source(s), and extent of contamination: Explosives testing and wastewater discharges associated with ammonium nitrate slurry were last conducted in 1975. The steady-state (stable) nitrate plumes are large in areal extent (41 acres) but restricted to a fractured bedrock aquifer system that has limited production capacity.
- Hydrogeologic characteristics: The low hydraulic conductivity limits the groundwater flow velocity and makes active technologies such as groundwater extraction and treatment extremely difficult.
- Reliability of exposure controls: The area is under DOE/NNSA and SNL/NM personnel control. Land use controls either are in place or easily implemented to prevent exposure.
- Community preferences: To be determined during stakeholder outreach.
- Financial resources of the facility: DOE/NNSA and SNL/NM personnel would request adequate funding from Congress to operate the cleanup until remedial objectives are met.

The Long-Term Monitoring Alternative passes Threshold Criterion 2.

Threshold Criterion 3: Control the Source or Sources of Releases so as to Reduce or Eliminate, to the Extent Practicable, Further Releases of Contaminants that may Pose a Threat to Human Health and the Environment

The original SNL/NM primary sources of the nitrate (explosives testing and wastewater discharges associated with ammonium nitrate slurry) have been eliminated. No such activities have occurred since 1975.

The Long-Term Monitoring Alternative passes Threshold Criterion 3.

Threshold Criterion 4: Comply with Standards for Management of Wastes

The Long-Term Monitoring Alternative would comply with all applicable state and federal regulations regarding waste management.

The Long-Term Monitoring Alternative passes Threshold Criterion 4.

Alternative 1 Balancing Criteria

Balancing Criterion 1: Long-Term Reliability and Effectiveness

Land use controls would be maintained during the course of the remedy. A Contingency Plan would be developed that identifies measures that would be taken if the remedy does not proceed as anticipated.

Balancing Criterion 2: Reduction of Toxicity, Mobility, or Volume

Although the Long-Term Monitoring Alternative would likely not reduce the toxicity, mobility, or volume of nitrate, there is no risk to human health or the environment, even if no degradation occurred. No hazardous byproducts would be produced during the remedy implementation. The mass of dissolved nitrate would decrease proportionately to the decrease in nitrate concentrations thereby anticipate achieving remedial objectives over time through dispersion and dilution.

Balancing Criterion 3: Short-Term Effectiveness

No risks to human health or the environment have been identified for the BSG AOC nitrate plumes. There would be no risk of worker exposure to contaminants during remedy implementation (groundwater sampling) that cannot be easily managed as part of the existing SNL/NM monitoring program. No additional risks would be incurred.

Balancing Criterion 4: Feasibility

The Long-Term Monitoring Alternative is feasible and readily implementable. The monitoring well network is already in place. No issues have been identified related to remedy installation, operation and maintenance, permitting/approvals, availability of necessary equipment, services, and expertise. The alternative can be implemented quickly and easily.

Balancing Criterion 5: Cost

The estimated total Present Value cost of the Long-Term Monitoring Alternative (in 2022 dollars) is $10,977,650. A detailed cost breakdown is presented in Appendix K.

7.3.2 Evaluation of Alternative 2: Monitored Natural Attenuation

Alternative 2 Threshold Criteria

Threshold Criterion 1: Be Protective of Human Health and the Environment

The MNA Alternative would be protective of human health and the environment because:

- There is no current or projected use of groundwater near the BSG AOC.
- The nearest receptor is production well KAFB-4, which is located approximately 9 miles from the BSG AOC along the groundwater flow path.
- There is no potential for formation of hazardous degradation products.
- There are no hazards associated with implementation, operation, and maintenance of the alternative that cannot be easily managed.

The MNA Alternative passes Threshold Criterion 1.

Threshold Criterion 2: Attain Media Cleanup Standard or Alternative, Approved Risk-Based Cleanup Goals

The MNA Alternative is expected to achieve remedial objectives over time by dispersion, dilution, and possibly some degree of denitrification. The timeframe is uncertain and is assumed to be 38 years for costing purposes.

The MNA Alternative passes Threshold Criterion 2.

Threshold Criterion 3: Control the Source or Sources of Releases so as to Reduce or Eliminate, to the Extent Practicable, Further Releases of Contaminants that may Pose a Threat to Human Health and the Environment

The original SNL/NM primary sources of the nitrate (explosives testing and wastewater discharges involving ammonium nitrate slurry) have been eliminated. No such activities have occurred since 1975.

The MNA Alternative passes Threshold Criterion 3.

Threshold Criterion 4: Comply with Standards for Management of Wastes

The Monitored Natural Attenuation Alternative would comply with all applicable state and federal regulations regarding waste management.

The MNA Alternative passes Threshold Criterion 4.

Alternative 2 Balancing Criteria

Balancing Criterion 1: Long-Term Reliability and Effectiveness

Land use controls would be maintained during the remedy. A Contingency Plan would be developed that identifies measures that would be taken if the remedy does not proceed as anticipated.

Balancing Criterion 2: Reduction of Toxicity, Mobility, or Volume

The MNA Alternative might reduce the toxicity, mobility, or volume of nitrate. There is no risk to human health or the environment even if no degradation occurred. No hazardous byproducts would be produced during the remedy implementation. The mass of dissolved nitrate would decline proportionately to the decrease in nitrate concentrations thereby anticipate achieving remedial objectives over time by dispersion, dilution, and possibly some degree of denitrification.

Balancing Criterion 3: Short-Term Effectiveness

No risks to human health or the environment have been identified for the BSG AOC nitrate plumes. There would be no risk of worker exposure to contaminants during remedy implementation that cannot be easily managed as part of the existing SNL/NM monitoring program. No additional risks would be incurred.

Balancing Criterion 4: Feasibility

The MNA Alternative is feasible and readily implementable. The monitoring well network is already in place. No issues have been identified related to remedy installation, operation and maintenance, permitting/approvals, availability of necessary equipment, services, and expertise. The alternative can be implemented quickly and easily.

Balancing Criterion 5: Cost

The estimated total Present Value cost of the MNA Alternative (in 2022 dollars) is $7,683,612. A detailed cost breakdown is presented in Appendix K.

7.3.3 Evaluation of Alternative 3: Groundwater Extraction, Treatment, and Reinjection

Alternative 3 Threshold Criteria

Threshold Criterion 1: Be Protective of Human Health and the Environment

The Groundwater Extraction, Treatment, and Reinjection Alternative would be protective of human health and the environment because:

- There is no current or projected use of groundwater near the BSG AOC.
- The nearest receptor is production well KAFB-4, which is located approximately 9 miles from the BSG AOC.
- There is no potential for formation of hazardous degradation products.
- There are no hazards associated with implementation, operation, and maintenance of the remedy that cannot be easily managed.

The Groundwater Extraction, Treatment, and Reinjection Alternative passes Threshold Criterion 1.

Threshold Criterion 2: Attain Media Cleanup Standard or Alternative, Approved Risk-Based Cleanup Goals

The Groundwater Extraction, Treatment, and Reinjection Alternative would achieve remedial objectives for nitrate by removing (pumping) all groundwater contaminated by nitrate above the EPA MCL. This Alternative has been constructed to achieve this objective within 20 years of initiating groundwater extraction.

The Groundwater Extraction, Treatment, and Reinjection Alternative passes Threshold Criterion 2.

Threshold Criterion 3: Control the Source or Sources of Releases so as to Reduce or Eliminate, to the Extent Practicable, Further Releases of Contaminants that may Pose a Threat to Human Health and the Environment

The original SNL/NM primary sources of the nitrate (explosives testing and wastewater discharges associated with ammonium nitrate slurry) have been eliminated. No such testing or discharges have occurred since 1975.

The Groundwater Extraction, Treatment, and Reinjection Alternative passes Threshold Criterion 3.

Threshold Criterion 4: Comply with Standards for Management of Wastes

The Groundwater Extraction, Treatment, and Reinjection Alternative would comply with all applicable state and federal regulations regarding waste management.

The Groundwater Extraction, Treatment, and Reinjection Alternative passes Threshold Criterion 4.

Alternative 3 Balancing Criteria

Balancing Criterion 1: Long-Term Reliability and Effectiveness

Groundwater extraction is a proven, effective technology for the remediation of nitrate-contaminated groundwater.

Balancing Criterion 2: Reduction of Toxicity, Mobility, or Volume

Groundwater extraction and treatment would not reduce the toxicity of nitrate because the nitrate would be transferred to ion-exchange resin. The mobility of nitrate would not be reduced. The volume of nitrate in groundwater would be reduced by transferring it onto ion-exchange resin, which would require offsite regeneration.

Balancing Criterion 3: Short-Term Effectiveness

No risks to human health or the environment have been identified for the BSG AOC nitrate plumes. There would be no risk of worker exposure to contaminants during remedy implementation that cannot be easily managed as part of the existing SNL/NM monitoring program. No additional risks would be incurred.

Balancing Criterion 4: Feasibility

Implementing a groundwater extraction, treatment, and reinjection remedy would be challenging. Factors specific to the BSG AOC include:

- The installation of 12 extraction wells, 12 reinjection wells, 4 hydraulic communication test wells, and approximately 1.1 miles of double-contained, buried pipeline would be required. Typical groundwater extraction and treatment remedies are effective for remediating high-concentration contaminant source areas or protecting a nearby sensitive receptor. However, such remedies have high capital and operation/maintenance costs due to issues such as biofouling of well casings and the difficulty of reinjecting water into a bedrock aquifer that has low hydraulic conductivities and discontinuous fracture patterns.
- The low hydraulic conductivity and tortuous pathways in the fractured bedrock aquifer system severely limit the yield of extraction wells; sustained pumping may not be possible. The maximum sustainable yield from an individual extraction well at the BSG AOC is estimated at 1.25 gpm or less.
- The pre-existing infrastructure and rugged topography in the BSG AOC would make installation of multiple wells and associated pipelines for extracted and treated water difficult and expensive.
- Removing nitrate from extracted groundwater would generate a large quantity of waste (regeneration brine) to be treated at an offsite facility.

Balancing Criterion 5: Cost

The estimated total Present Value cost of the Groundwater Extraction, Treatment, and Reinjection Alternative (in 2022 dollars) is $26,793,676. A detailed cost breakdown is presented in Appendix K.

7.4 Preferred Remedy

The Long-Term Monitoring Alternative is the preferred remedy for groundwater in the BSG AOC. This alternative meets the threshold criteria and is readily implementable.

Nitrate concentrations in groundwater are low at this site (slightly exceeding the EPA MCL), are inaccessible to onsite receptors, and do not pose a potentially unacceptable risk to offsite receptors. Alternative 1 includes development of a Contingency Plan that would provide mechanisms for changing the remedial approach if the remedy does not proceed as anticipated.

Long-Term Monitoring is the preferred remedy for the BSG AOC, because:

There is No Unacceptable Risk to Receptors and / or Foreseeable Groundwater Beneficial Use

- There is no current or anticipated use of groundwater near the BSG AOC. The nearest receptor is production well KAFB-4, which is approximately 9 miles from the BSG AOC. Thus, there is no foreseeable risk to human health or threat to beneficial use of groundwater.

- The two steady-state (stable) nitrate plumes are in a remote part of KAFB where public access is restricted.
- Groundwater in the fractured bedrock aquifer system is relatively deep. The depth to saturated bedrock fractures with NPN concentrations exceeding the EPA MCL ranges from approximately 180 to 380 ft bgs. There is no potential for direct human contact or exposure to groundwater contaminants near the BSG AOC.

There Are No Remaining Active Sources of Contaminant Release at the BSG AOC

- Explosive testing and wastewater discharges associated with ammonium nitrate slurry have not been conducted at the BSG AOC since 1975.
- The relative stable or slightly decreasing or increasing concentrations of nitrate in groundwater for the last 20 years indicates that no significant amounts of residual nitrate remaining in the alluvium or shallow bedrock would result in future impacts to groundwater at higher concentrations than are now present.

BSG AOC Contaminant Concentrations Are Relatively Low

- Nitrate concentrations only slightly exceed the EPA MCL. The nitrate plumes at the BSG AOC are located in a remote eastern part of KAFB.
- Nitrate concentrations in groundwater are slightly decreasing to slightly increasing.

Attenuation is Projected to Occur within a Reasonable Timeframe

- Natural processes might reduce concentrations to below the EPA MCL in a reasonable timeframe.

Land Use Controls can be Controlled, Maintained, or Implemented

- DOE/NNSA and SNL/NM personnel are expected to retain stewardship of the site for the foreseeable future.
- If land use changes at the BSG AOC, or transfer of the property from DOE/NNSA and SNL/NM personnel control were to occur in the future, the remedy would be reevaluated to ensure the protectiveness of the remedy.
- Existing or readily implementable land use controls would prevent any exposure to contaminants. These controls would include site access controls and production well drilling restrictions.

The Remedy is Readily Implementable

- A Long-Term Monitoring remedy is easily implemented. The monitoring well network is already in place.
- A Long-Term Monitoring remedy would have few detrimental impacts on ongoing programmatic operations in the area.
- A Long-Term Monitoring remedy minimizes safety risks to field personnel otherwise present during drilling, construction, and operation of more active measures.
- Demonstrating a MNA remedy to be effective might be difficult. Groundwater analyses indicate that denitrification might not be occurring.

- Construction of the Groundwater Extraction, Treatment, and Reinjection remedy would be difficult to implement at the BSG AOC, which is an active testing facility.

Performance Assurance Measures are Included

- The Long-Term Monitoring Alternative would include groundwater monitoring until remedial objectives are achieved.
- A Contingency Plan would include measures to be implemented if the remedy does not proceed as anticipated. The Plan would include topics such as:
  - Groundwater elevations do not remain stable.
  - Nitrate concentrations unexpectedly increase.
- Land use or groundwater use in the area changes such that there is potential exposure to contaminants, or new land use controls are needed.
- Groundwater flow direction or velocity change significantly.
  - Substances that are not currently COCs are detected above EPA MCLs.
  - Regulatory cleanup standards are adjusted (for example, a revision to the EPA MCL for nitrate).

7.5 Remedial Alternative Design Criteria

Design criteria are used to: (a) measure meaningful progress toward achieving remedial objectives, (b) show that the remedy remains protective to human health and the environment during the lifecycle of the remedy, and (c) verify that the remedy complies with regulatory requirements.

Analysis of performance monitoring data leads to periodic decisions on whether the remedy is performing as expected and whether the remedy would ultimately achieve the remedial objectives.

Design criteria and actions for the Long-Term Monitoring Alternative at the BSG AOC include:

- Measuring and plotting groundwater elevations in the fractured bedrock aquifer system to verify that our understanding of the CSM remains valid.
- Monitoring nitrate concentrations and distribution to verify that the remedy is performing as anticipated.
- Collecting groundwater-monitoring data using consistent sampling and analytical methods in order to support operational decisions for optimizing the monitoring program, and for regulatory compliance.
- Collecting sufficient data to support operational decisions, changes to field procedures, and revisions to the remedial approach (including implementation of the Contingency Plan, if necessary).
- Implementing (or maintaining) land use controls to protect human health and the environment during the remediation timeframe.
- Conducting the remedial action in compliance with applicable regulatory requirements.

These criteria (and corresponding actions) would be used in developing the detailed remedial design that would be included in the Corrective Measures Implementation Plan.

7.6 Corrective Measures Implementation Plan

As stated in the Section VII.D.2 of the Consent Order, the Corrective Measures Implementation Plan would outline the design, construction, operation, maintenance, and performance monitoring for the selected remedy, and a schedule for implementation.

7.6.1 Corrective Measures Implementation Plan Outline

The following is a draft outline of the key components of the Corrective Measures Implementation Plan and includes the required elements listed in the Consent Order. Some of the elements stated in the Consent Order (such as results of pilot tests, construction work plans, and engineering design drawings and specifications) are not included in this outline because they are not applicable to the DOE/NNSA and its M&O contractor for SNL/NM preferred remedy (Long-Term Monitoring) for nitrate.

The proposed outline is:

1. **Introduction**
2. **Background Information**
3. **Description of Selected Final Remedy**
    - 3.1 Remediation System Objectives
    - 3.2 Cleanup Goals
4. **Remedy Implementation**
    - 4.1 Implementation Team Qualifications
    - 4.2 Well Network Description and Specifications
    - 4.3 Operation and Maintenance Plan
    - 4.4 Waste Management Plan
5. **Remedy Performance Monitoring**
    - 5.1 Sampling and Analysis Plan
    - 5.2 Contingency Plan
    - 5.3 Land Use Controls Implementation Plan
6. **Schedule**
    - 6.1 Implementation Schedule
    - 6.2 Reporting Schedule
7. **Appendices**

7.6.2 Estimated Schedule for Initiating Corrective Measures Implementation and Associated Deliverables

Alternatives 1 and 2 are similar in scope. Table 7-5 presents the estimated Corrective Measures Implementation schedule for Alternative 1 - Long-Term Monitoring and Alternative 2 - MNA. Table 7-6 presents the schedule for Alternative 3 - Groundwater Extraction, Treatment, and Reinjection. The schedules include tasks, documents, and milestones. This CCM/CME Report and the Corrective Measures Implementation Plan are identified deliverables and have clearly defined NMED HWB and public review/comment and comment resolution periods as well as the required NMED HWB review and approval steps.

Table 7-5. Preliminary Schedule for Conducting Either the Long-Term Monitoring Alternative or the Monitored Natural Attenuation Alternative at the BSG AOC

Activity	Date	Comments
Submittal of CCM/CME Report to NMED HWB	01/31/2023	Based on Extension Letter
Quarterly Water Level Measurements	Ongoing	In accordance with AGMR protocol
Semiannual Groundwater Sampling	Ongoing	In accordance with AGMR protocol
NMED HWB preparation of Selected Remedy Fact Sheet / Statement of Basis	07/31/2023	Tentative completion date, assumes NMED HWB does not request supplemental information
NMED HWB approval of CCM/CME Report	12/31/2023	Tentative completion date, dependent upon public comments
Public Meeting and Public Hearing process	06/01/2025	Tentative completion date
NMED HWB issues a Decision for Final Remedy	09/01/2025	Tentative completion date
Submittal of CMI Plan to NMED HWB	09/01/2026	Tentative completion date
NMED HWB approval of CMI Plan	12/31/2026	Tentative completion date
Implementation of Corrective Measures	01/01/2027	Tentative start date of remedy – sampling and measuring water levels
Submittal of the first Five-year Performance Monitoring Report	12/31/2032	Tentative completion date
Submittal of second Five-year Performance Monitoring Report	12/31/2037	Tentative completion date
Submittal of third Five-year Performance Monitoring Report	12/31/2042	Tentative completion date
Submittal of fourth Five-year Performance Monitoring Report	12/31/2047	Tentative completion date
Submittal of fifth Five-year Performance Monitoring Report	12/31/2052	Tentative completion date
Submittal of sixth Five-year Performance Monitoring Report	12/31/2057	Tentative completion date
Verification sampling Eastern Plume after 30 years	12/31/2058	Tentative completion date after two years (2057 and 2058) of verification sampling
Submittal of CMI Report	12/31/2059	Tentative completion date
NMED HWB Approval of CMI Report	12/31/2060	Tentative completion date
Monitoring of Sentry Wells starts	2059	Starts 2059, continues indefinitely
Plug and abandon Corrective Measures monitoring wells	2062	Start time is dependent on receiving NMED HWB approval of Corrective Action Complete
Submittal of P&A Report	2063	Tentative date

NOTES:

The timing of NMED HWB activities is less than the review times cited in New Mexico Administrative Code 4.2.I.101 (NMED August 2006).

AGMR = Annual Groundwater Monitoring Report.
AOC = Area of Concern.
BSG = Burn Site Groundwater.
CCM/CME = Current Conceptual Model/Corrective Measures Evaluation.
CMI = Corrective Measures Implementation.
NMED HWB = New Mexico Environment Department Hazardous Waste Bureau.
P&A = Plugging and abandonment.

Table 7-6. Preliminary Schedule for Conducting the Groundwater Extraction, Treatment, and Reinjection Alternative at the BSG AOC

Activity	Date	Comments
Submittal of CCM/CME Report to NMED HWB	01/31/2023	Submittal date based on Extension Letter
Quarterly Water Level Measurements	Ongoing	In accordance with AGMR protocol
Semiannual Groundwater Sampling	Ongoing	In accordance with AGMR protocol
NMED HWB preparation of Selected Remedy Fact Sheet / Statement of Basis	07/31/2023	Tentative completion date, assumes NMED HWB does not request supplemental information
NMED HWB approval of CCM/CME Report	12/31/2023	Tentative completion date
Public Meeting and Public Hearing process	06/01/2025	Tentative completion date
NMED HWB issues a Decision for Final Remedy	09/01/2025	Tentative completion date
Submittal of CMI Plan to NMED HWB	09/01/2026	Tentative completion date
NMED HWB approval of CMI Plan	12/31/2026	Tentative completion date
Start Implementation of Corrective Measures	1/1/2027	Start depth-to-water measurements and sampling of monitoring wells
Installation of extraction, reinjection, and test wells	12/31/2028	Tentative completion date
Construction of treatment systems and infrastructure.	12/31/2029	Tentative completion date
Start full-scale operation at Eastern and Western Plumes	1/01/2030	Tentative start date for full scale operation of extraction, treatment, and reinjection systems
Submittal of the first Five-year Performance Monitoring Report	12/31/2035	Tentative completion date
Verification sampling Western Plume after 5 years operation	12/31/2036	Tentative completion date after two years (2035 and 2036) of verification sampling
Submittal of second Five-year Performance Monitoring Report	12/31/2040	Tentative completion date
Submittal of third Five-year Monitoring Report	12/31/2045	Tentative completion date
Submittal of fourth Five-year Performance Monitoring Report	12/31/2050	Tentative completion date (after 20 years of active
Verification sampling Eastern Plume after 20 years operation	12/31/2051	Tentative completion date after two years (2050 and 2051) of verification sampling
Submittal of CMI Report	12/31/2052	Tentative completion date
NMED HWB Approval of CMI Report	12/31/2053	Tentative completion date
Monitoring of Sentry Wells at western edge of BSG AOC	2052	Starts 2052, continues indefinitely. Occurs after remedy is completed
Plug and abandon Corrective Measures wells (monitoring, extraction, and reinjection)	2055	Start time is dependent on receiving NMED HWB approval of Corrective Action Complete
Submittal of P&A Report	2056	Tentative date

Table 7-6. Preliminary Schedule for Conducting the Groundwater Extraction, Treatment, and Reinjection Alternative at the BSG AOC *(concluded)*

NOTES:

The timing of NMED HWB activities is less than the review times cited in New Mexico Administrative Code 4.2.I.101 (NMED August 2006).

AGMR = Annual Groundwater Monitoring Report.
AOC = Area of Concern.
BSG = Burn Site Groundwater.
CCM/CME = Current Conceptual Model/Corrective Measures Evaluation.
CMI = Corrective Measures Implementation.
NMED HWB = New Mexico Environment Department Hazardous Waste Bureau.
P&A = Plugging and abandonment.

8. CONCLUSIONS

The primary conclusions of this CCM/CME Report are:

- The BSG AOC overlies a hydrogeologically complex fractured bedrock aquifer system.
- Nitrate is the only COC for groundwater in the BSG AOC.
- Nitrate concentrations exceed the EPA MCL at two discontinuous plumes in the AOC.
- The lateral extents of the two nitrate plumes are stable. The plumes are at steady-state (stable) conditions. NPN concentrations are mostly decreasing to stable.
- There are no ongoing primary sources of anthropogenic nitrate to groundwater. The plumes are the result of past releases that have subsequently developed to their present dimensions through dispersion and dilution.
- Nitrate concentrations are expected to be stable or decrease as a result of natural groundwater mechanisms (advection, dispersion, dilution, diffusion and possibly denitrification).
- No potable production wells (potential receptors) are completed in the vicinity of the nitrate-impacted groundwater at the site. The nearest downgradient potable production well is located approximately 9 miles from the site.
- There is no threat to human health and the environment.
- After a review of potential remedial technologies three remedial alternatives were developed and evaluated in this CME:
  - Alternative 1: Long-Term Monitoring
  - Alternative 2: MNA
  - Alternative 3: Groundwater Extraction, Treatment, and Reinjection
- Groundwater Extraction, Treatment, and Reinjection is unsuitable for addressing the two nitrate plumes at the BSG AOC. This is primarily due to:
  - The large areal extents of the two stable nitrate plumes.
  - Low hydraulic conductivity and the erratic groundwater path of fracture flow that severely restrict extraction rates or reinjection rates.
  - The extremely high capital and operation/maintenance costs associated with groundwater extraction technologies.
- Because there is no current use of groundwater in the nitrate-impacted area. Any nitrate reaching the offsite production wells would be naturally attenuated to far below the EPA MCL or non-detect.
- The preferred remedy (Long-Term Monitoring Alternative) is protective of human health and the environment, implementable, cost-effective, and compliant with environmental regulations.
- The estimated remedial timeframe is 38 years.

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Appendix A
Historical Timeline of the Burn Site Groundwater Area of Concern

Historical Timeline of the Burn Site Groundwater Area of Concern

Month	Year	Event	Reference
	1967-early 1980s	HE outdoor testing conducted at the BSG AOC until early 1980s. Burn testing began in 1970s using excavation pits and portable burn pans with JP-4. Open detonations of HE materials conducted. Wastewater discharged into unlined pits.	SNL November 2001
	1987	Eighteen potential SWMUs were identified during the Comprehensive Environmental Assessment and Response Program investigation. HE compounds, nitrate, and diesel range organics identified as potential COCs.	DOE September 1987
February	1996	Burn Site Well (a non-potable production well) was installed at the eastern edge of the HE testing area.	SNL April 2008a
November	1996	Groundwater sample from Burn Site Well yielded nitrate concentration of 25 mg/L.	SNL January 2005
July	1997	NMED/DOE OB, DOE, and SNL/NM personnel agreed on installation of deep and shallow monitoring wells and one year of quarterly sampling.	SNL July 1997
November	1997	Monitoring wells CYN-MW2S and 12AUP01 were installed to serve as piezometers. Piezometers are constructed of narrow-diameter casing and not used for collecting groundwater samples.	SNL June 1998
December	1997	Monitoring well CYN-MW1D installed.	SNL June 1998
February	1998	Site-Wide Hydrogeologic Characterization Project, Calendar Year 1995 Annual Report containing description of BSG hydrogeology submitted.	SNL February 1998
March	1999	GWPP Fiscal Year 1998 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL March 1999
June	1999	Monitoring wells CYN-MW3 and CYN-MW4 installed.	SNL November 2001
	Various (e.g., 1994)	BSG AOC SWMUs 94 and 65 proposed and approved for NFA/CAC.	Numerous references, for example: SNL February 2004
March	2000	GWPP Fiscal Year 1999 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL March 2000
April	2001	GWPP Fiscal Year 2000 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL April 2001
August	2001	Monitoring well CYN-MW5 installed 1.7 miles west of the BSG AOC.	SNL June 2005
November	2001	Comprehensive BSG Investigation Report documenting hydrogeologic characteristics of the study area prepared.	SNL November 2001
March	2002	GWPP Fiscal Year 2001 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL March 2002
March	2003	GWPP Fiscal Year 2002 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL March 2003
June	2003	Further refinements of the hydrogeologic setting of the BSG AOC are presented.	Van Hart June 2003
	2003	Burn Site Well (non-potable production well) removed from use.	None
March	2004	GWPP Fiscal Year 2003 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL March 2004
April	2004	Compliance Order on Consent lists BSG as an AOC that requires a CME.	NMED April 2004
June	2004	A CCM of the BSG AOC prepared.	SNL June 2004a
June	2004	A CME Work Plan for the BSG AOC prepared.	SNL June 2004b
January	2005	Nitrate source evaluation of deep soil in the BSG AOC performed.	SNL January 2005
February	2005	NMED required additional site characterization and the preparation of an Interim Measures Work Plan.	NMED February 2005
May	2005	BSG Interim Measures Work Plan submitted.	SNL May 2005
July	2005	NMED sent an RSI for the Interim Measures Work Plan.	NMED July 2005

Refer to footnotes at the bottom of the table.

Historical Timeline of the Burn Site Groundwater Area of Concern *(Continued)*

Month	Year	Event	Reference
August	2005	Response for RSI is submitted to the NMED.	SNL August 2005
October	2005	GWPP Fiscal Year 2004 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL October 2005
December	2005	Monitoring wells CYN-MW6 and CYN-MW7 installed.	SNL October 2006
January	2006	Monitoring well CYN-MW8 installed.	SNL October 2006
March	2007	GWPP Fiscal Year 2006 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL March 2007
March	2008	GWPP Fiscal Year 2007 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL March 2008
April	2008	BSG CCM resubmitted.	SNL April 2008a
April	2008	BSG CME Work Plan resubmitted.	SNL April 2008b
April	2009	NMED required supplemental characterization of soil and groundwater in the BSG AOC.	NMED April 2009
June	2009	GWPP Calendar Year 2008 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL June 2009
November	2009	BSG Characterization Work Plan submitted.	SNL November 2009
February	2010	Received notice of conditional approval for the November 2009 BSG Characterization Work Plan.	NMED February 2010
July	2010	Completed subsurface soil sampling at 10 deep soil boring locations to determine contaminant sources.	SNL November 2009
July	2010	Installed four groundwater monitoring wells (CYN-MW9, CYN-MW10, CYN-MW11, and CYN-MW12) to determine extent of groundwater contamination.	SNL January 2012
September	2010	An extension request for the BSG CME Report submitted.	SNL September 2010
October	2010	Received approval of a time extension for submittal of the BSG CME Report.	NMED October 2010
October	2010	GWPP Calendar Year 2009 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL October 2010
August	2011	Received approval of the March 2008 CME Work Plan.	NMED August 2011
September	2011	GWPP Calendar Year 2010 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL September 2011
January	2012	Summary Report for BSG Characterization Field Program submitted.	SNL January 2012
February	2012	Monitoring Well Plug and Abandonment Plan and Well Construction Plan for BSG wells and status of CYN-MW3 submitted.	SNL February 2012
April	2012	Received notice of approval for the January 2012 BSG Monitoring Well Plug and Abandonment Plan and Well Construction Plan.	NMED April 2012
June	2012	Received notice of approval for the January 2012 Summary Report for BSG Characterization Field Program.	NMED June 2012
September	2012	GWPP Calendar Year 2011 Annual Groundwater Monitoring Report provided BSG analytical data.	SNL September 2012
December	2012	Completed field program to decommission BSG monitoring wells 12AUP01, CYN-MW1D, CYN-MW2S, and install monitoring well CYN-MW13.	SNL March 2013
August	2013	Submitted an Extension Request to the NMED for the BSG CME Report to March 31, 2013.	DOE August 2013
September	2013	Groundwater sampling analytical results for BSG wells reported in the Calendar Year 2012 SNL/NM Annual Groundwater Monitoring Report.	SNL September 2013a
September	2013	Monitoring Well Plug and Abandonment Plan and Well Construction Plan for Installation of Groundwater Monitoring Wells CYN-MW14 and CYN-MW15 submitted.	SNL September 2013b
October	2013	DOE Office of Environmental Management submitted the first Internal Remedy Review of the BSG AOC to DOE/NNSA Sandia Field Office.	DOE October 2013

Refer to footnotes at the bottom of the table.

Historical Timeline of the Burn Site Groundwater Area of Concern *(Continued)*

Month	Year	Event	Reference
January	2014	DOE/NNSA requested an extension to the delivery date of the BSG CME Report to March 31, 2016.	DOE January 2014
June	2014	Received approval for the installation of groundwater monitoring wells CYN-MW14A and CYN-MW15.	NMED June 2014a
June	2014	NMED approved the proposed extension request for the BSG CME Report to March 31, 2016.	NMED June 2014b
June	2014	Groundwater sampling analytical results for BSG wells reported in the Calendar Year 2013 SNL/NM Annual Groundwater Monitoring Report.	SNL June 2014
November	2014	DOE Office of Environmental Management submitted the second Internal Remedy Review of the BSG AOC to DOE/NNSA Sandia Field Office.	DOE November 2014
December	2014	Installed groundwater monitoring wells CYN-MW14A and CYN-MW15.	SNL April 2015
April	2015	Summary Report for Installation of Groundwater Monitoring Wells CYN-MW14A and CYN-MW15 submitted.	SNL April 2015
May	2015	DOE Office of Environmental Management submitted the third Internal Remedy Review of the BSG AOC to DOE/NNSA Sandia Field Office.	DOE May 2015
June	2015	Received approval for the Installation Report for CYN-MW14A and CYN-MW15.	NMED June 2015
June	2015	Groundwater sampling analytical results for BSG wells reported in the Calendar Year 2014 SNL/NM Annual Groundwater Monitoring Report.	SNL June 2015
March	2016	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 for the weight-of-evidence activities.	NMED April 2016
June	2016	Aquifer Pumping Test Work Plan submitted.	SNL June 2016a
June	2016	Groundwater sampling analytical results for BSG wells reported in the Calendar Year 2015 SNL/NM Annual Groundwater Monitoring Report.	SNL June 2016b
June	2016	Aquifer Pumping Test Work Plan approved.	NMED June 2016
July	2016	Stable Isotope denitrification and groundwater age dating report summary.	Madrid et. al. July 2016
March	2017	Field requirements of the Aquifer Pumping Test were completed, including long-term transducer study, step drawdown test, constant rate test, and groundwater interval sampling for nitrate.	SNL December 2017
May	2017	Preliminary results of the pumping test were shared with NMED on May 10, 2017 at the NMED District 1 office.	SNL December 2017
June	2017	Groundwater sampling analytical results for BSG wells reported in the Calendar Year 2016 SNL/NM Annual Groundwater Monitoring Report.	SNL July 2017
November	2017	Requested an extension for the submittal of recommendations for further characterization activities.	DOE November 2017
November	2017	Extension request approved.	NMED November 2017
December	2017	Aquifer Pumping Test Report submitted.	SNL December 2017
January	2018	Aquifer Pumping Test Report approved.	NMED January 2018
June	2018	Proposed recommendations for additional site characterization.	DOE June 2018
June	2018	NMED disapproved the proposed recommendations and required the submittal of a Well Installation Work Plan.	NMED June 2018
June	2018	Groundwater sampling analytical results for BSG wells reported in the Calendar Year 2017 SNL/NM Annual Groundwater Monitoring Report.	SNL June 2018

Refer to footnotes at the bottom of the table.

Historical Timeline of the Burn Site Groundwater Area of Concern *(Concluded)*

Month	Year	Event	Reference
January	2019	Monitoring Well Installation Work Plan for CYN-MW16 through CYN-MW23 submitted.	SNL January 2019
February	2019	NMED approved the Monitoring Well Installation Work Plan.	NMED February 2019
June	2019	Groundwater sampling analytical results for BSG wells reported in the Calendar Year 2018 SNL/NM Annual Groundwater Monitoring Report.	SNL June 2019
September	2019	Monitoring well field program started.	SNL May 2020
December	2019	Monitoring well field program completed. Four monitoring wells (CYN-MW16, CYN-MW17, CYN-MW18, and CYN-MW19) were installed and sampled.	SNL May 2020
May	2020	Monitoring Well Installation Report for CYN-MW16 through CYN-MW19 submitted.	SNL May 2020
June	2020	Extension request for CCM/CME submitted.	SNL June 2020a
June	2020	Groundwater sampling analytical results for BSG wells reported in the Calendar Year 2019 SNL/NM Annual Groundwater Monitoring Report.	SNL June 2020b
July	2020	NMED approved the Monitoring Well Installation Report.	NMED July 2020a
July	2020	NMED approved the CCM/CME extension request (new due date is January 31, 2023).	NMED July 2020b
September	2020	Preliminary results from the first four quarterly sampling events at the four new monitoring wells were shared with the NMED on September 23, 2020.	SNL June 2021
November	2020	Final perchlorate sampling event at CYN-MW15 based on four consecutive non detects.	SNL April 2021
May	2021	Preliminary results from the first six quarterly sampling events at the four new monitoring wells were shared with the NMED on May 11, 2021.	SNL October 2021
June	2021	Groundwater sampling analytical results for BSG wells reported in the Calendar Year 2020 SNL/NM Annual Groundwater Monitoring Report.	SNL June 2021
November	2021	An evaluation of the groundwater monitoring well network was sent to the NMED on November 5, 2021.	DOE November 2021
December	2021	NMED approved the evaluation of the groundwater monitoring well network.	NMED December 2021
June	2022	Groundwater sampling analytical results for BSG wells reported in the Calendar Year 2021 SNL/NM Annual Groundwater Monitoring Report.	SNL June 2022

NOTES:

AOC = Area of Concern.
BSG = Burn Site Groundwater.
CAC = Corrective Action Complete.
CCM = Current Conceptual Model.
CME = Corrective Measures Evaluation.
CYN = Canyons.
COC = Constituent of concern.
DOE = U.S. Department of Energy.
GWPP = Groundwater Protection Program.
HE = High explosive.
JP-4 = Jet propellant, fuel grade 4.
mg/L = Milligram(s) per liter.
MW = Monitoring well.
NFA = No Further Action.
NMED = New Mexico Environment Department.
NNSA = National Nuclear Security Administration.
OB = Oversight Bureau.
RSI = Request for Supplemental Information.
SNL/NM = Sandia National Laboratories, New Mexico.
SWMU = Solid Waste Management Unit.

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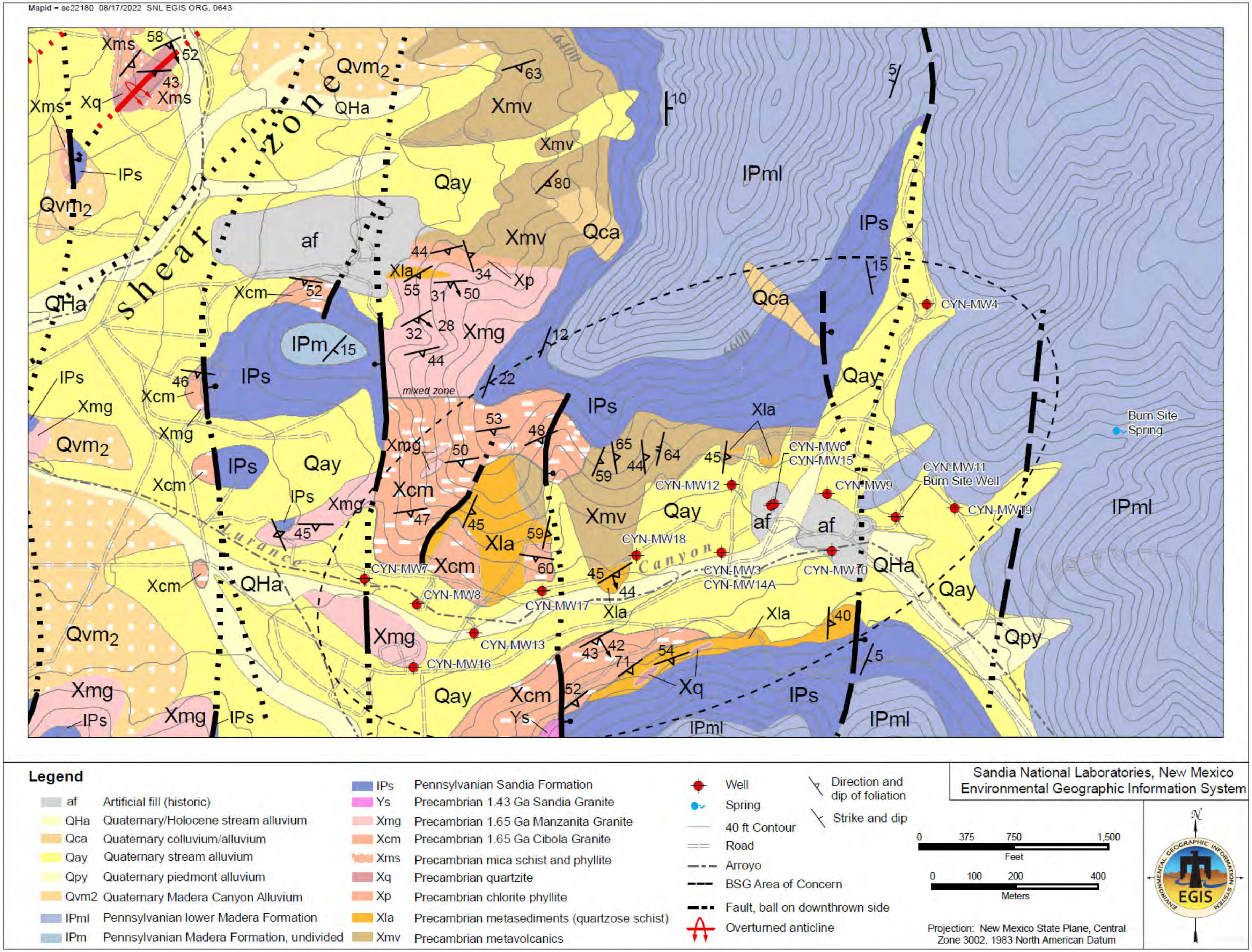
Appendix B

Geologic Map of the BSG AOC with a Description of Geologic Mapping Units



Geologic Map of the BSG AOC

Geologic Map Unit Descriptions

From the **Geology of Tijeras Quadrangle, Bernalillo County, New Mexico,** by Karl E. Karlstrom, Sean D. Connell, Charles A. Ferguson, Adam S. Read, Glenn R. Osburn, Eric Kirby, John Abbott, Christopher Hitchcock, Keith Kelson, Jay Noller, Thomas Sawyer, Steven Ralser, David W. Love, Matthew Nyman, and Paul W. Bauer. NMBMMR Open File Map Series, OF–GM–4, Map last modified 28 February 2000: https://ngmdb.usgs.gov/Prodesc/proddesc_73228.htm

CENOZOIC DEPOSITS

Neogene (Quaternary and Tertiary) System

Colluvial, landslide, eolian, and anthropogenic deposits

Thin surficial deposits derived from wind and mass-movement processes, or extensive areas disturbed by open pit aggregate mining or construction.

af **Artificial fill (Historic) —** Dumped fill and areas affected by human disturbances. Locally mapped where areally extensive or geologic contacts are obscured.

Qca **Colluvium and alluvium, undivided (Holocene to upper-middle Pleistocene) —** Poorly consolidated, poorly sorted and stratified, fine- to coarse-grained, clast- and matrix-supported deposits derived from a variety of mass-movement hill slope processes, including debris flow, shallow slump and creep. Gravel clasts are typically angular to subangular and composition reflects local provenance. Soils locally exhibit Stage I to III carbonate morphology. Clasts are typically angular and composition generally reflects local provenance. Commonly surrounds small undivided inliers of Madera Formation limestone on the eastern dip-slope of the Sandia Mountains. Differentiated where areally extensive, thick, or where geologic contacts are obscured. Variable thickness, up to 12 ft (4 m).

Stream-valley Alluvium

Typically contains poorly to well sorted and stratified, clast- and matrix-supported sand and gravel with minor muddy sand interbeds associated with modern and late Pleistocene entrenched arroyos and streams originating in the Sandia and Manzanita Mountains. Deposits unconformably overlie Santa Fe Group deposits and older rocks, and are differentiated on the basis of inset relationships and soil-morphology.

QHa **Youngest stream alluvium, undivided (Historic to upper Holocene)** — Unconsolidated deposits of brown, light gray-brown, and yellowish-brown (10YR) sand, silty to clayey sand, and gravel. Underlies modern arroyos and inset against younger stream alluvium (*Qay*). Color and clast composition varies with drainage-basin composition, but gravel typically contains limestone, gneiss, quartzite, sandstone, granite and metarhyolite. Deposit surface exhibits no pedogenic development, and unit locally forms small alluvial fans within low-order tributary drainages of Madera and Tijeras Canyons. Locally divided into an older terrace (*QHao*) on the basis of inset relationships. Deposits locally contain asphalt fragments and construction debris. The age is constrained by radiocarbon dates ranging between 1,000 to 3,000 years BP (Thomas *et al.*, 1995, p. 2-37 and 2-43). Correlative to units *H8* and *H9* of Thomas *et al.* (1995), and correlative to geomorphic surface *Q9* of Connell (1995, 1996). Variable thickness from 0-10 ft (0-3 m).

Qay **Younger stream alluvium (Holocene to uppermost Pleistocene)** — Poorly consolidated deposits of light brown to dark-gray, fine-grained silty sand with minor pebbly sand and clayey sand interbeds; pebble lenses are common along basal contact. Unit forms broad terraces ranging from 8-30 ft (3-9 m) above *Tijeras* and *Madera Creeks*. Two terrace levels are locally recognized, but not differentiated, within Tijeras Canyon. Clasts are chiefly rounded limestone with minor granite, metavolcanic and gneiss within Madera Canyon. The trunk stream of the Tijeras Canyon drainage is divided into unit *Qayt*. Locally includes undivided stream alluvium (*QHa*) in narrow arroyos. Soils are weakly developed and exhibit Stage I and II carbonate morphology. Deposit age is constrained by a radiocarbon of about 10,000 years BP (Thomas *et al.*, 1995, p. 2-43). Correlative to unit *H7* of Thomas *et al.* (1995), and correlative to geomorphic surfaces *Q8-Q9* of Connell (1995, 1996). Variable thickness from 0-20 ft (0-6m).

Eastern-margin piedmont slope deposits

Typically contains poorly to moderately sorted and stratified, clast- and matrix-supported sand and gravel with minor muddy sand interbeds associated coalescent range-front alluvial fans in the Sandia Mountains and Four Hills salient. Deposits unconformably overlie Santa Fe Group deposits and older rocks, and are differentiated on the basis of inset relationships and soil-morphology. Clasts are commonly angular to subangular granite with minor subrounded limestone.

Qpy **Younger eastern-margin piedmont alluvium (Holocene to uppermost Pleistocene) —** Poorly to moderately sorted and stratified gravel, sand with minor silt-clay mixtures inset against eastern-margin piedmont alluvium (*Qpm*). Deposit surface (top) is moderately dissected and exhibits well developed to subdued bar-and-swale topography. Soils possess Stage I to II carbonate morphology and weakly to moderately developed clay films. Generally correlative to units *H7-H9* of Thomas *et al.* (1995). Variable thickness from 0-30 ft (0-9 m).

Alluvium of Madera Canyon

Typically contains poorly to well sorted and stratified, clast- and matrix-supported sand and gravel with minor muddy sand interbeds associated with modern and late Pleistocene entrenched arroyos and streams originating in the northern Manzanita Mountains. Deposits unconformably overlie pre-Cenozoic rocks, and are differentiated on the basis of inset relationships and soil-morphology. Clasts are commonly angular to subrounded limestone, metarhyolite, gneiss, and quartzite.

Qvm2 **Younger subunit (upper to middle Pleistocene) —** Poorly to moderately consolidated and poorly to moderately sorted deposits of very pale-brown to strong yellowish-brown (7.5-10YR), poorly to moderately stratified and sorted, silty clay and loamy sand and gravel. Soils are moderately developed and possess Stage II to III carbonate morphology and few to common, thin to moderately thick clay films. Probably correlative to stream alluvium of Tijeras Canyon (*Qpmt1*), and generally correlative to units *P5-P6* of Thomas *et al.* (1995).

PALEOZOIC ROCKS

Upper and Middle Pennsylvanian

IPm **Madera Formation, undivided —** Two informal members, an arkosic limestone and a gray limestone, are recognized but not differentiated. The upper and lower members are respectively generally correlative to the Wild Cow Formation and Los Moyos Limestone (Formation) of the Madera Group of Myers and McKay (1976). These informal member names are used because the units were lithostratigraphically defined on the Sedillo (Read *et al.*, 1999) and Tijeras (Karlstrom *et al.*, 1994) 7.5-minute quadrangles rather than biostratigraphically defined and may therefore not strictly correlate with the units defined by Myers and McKay (1976). The Madera Group nomenclature was abandoned because of the gradational contacts between members and the difficulty of distinguishing these contacts in the field. Total thickness is approximately 1,320 ft (402 m) near Cedro Peak to the southeast (Myers and McKay, 1976) and 1,260 ft (385 m) on the Crest of Montezuma (Picha, 1982) to the north (consistent with thickness estimates based on map relationships in the study area).

IPm$_l$ **Madera Formation, lower gray limestone —** A sequence of often fossiliferous and massively bedded cliff-forming wavy laminated and cherty micritic limestone interbedded with shales. Shale is particularly abundant near the base of this member where it grades into the Sandia Formation. Generally correlative with the Los Moyos Limestone of Myers and McKay (1976).

IPs **Sandia Formation —** Consists of a variety of lithologies including, in descending stratigraphic order: interbedded brown claystone and gray limestone, massive gray limestone, and a lower olive-brown to gray, subarkosic, fine- to coarse-grained sandstone. The contact with overlying Madera Formation (*m*) is chosen at the base of the lowest thick, ledge-forming limestone. The lower contact is unconformable with the Arroyo Peñasco Group or Proterozoic crystalline rocks. Isolated thin outcrops in Tijeras Canyon of sandstone and limestone from the Espiritu Santo Member of the Arroyo Peñasco Group (see Szabo, 1953; Armstrong, 1967; Armstrong and Mamet, 1974, Kelley and Northrop, 1975) generally remain undifferentiated from the Sandia Formation. Limestone in the Sandia Formation is distinct from limestone in the overlying Madera Formation as they are typically thinner-bedded, clast-supported, greenish, and contain abundant siliciclastic material. Approximately 170 ft (50 m) thick.

PROTEROZOIC ROCKS

Mesoproterozoic igneous rocks

Ys **Sandia granite** — Mainly megacrystic biotite monzogranite to granodiorite. K-feldspar megacrysts, up to several cm long, are commonly aligned in a magmatic foliation; contains numerous ellipsoidal enclaves of microdiorite, fine-grained granite, and gabbro (interpreted to be mingled mafic magmas, *Ye*), and xenoliths of quartzite, mica schist, and mafic metavolcanic rock. Pegmatites (*Yp*), aplites (*Ya*), and quartz veins are ubiquitous. Various dates are available from geochronologic sample *Locality 3*: U-Pb zircon plus sphene 1,455±12 Ma (Tilton and Grunenfelder, 1968, recalculated by S. Getty, unpublished); U-Pb zircon of 1,437±47 Ma (Steiger and Wasserburg, 1966, recalculated in Kirby *et al*., 1995); U-Pb zircon of 1,446±26 Ma (D. Unruh, unpublished data); *Locality 3* also has 40Ar/39Ar analyses from hornblende of 1,422±3 Ma (Kirby *et al*., 1995); *Locality 2* has an 40Ar/39Ar date of 1,423±2 Ma (Karlstrom *et al*., 1997b).

Paleoproterozoic rocks

Xmg **Manzanita granite —** Strongly foliated very coarse-grained biotite monzogranite (biotite is chloritized). UPb zircon date of 1,645 ±16 Ma (Brown *et al.*, 1999) from the Mt. Washington 7.5-minute quadrangle (Karlstrom *et al.*, 1997a).

Xcm **Medium-grained Cibola monzogranite —** Equigranular, medium-grained, two-mica monzogranite; average grain size is 1-3 mm. Biotite-muscovite monzogranite with U-Pb dates of 1,632 ±45 Ma (geochronologic sample *Locality 5*), from north of the Tijeras fault and 1,659±13 Ma (*Locality 6*) from south of the Tijeras fault (D. Unruh, 1998 unpublished data).

Xms	**Mica schist, quartz-muscovite schist, and phyllite —** Commonly rust red from hematitic staining, strongly crenulated and commonly crowded with boudinaged and folded stringers and lenses of vein quartz. Includes Coyote schist and Coyote phyllite of Cavin (1985).
Xq	**Quartzite —** Thick-bedded to massive and gray to milky-white quartz arenite with crossbedding and bedding defined by bands of iron oxides. Pelitic partings and interbeds contain aluminum silicates. Includes Cerro Pelon and Coyote quartzites of Cavin (1985) and Cibola quartzite of Connolly (1981). *Locality 4* has an 40Ar/39Ar date of 1,423±2 Ma (Kirby *et al.*, 1995).
Xp	**Chlorite-amphibole phyllite and schist —** Metasedimentary and volcaniclastic rocks that grade from mafic metavolcanics to lithic arenites. Includes metasedimentary rocks of the Tijeras greenstone of Connolly (1981) and part of the Coyote phyllite of Cavin (1985).
Xla	**Metamorphosed lithic arenite —** Quartz schist, quartz-chlorite schist, and quartzite (*Xq*), interlayered with volcaniclastic schists (*Xp*); quartzite locally contains alumino-silicates. Includes the Tijeras quartzite of Connolly (1981) and the Isleta metasediments of Parchman (1981).
Xmv	**Mafic metavolcanic rocks —** Heterogeneous unit consisting of massive to schistose metabasalt and metaandesite with subordinate chlorite phyllite and schist of volcaniclastic origin. Coarse dioritic units may locally intrude the volcanic rocks. Includes the Tijeras greenstone of Connolly (1981), Coyote greenstone of Cavin (1985), and Isleta metavolcanics of Parchman (1981).

Appendix C
Borehole Lithologic Logs for Active Monitoring Wells in the BSG AOC

Borehole Lithologic Log for Monitoring Well CYN-MW3

Drilling Contractor:	Water Development Co., Inc.
Dates of Drilling, Installation, and Development:	June 14 through June 18, 1999
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	148
Ground Elevation, feet above mean sea level (NAVD 88):	6311.9
Completion Zone:	Bedrock--Precambrian Phyllite/Schist
Screen, feet below ground surface:	120 to 130
Initial Water Level, feet below ground surface:	104
Rig Geologist:	Unknown

Depth, feet below ground surface	Description
0 to 38	Alluvium, dry. The base alluvium/top Precambrian was logged at 38 feet and casing refusal occurred at 40 feet.
38 to 124	Phyllite/schist, dry.
124 to 148	Phyllite/schist, fractured. Groundwater was encountered while drilling at 124 feet. The water level subsequently rose to 104 feet.

Note: No lithologic log field form is available in SNL Records Center for CYN-MW3. The above descriptions were provided in Section 2.4 of the report titled *Groundwater Investigation Canyons Test Area, Operable Unit 1333 Burn Site, Lurance Canyon* (SNL/NM November 2001).

Borehole Lithologic Log for Monitoring Well CYN-MW4

Drilling Contractor:	Water Development Co., Inc.
Dates of Drilling, Installation, and Development:	June 12 through June 18, 1999
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	318
Ground Elevation, feet above mean sea level (NAVD 88):	6454.7
Completion Zone:	Bedrock--Precambrian Quartzite
Screen, feet below ground surface:	260 to 280
Initial Water Level, feet below ground surface:	218
Rig Geologist:	Unknown

Depth, feet below ground surface	Description
0 to 21	Alluvium.
21 to 40	Pennsylvanian Madera Group limestones and sandstones.
40 to 85	Pennsylvanian Sandia Formation sandstones.
85 to 264	Precambrian phyllite/Schist.
264 to 318	Precambrian quartzite, fractured, brittle. The well was drilled to TD without indications of saturated conditions; after overnight shutdown, the water level rose to a depth of 218 feet. The degree of fracturing in the bedrock was significantly less than in CYN-MW3; it is plausible that the top of the saturated zone was above 318 feet (possibly at 264 feet) but that the small amount of water flowing into the borehole was not detectable while drilling. The placement of the screen was based on the location of the maximum water-producing zone and prevalence of fractures within the quartzite.

Note: No lithologic log field form is available in SNL Records Center for CYN-MW4. The above descriptions were provided in Section 2.4 of the report titled *Groundwater Investigation Canyons Test Area, Operable Unit 1333 Burn Site, Lurance Canyon* (SNL/NM November 2001).

Borehole Lithologic Log for Monitoring Well CYN-MW6

Drilling Contractor:	Water Development Co., Inc.
Dates of Drilling, Installation, and Development:	December 7 through December 9, 2005
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	165
Ground Elevation, feet above mean sea level (NAVD 88):	6340.5
Completion Zone:	Bedrock--Precambrian Phyllite
Screen, feet below ground surface:	141.5 to 161.3
Initial Water Level, feet below ground surface:	136.8
Rig Geologist:	Robert Cooper

Depth, feet below ground surface	Description
0 to 12	Sandy gravel/gravelly sand, medium brown, fill material included 1 inch diameter cable and other scrap metal encountered to 2 feet.
12 to 140	Phyllite, pale red purple (5RP 6/2) to grayish red purple (5RP 4/2), with slatey cleavage, schistosity, fissile, greasy feel on larger cuttings, lustrous sheen.
140 to 155	Phyllite, pale red purple (5RP 6/2) to grayish red purple (5RP 4/2), driller comment: at 142 to 147 feet softer drilling with drill rate increased and amount of dust decreased, firmer drilling at 147 feet, no moisture observed in cuttings.
155 to 165	Phyllite, pale red purple (5RP 6/2) to grayish red purple (5RP 4/2), driller comment: at 155 feet stop drilling for one hour and water enters borehole to ~145 feet.

Note: Video logging indicated productive fracture zone at 142 feet.

Borehole Lithologic Log for Monitoring Well CYN-MW7

Drilling Contractor:	Water Development Co., Inc.
Dates of Drilling, Installation, and Development:	November 28 through December 6, 2005
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	356
Ground Elevation, feet above mean sea level (NAVD 88):	6213.7
Completion Zone:	Bedrock--Precambrian Granitic Gneiss
Screen, feet below ground surface:	315.0 to 334.2
Initial Water Level, feet below ground surface:	294
Rig Geologist:	Robert Cooper

Depth, feet below ground surface	Description
0 to 7	Sandy silt, medium brown, silt containing 5 to 10 % medium to coarse sand.
7 to 15	Silty sand and gravel, medium brown, subangular to subrounded gravel consisting of mostly granite, limestone, and rhyolite from medium pebble to small boulder.
15 to 20	Silty sand and gravel, significant decrease in silt and sand, and gravel has increase in limestone percentage.
20 to 35	Silty sand and gravel, further increase in limestone cobble percentage, cuttings from 30 ft are mostly limestone fragments.
35 to 53	Pennsylvanian Limestone, medium dark gray (N4) to grayish black (N2), contains fossil fragments.
53 to 135	Granite, moderate orange pink (10R 7/4) to pale reddish brown (10R 5/4).
135 to 145	Granite, moderate orange pink (10R 7/4) to pale reddish brown (10R 5/4), driller comment: drilling rate increased rapidly, possible fracture zone, cuttings contain some iron staining.
145 to 185	Granite, moderate orange pink (10R 7/4) to pale reddish brown (10R 5/4), driller comment: borehole blow out and loss of cuttings return from ~135 to 178 feet.
185 to 250	Granite, moderate orange pink (10R 7/4) to pale reddish brown (10R 5/4), cuttings contain small amount of iron staining.
250 to 305	Granite, moderate orange pink (10R 7/4) to pale reddish brown (10R 5/4), cuttings contain significant amount of white quartz, driller comment: possibly making some water at 285 feet.
305 to 356	Granite, moderate orange pink (10R 7/4) to pale reddish brown (10R 5/4), cuttings contain small amount of iron staining, driller comment: not adding water but borehole making water at 325 feet.

Note: Video logging encountered cloudy water.

Borehole Lithologic Log for Monitoring Well CYN-MW8

Drilling Contractor:	Water Development Co., Inc.
Dates of Drilling, Installation, and Development:	January 3 through January 12, 2006
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	365
Ground Elevation, feet above mean sea level (NAVD 88):	6227.8
Completion Zone:	Bedrock--Precambrian Granitic Gneiss
Screen, feet below ground surface:	338.5 to 3358.3
Initial Water Level, feet below ground surface:	326
Rig Geologist:	Robert Cooper

Depth, feet below ground surface	Description
0 to 7	Sandy silt, medium brown, silt containing 5 to 10 % medium to coarse sand.
7 to 15	Silty sand and gravel, medium brown, subangular to subrounded gravel consisting of mostly granite and rhyolite with some limestone from medium pebble to small boulder.
15 to 26	Silty sand and gravel, significant decrease in silt and sand and gravel has increase in limestone percentage.
26 to 30	Granite, moderate orange pink (10R 7/4) to pale reddish brown (10R 5/4), with a small amount of limestone fragments.
30 to 345	Granite, moderate orange pink (10R 7/4) to pale reddish brown (10R 5/4).
345 to 365	Granite, moderate orange pink (10R 7/4) to pale reddish brown (10R 5/4), driller comment: water accumulated in borehole at 345 feet after overnight, no water observed during drilling to 365 feet.

Note: Video logging indicated productive fracture zone at 341 feet.

Borehole Lithologic Log for Monitoring Well CYN-MW9

Drilling Contractor:	Water Development Co., Inc.
Dates of Drilling, Installation, and Development:	July 12 through July 27, 2010
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	207
Ground Elevation, feet above mean sea level (NAVD 88):	6358.5
Completion Zone:	Bedrock--Precambrian Phyllite
Screen, feet below ground surface:	175.8 to 195.8
Initial Water Level, feet below ground surface:	160.5
Rig Geologist:	Clinton Lum

Depth, feet below ground surface	Description
0 to 10	Clay with some sand (CL), moderate brown (5YR 4/4 to 5YR 3/4), slightly damp.
10 to 15	Sandy clay with limestone gravel (GW), matrix is grayish orange pink (5YR 7/2) to light brown (5YR 6/4), might be weathered phyllite gravel and artificial fill.
15 to 18	Gravel with clay matrix (GW), moderate brown (5YR 4/4 to 5YR 3/4), with limestone gravel.
18 to 20	Sand, well graded (GP), light brown (5YR 6/4), aeolian sand.
20 to 35	Sand, fine grained aeolian (GW), with limestone gravel, grayish orange (10YR 7/4) to grayish orange pink (5YR 7/2).
35 to 50	Phyllite/schist, unweathered, dusky green (5G 3/2), cuttings mixed with sand and limestone gravel, at depth the phyllite/schist transitioned to mostly medium dark gray (N4) to grayish blue (5PB 5/2).
50 to 175	Phyllite/schist, unweathered dusky green (5G 3/2) with layering, no hint of moisture, powdered matrix cuttings range from light gray (N7) to medium light gray (N6) with a blue tint.
175 to 207	Phyllite/schist, as above, moist, drillers comments: making water at 176 feet.

Borehole Lithologic Log for Monitoring Well CYN-MW10

Drilling Contractor:	Water Development Co., Inc.
Dates of Drilling, Installation, and Development:	July 14 through July 28, 2010
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	181
Ground Elevation, feet above mean sea level (NAVD 88):	6342.8
Completion Zone:	Bedrock--Precambrian Phyllite
Screen, feet below ground surface:	150.4 to 170.4
Initial Water Level, feet below ground surface:	117.8
Rig Geologist:	Clinton Lum

Depth, feet below ground surface	Description
0 to 20	Sand, fine grained (GW), uniform, pale yellowish brown (10YR 6/2), interbedded with limestone gravel, dry.
20 to 35	Sand, fine grained (GW), uniform, very pale orange (10YR 8/2) to grayish orange (10YR 7/4), limestone gravel content is increasing with depth.
35 to 149	Phyllite/schist, pale purple (5P 6/2) layered with grayish purple (5P 4/2).
149 to 181	Phyllite/schist, pale purple (5P 6/2) layered with grayish purple (5P 4/2), damp, moisture observed at 160 feet.

Borehole Lithologic Log for Monitoring Well CYN-MW11

Drilling Contractor:	Water Development Co., Inc.
Dates of Drilling, Installation, and Development:	July 15 through July 29, 2010
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	258
Ground Elevation, feet above mean sea level (NAVD 88):	6371.9
Completion Zone:	Bedrock--Precambrian Phyllite
Screen, feet below ground surface:	229.8 to 249.8
Initial Water Level, feet below ground surface:	95
Rig Geologist:	Clinton Lum

Depth, feet below ground surface	Description
0 to 10	Silty sand, with gravel layers (GW), grayish orange (10 YR7/4) to pale yellowish brown (10YR 6/2), limestone gravel ¼ to ½ inch, matrix is slightly moist.
20 to 29	Silty sand, with gravel layers (GW), grayish orange (10 YR7/4) to moderate yellowish brown (10YR 5/4), limestone gravel ¼ to 1 inch, lag gravel just above 29 feet, moisture content increased slightly.
29 to 50	Phyllite/schist, light brownish gray (8YR 6/1) to pale red (10R 6/2), dry.
50 to 90	Phyllite/schist, pale red (10R 6/2), dry.
90 to 150	Phyllite/schist, pale red (10R 6/2), occasional gravel lag from upper borehole, slightly moist, with increasing depth small amount of water produced.
150 to 190	Phyllite/schist, color change to slightly gray, light brownish gray (5YR6/1) to pale red (10R 6/2), increasing gray content with depth.
190 to 210	Phyllite/schist, light gray (N7) to medium light gray (N6), driller comment: 194 to 206 feet many fractures encountered, and difficult drilling.
210 to 258	Phyllite/schist, light bluish gray (SB 7/1), moist cuttings at 226 feet, confirmed water at 230 feet, high volume of water produced from 231 to 251 feet.

Borehole Lithologic Log for Monitoring Well CYN-MW12

Drilling Contractor:	Water Development Co., Inc.
Dates of Drilling, Installation, and Development:	July 20 through July 29, 2010
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	290
Ground Elevation, feet above mean sea level (NAVD 88):	6342.9
Completion Zone:	Bedrock--Precambrian Phyllite
Screen, feet below ground surface:	252.5 to 272.5
Initial Water Level, feet below ground surface:	203.5
Rig Geologist:	Michael Skelly

Depth, feet below ground surface	Description
0 to 5	Sand and gravel (GW), moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2), sand is mostly medium to coarse, some fine gravel is subangular to subrounded, mostly limestone and phyllite, possibly artificial fill, dry to slightly damp.
5 to 10	Sand and gravel (GW/SP), pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4), sand is mostly medium, possibly native soils, dry.
10 to 16	Sand and gravel (SP), grayish orange (10YR 7/4), mostly fine sand, well sorted, well rounded, possibly aeolian, gravel mostly pea sized some coarser, gravel lithologies are limestone, phyllite, and olive brown sandstone, dry to slightly damp.
16 to 110	Phyllite, powdered matrix cuttings are pale red purple (5RP 6/2) to grayish red purple (5RP 4/2), individual clasts are mottled red, purple, gray, green, and brown, some quartz stringers that are white or red or brown, dry.
110 to 142	Phyllite, pale red (10R 6/2) to pale red purple (5RP 6/2), dry.
142 to 150	Phyllite, major color change to light bluish gray (5B 7/1) and grayish blue green (5BG 5/2), color change possibly due to more chlorite, dry.
150 to 170	Phyllite, light bluish gray (5B 7/1) and grayish blue green (5BG 5/2), more abundant red and white quartz veins, dry.
170 to 190	Phyllite, light bluish gray (5B 7/1) and grayish blue green (5BG 5/2), dry.
190 to 210	Phyllite, light bluish gray (5B 7/1) and grayish blue green (5BG 5/2), more abundant red, pink, and white quartz veins and quartzite, dry.
210 to 250	Phyllite, light bluish gray (5B 7/1) and grayish blue green (5BG 5/2), driller comment: rough drilling conditions at 230 to 250 feet, dry.
250 to 270	Phyllite, light bluish gray (5B 7/1) and grayish blue green (5BG 5/2), brick red fine-grained material (possibly fault gouge) coming up with the phyllite, damp cuttings starting at 253 feet, free water being made at 261 feet.
270 to 290	Phyllite, light bluish gray (5B 7/1) and grayish blue green (5BG 5/2), saturated.

Borehole Lithologic Log for Monitoring Well CYN-MW13

Drilling Contractor:	Boart Longyear
Dates of Drilling, Installation, and Development:	November 27 through December 5, 2012
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	403
Ground Elevation, feet above mean sea level (NAVD 88):	6236.0
Completion Zone:	Bedrock--Precambrian Granitic Gneiss
Screen, feet below ground surface:	376.8 to 396.8
Initial Water Level, feet below ground surface:	322.1
Rig Geologist:	John R. Copland

Depth, feet below ground surface	Description
0 to 29	Gravel (GW), poorly sorted, light brown, 10% silt and clay, 30% fine sand to pebbles, 60% subangular to subrounded gravel derived from limestone, granitic, and metamorphic rocks, driller comments: erratic penetration rate due to occasional cobbles, dry.
29 to 350	Granitic gneiss, chlorite rich, weathered bedrock not apparent in cuttings, consistent penetration rate from 108 feet to 403 feet, consistent lithology to 403 feet, dry.
350 to 403	Granitic gneiss, chlorite rich, slightly moist zones at 350 to 355 feet and from 360 to 375 feet, first groundwater at 379 feet.

Note: Video logging indicated groundwater at 379 feet.

Borehole Lithologic Log for Monitoring Well CYN-MW14A

Drilling Contractor:	National EWP
Dates of Drilling, Installation, and Development:	November 16 through December 4, 2014
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	298.6
Ground Elevation, feet above mean sea level (NAVD 88):	6313.5
Completion Zone:	Bedrock--Precambrian Phyllite
Screen, feet below ground surface:	263.6 to 293.6
Initial Water Level, feet below ground surface:	183
Rig Geologist:	John R. Copland

Depth, feet below ground surface	Description
0 to 35	Gravely sand (GW), yellowish brown (10YR 5/4), poorly sorted, 50% fine to coarse sand, 45% limestone gravel, 5% silt and clay, gravel source rocks (up to 1 inch) are mostly limestone, few granitic and metamorphics (phyllite and quartzite), minor mafics, angular to subrounded grains, dry.
35 to 152	Phyllite, reddish purple (10R 4/1 to 2.5TR 3/3), micaceous, dry.
152 to 285	Phyllite, greenish grey (GLEY2 5/5B to GLEY2 5/10G), driller comments: harder drilling, dry.
285 to 299	Phyllite, greenish grey (GLEY2 5/5B to GLEY2 5/10G), driller comments: harder drilling, slightly damp cuttings, drilled to total depth and no groundwater noticeable at end of the workday, let borehole site overnight, next morning measure water level at 183.4 feet.

Note: Video logging indicated productive fracture zone at 286.3 to 286.7 feet. Minor amount of water at 280 feet.

Borehole Lithologic Log for Monitoring Well CYN-MW15

Drilling Contractor:	National EWP
Dates of Drilling, Installation, and Development:	November 14 through November 18, 2014
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	195
Ground Elevation, feet above mean sea level (NAVD 88):	6342.3
Completion Zone:	Bedrock--Precambrian Phyllite
Screen, feet below ground surface:	160.0 to 190.0
Initial Water Level, feet below ground surface:	153.6
Rig Geologist:	Michael F. Skelly

Depth, feet below ground surface	Description
0 to 8	Artificial fill consisting of compacted clay, sand and gravel (GW) with occasional debris (concrete), dry.
8 to 144	Phyllite, reddish purple (10R 4/1 to 2.5YR 3/3), micaceous, highly fractured, dry.
144 to 174	Phyllite, greenish grey (GLEY2 5/5B to GLEY2 5/10G), micaceous, dry.
174 to 180	Phyllite, greenish grey (GLEY2 5/5B to GLEY2 5/10G), micaceous, increasingly damp cuttings, standby (no air lifting) for 10 minutes then minor amount of groundwater produced by air lifting when drilling resumes. Possible first water at 174 feet.
180 to 190	Phyllite, greenish grey (GLEY2 5/5B to GLEY2 5/10G), micaceous, damp cuttings to total depth but variable amount of groundwater produced.

Borehole Lithologic Log for Monitoring Well CYN-MW16

Drilling Contractor:	Cascade Drilling LP
Dates of Drilling, Installation, and Development:	October 1 through November 5, 2019
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	414.2
Ground Elevation, feet above mean sea level (NAVD 88):	6247.4
Completion Zone:	Bedrock--Precambrian Granitic Gneiss
Screen, feet below ground surface:	375.6 to 405.6
Initial Water Level, feet below ground surface:	338.6
Rig Geologist:	Michael F. Skelly

Depth, feet below ground surface	Description
0 to 10	Sand and gravel (GW), sand is very pale orange (10YR 8/2) to pale yellowish brown (10YR 6/2), mostly fine sand, some medium sand, some silt, gravel is coarse to cobble sized, mostly medium gray limestone, dry.
10 to 20	Sand and gravel (GW), more pale yellowish brown (10YR 6/2) than above, dry.
20 to 30	Sand and gravel (GW), pale yellowish brown (10YR 6/2), less coarse gravel, dry.
30 to 52	Gravel, all limestone fragments, driller comment: competent bedrock (possibly a coarse gravel lag), dry.
52 to 155	Granitic gneiss, gray to pink, coarse grained, dry.
155 to 156	Granitic gneiss, cuttings have pale red (5R 6/2) to moderate red (5R 5/4) staining (possible mineralized zone), dry.
156 to 375	Granitic gneiss, gray to pink, coarse grained, dry.
375 to 395	Granitic gneiss, gray to pink, coarse grained, dry to slightly damp, driller comment: softer drilling/productive zone from 390 to 395 feet.
395 to 414	Granitic gneiss, gray to pink, coarse grained, damp to wet (but no free water).

Borehole Lithologic Log for Monitoring Well CYN-MW17

Drilling Contractor:	Cascade Drilling LP
Dates of Drilling, Installation, and Development:	October 7 through November 6, 2019
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	415
Ground Elevation, feet above mean sea level (NAVD 88):	6266.6
Completion Zone:	Bedrock--Precambrian Granitic Gneiss
Screen, feet below ground surface:	370.3 to 400.3
Initial Water Level, feet below ground surface:	357.7
Rig Geologist:	Michael F. Skelly

Depth, feet below ground surface	Description
0 to 14	Silty sand, moderate yellowish brown (10YR 5/4) to dark yellowish brown, mostly fine to medium sand, occasional gravel (to 1 inch), dry.
14 to 95	Granitic gneiss, powdered matrix cuttings are very pale orange (10YR 8/2) to grayish orange (10YR 4/4), decomposed bedrock, dry.
95 to 375	Granitic gneiss, pale yellowish brown (10YR 6/2), driller comment: encountered void or fracture zone from 150 to 153 feet/180 feet/357 to 360 feet/370 feet. Firm drilling at 215 feet, dry.
375 to 380	Granitic gneiss, pale yellowish brown (10YR 6/2), dry to slightly damp, first water at 377 feet.
380 to 384	Phyllite/schist (?), bluish gray (5B 5/1) to dark greenish gray (5G 4/1) to dark gray (N3), aphanitic to fine grained, dry to slightly damp.
384 to 415	Granitic gneiss, pale yellowish brown (10YR 6/2), driller comment: firm drilling at 390 feet, dry to slightly damp.

Borehole Lithologic Log for Monitoring Well CYN-MW18

Drilling Contractor:	Cascade Drilling LP
Dates of Drilling, Installation, and Development:	October 14 through November 7, 2019
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	315
Ground Elevation, feet above mean sea level (NAVD 88):	6301.5
Completion Zone:	Bedrock--Precambrian Phyllite/Quartzite
Screen, feet below ground surface:	270.4 to 300.4
Initial Water Level, feet below ground surface:	242.6
Rig Geologist:	Michael F. Skelly

Depth, feet below ground surface	Description
0 to 10	Sand and gravel, pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4), mostly fine to medium sand, some silt, gravel to cobble size with the following lithologies: limestone (mostly), quartzite, and phyllite, all with calcareous rind, dry.
10 to 24	Silt and sand, grayish orange (10YR 7/4) to dark yellowish orange (10YR 6/6), sand is mostly fine, possibly aeolian, trace of gravel (to 1 inch), mostly limestone, dry.
24 to 55	Phyllite/quartzite, powdered matrix cuttings are pale red (10R 6/2) to pale red purple (5RP 6/2), individual rock fragments can be brown, gray, purple, clear (quartz), fair amount of limonite staining and cubic pseudomorphs on some rock fragments, trace of brassy sulfide (pyrite?), dry.
55 to 130	Phyllite/quartzite, pale red (10R 6/2) to pale red purple (5RP 6/2), more phyllite than above, less limonite coatings/staining than above, clear to brown quartz fragments, dry.
130 to 145	Phyllite/quartzite, powdered matrix cuttings are very pale orange (10YR 8/2) to grayish orange (10YR 7/4), individual rock fragments are more green-gray, dry.
145 to 275	Phyllite/quartzite, pale greenish yellow (10Y 8/2) to yellowish gray (5Y 7/2), individual rock fragments are more green-gray, at 175 feet and deeper sulfides (galena, chalcopyrite, pyrite?) are becoming more abundant, driller comment: firm drilling, dry.
275 to 315	Phyllite/quartzite, pale greenish yellow (10Y 8/2) to yellowish gray (5Y 7/2), trace of sulfide minerals, driller comment: returned dust is diminished possibly in groundwater at 270 feet, damp at 275 feet, wet at 315 feet.

Borehole Lithologic Log for Monitoring Well CYN-MW19

Drilling Contractor:	Cascade Drilling LP
Dates of Drilling, Installation, and Development:	October 21 through November 8, 2019
Drilling Method:	Air-Rotary Casing Hammer/Air-Rotary
Total Depth of Borehole, feet:	95.6
Ground Elevation, feet above mean sea level (NAVD 88):	6408.1
Completion Zone:	Bedrock—Pennsylvanian Limestone/Precambrian Phyllite
Screen, feet below ground surface:	59.3 to 89.3
Initial Water Level, feet below ground surface:	43.4
Rig Geologist:	Michael F. Skelly/John R. Copland

Depth, feet below ground surface	Description
0 to 4	Silty sand, pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4), trace of gravel, mostly limestone and quartzite, dry.
4 to 10	Limestone/sandstone, light brownish gray (5YR 6/1), dry.
10 to 20	Shale, light brownish gray (5YR 6/1), fissile, dry.
20 to 70	Limestone, light brownish gray (5YR 6/1), driller comment: making water at 55 feet, cuttings are dry.
70 to 95	Phyllite, powdered matrix cuttings are pale red purple (5RP 6/2), large clasts are vey dusky red purple (5RP 2/2), fissile, wet.

Appendix D
Construction Details for Monitoring and Production Wells in the Burn Site Groundwater Area of Concern

Appendix D
Construction Details for Monitoring and Production Wells in the Burn Site Groundwater Area of Concern

Well ID	Type	Measuring Point [a, b] (ft amsl, NAVD 88)	Ground Surface [b] (ft amsl, NAVD 88)	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Top of Screen (ft amsl)	Bottom of Screen (ft amsl)	Casing Total Depth (ft bgs)	Casing, Inner Diameter (inches)	Casing Material	Lithology of Screened Interval	Installation Date	P&A Date, if Applicable
12AUP01	MW	6357.00	6355.0	52.5	57.5	6302.5	6297.5	58.1	2.0	PVC	Alluvium and bedrock (granitic gneiss)	19-Nov-1996	14-Nov-2012
Burn Site Well	Px	6374.66	6372.9	231.0	341.0	6141.9	6031.9	341.0	4.0	PVC	Bedrock (schist and granite)	20-Feb-1986	Inactive 2003
CYN-MW1D	MW	6239.59	6236.7	372.0	382.0	5864.7	5854.7	392.0	5.1	S	Bedrock (granitic gneiss)	22-Dec-1997	15-Nov-2012
CYN-MW2S	MW	6239.41	6236.7	23.6	28.6	6213.1	6208.1	34.2	4.0	PVC	Alluvium and bedrock (granitic gneiss)	22-Dec-1997	15-Nov-2012
CYN-MW3	MW	6313.26	6311.9	120.0	130.0	6191.9	6181.9	135.0	5.0	PVC	Bedrock (metamorphics)	18-Jun-1999	
CYN-MW4	MW	6455.48	6454.7	260.0	280.0	6194.7	6174.7	290.0	5.0	PVC	Bedrock (quartzite)	18-Jun-1999	
CYN-MW6	MW	6343.37	6340.5	141.5	161.3	6199.0	6179.2	161.7	5.0	PVC	Bedrock (metamorphics)	09-Dec-2005	
CYN-MW7	MW	6216.35	6213.7	315.0	334.2	5898.7	5879.5	339.9	5.0	PVC	Bedrock (granitic gneiss)	06-Dec-2005	
CYN-MW8	MW	6230.11	6227.8	338.5	358.3	5889.3	5869.5	363.4	5.0	PVC	Bedrock (granitic gneiss)	12-Jan-2006	
CYN-MW9	MW	6360.67	6358.5	175.8	195.8	6182.7	6162.7	200.8	4.8	PVC	Bedrock (metamorphics)	27-Jul-2010	
CYN-MW10	MW	6345.45	6342.8	150.4	170.4	6192.4	6172.4	175.4	4.8	PVC	Bedrock (metamorphics)	28-Jul-2010	
CYN-MW11	MW	6374.41	6371.9	229.8	249.8	6142.1	6122.1	254.8	4.8	PVC	Bedrock (metamorphics)	29-Jul-2010	
CYN-MW12	MW	6345.16	6342.9	252.5	272.5	6090.4	6070.4	277.5	4.8	PVC	Bedrock (metamorphics)	29-Jul-2010	
CYN-MW13	MW	6237.79	6236.0	376.8	396.8	5859.2	5839.2	402.2	4.8	PVC	Bedrock (granitic gneiss)	05-Dec-2012	
CYN-MW14A	MW	6315.85	6313.5	263.6	293.6	6049.9	6019.9	298.6	4.8	PVC	Bedrock (metamorphics)	09-Dec-2014	
CYN-MW15	MW	6344.44	6342.3	162.2	192.2	6180.1	6150.1	195.0	4.8	PVC	Bedrock (metamorphics)	08-Dec-2014	
CYN-MW16	MW	6249.60	6247.4	375.6	405.6	5871.8	5841.8	410.6	4.75	PVC	Bedrock (granitic gneiss)	5-Nov-2019	
CYN-MW17	MW	6268.95	6266.6	370.3	400.3	5896.3	5866.3	405.3	4.75	PVC	Bedrock (granitic gneiss)	6-Nov-2019	
CYN-MW18	MW	6304.02	6301.5	270.4	300.4	6031.1	6001.1	305.4	4.75	PVC	Bedrock (metamorphics)	7-Nov-2019	
CYN-MW19	MW	6410.43	6408.1	59.3	89.3	6348.8	6318.8	94.3	4.75	PVC	Bedrock (metamorphics)	8-Nov-2019	

Notes:
[a] Measuring Point is the elevation for the top of well casing, typically the top of PVC casing, that is used for measuring and calculating groundwater elevations.
[b] Elevations are relative to the NAVD 88, New Mexico State Plane Coordinate System, Central Zone.

amsl = Above mean sea level.
bgs = Below ground surface.
CYN = Canyons (monitoring well designation only).
ft = Foot (feet).
ID = Identifier.
MW = Monitoring Well.
NAVD 88 = North American Vertical Datum of 1988.
P&A = Plugged and abandoned (decommissioned).
Px = Production well (water supply well) used for non-potable purposes such as conducting burn tests.
PVC = Polyvinyl chloride.
S = Steel (carbon steel).
12AUP = Environmental Restoration Site 12A underflow piezometer.

Appendix E
Well Diagrams for Active and Decommissioned Monitoring Wells and Piezometers in the Burn Site Groundwater Area of Concern

Well Name:	12AUP01	**Drilling Contractor:**	STEWART BROTHERS
Project Name:	BURN SITE GW	**Drilling Method:**	HOLLOW STEM AUGER
NMOSE Well File Code:	RG-90065, Point of Diversion: 1	**Borehole Depth (FBGS):**	58.09
Owner Name:	SNL/NM	**Casing Depth (FBGS):**	58.09
Date Drilling Started:	NOV 19, 1996	**Geo Location:**	BURN SITE GROUNDWATER AOC
Date Well Dev. Completed:	NOV 19, 1996	**Completion Zone:**	BEDROCK-ALLUVIUM CONTACT
		Completion Formation:	ALVM & PRE-C GRANITIC GNEISS

Survey Data

Survey Date:

Surveyed By:

State Plane Coordinates: NAD 83

(X) Easting:	1592893.33
(Y) Northing:	1457341.33

Survey Elevations (FAMSL) NAVD 88

Protective Casing:	
Top of Inner Well Casing:	6357.00
Concrete Pad:	6355.00
Ground Surface:	6355.0

Calculated Depths and Elevations

Initial Depth to Water (FBGS)

Date Initial Depth Measured:

Last Measured Water Elevation (FAMSL):

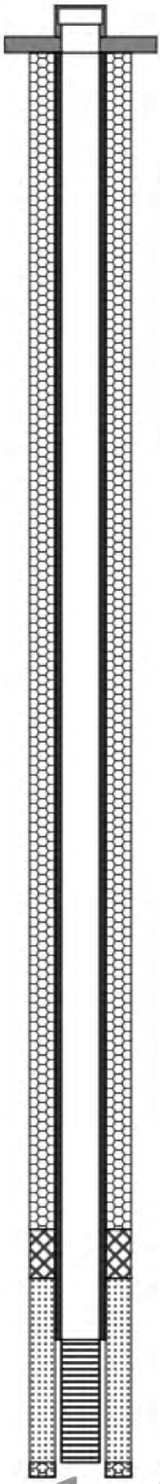
Date Last Measured:

Miscellaneous Information

Screen Slot Size (in.):	0.01
Date Updated:	AUG 24, 2022
Date Printed from EDMS:	AUG 30, 2022

Comments:

NO SAMPLING, AUGER CUTTINGS WERE LOGGED, DRY WHEN INSTALLED. WELL WAS DRY FOR 16 YEARS EXCEPT FOR 1-2 INCHES OF WATER IN SEPTEMBER 1986. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES. WELL WAS PLUGGED AND ABANDONED ON 11/14/2012. WELL WAS ALMOST ALWAYS DRY. ELEVATIONS ESTIMATED FROM TOPOGRAPHIC GIS COVERAGE. WELL WAS DECOMMISSIONED 11/14/12.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	58.1	58.1		7.75
■	CASING	SCHEDULE 40 PVC	0.0	52.5	52.5		2
▣	CUTTINGS/SAND		0.0	48.0	48.0		
☒	SEAL	BENTONITE PELLE...	48.0	50.0	2.0		
⊞	PRIMARY PACK	10/20 SILICA SAND	50.0	58.1	8.1		
☰	SCREEN	SCH 40 PVC	52.5	57.5	5.0		2
▣	BOTTOM CAP/SU...	SCHEDULE 40 PVC	57.5	58.1	0.6		

Plugged and Abandoned

Well Name: CYN-MW1D
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, Point of Diversion: 21
Owner Name: SNL/NM
Date Drilling Started: NOV 21, 1997
Date Well Dev. Completed: DEC 22, 1997

Drilling Contractor: STEWART BROTHERS
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 392.00
Casing Depth (FBGS): 392.00
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN GRANITIC GNEISS

Survey Data

Survey Date: FEB 16, 1998
Surveyed By: JAMES WHEELER
State Plane Coordinates: NAD 83
(X) Easting: 1590234.04
(Y) Northing: 1456166.83

Survey Elevations (FAMSL) NAVD 88

Protective Casing: 6240.04
Top of Inner Well Casing: 6239.59
Concrete Pad: 6237.13
Ground Surface: 6236.7

Calculated Depths and Elevations

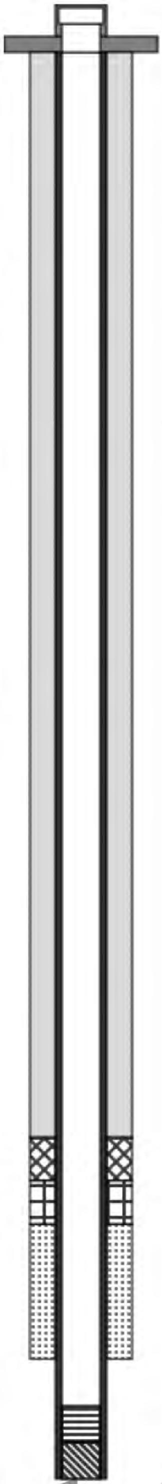
Initial Depth to Water (FBGS) 320.00
Date Initial Depth Measured: DEC 22, 1997
Last Measured Water Elevation (FAMSL): 5912.56
Date Last Measured: OCT 18, 2012

Miscellaneous Information

Screen Slot Size (in.): 0.125
Date Updated: AUG 24, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

FIRST GROUNDWATER OBSERVED AT 375 FBGS DURING DRILLING (GROUNDWATER INVESTIGATION CANYONS TEST AREA, SNL/NM NOV 2001). COLOG BIPS TELEVIEWER RUN IN BOREHOLE TO QUANTITIVELY MEASURE FRACTURE PATTERNS, ONLY ONE SIGNIFICANT SATURATED FRACTURE PRESENT, 4 MILLIMETER APETURE AT 373.6 FBGS. SCREEN HAD VERTICAL SLOTS 0.125 INCHES WIDE. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES. WELL WAS DECOMMISSIONED 11/15/12. REPLACED BY WELL CYN-MW13.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.9

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	392.0	392.0		12
■	CASING	LOW CARBON ST...	0.0	392.0	392.0	5.125	5.625
□	GROUT/BACKF...	BENTONITE CEM...	0.0	298.5	298.5		
☒	SEAL	BENTONITE PEL...	298.0	310.0	12.0		
⊞	SECONDARY P...	40/60 SAND	310.0	322.0	12.0		
⊡	PRIMARY PACK	3/8" GRAVEL	322.0	359.0	37.0		
☰	SCREEN	LOW CARBON ST...	372.0	382.0	10.0	5.125	5.625
▨	SUMP	LOW CARBON ST...	382.0	392.0	10.0	5.125	5.625

Plugged and Abandoned

Well Name:	CYN-MW2S	**Drilling Contractor:**	STEWART BROTHERS
Project Name:	BURN SITE GW	**Drilling Method:**	ARCH
NMOSE Well File Code:	RG-90065, Point of Diversion: 22	**Borehole Depth (FBGS):**	35.20
Owner Name:	SNL/NM	**Casing Depth (FBGS):**	34.20
Date Drilling Started:	DEC 20, 1997	**Geo Location:**	BURN SITE GROUNDWATER AOC
Date Well Dev. Completed:	DEC 22, 1997	**Completion Zone:**	BEDROCK/ALLUVIUM INTERFACE
		Completion Formation:	ALVM & PRE-C GRANITIC GNEISS

Survey Data

Survey Date:	FEB 16, 1998
Surveyed By:	JAMES WHEELER
State Plane Coordinates:	NAD 83
(X) Easting:	1590220.48
(Y) Northing:	1456147.54

Survey Elevations (FAMSL) NAVD 88

Protective Casing:	6239.82
Top of Inner Well Casing:	6239.41
Concrete Pad:	6237.03
Ground Surface:	6236.7

Calculated Depths and Elevations

Initial Depth to Water (FBGS)

Date Initial Depth Measured:

Last Measured Water Elevation (FAMSL):

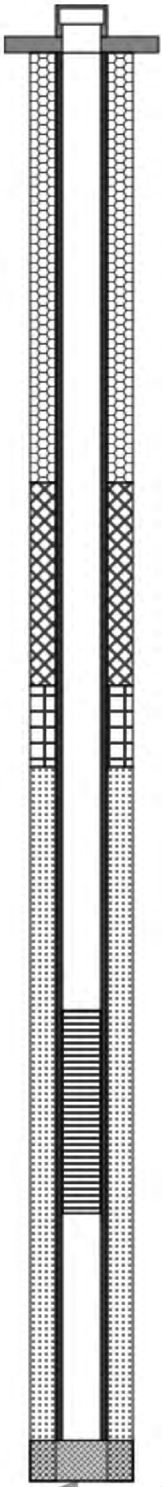
Date Last Measured:

Miscellaneous Information

Screen Slot Size (in.):	0.02
Date Updated:	JAN 18, 2016
Date Printed from EDMS:	AUG 30, 2022

Comments:

CYN-MW2S COMPLETED TO MONITOR POTENTIAL UNDERFLOW AT BEDROCK/ALLUVIUM INTERFACE. NO GROUNDWATER PRESENT IN 16 YEARS OF MONITORING. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES. WELL WAS DECOMMISSIONED 11/15/12.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.7

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	35.2	35.2		8
■	CASING	SCH 00 PVC	0.0	34.2	34.2	4	4.5
⊠	BACKFILL	PORTLAND CEMENT	0.0	10.6	10.6		
☒	SEAL	BENTONITE PELLETS	10.6	15.6	5.0		
⊞	SECONDARY PACK	40-60 SAND	15.6	17.6	2.0		
⊡	PRIMARY PACK	10-20 SAND	17.6	35.2	17.6		
▤	SCREEN	SCH 80 PVC	23.6	28.6	5.0	4	4.5
▨	PLUG BACK	10-20 SAND	34.2	35.2	1.0		

Plugged and Abandoned

Well Name: CYN-MW3
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, Point of Diversion: 23
Owner Name: SNL/NM
Date Drilling Started: JUN 14, 1999
Date Well Dev. Completed: JUN 18, 1999

Drilling Contractor: WDC INC.
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 148.00
Casing Depth (FBGS): 135.00
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN PHYLLITE/SCHIST

Survey Data

Survey Date: AUG 18, 2010
Surveyed By: STEPHEN TOLER
State Plane Coordinates: NAD 83
(X) Easting: 1592168.20
(Y) Northing: 1456774.34

Survey Elevations (FAMSL) NAVD 88

Protective Casing: 6313.85
Top of Inner Well Casing: 6313.26
Concrete Pad: 6312.52
Ground Surface: 6311.9

Calculated Depths and Elevations

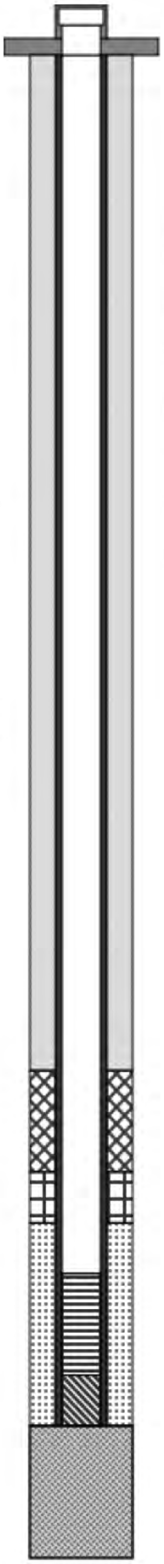
Initial Depth to Water (FBGS) 104.00
Date Initial Depth Measured: JUN 01, 1999
Last Measured Water Elevation (FAMSL): 6175.56
Date Last Measured: MAR 04, 2019

Miscellaneous Information

Screen Slot Size (in.): 0.05
Date Updated: AUG 24, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

FIRST GROUNDWATER ENCOUNTERED IN FRACTURED SCHIST AND PHYLLITE AT 124 FBGS DURING DRILLING (GROUNDWATER INVESTIGATION - CANYONS TEST AREA, SNL/NM NOV. 2001).



Completion Data Measured Depths (FBGS)

Casing Stickup: 1.4

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	148.0	148.0		
■	CASING	SCHEDULE 80 PVC	0.0	135.0	135.0	5	5.5
□	GROUT/BACKFI...	BENTONITE SLURRY	0.0	100.0	100.0		
☒	SEAL	BENTONITE PELLETS	100.0	110.0	10.0		
⊞	SECONDARY P...	20-40 COLORADO S...	110.0	115.0	5.0		
⊡	PRIMARY PACK	4-8 COLORADO SAND	115.0	135.0	20.0		
⊟	SCREEN	SCHEDULE 80 PVC	120.0	130.0	10.0	5	5.5
▧	SUMP	SCHEDULE 80 PVC	130.0	135.0	5.0	5	5.5
▨	PLUG BACK	4-8 COLORADO SAND	135.0	148.0	13.0		

Well Name:	CYN-MW4	**Drilling Contractor:**	WDC INC.
Project Name:	BURN SITE GW	**Drilling Method:**	ARCH/AIR ROTARY
NMOSE Well File Code:	RG-90065, Point of Diversion: 24	**Borehole Depth (FBGS):**	318.00
Owner Name:	SNL/NM	**Casing Depth (FBGS):**	290.00
Date Drilling Started:	JUN 12, 1999	**Geo Location:**	BURN SITE GROUNDWATER AOC
Date Well Dev. Completed:	JUN 18, 1999	**Completion Zone:**	BEDROCK
		Completion Formation:	PRECAMBRIAN QUARTZITE

Survey Data

Survey Date:	SEP 14, 1999
Surveyed By:	ASCI-VLADIMIR JIRIK
State Plane Coordinates:	NAD 83
(X) Easting:	1593795.99
(Y) Northing:	1458765.86

Survey Elevations (FAMSL) NAVD 88

Protective Casing:	6456.48
Top of Inner Well Casing:	6455.48
Concrete Pad:	6454.92
Ground Surface:	6454.7

Calculated Depths and Elevations

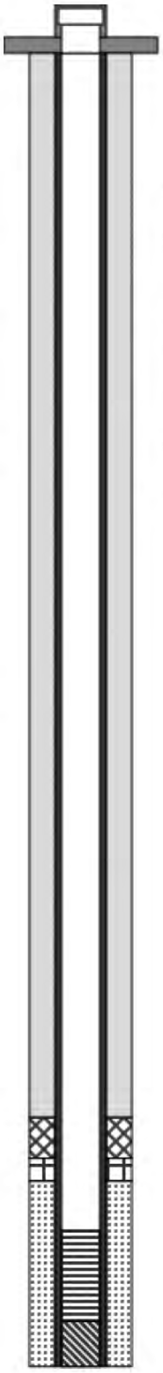
Initial Depth to Water (FBGS)	218.00
Date Initial Depth Measured:	JUN 01, 1999
Last Measured Water Elevation (FAMSL):	6215.06
Date Last Measured:	JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.):	0.02
Date Updated:	SEP 22, 2022
Date Printed from EDMS:	SEP 22, 2022

Comments:

UPGRADIENT WELL FOR BURN SITE. GROUNDWATER ZONE WAS NOT OBVIOUS DURING DRILLING. GROUNDWATER INFERRED TO BE FIRST ENCOUNTERED IN FRACTURED QUARTZITE AT 264 FBGS (GROUNDWATER INVESTIGATION COYOTE TEST AREA, SNL/NM NOV. 2001). 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 0.8

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	318.0	318.0		10
■	CASING	SCHEDULE 80 PVC	0.0	290.0	290.0	5	5.5
□	GROUT/BACKFI...	BENTONITE GROUT	0.0	235.0	235.0		
☒	SEAL	BENTONITE PELLETS	235.0	244.0	9.0		
⊞	SECONDARY P...	20-40 COLORADO S...	244.0	249.0	5.0		
⊡	PRIMARY PACK	4-8 COLORADO SAND	249.0	290.0	41.0		
⊟	SCREEN	SCHEDULE 80 PVC	260.0	280.0	20.0	5	5.5
▧	SUMP	SCHEDULE 80 PVC	280.0	290.0	10.0	5	5.5

Well Name:	CYN-MW6	**Drilling Contractor:**	WDC INC.
Project Name:	BURN SITE GW	**Drilling Method:**	ARCH/AIR ROTARY
NMOSE Well File Code:	RG-90065, Point of Diversion: 26	**Borehole Depth (FBGS):**	165.00
Owner Name:	SNL/NM	**Casing Depth (FBGS):**	161.69
Date Drilling Started:	DEC 07, 2005	**Geo Location:**	BURN SITE GROUNDWATER AOC
Date Well Dev. Completed:	DEC 09, 2005	**Completion Zone:**	BEDROCK
		Completion Formation:	PRECAMBRIAN PHYLLITE

Survey Data

Survey Date: AUG 18, 2010

Surveyed By: STEPHEN TOLER

State Plane Coordinates: NAD 83

(X) Easting: 1592563.70

(Y) Northing: 1457170.60

Survey Elevations (FAMSL) NAVD 88

Protective Casing: 6343.74

Top of Inner Well Casing: 6343.37

Concrete Pad: 6340.76

Ground Surface: 6340.5

Calculated Depths and Elevations

Initial Depth to Water (FBGS) 136.75

Date Initial Depth Measured:

Last Measured Water Elevation (FAMSL): 6181.94

Date Last Measured: JUL 07, 2022

Miscellaneous Information

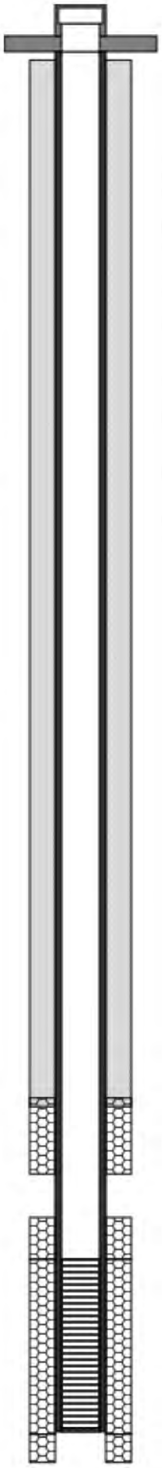
Screen Slot Size (in.): 0.02

Date Updated: AUG 24, 2022

Date Printed from EDMS: AUG 30, 2022

Comments:

NO WATER DETECTED DURING DRILLING. VIDEO LOG SHOWED PARTICLES MOVING IN GROUNDWATER ADJACENT TO FRACTURES AT 142 FBGS. NO SUMP INSTALLED IN WELL.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.9

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	165.0	165.0		
■	CASING	SCHEDULE 80 PVC	0.0	161.7	161.7	5	5.5
□	GROUT/BACKFILL	BENTONITE GRO...	1.0	122.6	122.6		
▦	BENTONITE CHIP...	HYDRATED BENT...	122.6	131.5	8.9		
▦	PRIMARY FILTER...	10/20 SILICA SAND	136.6	141.5	4.9		
▦	PRIMARY FILTER...	10/20 SILICA SAND	141.5	162.0	20.5		
☰	SCREEN	SCHEDULE 80 PVC	141.5	161.3	19.8	5	5.5
▧	SUMP	SCHEDULE 80 PVC	161.3	161.7	0.4	5	5.5
▦	SLOUGH PLUG BA...		162.0	165.0	3.3		

Well Name: CYN-MW7
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, Point of Diversion: 27
Owner Name: SNL/NM
Date Drilling Started: NOV 28, 2005
Date Well Dev. Completed: DEC 06, 2005

Drilling Contractor: WDC INC.
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 356.00
Casing Depth (FBGS): 339.90
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN GRANITIC GNEISS

Survey Data

Survey Date: MAR 09, 2006
Surveyed By: ALBUQUERQUE SURVEYING COMPANY

State Plane Coordinates: NAD 83

(X) Easting: 1589340.22
(Y) Northing: 1456589.07

Survey Elevations (FAMSL) NAVD 88

Protective Casing: 6216.78
Top of Inner Well Casing: 6216.35
Concrete Pad: 6213.90
Ground Surface: 6213.7

Calculated Depths and Elevations

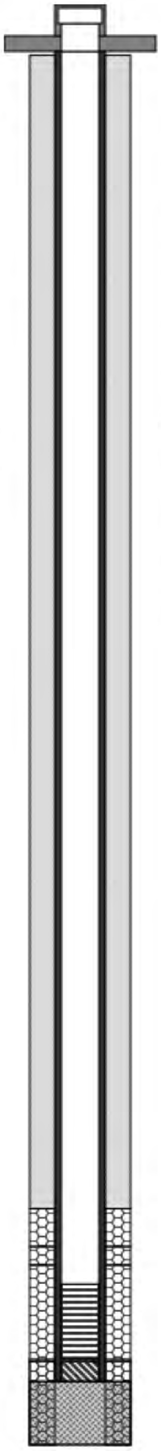
Initial Depth to Water (FBGS) 294.00
Date Initial Depth Measured: NOV 30, 2005
Last Measured Water Elevation (FAMSL): 5907.76
Date Last Measured: JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: AUG 24, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

GROUNDWATER FIRST ENCOUNTERED AT 325 FBGS DURING DRILLING. BOREHOLE WAS VIDEO LOGGED; SATURATED FRACTURE ZONE 325-330 FTBGS. WELL DAMAGED DURING DEVELOPMENT. REPAIRED BY PLACING PVC PLUG ON BOTTOM AND APPROX 4.5 FT. OF SAND. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES. 9/7/11 - WELL WAS REDEVELOPED ON 9/1/11.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.7

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	356.0	356.0		
■	CASING	SCHEDULE 80 PVC	0.0	339.9	339.9	5	5.5
□	GROUT/BACKFILL	BENTONITE GRO...	1.0	295.7	294.7		
⊠	BENTONITE CHIP S...	HYDRATED BEN...	295.7	305.4	9.7		
⊠	SECONDARY BUFF...	40/80 SILICA SAND	305.4	310.1	4.7		
⊠	PRIMARY FILTER P...	10/20 SILICA SAND	310.1	356.0	46.0		
▤	SCREEN	SCHEDULE 80 PVC	315.0	334.2	19.2	5	5.5
⊠	PVC PLUG		334.2	334.7	0.5		
▧	SUMP	10/20 SILICA SAND	334.7	339.9	5.2	5	5.5
⊠	SAND INTRUSION...	10/20 SILICA SAND	334.7	339.9	5.2		
▩	PLUG BACK		339.9	356.0	16.1		

Well Name: CYN-MW8
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, Point of Diversion: 28
Owner Name: SNL/NM
Date Drilling Started: JAN 03, 2006
Date Well Dev. Completed: JAN 12, 2006

Drilling Contractor: WDC INC.
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 365.00
Casing Depth (FBGS): 363.43
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN GRANITIC GNEISS

Survey Data

Survey Date: MAR 09, 2006
Surveyed By: ALBUQUERQUE SURVEYING COMPANY

State Plane Coordinates: NAD 83
(X) Easting: 1589756.06
(Y) Northing: 1456386.76

Survey Elevations (FAMSL) NAVD 88

Protective Casing: 6230.96
Top of Inner Well Casing: 6230.11
Concrete Pad: 6227.95
Ground Surface: 6227.8

Calculated Depths and Elevations

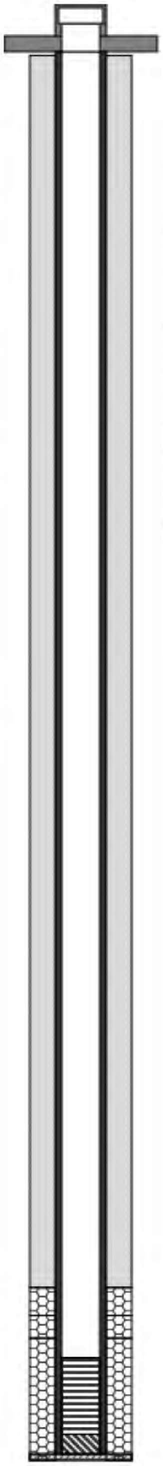
Initial Depth to Water (FBGS) 326.00
Date Initial Depth Measured: JAN 06, 2006
Last Measured Water Elevation (FAMSL): 5905.72
Date Last Measured: JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: AUG 24, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

NO SIGNS OF GROUNDWATER WHILE DRILLING TO 345 FBGS. GROUNDWATER AT 345 FBGS AFTER LETTING BOREHOLE STAND OVER NIGHT. VIDEO LOG SHOWED GROUNDWATER BEARING FRACTURE ZONE IN GRANITIC GNEISS AT 341-346 FBGS. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.3

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	365.0	365.0		
■	CASING	SCHEDULE 80 P...	0.0	363.4	363.4	5	5.5
□	GROUT/BACKFILL	BENTONITE GR...	1.0	320.3	319.3		
▨	BENTONITE CHIP S...	HYDRATED BEN...	320.3	327.5	7.2		
▨	SECONDARY BUFF...	40/80 SILICA SA...	327.5	333.4	5.9		
▨	PRIMARY FILTER P...	10/20 SILICA SA...	333.4	365.0	31.7		
☰	SCREEN	SCHEDULE 80 P...	338.5	358.3	19.8	5	5.5
▧	SUMP	PVC	358.3	363.4	5.2	5	5.5
▩	PLUG BACK	10/20 SILICA SA...	363.4	365.0	1.6		

Well Name:	CYN-MW9
Project Name:	BURN SITE GW
NMOSE Well File Code:	RG-90065, POINT OF DIVERSION: 109
Owner Name:	SNL/NM
Date Drilling Started:	JUL 12, 2010
Date Well Dev. Completed:	JUL 27, 2010

Drilling Contractor:	WDC INC.
Drilling Method:	ARCH/AIR ROTARY
Borehole Depth (FBGS):	207.00
Casing Depth (FBGS):	200.80
Geo Location:	BURN SITE GROUNDWATER AOC
Completion Zone:	BEDROCK
Completion Formation:	PRECAMBRIAN PHYLLITE

Survey Data

Survey Date:	AUG 18, 2010
Surveyed By:	STEPHEN TOLER
State Plane Coordinates:	NAD 83
(X) Easting:	1593006.71
(Y) Northing:	1457261.48

Survey Elevations (FAMSL) NAVD 88

Protective Casing:	6361.18
Top of Inner Well Casing:	6360.67
Concrete Pad:	6358.77
Ground Surface:	6358.5

Calculated Depths and Elevations

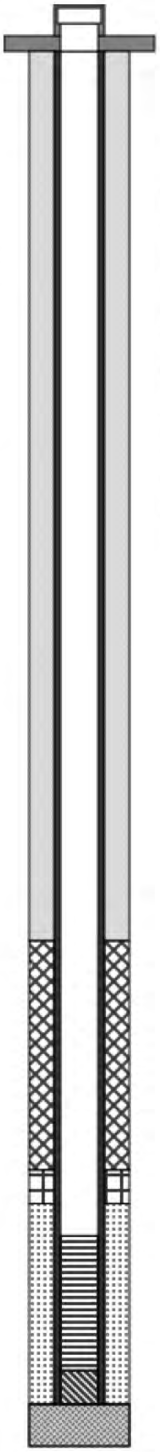
Initial Depth to Water (FBGS)	160.50
Date Initial Depth Measured:	JUL 13, 2010
Last Measured Water Elevation (FAMSL):	6173.81
Date Last Measured:	JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.):	0.02
Date Updated:	AUG 25, 2022
Date Printed from EDMS:	AUG 30, 2022

Comments:

FIRST GROUNDWATER POSSIBLY ENCOUNTERED DURING DRILLING AT 180 FBGS. 5 IN. PVC BUNG INSTALLED IN BOTTOM OF SUMP.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.2

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	207.0	207.0		9.625
■	CASING	PVC	0.0	200.8	200.8	4.77	5.56
☐	GROUT/BACK...	BENT. GROUT/CON...	0.0	132.0	132.0		
☒	SEAL	3/8 IN. BENT. CHIPS	132.0	166.0	34.0		
⊞	SECONDARY...	60 SILICA SAND	166.0	171.0	5.0		
⊡	PRIMARY PA...	10-20 SILICA SAND	171.0	200.8	29.8		
☰	SCREEN	PVC	175.8	195.8	20.0	4.77	5.56
▧	SUMP	PVC	195.8	200.8	5.0	4.77	5.56
▩	PLUG BACK	10-20 SILICA SAND	200.8	207.0	6.2		

Well Name: CYN-MW10
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, POINT OF DIVERSION: 110
Owner Name: SNL/NM
Date Drilling Started: JUL 14, 2010
Date Well Dev. Completed: JUL 28, 2010

Drilling Contractor: WDC INC.
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 181.00
Casing Depth (FBGS): 175.40
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN PHYLLITE

Survey Data

Survey Date: AUG 18, 2010
Surveyed By: STEPHEN TOLER
State Plane Coordinates: NAD 83
(X) Easting: 1593043.38
(Y) Northing: 1456813.04

Survey Elevations (FAMSL) NAVD 88

Protective Casing: 6346.00
Top of Inner Well Casing: 6345.45
Concrete Pad: 6343.32
Ground Surface: 6342.8

Calculated Depths and Elevations

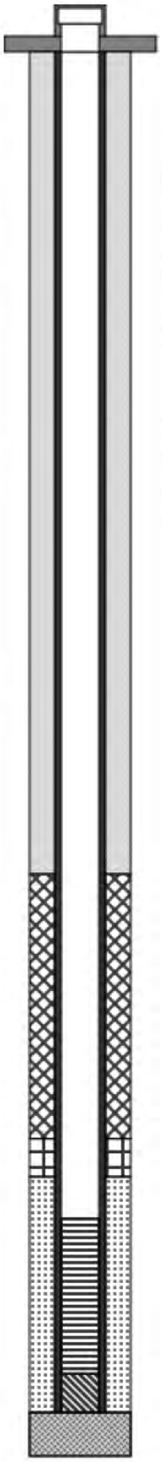
Initial Depth to Water (FBGS) 117.83
Date Initial Depth Measured: JUL 16, 2010
Last Measured Water Elevation (FAMSL): 6198.68
Date Last Measured: JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: AUG 25, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

AQUIFER IS SEMI-CONFINED, FIRST VERY DAMP CUTTINGS SEEN DURING DRILLING WAS AT ~160 FBGS. BOREHOLE CUTTINGS AND SAND WERE USED IN THE PLUG BACK INTERVAL. 5 IN. PVC BUNG INSTALLED IN BOTTOM OF SUMP.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.7

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	181.0	181.0		9.625
■	CASING	PVC	0.0	175.4	175.4	4.77	5.56
☐	GROUT/BACK...	BENT. GROUT/CE...	0.0	106.0	106.0		
☒	SEAL	3/8 IN. BENT. CHIPS	106.0	140.1	34.1		
⊞	SECONDARY P...	60 SILICA SAND	140.1	145.0	4.9		
⊡	PRIMARY PACK	10-20 SILICA SAND	145.0	175.4	30.4		
☰	SCREEN	PVC	150.4	170.4	20.0	4.77	5.56
▧	SUMP	PVC	170.4	175.4	5.0	4.77	5.56
▩	PLUG BACK	10-20 SILICA SAND	175.4	181.0	5.6		

Well Name:	CYN-MW11	**Drilling Contractor:**	WDC EXPLORATION & WELLS
Project Name:	BURN SITE GW	**Drilling Method:**	ARCH/AIR ROTARY
NMOSE Well File Code:	RG-90065, POINT IF DIVERSION: 111	**Borehole Depth (FBGS):**	258.00
Owner Name:	SNL/NM	**Casing Depth (FBGS):**	254.80
Date Drilling Started:	JUL 15, 2010	**Geo Location:**	BURN SITE GROUNDWATER AOC
Date Well Dev. Completed:	JUL 29, 2010	**Completion Zone:**	BEDROCK
		Completion Formation:	PRECAMBRIAN PHYLLITE

Survey Data

Survey Date:	AUG 18, 2010
Surveyed By:	STEPHEN TOLER
State Plane Coordinates:	NAD 83
(X) Easting:	1593549.25
(Y) Northing:	1457079.74

Survey Elevations (FAMSL) NAVD 88

Protective Casing:	6374.87
Top of Inner Well Casing:	6374.41
Concrete Pad:	6372.27
Ground Surface:	6371.9

Calculated Depths and Elevations

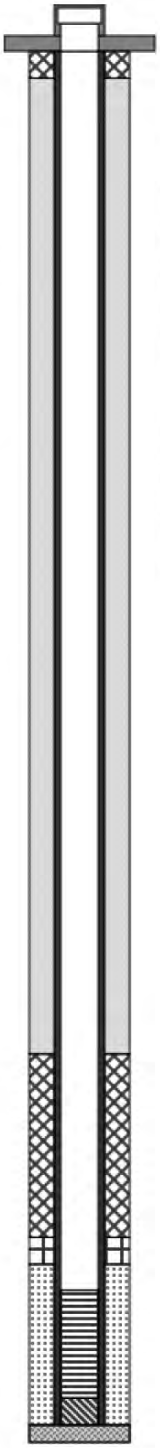
Initial Depth to Water (FBGS)	95.00
Date Initial Depth Measured:	JUL 16, 2010
Last Measured Water Elevation (FAMSL):	6245.51
Date Last Measured:	JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.):	0.02
Date Updated:	AUG 25, 2022
Date Printed from EDMS:	AUG 30, 2022

Comments:

AQUIFER IS SEMI-CONFINED, FIRST FREE WATER DURING DRILLING AT ~230 FBGS. 5 INCH PVC BUNG INSTALLED IN BOTTOM OF SUMP. FIRST GROUNDWATER ENCOUNTERED IN FRACTURED PHYLLITE AT 230 FBGS DURING DRILLING.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.5

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	258.0	258.0		9.625
■	CASING	PVC	0.0	254.8	254.8	4.77	5.56
☒	SEAL	CEMENT	0.0	5.0	5.0		
☐	GROUT/BACK...	BENT. GROUT/CE...	5.0	186.0	181.0		
☒	SEAL	3/8 IN. BENT. CHIPS	186.0	220.0	34.0		
⊞	SECONDARY P...	60 SILICA SAND	220.0	225.0	5.0		
⊡	PRIMARY PACK	10-20 SILICA SAND	225.0	254.8	29.8		
⊟	SCREEN	PVC	229.8	249.8	20.0	4.77	5.56
▧	SUMP	PVC	249.8	254.8	5.0	4.77	5.56
▩	PLUG BACK	10-20 SILICA SAND	254.8	258.0	3.2		

Well Name: CYN-MW12
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, POINT OF DIVERSION: 112
Owner Name: SNL/NM
Date Drilling Started: JUL 20, 2010
Date Well Dev. Completed: JUL 29, 2010

Drilling Contractor: WDC INC.
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 290.00
Casing Depth (FBGS): 277.50
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN PHYLLITE

Survey Data

Survey Date: AUG 18, 2010
Surveyed By: STEPHEN TOLER
State Plane Coordinates: NAD 83
(X) Easting: 1592251.79
(Y) Northing: 1457335.12

Survey Elevations (FAMSL) NAVD 88

Protective Casing: 6345.67
Top of Inner Well Casing: 6345.16
Concrete Pad: 6343.15
Ground Surface: 6342.9

Calculated Depths and Elevations

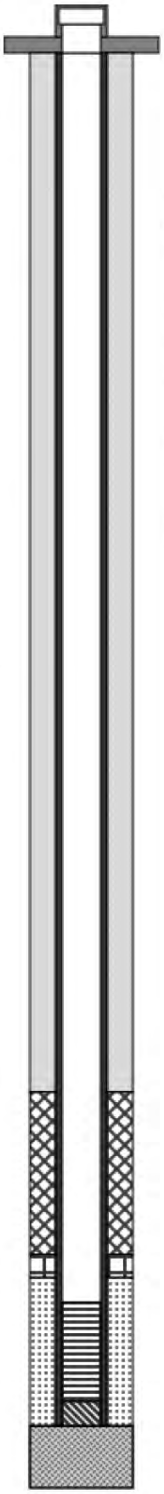
Initial Depth to Water (FBGS) 203.50
Date Initial Depth Measured: JUL 23, 2010
Last Measured Water Elevation (FAMSL): 6115.98
Date Last Measured: JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: AUG 25, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

AQUIFER IS SEMI-CONFINED, FIRST FREE WATER SEEN DURING DRILLING AT ~261 FBGS. 5 IN. PVC BUNG INSTALLED IN BOTTOM OF SUMP.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.3

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	290.0	290.0		9.625
■	CASING	PVC	0.0	277.5	277.5	4.77	5.56
□	GROUT/BACK...	BENT. GROUT/CE...	0.0	210.0	210.0		
☒	SEAL	3/8 IN. BENT. CHIPS	210.0	242.8	32.8		
⊞	SECONDARY P...	60 SILICA SAND	242.8	247.5	4.7		
⊞	PRIMARY PACK	10-20 SILICA SAND	247.5	277.5	30.0		
▤	SCREEN	PVC	252.5	272.5	20.0	4.77	5.56
▧	SUMP	PVC	272.5	277.5	5.0	4.77	5.56
▩	PLUG BACK	10-20 SILICA SAND	277.5	290.0	12.5		

Well Name: CYN-MW13
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, POINT OF DIVERSION: 122
Owner Name: SNL/NM
Date Drilling Started: NOV 27, 2012
Date Well Dev. Completed: DEC 05, 2012

Drilling Contractor: BOART LONGYEAR
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 403.00
Casing Depth (FBGS): 402.20
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN GRANITIC GNEISS

Survey Data

Survey Date: FEB 08, 2013
Surveyed By: STEPHEN TOLER

State Plane Coordinates: NAD 83
(X) Easting: 1590207.12
(Y) Northing: 1456160.73

Survey Elevations (FAMSL) NAVD 88

Protective Casing: 6238.38
Top of Inner Well Casing: 6237.79
Concrete Pad: 6236.45
Ground Surface: 6236.0

Calculated Depths and Elevations

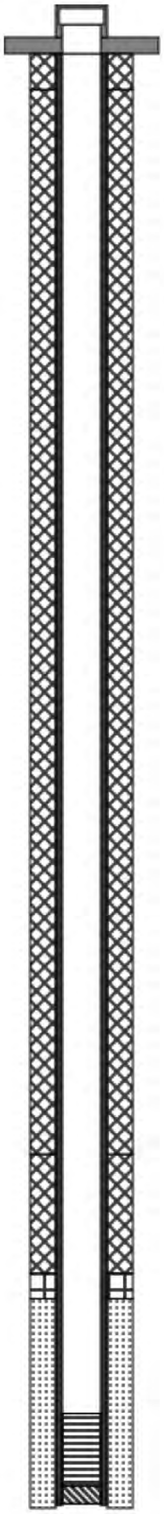
Initial Depth to Water (FBGS) 322.10
Date Initial Depth Measured: DEC 05, 2012
Last Measured Water Elevation (FAMSL): 5907.30
Date Last Measured: JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: AUG 25, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

SPUDDED IN ALLUVIUM. VIDEO LOG SHOWED FRACTURED BEDROCK ZONE FROM 379-394 FBGS. MOST SIGNIFICANT FRACTURES FROM 387-391 FBGS. CONFINED CONDITIONS. AIR ROTARY CASING HAMMER AND TRI-CONE BIT (9.875-INCH) TO 29 FBGS AND 10.75-INCH STEEL SURFACE CASING SET TO THAT DEPTH. TOP OF BEDROCK AT 29 FBGS. FIRST GROUNDWATER ENCOUNTERED AT 379 FBGS DURING DRILLING. THE STEEL SURFACE CASING EXTENDS ABOVE GROUND SURFACE AND ALSO SERVES AS STOVEPIPE. AIR ROTARY DOWNHOLE HAMMER WITH BUTTON BIT (9.875-INCH) TO 403 FBGS. WELL DEVELOPED ON 12/5/12. BOTTOM CAP (SCH 80 PVC) WITH PVC INSERT FROM 401.8 TO 402.2 FBGS. SURVEYING CONTROL INC. USED NAD83/NAVD88.



Completion Data Measured Depths (FBGS)

Casing Stickup: 1.8

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	403.0	403.0	10	
■	CASING	SCHEDULE 80 PVC	0.0	402.2	402.2	4.75	5.625
☒	SEAL	CEMENT	0.0	10.0	10.0		
☒	SEAL	BENTONITE GRO...	10.0	305.0	295.0		
☒	SEAL	BENTONITE CHIPS	305.0	338.0	33.0		
⊞	SECONDARY PA...	CSS #60	338.0	345.0	7.0		
⊡	PRIMARY PACK	CSS #10-20	345.0	403.0	58.0		
⊟	SCREEN	SCHEDULE 80 PVC	376.8	396.8	20.0	4.75	5.625
▧	SUMP	SCHEDULE 80 PVC	396.8	401.8	5.0	4.75	5.625

Well Name: CYN-MW14A
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065 POINT OF DIVERSION: 123
Owner Name: SNL/NM
Date Drilling Started: NOV 16, 2014
Date Well Dev. Completed: DEC 04, 2014

Drilling Contractor: NATIONAL EWP
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 298.60
Casing Depth (FBGS): 298.60
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN PHYLLITE

Survey Data

Survey Date: JAN 30, 2015
Surveyed By: STEPHEN TOLER
State Plane Coordinates: NAD 83
(X) Easting: 1592169.19
(Y) Northing: 1456799.62

Survey Elevations (FAMSL) NAVD 88

Protective Casing: 6316.39
Top of Inner Well Casing: 6315.85
Concrete Pad: 6313.76
Ground Surface: 6313.5

Calculated Depths and Elevations

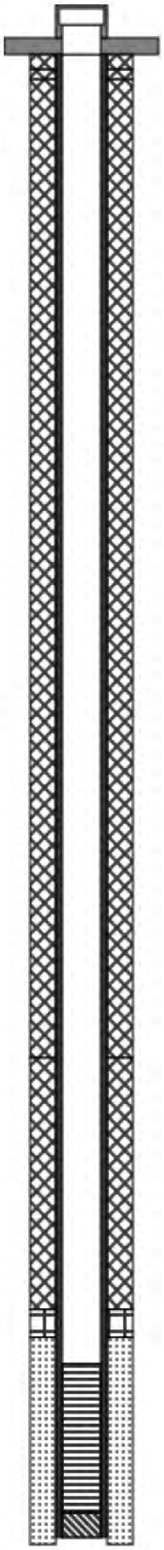
Initial Depth to Water (FBGS) 183.00
Date Initial Depth Measured: NOV 12, 2014
Last Measured Water Elevation (FAMSL): 6117.66
Date Last Measured: JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: AUG 25, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

BOREHOLE DID NOT INTERCEPT A SHALLOW FRACTURE ZONE AND WAS NOT COMPLETED AS A REPLACEMENT WELL FOR CYN-MW3 AS PLANNED. VIDEO LOGGING OF DRY BOREHOLE SHOWED FRACTURE ZONES AT 279.6 TO 280.1 FBGS AND FROM 286.3 TO 286.7 FBGS. NO WEEPING FRACTURES. RIG CHATTER AND POSSIBLY DAMP CUTTINGS AT 285 FBGS. NO GROUNDWATER NOTICABLE WITH WATER-LEVEL METER AT END OF WORK DAY WHILE AIR LIFTING. NEXT MORNING, GROUNDWATER LEVEL AT 182 FBGS IN OPEN BOREHOLE. THE WATER BEARING FRACTURE ZONE IS INFERED TO BE 286.3 TO 286.7.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.5

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	298.6	298.6		
■	CASING	SCHEDULE 80 PVC	0.0	298.6	298.6	5	6
☒	SEAL	CONCRETE	0.0	3.0	3.0		
☒	SEAL	BENTONITE CHIPS	3.0	5.0	2.0		
☒	SEAL	BENTONITE GROUT	5.0	202.0	197.0		
☒	SEAL	BENTONITE CHIPS	202.0	252.7	50.7		
⊞	SECONDARY PACK	#60 SAND	252.7	258.3	5.6		
⊡	PRIMARY PACK	#10-20 SAND	258.3	300.0	41.7		
▤	SCREEN	SCHEDULE 80 PVC	263.6	293.6	30.0	5	6
▧	SUMP	SCHEDULE 80 PVC	293.6	298.6	5.0	5	6

Well Name: CYN-MW15
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, POINT OF DIVERSION: 124
Owner Name: SNL/NM
Date Drilling Started: NOV 14, 2014
Date Well Dev. Completed: NOV 18, 2014

Drilling Contractor: NATIONAL EWP
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 195.00
Casing Depth (FBGS): 195.00
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN PHYLLITE

Survey Data

Survey Date: JAN 30, 2015
Surveyed By: STEPHEN TOLER
State Plane Coordinates: NAD 83
(X) Easting: 1592586.39
(Y) Northing: 1457182.99

Survey Elevations (FAMSL) NAVD 88

Protective Casing: 6345.19
Top of Inner Well Casing: 6344.44
Concrete Pad: 6342.74
Ground Surface: 6342.3

Calculated Depths and Elevations

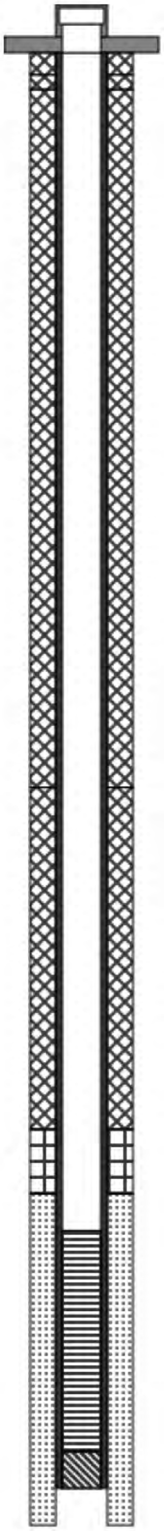
Initial Depth to Water (FBGS) 153.65
Date Initial Depth Measured: NOV 18, 2014
Last Measured Water Elevation (FAMSL): 6170.24
Date Last Measured: JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: AUG 25, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

WELL INSTALLED AS REPLACEMENT FOR CYN-MW6. GROUNDWATER ENCOUNTERED AT APPROXIMATELY 174 FBGS WHILE DRILLING WITH DAMP CUTTINGS. DURING DRILLING, NO WATER PRODUCTION APPARENTLY FROM 185 TO 200 FBGS. WATER LEVEL ROSE TO APPROXIMATELY 155 FBGS OVERNIGHT.. VIDEO LOGGING THROUGH CLOUDY WATER WAS NOT USEFUL FOR DETERMING SATURATED FRACTURE ZONE; DRY BOREHOLE ABOVE WATER COLUMN - DID NOT HAVE ANY SIGNIFICANT FRACURES OR WEEPING FRACURES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.2

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	195.0	195.0		
■	CASING	SCHEDULE 80 PVC	0.0	195.0	195.0	4.75	5.5
☒	SEAL	CONCRETE	0.0	3.0	3.0		
☒	SEAL	BENTONITE CHIPS	3.0	5.0	2.0		
☒	SEAL	BENTONITE GRO...	5.0	99.8	94.8		
☒	SEAL	BENTONITE CHIPS	99.8	146.2	46.4		
⊞	SECONDARY PA...	#60 SAND	146.2	155.0	8.8		
⊡	PRIMARY PACK	#10-20 SAND	155.0	200.0	45.0		
☰	SCREEN	SCHEDULE 80 PVC	160.0	190.0	30.0	4.75	5.5
▧	SUMP	SCHEDULE 80 PVC	190.0	195.0	5.0	4.75	5.5

Well Name: CYN-MW16
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, POINT OF DIVERSION: 129
Owner Name: SNL/NM
Date Drilling Started: OCT 01, 2019
Date Well Dev. Completed: NOV 05, 2019

Drilling Contractor: CASCADE DRILLING LP
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 414.20
Casing Depth (FBGS): 410.60
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN GRANITIC GNEISS

Survey Data

Survey Date: DEC 16, 2019
Surveyed By: BENJAMIN A. ARAGON, NMPS 15268
State Plane Coordinates: NAD 83
(X) Easting: 1589728.64
(Y) Northing: 1455888.65

Survey Elevations (FAMSL)

Protective Casing: 6250.47
Top of Inner Well Casing: 6249.60
Concrete Pad: 6247.64
Ground Surface: 6247.4

Calculated Depths and Elevations

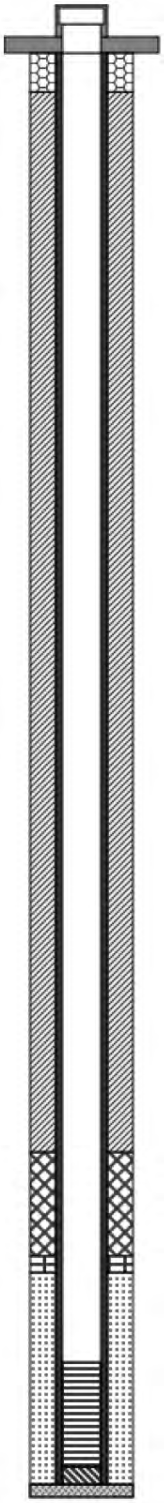
Initial Depth to Water (FBGS) 338.60
Date Initial Depth Measured: NOV 04, 2019
Last Measured Water Elevation (FAMSL): 5907.17
Date Last Measured: JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: AUG 25, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

WELL COMPLETED IN PRECAMBRIAN BEDROCK. INITIAL DEPTH TO WATER ON 11/4/2019 BEFORE WELL DEVELOPMENT. CASING STICKUP MEASURED FROM TOP OF PVC TO GROUND SURFACE. CASING DEPTH MEASURED ON 11/5/2019 AFTER WELL DEVELOPMENT.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.2

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	414.2	414.2		
■	CASING	SCHEDULE 80 PVC	0.0	410.6	410.6	4.75	5.5
◲	SURFACE SEAL	QUIKRETE	0.0	11.2	11.2		
▨	GROUT	QUIK-GROUT	11.2	315.3	304.1		
☒	SEAL	3/8" BENTONITE C...	315.3	345.1	29.8		
⊞	SECONDARY P...	#60 PW GILLIBRAND	345.1	349.8	4.7		
⊡	PRIMARY PACK	#10-20 CO SILICA S...	349.8	410.6	60.8		
☰	SCREEN	SCHEDULE 80 PVC	375.6	405.6	30.0	4.75	5.5
▧	SUMP	SCHEDULE 80 PVC	405.6	410.6	5.0	4.75	5.5
▩	PLUG BACK	#10-20 CO SILICA S...	410.6	414.2	3.6		

Well Name:	CYN-MW17
Project Name:	BURN SITE GW
NMOSE Well File Code:	RG-90065, POINT OF DIVERSION: 130
Owner Name:	SNL/NM
Date Drilling Started:	OCT 07, 2019
Date Well Dev. Completed:	NOV 06, 2019

Drilling Contractor:	CASCADE DRILLING LP
Drilling Method:	ARCH/AIR ROTARY
Borehole Depth (FBGS):	415.00
Casing Depth (FBGS):	405.27
Geo Location:	BURN SITE GROUNDWATER AOC
Completion Zone:	BEDROCK
Completion Formation:	PRECAMBRIAN GRANITIC GNEISS

Survey Data

Survey Date:	DEC 16, 2019
Surveyed By:	BENJAMIN A. ARAGON, NMPS 15268
State Plane Coordinates:	NAD 83
(X) Easting:	1590747.05
(Y) Northing:	1456494.58

Survey Elevations (FAMSL)

Protective Casing:	6269.84
Top of Inner Well Casing:	6268.95
Concrete Pad:	6266.86
Ground Surface:	6266.6

Calculated Depths and Elevations

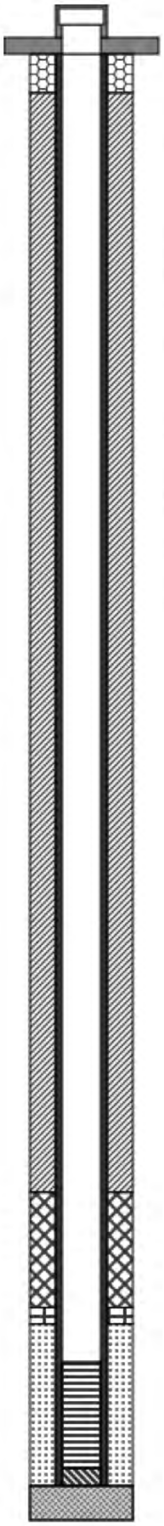
Initial Depth to Water (FBGS)	357.77
Date Initial Depth Measured:	NOV 05, 2019
Last Measured Water Elevation (FAMSL):	5907.28
Date Last Measured:	JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.):	0.02
Date Updated:	AUG 25, 2022
Date Printed from EDMS:	AUG 30, 2022

Comments:

WELL COMPLETED IN PRECAMBRIAN BEDROCK. INITIAL DEPTH TO WATER ON 11/5/2019 BEFORE WELL DEVELOPMENT. CASING STICKUP MEASURED FROM TOP OF PVC TO GROUND SURFACE. CASING DEPTH MEASURED ON 11/6/2019 AFTER WELL DEVELOPMENT.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.3

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	415.0	415.0		
■	CASING	SCHEDULE 80 PVC	0.0	405.3	405.3	4.75	5.5
⊞	SURFACE SEAL	QUIKRETE	0.0	11.0	11.0		
▨	GROUT	QUIK-GROUT	11.0	322.2	311.2		
☒	SEAL	3/8" BENTONITE C...	322.2	354.8	32.6		
⊞	SECONDARY P...	#60 PW GILLIBRAND	354.8	359.5	4.7		
⊡	PRIMARY PACK	#10-20 CO SILICA S...	359.5	405.3	45.8		
☰	SCREEN	SCHEDULE 80 PVC	370.3	400.3	30.0	4.75	5.5
▧	SUMP	SCHEDULE 80 PVC	400.3	405.3	5.0	4.75	5.5
▩	PLUG BACK	#10-20 CO SILICA S...	405.3	415.0	9.7		

Well Name: CYN-MW18
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, POINT OF DIVERSION: 131
Owner Name: SNL/NM
Date Drilling Started: OCT 14, 2019
Date Well Dev. Completed: NOV 07, 2019

Drilling Contractor: CASCADE DRILLING LP
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 315.00
Casing Depth (FBGS): 305.41
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PRECAMBRIAN PHYLLITE/QUARTZITE

Survey Data

Survey Date: DEC 16, 2019
Surveyed By: BENJAMIN A. ARAGON, NMPS 15268

State Plane Coordinates: NAD 83
(X) Easting: 1591494.87
(Y) Northing: 1456776.53

Survey Elevations (FAMSL)

Protective Casing: 6304.86
Top of Inner Well Casing: 6304.02
Concrete Pad: 6301.88
Ground Surface: 6301.5

Calculated Depths and Elevations

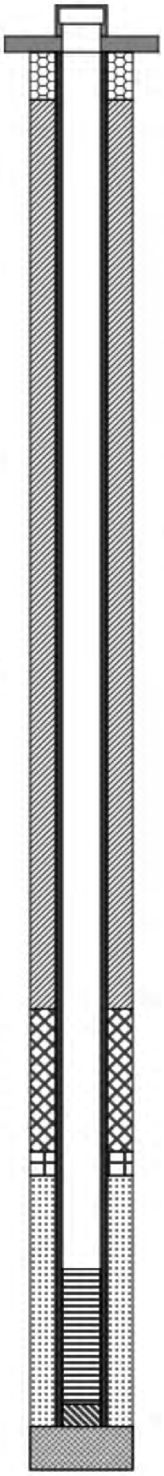
Initial Depth to Water (FBGS) 242.61
Date Initial Depth Measured: NOV 07, 2019
Last Measured Water Elevation (FAMSL): 6052.05
Date Last Measured: JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: AUG 25, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

WELL COMPLETED IN PRECAMBRIAN BEDROCK. INITIAL DEPTH TO WATER ON 11/7/2019 BEFORE WELL DEVELOPMENT. CASING STICKUP MEASURED FROM TOP OF PVC TO GROUND SURFACE. CASING DEPTH MEASURED ON 11/7/2019 AFTER WELL DEVELOPMENT.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.5

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	315.0	315.0		
■	CASING	SCHEDULE 80 PVC	0.0	305.4	305.4	4.75	5.5
▣	SURFACE SEAL	QUIKRETE	0.0	10.6	10.6		
▨	GROUT	QUIK-GROUT	10.6	212.6	202.0		
☒	SEAL	3/8" BENTONITE C...	212.6	244.3	31.7		
⊞	SECONDARY P...	#60 PW GILLIBRAND	244.3	249.6	5.3		
⊡	PRIMARY PACK	#10-20 CO SILICA S...	249.6	305.4	55.8		
☰	SCREEN	SCHEDULE 80 PVC	270.4	300.4	30.0	4.75	5.5
▧	SUMP	SCHEDULE 80 PVC	300.4	305.4	5.0	4.75	5.5
▩	PLUG BACK	#10-20 CO SILICA S...	305.4	315.0	9.6		

Well Name: CYN-MW19
Project Name: BURN SITE GW
NMOSE Well File Code: RG-90065, POINT OF DIVERSION: 132
Owner Name: SNL/NM
Date Drilling Started: OCT 21, 2019
Date Well Dev. Completed: NOV 08, 2019

Drilling Contractor: CASCADE DRILLING LP
Drilling Method: ARCH/AIR ROTARY
Borehole Depth (FBGS): 95.60
Casing Depth (FBGS): 94.27
Geo Location: BURN SITE GROUNDWATER AOC
Completion Zone: BEDROCK
Completion Formation: PENN LIMESTONE/PRE-C PHYLLITE

Survey Data

Survey Date: DEC 16, 2019
Surveyed By: BENJAMIN A. ARAGON, NMPS 15268
State Plane Coordinates: NAD 83
(X) Easting: 1594016.29
(Y) Northing: 1457149.89

Survey Elevations (FAMSL)

Protective Casing: 6411.32
Top of Inner Well Casing: 6410.43
Concrete Pad: 6408.36
Ground Surface: 6408.1

Calculated Depths and Elevations

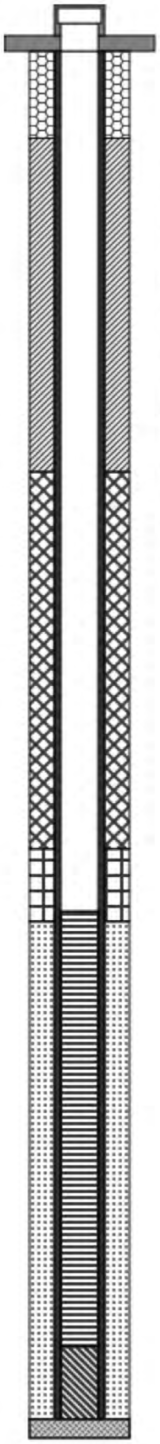
Initial Depth to Water (FBGS) 43.40
Date Initial Depth Measured: NOV 07, 2019
Last Measured Water Elevation (FAMSL): 6363.70
Date Last Measured: JUL 07, 2022

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: AUG 25, 2022
Date Printed from EDMS: AUG 30, 2022

Comments:

WELL COMPLETED IN PALEOZOIC LIMESTONE AND PRECAMBRIAN BEDROCK. INITIAL DEPTH TO WATER ON 11/7/2019 BEFORE WELL DEVELOPMENT.
CASING STICKUP MEASURED FROM TOP OF PVC TO GROUND SURFACE. CASING DEPTH MEASURED ON 11/8/2019 AFTER WELL DEVELOPMENT.

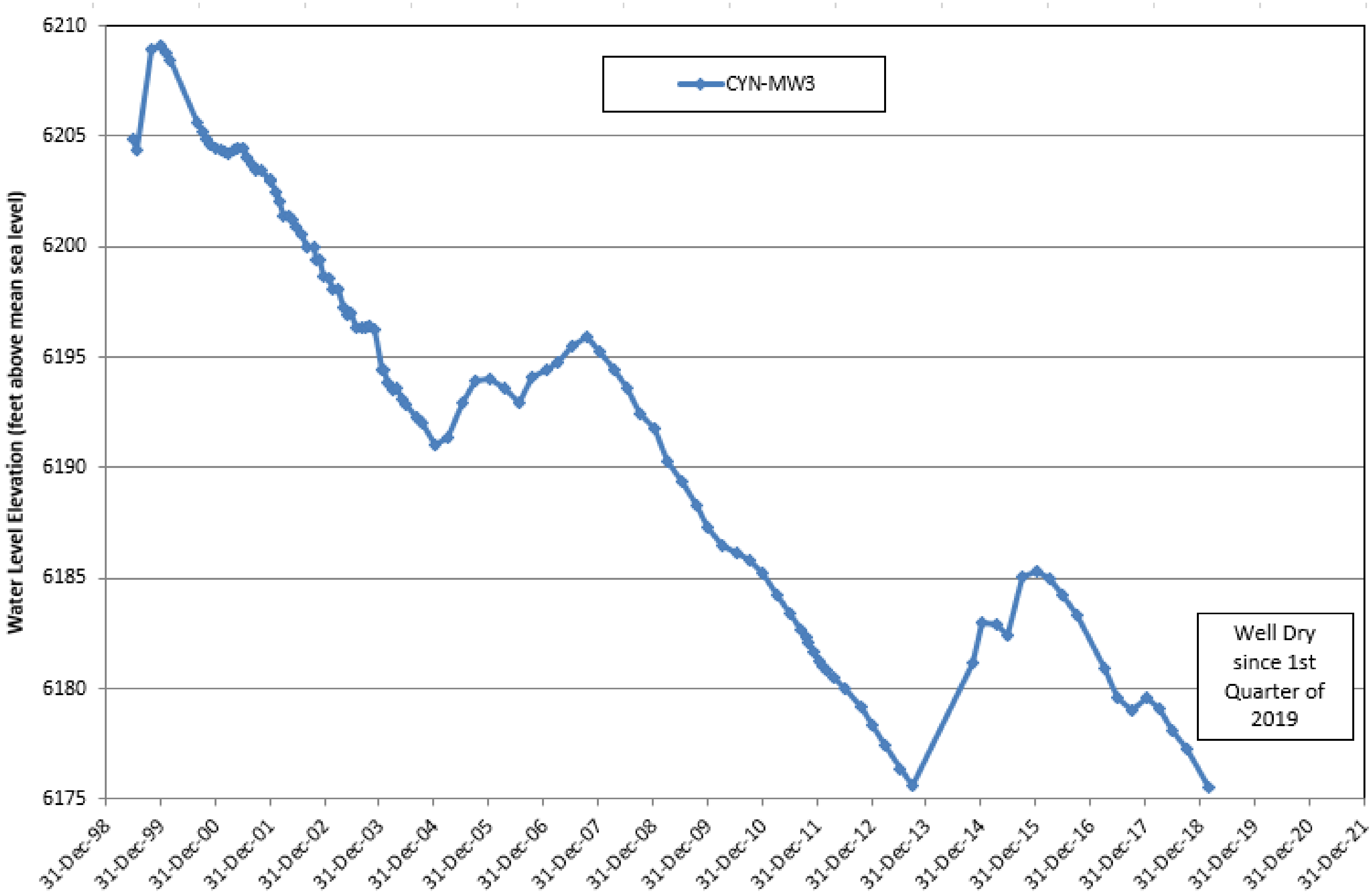


Completion Data Measured Depths (FBGS)

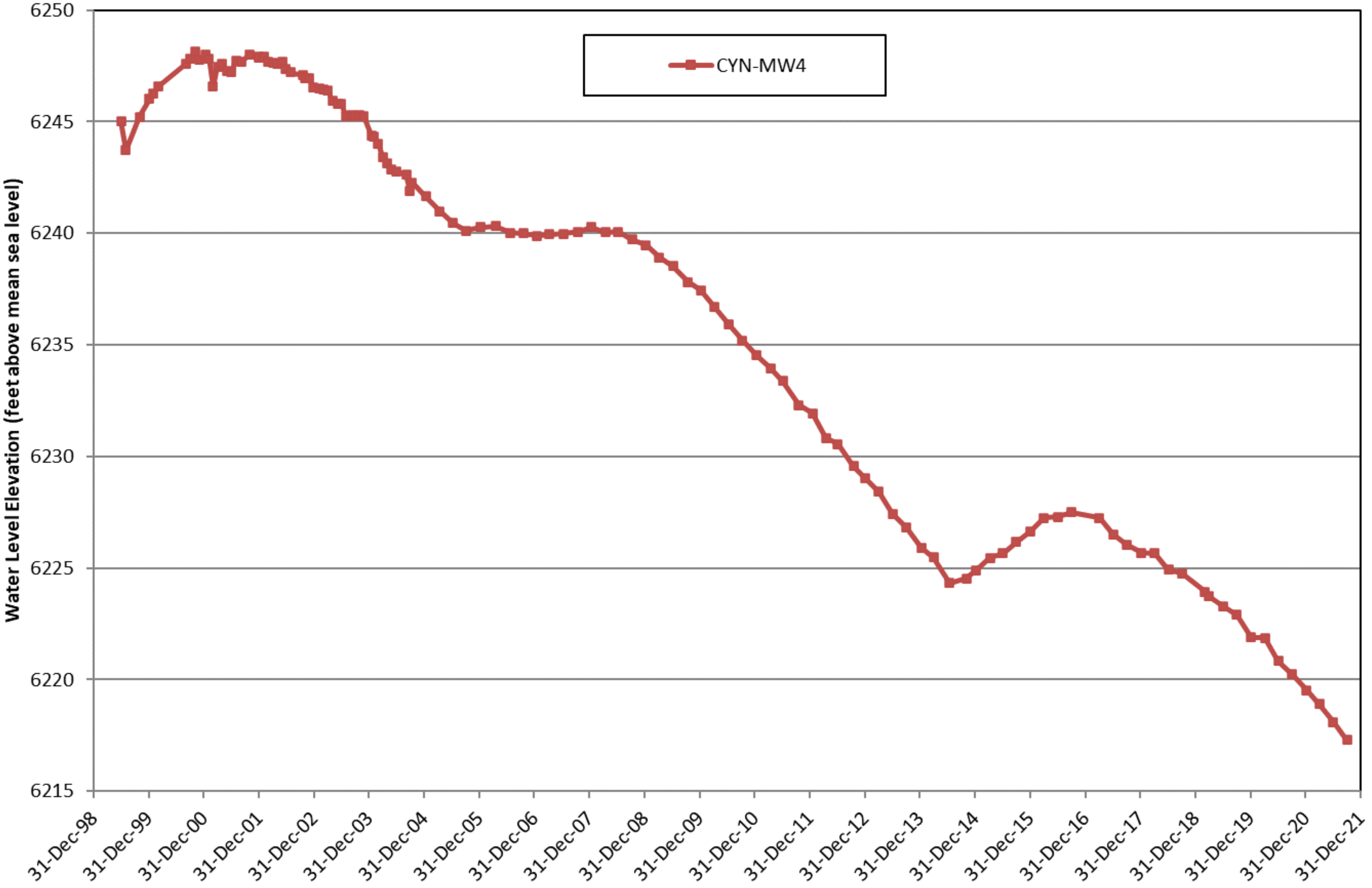
Casing Stickup: 2.3

	Interval	Material	Start	Stop	Length	ID	OD
	BOREHOLE		0.0	95.6	95.6		
■	CASING	SCHEDULE 80 PVC	0.0	94.3	94.3	4.75	5.5
⊡	SURFACE SEAL	QUIKRETE	0.0	6.0	6.0		
▨	GROUT	QUIK-GROUT	6.0	29.0	23.0		
☒	SEAL	3/8" BENTONITE CH...	29.0	55.0	26.0		
⊞	SECONDARY PA...	#60 PW GILLIBRAND	55.0	60.0	5.0		
☰	SCREEN	SCHEDULE 80 PVC	59.3	89.3	30.0	4.75	5.5
⊞	PRIMARY PACK	#10-20 CO SILICA S...	60.0	94.3	34.3		
▧	SUMP	SCHEDULE 80 PVC	89.3	94.3	5.0	4.75	5.5
▩	PLUG BACK	#10-20 CO SILICA S...	94.3	95.6	1.3		

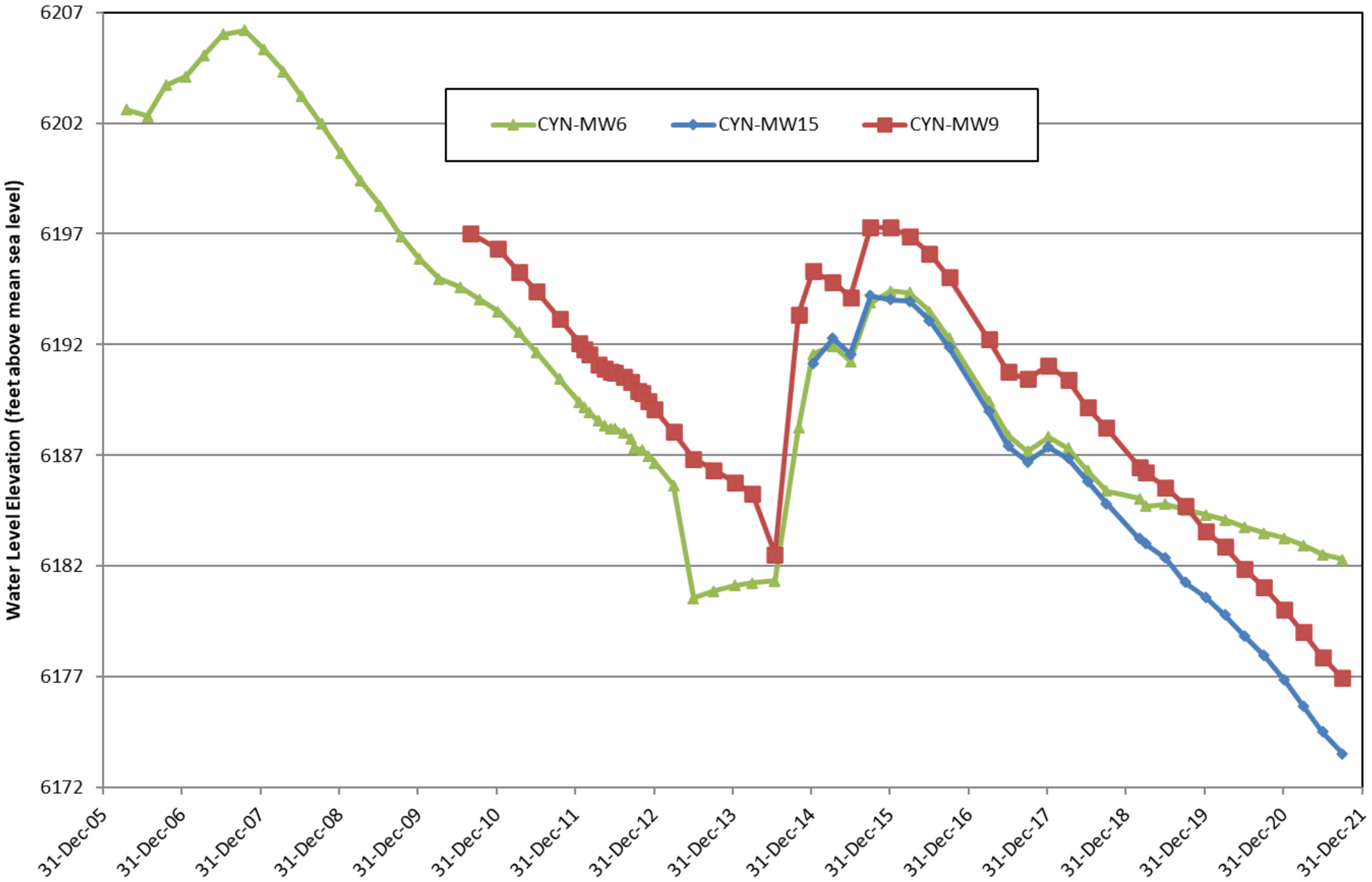
Appendix F
Burn Site Groundwater Hydrographs



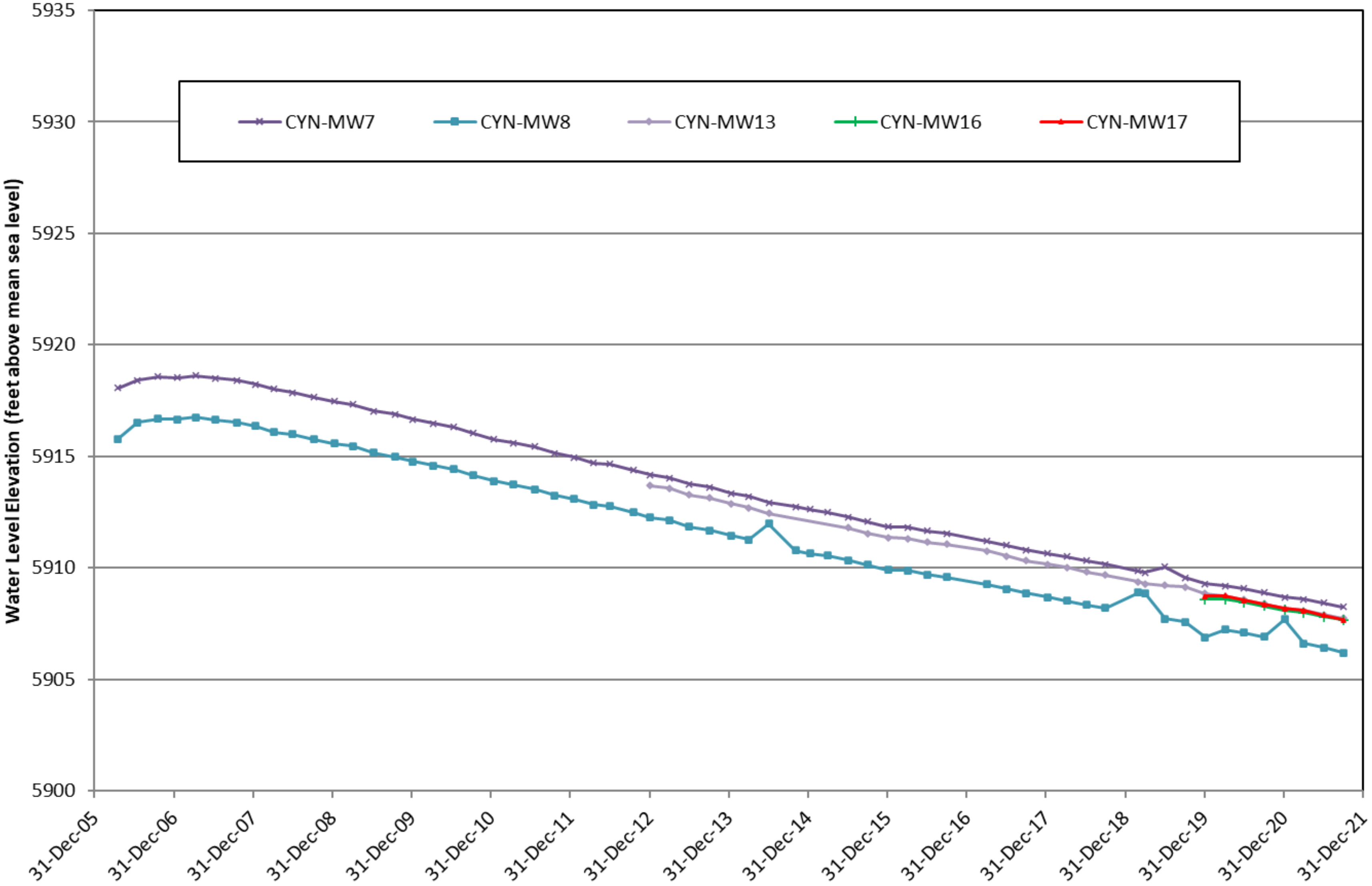
Burn Site Groundwater Area of Concern Monitoring Well CYN-MW3



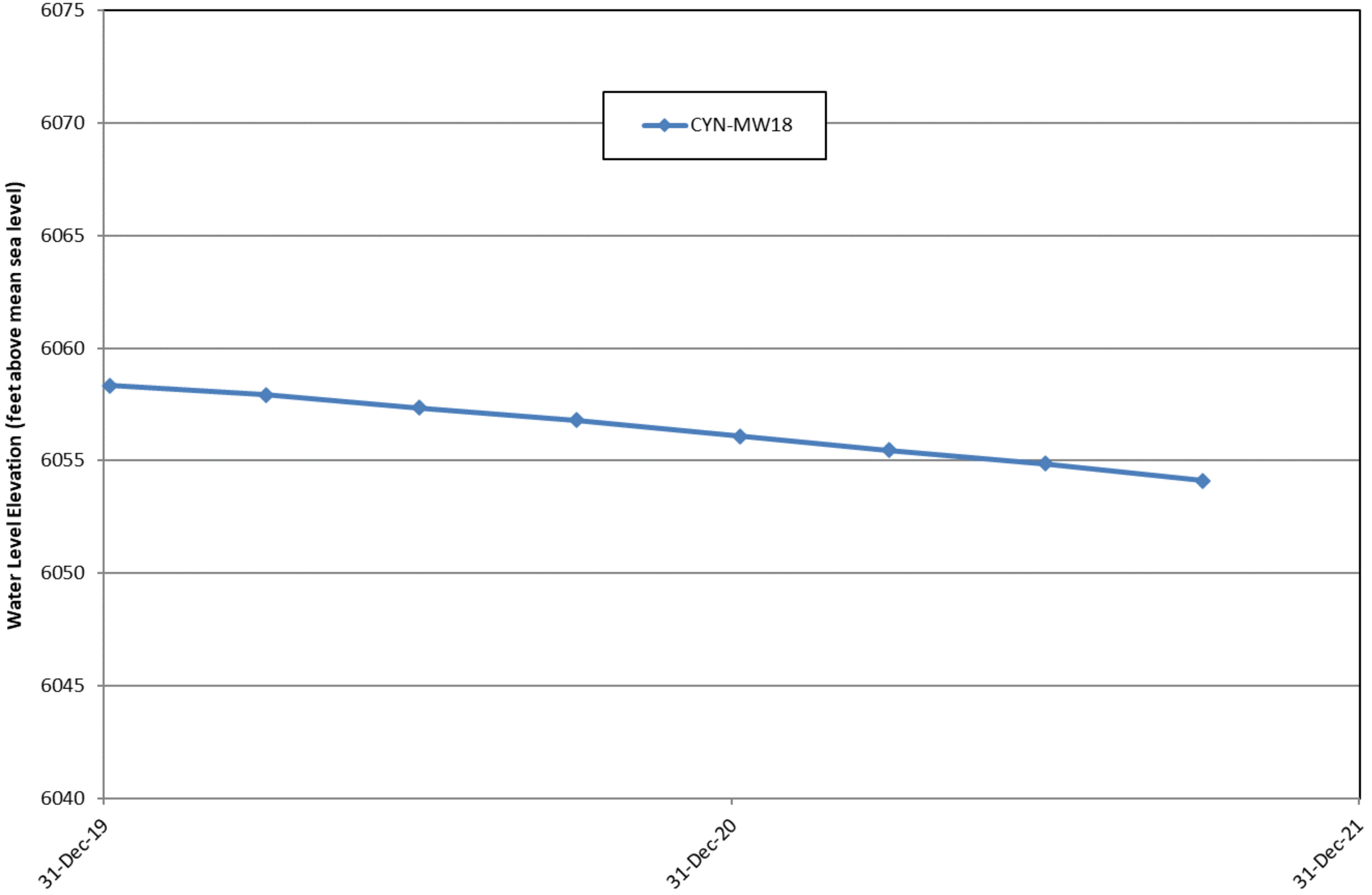
Burn Site Groundwater Area of Concern Monitoring Well CYN-MW4



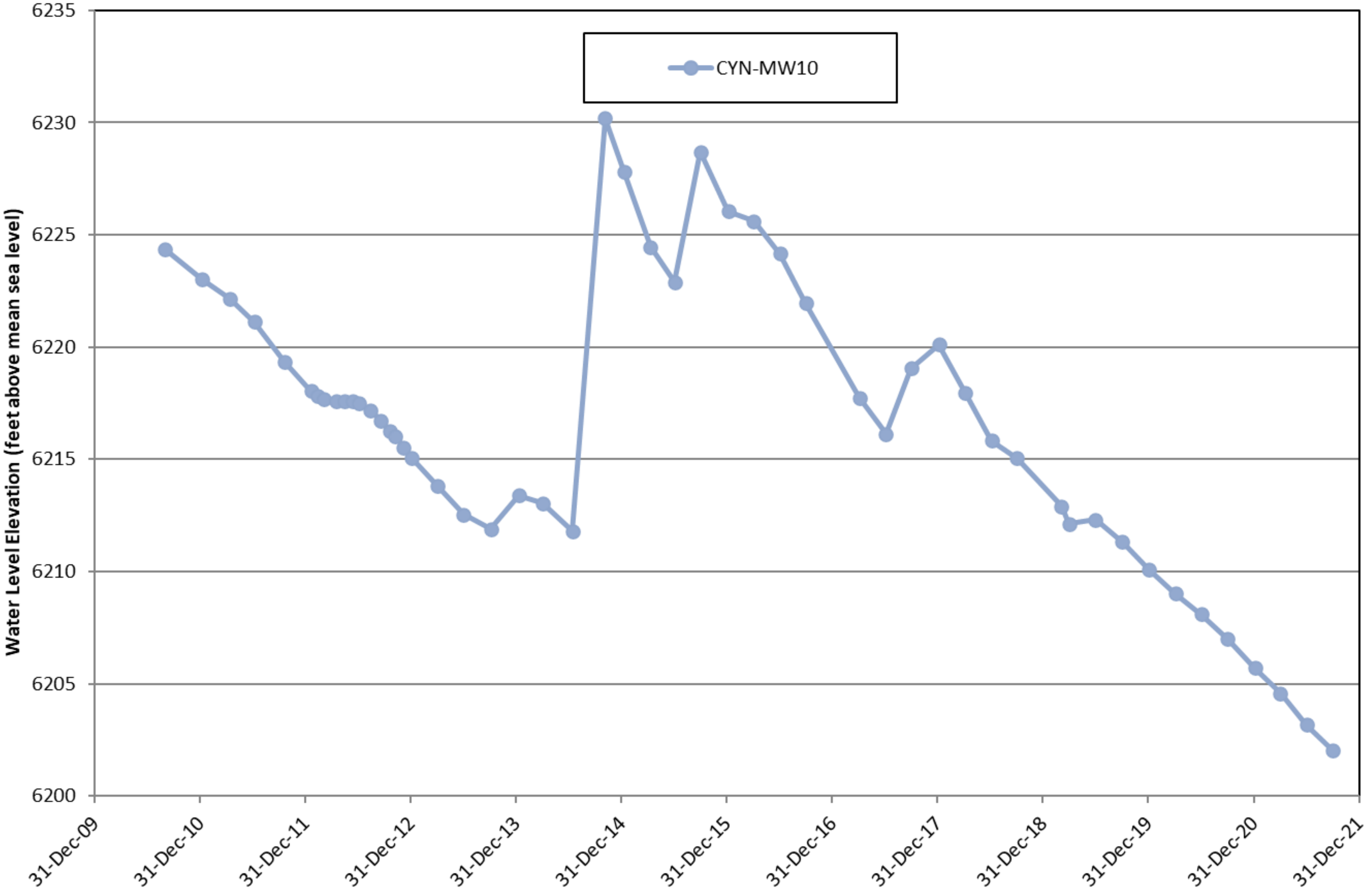
Burn Site Groundwater Area of Concern Monitoring Wells CYN-MW6, CYN-MW9, and CYN-MW15



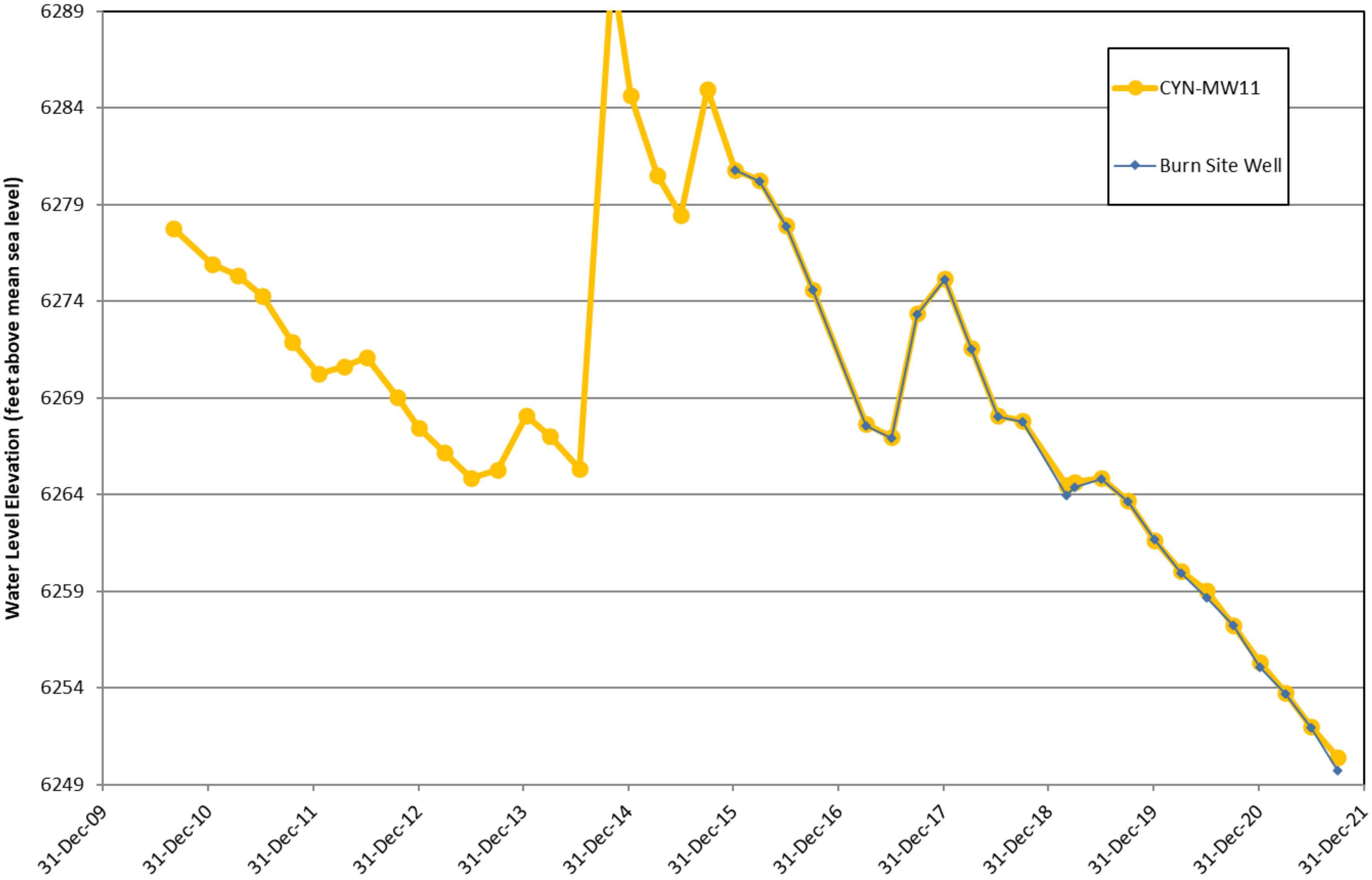
Burn Site Groundwater Area of Concern Monitoring Wells CYN-MW7, CYN-MW8, CYN-MW13, CYN-MW16, and CYN-MW17



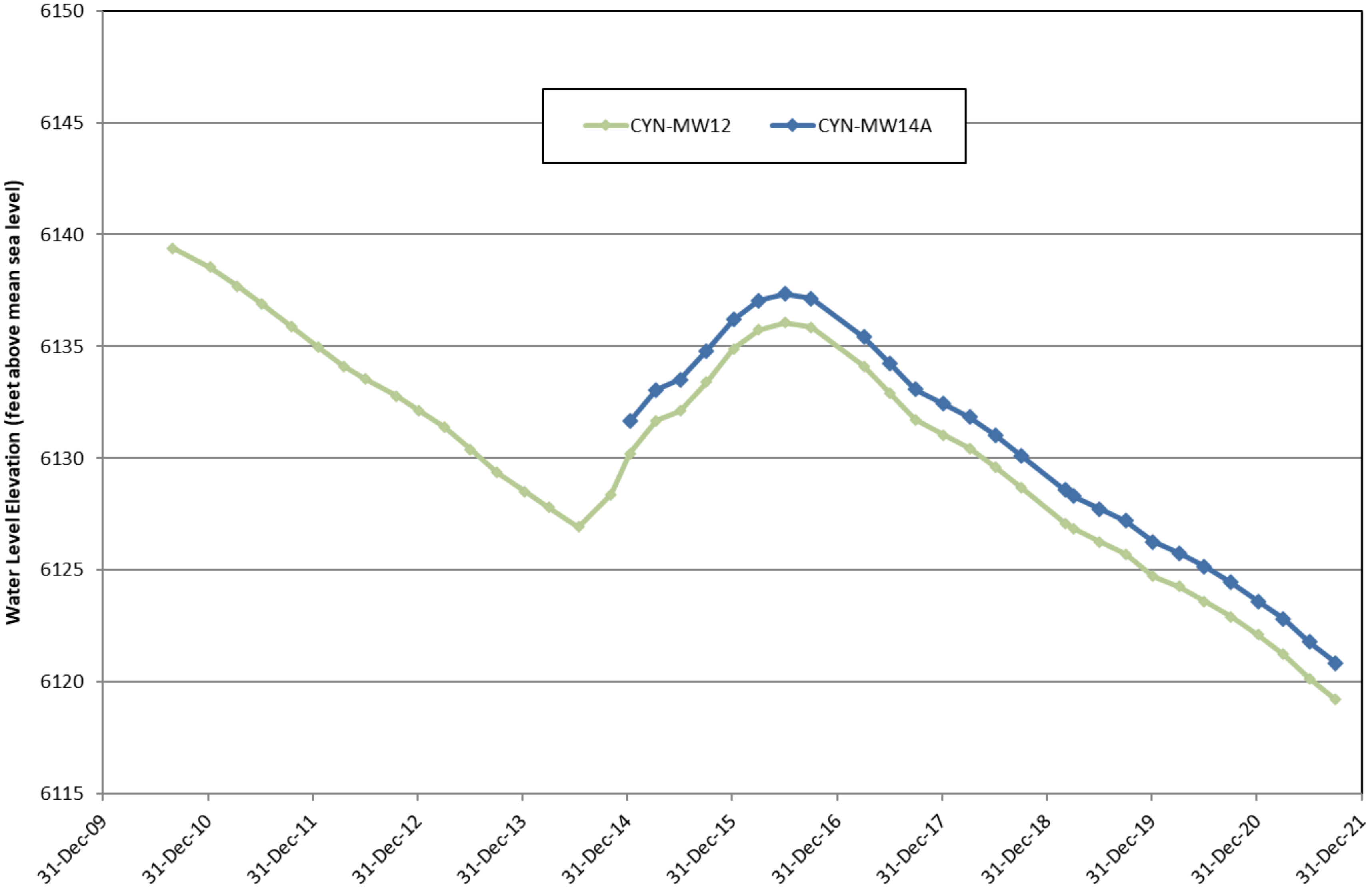
Burn Site Groundwater Area of Concern Monitoring Well CYN-MW18



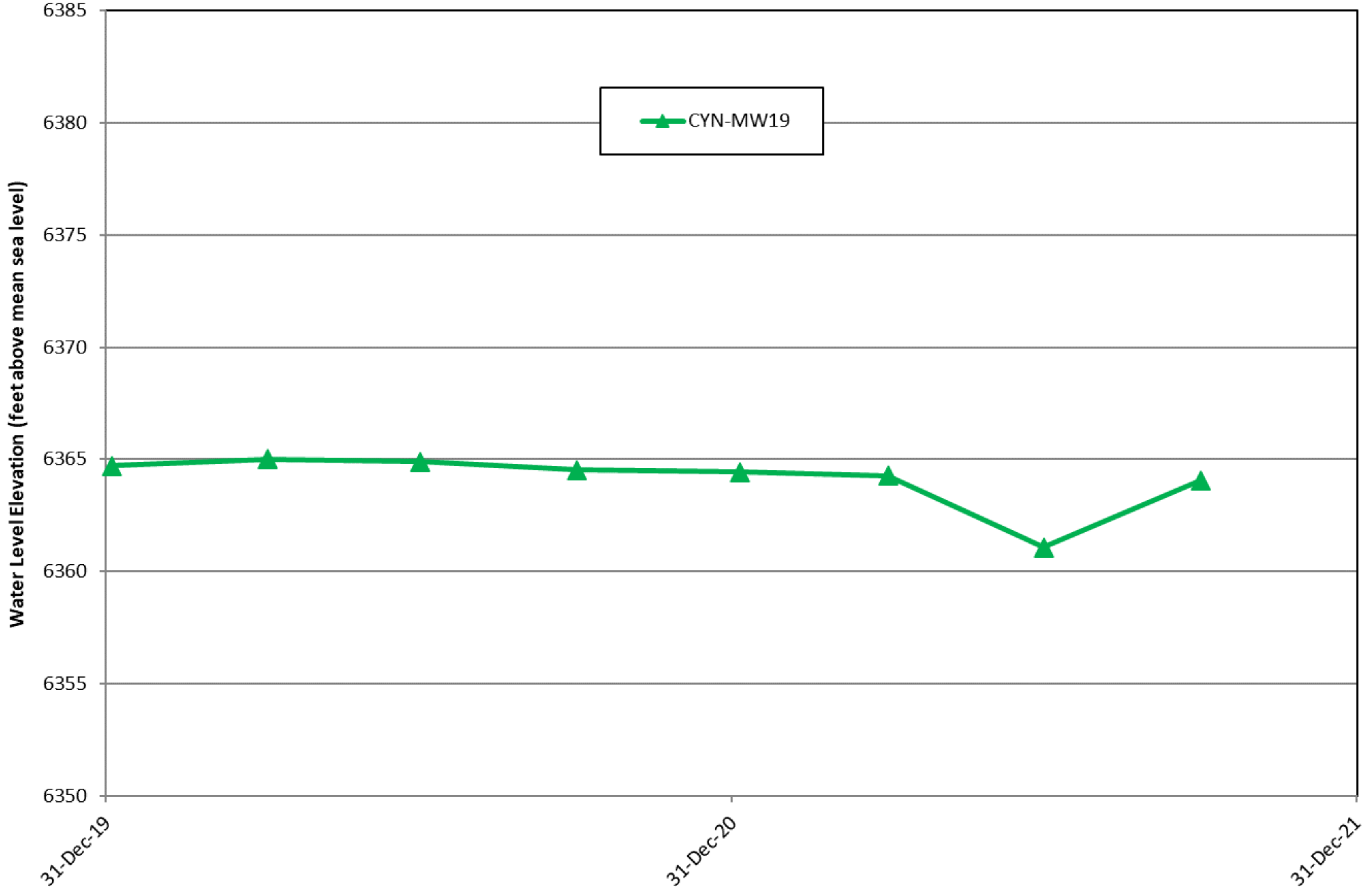
Burn Site Groundwater Area of Concern Monitoring Well CYN-MW10



Burn Site Groundwater Area of Concern Monitoring Well CYN-MW11 and Burn Site Well



Burn Site Groundwater Area of Concern Monitoring Wells CYN-MW12 and CYN-MW14A

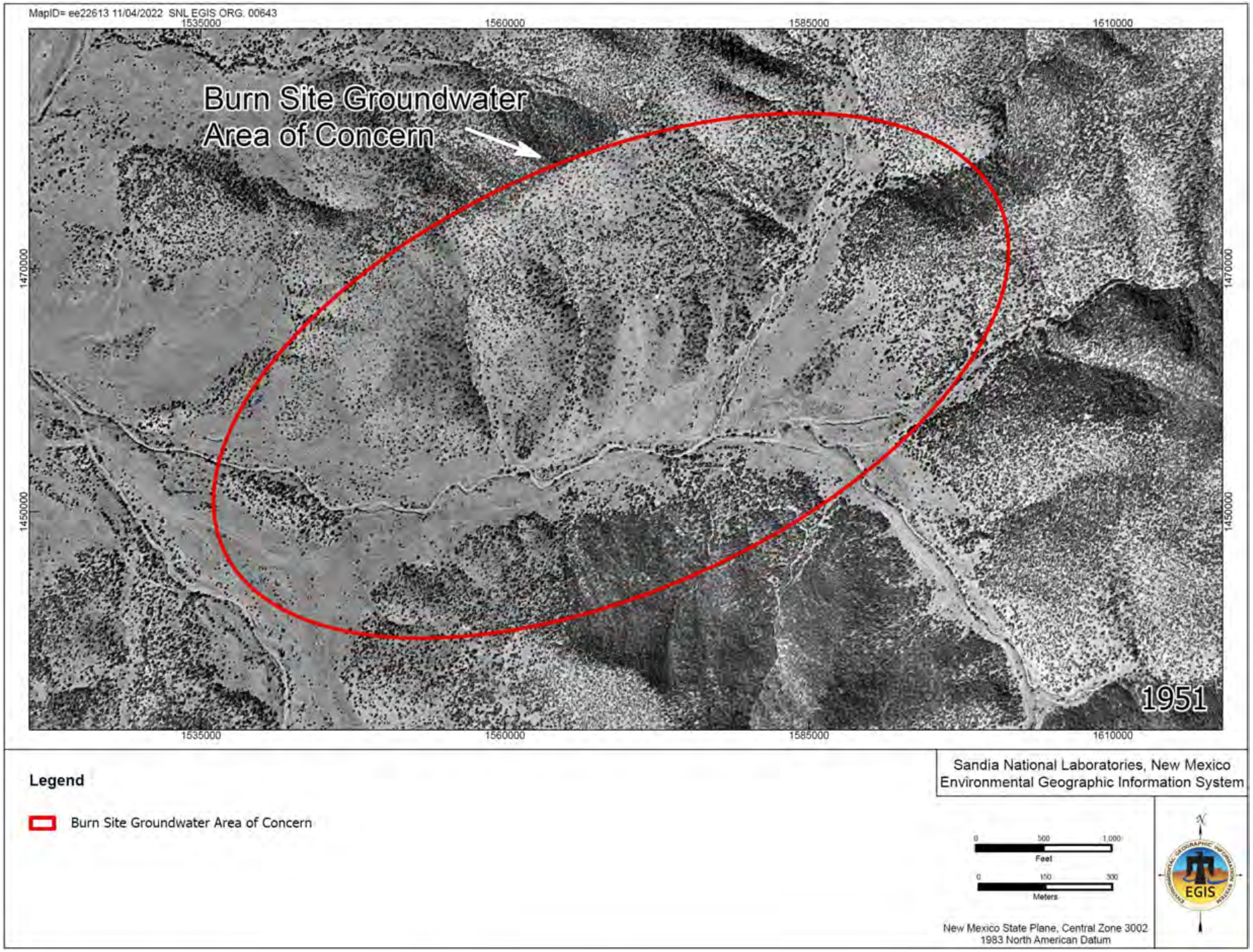


Burn Site Groundwater Area of Concern Monitoring Well CYN-MW19

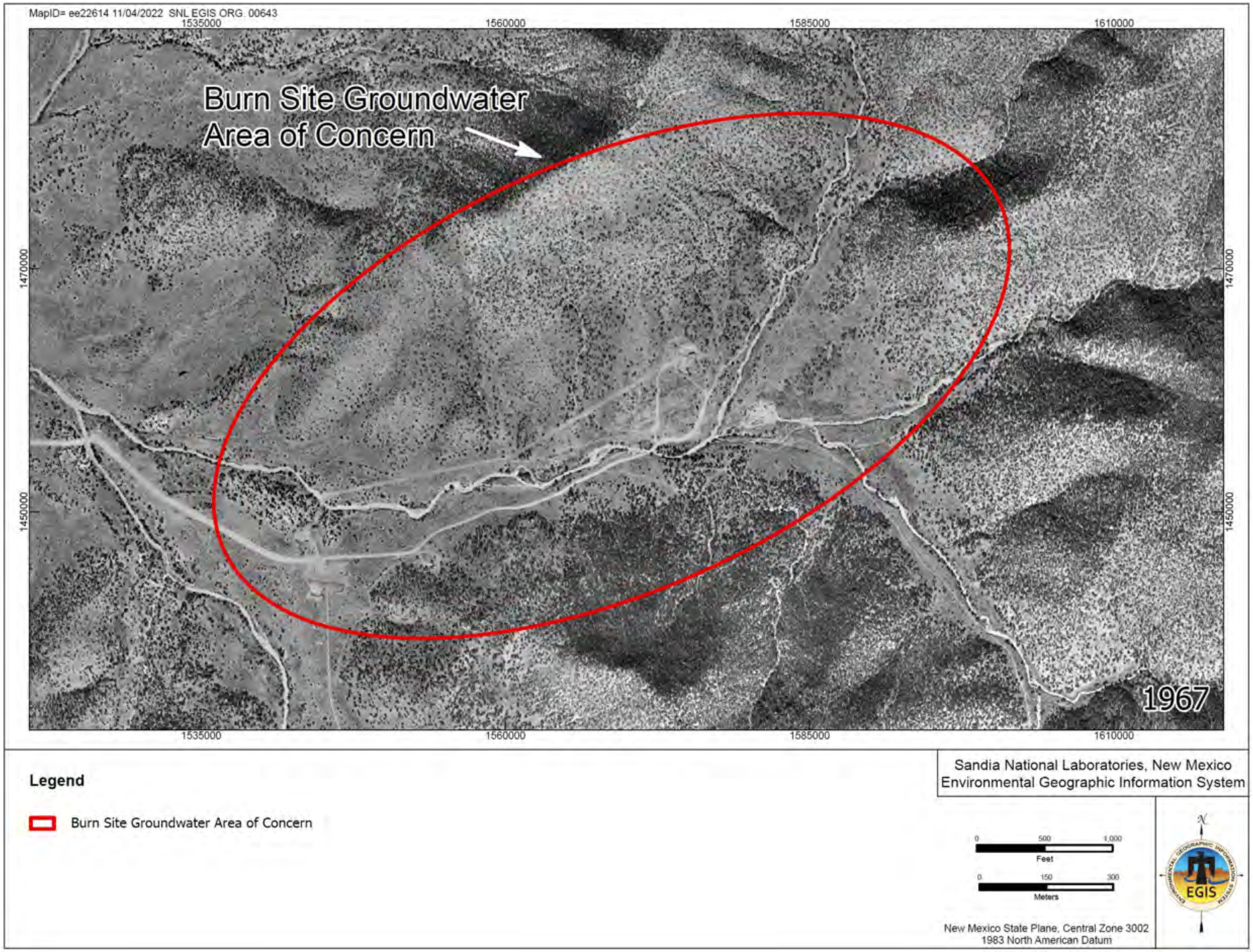
Appendix G

Historical Air Photographs of the Burn Site Groundwater Area of Concern

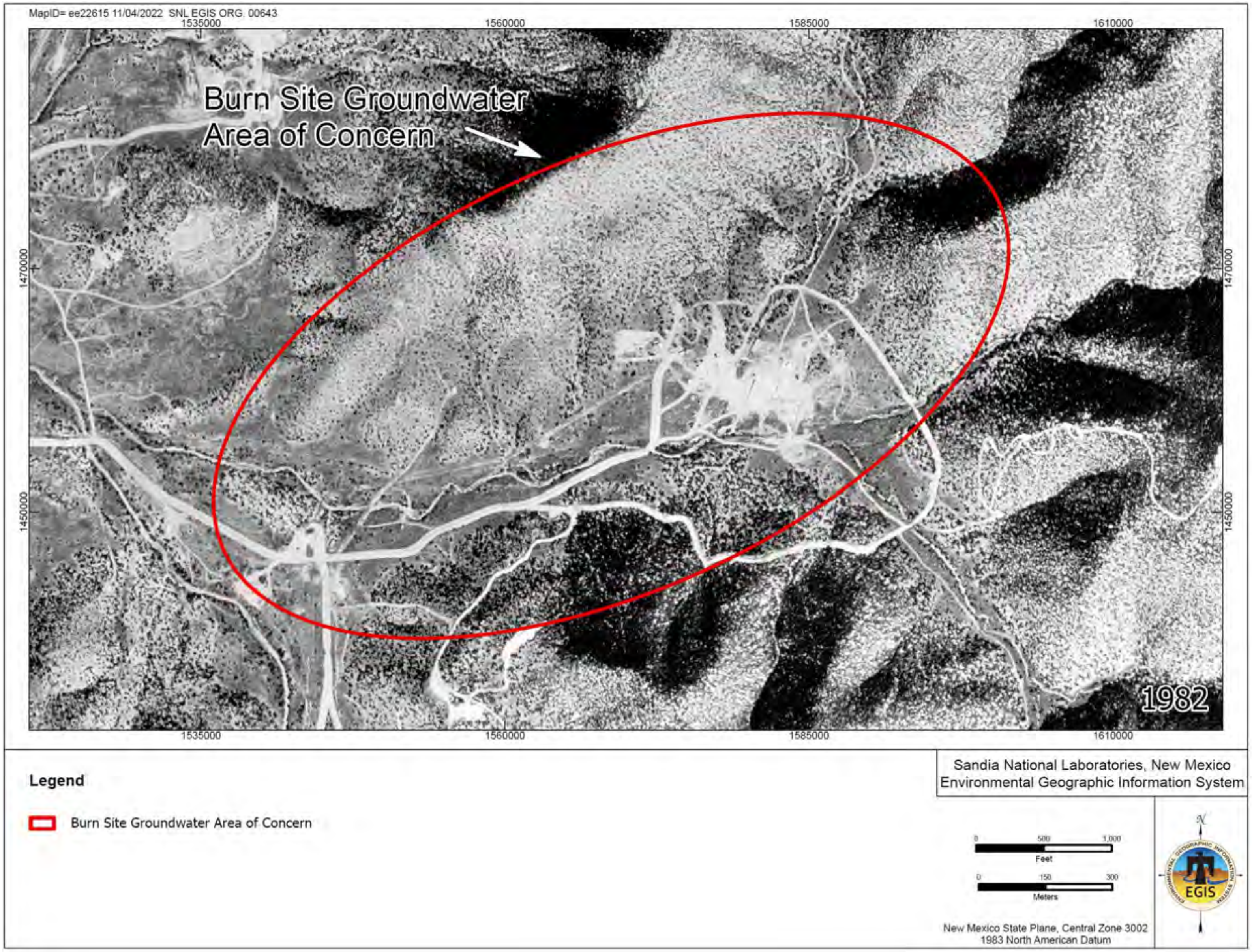
1951 to 2020



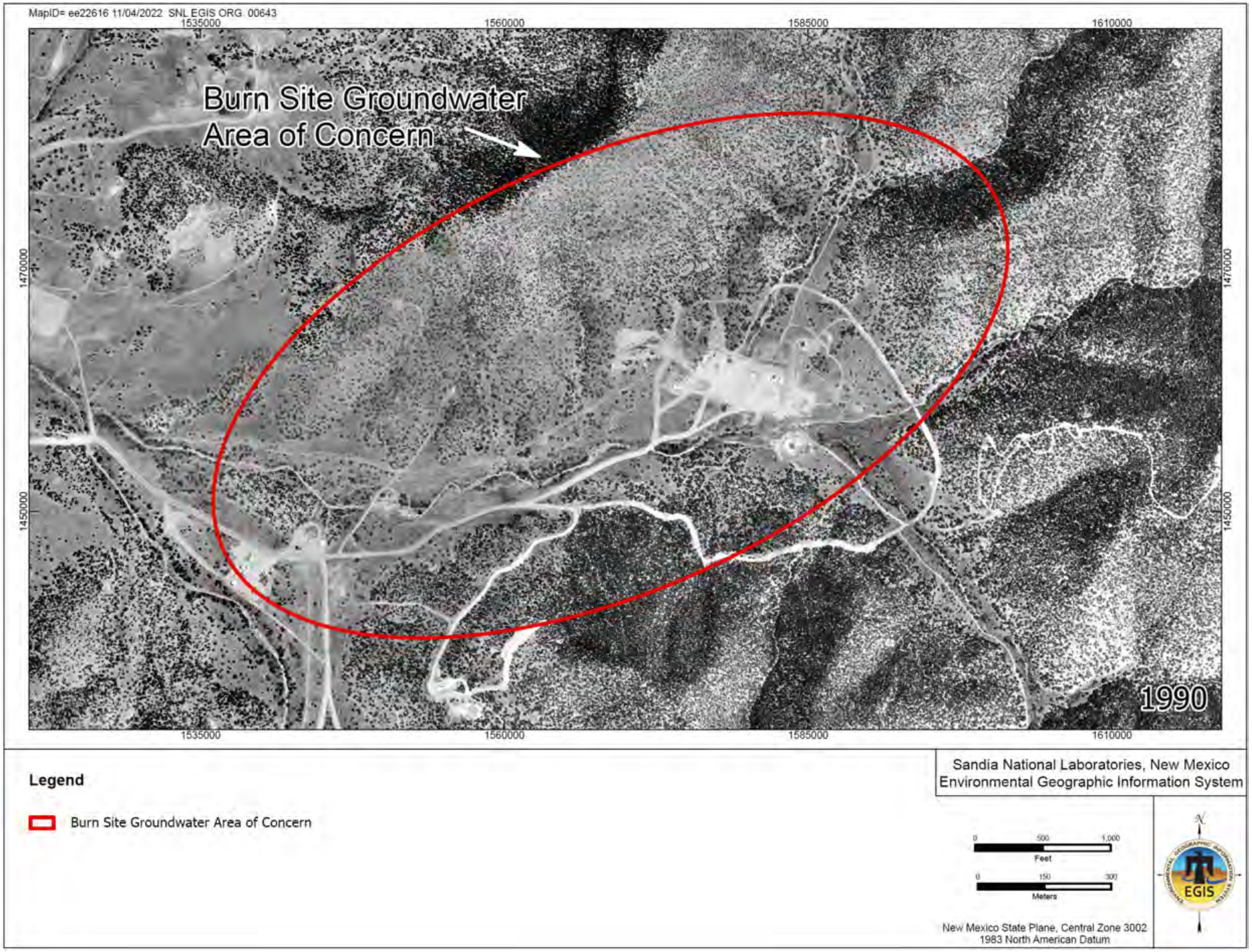
Burn Site Groundwater Area of Concern, 1951



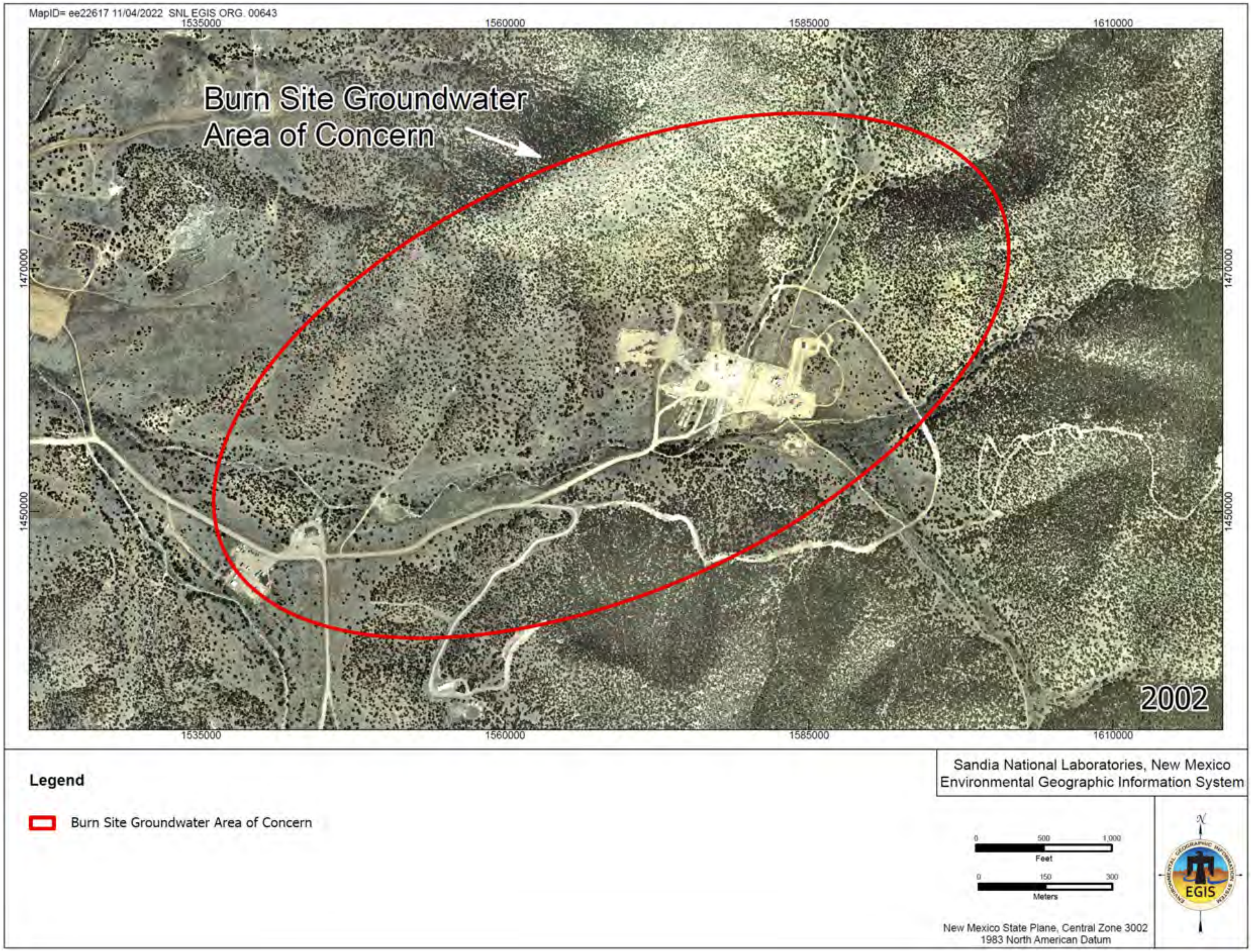
Burn Site Groundwater Area of Concern, 1967



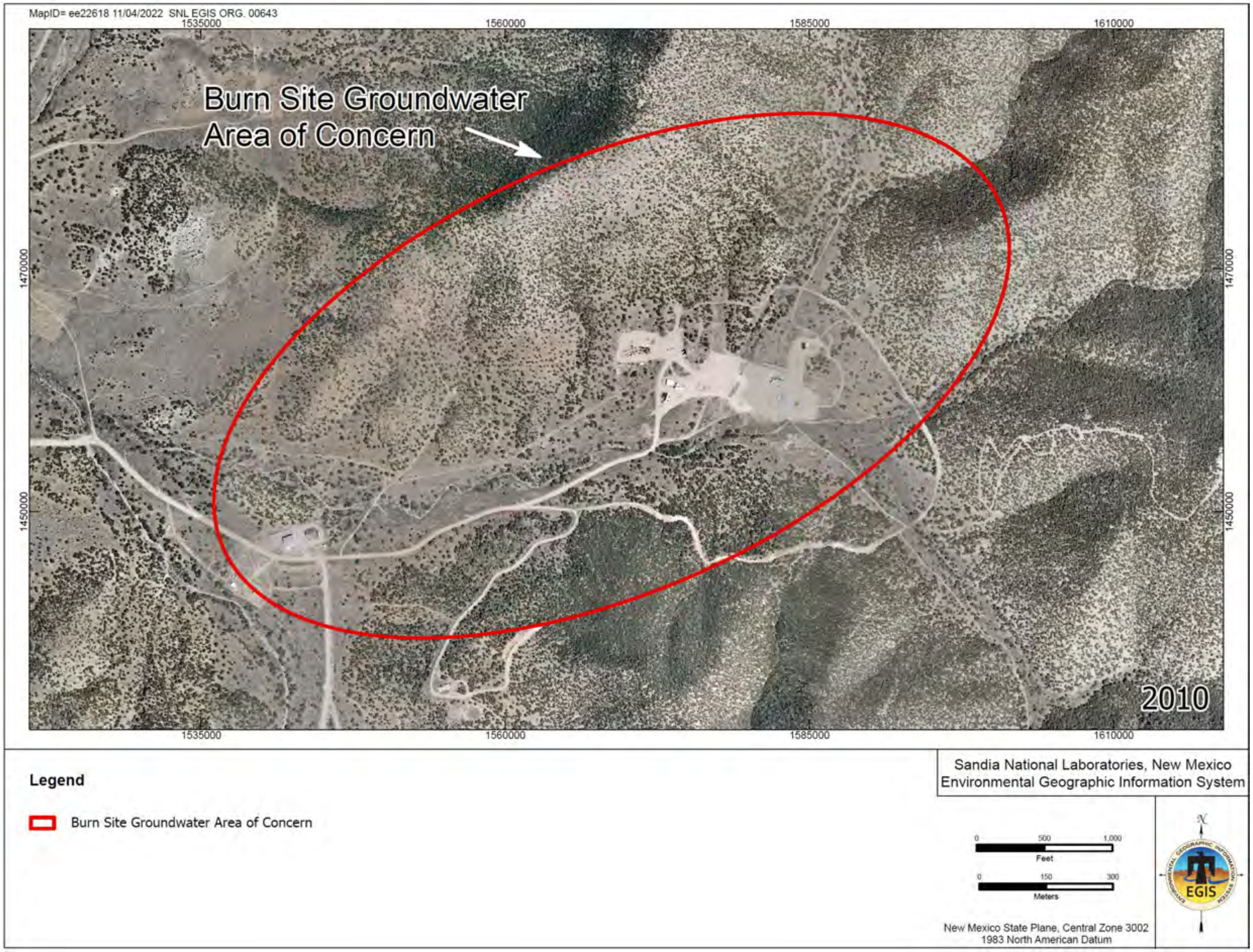
Burn Site Groundwater Area of Concern, 1982



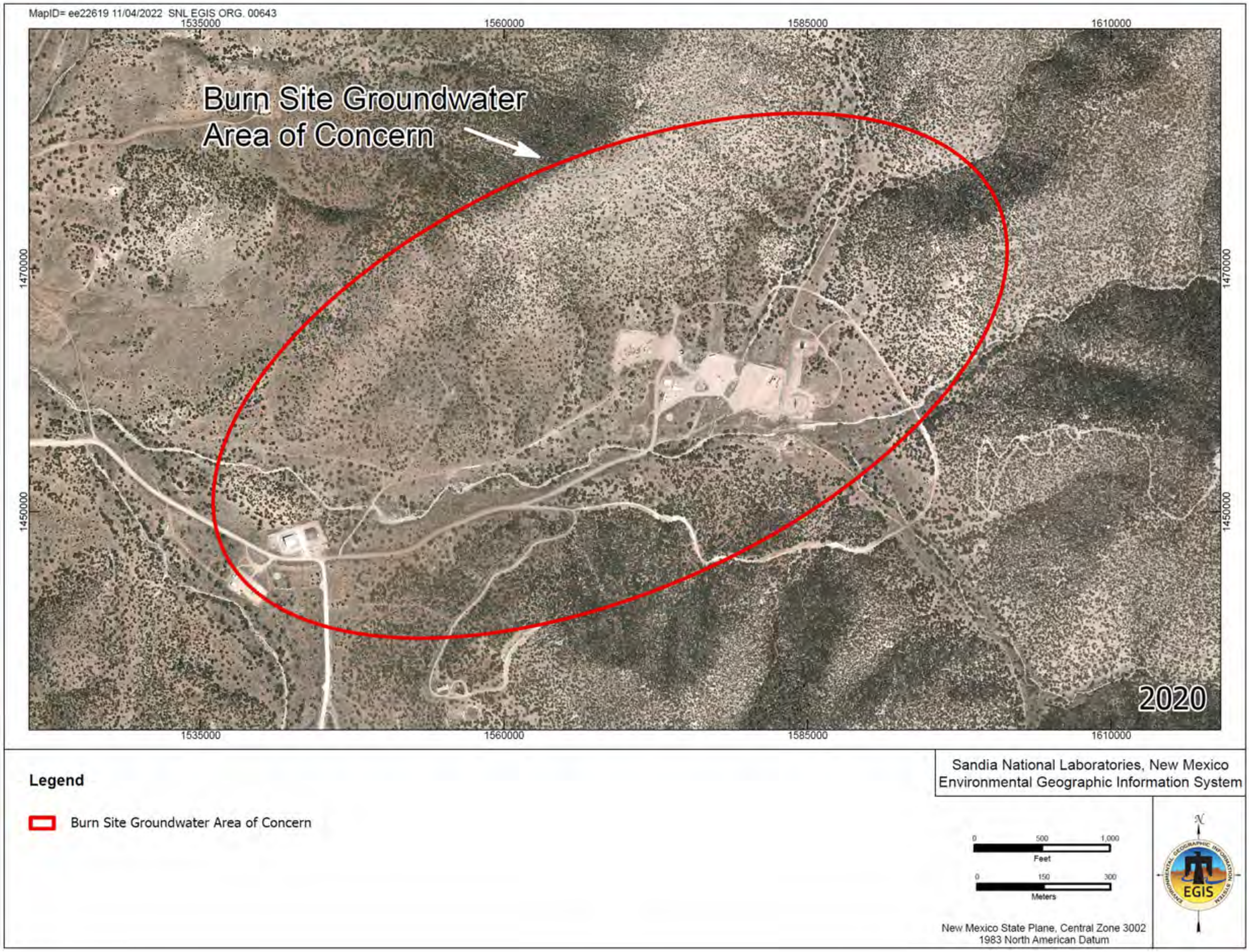
Burn Site Groundwater Area of Concern, 1990



Burn Site Groundwater Area of Concern, 2002



Burn Site Groundwater Area of Concern, 2010



Burn Site Groundwater Area of Concern, 2020

Appendix H
Site Summary Sheets for Solid Waste Management Units in the Burn Site Groundwater Area of Concern

SWMU Number	SWMU Name
12A	Open Arroyo Channel
12B	Buried Debris in Graded Area
13	LCBS Oil Surface Impoundment (Lurance Canyon Burn Site)
28-4	Mine Shafts
28-5	Mine Shafts
28-6	Mine Shafts
28-8	Mine Shafts
65-A	Lurance Canyon Explosive Test Site: Small Debris Mound
65-B	Lurance Canyon Explosive Test Site: Primary Detonation Area
65-C	Lurance Canyon Explosive Test Site: Secondary Detonation Area
65-D	Lurance Canyon Explosive Test Site: Near Field Dispersion Area
65-E	Far Field Dispersion Area
94-A	Aboveground Tanks, Lurance Canyon Burn Site
94-B	Debris/Soil Mound Area
94-C	Bomb Burner Area and Discharge Line
94-D	Lurance Canyon Burn Site: Bomb Burner Discharge Pit
94-E	Lurance Canyon Burn Site: Small Surface Impoundment
94-F	LAARC Discharge Pit
94-G	Scrap Yard, Lurance Canyon Burn Site
94-H	Fuel Spill at Open Pool Test Area, Lurance Canyon Burn Site
160	Bldg. 9832 Septic System

Exceptional service in the national interest

Sandia National Laboratories

Site 12: Burial Site/Open Dump (Lurance Canyon)

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) Site 12 is identified as Burial Site/Open Dump (Lurance Canyon) in the Hazardous and Solid Waste Amendments (HSWA) Module. It covers approximately 0.6 acres (ac) and includes the upper open arroyo channel as ER Site 12A, and the lower, buried portion of the arroyo channel as ER Site 12B.

Based on a review of available historical aerial photographs, the Burial Site/Open Dump was undeveloped prior to 1971. A 1975 historical aerial photograph indicates site grading activities had buried a small portion of the arroyo. In a 1983 historical aerial photograph, the central and southern portions of the arroyo channel, which dissects ER Site 65, have been filled. Based on this record, activity at ER Site 12B may have been associated with historical disposal of testing debris from ER Site 65 or the construction activities associated with ER Site 94.

ER Site 12A - Open Arroyo

Prior to 1990, approximately eight to 10 drums, wooden pallets, twisted metal, and concrete blocks were disposed of in the open arroyo channel of ER Site 12A. In 1990, drums of waste washed into Site 12A from an unknown upstream location. Sandia National Laboratories (SNL) Waste Management personnel removed and disposed of the drums. An upstream survey of the arroyo confirmed there were no additional drums still present, only small amounts of concrete and wood debris.

This site extends from the approximate location of some concrete blocks and debris on the north, to the junction with the filled arroyo channel immediately north of the cable rack. It is approximately 300 feet (ft) long and 20 ft to 30 ft wide.

ER Site 12B - Buried Debris in Graded Area

This site was the filled portion of the arroyo; and based on historical aerial photos, was approximately 450 ft long and 20 ft to 30 ft wide. It extended south from the cable rack to a road just north of the historic drainage confluence with the Lurance Canyon main arroyo channel.

Corrective Action

Sites 12A and 12B were identified during the Comprehensive Environmental Assessment and Response Program (CEARP) investigation and the *Resource Conservation and Recovery Act* (RCRA) Facility Assessment (RFA) in late 1987. Personnel interviews indicate possible metal objects, wood, and possibly depleted uranium (DU), lead, and beryllium may have been disposed of at the sites. Most of the information obtained appears more applicable to Site 12B than Site 12A, since Site

U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

Sandia National Laboratories

12B was graded over and Site 12A remained open and relatively free of debris.

In October 1993, Kirkland Air Force Base (KAFB) conducted an unexploded ordnance/high explosives (UXO/HE) visual survey. One live trip flare was discovered around Site 12A. A second visual survey was conducted just prior to confirmatory soil sampling in May 1996. No ordnance or ordnance debris was found during this survey.

ER Site 12A - Open Arroyo

In 1993, a visual survey for surface UXO/HE was conducted. Heavy metal fragments were found in the hills surrounding the site. In May 1995, a radiological voluntary corrective measure (VCM), including post-cleanup (verification) sampling, was conducted; and later in July 1995, scoping sampling was conducted, but no contamination was found.

Solid Waste Management Units (SWMU) 12A was proposed for confirmatory sampling no further action (NFA) decision, based on evidence suggesting no release to the environment occurred or is likely to occur in the future.

ER Site 12B - Buried Debris in Graded Area

A gamma radiation survey conducted by RUST Geotech found point sources of DU at 12B. From March 1995 to October 1996, a radiological VCM and post-cleanup or verification sampling was conducted.

A surface geophysical survey was conducted in November 1996.

In December 1996, a passive soil-vapor survey to evaluate subsurface contamination took place. Presence of subsurface contaminants of concern could not be determined. During the period between June and September 1997, a VCM and verification sampling, in addition to surface water control measures (i.e., dams and berms), were installed and maintained.

Six verification locations were resampled before the arroyo was filled in December 1997.

Constituents Investigated

HE

Metals

Beryllium

VOCs

Semivolatile organic compounds (SVOCs).

Institutional Controls

The NMED has determined that site remediation is complete, and no controls are needed. However, as a best management practice, LTES has established administrative institutional controls (IC) to track this site in the SNL IC database.

Current Regulatory Status

Site 12A - Corrective action is complete at Site 12A, and no further action is required. This site is acceptable for residential land use, and there are no restrictions on future activities. The NMED approved completion of corrective action in September 2000.

Site 12B - Corrective action is complete at Site 12A, and no further action is required. This site is acceptable for residential land-use, and there are no restrictions on future activities. The NMED approved completion of corrective action in July 2000.

Results of Risk Analysis

Not applicable.

Waste Volume Estimated/Generated

A combined surface radiation VCM for Sites 12, 13, 65, and 94 has generated 200 drums of radioactive waste. The VCM at Site 12B, conducted in late fiscal year (FY) 1997, generated approximately 3,200 cubic yards (yd^3) of soil and approximately 65 yd^3 of scrap metal and debris, including one drum of radioactive lead, two drums of nonradioactive lead, 4 yd^3 of radioactive metal, 12 yd^3 of radioactive debris, and several batteries containing hazardous constituents. The excavated soil has been sampled, verified clean, and is being used as fill material for excavations associated with the Site 94 voluntary corrective actions (VCAs).

Site 0012B: Burial Site/Open Dump (Lurance Canyon)

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 12 is identified as Burial Site/Open Dump (Lurance Canyon) in the HSWA Module. It covers approximately 0.6 acres and includes the upper open arroyo channel as ER site 12A and the lower buried portion of the arroyo channel as ER site 12B.

Based on a review of available historical aerial photographs, the burial site/open dump was undeveloped prior to 1971. A 1975 historical aerial photograph indicates site grading activities had buried a small portion of the arroyo. In a 1983 historical aerial photograph, the central and southern portions of the arroyo channel that dissects ER site 65 have been filled. Based on this record, activity at ER site 12B may have been associated with historical disposal of testing debris from ER site 65 or the construction activities associated with ER site 94.

ER Site 12A - Open Arroyo

Prior to 1990, approximately eight to ten drums, wooden pallets, twisted metal, and concrete blocks were disposed of in the open arroyo channel of ER site 12A. In 1990, drums of waste washed into site 12A from an unknown upstream location. Sandia National Laboratories (SNL) Waste Management personnel removed and disposed of the drums. An upstream survey of the arroyo confirmed that no additional drums and only small amounts of concrete and wood debris were still present.

This site extends from the approximate location of some concrete blocks and debris on the north to the junction with the filled arroyo channel immediately north of the cable rack. It is approximately 300-feet (ft) long and 20- to 30-ft wide.

ER Site 12B - Buried Debris in Graded Area

This site was the filled portion of the arroyo, which was approximately 450-ft long and 20- to 30-ft wide, based on historical aerial photographs. It extended south from the cable rack to a road just north of the historic drainage confluence with the Lurance Canyon main arroyo channel.

Corrective Action

Sites 12A and 12B were identified during the Comprehensive Environmental Assessment and Response Program (CEARP) investigation- and the *Resource Conservation and Recovery Act* (RCRA) Facility Assessment (RFA) in late 1987. Personnel interviews indicate that possible metal objects, wood, and possibly depleted uranium (DU), lead, and beryllium may have been disposed of at the sites. Most information obtained appears more applicable to site 12B than 12A, since site 12B was graded over and site 12A remained open and relatively free of debris.

In October 1993, Kirtand Air Force Base (KAFB) personnel conducted an unexploded ordnance/high explosive (UXO/HE) visual survey. One live trip flare was discovered around site 12A. A second visual survey was conducted just prior to confirmatory soil sampling in May 1996. No ordnance or ordnance debris was found during this survey.

ER Site 12A - Open Arroyo

In 1993, a visual survey for surface UXO/HE was conducted. Heavy metal fragments were found in the hills surrounding the site. In May 1995, a radiological voluntary corrective measure (VCM), including post cleanup (verification) sampling was conducted and later in July 1995, scoping sampling was conducted, but no contamination was found.

Solid Waste Management Unit (SWMU) 12A was proposed for confirmatory sampling NFA decision based on the evidence suggesting no release to the environment occurred or is likely to occur in the future.

ER Site 12B - Buried Debris in Graded Area

A Gamma radiation survey conducted by RUST Geotech found point sources of DU at site 12B. From March 1995 to October 1996, a radiological voluntary corrective measure (VCM) and post-clean-up or verification sampling was conducted.

A surface geophysical survey was conducted in November 1996.

In December 1996, a passive soil vapor survey to evaluate subsurface contamination was performed. Presence of subsurface contaminants of concern could not be determined. During the period between June and September 1997 a voluntary corrective measure and verification sampling in addition to surface water control measures (dams and berms) were installed and maintained.

Six verification locations were resampled before the arroyo was filled in December 1997.

Constituents Investigated

High explosives (HE), metals, and beryllium, volatile organic compounds (VOC), and semivolatile organic compounds (SVOC).

Institutional Controls

The New Mexico Environment Department (NMED) has determined site remediation is complete for sites 12A and 12B, and no controls are needed. However, as a best management practice, LTES has established administrative institutional controls (IC) to track this site in the IC database.

Current Regulatory Status

Corrective action is complete at site 12A, and no further action is required. This site is acceptable for residential land use, and there are no restrictions on future activities. NMED approved completion of corrective action in September 2000.

Corrective action is complete at site 12A, and no further action is required. This site is acceptable for residential land use, and there are no restrictions on future activities. NMED approved completion of corrective action in July 2000.

Results of Risk Analysis

Not applicable.

Waste Volume Estimated/Generated

A combined surface radiation VCM for sites 12, 13, 65, and 94 has generated 200 drums of radioactive waste. The VCM at Site 12B, conducted in late FY97, generated approximately 3,200 cubic yards of soil and approximately

65 cubic yards of scrap metal and debris including one drum of radioactive lead, two drums of nonradioactive lead, four cubic yards of radioactive metal, 12 cubic yards of radioactive debris, and several batteries containing hazardous constituents. The excavated soil has been sampled, verified clean, and is being used as fill material for excavations associated with the site 94 VCAs.

Site 0013: Oil Surface Impoundment (Lurance Canyon Burn Site)

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 13 is identified as the Oil Surface Impoundment site by the Hazardous and Solid Waste Amendments (HSWA) module. It covers approximately 0.5 acres in the Lurance Canyon Burn Site area in the Canyons Test area of operational unit (OU) 1333.

Site 13 is located within the general area of ER site 94. Historical investigations concluded this site was used for fire survivability tests conducted on transport containers and on weapon and satellite components. Water containing residual jet fuel was discharged into an unlined impoundment and percolated into soil. ER site 65A, a small dirt-covered bunker, is located on the southeast edge of the oil surface impoundment.

Corrective Action

Site 13 was added to the HSWA module in November 1993 after the Comprehensive Environmental Assessment and Response Program (CEARP) Phase I investigation. In 1994, a radiation survey was conducted at the site, but no radioactive anomalies were detected. In September 1994, a visual survey for unexploded ordnance / high explosive (UXO/HE) materials was performed, and the results showed no UXO/HE material present.

The OOU 1333 *Resource Conservation and Recovery Act* (RCRA) Facility Investigation (RFI) work plan was submitted to Environmental Protection Agency (EPA) for approval in January 1996. In May of 1996, confirmatory soil sampling and trenching conducted was conducted at the site. Four trenches were excavated with a backhoe to a maximum depth of 14 feet. Soil samples were collected from surface soil and from trenches. Very low concentrations of petroleum hydrocarbons and metals were detected.

In December 1999, following a review of Sandia National Laboratories' (SNL) response to a request for supplemental information (RSI), the New Mexico Environment Department (NMED) indicated the site was accepted for NFA.

Constituents Investigated

Total petroleum hydrocarbons (including JP-4), metals, volatile organic compounds (VOC), and semivolatile organic compounds (SVOC).

Institutional Controls

The NMED determined site remediation is complete, and no controls are needed. However, as a best management practice, LTES has established administrative institutional controls (IC) to track this site in the IC database.

Current Regulatory Status

Corrective action is complete at ER site 13, and no further action is required. This site is acceptable for residential land use, and there are no restrictions on future activities. NMED approved completion of corrective action in July 2000.

Results of Risk Analysis

Not applicable.

Waste Volume Estimated/Generated

Sampling waste from the RFI field program was negligible.

Site 0028_4: Mine Shafts

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

There are 10 mine shafts (Environmental Restoration (ER) sites 28-1 to 28-10) where mining activity took place. The mines included as 'ER site 28' have long since been abandoned or were never worked beyond some very limited prospecting. The individual mine locations vary considerably. Old mine features, (including adits, shafts, and prospecting pits) are the remnants of mineral mining activities conducted in the early to mid-1900s. Fluorite was the most common mineral mined, but barite, galena, and other sulfide minerals also were apparently mined based on examination of tailings piles. These mines are not ER sites due to their mining activities, but because speculation that these remnant sites may have been used to dispose of various wastes. According to Comprehensive Environmental Assessment and Response Program (CEARP) interviews, various wastes may have been placed in the mine(s); however, no evidence to support these rumors exists. Based on follow-up interviews, at least one rumor regarding the disposal of explosives in a mine is false. The CEARP findings also state a radiometric study was conducted by Sandia National Laboratories (SNL)/New Mexico (NM) personnel and no significantly above background radiation levels were detected, and "no entry was made into the mines."

Corrective Action

Kirtland Air Force Base [KAFB] and various SNL/NM groups conducted five, well-documented field inspections /investigations efforts (one by KAFB and four by SNL/NM). All investigative efforts shared the same objective of determining if the mines had been used for any activities that resulted in an environmental problem/concern. Secondary objectives included mapping the mines, surveying their locations, and documenting each location with photographs.

A base-wide radiation survey was conducted in the 1982 to1983 timeframe. All sites were investigated by collecting *in-situ* readings and soil samples. The purpose of this study was to first determine whether radiation levels above background levels were present, and if so, determine what radionuclides were responsible for the elevated readings. The radiation spectra from *in-situ* instrument readings and soil sample analytical results showed nothing more than slight variations in background readings due to the types of rocks found at each location. Visual inspections performed during the revealed nothing that conflicts with this conclusion.

Personnel from the KAFB 377th Air Base Wing Environmental Management and Restoration conducted detailed mapping and inspection surveys of ER site 28-10 in early August 1993. This work was part of the overall effort aimed at defining ownership of the mines, as well as providing sound documentation of the condition and status of the mines. Inspections focused on looking for evidence of postmining activity.

In late August 1993, SNL/NM environmental Restoration lead investigator toured the confirmed locations previously surveyed in 1982 to 1983. The purpose was to confirm the locations of the identified mine sites from the 1982 to 1983 original survey.

Four main inspections were conducted by SNL/NM personnel from November 1994 to March 1995. All locations were visited at least twice, and all were thoroughly inspected from the surface. KAFB personnel most familiar with the mine sites were present for one of the inspections. ER site 28-10 could be completely inspected from the surface. A small amount of slag material has been noted in the tailings pile surrounding the top of the shaft. This material is very porous and based on the small volume of this material and lack of any other indications of non-mining debris, it was concluded that this slag material was related to the original mining activities.

Eight of the 10 ER site 28 locations show no evidence of any postmining activity and, therefore, do not pose a threat of a release.

Constituents Investigated

None.

Institutional Controls

The New Mexico Environment Department (NMED) determined site remediation is complete, and no controls are needed. However, due to ES&H concerns, the LTES has established administrative institutional controls (IC) to track this site in the SNL IC database.

Current Regulatory Status

Corrective action is complete at ER site 28-4 and no further action is required. This site is acceptable for residential land use and there are no restrictions on future activities. The NMED approved completion of corrective action. The mine was plugged in May 2005.

Results of Risk Analysis

No risk analysis was necessary.

Waste Volume Estimated/Generated

No waste was generated.

Site 0028_5: Mine Shafts

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

There are 10 mine shafts (Environmental Restoration (ER) sites 28-1 to 28-10) where mining activity took place. The mines included as 'ER site 28' have long since been abandoned or were never worked beyond some very limited prospecting. The individual mine locations vary considerably. Old mine features, (including adits, shafts, and prospecting pits) are the remnants of mineral mining activities conducted in the early to mid-1900s. Fluorite was the most common mineral mined, but barite, galena, and other sulfide minerals also were apparently mined based on examination of tailings piles. These mines are not ER sites due to their mining activities, but because speculation that these remnant sites may have been used to dispose of various wastes. According to Comprehensive Environmental Assessment and Response Program (CEARP) interviews, various wastes may have been placed in the mine(s); however, no evidence to support these rumors exists. Based on follow-up interviews, at least one rumor regarding the disposal of explosives in a mine is false. The CEARP findings also state a radiometric study was conducted by Sandia National Laboratories (SNL)/New Mexico (NM) personnel and no significantly above background radiation levels were detected, and "no entry was made into the mines."

Corrective Action

Kirtland Air Force Base [KAFB] and various SNL/NM groups conducted five, well-documented field inspections /investigations efforts (one by KAFB and four by SNL/NM). All investigative efforts shared the same objective of determining if the mines had been used for any activities that resulted in an environmental problem/concern. Secondary objectives included mapping the mines, surveying their locations, and documenting each location with photographs.

A base-wide radiation survey was conducted in the 1982 to1983 timeframe. All sites were investigated by collecting *in-situ* readings and soil samples. The purpose of this study was to first determine whether radiation levels above background levels were present, and if so, determine what radionuclides were responsible for the elevated readings. The radiation spectra from *in-situ* instrument readings and soil sample analytical results showed nothing more than slight variations in background readings due to the types of rocks found at each location. Visual inspections performed during the revealed nothing that conflicts with this conclusion.

Personnel from the KAFB 377th Air Base Wing Environmental Management and Restoration conducted detailed mapping and inspection surveys of ER site 28-10 in early August 1993. This work was part of the overall effort aimed at defining ownership of the mines, as well as providing sound documentation of the condition and status of the mines. Inspections focused on looking for evidence of postmining activity.

In late August 1993, SNL/NM environmental Restoration lead investigator toured the confirmed locations previously surveyed in 1982 to 1983. The purpose was to confirm the locations of the identified mine sites from the 1982 to 1983 original survey.

Four main inspections were conducted by SNL/NM personnel from November 1994 to March 1995. All locations were visited at least twice, and all were thoroughly inspected from the surface. KAFB personnel most familiar with the mine sites were present for one of the inspections. ER site 28-10 could be completely inspected from the surface. A small amount of slag material has been noted in the tailings pile surrounding the top of the shaft. This material is very porous and based on the small volume of this material and lack of any other indications of non-mining debris, it was concluded that this slag material was related to the original mining activities.

Eight of the 10 ER site 28 locations show no evidence of any postmining activity and, therefore, do not pose a threat of a release.

Constituents Investigated

None.

Institutional Controls

The New Mexico Environment Department (NMED) determined site remediation is complete, and no controls are needed. However, as a best management practice, the LTES has established administrative institutional controls (IC) to track this site in the SNL IC database.

Current Regulatory Status

Corrective action is complete at ER site 28-5 and no further action is required. This site is acceptable for residential land use and there are no restrictions on future activities. The NMED approved completion of corrective action. The mine was plugged in May 2005.

Results of Risk Analysis

No risk analysis was necessary.

Waste Volume Estimated/Generated

No waste was generated.

Site 0028_6: Mine Shafts

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

There are 10 mine shafts (Environmental Restoration (ER) sites 28-1 to 28-10) where mining activity took place. The mines included as 'ER site 28' have long since been abandoned or were never worked beyond some very limited prospecting. The individual mine locations vary considerably. Old mine features, (including adits, shafts, and prospecting pits) are the remnants of mineral mining activities conducted in the early to mid-1900s. Fluorite was the most common mineral mined, but barite, galena, and other sulfide minerals also were apparently mined based on examination of tailings piles. These mines are not ER sites due to their mining activities, but because speculation that these remnant sites may have been used to dispose of various wastes. According to Comprehensive Environmental Assessment and Response Program (CEARP) interviews, various wastes may have been placed in the mine(s); however, no evidence to support these rumors exists. Based on follow-up interviews, at least one rumor regarding the disposal of explosives in a mine is false. The CEARP findings also state a radiometric study was conducted by Sandia National Laboratories (SNL)/New Mexico (NM) personnel and no significantly above background radiation levels were detected, and "no entry was made into the mines."

ER site 28-6 is located on the north central part of the Withdrawn Lands on the north side of Lurance Canyon, approximately 2,000 feet northwest of Site 28-4 on a small ridge. The site is bounded to the north by ER Site 236 and to the west by ER Site 63A, 63B, and 236. ER Site 28-6 is comprised of a single vertical shaft that is approximately 15 feet deep and 5 feet in diameter. A small collar of tailings material surrounds the shaft. This site is easily inspected from the surface and no evidence of postmining activity exists.

Corrective Action

Kirtland Air Force Base [KAFB] and various SNL/NM groups conducted five, well-documented field inspections /investigations efforts (one by KAFB and four by SNL/NM). All investigative efforts shared the same objective of determining if the mines had been used for any activities that resulted in an environmental problem/concern. Secondary objectives included mapping the mines, surveying their locations, and documenting each location with photographs.

A base-wide radiation survey was conducted in the 1982 to1983 timeframe. All sites were investigated by collecting *in-situ* readings and soil samples. The purpose of this study was to first determine whether radiation levels above background levels were present, and if so, determine what radionuclides were responsible for the elevated readings. The radiation spectra from *in-situ* instrument readings and soil sample analytical results showed nothing more than slight variations in background readings due to the types of rocks found at each location. Visual inspections performed during the revealed nothing that conflicts with this conclusion.

Personnel from the KAFB 377th Air Base Wing Environmental Management and Restoration conducted detailed mapping and inspection surveys of ER site 28-10 in early August 1993. This work was part of the overall effort aimed at defining ownership of the mines, as well as providing sound documentation of the condition and status of the mines. Inspections focused on looking for evidence of postmining activity.

In late August 1993, SNL/NM environmental Restoration lead investigator toured the confirmed locations previously surveyed in 1982 to 1983. The purpose was to confirm the locations of the identified mine sites from the 1982 to 1983 original survey.

Four main inspections were conducted by SNL/NM personnel from November 1994 to March 1995. All locations were visited at least twice, and all were thoroughly inspected from the surface. KAFB personnel most familiar with the mine sites were present for one of the inspections. ER site 28-10 could be completely inspected from the surface. A small amount of slag material has been noted in the tailings pile surrounding the top of the shaft. This material is very porous and based on the small volume of this material and lack of any other indications of non-mining debris, it was concluded that this slag material was related to the original mining activities.

A January 1997 report on internal evaluations of shaft features identified the presence of Townsend's big-eared bats and scattered guano pellets at ER sites 28-3 and 28-6. It was recommended that slow backfilling of fill material into the hole over the course of a day would drive the bats out of the mines.

More recent safety surveys of mine 28-1, 28-3, 28-6, and 28-10 found no elevated radiation.

ER site 28-6 shows no evidence of any postmining activity and therefore does not pose a threat of a release. The mine was plugged in May 2005.

Constituents Investigated

Radionuclides.

Institutional Controls

The New Mexico Environment Department (NMED) determined site remediation is complete, and no controls are needed. However, as a best management practice, the LTES has established administrative institutional controls (IC) to track this site in the SNL IC database.

Current Regulatory Status

Corrective action is complete at ER site 28-6 and no further action is required. This site is acceptable for residential land use and there are no restrictions on future activities. The NMED approved completion of corrective action.

Results of Risk Analysis

No risk analysis was necessary.

Waste Volume Estimated/Generated

No waste was generated.

Site 0028_8: Mine Shafts

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

There are 10 mine shafts (Environmental Restoration (ER) sites 28-1 to 28-10) where mining activity took place. The mines included as 'ER site 28' have long since been abandoned or were never worked beyond some very limited prospecting. The individual mine locations vary considerably. Old mine features, (including adits, shafts, and prospecting pits) are the remnants of mineral mining activities conducted in the early to mid-1900s. Fluorite was the most common mineral mined, but barite, galena, and other sulfide minerals also were apparently mined based on examination of tailings piles. These mines are not ER sites due to their mining activities, but because speculation that these remnant sites may have been used to dispose of various wastes. According to Comprehensive Environmental Assessment and Response Program (CEARP) interviews, various wastes may have been placed in the mine(s); however, no evidence to support these rumors exists. Based on follow-up interviews, at least one rumor regarding the disposal of explosives in a mine is false. The CEARP findings also state a radiometric study was conducted by Sandia National Laboratories (SNL)/New Mexico (NM) personnel and no significantly above background radiation levels were detected, and "no entry was made into the mines."

ER site 28-8 is located on the north—central part of the withdrawn lands on the north side of Lurance Canyon, approximately 2,000 feet northwest of ER site 28-4 on the same small hill/ridge as ER site 28-6. This site is in the immediate vicinity of ER site 28-6 and is a very small depression/excavation. It is probably a prospecting pit abandoned prior to significant excavation. This feature is insignificant and shows no evidence of postmining activity.

Corrective Action

Kirtland Air Force Base [KAFB] and various SNL/NM groups conducted five, well-documented field inspections /investigations efforts (one by KAFB and four by SNL/NM). All investigative efforts shared the same objective of determining if the mines had been used for any activities that resulted in an environmental problem/concern. Secondary objectives included mapping the mines, surveying their locations, and documenting each location with photographs.

A base-wide radiation survey was conducted in the 1982 to1983 timeframe. All sites were investigated by collecting *in-situ* readings and soil samples. The purpose of this study was to first determine whether radiation levels above background levels were present, and if so, determine what radionuclides were responsible for the elevated readings. The radiation spectra from *in-situ* instrument readings and soil sample analytical results showed nothing more than slight variations in background readings due to the types of rocks found at each location. Visual inspections performed during the revealed nothing that conflicts with this conclusion.

Personnel from the KAFB 377th Air Base Wing Environmental Management and Restoration conducted detailed mapping and inspection surveys of ER site 28-10 in early August 1993. This work was part of the overall effort aimed at defining ownership of the mines, as well as providing sound documentation of the condition and status of the mines. Inspections focused on looking for evidence of postmining activity.

In late August 1993, SNL/NM environmental Restoration lead investigator toured the confirmed locations previously surveyed in 1982 to 1983. The purpose was to confirm the locations of the identified mine sites from the 1982 to 1983 original survey.

Four main inspections were conducted by SNL/NM personnel from November 1994 to March 1995. All locations were visited at least twice, and all were thoroughly inspected from the surface. KAFB personnel most familiar with the mine sites were present for one of the inspections. ER site 28-10 could be completely inspected from the surface. A small amount of slag material has been noted in the tailings pile surrounding the top of the shaft. This material is very porous and based on the small volume of this material and lack of any other indications of non-mining debris, it was concluded that this slag material was related to the original mining activities.

ER site 28-8 shows no evidence of any postmining activity and, therefore, does not pose a threat of a release. The mine was plugged in May 2005.

Constituents Investigated

Radionuclides.

Institutional Controls

The New Mexico Environment Department (NMED) determined site remediation is complete, and no controls are needed. However, as a best management practice, the LTES has established administrative institutional controls (IC) to track this site in the SNL IC database.

Current Regulatory Status

Corrective action is complete at ER site 28-8 and no further action is required. This site is acceptable for residential land use and there are no restrictions on future activities. The NMED approved completion of corrective action in September 1997.

Results of Risk Analysis

No risk analysis was necessary.

Waste Volume Estimated/Generated

No waste was generated.

Site 0065A: Lurance Canyon Explosive Test Site (Small Debris Mound)

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 65 is identified by the *Hazardous and Solid Waste Amendments* (HSWA) module as the Lurance Canyon Explosive Test Site (LCETS). The site is situated on the canyon-floor alluvium in the upper reaches of the Lurance Canyon drainage. The canyon is surrounded by moderately steep, sloping canyon walls. The immediate topographic relief around the site is over 500 feet (ft). A 25- to 50-ft-wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls, except for the western drainage of the Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access into Lurance Canyon.

The location of ER site 65 is coincident with ER sites 94, 12, and 13. ER site 65 was used from the late 1960s to the early 1980s for general explosives tests. Due to the overlap in location and periods of testing at ER sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in the descriptions of each ER site.

ER site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (nonpetroleum fuel fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER site 94.

Interviews with past Sandia National Laboratories/New Mexico (SNL/NM) personnel and historical aerial photographs have been used to reconstruct past operations at ER site 65. Aerial photographs indicate that construction of ER site 65 had begun by October 1967. It was established as an explosives test area designed with a 10,000-ft dispersion radius to provide a buffer for open detonations of up to 10,000 pounds (lbs) of high explosives (HE). The test site was in full operation by 1971 and several structures were visible. A firebreak road was constructed around the site between 1967 and mid-1971 to protect the surrounding area from accidental fires caused by detonation of explosives or burn testing.

Bunker 9830, also visible in the 1971 historical aerial photograph, is located in the northwest portion of ER site 65. It was originally intended to house instrumentation trailers for site activities. Instrumentation trailers for ER site 94 are presently stationed outside the bunker. The bunker was reported to be the control point for explosives tests, as well as a shelter for staff during burn tests

involving explosive materials. The eastern half of Bunker 9830 was also used for burn tests on nuclear reactor control cables and fire suppressant tests.

The 1971 historical aerial photograph also shows a shallow depression that is located approximately 200 ft south of Bunker 9830. This depression served as part of a foundation for a camera bunker that was constructed after 1971. The camera bunker is reported to have been used to record large explosions that were detonated to the immediate area east of the bunker. The camera bunker is currently part of ER site 94.

All open detonation explosives tests were concluded by the early 1980s. The frequency of testing from 1968 to 1980 has been estimated at approximately 20 tests per year. Based on information provided in the interviews, open detonation explosives tests were conducted within the primary and secondary detonation areas.

In addition to open detonation explosives tests, fuel-fire burn tests of test units containing explosives were conducted at ER site 65 using excavated pits from 1969 to 1979. Portable pans and engineered burn structures completely replaced burn pit tests by 1979. From the mid-1970s, a variety of nonpetroleum-fuel-fire burn tests were conducted. These tests included slow-heat detonations, TABS tests, rocket propellant burn tests, liquid oxygen torch tests, and wood crib fire tests. Small explosive tests were also conducted in the CON-CON unit in 1982.

Bunker 9830, the camera bunker, the Bomb Burner Unit trench, a small debris mound, and a fire break periphery road are the only remaining features associated with LCETS activities. The CON-CON unit was removed in 1988 and the Smoke Emission Reduction Facility (SMERF) was constructed on its site.

Based on the location of the detonations and the types of tests conducted at ER site 65, the site has been divided into five subunits.

Environmental Restoration (ER) site 65A, the Small Debris Mound, covers an area of less than 0.1 acre on the southeast rim of the Oil Surface Impoundment (ER site 13). This small mound contained soil, limestone blocks, and concrete rubble and may have been the location of a propagation test. Two interview records identified the small debris mound as a small concrete bunker covered with soil and two records speculated the propagation test took place there.

Corrective Action

In April 1993 a radiation survey of roads surrounding ER site 65 is conducted by the SNL Radiation Protection Office (RPO). No radioactivity was detected in the air-born or direct scan swipe samples.

An unexploded ordnance/high explosives (UXO/HE) survey of ER site 65 was conducted in October 1993. Although one trip flare was reported in the area of the "New Burn Site," the UXO/HE report shows no data indicating live ordnance within ER site 65 boundaries.

In December 1993, a gamma radiation survey was conducted, but no radiological anomalies were found. In September 1995, ER site 65 divided into five subunits based on location and types of tests.

An *Resource Conservation and Recovery Act* (RCRA) Facility Investigation (RFI) work plan was submitted for regulatory approval in January 1996. A surface radiation voluntary corrective measure (VCM) of sites 12, 13, 65, and 94 was completed in May 1996. Samples for all of the areas associated with ER site 65 testing activities were collected according to the work plan.

Initial sampling at ER site 65A was conducted in May 1996 uncovered an intact storage bunker. The soil and debris contents of this bunker were sampled in April 1998, and the bunker was demolished and disposed of as nonregulated waste. This led to additional sampling in accordance with the Operating Unit (OU) 1333 RFI work plan and Field Implementation Plan.

From May 1996 through May 1998, 11 soil samples were collected from around and inside the bunker. Only samples from inside the bunker showed levels of contaminant of concern (COCs) above ecological risk-based values. No gamma activities were detected above background levels. High explosives were not detected in any of the samples.

In March 1999, a voluntary corrective action (VCA) was performed to demolish, remove, and dispose of the bunker, and perform confirmatory sampling under bunker floor. Two confirmatory samples were collected. No COCs above background were detected.

Constituents Investigated

High explosives (HE), metals, radionuclides, semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), and polyvinyl chloride (PVC).

Institutional Controls

The New Mexico Environment Department (NMED) determined site remediation is complete, and no controls are needed. However, as a best management practice, the LTES has established administrative institutional controls (IC) to track this site in the SNL IC database.

Current Regulatory Status

Corrective action is complete at ER site 65A and no further action is required. It is acceptable for residential land use, and there are no restrictions on future activities as noted under Institutional Controls. The NMED approved completion of corrective action for ER site 65A in September 2000. The site is listed on Table A.2 of the permit.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for the site. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario. The results of the risk assessment were below the NMED risk guidelines for industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land-use scenario.

Waste Volume Estimated/Generated

A combined surface radiation VCM for sites 12, 13, 65, and 94 has generated 200 drums of radioactive waste. Approximately 100 cubic yards of nonregulated waste were generated and disposed of during the demolition of the site 65A bunker.

Site 0065B: Lurance Canyon Explosive Test Site (Primary Detonation Area)

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 65 is identified by the *Hazardous and Solid Waste Amendments* (HSWA) module as the Lurance Canyon Explosive Test Site (LCETS). The site is situated on the canyon-floor alluvium in the upper reaches of the Lurance Canyon drainage. The canyon is surrounded by moderately steep, sloping canyon walls. The immediate topographic relief around the site is over 500 feet (ft). A 25- to 50-ft-wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls, except for the western drainage of the Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access into Lurance Canyon.

The location of ER site 65 is coincident with ER sites 94, 12, and 13. ER site 65 was used from the late 1960s to the early 1980s for general explosives tests. Due to the overlap in location and periods of testing at ER sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in the descriptions of each ER site.

ER site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (nonpetroleum fuel fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER site 94.

Interviews with past Sandia National Laboratories/New Mexico (SNL/NM) personnel and historical aerial photographs have been used to reconstruct past operations at ER site 65. Aerial photographs indicate that construction of ER site 65 had begun by October 1967. It was established as an explosives test area designed with a 10,000-ft dispersion radius to provide a buffer for open detonations of up to 10,000 pounds (lbs) of high explosives (HE). The test site was in full operation by 1971 and several structures were visible. A firebreak road was constructed around the site between 1967 and mid-1971 to protect the surrounding area from accidental fires caused by detonation of explosives or burn testing.

Bunker 9830, also visible in the 1971 historical aerial photograph, is located in the northwest portion of ER site 65. It was originally intended to house instrumentation trailers for site activities. Instrumentation trailers for ER site 94 are presently stationed outside the bunker. The bunker was reported to be the control point for explosives tests, as well as a shelter for staff during burn tests

involving explosive materials. The eastern half of Bunker 9830 was also used for burn tests on nuclear reactor control cables and fire suppressant tests.

The 1971 historical aerial photograph also shows a shallow depression that is located approximately 200 ft south of Bunker 9830. This depression served as part of a foundation for a camera bunker that was constructed after 1971. The camera bunker is reported to have been used to record large explosions that were detonated to the immediate area east of the bunker. The camera bunker is currently part of ER site 94.

All open detonation explosives tests were concluded by the early 1980s. The frequency of testing from 1968 to 1980 has been estimated at approximately 20 tests per year. Based on information provided in the interviews, open detonation explosives tests were conducted within the primary and secondary detonation areas.

In addition to open detonation explosives tests, fuel-fire burn tests of test units containing explosives were conducted at ER site 65 using excavated pits from 1969 to 1979. Portable pans and engineered burn structures completely replaced burn pit tests by 1979. From the mid-1970s, a variety of nonpetroleum-fuel-fire burn tests were conducted. These tests included slow-heat detonations, TABS tests, rocket propellant burn tests, liquid oxygen torch tests, and wood crib fire tests. Small explosive tests were also conducted in the CON-CON unit in 1982.

Bunker 9830, the camera bunker, the Bomb Burner Unit trench, a small debris mound, and a fire break periphery road are the only remaining features associated with LCETS activities. The CON-CON unit was removed in 1988 and the Smoke Emission Reduction Facility (SMERF) was constructed on its site.

Based on the location of the detonations and the types of tests conducted at ER site 65, the site has been divided into five subunits.

Environmental Restoration site 65B covers approximately 3.3 acres of the western portion of ER site 65. The site was the detonation area for general explosives tests, miscellaneous burn tests, slow-heat tests, and a TABS test. The boundaries of this subunit were defined by historical aerial photographs and interview records.

Corrective Action

In October 1993, a visual survey was conducted for the presence of unexploded ordnance (UXO) and high explosives (HE) on the ground surface at ER site(s) 65. A surface gamma radiation survey was conducted during November and December 1993 and January 1994. This survey was conducted over all ER site 65 sites, as the five subunits had not been defined at the time of this survey. All anomalies associated with the LCETS open burning/detonation activities were slated for a voluntary corrective measure (VCM).

From December 1993 to January 1994, SNL/Radiation Protection Operations (RPO) conducted follow-up survey of anomalies found in the gamma radiation survey. None of the results yielded dose rates above the limits for site workers, eliminating the need for pre-voluntary corrective measure (VCM) removal.

Initial VCM activities conducted in March 1995 consisted of small point source (mostly depleted uranium [DU] fragments) removal. In July 1995, as part of a project-wide scoping sampling program to determine site ranking and prioritization, five soil-sampling locations were selected with one surface and one subsurface soil sample collected and analyzed from each location. The purpose of this effort was to obtain preliminary analytical data to support the SNL/ ER project site ranking and prioritization. Barium and lead were detected in the samples. Barium concentrations were below the established background limits, and four of the 10 lead concentrations detected exceeded the background limit. One sample showed uranium-238 results above the background activity limit.

A VCM was conducted from May to October 1996 to remove a large area with contaminants of concern (COC) sources. Following the VCM activities, post-cleanup verification samples were collected throughout ER site 65. Confirmatory soil sampling was conducted in April 1998 to determine levels of COCs remaining at the site. In January 1999, confirmatory resampling was conducted at ER site 65B of soils from the TABS test location A.

It was concluded that no contaminants of concern were present in concentrations considered hazardous to human health for an industrial land-use scenario.

Constituents Investigated

High explosives (HE), metals, radionuclides, semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), and polyvinyl chloride (PVC).

Institutional Controls

The New Mexico Environment Department (NMED) determined site remediation is complete, and no controls are needed. However, as a best management practice, the LTES has established administrative institutional controls (IC) to track this site in the SNL IC database.

Current Regulatory Status

Corrective action is complete at ER site 65B and no further action is required. It is acceptable for residential land use, and there are no restrictions on future activities as noted under institutional controls (IC). The NMED approved completion of corrective action for ER site 65B in September 2000. The site is listed on Table A.2 of the permit.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for the site. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario. The results of the risk assessment were below the NMED risk guidelines for industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land-use scenario.

Waste Volume Estimated/Generated

A combined surface radiation VCM for sites 12, 13, 65, and 94 has generated 200 drums of radioactive waste. Approximately 100 cubic yards of nonregulated waste were generated and disposed of during the demolition of the site 65A bunker.

Exceptional service in the national interest

Sandia National Laboratories

Site 0065C: Lurance Canyon Explosive Test Site (Secondary Detonation Area)

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 65 is identified by the *Hazardous and Solid Waste Amendments* (HSWA) module as the Lurance Canyon Explosive Test Site (LCETS). The site is situated on the canyon-floor alluvium in the upper reaches of the Lurance Canyon drainage. The canyon is surrounded by moderately steep, sloping canyon walls. The immediate topographic relief around the site is over 500 feet (ft). A 25- to 50-ft-wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls, except for the western drainage of the Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access into Lurance Canyon.

The location of ER site 65 is coincident with ER sites 94, 12, and 13. ER site 65 was used from the late 1960s to the early 1980s for general explosives tests. Due to the overlap in location and periods of testing at ER sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in the descriptions of each ER site.

ER site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (nonpetroleum fuel fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER site 94.

Interviews with past Sandia National Laboratories/New Mexico (SNL/NM) personnel and historical aerial photographs have been used to reconstruct past operations at ER site 65. Aerial photographs indicate that construction of ER site 65 had begun by October 1967. It was established as an explosives test area designed with a 10,000-ft dispersion radius to provide a buffer for open detonations of up to 10,000 pounds (lbs) of high explosives (HE). The test site was in full operation by 1971 and several structures were visible. A firebreak road was constructed around the site between 1967 and mid-1971 to protect the surrounding area from accidental fires caused by detonation of explosives or burn testing.

Bunker 9830, also visible in the 1971 historical aerial photograph, is located in the northwest portion of ER site 65. It was originally intended to house instrumentation trailers for site activities. Instrumentation trailers for ER site 94 are presently stationed outside the bunker. The bunker was reported to be the control point for explosives tests, as well as a shelter for staff during burn tests

involving explosive materials. The eastern half of Bunker 9830 was also used for burn tests on nuclear reactor control cables and fire suppressant tests.

The 1971 historical aerial photograph also shows a shallow depression that is located approximately 200 ft south of Bunker 9830. This depression served as part of a foundation for a camera bunker that was constructed after 1971. The camera bunker is reported to have been used to record large explosions that were detonated to the immediate area east of the bunker. The camera bunker is currently part of ER site 94.

All open detonation explosives tests were concluded by the early 1980s. The frequency of testing from 1968 to 1980 has been estimated at approximately 20 tests per year. Based on information provided in the interviews, open detonation explosives tests were conducted within the primary and secondary detonation areas.

In addition to open detonation explosives tests, fuel-fire burn tests of test units containing explosives were conducted at ER site 65 using excavated pits from 1969 to 1979. Portable pans and engineered burn structures completely replaced burn pit tests by 1979. From the mid-1970s, a variety of nonpetroleum-fuel-fire burn tests were conducted. These tests included slow-heat detonations, TABS tests, rocket propellant burn tests, liquid oxygen torch tests, and wood crib fire tests. Small explosive tests were also conducted in the CON-CON unit in 1982.

Bunker 9830, the camera bunker, the Bomb Burner Unit trench, a small debris mound, and a fire break periphery road are the only remaining features associated with LCETS activities. The CON-CON unit was removed in 1988 and the Smoke Emission Reduction Facility (SMERF) was constructed on its site.

Based on the location of the detonations and the types of tests conducted at ER site 65, the site has been divided into five subunits.

Environmental Restoration site 65C, the Secondary Detonation Area, lies on approximately 1.3 acres north of the Oil Surface Impoundment. The boundaries of the site were defined by historical aerial photographs and test reports. The site was the burn pit area for the Cloudmaker tests, ammonium nitrate burn tests involving fuel-rod containers, liquid fuel fire, and solid rocket propellant burn tests on Pioneer capsules, plutonium shipping container tests, and the TC-708 emergency denial device test. The site was re-graded since testing activities ceased in the early 1970s significantly altering the ground surface at this site, so no evidence of the pits associated with past testing exists.

Corrective Action

Initially investigated under the Department of Energy (DOE) Comprehensive Environmental Assessment Response Program (CEARP) investigation in the mid-1980s, the site was identified as a potential release site of JP-4, diesel fuels, and metals. A preliminary investigation was conducted in 1993, which included background information reviews, interviews, field surveys, and scooping sampling.

In October 1993, a visual survey was conducted for the presence of unexploded ordnance (UXO) and high explosives (HE) on the ground surface at ER site 65. A surface gamma radiation survey was conducted during November and December 1993 and January 1994. This survey was conducted over all ER site 65 sites, as the five subunits had not been defined at the time of this survey. All anomalies associated with the LCETS open burning/detonation activities were slated for a voluntary corrective measure (VCM).

In July 1995, ER site 65C was investigated as part of a sitewide scoping sampling program. The purpose of this effort was to obtain preliminary analytical data to support the Sandia National Laboratories (SNL)/ ER project site ranking and prioritization. Three borehole locations were selected within the ER site 65C boundaries. A surface and subsurface sample were taken from each borehole. Barium and lead were detected in the soil samples, but both were below the background limits established.

Voluntary corrective measure activities were conducted in March 1995, and May, June, and October 1996. No radiological anomalies were identified within the boundaries of ER site 65C. Anomalies present in other areas of ER site 65 were removed in March 1995. Larger area sources were removed in May, June, and October 1996.

Confirmatory soil sampling was conducted in April 1998 to determine levels of contaminants of concern (COCs) remaining at the site. In February 1999, confirmatory resampling was conducted at ER site 65C of soils from one sampling location.

Barium results were all elevated above the maximum background concentrations at one location.

Beryllium results were all elevated above the maximum background concentrations at four locations, and mercury results were all elevated above the maximum background concentrations at one location. Radionuclide results revealed one location exceeding background concentration of uranium-235 and two samples exceeding the background concentration for gross alpha.

Constituents Investigated

High explosives (HE), metals, radionuclides, semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), and polyvinyl chloride (PVC).

Institutional Controls

The New Mexico Environment Department (NMED) determined site remediation is complete, and no controls are needed. However, as a best management practice, the LTES has established administrative institutional controls (IC) to track this site in the SNL IC database.

Current Regulatory Status

Corrective action is complete at ER site 65C and no further action is required. It is acceptable for residential land use, and there are no restrictions on future activities as noted under Institutional Controls. The NMED approved completion of corrective action for ER sites 65C in September 2000. The site is listed on Table A.2 of the permit.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for the site. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario. The results of the risk assessment were below the NMED risk guidelines for industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land-use scenario.

Waste Volume Estimated/Generated

A combined surface radiation VCM for sites 12, 13, 65, and 94 has generated 200 drums of radioactive waste. Approximately 100 cubic yards of nonregulated waste were generated and disposed of during the demolition of the site 65A bunker.

Site 0065D: Lurance Canyon Explosive Test Site (Near-field Dispersion Area)

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 65 is identified by the *Hazardous and Solid Waste Amendments* (HSWA) module as the Lurance Canyon Explosive Test Site (LCETS). The site is situated on the canyon-floor alluvium in the upper reaches of the Lurance Canyon drainage. The canyon is surrounded by moderately steep, sloping canyon walls. The immediate topographic relief around the site is over 500 feet (ft). A 25- to 50-ft-wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls, except for the western drainage of the Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access into Lurance Canyon.

The location of ER site 65 is coincident with ER sites 94, 12, and 13. ER site 65 was used from the late 1960s to the early 1980s for general explosives tests. Due to the overlap in location and periods of testing at ER sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in the descriptions of each ER site.

ER site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (nonpetroleum fuel fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER site 94.

Interviews with past Sandia National Laboratories/New Mexico (SNL/NM) personnel and historical aerial photographs have been used to reconstruct past operations at ER site 65. Aerial photographs indicate that construction of ER site 65 had begun by October 1967. It was established as an explosives test area designed with a 10,000-ft dispersion radius to provide a buffer for open detonations of up to 10,000 pounds (lbs) of high explosives (HE). The test site was in full operation by 1971 and several structures were visible. A firebreak road was constructed around the site between 1967 and mid-1971 to protect the surrounding area from accidental fires caused by detonation of explosives or burn testing.

Bunker 9830, also visible in the 1971 historical aerial photograph, is located in the northwest portion of ER site 65. It was originally intended to house instrumentation trailers for site activities. Instrumentation trailers for ER site 94 are presently stationed outside the bunker. The bunker was reported to be the control point for explosives tests, as well as a shelter for staff during burn tests

involving explosive materials. The eastern half of Bunker 9830 was also used for burn tests on nuclear reactor control cables and fire suppressant tests.

The 1971 historical aerial photograph also shows a shallow depression that is located approximately 200 ft south of Bunker 9830. This depression served as part of a foundation for a camera bunker that was constructed after 1971. The camera bunker is reported to have been used to record large explosions that were detonated to the immediate area east of the bunker. The camera bunker is currently part of ER site 94.

All open detonation explosives tests were concluded by the early 1980s. The frequency of testing from 1968 to 1980 has been estimated at approximately 20 tests per year. Based on information provided in the interviews, open detonation explosives tests were conducted within the primary and secondary detonation areas.

In addition to open detonation explosives tests, fuel-fire burn tests of test units containing explosives were conducted at ER site 65 using excavated pits from 1969 to 1979. Portable pans and engineered burn structures completely replaced burn pit tests by 1979. From the mid-1970s, a variety of nonpetroleum-fuel-fire burn tests were conducted. These tests included slow-heat detonations, TABS tests, rocket propellant burn tests, liquid oxygen torch tests, and wood crib fire tests. Small explosive tests were also conducted in the CON-CON unit in 1982.

Bunker 9830, the camera bunker, the Bomb Burner Unit trench, a small debris mound, and a fire break periphery road are the only remaining features associated with LCETS activities. The CON-CON unit was removed in 1988 and the Smoke Emission Reduction Facility (SMERF) was constructed on its site.

Based on the location of the detonations and the types of tests conducted at ER site 65, the site has been divided into five subunits.

ER site 65D lies on approximately 8.0 acres of land at a mean elevation of 6,325 ft above sea level (asl). The site represents the nearest extent of the fragmentation area associated with open-detonation tests at the LCETS. The fragmentation boundary was confirmed by the surface gamma radiation survey performed in 1994. Tests conducted at ER site 65D include miscellaneous burn tests, cone tests, and slow-heat tests. The area is considered a dispersion area for general explosives test activities conducted at ER sites 65B and 65C. Since this site is the current on-site worker area for ER site 94 activities, the ground surface has been disturbed by ongoing grading activities.

Corrective Action

In October 1993, Kirtland Air Force Base (KAFB) personnel conducted a visual survey for the presence of unexploded ordnance (UXO) and high explosives (HE) on the ground surface at ER site 65. The survey identified one trip flare as live ordnance, and one slap flare and one rifle-propelled illuminator round as ordnance debris. The survey report documented metal fragments were found in the hills surrounding these sites. A radiation survey was performed that included a 100 percent surface coverage of the site.

During November and December 1993 and January 1994, a phase I surface gamma radiation survey of ER site 65 was performed in conjunction with ER sties 12, 13, and 94. Anomalies identified were either identified as point or area sources. All anomalies occurring within the active, graded portion (65D) were point sources consisting of thin, black depleted uranium (DU) fragments that ranged in size from 0.75 to 2 inches mainly found in the hill slopes comprising ER Site 65E. Where fragments were not visible, the response of the radiological survey instruments suggests that the anomalies soil point sources in ER site 65D were the result of buried DU fragments. These soil area sources were located exclusively in ER site 65D.

In July 1995, ER site 65D was investigated as part of a site-wide scoping program. Three sampling locations were selected within the boundary of the site. A surface sample and subsurface sample were collected from each location. Barium and lead were detected in the soil samples. Barium concentrations were below the background limit, and the lead concentrations were all estimated, with four out of the six samples exceeding the background limit. Neither HE nor uranium was detected in any samples above the minimum detectable activity (MDA).

In March 1995 and May, June, and October 1996, VCM activities consisted of the identification and removal of buried DU fragments and soil area sources at ER site 65D.

A VCM was performed in from May to October 1996 to remove a large area of potential contaminant sources. Following all VCM activities, post-cleanup verification samples were collected throughout ER site 65. Larger area sources were remediated in May June and October 1996. After radiologically contaminated soils were removed, 21 post-cleanup samples were collected from areas that had exhibited the highest residual gamma radiation readings detected during the phase I radiological survey.

Confirmatory soil sampling was conducted in April 1998 to determine the levels of contaminants of concern remaining at the site.

Constituents Investigated

High explosives (HE), metals, radionuclides, semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), and polyvinyl chloride (PVC).

Institutional Controls

The New Mexico Environment Department (NMED) determined site remediation is complete, and no controls are needed. However, as a best management practice, the LTES has established administrative institutional controls (IC) to track this site in the SNL IC database.

Current Regulatory Status

Corrective action is complete at ER site 65D and no further action is required. It is acceptable for residential land use, and there are no restrictions on future activities as noted under Institutional Controls. The NMED approved completion of corrective action for ER site 65D in September 2000. The site is listed on Table A.2 of the Permit.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for the site. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario. The results of the risk assessment were below the NMED risk guidelines for industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land-use scenario.

Waste Volume Estimated/Generated

A combined surface radiation VCM for sites 12, 13, 65, and 94 has generated 200 drums of radioactive waste. Approximately 100 cubic yards of nonregulated waste were generated and disposed of during the demolition of the site 65A bunker.

Site 0065E: Lurance Canyon Explosive Test Site (Far-field Dispersion Area)

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 65 is identified by the *Hazardous and Solid Waste Amendments* (HSWA) module as the Lurance Canyon Explosive Test Site (LCETS). The site is situated on the canyon-floor alluvium in the upper reaches of the Lurance Canyon drainage. The canyon is surrounded by moderately steep, sloping canyon walls. The immediate topographic relief around the site is over 500 feet (ft). A 25- to 50-ft-wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls, except for the western drainage of the Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access into Lurance Canyon.

The location of ER site 65 is coincident with ER sites 94, 12, and 13. ER site 65 was used from the late 1960s to the early 1980s for general explosives tests. Due to the overlap in location and periods of testing at ER sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in the descriptions of each ER site.

ER Site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (nonpetroleum fuel fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER site 94.

Interviews with past Sandia National Laboratories/New Mexico (SNL/NM) personnel and historical aerial photographs have been used to reconstruct past operations at ER site 65. Aerial photographs indicate that construction of ER site 65 had begun by October 1967. It was established as an explosives test area designed with a 10,000-ft dispersion radius to provide a buffer for open detonations of up to 10,000 pounds (lbs) of high explosives (HE). The test site was in full operation by 1971 and several structures were visible. A firebreak road was constructed around the site between 1967 and mid-1971 to protect the surrounding area from accidental fires caused by detonation of explosives or burn testing.

Bunker 9830, also visible in the 1971 historical aerial photograph, is located in the northwest portion of ER site 65. It was originally intended to house instrumentation trailers for site activities. Instrumentation trailers for ER site 94 are presently stationed outside the bunker. The bunker was reported to be the control point for explosives tests, as well as a shelter for staff during burn tests involving explosive materials. The eastern half of Bunker 9830 was also used for burn tests on nuclear reactor control cables and fire suppressant tests.

The 1971 historical aerial photograph also shows a shallow depression that is located approximately 200 ft south of Bunker 9830. This depression served as part of a foundation for a camera bunker that was constructed after 1971. The camera bunker is reported to have been used to record large explosions that were detonated to the immediate area east of the bunker. The camera bunker is currently part of ER site 94.

All open detonation explosives tests were concluded by the early 1980s. The frequency of testing from 1968 to 1980 has been estimated at approximately 20 tests per year. Based on information provided in the interviews, open detonation explosives tests were conducted within the primary and secondary detonation areas.

In addition to open detonation explosives tests, fuel-fire burn tests of test units containing explosives were conducted at ER site 65 using excavated pits from 1969 to 1979. Portable pans and engineered burn structures completely replaced burn pit tests by 1979. From the mid-1970s, a variety of nonpetroleum-fuel-fire burn tests were conducted. These tests included slow-heat detonations, TABS tests, rocket propellant burn tests, liquid oxygen torch tests, and wood crib fire tests. Small explosive tests were also conducted in the CON-CON unit in 1982.

Bunker 9830, the camera bunker, the Bomb Burner Unit trench, a small debris mound, and a fire break periphery road are the only remaining features associated with LCETS activities. The CON-CON unit was removed in 1988 and the Smoke Emission Reduction Facility (SMERF) was constructed on its site.

Based on the location of the detonations and the types of tests conducted at ER site 65, the site has been divided into five subunits.

ER site 65E lies on approximately 77 acres of land at a mean elevation of 6,365 ft above sea level (asl). This site represents the farthest extent of the fragmentation area associated with the open detonation tests at LCETS. The fragmentation boundary was confirmed by the surface gamma radiation survey performed in 1994. No documented tests were conducted at ER site 65E, but the area is considered a dispersion area for general explosives testing activities from ER sites 65B and 65C.

The Burn Site Spring is an ephemeral spring or seep approximately 1,200 ft northeast of ER site 65E. The spring discharges small quantities of water from fractures and/or bedding plane permeability within the carbonate rocks.

Corrective Action

A radiation survey that was performed included a 70-percent surface coverage (10-ft grid) of this site.

From May to October 1996, a voluntary corrective measure (VCM) was conducted for the removal of large area sources. Confirmatory samples were taken from areas with the highest gamma activity radiation sources. Where laboratory minimum detection levels (MDL) were above background levels, the MDL was used in the risk assessment. Beryllium and selenium results were above background levels (3 out of 17 samples), and uranium-238, uranium-235, and cesium-137 were above background in three locations.

In March and June 1996, surface and near-surface soil samples were collected from 16 locations at ER site 65E. During the June sampling, soil samples associated with mound 1 were taken. Soil samples from the arroyo sediment were collected from five locations within the main channel of the Lurance Canyon arroyo. The samples were analyzed for metals, HE, and radionuclides.

Confirmatory resampling was conducted in March 1998, and no HE was detected. The primary release mechanism for contamination at ER site 65E is fallout of test material shrapnel from the explosives and burn test activities. Although HE was involved in the test conducted at ER sites 65B and 65C, no HE compounds were detected in the surface and near-surface soils collected from the ER site 65E sample locations.

Constituents Investigated

High explosives (HE), metals, radionuclides, semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), and polyvinyl chloride (PVC).

Institutional Controls

The New Mexico Environment Department (NMED) determined site remediation is complete, and no controls are needed. However, as a best management practice, the LTES has established administrative institutional controls (IC) to track this site in the SNL IC database.

Current Regulatory Status

Corrective action is complete at ER site 65E and no further action is required. It is acceptable for residential land use, and there are no restrictions on future activities as noted under Institutional Controls. The NMED approved completion of corrective action for ER site 65E in July 2000. The site is listed on Table A.2 of the permit.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for the site. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario. The results of the risk assessment were below the NMED risk guidelines for the industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land use scenario.

Waste Volume Estimated/Generated

A combined surface radiation VCM for ER sites 12, 13, 65, and 94 has generated 200 drums of radioactive waste. Approximately 100 cubic yards of nonregulated waste were generated and disposed of during the demolition of the site 65A bunker.

Site 0094A: Lurance Canyon Burn Site (Aboveground Tanks)

Primary Contact: Long-Term Environmental Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 94 consists of 8 sub-units (A-H) and is identified as Lurance Canyon Burn Site (LCBS) in the HSWA Module. The site is located on the canyon floor alluvium in the closed upper reaches of the Lurance Canyon drainage on land withdrawn from the USFS by the USAF and permitted to the DOE. It is surrounded by moderately steep, sloping canyon walls. The site is constructed on a large graded area, and the immediate topographic relief around the site is over 500 ft. A 25- to 50-ft wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls except for the western drainage into Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access road into Lurance Canyon and the LCBS.

The location of ER Site 94 coincides with ER Site 65 Lurance Canyon Explosive Test Site, an inactive site used for high explosives (HE) tests and for liquid and solid propellant burn tests. The LCBS is currently used for testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components. Only a few of the permanent, engineered structures at the site are currently active. Historical aerial photographs indicate that the transition of testing activities from predominantly open detonation explosives testing and JP-4 fuel fires in excavated pits (ER Site 65) to open burning with JP-4 fuel fires in portable burn pans (ER Site 94) occurred between 1971 and 1982. Based on test reports and interviews, open burning with JP-4 fuel fires in portable burn pans began by 1975. By 1980, the first permanent, engineered burn unit was constructed on the site of the former Primary Detonation Area (ER Site 65B) and was in operation. The scrap yard was established in the northwestern portion of the site within the boundary of the former Far Field Dispersion Area (ER Site 65F). The scrap yard has been used to store spare materials used in explosives and burn tests and is currently used for storing nonliquid materials and used equipment.

By 1983, the LCBS was constructed. It consisted of five permanent, engineered burn units, including the Large Open Burn Pit (LOBP), the Small Open Burn Pit (SOBP), the Light Airtransport Accident Resistant Container (LAARC) Unit, the Bomb Burner Unit, the Small Wind-Shielded (SWISH) Unit, and the Conical Containment (CON-CON) Unit. They were sited on the graded area that had been the Primary

Detonation Area (ER Site 65B) and Near Field Dispersion Area (ER Site 65D). Two of the burn units (the SWISH Unit and later, the Smoke Emissions Reduction Facility [SMERF]) were

constructed to provide testing facilities that would eliminate wind effects and provide accurate temperature control and instrumentation for test monitoring. A small surface impoundment is also visible southeast of Bunker 9830. Engineered soil berms had also been constructed by 1983 in the southeastern portion of the site for flood protection from the main arroyo in Lurance Canyon.

The CON-CON Unit was dismantled prior to 1989 and by 1992 a new burn unit (SMERF) was constructed on its site. Prior to 1992, a debris/soil mound area was created in the southern portion of the LCBS, immediately north of the main arroyo in Lurance Canyon. This debris/soil mound may be associated with on-going grading activities at the site. Northeast of the debris/soil mound area is another soil mound that was created during the remediation of a wastewater spill from a permanent engineered unit that occurred on March 20, 1992.

Burn testing at the LCBS has always been conducted with JP-4 fuel pool fires in open portable pans or contained within the permanent engineered structures. Pool fires provide the closest simulation of accidents involving flammable liquids. For the tests, the pans are filled with approximately 1 to 2 ft of water and an average 8-in. layer of JP-4 fuel. The test unit, such as a transportation container, is placed on a stand above the fuel. The fuel is ignited and the fire typically burns until the JP-4 fuel is consumed. The length of the test is controlled by the volume (thickness) of the JP-4 fuel layer. After a burn test is completed, test units are retrieved and salvageable materials are collected and stored in the scrap yard located in the northwest portion of the site. Any test object residue (e.g., metal slag) is recovered with the test unit and removed from the site by the testing group. Only small residue particulates may be left in the water following the burn test. While no testing is currently conducted on components containing radioactive materials, ER Sites 94B and C are currently classified as RMMAs because of the presence of residual DU in the soil from earlier burn tests and from former explosives testing activities associated with ER Site 65 which was abolished as an RMMA following submittal of NFAs for all Site 65 sub-units. ER Site 94G is classified as an RMMA because the scrap material stored in the yard may have some radioactive contamination since some of it was used in tests conducted at Site 65 sub-units.

Due to the overlap in location and periods of testing at ER Sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in descriptions of each ER site.

ER Site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (non-petroleum fuel-fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER Site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER Site 94.

In order to facilitate site characterization, ER Site 94 has been subdivided into the following eight sub-units that represent areas where hazardous constituents may have been released.

ER Site 94A includes all of the current and historic aboveground tank storage locations at ER Site 94, including the current tank location north of the LOBP, the current tank location north of the LAARC Unit, and the former tank location north of the Bomb Burner Unit. These tank areas have been included due to documented and potential accidental releases of JP-4 fuel. ER Site 94A is comprised of three individual areas having a total surface area of 0.8 acres.

Corrective Action

In 1993, preliminary investigations were conducted which included background information reviews, interviews, field surveys, and scoping sampling.

In October 1993, Kirtland Air Force Base (KAFB) explosive ordnance disposal (EOD) personnel conducted a visual survey for unexploded ordnance (UXO) over the entire LCBS area. One trip flare was removed as live ordnance along with some ordnance debris.

During November and December 1993, and January 1994, a surface gamma radiation survey of ER Site 94 was conducted. Nine point-source and two area-source gamma radiation anomalies were removed from within the boundaries of Site 94B.

A passive soil vapor survey was conducted for the entire burn site in February 1998. Eighteen soil-gas points were located within the boundaries of Site 94B; no significant levels of organic compounds were detected as a result of this survey.

Based on results of the SVS and comments from NMED in the RSI and NOD, RFI sampling was conducted at all subunits at the Burn site in 1998 with the exception of the active Scrap Yard Site

94G. To determine the extent of fuel contamination at Site 94F, a second phase of characterization was conducted in 1999 that consisted of an active soil gas survey and soil sampling. Additional characterization was also conducted at Sites 94B & 94C and baseline sampling was conducted at Site 94G.

The drain line at site 94C was shown to have fixed radiological contamination and was excavated and removed from the trench in 1999. Rad surveys of the Site 94C trench sidewalls revealed an area of DU contaminated soil, a small DU contaminated soil area was also found at site 94B.

In April 1999, surface debris was removed from the site including scrap metal, concrete, and lead sheets. In May 1999, a geophysical survey indicated two anomalies associated with the large debris mound. The anomalies were removed and the mound was leveled. One of the anomalies, determined to be radioactively contaminated, was disposed as radioactive waste.

In response to a Request for Supplemental Information (RSI) from the New Mexico Environment Department (NMED), SNL agreed to additional characterization of two areas within the site. Subsequently, a Voluntary Corrective Action (VCA) was planned to further investigate the soil mounds and to collect samples from the adjacent arroyo.

In July 1999, soil samples were collected from two locations approximately two feet within the small jet propulsion fuel grade 4 (JP-4)/wastewater spill soil pile. In addition, five surface samples were collected from four locations in the adjacent arroyo channel. All samples were analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides.

In August 1999, a radiological survey was conducted over the entire surface of Site 94B. One small piece of depleted uranium (DU) was removed from the site and an area source was identified and marked. Further investigation showed the area source to be a layer of blackened DU contaminated soil approximately 1ft bgs.

Voluntary Corrective Actions were conducted at Sites 94B, C, & F in March and April of 2000. Radiologically contaminated soils were excavated at sites 94B & C and staged for disposal. Fuel contaminated soils were excavated at Site 94F. All soil with petroleum contamination was removed to bedrock at a depth of approximately 18 feet. The soils were disposed at a land farm or landfill, as appropriate, in the summer of 2000.

After discovery in August 2000 an RFI was conducted at ER site 94H to determine the extent of contamination. A VCA to remove the petroleum-contaminated soil was conducted in July 2001,

approximately 900 cubic yards of soil were removed.

In April 2000, an excavator was used to remove the contaminated soil layer. The resulting excavation was approximately 10 ft by 15 ft by 3.5 ft deep. Five confirmatory soil samples were collected from the base and sidewalls of the excavation. All samples were analyzed for radionuclides and one sample was also analyzed for VOCs, SVOCs, HE, and RCRA metals plus beryllium and uranium. Results indicated that the excavated area was clean and it was subsequently backfilled with clean soil.

Also in April 2000, a trench was cut through the JP-4 wastewater spill soil pile and a soil sample was collected from the native soil beneath the pile. The sample was analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides. In addition, soil samples were collected at two arroyo locations due to laboratory problems with the original analyses.

In November 2000, an estimated 25 cu yds of DU-contaminated soil that had been staged in ER Site 94B was disposed at an off-site facility.

In December 2000, a final radiological survey was conducted over the area and five confirmatory soil samples were collected. Results of these analyses indicated that residual DU levels are below risk levels and no further cleanup was required.

In July 1995, Site 94F was investigated as part of a site-wide scoping sampling program. Total petroleum hydrocarbon (TPH) and VOC results confirmed the presence of fuel-related compounds in the soil beneath the discharge pit. In February to March 1998, a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted to determine the extent of contamination at the site. A passive soil-vapor survey was conducted over the entire LCBS. Six surface-soil samples and three subsurface samples from one borehole were collected in the vicinity of the LAARC discharge pit. Analytical data from the RFI was sufficient to confirm the presence of contamination but additional sampling was required to verify the horizontal and vertical extent of contamination at Site 94F.

In November 1998, a second RFI was conducted to define the extent of contamination at the site for the purpose of remediation planning. Twenty-two active soil-gas samples were collected from the area surrounding the LAARC Unit and discharge pit. Following evaluation of the soil-gas results, 14 subsurface soil samples were collected from nine boreholes. Analytical results from these samples were used to identify the extent of contamination for excavation and to provide waste characterization data for planning disposal of excavated soils.

Based on the results of the RFI, a conceptual model was developed which indicated that contamination at this site was likely the primary source of groundwater contamination in the area and a Voluntary Corrective Action (VCA) source removal was planned. In consultation with the New Mexico Environment Department (NMED) it was determined that a level of 100 mg/kg of diesel range organics (DRO) in soil would be used as the cleanup criterion. All soil with DRO levels greater than 100 mg/kg would be excavated and disposed at an appropriate facility.

The source removal VCA was conducted during March and April 2000. Excavation continued until analytical results from the sidewall samples were less than 100 mg/kg DRO and until bedrock was encountered. Although some bedrock at the base of the excavation contained DRO above the cleanup level it was determined that further excavation was not feasible. Representatives from the NMED, including the Groundwater Bureau, inspected the excavation and concurred that the source removal objective of the VCA had been met.

A total of 856 cu yds of soil with DRO greater than 1000 mg/kg was excavated and stockpiled for

disposal at the off-site facility. An additional 336 cu yds of excavated soils appropriate for disposal at the KAFB landfill was stockpiled. In addition, approximately 2000 cu yds of clean soil, removed to provide access to the underlying contamination, was set aside to be used for backfill.

During excavation, a layer of depleted uranium (DU)-contaminated soil was encountered. This soil was segregated and managed for off-site disposal as radioactive waste.

Confirmatory soil samples were collected from 17 locations around the sidewalls of the excavation and analyzed for DRO. An additional 10 samples, consisting of crushed bedrock, were collected from locations in the bottom of the excavation and analyzed for DRO. Duplicate samples were collected at eight locations and analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and RCRA metals plus beryllium at an off-site laboratory. All soil samples from the sidewalls were below the established cleanup level. DRO levels in the crushed bedrock samples from the base of the excavation ranged from 160 - 12,000 mg/kg. VOC and SVOC fuel-related components were detected in three of the eight samples; no fuel-related components were detected in any samples from the excavation sidewalls. Methylene chloride and acetone were detected in four samples but determined to be laboratory contamination due to detections in the method blank. Five metals were detected above background concentrations.

Six soil samples were collected from the two clean soil piles and analyzed for DRO. Following a review of the results this soil was determined to be clean and used as backfill in the excavation. Six samples were collected from the vicinity of the DU contamination and analyzed using gamma spectroscopy. U-238 was the only radionuclide detected above minimum detectable activities (MDAs) with four of the six samples above background activities.

Constituents Investigated

Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Jet fuel (JP-4 and JP-8), High Explosive (HE), and Metals.

Institutional Controls

The NMED determined site remediation is complete, and no controls are needed. However, as a best management practice, LTES has established administrative institutional controls (IC) to track this site in the Sandia National Laboratories (SNL) IC database.

Current Regulatory Status

Corrective action is complete at ER site 94A, and no further action is required. This site is acceptable for residential land use, and there are no restrictions on future activities. The NMED approved completion of corrective action in July 2000.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for ER Sites 94A, B, C, E, F, G, and H. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario.

The results of the risk assessment were below the NMED risk guidelines for both the industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land use scenario for site 94A.

The constituent n-nitrosodi-n-propylamine was the main contributor to the overall risks.

Waste Volume Estimated/Generated

A combined surface radiation VCM for Sites 12, 13, 65, and 94 generated 200 drums of low-level radioactive waste. The VCAs for sites 94B, 94C, and 94F generated approximately 1,200 cubic yards of fuel contaminated soil and 60 cubic yards of low- level radioactive waste. The VCA at 94H generated approximately 900 cubic yards of fuel contaminated soil.

Site 0094B: Lurance Canyon Burn Site (Debris/Soil Mound Area)

Primary Contact: Long-Term Environmental Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 94 consists of 8 sub-units (A-H) and is identified as Lurance Canyon Burn Site (LCBS) in the HSWA Module. The site is located on the canyon floor alluvium in the closed upper reaches of the Lurance Canyon drainage on land withdrawn from the USFS by the USAF and permitted to the DOE. It is surrounded by moderately steep, sloping canyon walls. The site is constructed on a large graded area, and the immediate topographic relief around the site is over 500 ft. A 25- to 50-ft wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls except for the western drainage into Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access road into Lurance Canyon and the LCBS.

The location of ER Site 94 coincides with ER Site 65 Lurance Canyon Explosive Test Site, an inactive site used for high explosives (HE) tests and for liquid and solid propellant burn tests. The LCBS is currently used for testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components. Only a few of the permanent, engineered structures at the site are currently active. Historical aerial photographs indicate that the transition of testing activities from predominantly open detonation explosives testing and JP-4 fuel fires in excavated pits (ER Site 65) to open burning with JP-4 fuel fires in portable burn pans (ER Site 94) occurred between 1971 and 1982. Based on test reports and interviews, open burning with JP-4 fuel fires in portable burn pans began by 1975. By 1980, the first permanent, engineered burn unit was constructed on the site of the former Primary Detonation Area (ER Site 65B) and was in operation. The scrap yard was established in the northwestern portion of the site within the boundary of the former Far Field Dispersion Area (ER Site 65F). The scrap yard has been used to store spare materials used in explosives and burn tests and is currently used for storing nonliquid materials and used equipment.

By 1983, the LCBS was constructed. It consisted of five permanent, engineered burn units, including the Large Open Burn Pit (LOBP), the Small Open Burn Pit (SOBP), the Light Airtransport Accident Resistant Container (LAARC) Unit, the Bomb Burner Unit, the Small Wind-Shielded (SWISH) Unit, and the Conical Containment (CON-CON) Unit. They were sited on the graded area that had been the Primary

Detonation Area (ER Site 65B) and Near Field Dispersion Area (ER Site 65D). Two of the burn units (the SWISH Unit and later, the Smoke Emissions Reduction Facility [SMERF]) were

constructed to provide testing facilities that would eliminate wind effects and provide accurate temperature control and instrumentation for test monitoring. A small surface impoundment is also visible southeast of Bunker 9830. Engineered soil berms had also been constructed by 1983 in the southeastern portion of the site for flood protection from the main arroyo in Lurance Canyon.

The CON-CON Unit was dismantled prior to 1989 and by 1992 a new burn unit (SMERF) was constructed on its site. Prior to 1992, a debris/soil mound area was created in the southern portion of the LCBS, immediately north of the main arroyo in Lurance Canyon. This debris/soil mound may be associated with on-going grading activities at the site. Northeast of the debris/soil mound area is another soil mound that was created during the remediation of a wastewater spill from a permanent engineered unit that occurred on March 20, 1992.

Burn testing at the LCBS has always been conducted with JP-4 fuel pool fires in open portable pans or contained within the permanent engineered structures. Pool fires provide the closest simulation of accidents involving flammable liquids. For the tests, the pans are filled with approximately 1 to 2 ft of water and an average 8-in. layer of JP-4 fuel. The test unit, such as a transportation container, is placed on a stand above the fuel. The fuel is ignited and the fire typically burns until the JP-4 fuel is consumed. The length of the test is controlled by the volume (thickness) of the JP-4 fuel layer. After a burn test is completed, test units are retrieved and salvageable materials are collected and stored in the scrap yard located in the northwest portion of the site. Any test object residue (e.g., metal slag) is recovered with the test unit and removed from the site by the testing group. Only small residue particulates may be left in the water following the burn test. While no testing is currently conducted on components containing radioactive materials, ER Sites 94B and C are currently classified as RMMAs because of the presence of residual DU in the soil from earlier burn tests and from former explosives testing activities associated with ER Site 65 which was abolished as an RMMA following submittal of NFAs for all Site 65 sub-units. ER Site 94G is classified as an RMMA because the scrap material stored in the yard may have some radioactive contamination since some of it was used in tests conducted at Site 65 sub-units.

Due to the overlap in location and periods of testing at ER Sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in descriptions of each ER site.

ER Site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (non-petroleum fuel-fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER Site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER Site 94.

In order to facilitate site characterization, ER Site 94 has been subdivided into the following eight sub-units that represent areas where hazardous constituents may have been released.

ER Site 94B comprises approximately 0.6 acre and was a debris/soil mound area located south of the Bomb Burner Unit and Smoke Emission Reduction Facility (SMERF), and north of the main arroyo. This site is primarily the product of grading and soil redistribution during the evolution of the Lurance Canyon Burn Site (LCBS) into the present configuration. It was established as a sub-unit because of the lack of definitive information about past activities that may have created the mounds and the presence of beta/gamma radiological anomalies. A small soil pile northeast of the site was determined to be waste from a JP-4/wastewater spill at the SMERF facility on March 20, 1992.

Corrective Action

In 1993, preliminary investigations were conducted which included background information reviews, interviews, field surveys, and scoping sampling.

In October 1993, Kirtland Air Force Base (KAFB) explosive ordnance disposal (EOD) personnel conducted a visual survey for unexploded ordnance (UXO) over the entire LCBS area. One trip flare was removed as live ordnance along with some ordnance debris.

During November and December 1993, and January 1994, a surface gamma radiation survey of ER Site 94 was conducted. Nine point-source and two area-source gamma radiation anomalies were removed from within the boundaries of Site 94B.

A passive soil vapor survey was conducted for the entire burn site in February 1998. Eighteen soil-gas points were located within the boundaries of Site 94B; no significant levels of organic compounds were detected as a result of this survey.

Based on results of the SVS and comments from NMED in the RSI and NOD, RFI sampling was conducted at all subunits at the Burn site in 1998 with the exception of the active Scrap Yard Site

94G. To determine the extent of fuel contamination at Site 94F, a second phase of characterization was conducted in 1999 that consisted of an active soil gas survey and soil sampling. Additional characterization was also conducted at Sites 94B & 94C and baseline sampling was conducted at Site 94G.

The drain line at site 94C was shown to have fixed radiological contamination and was excavated and removed from the trench in 1999. Rad surveys of the Site 94C trench sidewalls revealed an area of DU contaminated soil, a small DU contaminated soil area was also found at site 94B.

In April 1999, surface debris was removed from the site including scrap metal, concrete, and lead sheets. In May 1999, a geophysical survey indicated two anomalies associated with the large debris mound. The anomalies were removed and the mound was leveled. One of the anomalies, determined to be radioactively contaminated, was disposed as radioactive waste.

In response to a Request for Supplemental Information (RSI) from the New Mexico Environment Department (NMED), SNL agreed to additional characterization of two areas within the site. Subsequently, a Voluntary Corrective Action (VCA) was planned to further investigate the soil mounds and to collect samples from the adjacent arroyo.

In July 1999, soil samples were collected from two locations approximately two feet within the small jet propulsion fuel grade 4 (JP-4)/wastewater spill soil pile. In addition, five surface samples were collected from four locations in the adjacent arroyo channel. All samples were analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides.

In August 1999, a radiological survey was conducted over the entire surface of Site 94B. One small piece of depleted uranium (DU) was removed from the site and an area source was identified and marked. Further investigation showed the area source to be a layer of blackened DU contaminated soil approximately 1ft bgs.

Voluntary Corrective Actions were conducted at Sites 94B, C, & F in March and April of 2000. Radiologically contaminated soils were excavated at sites 94B & C and staged for disposal. Fuel contaminated soils were excavated at Site 94F. All soil with petroleum contamination was removed to bedrock at a depth of approximately 18 feet. The soils were disposed at a land farm or landfill, as appropriate, in the summer of 2000.

After discovery in August 2000 an RFI was conducted at ER site 94H to determine the extent of contamination. A VCA to remove the petroleum-contaminated soil was conducted in July 2001,

approximately 900 cubic yards of soil were removed.

In April 2000, an excavator was used to remove the contaminated soil layer. The resulting excavation was approximately 10 ft by 15 ft by 3.5 ft deep. Five confirmatory soil samples were collected from the base and sidewalls of the excavation. All samples were analyzed for radionuclides and one sample was also analyzed for VOCs, SVOCs, HE, and RCRA metals plus beryllium and uranium. Results indicated that the excavated area was clean and it was subsequently backfilled with clean soil.

Also in April 2000, a trench was cut through the JP-4 wastewater spill soil pile and a soil sample was collected from the native soil beneath the pile. The sample was analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides. In addition, soil samples were collected at two arroyo locations due to laboratory problems with the original analyses.

In November 2000, an estimated 25 cu yds of DU-contaminated soil that had been staged in ER Site 94B was disposed at an off-site facility.

In December 2000, a final radiological survey was conducted over the area and five confirmatory soil samples were collected. Results of these analyses indicated that residual DU levels are below risk levels and no further cleanup was required.

In July 1995, Site 94F was investigated as part of a site-wide scoping sampling program. Total petroleum hydrocarbon (TPH) and VOC results confirmed the presence of fuel-related compounds in the soil beneath the discharge pit. In February to March 1998, a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted to determine the extent of contamination at the site. A passive soil-vapor survey was conducted over the entire LCBS. Six surface-soil samples and three subsurface samples from one borehole were collected in the vicinity of the LAARC discharge pit. Analytical data from the RFI was sufficient to confirm the presence of contamination but additional sampling was required to verify the horizontal and vertical extent of contamination at Site 94F.

In November 1998, a second RFI was conducted to define the extent of contamination at the site for the purpose of remediation planning. Twenty-two active soil-gas samples were collected from the area surrounding the LAARC Unit and discharge pit. Following evaluation of the soil-gas results, 14 subsurface soil samples were collected from nine boreholes. Analytical results from these samples were used to identify the extent of contamination for excavation and to provide waste characterization data for planning disposal of excavated soils.

Based on the results of the RFI, a conceptual model was developed which indicated that contamination at this site was likely the primary source of groundwater contamination in the area and a Voluntary Corrective Action (VCA) source removal was planned. In consultation with the New Mexico Environment Department (NMED) it was determined that a level of 100 mg/kg of diesel range organics (DRO) in soil would be used as the cleanup criterion. All soil with DRO levels greater than 100 mg/kg would be excavated and disposed at an appropriate facility.

The source removal VCA was conducted during March and April 2000. Excavation continued until analytical results from the sidewall samples were less than 100 mg/kg DRO and until bedrock was encountered. Although some bedrock at the base of the excavation contained DRO above the cleanup level it was determined that further excavation was not feasible. Representatives from the NMED, including the Groundwater Bureau, inspected the excavation and concurred that the source removal objective of the VCA had been met.

A total of 856 cu yds of soil with DRO greater than 1000 mg/kg was excavated and stockpiled for

disposal at the off-site facility. An additional 336 cu yds of excavated soils appropriate for disposal at the KAFB landfill was stockpiled. In addition, approximately 2000 cu yds of clean soil, removed to provide access to the underlying contamination, was set aside to be used for backfill.

During excavation, a layer of depleted uranium (DU)-contaminated soil was encountered. This soil was segregated and managed for off-site disposal as radioactive waste.

Confirmatory soil samples were collected from 17 locations around the sidewalls of the excavation and analyzed for DRO. An additional 10 samples, consisting of crushed bedrock, were collected from locations in the bottom of the excavation and analyzed for DRO. Duplicate samples were collected at eight locations and analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and RCRA metals plus beryllium at an off-site laboratory. All soil samples from the sidewalls were below the established cleanup level. DRO levels in the crushed bedrock samples from the base of the excavation ranged from 160 - 12,000 mg/kg. VOC and SVOC fuel-related components were detected in three of the eight samples; no fuel-related components were detected in any samples from the excavation sidewalls. Methylene chloride and acetone were detected in four samples but determined to be laboratory contamination due to detections in the method blank. Five metals were detected above background concentrations.

Six soil samples were collected from the two clean soil piles and analyzed for DRO. Following a review of the results this soil was determined to be clean and used as backfill in the excavation. Six samples were collected from the vicinity of the DU contamination and analyzed using gamma spectroscopy. U-238 was the only radionuclide detected above minimum detectable activities (MDAs) with four of the six samples above background activities.

Constituents Investigated

Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Jet fuel (JP-4 and JP-8), High Explosive (HE), and Metals.

Institutional Controls

The NMED has determined that site remediation is complete and these sites pass the residential risk acceptable range, but due to the sites spatial relationship to SWMU 65, where there is "..potential for unknown occurrences of buried DU", the NMED wants controls implemented. Additional information regarding Institutional Controls at this site can be obtained from the SNL IC tracking database.

Current Regulatory Status

Corrective action is complete at ER Site 94B, and no further action is required. It is acceptable for residential land use, however, the NMED would like industrial land use imposed. During the permit negotiations, the final land use determination will be made. NMED approved completion of corrective action in April 2005, and the site is listed on Table A.2 of the Permit.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for ER Sites 94A, B, C, E, F, G, and H. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario.

The results of the risk assessment were below the NMED risk guidelines for both the industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land use scenario for site 94B.

Waste Volume Estimated/Generated

A combined surface radiation VCM for Sites 12, 13, 65, and 94 generated 200 drums of low level radioactive waste. The VCAs for sites 94B, 94C, and 94F generated approximately 1,200 cubic yards of fuel contaminated soil and 60 cubic yards of low level radioactive waste. The VCA at 94H generated approximately 900 cubic yards of fuel contaminated soil.

Site 0094C: Lurance Canyon Burn Site (Bomb Burner Area and Discharge Line)

Primary Contact: Long-Term Environmental Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 94 consists of 8 sub-units (A-H) and is identified as Lurance Canyon Burn Site (LCBS) in the HSWA Module. The site is located on the canyon floor alluvium in the closed upper reaches of the Lurance Canyon drainage on land withdrawn from the USFS by the USAF and permitted to the DOE. It is surrounded by moderately steep, sloping canyon walls. The site is constructed on a large graded area, and the immediate topographic relief around the site is over 500 ft. A 25- to 50-ft wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls except for the western drainage into Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access road into Lurance Canyon and the LCBS.

The location of ER Site 94 coincides with ER Site 65 Lurance Canyon Explosive Test Site, an inactive site used for high explosives (HE) tests and for liquid and solid propellant burn tests. The LCBS is currently used for testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components. Only a few of the permanent, engineered structures at the site are currently active. Historical aerial photographs indicate that the transition of testing activities from predominantly open detonation explosives testing and JP-4 fuel fires in excavated pits (ER Site 65) to open burning with JP-4 fuel fires in portable burn pans (ER Site 94) occurred between 1971 and 1982. Based on test reports and interviews, open burning with JP-4 fuel fires in portable burn pans began by 1975. By 1980, the first permanent, engineered burn unit was constructed on the site of the former Primary Detonation Area (ER Site 65B) and was in operation. The scrap yard was established in the northwestern portion of the site within the boundary of the former Far Field Dispersion Area (ER Site 65F). The scrap yard has been used to store spare materials used in explosives and burn tests and is currently used for storing nonliquid materials and used equipment.

By 1983, the LCBS was constructed. It consisted of five permanent, engineered burn units, including the Large Open Burn Pit (LOBP), the Small Open Burn Pit (SOBP), the Light Airtransport Accident Resistant Container (LAARC) Unit, the Bomb Burner Unit, the Small Wind-Shielded (SWISH) Unit, and the Conical Containment (CON-CON) Unit. They were sited on the graded area that had been the Primary

Detonation Area (ER Site 65B) and Near Field Dispersion Area (ER Site 65D). Two of the burn units (the SWISH Unit and later, the Smoke Emissions Reduction Facility [SMERF]) were

constructed to provide testing facilities that would eliminate wind effects and provide accurate temperature control and instrumentation for test monitoring. A small surface impoundment is also visible southeast of Bunker 9830. Engineered soil berms had also been constructed by 1983 in the southeastern portion of the site for flood protection from the main arroyo in Lurance Canyon.

The CON-CON Unit was dismantled prior to 1989 and by 1992 a new burn unit (SMERF) was constructed on its site. Prior to 1992, a debris/soil mound area was created in the southern portion of the LCBS, immediately north of the main arroyo in Lurance Canyon. This debris/soil mound may be associated with on-going grading activities at the site. Northeast of the debris/soil mound area is another soil mound that was created during the remediation of a wastewater spill from a permanent engineered unit that occurred on March 20, 1992.

Burn testing at the LCBS has always been conducted with JP-4 fuel pool fires in open portable pans or contained within the permanent engineered structures. Pool fires provide the closest simulation of accidents involving flammable liquids. For the tests, the pans are filled with approximately 1 to 2 ft of water and an average 8-in. layer of JP-4 fuel. The test unit, such as a transportation container, is placed on a stand above the fuel. The fuel is ignited and the fire typically burns until the JP-4 fuel is consumed. The length of the test is controlled by the volume (thickness) of the JP-4 fuel layer. After a burn test is completed, test units are retrieved and salvageable materials are collected and stored in the scrap yard located in the northwest portion of the site. Any test object residue (e.g., metal slag) is recovered with the test unit and removed from the site by the testing group. Only small residue particulates may be left in the water following the burn test. While no testing is currently conducted on components containing radioactive materials, ER Sites 94B and C are currently classified as RMMAs because of the presence of residual DU in the soil from earlier burn tests and from former explosives testing activities associated with ER Site 65 which was abolished as an RMMA following submittal of NFAs for all Site 65 sub-units. ER Site 94G is classified as an RMMA because the scrap material stored in the yard may have some radioactive contamination since some of it was used in tests conducted at Site 65 sub-units.

Due to the overlap in location and periods of testing at ER Sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in descriptions of each ER site.

ER Site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (non-petroleum fuel-fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER Site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER Site 94.

In order to facilitate site characterization, ER Site 94 has been subdivided into the following eight sub-units that represent areas where hazardous constituents may have been released.

ER Site 94C occupies an area of 0.2 acres surrounding the Bomb Burner Unit and the Bomb Burner Unit trench. An underground corrugated culvert extended from the Bomb Burner Unit to a discharge pit (ER Site 94D) located between the access road and the arroyo. The Bomb Burner Unit itself has been decontaminated and decommissioned and is not included as a sub-unit. Release of potential COCs outside of the Bomb Burner Unit were characterized as part of ER Site 94C. Releases of potential COCs from the TABS Test location, portable pan tests, rocket propellant tests, slow-heat tests, and uncontained pool fires that occurred in the Bomb Burner Unit trench were also characterized.

Corrective Action

In 1993, preliminary investigations were conducted which included background information reviews, interviews, field surveys, and scoping sampling.

In October 1993, Kirtland Air Force Base (KAFB) explosive ordnance disposal (EOD) personnel conducted a visual survey for unexploded ordnance (UXO) over the entire LCBS area. One trip flare was removed as live ordnance along with some ordnance debris.

During November and December 1993, and January 1994, a surface gamma radiation survey of ER Site 94 was conducted. Nine point-source and two area-source gamma radiation anomalies were removed from within the boundaries of Site 94B.

A passive soil vapor survey was conducted for the entire burn site in February 1998. Eighteen soil-gas points were located within the boundaries of Site 94B; no significant levels of organic compounds were detected as a result of this survey.

Based on results of the SVS and comments from NMED in the RSI and NOD, RFI sampling was conducted at all subunits at the Burn site in 1998 with the exception of the active Scrap Yard Site

94G. To determine the extent of fuel contamination at Site 94F, a second phase of characterization was conducted in 1999 that consisted of an active soil gas survey and soil sampling. Additional characterization was also conducted at Sites 94B & 94C and baseline sampling was conducted at Site 94G.

The drain line at site 94C was shown to have fixed radiological contamination and was excavated and removed from the trench in 1999. Rad surveys of the Site 94C trench sidewalls revealed an area of DU contaminated soil, a small DU contaminated soil area was also found at site 94B.

In April 1999, surface debris was removed from the site including scrap metal, concrete, and lead sheets. In May 1999, a geophysical survey indicated two anomalies associated with the large debris mound. The anomalies were removed and the mound was leveled. One of the anomalies, determined to be radioactively contaminated, was disposed as radioactive waste.

In response to a Request for Supplemental Information (RSI) from the New Mexico Environment Department (NMED), SNL agreed to additional characterization of two areas within the site. Subsequently, a Voluntary Corrective Action (VCA) was planned to further investigate the soil mounds and to collect samples from the adjacent arroyo.

In July 1999, soil samples were collected from two locations approximately two feet within the small jet propulsion fuel grade 4 (JP-4)/wastewater spill soil pile. In addition, five surface samples were collected from four locations in the adjacent arroyo channel. All samples were analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides.

In August 1999, a radiological survey was conducted over the entire surface of Site 94B. One small piece of depleted uranium (DU) was removed from the site and an area source was identified and marked. Further investigation showed the area source to be a layer of blackened DU contaminated soil approximately 1ft bgs.

Voluntary Corrective Actions were conducted at Sites 94B, C, & F in March and April of 2000. Radiologically contaminated soils were excavated at sites 94B & C and staged for disposal. Fuel contaminated soils were excavated at Site 94F. All soil with petroleum contamination was removed to bedrock at a depth of approximately 18 feet. The soils were disposed at a land farm or landfill, as appropriate, in the summer of 2000.

After discovery in August 2000 an RFI was conducted at ER site 94H to determine the extent of contamination. A VCA to remove the petroleum-contaminated soil was conducted in July 2001, approximately 900 cubic yards of soil were removed.

In April 2000, an excavator was used to remove the contaminated soil layer. The resulting excavation was approximately 10 ft by 15 ft by 3.5 ft deep. Five confirmatory soil samples were collected from the base and sidewalls of the excavation. All samples were analyzed for radionuclides and one sample was also analyzed for VOCs, SVOCs, HE, and RCRA metals plus beryllium and uranium. Results indicated that the excavated area was clean and it was subsequently backfilled with clean soil.

Also in April 2000, a trench was cut through the JP-4 wastewater spill soil pile and a soil sample was collected from the native soil beneath the pile. The sample was analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides. In addition, soil samples were collected at two arroyo locations due to laboratory problems with the original analyses.

In November 2000, an estimated 25 cu yds of DU-contaminated soil that had been staged in ER Site 94B was disposed at an off-site facility.

In December 2000, a final radiological survey was conducted over the area and five confirmatory soil samples were collected. Results of these analyses indicated that residual DU levels are below risk levels and no further cleanup was required.

In July 1995, Site 94F was investigated as part of a site-wide scoping sampling program. Total petroleum hydrocarbon (TPH) and VOC results confirmed the presence of fuel-related compounds in the soil beneath the discharge pit. In February to March 1998, a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted to determine the extent of contamination at the site. A passive soil-vapor survey was conducted over the entire LCBS. Six surface-soil samples and three subsurface samples from one borehole were collected in the vicinity of the LAARC discharge pit. Analytical data from the RFI was sufficient to confirm the presence of contamination but additional sampling was required to verify the horizontal and vertical extent of contamination at Site 94F.

In November 1998, a second RFI was conducted to define the extent of contamination at the site for the purpose of remediation planning. Twenty-two active soil-gas samples were collected from the area surrounding the LAARC Unit and discharge pit. Following evaluation of the soil-gas results, 14 subsurface soil samples were collected from nine boreholes. Analytical results from these samples were used to identify the extent of contamination for excavation and to provide waste characterization data for planning disposal of excavated soils.

Based on the results of the RFI, a conceptual model was developed which indicated that contamination at this site was likely the primary source of groundwater contamination in the area and a Voluntary Corrective Action (VCA) source removal was planned. In consultation with the New Mexico Environment Department (NMED) it was determined that a level of 100 mg/kg of diesel range organics (DRO) in soil would be used as the cleanup criterion. All soil with DRO levels greater than 100 mg/kg would be excavated and disposed at an appropriate facility.

The source removal VCA was conducted during March and April 2000. Excavation continued until analytical results from the sidewall samples were less than 100 mg/kg DRO and until bedrock was encountered. Although some bedrock at the base of the excavation contained DRO above the cleanup level it was determined that further excavation was not feasible. Representatives from the NMED, including the Groundwater Bureau, inspected the excavation and concurred that the source removal objective of the VCA had been met.

A total of 856 cu yds of soil with DRO greater than 1000 mg/kg was excavated and stockpiled for disposal at the off-site facility. An additional 336 cu yds of excavated soils appropriate for disposal at the KAFB landfill was stockpiled. In addition, approximately 2000 cu yds of clean soil, removed to provide access to the underlying contamination, was set aside to be used for backfill.

During excavation, a layer of depleted uranium (DU)-contaminated soil was encountered. This soil was segregated and managed for off-site disposal as radioactive waste.

Confirmatory soil samples were collected from 17 locations around the sidewalls of the excavation and analyzed for DRO. An additional 10 samples, consisting of crushed bedrock, were collected from locations in the bottom of the excavation and analyzed for DRO. Duplicate samples were collected at eight locations and analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and RCRA metals plus beryllium at an off-site laboratory. All soil samples from the sidewalls were below the established cleanup level. DRO levels in the crushed bedrock samples from the base of the excavation ranged from 160 - 12,000 mg/kg. VOC and SVOC fuel-related components were detected in three of the eight samples; no fuel-related components were detected in any samples from the excavation sidewalls. Methylene chloride and acetone were detected in four samples but determined to be laboratory contamination due to detections in the method blank. Five metals were detected above background concentrations.

Six soil samples were collected from the two clean soil piles and analyzed for DRO. Following a review of the results this soil was determined to be clean and used as backfill in the excavation. Six samples were collected from the vicinity of the DU contamination and analyzed using gamma spectroscopy. U-238 was the only radionuclide detected above minimum detectable activities (MDAs) with four of the six samples above background activities.

Constituents Investigated

Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Jet fuel (JP-4 and JP-8), High Explosive (HE), and Metals.

Institutional Controls

The NMED has determined that site remediation is complete and no controls are needed. However, as a best management practice, LTES has established administrative institutional controls (IC) to track this site in the IC database.

Current Regulatory Status

Corrective action is complete at ER Site 94C, and no further action is required. This site is acceptable for residential land use, and there are no restrictions on future activities. NMED approved completion of corrective action in November 2001.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for ER Sites 94A, B, C, E, F, G, and H. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario.

The results of the risk assessment were below the NMED risk guidelines for both the industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land use scenario at site 94C.

Waste Volume Estimated/Generated

A combined surface radiation VCM for Sites 12, 13, 65, and 94 generated 200 drums of low level radioactive waste. The VCAs for sites 94B, 94C, and 94F generated approximately 1,200 cubic yards of fuel contaminated soil and 60 cubic yards of low level radioactive waste. The VCA at 94H generated approximately 900 cubic yards of fuel contaminated soil.

Site 0094D: Lurance Canyon Burn Site (Bomb Burner Discharge Pit)

Primary Contact: Long-Term Environmental Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 94 consists of 8 sub-units (A-H) and is identified as Lurance Canyon Burn Site (LCBS) in the HSWA Module. The site is located on the canyon floor alluvium in the closed upper reaches of the Lurance Canyon drainage on land withdrawn from the USFS by the USAF and permitted to the DOE. It is surrounded by moderately steep, sloping canyon walls. The site is constructed on a large graded area, and the immediate topographic relief around the site is over 500 ft. A 25- to 50-ft wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls except for the western drainage into Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access road into Lurance Canyon and the LCBS.

The location of ER Site 94 coincides with ER Site 65 Lurance Canyon Explosive Test Site, an inactive site used for high explosives (HE) tests and for liquid and solid propellant burn tests. The LCBS is currently used for testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components. Only a few of the permanent, engineered structures at the site are currently active. Historical aerial photographs indicate that the transition of testing activities from predominantly open detonation explosives testing and JP-4 fuel fires in excavated pits (ER Site 65) to open burning with JP-4 fuel fires in portable burn pans (ER Site 94) occurred between 1971 and 1982. Based on test reports and interviews, open burning with JP-4 fuel fires in portable burn pans began by 1975. By 1980, the first permanent, engineered burn unit was constructed on the site of the former Primary Detonation Area (ER Site 65B) and was in operation. The scrap yard was established in the northwestern portion of the site within the boundary of the former Far Field Dispersion Area (ER Site 65F). The scrap yard has been used to store spare materials used in explosives and burn tests and is currently used for storing nonliquid materials and used equipment.

By 1983, the LCBS was constructed. It consisted of five permanent, engineered burn units, including the Large Open Burn Pit (LOBP), the Small Open Burn Pit (SOBP), the Light Airtransport Accident Resistant Container (LAARC) Unit, the Bomb Burner Unit, the Small Wind-Shielded (SWISH) Unit, and the Conical Containment (CON-CON) Unit. They were sited on the graded area that had been the Primary

Detonation Area (ER Site 65B) and Near Field Dispersion Area (ER Site 65D). Two of the burn units (the SWISH Unit and later, the Smoke Emissions Reduction Facility [SMERF]) were

constructed to provide testing facilities that would eliminate wind effects and provide accurate temperature control and instrumentation for test monitoring. A small surface impoundment is also visible southeast of Bunker 9830. Engineered soil berms had also been constructed by 1983 in the southeastern portion of the site for flood protection from the main arroyo in Lurance Canyon.

The CON-CON Unit was dismantled prior to 1989 and by 1992 a new burn unit (SMERF) was constructed on its site. Prior to 1992, a debris/soil mound area was created in the southern portion of the LCBS, immediately north of the main arroyo in Lurance Canyon. This debris/soil mound may be associated with on-going grading activities at the site. Northeast of the debris/soil mound area is another soil mound that was created during the remediation of a wastewater spill from a permanent engineered unit that occurred on March 20, 1992.

Burn testing at the LCBS has always been conducted with JP-4 fuel pool fires in open portable pans or contained within the permanent engineered structures. Pool fires provide the closest simulation of accidents involving flammable liquids. For the tests, the pans are filled with approximately 1 to 2 ft of water and an average 8-in. layer of JP-4 fuel. The test unit, such as a transportation container, is placed on a stand above the fuel. The fuel is ignited and the fire typically burns until the JP-4 fuel is consumed. The length of the test is controlled by the volume (thickness) of the JP-4 fuel layer. After a burn test is completed, test units are retrieved and salvageable materials are collected and stored in the scrap yard located in the northwest portion of the site. Any test object residue (e.g., metal slag) is recovered with the test unit and removed from the site by the testing group. Only small residue particulates may be left in the water following the burn test. While no testing is currently conducted on components containing radioactive materials, ER Sites 94B and C are currently classified as RMMAs because of the presence of residual DU in the soil from earlier burn tests and from former explosives testing activities associated with ER Site 65 which was abolished as an RMMA following submittal of NFAs for all Site 65 sub-units. ER Site 94G is classified as an RMMA because the scrap material stored in the yard may have some radioactive contamination since some of it was used in tests conducted at Site 65 sub-units.

Due to the overlap in location and periods of testing at ER Sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in descriptions of each ER site.

ER Site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (non-petroleum fuel-fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER Site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER Site 94.

In order to facilitate site characterization, ER Site 94 has been subdivided into the following eight sub-units that represent areas where hazardous constituents may have been released.

ER Site 94D encompasses the area of the discharge pit at the point of entry from the discharge line. The discharge pit received all wastewater from operation of the Bomb Burner Unit. The site covers less than 0.1 acre.

Corrective Action

In 1993, preliminary investigations were conducted which included background information reviews, interviews, field surveys, and scoping sampling.

In October 1993, Kirtland Air Force Base (KAFB) explosive ordnance disposal (EOD) personnel conducted a visual survey for unexploded ordnance

(UXO) over the entire LCBS area. One trip flare was removed as live ordnance along with some ordnance debris.

During November and December 1993, and January 1994, a surface gamma radiation survey of ER Site 94 was conducted. Nine point-source and two area-source gamma radiation anomalies were removed from within the boundaries of Site 94B.

A passive soil vapor survey was conducted for the entire burn site in February 1998. Eighteen soil-gas points were located within the boundaries of Site 94B; no significant levels of organic compounds were detected as a result of this survey.

Based on results of the SVS and comments from NMED in the RSI and NOD, RFI sampling was conducted at all subunits at the Burn site in 1998 with the exception of the active Scrap Yard Site

94G. To determine the extent of fuel contamination at Site 94F, a second phase of characterization was conducted in 1999 that consisted of an active soil gas survey and soil sampling. Additional characterization was also conducted at Sites 94B & 94C and baseline sampling was conducted at Site 94G.

The drain line at site 94C was shown to have fixed radiological contamination and was excavated and removed from the trench in 1999. Rad surveys of the Site 94C trench sidewalls revealed an area of DU contaminated soil, a small DU contaminated soil area was also found at site 94B.

In April 1999, surface debris was removed from the site including scrap metal, concrete, and lead sheets. In May 1999, a geophysical survey indicated two anomalies associated with the large debris mound. The anomalies were removed and the mound was leveled. One of the anomalies, determined to be radioactively contaminated, was disposed as radioactive waste.

In response to a Request for Supplemental Information (RSI) from the New Mexico Environment Department (NMED), SNL agreed to additional characterization of two areas within the site. Subsequently, a Voluntary Corrective Action (VCA) was planned to further investigate the soil mounds and to collect samples from the adjacent arroyo.

In July 1999, soil samples were collected from two locations approximately two feet within the small jet propulsion fuel grade 4 (JP-4)/wastewater spill soil pile. In addition, five surface samples were collected from four locations in the adjacent arroyo channel. All samples were analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides.

In August 1999, a radiological survey was conducted over the entire surface of Site 94B. One small piece of depleted uranium (DU) was removed from the site and an area source was identified and marked. Further investigation showed the area source to be a layer of blackened DU contaminated soil approximately 1ft bgs.

Voluntary Corrective Actions were conducted at Sites 94B, C, & F in March and April of 2000. Radiologically contaminated soils were excavated at sites 94B & C and staged for disposal. Fuel contaminated soils were excavated at Site 94F. All soil with petroleum contamination was removed to bedrock at a depth of approximately 18 feet. The soils were disposed at a land farm or landfill, as appropriate, in the summer of 2000.

After discovery in August 2000 an RFI was conducted at ER site 94H to determine the extent of contamination. A VCA to remove the petroleum-contaminated soil was conducted in July 2001, approximately 900 cubic yards of soil were removed.

In April 2000, an excavator was used to remove the contaminated soil layer. The resulting excavation was approximately 10 ft by 15 ft by 3.5 ft deep. Five confirmatory soil samples were collected from the base and sidewalls of the excavation. All samples were analyzed for radionuclides and one sample was also analyzed for VOCs, SVOCs, HE, and RCRA metals plus beryllium and uranium. Results indicated that the excavated area was clean and it was subsequently backfilled with clean soil.

Also in April 2000, a trench was cut through the JP-4 wastewater spill soil pile and a soil sample was collected from the native soil beneath the pile. The sample was analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides. In addition, soil samples were collected at two arroyo locations due to laboratory problems with the original analyses.

In November 2000, an estimated 25 cu yds of DU-contaminated soil that had been staged in ER Site 94B was disposed at an off-site facility.

In December 2000, a final radiological survey was conducted over the area and five confirmatory soil samples were collected. Results of these analyses indicated that residual DU levels are below risk levels and no further cleanup was required.

In July 1995, Site 94F was investigated as part of a site-wide scoping sampling program. Total petroleum hydrocarbon (TPH) and VOC results confirmed the presence of fuel-related compounds in the soil beneath the discharge pit. In February to March 1998, a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted to determine the extent of contamination at the site. A passive soil-vapor survey was conducted over the entire LCBS. Six surface-soil samples and three subsurface samples from one borehole were collected in the vicinity of the LAARC discharge pit. Analytical data from the RFI was sufficient to confirm the presence of contamination but additional sampling was required to verify the horizontal and vertical extent of contamination at Site 94F.

In November 1998, a second RFI was conducted to define the extent of contamination at the site for the purpose of remediation planning. Twenty-two active soil-gas samples were collected from the area surrounding the LAARC Unit and discharge pit. Following evaluation of the soil-gas results, 14 subsurface soil samples were collected from nine boreholes. Analytical results from these samples were used to identify the extent of contamination for excavation and to provide waste characterization data for planning disposal of excavated soils.

Based on the results of the RFI, a conceptual model was developed which indicated that contamination at this site was likely the primary source of groundwater contamination in the area and a Voluntary Corrective Action (VCA) source removal was planned. In consultation with the New Mexico Environment Department (NMED) it was determined that a level of 100 mg/kg of diesel range organics (DRO) in soil would be used as the cleanup criterion. All soil with DRO levels greater than 100 mg/kg would be excavated and disposed at an appropriate facility.

The source removal VCA was conducted during March and April 2000. Excavation continued until analytical results from the sidewall samples were less than 100 mg/kg DRO and until bedrock was encountered. Although some bedrock at the base of the excavation contained DRO above the cleanup level it was determined that further excavation was not feasible. Representatives from the NMED, including the Groundwater Bureau, inspected the excavation and concurred that the source removal objective of the VCA had been met.

A total of 856 cu yds of soil with DRO greater than 1000 mg/kg was excavated and stockpiled for disposal at the off-site facility. An additional 336 cu yds of excavated soils appropriate for disposal at the KAFB landfill was stockpiled. In addition, approximately 2000 cu yds of clean soil, removed to provide access to the underlying contamination, was set aside to be used for backfill.

During excavation, a layer of depleted uranium (DU)-contaminated soil was encountered. This soil was segregated and managed for off-site disposal as radioactive waste.

Confirmatory soil samples were collected from 17 locations around the sidewalls of the excavation and analyzed for DRO. An additional 10 samples, consisting of crushed bedrock, were collected from locations in the bottom of the excavation and analyzed for DRO. Duplicate samples were collected at eight locations and analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and RCRA metals plus beryllium at an off-site laboratory. All soil samples from the sidewalls were below the established cleanup level. DRO levels in the crushed bedrock samples from the base of the excavation ranged from 160 - 12,000 mg/kg. VOC and SVOC fuel-related components were detected in three of the eight samples; no fuel-related components were detected in any samples from the excavation sidewalls. Methylene chloride and acetone were detected in four samples but determined to be laboratory contamination due to detections in the method blank. Five metals were detected above background concentrations.

Six soil samples were collected from the two clean soil piles and analyzed for DRO. Following a review of the results this soil was determined to be clean and used as backfill in the excavation. Six samples were collected from the vicinity of the DU contamination and analyzed using gamma spectroscopy. U-238 was the only radionuclide detected above minimum detectable activities (MDAs) with four of the six samples above background activities.

Constituents Investigated

Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Jet fuel (JP-4 and JP-8), High Explosive (HE), and Metals.

Institutional Controls

The NMED has determined that site remediation is complete and no controls are needed. However, as a best management practice, LTES has established administrative institutional controls (IC) to track this site in the IC database.

Current Regulatory Status

Corrective action is complete at ER Site 94D, and no further action is required. This site is acceptable for residential land use, and there are no restrictions on future activities. NMED approved completion of corrective action in September 2000.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for ER Sites 94A, B, C, E, F, G, and H. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario.

SNL is proposing a risk-based No Further Action (NFA) decision for Solid Waste Management (SWMU) 94D, Bomb Burner Discharge Pit. Review and analysis of all relevant data for SWMU 94D indicate that concentrations of constituents of concern at this site are less than applicable risk assessment action levels. Thus, SWMU 94D is proposed for an NFA decision based upon confirmatory sampling data demonstrating that COCs that could have been released from the SWMU into the environment pose an acceptable level of risk under current and projected future land uses as set forth by Criterion 5, which states, "The SWMU/AOC has been characterized or remediated in accordance with current applicable state or federal regulation, and the available data indicate that contaminants pose an acceptable level of risk under current and projected future land use (NMED March 1998).

Waste Volume Estimated/Generated

A combined surface radiation VCM for Sites 12, 13, 65, and 94 generated 200 drums of low-level radioactive waste. The VCAs for sites 94B, 94C, and 94F generated approximately 1,200 cubic yards of fuel contaminated soil and 60 cubic yards of low-level radioactive waste. The VCA at 94H generated approximately 900 cubic yards of fuel contaminated soil.

Site 0094E: Lurance Canyon Burn Site (Small Surface Impoundment)

Primary Contact: Long-Term Environmental Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 94 consists of 8 sub-units (A-H) and is identified as Lurance Canyon Burn Site (LCBS) in the HSWA Module. The site is located on the canyon floor alluvium in the closed upper reaches of the Lurance Canyon drainage on land withdrawn from the USFS by the USAF and permitted to the DOE. It is surrounded by moderately steep, sloping canyon walls. The site is constructed on a large graded area, and the immediate topographic relief around the site is over 500 ft. A 25- to 50-ft wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls except for the western drainage into Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access road into Lurance Canyon and the LCBS.

The location of ER Site 94 coincides with ER Site 65 Lurance Canyon Explosive Test Site, an inactive site used for high explosives (HE) tests and for liquid and solid propellant burn tests. The LCBS is currently used for testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components. Only a few of the permanent, engineered structures at the site are currently active. Historical aerial photographs indicate that the transition of testing activities from predominantly open detonation explosives testing and JP-4 fuel fires in excavated pits (ER Site 65) to open burning with JP-4 fuel fires in portable burn pans (ER Site 94) occurred between 1971 and 1982. Based on test reports and interviews, open burning with JP-4 fuel fires in portable burn pans began by 1975. By 1980, the first permanent, engineered burn unit was constructed on the site of the former Primary Detonation Area (ER Site 65B) and was in operation. The scrap yard was established in the northwestern portion of the site within the boundary of the former Far Field Dispersion Area (ER Site 65F). The scrap yard has been used to store spare materials used in explosives and burn tests and is currently used for storing nonliquid materials and used equipment.

By 1983, the LCBS was constructed. It consisted of five permanent, engineered burn units, including the Large Open Burn Pit (LOBP), the Small Open Burn Pit (SOBP), the Light Airtransport Accident Resistant Container (LAARC) Unit, the Bomb Burner Unit, the Small Wind-Shielded (SWISH) Unit, and the Conical Containment (CON-CON) Unit. They were sited on the graded area that had been the Primary

Detonation Area (ER Site 65B) and Near Field Dispersion Area (ER Site 65D). Two of the burn units (the SWISH Unit and later, the Smoke Emissions Reduction Facility [SMERF]) were

constructed to provide testing facilities that would eliminate wind effects and provide accurate temperature control and instrumentation for test monitoring. A small surface impoundment is also visible southeast of Bunker 9830. Engineered soil berms had also been constructed by 1983 in the southeastern portion of the site for flood protection from the main arroyo in Lurance Canyon.

The CON-CON Unit was dismantled prior to 1989 and by 1992 a new burn unit (SMERF) was constructed on its site. Prior to 1992, a debris/soil mound area was created in the southern portion of the LCBS, immediately north of the main arroyo in Lurance Canyon. This debris/soil mound may be associated with on-going grading activities at the site. Northeast of the debris/soil mound area is another soil mound that was created during the remediation of a wastewater spill from a permanent engineered unit that occurred on March 20, 1992.

Burn testing at the LCBS has always been conducted with JP-4 fuel pool fires in open portable pans or contained within the permanent engineered structures. Pool fires provide the closest simulation of accidents involving flammable liquids. For the tests, the pans are filled with approximately 1 to 2 ft of water and an average 8-in. layer of JP-4 fuel. The test unit, such as a transportation container, is placed on a stand above the fuel. The fuel is ignited and the fire typically burns until the JP-4 fuel is consumed. The length of the test is controlled by the volume (thickness) of the JP-4 fuel layer. After a burn test is completed, test units are retrieved and salvageable materials are collected and stored in the scrap yard located in the northwest portion of the site. Any test object residue (e.g., metal slag) is recovered with the test unit and removed from the site by the testing group. Only small residue particulates may be left in the water following the burn test. While no testing is currently conducted on components containing radioactive materials, ER Sites 94B and C are currently classified as RMMAs because of the presence of residual DU in the soil from earlier burn tests and from former explosives testing activities associated with ER Site 65 which was abolished as an RMMA following submittal of NFAs for all Site 65 sub-units. ER Site 94G is classified as an RMMA because the scrap material stored in the yard may have some radioactive contamination since some of it was used in tests conducted at Site 65 sub-units.

Due to the overlap in location and periods of testing at ER Sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in descriptions of each ER site.

ER Site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (non-petroleum fuel-fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER Site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER Site 94.

In order to facilitate site characterization, ER Site 94 has been subdivided into the following eight sub-units that represent areas where hazardous constituents may have been released.

ER Site 94E is located approximately 250 ft southeast of Bunker 9830 and east of the camera bunker. The impoundment was used for several fuel-fire burn tests and may have received wastewater from some portable pan burn tests. The impoundment also receives surface-water runoff from the graded area. The site occupies 0.2 acres.

Corrective Action

In 1993, preliminary investigations were conducted which included background information reviews, interviews, field surveys, and scoping sampling.

In October 1993, Kirtland Air Force Base (KAFB) explosive ordnance disposal (EOD) personnel conducted a visual survey for unexploded ordnance (UXO) over the entire LCBS area. One trip flare was removed as live ordnance along with some ordnance debris.

During November and December 1993, and January 1994, a surface gamma radiation survey of ER Site 94 was conducted. Nine point-source and two area-source gamma radiation anomalies were removed from within the boundaries of Site 94B.

A passive soil vapor survey was conducted for the entire burn site in February 1998. Eighteen soil-gas points were located within the boundaries of Site 94B; no significant levels of organic compounds were detected as a result of this survey.

Based on results of the SVS and comments from NMED in the RSI and NOD, RFI sampling was conducted at all subunits at the Burn site in 1998 with the exception of the active Scrap Yard Site

94G. To determine the extent of fuel contamination at Site 94F, a second phase of characterization was conducted in 1999 that consisted of an active soil gas survey and soil sampling. Additional characterization was also conducted at Sites 94B & 94C and baseline sampling was conducted at Site 94G.

The drain line at site 94C was shown to have fixed radiological contamination and was excavated and removed from the trench in 1999. Rad surveys of the Site 94C trench sidewalls revealed an area of DU contaminated soil, a small DU contaminated soil area was also found at site 94B.

In April 1999, surface debris was removed from the site including scrap metal, concrete, and lead sheets. In May 1999, a geophysical survey indicated two anomalies associated with the large debris mound. The anomalies were removed and the mound was leveled. One of the anomalies, determined to be radioactively contaminated, was disposed as radioactive waste.

In response to a Request for Supplemental Information (RSI) from the New Mexico Environment Department (NMED), SNL agreed to additional characterization of two areas within the site. Subsequently, a Voluntary Corrective Action (VCA) was planned to further investigate the soil mounds and to collect samples from the adjacent arroyo.

In July 1999, soil samples were collected from two locations approximately two feet within the small jet propulsion fuel grade 4 (JP-4)/wastewater spill soil pile. In addition, five surface samples were collected from four locations in the adjacent arroyo channel. All samples were analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides.

In August 1999, a radiological survey was conducted over the entire surface of Site 94B. One small piece of depleted uranium (DU) was removed from the site and an area source was identified and marked. Further investigation showed the area source to be a layer of blackened DU contaminated soil approximately 1ft bgs.

Voluntary Corrective Actions were conducted at Sites 94B, C, & F in March and April of 2000. Radiologically contaminated soils were excavated at sites 94B & C and staged for disposal. Fuel contaminated soils were excavated at Site 94F. All soil with petroleum contamination was removed to bedrock at a depth of approximately 18 feet. The soils were disposed at a land farm or landfill, as appropriate, in the summer of 2000.

After discovery in August 2000 an RFI was conducted at ER site 94H to determine the extent of contamination. A VCA to remove the petroleum-contaminated soil was conducted in July 2001, approximately 900 cubic yards of soil were removed.

In April 2000, an excavator was used to remove the contaminated soil layer. The resulting excavation was approximately 10 ft by 15 ft by 3.5 ft deep. Five confirmatory soil samples were collected from the base and sidewalls of the excavation. All samples were analyzed for radionuclides and one sample was also analyzed for VOCs, SVOCs, HE, and RCRA metals plus beryllium and uranium. Results indicated that the excavated area was clean and it was subsequently backfilled with clean soil.

Also in April 2000, a trench was cut through the JP-4 wastewater spill soil pile and a soil sample was collected from the native soil beneath the pile. The sample was analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides. In addition, soil samples were collected at two arroyo locations due to laboratory problems with the original analyses.

In November 2000, an estimated 25 cu yds of DU-contaminated soil that had been staged in ER Site 94B was disposed at an off-site facility.

In December 2000, a final radiological survey was conducted over the area and five confirmatory soil samples were collected. Results of these analyses indicated that residual DU levels are below risk levels and no further cleanup was required.

In July 1995, Site 94F was investigated as part of a site-wide scoping sampling program. Total petroleum hydrocarbon (TPH) and VOC results confirmed the presence of fuel-related compounds in the soil beneath the discharge pit. In February to March 1998, a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted to determine the extent of contamination at the site. A passive soil-vapor survey was conducted over the entire LCBS. Six surface-soil samples and three subsurface samples from one borehole were collected in the vicinity of the LAARC discharge pit. Analytical data from the RFI was sufficient to confirm the presence of contamination but additional sampling was required to verify the horizontal and vertical extent of contamination at Site 94F.

In November 1998, a second RFI was conducted to define the extent of contamination at the site for the purpose of remediation planning. Twenty-two active soil-gas samples were collected from the area surrounding the LAARC Unit and discharge pit. Following evaluation of the soil-gas results, 14 subsurface soil samples were collected from nine boreholes. Analytical results from these samples were used to identify the extent of contamination for excavation and to provide waste characterization data for planning disposal of excavated soils.

Based on the results of the RFI, a conceptual model was developed which indicated that contamination at this site was likely the primary source of groundwater contamination in the area and a Voluntary Corrective Action (VCA) source removal was planned. In consultation with the New Mexico Environment Department (NMED) it was determined that a level of 100 mg/kg of diesel range organics (DRO) in soil would be used as the cleanup criterion. All soil with DRO levels greater than 100 mg/kg would be excavated and disposed at an appropriate facility.

The source removal VCA was conducted during March and April 2000. Excavation continued until analytical results from the sidewall samples were less than 100 mg/kg DRO and until bedrock was encountered. Although some bedrock at the base of the excavation contained DRO above the cleanup level it was determined that further excavation was not feasible. Representatives from the NMED, including the Groundwater Bureau, inspected the excavation and concurred that the source removal objective of the VCA had been met.

A total of 856 cu yds of soil with DRO greater than 1000 mg/kg was excavated and stockpiled for disposal at the off-site facility. An additional 336 cu yds of excavated soils appropriate for disposal at the KAFB landfill was stockpiled. In addition, approximately 2000 cu yds of clean soil, removed to provide access to the underlying contamination, was set aside to be used for backfill.

During excavation, a layer of depleted uranium (DU)-contaminated soil was encountered. This soil was segregated and managed for off-site disposal as radioactive waste.

Confirmatory soil samples were collected from 17 locations around the sidewalls of the excavation and analyzed for DRO. An additional 10 samples, consisting of crushed bedrock, were collected from locations in the bottom of the excavation and analyzed for DRO. Duplicate samples were collected at eight locations and analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and RCRA metals plus beryllium at an off-site laboratory. All soil samples from the sidewalls were below the established cleanup level. DRO levels in the crushed bedrock samples from the base of the excavation ranged from 160 - 12,000 mg/kg. VOC and SVOC fuel-related components were detected in three of the eight samples; no fuel-related components were detected in any samples from the excavation sidewalls. Methylene chloride and acetone were detected in four samples but determined to be laboratory contamination due to detections in the method blank. Five metals were detected above background concentrations.

Six soil samples were collected from the two clean soil piles and analyzed for DRO. Following a review of the results this soil was determined to be clean and used as backfill in the excavation. Six samples were collected from the vicinity of the DU contamination and analyzed using gamma spectroscopy. U-238 was the only radionuclide detected above minimum detectable activities (MDAs) with four of the six samples above background activities.

Constituents Investigated

Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Jet fuel (JP-4 and JP-8), High Explosive (HE), and Metals.

Institutional Controls

The NMED has determined that site remediation is complete and no controls are needed. However, as a best management practice, LTES has established administrative institutional controls (IC) to track this site in the IC database.

Current Regulatory Status

Corrective action is complete at ER Site 94E, and no further action is required. This site is acceptable for residential land use, and there are no restrictions on future activities. NMED approved completion of corrective action in September 2000.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for ER Sites 94A, B, C, E, F, G, and H. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario.

The results of the risk assessment were below the NMED risk guidelines for both the industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land use scenario at site 94E.

Chromium was the main contributor to the overall risks.

Waste Volume Estimated/Generated

A combined surface radiation VCM for Sites 12, 13, 65, and 94 generated 200 drums of low-level radioactive waste. The VCAs for sites 94B, 94C, and 94F generated approximately 1,200 cubic yards of fuel contaminated soil and 60 cubic yards of low-level radioactive waste. The VCA at 94H generated approximately 900 cubic yards of fuel contaminated soil.

Site 0094F: Lurance Canyon Burn Site (Light Air-transport Accident Resistant Container Discharge Pit)

Primary Contact: Long-Term Environmental Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 94 consists of 8 sub-units (A-H) and is identified as Lurance Canyon Burn Site (LCBS) in the HSWA Module. The site is located on the canyon floor alluvium in the closed upper reaches of the Lurance Canyon drainage on land withdrawn from the USFS by the USAF and permitted to the DOE. It is surrounded by moderately steep, sloping canyon walls. The site is constructed on a large graded area, and the immediate topographic relief around the site is over 500 ft. A 25- to 50-ft wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls except for the western drainage into Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access road into Lurance Canyon and the LCBS.

The location of ER Site 94 coincides with ER Site 65 Lurance Canyon Explosive Test Site, an inactive site used for high explosives (HE) tests and for liquid and solid propellant burn tests. The LCBS is currently used for testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components. Only a few of the permanent, engineered structures at the site are currently active. Historical aerial photographs indicate that the transition of testing activities from predominantly open detonation explosives testing and JP-4 fuel fires in excavated pits (ER Site 65) to open burning with JP-4 fuel fires in portable burn pans (ER Site 94) occurred between 1971 and 1982. Based on test reports and interviews, open burning with JP-4 fuel fires in portable burn pans began by 1975. By 1980, the first permanent, engineered burn unit was constructed on the site of the former Primary Detonation Area (ER Site 65B) and was in operation. The scrap yard was established in the northwestern portion of the site within the boundary of the former Far Field Dispersion Area (ER Site 65F). The scrap yard has been used to store spare materials used in explosives and burn tests and is currently used for storing nonliquid materials and used equipment.

By 1983, the LCBS was constructed. It consisted of five permanent, engineered burn units, including the Large Open Burn Pit (LOBP), the Small Open Burn Pit (SOBP), the Light Airtransport Accident Resistant Container (LAARC) Unit, the Bomb Burner Unit, the Small Wind-Shielded (SWISH) Unit, and the Conical Containment (CON-CON) Unit. They were sited on the graded area that had been the Primary

Detonation Area (ER Site 65B) and Near Field Dispersion Area (ER Site 65D). Two of the burn units (the SWISH Unit and later, the Smoke Emissions Reduction Facility [SMERF]) were

constructed to provide testing facilities that would eliminate wind effects and provide accurate temperature control and instrumentation for test monitoring. A small surface impoundment is also visible southeast of Bunker 9830. Engineered soil berms had also been constructed by 1983 in the southeastern portion of the site for flood protection from the main arroyo in Lurance Canyon.

The CON-CON Unit was dismantled prior to 1989 and by 1992 a new burn unit (SMERF) was constructed on its site. Prior to 1992, a debris/soil mound area was created in the southern portion of the LCBS, immediately north of the main arroyo in Lurance Canyon. This debris/soil mound may be associated with on-going grading activities at the site. Northeast of the debris/soil mound area is another soil mound that was created during the remediation of a wastewater spill from a permanent engineered unit that occurred on March 20, 1992.

Burn testing at the LCBS has always been conducted with JP-4 fuel pool fires in open portable pans or contained within the permanent engineered structures. Pool fires provide the closest simulation of accidents involving flammable liquids. For the tests, the pans are filled with approximately 1 to 2 ft of water and an average 8-in. layer of JP-4 fuel. The test unit, such as a transportation container, is placed on a stand above the fuel. The fuel is ignited and the fire typically burns until the JP-4 fuel is consumed. The length of the test is controlled by the volume (thickness) of the JP-4 fuel layer. After a burn test is completed, test units are retrieved and salvageable materials are collected and stored in the scrap yard located in the northwest portion of the site. Any test object residue (e.g., metal slag) is recovered with the test unit and removed from the site by the testing group. Only small residue particulates may be left in the water following the burn test. While no testing is currently conducted on components containing radioactive materials, ER Sites 94B and C are currently classified as RMMAs because of the presence of residual DU in the soil from earlier burn tests and from former explosives testing activities associated with ER Site 65 which was abolished as an RMMA following submittal of NFAs for all Site 65 sub-units. ER Site 94G is classified as an RMMA because the scrap material stored in the yard may have some radioactive contamination since some of it was used in tests conducted at Site 65 sub-units.

Due to the overlap in location and periods of testing at ER Sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in descriptions of each ER site.

ER Site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (non-petroleum fuel-fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER Site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER Site 94.

In order to facilitate site characterization, ER Site 94 has been subdivided into the following eight sub-units that represent areas where hazardous constituents may have been released.

Site 94F comprises approximately 0.5 acre and was used to receive wastewater from suppression of test fires in the adjacent Light Air-transport Accident Resistant Container (LAARC) Unit. The LAARC Unit was used for 63 fire tests between 1980 and 1987. The LAARC discharge pit was unlined and the wastewater, which contained residual jet fuel, infiltrated into the underlying soil. Site 94F was established based upon the release of fuel components and was the potential source of groundwater contamination at the LCBS.

Corrective Action

In 1993, preliminary investigations were conducted which included background information reviews, interviews, field surveys, and scoping sampling.

In October 1993, Kirtland Air Force Base (KAFB) explosive ordnance disposal (EOD) personnel conducted a visual survey for unexploded ordnance (UXO) over the entire LCBS area. One trip flare was removed as live ordnance along with some ordnance debris.

During November and December 1993, and January 1994, a surface gamma radiation survey of ER Site 94 was conducted. Nine point-source and two area-source gamma radiation anomalies were removed from within the boundaries of Site 94B.

A passive soil vapor survey was conducted for the entire burn site in February 1998. Eighteen soil-gas points were located within the boundaries of Site 94B; no significant levels of organic compounds were detected as a result of this survey.

Based on results of the SVS and comments from NMED in the RSI and NOD, RFI sampling was conducted at all subunits at the Burn site in 1998 with the exception of the active Scrap Yard Site

94G. To determine the extent of fuel contamination at Site 94F, a second phase of characterization was conducted in 1999 that consisted of an active soil gas survey and soil sampling. Additional characterization was also conducted at Sites 94B & 94C and baseline sampling was conducted at Site 94G.

The drain line at site 94C was shown to have fixed radiological contamination and was excavated and removed from the trench in 1999. Rad surveys of the Site 94C trench sidewalls revealed an area of DU contaminated soil, a small DU contaminated soil area was also found at site 94B.

In April 1999, surface debris was removed from the site including scrap metal, concrete, and lead sheets. In May 1999, a geophysical survey indicated two anomalies associated with the large debris mound. The anomalies were removed and the mound was leveled. One of the anomalies, determined to be radioactively contaminated, was disposed as radioactive waste.

In response to a Request for Supplemental Information (RSI) from the New Mexico Environment Department (NMED), SNL agreed to additional characterization of two areas within the site. Subsequently, a Voluntary Corrective Action (VCA) was planned to further investigate the soil mounds and to collect samples from the adjacent arroyo.

In July 1999, soil samples were collected from two locations approximately two feet within the small jet propulsion fuel grade 4 (JP-4)/wastewater spill soil pile. In addition, five surface samples were collected from four locations in the adjacent arroyo channel. All samples were analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides.

In August 1999, a radiological survey was conducted over the entire surface of Site 94B. One small piece of depleted uranium (DU) was removed from the site and an area source was identified and marked. Further investigation showed the area source to be a layer of blackened DU contaminated soil approximately 1ft bgs.

Voluntary Corrective Actions were conducted at Sites 94B, C, & F in March and April of 2000. Radiologically contaminated soils were excavated at sites 94B & C and staged for disposal. Fuel contaminated soils were excavated at Site 94F. All soil with petroleum contamination was removed to bedrock at a depth of approximately 18 feet. The soils were disposed at a land farm or landfill, as appropriate, in the summer of 2000.

After discovery in August 2000 an RFI was conducted at ER site 94H to determine the extent of contamination. A VCA to remove the petroleum-contaminated soil was conducted in July 2001,

approximately 900 cubic yards of soil were removed.

In April 2000, an excavator was used to remove the contaminated soil layer. The resulting excavation was approximately 10 ft by 15 ft by 3.5 ft deep. Five confirmatory soil samples were collected from the base and sidewalls of the excavation. All samples were analyzed for radionuclides and one sample was also analyzed for VOCs, SVOCs, HE, and RCRA metals plus beryllium and uranium. Results indicated that the excavated area was clean and it was subsequently backfilled with clean soil.

Also in April 2000, a trench was cut through the JP-4 wastewater spill soil pile and a soil sample was collected from the native soil beneath the pile. The sample was analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides. In addition, soil samples were collected at two arroyo locations due to laboratory problems with the original analyses.

In November 2000, an estimated 25 cu yds of DU-contaminated soil that had been staged in ER Site 94B was disposed at an off-site facility.

In December 2000, a final radiological survey was conducted over the area and five confirmatory soil samples were collected. Results of these analyses indicated that residual DU levels are below risk levels and no further cleanup was required.

In July 1995, Site 94F was investigated as part of a site-wide scoping sampling program. Total petroleum hydrocarbon (TPH) and VOC results confirmed the presence of fuel-related compounds in the soil beneath the discharge pit. In February to March 1998, a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted to determine the extent of contamination at the site. A passive soil-vapor survey was conducted over the entire LCBS. Six surface-soil samples and three subsurface samples from one borehole were collected in the vicinity of the LAARC discharge pit. Analytical data from the RFI was sufficient to confirm the presence of contamination but additional sampling was required to verify the horizontal and vertical extent of contamination at Site 94F.

In November 1998, a second RFI was conducted to define the extent of contamination at the site for the purpose of remediation planning. Twenty-two active soil-gas samples were collected from the area surrounding the LAARC Unit and discharge pit. Following evaluation of the soil-gas results, 14 subsurface soil samples were collected from nine boreholes. Analytical results from these samples were used to identify the extent of contamination for excavation and to provide waste characterization data for planning disposal of excavated soils.

Based on the results of the RFI, a conceptual model was developed which indicated that contamination at this site was likely the primary source of groundwater contamination in the area and a Voluntary Corrective Action (VCA) source removal was planned. In consultation with the New Mexico Environment Department (NMED) it was determined that a level of 100 mg/kg of diesel range organics (DRO) in soil would be used as the cleanup criterion. All soil with DRO levels greater than 100 mg/kg would be excavated and disposed at an appropriate facility.

The source removal VCA was conducted during March and April 2000. Excavation continued until analytical results from the sidewall samples were less than 100 mg/kg DRO and until bedrock was encountered. Although some bedrock at the base of the excavation contained DRO above the cleanup level it was determined that further excavation was not feasible. Representatives from the NMED, including the Groundwater Bureau, inspected the excavation and concurred that the source removal objective of the VCA had been met.

A total of 856 cu yds of soil with DRO greater than 1000 mg/kg was excavated and stockpiled for

disposal at the off-site facility. An additional 336 cu yds of excavated soils appropriate for disposal at the KAFB landfill was stockpiled. In addition, approximately 2000 cu yds of clean soil, removed to provide access to the underlying contamination, was set aside to be used for backfill.

During excavation, a layer of depleted uranium (DU)-contaminated soil was encountered. This soil was segregated and managed for off-site disposal as radioactive waste.

Confirmatory soil samples were collected from 17 locations around the sidewalls of the excavation and analyzed for DRO. An additional 10 samples, consisting of crushed bedrock, were collected from locations in the bottom of the excavation and analyzed for DRO. Duplicate samples were collected at eight locations and analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and RCRA metals plus beryllium at an off-site laboratory. All soil samples from the sidewalls were below the established cleanup level. DRO levels in the crushed bedrock samples from the base of the excavation ranged from 160 - 12,000 mg/kg. VOC and SVOC fuel-related components were detected in three of the eight samples; no fuel-related components were detected in any samples from the excavation sidewalls. Methylene chloride and acetone were detected in four samples but determined to be laboratory contamination due to detections in the method blank. Five metals were detected above background concentrations.

Six soil samples were collected from the two clean soil piles and analyzed for DRO. Following a review of the results this soil was determined to be clean and used as backfill in the excavation. Six samples were collected from the vicinity of the DU contamination and analyzed using gamma spectroscopy. U-238 was the only radionuclide detected above minimum detectable activities (MDAs) with four of the six samples above background activities.

Constituents Investigated

Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Jet fuel (JP-4 and JP-8), High Explosive (HE), and Metals.

Institutional Controls

The NMED has determined that site remediation is complete and these sites pass the residential risk acceptable range, but due to the sites spatial relationship to SWMU 65, where there is "..potential for unknown occurrences of buried DU", the NMED wants controls implemented. Additional information regarding Institutional Controls at this site can be obtained from the SNL IC tracking database.

Current Regulatory Status

Corrective action is complete at ER Site 94F, and no further action is required. It is acceptable for residential land use, however, the NMED would like industrial land use imposed. During the permit negotiations, the final land use determination will be made. NMED approved completion of corrective action in April 2005, and the site is listed on Table A.2 of the Permit.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for ER Sites 94A, B, C, E, F, G, and H. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario.

The results of the risk assessment were below the NMED risk guidelines for both the industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land use scenario at site 94F.

Waste Volume Estimated/Generated

A combined surface radiation VCM for Sites 12, 13, 65, and 94 generated 200 drums of low-level radioactive waste. The VCAs for sites 94B, 94C, and 94F generated approximately 1,200 cubic yards of fuel contaminated soil and 60 cubic yards of low- level radioactive waste. The VCA at 94H generated approximately 900 cubic yards of fuel contaminated soil.

Site 0094G: Lurance Canyon Burn Site (Scrap Yard)

Primary Contact: Long-Term Environmental Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 94 consists of 8 sub-units (A-H) and is identified as Lurance Canyon Burn Site (LCBS) in the HSWA Module. The site is located on the canyon floor alluvium in the closed upper reaches of the Lurance Canyon drainage on land withdrawn from the USFS by the USAF and permitted to the DOE. It is surrounded by moderately steep, sloping canyon walls. The site is constructed on a large graded area, and the immediate topographic relief around the site is over 500 ft. A 25- to 50-ft wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls except for the western drainage into Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access road into Lurance Canyon and the LCBS.

The location of ER Site 94 coincides with ER Site 65 Lurance Canyon Explosive Test Site, an inactive site used for high explosives (HE) tests and for liquid and solid propellant burn tests. The LCBS is currently used for testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components. Only a few of the permanent, engineered structures at the site are currently active. Historical aerial photographs indicate that the transition of testing activities from predominantly open detonation explosives testing and JP-4 fuel fires in excavated pits (ER Site 65) to open burning with JP-4 fuel fires in portable burn pans (ER Site 94) occurred between 1971 and 1982. Based on test reports and interviews, open burning with JP-4 fuel fires in portable burn pans began by 1975. By 1980, the first permanent, engineered burn unit was constructed on the site of the former Primary Detonation Area (ER Site 65B) and was in operation. The scrap yard was established in the northwestern portion of the site within the boundary of the former Far Field Dispersion Area (ER Site 65F). The scrap yard has been used to store spare materials used in explosives and burn tests and is currently used for storing nonliquid materials and used equipment.

By 1983, the LCBS was constructed. It consisted of five permanent, engineered burn units, including the Large Open Burn Pit (LOBP), the Small Open Burn Pit (SOBP), the Light Airtransport Accident Resistant Container (LAARC) Unit, the Bomb Burner Unit, the Small Wind-Shielded (SWISH) Unit, and the Conical Containment (CON-CON) Unit. They were sited on the graded area that had been the Primary

Detonation Area (ER Site 65B) and Near Field Dispersion Area (ER Site 65D). Two of the burn units (the SWISH Unit and later, the Smoke Emissions Reduction Facility [SMERF]) were constructed to provide testing facilities that would eliminate wind effects and provide accurate temperature control and instrumentation for test monitoring. A small surface impoundment is also visible southeast of Bunker 9830. Engineered soil berms had also been constructed by 1983 in the southeastern portion of the site for flood protection from the main arroyo in Lurance Canyon.

The CON-CON Unit was dismantled prior to 1989 and by 1992 a new burn unit (SMERF) was constructed on its site. Prior to 1992, a debris/soil mound area was created in the southern portion of the LCBS, immediately north of the main arroyo in Lurance Canyon. This debris/soil mound may be associated with on-going grading activities at the site. Northeast of the debris/soil mound area is another soil mound that was created during the remediation of a wastewater spill from a permanent engineered unit that occurred on March 20, 1992.

Burn testing at the LCBS has always been conducted with JP-4 fuel pool fires in open portable pans or contained within the permanent engineered structures. Pool fires provide the closest simulation of accidents involving flammable liquids. For the tests, the pans are filled with approximately 1 to 2 ft of water and an average 8-in. layer of JP-4 fuel. The test unit, such as a transportation container, is placed on a stand above the fuel. The fuel is ignited and the fire typically burns until the JP-4 fuel is consumed. The length of the test is controlled by the volume (thickness) of the JP-4 fuel layer. After a burn test is completed, test units are retrieved and salvageable materials are collected and stored in the scrap yard located in the northwest portion of the site. Any test object residue (e.g., metal slag) is recovered with the test unit and removed from the site by the testing group. Only small residue particulates may be left in the water following the burn test. While no testing is currently conducted on components containing radioactive materials, ER Sites 94B and C are currently classified as RMMAs because of the presence of residual DU in the soil from earlier burn tests and from former explosives testing activities associated with ER Site 65 which was abolished as an RMMA following submittal of NFAs for all Site 65 sub-units. ER Site 94G is classified as an RMMA because the scrap material stored in the yard may have some radioactive contamination since some of it was used in tests conducted at Site 65 sub-units.

Due to the overlap in location and periods of testing at ER Sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in descriptions of each ER site.

ER Site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (non-petroleum fuel-fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER Site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER Site 94.

In order to facilitate site characterization, ER Site 94 has been subdivided into the following eight sub-units that represent areas where hazardous constituents may have been released.

The Scrap Yard is located on 3.2 acres in the northwest portion of ER Site 94. Surplus test materials and equipment to support burn testing at the LCBS are stored there.

Corrective Action

In 1993, preliminary investigations were conducted which included background information reviews, interviews, field surveys, and scoping sampling.

In October 1993, Kirtland Air Force Base (KAFB) explosive ordnance disposal (EOD) personnel conducted a visual survey for unexploded ordnance (UXO) over the entire LCBS area. One trip flare was removed as live ordnance along with some ordnance debris.

During November and December 1993, and January 1994, a surface gamma radiation survey of ER Site 94 was conducted. Nine point-source and two area-source gamma radiation anomalies were removed from within the boundaries of Site 94B.

A passive soil vapor survey was conducted for the entire burn site in February 1998. Eighteen soil-gas points were located within the boundaries of Site 94B; no significant levels of organic compounds were detected as a result of this survey.

Based on results of the SVS and comments from NMED in the RSI and NOD, RFI sampling was conducted at all subunits at the Burn site in 1998 with the exception of the active Scrap Yard Site

94G. To determine the extent of fuel contamination at Site 94F, a second phase of characterization was conducted in 1999 that consisted of an active soil gas survey and soil sampling. Additional characterization was also conducted at Sites 94B & 94C and baseline sampling was conducted at Site 94G.

The drain line at site 94C was shown to have fixed radiological contamination and was excavated and removed from the trench in 1999. Rad surveys of the Site 94C trench sidewalls revealed an area of DU contaminated soil, a small DU contaminated soil area was also found at site 94B.

In April 1999, surface debris was removed from the site including scrap metal, concrete, and lead sheets. In May 1999, a geophysical survey indicated two anomalies associated with the large debris mound. The anomalies were removed and the mound was leveled. One of the anomalies, determined to be radioactively contaminated, was disposed as radioactive waste.

In response to a Request for Supplemental Information (RSI) from the New Mexico Environment Department (NMED), SNL agreed to additional characterization of two areas within the site. Subsequently, a Voluntary Corrective Action (VCA) was planned to further investigate the soil mounds and to collect samples from the adjacent arroyo.

In July 1999, soil samples were collected from two locations approximately two feet within the small jet propulsion fuel grade 4 (JP-4)/wastewater spill soil pile. In addition, five surface samples were collected from four locations in the adjacent arroyo channel. All samples were analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides.

In August 1999, a radiological survey was conducted over the entire surface of Site 94B. One small piece of depleted uranium (DU) was removed from the site and an area source was identified and marked. Further investigation showed the area source to be a layer of blackened DU contaminated soil approximately 1ft bgs.

Voluntary Corrective Actions were conducted at Sites 94B, C, & F in March and April of 2000. Radiologically contaminated soils were excavated at sites 94B & C and staged for disposal. Fuel contaminated soils were excavated at Site 94F. All soil with petroleum contamination was removed to bedrock at a depth of approximately 18 feet. The soils were disposed at a land farm or landfill, as appropriate, in the summer of 2000.

After discovery in August 2000 an RFI was conducted at ER site 94H to determine the extent of contamination. A VCA to remove the petroleum-contaminated soil was conducted in July 2001, approximately 900 cubic yards of soil were removed.

In April 2000, an excavator was used to remove the contaminated soil layer. The resulting excavation was approximately 10 ft by 15 ft by 3.5 ft deep. Five confirmatory soil samples were collected from the base and sidewalls of the excavation. All samples were analyzed for radionuclides and one sample was also analyzed for VOCs, SVOCs, HE, and RCRA metals plus beryllium and uranium.

Results indicated that the excavated area was clean and it was subsequently backfilled with clean soil.

Also in April 2000, a trench was cut through the JP-4 wastewater spill soil pile and a soil sample was collected from the native soil beneath the pile. The sample was analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides. In addition, soil samples were collected at two arroyo locations due to laboratory problems with the original analyses.

In November 2000, an estimated 25 cu yds of DU-contaminated soil that had been staged in ER Site 94B was disposed at an off-site facility.

In December 2000, a final radiological survey was conducted over the area and five confirmatory soil samples were collected. Results of these analyses indicated that residual DU levels are below risk levels and no further cleanup was required.

In July 1995, Site 94F was investigated as part of a site-wide scoping sampling program. Total petroleum hydrocarbon (TPH) and VOC results confirmed the presence of fuel-related compounds in the soil beneath the discharge pit. In February to March 1998, a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted to determine the extent of contamination at the site. A passive soil-vapor survey was conducted over the entire LCBS. Six surface-soil samples and three subsurface samples from one borehole were collected in the vicinity of the LAARC discharge pit. Analytical data from the RFI was sufficient to confirm the presence of contamination but additional sampling was required to verify the horizontal and vertical extent of contamination at Site 94F.

In November 1998, a second RFI was conducted to define the extent of contamination at the site for the purpose of remediation planning. Twenty-two active soil-gas samples were collected from the area surrounding the LAARC Unit and discharge pit. Following evaluation of the soil-gas results, 14 subsurface soil samples were collected from nine boreholes. Analytical results from these samples were used to identify the extent of contamination for excavation and to provide waste characterization data for planning disposal of excavated soils.

Based on the results of the RFI, a conceptual model was developed which indicated that contamination at this site was likely the primary source of groundwater contamination in the area and a Voluntary Corrective Action (VCA) source removal was planned. In consultation with the New Mexico Environment Department (NMED) it was determined that a level of 100 mg/kg of diesel range organics (DRO) in soil would be used as the cleanup criterion. All soil with DRO levels greater than 100 mg/kg would be excavated and disposed at an appropriate facility.

The source removal VCA was conducted during March and April 2000. Excavation continued until analytical results from the sidewall samples were less than 100 mg/kg DRO and until bedrock was encountered. Although some bedrock at the base of the excavation contained DRO above the cleanup level it was determined that further excavation was not feasible. Representatives from the NMED, including the Groundwater Bureau, inspected the excavation and concurred that the source removal objective of the VCA had been met.

A total of 856 cu yds of soil with DRO greater than 1000 mg/kg was excavated and stockpiled for disposal at the off-site facility. An additional 336 cu yds of excavated soils appropriate for disposal at the KAFB landfill was stockpiled. In addition, approximately 2000 cu yds of clean soil, removed to provide access to the underlying contamination, was set aside to be used for backfill.

During excavation, a layer of depleted uranium (DU)-contaminated soil was encountered. This soil was segregated and managed for off-site disposal as radioactive waste.

Confirmatory soil samples were collected from 17 locations around the sidewalls of the excavation and analyzed for DRO. An additional 10 samples, consisting of crushed bedrock, were collected from locations in the bottom of the excavation and analyzed for DRO. Duplicate samples were collected at eight locations and analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and RCRA metals plus beryllium at an off-site laboratory. All soil samples from the sidewalls were below the established cleanup level. DRO levels in the crushed bedrock samples from the base of the excavation ranged from 160 - 12,000 mg/kg. VOC and SVOC fuel-related components were detected in three of the eight samples; no fuel-related components were detected in any samples from the excavation sidewalls. Methylene chloride and acetone were detected in four samples but determined to be laboratory contamination due to detections in the method blank. Five metals were detected above background concentrations.

Six soil samples were collected from the two clean soil piles and analyzed for DRO. Following a review of the results this soil was determined to be clean and used as backfill in the excavation. Six samples were collected from the vicinity of the DU contamination and analyzed using gamma spectroscopy. U-238 was the only radionuclide detected above minimum detectable activities (MDAs) with four of the six samples above background activities.

Constituents Investigated

Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Jet fuel (JP-4 and JP-8), High Explosive (HE), and Metals.

Institutional Controls

The NMED has determined that site remediation is complete and no controls are needed. However, as a best management practice, LTES has established administrative institutional controls (IC) to track this site in the IC database.

Current Regulatory Status

Corrective action is complete at ER Site 94G, and no further action is required. This site is acceptable for residential land use, and there are no restrictions on future activities. NMED approved completion of corrective action in November 2001.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for ER Sites 94A, B, C, E, F, G, and H. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario.

The results of the risk assessment were below the NMED risk guidelines for both the industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land use scenario.

Chromium was the main contributor to the overall risks.

Waste Volume Estimated/Generated

A combined surface radiation VCM for Sites 12, 13, 65, and 94 generated 200 drums of low-level radioactive waste. The VCAs for sites 94B, 94C, and 94F generated approximately 1,200 cubic yards of fuel contaminated soil and 60 cubic yards of low- level radioactive waste. The VCA at 94H generated approximately 900 cubic yards of fuel contaminated soil.

Site 0094H: Lurance Canyon Burn Site (JP-8 Site)

Primary Contact: Long-Term Environmental Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 94 consists of 8 sub-units (A-H) and is identified as Lurance Canyon Burn Site (LCBS) in the HSWA Module. The site is located on the canyon floor alluvium in the closed upper reaches of the Lurance Canyon drainage on land withdrawn from the USFS by the USAF and permitted to the DOE. It is surrounded by moderately steep, sloping canyon walls. The site is constructed on a large graded area, and the immediate topographic relief around the site is over 500 ft. A 25- to 50-ft wide road is cut on the hillslopes as a firebreak and encircles the site. The canyon floor at the site is isolated by the canyon walls except for the western drainage into Arroyo del Coyote. Coyote Springs Road follows this drainage and is the main access road into Lurance Canyon and the LCBS.

The location of ER Site 94 coincides with ER Site 65 Lurance Canyon Explosive Test Site, an inactive site used for high explosives (HE) tests and for liquid and solid propellant burn tests. The LCBS is currently used for testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components. Only a few of the permanent, engineered structures at the site are currently active. Historical aerial photographs indicate that the transition of testing activities from predominantly open detonation explosives testing and JP-4 fuel fires in excavated pits (ER Site 65) to open burning with JP-4 fuel fires in portable burn pans (ER Site 94) occurred between 1971 and 1982. Based on test reports and interviews, open burning with JP-4 fuel fires in portable burn pans began by 1975. By 1980, the first permanent, engineered burn unit was constructed on the site of the former Primary Detonation Area (ER Site 65B) and was in operation. The scrap yard was established in the northwestern portion of the site within the boundary of the former Far Field Dispersion Area (ER Site 65F). The scrap yard has been used to store spare materials used in explosives and burn tests and is currently used for storing nonliquid materials and used equipment.

By 1983, the LCBS was constructed. It consisted of five permanent, engineered burn units, including the Large Open Burn Pit (LOBP), the Small Open Burn Pit (SOBP), the Light Airtransport Accident Resistant Container (LAARC) Unit, the Bomb Burner Unit, the Small Wind-Shielded (SWISH) Unit, and the Conical Containment (CON-CON) Unit. They were sited on the graded area that had been the Primary

Detonation Area (ER Site 65B) and Near Field Dispersion Area (ER Site 65D). Two of the burn units (the SWISH Unit and later, the Smoke Emissions Reduction Facility [SMERF]) were constructed to provide testing facilities that would eliminate wind effects and provide accurate temperature control and instrumentation for test monitoring. A small surface impoundment is also visible southeast of Bunker 9830. Engineered soil berms had also been constructed by 1983 in the southeastern portion of the site for flood protection from the main arroyo in Lurance Canyon.

The CON-CON Unit was dismantled prior to 1989 and by 1992 a new burn unit (SMERF) was constructed on its site. Prior to 1992, a debris/soil mound area was created in the southern portion of the LCBS, immediately north of the main arroyo in Lurance Canyon. This debris/soil mound may be associated with on-going grading activities at the site. Northeast of the debris/soil mound area is another soil mound that was created during the remediation of a wastewater spill from a permanent engineered unit that occurred on March 20, 1992.

Burn testing at the LCBS has always been conducted with JP-4 fuel pool fires in open portable pans or contained within the permanent engineered structures. Pool fires provide the closest simulation of accidents involving flammable liquids. For the tests, the pans are filled with approximately 1 to 2 ft of water and an average 8-in. layer of JP-4 fuel. The test unit, such as a transportation container, is placed on a stand above the fuel. The fuel is ignited and the fire typically burns until the JP-4 fuel is consumed. The length of the test is controlled by the volume (thickness) of the JP-4 fuel layer. After a burn test is completed, test units are retrieved and salvageable materials are collected and stored in the scrap yard located in the northwest portion of the site. Any test object residue (e.g., metal slag) is recovered with the test unit and removed from the site by the testing group. Only small residue particulates may be left in the water following the burn test. While no testing is currently conducted on components containing radioactive materials, ER Sites 94B and C are currently classified as RMMAs because of the presence of residual DU in the soil from earlier burn tests and from former explosives testing activities associated with ER Site 65 which was abolished as an RMMA following submittal of NFAs for all Site 65 sub-units. ER Site 94G is classified as an RMMA because the scrap material stored in the yard may have some radioactive contamination since some of it was used in tests conducted at Site 65 sub-units.

Due to the overlap in location and periods of testing at ER Sites 65 and 94, the criteria below were used to determine the types of operational tests and test structures to include in descriptions of each ER site.

ER Site 65 includes all operations or testing that involved general explosives tests, early burn tests that involved the excavation of pits into soil and sediment, miscellaneous (non-petroleum fuel-fire) burn tests, cone tests, a Torch Activated Burn System (TABS) test location, and slow-heat tests. ER Site 94 includes all burn tests involving portable pans and fixed-location structures or engineered burn units. A TABS test location also exists in ER Site 94.

In order to facilitate site characterization, ER Site 94 has been subdivided into the following eight sub-units that represent areas where hazardous constituents may have been released.

The JP-8 site was discovered in August 2000. The JP-8 site is located immediately west of the Large Open Burn Pool and covers approximately 0.1 acres. No details exist on the date of the release of JP-8 from underground piping that connected ER Site 94A to the LOBP. The piping has since been upgraded.

Corrective Action

In 1993, preliminary investigations were conducted which included background information reviews, interviews, field surveys, and scoping sampling.

In October 1993, Kirtland Air Force Base (KAFB) explosive ordnance disposal (EOD) personnel conducted a visual survey for unexploded ordnance (UXO) over the entire LCBS area. One trip flare was removed as live ordnance along with some ordnance debris.

During November and December 1993, and January 1994, a surface gamma radiation survey of ER Site 94 was conducted. Nine point-source and two area-source gamma radiation anomalies were removed from within the boundaries of Site 94B.

A passive soil vapor survey was conducted for the entire burn site in February 1998. Eighteen soil-gas points were located within the boundaries of Site 94B; no significant levels of organic compounds were detected as a result of this survey.

Based on results of the SVS and comments from NMED in the RSI and NOD, RFI sampling was conducted at all subunits at the Burn site in 1998 with the exception of the active Scrap Yard Site

94G. To determine the extent of fuel contamination at Site 94F, a second phase of characterization was conducted in 1999 that consisted of an active soil gas survey and soil sampling. Additional characterization was also conducted at Sites 94B & 94C and baseline sampling was conducted at Site 94G.

The drain line at site 94C was shown to have fixed radiological contamination and was excavated and removed from the trench in 1999. Rad surveys of the Site 94C trench sidewalls revealed an area of DU contaminated soil, a small DU contaminated soil area was also found at site 94B.

In April 1999, surface debris was removed from the site including scrap metal, concrete, and lead sheets. In May 1999, a geophysical survey indicated two anomalies associated with the large debris mound. The anomalies were removed and the mound was leveled. One of the anomalies, determined to be radioactively contaminated, was disposed as radioactive waste.

In response to a Request for Supplemental Information (RSI) from the New Mexico Environment Department (NMED), SNL agreed to additional characterization of two areas within the site. Subsequently, a Voluntary Corrective Action (VCA) was planned to further investigate the soil mounds and to collect samples from the adjacent arroyo.

In July 1999, soil samples were collected from two locations approximately two feet within the small jet propulsion fuel grade 4 (JP-4)/wastewater spill soil pile. In addition, five surface samples were collected from four locations in the adjacent arroyo channel. All samples were analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides.

In August 1999, a radiological survey was conducted over the entire surface of Site 94B. One small piece of depleted uranium (DU) was removed from the site and an area source was identified and marked. Further investigation showed the area source to be a layer of blackened DU contaminated soil approximately 1ft bgs.

Voluntary Corrective Actions were conducted at Sites 94B, C, & F in March and April of 2000. Radiologically contaminated soils were excavated at sites 94B & C and staged for disposal. Fuel contaminated soils were excavated at Site 94F. All soil with petroleum contamination was removed to bedrock at a depth of approximately 18 feet. The soils were disposed at a land farm or landfill, as appropriate, in the summer of 2000.

After discovery in August 2000 an RFI was conducted at ER site 94H to determine the extent of contamination. A VCA to remove the petroleum-contaminated soil was conducted in July 2001, approximately 900 cubic yards of soil were removed.

In April 2000, an excavator was used to remove the contaminated soil layer. The resulting excavation was approximately 10 ft by 15 ft by 3.5 ft deep. Five confirmatory soil samples were collected from the base and sidewalls of the excavation. All samples were analyzed for radionuclides and one sample was also analyzed for VOCs, SVOCs, HE, and RCRA metals plus beryllium and uranium. Results indicated that the excavated area was clean and it was subsequently backfilled with clean soil.

Also in April 2000, a trench was cut through the JP-4 wastewater spill soil pile and a soil sample was collected from the native soil beneath the pile. The sample was analyzed for VOCs, SVOCs, RCRA metals, HE, and radionuclides. In addition, soil samples were collected at two arroyo locations due to laboratory problems with the original analyses.

In November 2000, an estimated 25 cu yds of DU-contaminated soil that had been staged in ER Site 94B was disposed at an off-site facility.

In December 2000, a final radiological survey was conducted over the area and five confirmatory soil samples were collected. Results of these analyses indicated that residual DU levels are below risk levels and no further cleanup was required.

In July 1995, Site 94F was investigated as part of a site-wide scoping sampling program. Total petroleum hydrocarbon (TPH) and VOC results confirmed the presence of fuel-related compounds in the soil beneath the discharge pit. In February to March 1998, a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted to determine the extent of contamination at the site. A passive soil-vapor survey was conducted over the entire LCBS. Six surface-soil samples and three subsurface samples from one borehole were collected in the vicinity of the LAARC discharge pit. Analytical data from the RFI was sufficient to confirm the presence of contamination but additional sampling was required to verify the horizontal and vertical extent of contamination at Site 94F.

In November 1998, a second RFI was conducted to define the extent of contamination at the site for the purpose of remediation planning. Twenty-two active soil-gas samples were collected from the area surrounding the LAARC Unit and discharge pit. Following evaluation of the soil-gas results, 14 subsurface soil samples were collected from nine boreholes. Analytical results from these samples were used to identify the extent of contamination for excavation and to provide waste characterization data for planning disposal of excavated soils.

Based on the results of the RFI, a conceptual model was developed which indicated that contamination at this site was likely the primary source of groundwater contamination in the area and a Voluntary Corrective Action (VCA) source removal was planned. In consultation with the New Mexico Environment Department (NMED) it was determined that a level of 100 mg/kg of diesel range organics (DRO) in soil would be used as the cleanup criterion. All soil with DRO levels greater than 100 mg/kg would be excavated and disposed at an appropriate facility.

The source removal VCA was conducted during March and April 2000. Excavation continued until analytical results from the sidewall samples were less than 100 mg/kg DRO and until bedrock was encountered. Although some bedrock at the base of the excavation contained DRO above the cleanup level it was determined that further excavation was not feasible. Representatives from the NMED, including the Groundwater Bureau, inspected the excavation and concurred that the source removal objective of the VCA had been met.

A total of 856 cu yds of soil with DRO greater than 1000 mg/kg was excavated and stockpiled for disposal at the off-site facility. An additional 336 cu yds of excavated soils appropriate for disposal at the KAFB landfill was stockpiled. In addition, approximately 2000 cu yds of clean soil, removed to provide access to the underlying contamination, was set aside to be used for backfill.

During excavation, a layer of depleted uranium (DU)-contaminated soil was encountered. This soil was segregated and managed for off-site disposal as radioactive waste.

Confirmatory soil samples were collected from 17 locations around the sidewalls of the excavation and analyzed for DRO. An additional 10 samples, consisting of crushed bedrock, were collected from locations in the bottom of the excavation and analyzed for DRO. Duplicate samples were collected at eight locations and analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and RCRA metals plus beryllium at an off-site laboratory. All soil samples from the sidewalls were below the established cleanup level. DRO levels in the crushed bedrock samples from the base of the excavation ranged from 160 - 12,000 mg/kg. VOC and SVOC fuel-related components were detected in three of the eight samples; no fuel-related components were detected in any samples from the excavation sidewalls. Methylene chloride and acetone were detected in four samples but determined to be laboratory contamination due to detections in the method blank. Five metals were detected above background concentrations.

Six soil samples were collected from the two clean soil piles and analyzed for DRO. Following a review of the results this soil was determined to be clean and used as backfill in the excavation. Six samples were collected from the vicinity of the DU contamination and analyzed using gamma spectroscopy. U-238 was the only radionuclide detected above minimum detectable activities (MDAs) with four of the six samples above background activities.

Constituents Investigated

Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Jet fuel (JP-4 and JP-8), High Explosive (HE), and Metals.

Institutional Controls

The NMED has determined that site remediation is complete and these sites pass the residential risk acceptable range, but due to the sites spatial relationship to SWMU 65, where there is "..potential for unknown occurrences of buried DU", the NMED wants controls implemented. Additional information regarding Institutional Controls at this site can be obtained from the SNL IC tracking database.

Current Regulatory Status

Corrective action is complete at ER Site 94H, and no further action is required. It is acceptable for residential land use, however, the NMED would like industrial land use imposed. During the permit negotiations, the final land use determination will be made. NMED approved completion of corrective action in April 2005, and the site is listed on Table A.2 of the Permit.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for ER Sites 94A, B, C, E, F, G, and H. The risk assessment analysis evaluated the potential for adverse health effects for an industrial and residential land-use scenario.

The results of the risk assessment were below the NMED risk guidelines for both the industrial and residential land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land use scenario at site 94H.

Waste Volume Estimated/Generated

A combined surface radiation VCM for Sites 12, 13, 65, and 94 generated 200 drums of low-level radioactive waste. The VCAs for sites 94B, 94C, and 94F generated approximately 1,200 cubic yards of fuel contaminated soil and 60 cubic yards of low- level radioactive waste. The VCA at 94H generated approximately 900 cubic yards of fuel contaminated soil.

Site 0160: Building 9832 Septic System

Primary Contact: Long-Term Stewardship Program
Phone: 505-284-9883
Last Update: January 2011

Site History

Environmental Restoration (ER) site 160 included the seepage pit serving the high explosives (HE) wastewater system for Building 9832. There is no septic system associated with this site.
Building 9832, the Vehicle Assembly Building, is located on the northwest corner of the intersection of the Burn Site road and the new Cable Site road, in Lurance Canyon. The building was constructed in 1968 for the preparation of explosive tests, involving explosive train assembly, propellant assemblies, parts degreasing, and painting of test assemblies. Wastewater from the assembly area cleanup, some of which may have contained nitroguanidine, ammonium nitrate, Composition C4, plastic bonded explosive (PBX)-9404, PBX-9205, and pentaerythritol tetranitrate (PETN), was discharged through a floor trough to a catch box and a seepage pit. A hand-washing sink, located inside the high bay on the east wall, empties into the trough just before it exits the building. The building has no toilet facilities or permanent water supply; water for washing was provided by a tanker truck to a holding tank located on the north side of the building.

During past operations, the floor in the HE assembly area was washed with water into the floor trough that discharged via a concrete channel covered with a steel lid to a catch box and seepage pit. The concrete channel exits the southeast end of the building, turns southwest and drains into the catch box, which contained a polyethylene filter bag for collecting heavy particles of waste HEs. The filter bags were periodically replaced and turned over to the U.S. Air Force (USAF) explosive ordnance disposal team for disposal. The floors are no longer washed down with water; since the late 1980s, they were swept and wet-mopped. The liquid overflow from the catch box entered a 1.5-meter (m; 5-foot [ft])-diameter by 2.4-m (8-ft)-deep seepage pit located on the southwest side of the fence. Estimated effluent volume has not been quantified. The seepage pit had reportedly not been used since 1981.

Depth to groundwater beneath the site is unknown. The nearest groundwater monitoring wells (CYN-MW7 and CYN-MW8) are approximately 1,000 ft north and northeast, respectively, of the site. Depths to water in these wells were measured at approximately 290 ft and 314 ft below ground surface in July 2008.

Corrective Action

A passive soil vapor survey was conducted in the seepage pit area in June 1994. No significant volatile organic compound (VOC) or semivolatile organic compound (SVOC) anomalies were detected as a result of this survey.

A total of 25 confirmatory soil samples were collected, in October 1994, from two boreholes on either side of the seepage pit. Samples were collected from depths of 8 ft and 18 ft, and were analyzed by gamma spectroscopy for VOCs, SVOCs, the HE compound trinitrotoluene (TNT), metals, isotopic uranium, and radionuclides. Trace levels of two VOCs were detected in the samples; and SVOCs and TNT were not detected. Cadmium and mercury were also detected at concentrations slightly higher than background in some of the metals samples. Radionuclide analyses indicated there was no evidence of radionuclide contamination at the site.

The seepage pit was backfilled, in place, with clean soil in late 1995 or early 1996.

A no further action (NFA) proposal for ER site 160 was submitted to the New Mexico Environment Department (NMED) in June 1996.

In response to requests and negotiations with the NMED, resampling of soil from a third borehole, drilled through the center and directly beneath the seepage pit at this site, was completed in January 1998. Soil samples had been previously collected, in October 1994, from a pair of borings located on either side of the seepage pit, but this method was considered inadequate by the NMED. Samples from the third borehole were also collected from depths of 8 ft and 18 ft, and were analyzed for VOCs, SVOCs, TNT, and *Resource Conservation and Recovery Act* (RCRA) metals. Analytical results for the additional soil samples collected from directly beneath the seepage pit were not significantly different from the analytical results for soil samples collected on either side of the seepage pit. NMED regulators agreed with this conclusion, and determined additional soil sampling beneath the seepage pit would not be required.

A request for supplemental information (RSI) on the NFA proposal was received from the NMED in June 1998. Sandia National Laboratories (SNL) replied to the NMED RSI in November 1998. June 9, 2000, the NMED found the NFA petition for site 160 to be acceptable. Information about the site was presented at a public poster session in May 2001. The NFA petition, without controls, for site 160 was officially approved by the NMED in November 2001, after completing the public review and permit modification process.

Constituents Investigated

VOCs, SVOCs, TNT, RCRA metals, isotopic uranium, and radionuclides.

Institutional Controls

The NMED has determined site remediation is complete, and no controls are needed. However, due to material management concerns, LTES has established institutional controls (IC) to track this site in the SNL IC tracking database, where additional information can be obtained.

Current Regulatory Status

Corrective action is complete at site 160, and NFA is needed to meet NMED requirements. The NMED approved completion of the corrective action in November 2001.

Results of Risk Analysis

Because contaminants of interest were present in concentrations greater than background-screening levels or because constituents were present that did not have background-screening numbers, it was necessary to perform a risk assessment for the site. The risk assessment analysis evaluated the potential for adverse health effects for industrial and residential land-use scenarios. The results of the risk assessment were below NMED risk guidelines for both land-use scenarios. In conclusion, human health risk is within the acceptable range according to NMED guidance for the residential land-use scenario.

Cadmium and methylene chloride were the main contributors to the overall risks.

Waste Volume Estimated/Generated

No waste was generated at this site.

Appendix I
Summary of the Potential Nitrate Sources for the Burn Site Groundwater Area of Concern Prepared During the Internal Remedy Review

Anthropogenic Sources from SNL/NM Historical Operations
Ammonium nitrate (AN) slurry in 3 types of tests (Cloudmaker, C-4 booster study, and fuel-rod containers). Four tests used a total of 42,100 pounds of AN slurry (SNL/NM June 1998). Test cylinders either detonated or were ruptured by over-pressuring and then detonated. Inferred dispersal/spillage of un-combusted slurry onto the ground surface at SWMU 65C and possibly up to 850 feet away with other known debris. The tests were conducted from 1969 through 1975. The amount of spillage is undocumented and unknown.
GSX (gelled slurry explosive) in a single test. Likely tested at SWMU 65C in about 1969 (Uncapher March 2015). GSX is a mixture of AN, aluminum, and polystyrene. Daisy Cutter bomb contained 12,600 pounds of GSX from a single test conducted in 1969.
Slurry total is 54,700 pounds. The total weight of AN slurry and GSX slurry (described in the two rows above) was 54,700 pounds.
Degradation products. Derived from partially combusted or ejected HE fragments following open-air detonations. HE compounds containing nitrate that degrade in the environment could be a source of nitrate that could be mobilized to GW by precipitation. The LANL 20-year weathering study identified 3 compounds that weathered quickly: TNT, Baratol, and Boracitol.
Open-air detonations. HE detonations were conducted at 65B and 65C from 1967 to 1993, with most of the detonations occurring prior to 1975. A minimum of 318 open-air detonations occurred from 1967 to 1993.
SWMU 12A drums. 8-10 drums were exposed by erosion at the northern tip of SWMU 12A and washed into 'ditch near the parking lot' [probably at 12B] in about 1990. One drum contained Tyvek, contents of other drums were not discussed but unlikely that drums would contain HE pieces or slurry.
SWUMU 12B Testing debris. Placed in the arroyo, included wire, metal supports, wood, and 'HE residue'. Unknown if this included slurry residue on remnants of Cloudmaker cylinders. As a standard safety protocol, visible solid pieces of HE would be either detonated in place, or picked up by USAF EOD personnel for disposal. However, slurry might have been just washed away with water.
Plastic explosives detonations. RDX, C-4, and HMX typically have no nitrate content unless nitrate-bearing initiators used.
Testing debris. Buried in scattered bunkers and soil/rock piles at the various SWMUs. Nitrate possibly leached from the debris prior to VCM removal activities in early 2000's.
Initiators. Various HE tests over many years have used a diverse variety of squibs, blasting caps, detonators, and initiators including small volumes of gun powder to set off the main HE charges. Not expected to be of much concern.
Wastewater discharges to earthen pits/impoundments. Five SWMUs (13, 65C, 94D, 94E, 94F) discharged wastewater as part of 127 pool-fire burn tests. Total known volume of wastewater is 483,000 gallons. Wastewater with residues of fuel oil and test debris likely percolated into alluvium and bedrock, and wastewater provided driving force and solution for contaminants to migrate deeper. Large wastewater volumes disposed during nine events of 34,000 gallons each at SWMU 13 during 1984 to 1987. The other sites had repeated (a total of 118) but smaller discharges of 1,500 gallons each from 1969 to 1987. Additional water was likely used for dust suppression across the BSG AOC.
Scrap yard. SWMU 94G may have stored some test fixtures that contained HE residues or materials, but considered unlikely.
Undocumented septic systems. No drain and septic system sites were identified. On site facilities in break trailer drains to aboveground holding tanks.
Animal manure. Possibly used as a fuel for some Burn Site tests (DOE May 1995). No other references or interviews mention the use of manure.
Explosive Assembly Bunker. SWMU 160 (Building 9832) Septic System for building supporting the Vehicle Assembly building for the Aerial Cable Facility. Several HE compounds were used including AN. The wash-down water flowed into the floor drain from 1968 to 1981.

Potential Anthropogenic Sources from Non-SNL/NM Historical Operations
Historic Mine Shafts. Five were investigated by SNL/NM as SWMUs but no SNL/NM activities occurred at the sites. All were proposed as No Further Action in December 1997 and Corrective Action Complete Without Controls status was approved by NMED. However, it is unknown if dynamite, nitroglycerin, or other nitrogen-bearing explosives were left underground from pre-1940s mining activities. • SWMU 28-3 (Eight Five Mine). Located in Sol se Mete Canyon approximately 1,000 ft south of the BSG AOC. • SWMU 28-4 (Blackbird Mine). Largest of the mine sites in the BSG AOC, surface of the mine located 600 feet southeast of CYN-MW13. In 1943, the shaft was at least 50 feet deep with an 87-ft long horizontal adit to southeast at the 42-ft level. Mineralized fault trace trends southeast possibly on trend with SWMU 28-5, and northwest towards well CYN-MW13. • SWMU 28-5 (unnamed tailings pile), located approximately 1,100 ft southeast of well CYN-MW13. • SWMU 28-6 (Red Hill Prospect), located approximately 2,000 ft northwest of well CYN-MW13. • SWMU 28-8 (unnamed mine site), located approximately 1,600 ft northwest of well CYN-MW13.
WWII tests or maneuvers. Burn Site area was withdrawn in 1943, not much known about wartime activities.
Modern era KAFB maneuvers. War games, miscellaneous flares and smoke grenades are found occasionally.
Limestone quarry. Associated with the Tijeras Cement Plant, located 2.8 miles north of the Burn Site and along a major N-S trending fault. Quarry work started in the 1950s using ANFO.
Undocumented military training or disposal activities. KAFB has nearby Combat Training Zones and Withdrawn Areas for military activities.
Off-base domestic septic systems. Low-density home sites in the East Mountains are located more than 2.9 miles east of the Burn Site.
Animal manure from pre-1940 grazing. Historically, sheep and cattle grazing occurred in the Manzanita Mountains.
Blasting for about 200 bunkers in Manzano Base. Base is located far down gradient (4 miles) of the BSG AOC. It is unknown what types of explosives were used (ANFO, GSX, or dynamite?).
Fertilizer usage at the Tijeras Arroyo Golf Course. The Tijeras Arroyo Golf Course is located 6 miles west of BSG AOC.
Watering of golf course using KAFB sewage-lagoons water in warm weather. The Tijeras Arroyo Golf Course is located 6 miles west of BSG AOC. Lagoons vertical drainage in cool weather, about 8.5 miles northwest of well CYN-MW13. The lagoons were used from 1962 to 1987.
DOE firearms training facility. Firing range located approximately 1.6 miles west of BSG AOC. Use of nitrogen-bearing materials is unlikely.
Natural Sources in Area
Enhanced leaching of natural nitrate. Possible geologic nitrate in soil and alluvium could be remobilized during grading of undisturbed land (16.35 acres) during 1966 construction activities. Grading also increased the soil permeability and allowed dust-suppression water and precipitation to infiltrate more readily. Well-developed caliche horizons (possible reservoir of nitrate deposits) are visible in the steep arroyo bank south of SWMU 13.
Biological fixation. Nitrogen gas accumulated by biological processes followed by the decomposition of organic matter (cacti, grasses, shrubs, and trees).
Nitrogen fixation. Lightning strikes produce nitrate followed by deposition.
Nitrate-bearing shale. Naturally occurring nitrate maybe emanating from the olive-drab to dark gray organic shale units of the Pennsylvanian Sandia Formation. This formation outcrops throughout the eastern portion of the BSG AOC, but most outcrops are the conglomeratic sandstone units. Most of the interbedded organic shale units are in covered slopes with unknown thicknesses, but presumably only tens of feet thick.
Nitrate-bearing metamorphic rocks. Naturally occurring nitrate maybe emanating from Precambrian phyllite and schist.

Natural Sources in Area (concluded)
Nitrate-bearing fracture-filling precipitates. Similar to caliche, may produce confining layer in the bedrock.
Nitrate-bearing groundwater. Possible upwelling of groundwater along faults bringing in water from unknown regional sources. Numerous faults trend north to south across the study area.

Notes:

Deflagration Incidents and Spillage of ammonium nitrate (AN) slurry. At least 42,100 pounds of AN slurry deflagrated and spread over the Burn Site. Composition: 50% ammonium nitrate, 35% aluminum powder, 14% water, and 1% gums/stabilizers. Two events resulted in widespread scattering of material. Also, most likely had spillage while mixing the slurry. AN is very soluble in water. This “fertilizer” would not have been cleaned up because it’s infeasible to clean up the ‘mud’ of uncombusted material (Ammerman, D., *pers. comm*., May 2017). The area was probably hosed down. Possibly spread by rainfall and wastewater discharges. Also, two detonations with combined 19,100 pounds of AN slurry. Also, two incidents of apparently deflagration. One is discussed in Littrell (Feb 1969) and the other is discussed in the SWMU 65/94 CAC proposals.

Limestone quarry located 2.8 miles north of the Burn Site and along a major N-S trending fault. Quarry work started in the 1950s; quarried area now totals 370 acres, calculated by Grace Fong, CE2 Corp, in about 2015. [Typical quarry operations have much spillage [10-15%] of ANFO (ammonium nitrate fuel oil) and many misfires.] Typical: 94% AN and 6% fuel oil.

Weathering of explosives is probably not a significant source of potential nitrate, even if the explosive contains some relevant nitrogen compounds. Inferred from DuBois and Baytos (May 1991). The exposed high explosives were PETN, HMX, RDX, TNT, Octol, Cyclotol, Composition B-3 (Comp B-3), PBX9404, PBX9011, PBX9010, Boracitol, and Baratol. Abstract – “Twelve high-explosive materials were buried in soil and exposed to the elements to determine their rate of disappearance from the environment. Only those explosives that contained TNT, barium nitrate, and boric acid disappeared at an environmentally significant rate.” The amounts of Baratol, Boracitol, Comp B-3, Cyclotol, and Octol, which contains water-soluble components, decreased with time. RDX, HMX, and PETN changed very little. Estimates of half-lives were made from normalized UV chart data by applying the first-order reaction-rate equations. The HE was buried in an undisturbed part of the Los Alamos forest for twenty years.

AN = Ammonium nitrate.
ANFO = Ammonium nitrate fuel oil.
AOC = Area of Concern.
BSG = Burn Site Groundwater
C-4 = Composition 4.
CYN = Canyons (monitoring well designation only).
EOD = Explosive ordnance disposal.
ft = Foot (feet).
GSX = Gelled slurry explosive.
HE = High explosives.
HMX = High-velocity military explosive.
KAFB = Kirtland Air Force Base.
LANL = Los Alamos National Laboratories.
RDX = Research department explosive.
SNL/NM = Sandia National Laboratories, New Mexico.
SWMU = Solid Waste Management Unit.
USAF = U.S. Air Force.
VCM = Voluntary Corrective Measure.

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Appendix J

Land Use Controls for Remedial Alternatives at the Burn Site Groundwater Area of Concern

Land Use Controls for Remedial Alternatives at the Burn Site Groundwater Area of Concern

1. INTRODUCTION

The land use controls for the Burn Site Groundwater (BSG) Area of Concern (AOC) are designed to prohibit residential or unrestricted land use of property with unmitigated contamination that could cause potential harm to human health, and to protect onsite and offsite human receptors. The controls are implemented in an integrated and layered approach to enhance their effectiveness and reliability, and to provide continued protection in the event that one or more controls become temporarily impaired. The U.S. Department of Energy and National Technology & Engineering Solutions of Sandia LLC (DOE/NTESS) would work with Kirtland Air Force Base (KAFB)/United States Air Force (USFS), and the U.S. Forest Service (USFS) to implement and maintain land use controls to mitigate potential exposure to contaminated groundwater. Most of these controls are already in place, including maintaining the existing site access control. The BSG AOC Corrective Measures Implementation Plan will include a Land Use Controls Implementation Plan that would be amended if site conditions change during the duration of the selected remedy.

Administrative and physical controls for the BSG AOC include:

- Information management;
- Restrictions on future land use;
- Restrictions on groundwater use;
- Awareness;
- Limited access restrictions; and
- Installing physical control features.

Maintenance of control measures, including routine surveillance, will be conducted as necessary to prevent deterioration or failure of controls. The administrative and physical controls are described in Section 2. The scope and frequency of surveillance and maintenance measures are described in Section 3. Periodic reporting is summarized in Section 4.

2. INSTITUTIONAL CONTROLS

2.1 Administrative Controls

The BSG AOC contains groundwater with nitrate concentrations that exceed the U.S. EPA maximum contaminant level. DOE expects to retain stewardship of the site for the foreseeable future. Land use for the foreseeable future is industrial with SNL personnel conducting explosive and fire-survivability research using indoor and outdoor facilities within the BSG AOC. Plans for future activities by DOE/NTESS, KAFB/USAF, and USFS programs within one-half mile of the BSG AOC shall be evaluated to identify aspects that are not consistent with the land use controls. If land use changes occur at the BSG AOC, or transfer of the property from DOE control were to occur in the future, DOE/NTESS, KAFB/USAF, and USFS would reevaluate the protectiveness of the remedy.

2.2 Physical Controls

The BSG AOC is located within the fenced boundaries of KAFB. Public access to KAFB is restricted. SNL Safeguards and Security Protective Force personnel typically conduct daily inspections of the Burn Site vicinity. Additional physical controls implemented by SNL personnel will consist of continuing to post warning and information signs. Access restrictions are intended to prevent inadvertent exposure of contaminated groundwater to onsite workers, visitors, and unauthorized trespassers.

The signs shall include the following information:

- Burn Site Groundwater Area of Concern label;
- Site-specific instructions; and
- Contact information for further direction.

3. MAINTENANCE OF INSTITUTIONAL CONTROLS

3.1 Maintenance of Administrative Controls

Records and information for the BSG AOC are maintained in written and/or electronic form at SNL. The records are kept current and are updated when new information becomes available or is generated. The records include the following:

- Site location and characteristics;
- Site history and corrective action;
- Land use permits or agreements with KAFB;
- Documentation of current site conditions, including information from annual inspections;
- Type of controls;
- Maintenance records;
- Planning information, including restrictions on future activities at the site; and
- Copies of reports previously submitted to the NMED.

3.2 Maintenance of Physical Controls

On an annual schedule, the following items will be inspected and documented:

- Condition of the groundwater remedy infrastructure (wells, well pads, roads, signage, staging areas, and remediation equipment if installed);
- Evidence of erosion, seepage, or subsidence;
- Evidence of newly-occurring or newly-visible contamination;

- Evidence of government activities that are not consistent with restrictions in place; and
- Evidence of trespassing/residential activities that would necessitate additional awareness measures and access restrictions for the site.

The inspection results will be evaluated for necessary maintenance, including repair, replacement, or installation.

4. REPORTING REQUIREMENTS

A Land Use Controls Site Inspection Report will be prepared on an annual basis and incorporated into the BSG AOC Five-year Performance Reports during remedy implementation. The site inspection report will document the following:

- Site inspection results;
- Maintenance and repair activities required;
- Status of maintenance and repair activities; and
- Other conditions or events at the site that affect the performance of the controls.

The Five-year Performance Report shall be submitted to the NMED HWB. Findings from the site inspection reports will be summarized in the BSG AOC chapter of the Annual Groundwater Monitoring Reports.

APPENDIX K: Cost Estimate Worksheets

Appendix K-1: Cost Estimate Work Sheets for the Long-Term Monitoring Alternative

Appendix K-2: Cost Estimate Work Sheets for the Monitoring Natural Attenuation Alternative

Appendix K-3: Cost Estimate Work Sheets for the Groundwater Extraction, Treatment, and Reinjection Alternative

APPENDIX K-1
COST ESTIMATE WORK SHEETS FOR THE LONG-TERM MONITORING ALTERNATIVE

Long Term Monitoring - Cost Work Sheets	**Cost, Base Year 2022**	**Year(s) Activity Occurs**	**Present Value**
Corrective Measures Implementation Plan	$118,857	2026	$118,857
Corrective Measures Design for CMI Plan	$80,514	2026	$80,514
Contingency Plan for CMI Plan	$71,458	2026	$71,458
Depth to water measurements	$15,656	2027 through 2060	$532,304
Groundwater well sampling	$69,132	2027 through 2060	$2,350,488
Groundwater laboratory analysis and validation NPN	$798	2027 through 2061	$27,930
Groundwater analytical data handling	$2,548	2027 through 2061	$89,180
Purge water transport and disposal	$7,036	2027 through 2061	$246,260
Purge water lab analysis and validation	$48,818	2027 through 2061	1,708,630
Well redevelopment	$230,576	2042	$230,576
Five Year Performance Monitoring Report	$841,560	2032, 2037, 2042, 2047, 2052, 2057	$5,049,360
Corrective Measures Implementation Report	$265,800	2058	$265,800
Well plugging and abandonment	$100,548	2062	$100,548
Well plugging and abandonment Report	$105,745	2063	$105,745
Totals, Alternative 1: LTM	**not applicable**	**2026 through 2063**	**$10,977,650**

COST WORKSHEET

Corrective Measures Implementation Plan **Alternative 1 - LTM**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Prepare Corrective Measure Implementation Plan with Sampling and Analysis Plan and a Land Use Controls Plan. Preparation of the CMI Plan is a one-year effort.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Corrective Measures Implementation Plan							
Prepare Draft							internal draft
Project Manager	32	HR	$251.00			$8,032	
Senior Scientist/Engineer	8	HR	$227.00			$1,816	
Staff Scientist/Engineer	4	HR	$205.00			$820	
Field Technician	4	HR	$168.00			$672	
Graphics Technician	16	HR	$179.00			$2,864	
Technical Editor/ Word Processor	12	HR	$169.00			$2,028	
Analytical Data Administrator	8	HR	$168.00			$1,344	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							internal draft
Project Manager	16	HR	$251.00			$4,016	
Senior Scientist/Engineer	4	HR	$227.00			$908	
Staff Scientist/Engineer	2	HR	$205.00			$410	
Field Technician	2	HR	$168.00			$336	
Graphics Technician	8	HR	$179.00			$1,432	
Technical Editor/ Word Processor	12	HR	$169.00			$2,028	
Analytical Data Administrator	1	HR	$168.00			$168	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final for submittal to regulatory agencies.
Project Manager	16	HR	$251.00			$4,016	
Senior Scientist/Engineer	4	HR	$227.00			$908	
Staff Scientist/Engineer	2	HR	$205.00			$410	
Field Technician	1	HR	$168.00			$168	
Graphics Technician	4	HR	$179.00			$716	
Technical Editor/ Word Processor	12	HR	$169.00			$2,028	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$500	$500	

SUBTOTAL					**$35,660**	

Sampling and Analysis Plan

Prepare Draft						internal draft
Project Manager	40	HR	$251.00		$10,040	
Senior Scientist/Engineer	40	HR	$227.00		$9,080	
Staff Scientist/Engineer	8	HR	$205.00		$1,640	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	32	HR	$179.00		$5,728	
Technical Editor/ Word Processor	24	HR	$169.00		$4,056	
Analytical Data Administrator	8	HR	$168.00		$1,344	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Draft Final						internal draft
Project Manager	8	HR	$251.00		$2,008	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	16	HR	$179.00		$2,864	
Technical Editor/ Word Processor	12	HR	$169.00		$2,028	
Analytical Data Administrator	4	HR	$168.00		$672	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Final						Final will be Appendix in CMI Plan.
Project Manager	8	HR	$169.00		$1,352	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	2	HR	$205.00		$410	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	8	HR	$179.00		$1,432	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	1	HR	$168.00		$168	
Production Supplies/Distribution costs	1	LS		$20	$20	
SUBTOTAL					**$48,686**	

Land Use Controls Plan

Prepare Draft						internal draft
Project Manager	12	HR	$251.00		$3,012	
Senior Scientist/Engineer	40	HR	$227.00		$9,080	
Staff Scientist/Engineer	8	HR	$205.00		$1,640	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	16	HR	$179.00		$2,864	
Technical Editor/ Word Processor	16	HR	$169.00		$2,704	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Draft Final						internal draft
Project Manager	6	HR	$251.00		$1,506	
Senior Scientist/Engineer	20	HR	$227.00		$4,540	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	8	HR	$179.00		$1,432	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Final						Final will be Appendix in CMI Plan.
Project Manager	3	HR	$251.00		$753	
Senior Scientist/Engineer	10	HR	$227.00		$2,270	
Staff Scientist/Engineer	2	HR	$205.00		$410	
Field Technician	0	4	$168.00		$0	
Graphics Technician	4	HR	$179.00		$716	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
SUBTOTAL					**$34,511**	
CMI Plan TOTAL COST					**$118,857**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

COST WORKSHEET

Corrective Measures Design for CMI Plan Alternative 1 - LTM

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base year: 2022

Work Statement:

Prepare Corrective Measure Design in support of CMI Plan. Includes O&M plan, Waste Management Plan, and the internal and Health and Safety Plan. No construction Design Plans/Specifications/associated construction schedule or Construction Quality Assurance Plan, are necessary. NEPA Checklist listed below.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Operation and Maintenance Plan							Prepare strategy for mini-SAPs and bottle orders.
Prepare Draft							Internal draft
Project Manager	24	HR	$251.00			$6,024	
Senior Scientist/Engineer	8	HR	$227.00			$1,816	
Staff Scientist/Engineer	4	HR	$205.00			$820	
Field Technician	4	HR	$168.00			$672	
Graphics Technician	8	HR	$179.00			$1,432	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	8	HR	$168.00			$1,344	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							Internal draft
Project Manager	8	HR	$251.00			$2,008	
Senior Scientist/Engineer	4	HR	$227.00			$908	
Staff Scientist/Engineer	2	HR	$205.00			$410	
Field Technician	2	HR	$168.00			$336	
Graphics Technician	4	HR	$179.00			$716	
Technical Editor/ Word Processor	8	HR	$169.00			$1,352	
Analytical Data Administrator	2	HR	$168.00			$336	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final will be an Appendix to the CMI Plan.
Project Manager	8	HR	$251.00			$2,008	
Senior Scientist/Engineer	2	HR	$227.00			$454	
Staff Scientist/Engineer	1	HR	$205.00			$205	
Field Technician	1	HR	$168.00			$168	
Graphics Technician	2	HR	$179.00			$358	
Technical Editor/ Word Processor	8	HR	$169.00			$1,352	
Analytical Data Administrator	0	HR	$168.00			$0	

Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL Operation and Maintenance Plan					**$25,963**	
Waste Management Plan						
Prepare Draft						
Project Manager	4	HR	$251.00		$1,004	Internal draft.
Senior Scientist/Engineer	16	HR	$227.00		$3,632	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	4	HR	$168.00		$672	
Graphics Technician	4	HR	$179.00		$716	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	4	HR	$168.00		$672	
Production Supplies/Distribution costs	0	LS		$20	$20	
Prepare Draft Final						Internal draft.
Project Manager	2	HR	$251.00		$502	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	2	HR	$179.00		$358	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	0	LS		$20	$20	
Prepare Final						Final will be an Appendix to the CMI Plan.
Project Manager	2	HR	$251.00		$502	
Senior Scientist/Engineer	2	HR	$227.00		$454	
Staff Scientist/Engineer	0	HR	$205.00		$0	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	0	HR	$179.00		$0	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$100	$100	
SUBTOTAL WMP					**$16,164**	
Health and Safety Plan						
Prepare Draft						Internal draft. Not submitted to regulators.
Project Manager	8	HR	$251.00		$2,008	
Senior Scientist/Engineer	24	HR	$227.00		$5,448	
Staff Scientist/Engineer	8	HR	$205.00		$1,640	
Field Technician	4	HR	$168.00		$672	
Graphics Technician	4	HR	$179.00		$716	

Technical Editor/ Word Processor	8		$169.00		$1,352	
Analytical Data Administrator	4	HR	$168.00		$672	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Draft Final						Internal draft. Not submitted to regulators.
Project Manager	4	HR	$251.00		$1,004	
Senior Scientist/Engineer	12	HR	$227.00		$2,724	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	2	HR	$168.00		$336	
Graphics Technician	2	HR	$179.00		$358	
Technical Editor/ Word Processor	4	HR	$169.00		$676	
Analytical Data Administrator	0		$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Final						Internal draft for review and approval. Not submitted to regulators.
Project Manager	2	HR	$251.00		$502	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	2	HR	$205.00		$410	
Field Technician	1	HR	$168.00		$168	
Graphics Technician	1	HR	$179.00		$179	
Technical Editor/ Word Processor	4	HR	$169.00		$676	
Analytical Data Administrator	0		$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
SUBTOTAL Health and Safety Plan					**$22,237**	
NEPA Checklist						Submit internal National Environmental Protection Act (NEPA) Checklist to DOE SFO. May require multiple cycles for approval. Not submitted to regulators.
Project Manager	40	HR	$251.00		$10,040	
Senior Scientist/Engineer	10	HR	$227.00		$2,270	
Staff Scientist/Engineer	10	HR	$205.00		$2,050	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	10	HR	$179.00		$1,790	Field GPS work and prepare figures.
Technical Editor/ Word Processor	0	HR	$169.00		$0	
Analytical Data Administrator	0	HR	$168.00		$0	
SUBTOTAL NEPA					**$16,150**	
CORRECTIVE MEASURES DESIGN TOTAL COST					**$80,514**	

Source of Cost Data:

Based on estimated level of effort for onsite staff to produce documents.

COST WORKSHEET

Contingency Plan for CMI Plan **Alternative 1 - LTM**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Prepare Contingency Plan to be submitted along with Corrective Measures Implementation Plan.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							internal draft
Project Manager	80	HR	$251.00			$20,080	
Senior Scientist/Engineer	24	HR	$227.00			$5,448	
Staff Scientist/Engineer	40	HR	$205.00			$8,200	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	16	HR	$179.00			$2,864	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							internal draft
Project Manager	40	HR	$251.00			$10,040	
Senior Scientist/Engineer	12	HR	$227.00			$2,724	
Staff Scientist/Engineer	20	HR	$205.00			$4,100	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	8	HR	$179.00			$1,432	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final will be an Appendix to the CMI Plan
Project Manager	20	HR	$251.00			$5,020	
Senior Scientist/Engineer	6	HR	$227.00			$1,362	
Staff Scientist/Engineer	4	HR	$205.00			$820	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	4	HR	$179.00			$716	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$500	$500	
TOTAL COST						**$71,458**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report. Estimated hours from TAG project.

COST WORKSHEET

Depth to water measurements Alternative 1 - LTM

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Depth-to-water measurement for 14 monitoring wells for 4 quarters in one year. Includes submittal of field data, QC, and database entry. Health and safety protection is Level D. Assume one day of field work per event.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	2	HR	$227.00			$454	Data QA.
Staff Scientist/Engineer	0	HR	$205.00			$0	
Field Technician	18	HR	$168.00			$3,024	DTW measurement at 14 monitoring wells including transportation to/from Burn Site from field office. Two technicians working together at remote site. 9-hour
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	2	HR	$168.00			$336	Data entry.
GSA pickup truck	1					$100	Assumed day charge.
Subtotal						$3,914	
Four events per year	4						four quarterly events per year
TOTAL COST						**$15,656**	

Source of Cost Data:

Practical knowledge from SNL projects.

COST WORKSHEET

Groundwater well sampling **Alternative 1 - LTM**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Groundwater sample collection from one monitoring well. Assumes well is sampled using a portable Bennett pump. Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	2	HR	$227.00			$454	Coordination of sampling task.
Staff Scientist/Engineer	2	HR	$205.00			$410	Coordination of sampling task.
Field Technician	18	HR	$168.00			$3,024	Groundwater sample collection requires a nine-hour workday for two technicians per well. Sample collection using portable pump system at a remote location. Includes equipment calibration and decontamination. Includes sample handling and delivery to SNL sample management office.
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	2	HR	$168.00			$336	
COST						**$4,224**	
Consumable Costs:	1	EA			$500.00	$500	Sample containers, ice packs, DI water, calibration fluids for field instruments.
Vehicles	1			$214.00		$214	Two vehicles: sampling van and pickup truck (4x4 with Tommy gate). Prorated $3,000 / 14 wells.
TOTAL COST						**$4,938**	

Source of Cost Data:

Practical knowledge from SNL projects.

COST WORKSHEET

Groundwater laboratory analysis and validation NPN — Alternative 1 - LTM

Site: Burn Site Groundwater Area of Concern — **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico — **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Analytical costs for one suite of groundwater sample analysis, and independent third party validation from one groundwater monitoring well for purposes of monitoring COC (Nitrate). GEL actual lab costs for August 2022. Quantity of 1.2 accounts for 20% QC samples (duplicates, equipment decontamination, etc.) samples.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - NPN as nitrogen	1.2	EA			$15.81	$19	Standard turn around time: EPA Method 353.2.
Level IV validation - NPN as nitrogen	1	EA			$23.72	$24	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Shipping	1	EA			$5.00	$5	FedEx overnight shipping charge per sample (prorated from shipping a cooler)
Subtotal off-site services costs						$48	
Subtotal equipment/supply costs + operational overhead						**$57**	
TOTAL COST						**$57**	

Source of Cost Data:

Analytical costs per analysis based on typical unit pricing in effect for Base Year 2022. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.). Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases.

COST WORKSHEET

Groundwater analytical data handling **Alternative 1 - LTM**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Receive and verify laboratory Electronic Data Deliverables (EDDs) analytical report. Upload validated data to database for one sampling event.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	4	HR	$227.00			$908	
Staff Scientist/Engineer	8	HR	$205.00			$1,640	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	8	HR	$168.00			$1,344	
TOTAL COST						**$2,548**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff for one sampling event (8 wells).

COST WORKSHEET

Purge water transport and disposal Alternative 1 - MNA

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Disposal of 55-gallon drums of purge water generated while sampling or redeveloping a monitoring well. Wastewater is transported from Burn Site to ERFO storage yard. After analytical results are reviewed, the drums are discharged to a sanitary sewer access point at ERFO. Disposed of using the 2022 POTW requirements. Health and safety protection is Level D. Assume three drums per monitoring well per event.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	0	HR	$227.00			$0	
Staff Scientist/Engineer	4	HR	$205.00			$820	Reviews analytical data. Prepares memorandum.
Field Technician	36	HR	$168.00			$6,048	Two technicians for 9 hours each to pick up and transport drums from Burn Site to ERFO. Includes completing related documentation. Drums moved later to nearby sewer manhole; two technicians for one day.
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	1	HR	$168.00			$168	
TOTAL COST						**$7,036**	

Source of Cost Data:

Based on current onsite contractor staff typical level of effort for similar onsite operations.

COST WORKSHEET

## Purge water lab analysis and validation		Alternative 1 - LTM

Site: Burn Site Groundwater Area of Concern		**Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico		**Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Analytical costs for one suite of groundwater sample analyses to ensure compliance with requirements for discharge of purge water to the POTW.   Third-party validation is required.   Samples are collected from the sampling manifold in the ERFO sampling van while collecting environmental samples. Laboratory standard TAT (turn around time) is 30 days. Analytical results from each sampled well are used for POTW compliance purposes.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - VOCs	1.2	EA			128.06	$154	Standard TAT: SW846-8260D
Level IV validation - VOCs	1	EA			192.09	$192	Third-party validation. 100% of all analyses
Lab analysis - Unfiltered TAL Metals plus Uranium	1.2	EA			201.31	$242	Standard TAT: SW846-6020B/7470A
Level IV validation - TAL Metals incl. Uranium	1	EA			301.97	$302	Third-party validation. 100% of all analyses
Lab analysis - Gamma spec (short list: Am241, Cs137, Co60, K40)	1.2	EA			93.81	$113	Standard TAT: EPA Method 901.1
Level IV validation - Gamma spec (short list)	1	EA			140.72	$141	Third-party validation. 100% of all analyses
Lab analysis - Gross Alpha/Beta	1.2	EA			68.52	$82	Standard TAT: EPA 900.0
Level IV validation - Gross Alpha/Beta	1	EA			102.78	$103	Third-party validation. 100% of all analyses
Lab analysis - Tritium	1.2	EA			55.34	$66	Standard TAT: EPA Method 906.0M
Level IV validation - Tritium	1	EA			83.01	$83	Third-party validation. 100% of all analyses
Lab analysis - Isotopic Uranium	1.2	EA			132.28	$159	Standard TAT: HASL 300
Level IV validation - Isotopic Uranium	1	EA			198.42	$198	Third-party validation. 100% of all analyses
Lab analysis - Alkalinity	1.2	EA			36.36	$44	Standard TAT: SM2320B
Level IV validation - Alkalinity	1	EA			54.54	$55	Third-party validation. 100% of all analyses
Lab analysis - Anions (Bromide, Chloride, Fluoride, Sulfate)	1.2	EA			80.12	$96	Standard TAT: SW846-9056A
Level IV validation - Anions (Bromide, Chloride, Fluoride, Sulfate)	1	EA			120.18	$120	Third-party validation. 100% of all analyses
Lab analysis - TPH Diesel Range Organics	1.2	EA			67.98	$82	Standard TAT: EPA Method 8015D
Level IV validation - TPH Diesel Range Organics	1	EA			101.97	$102	Third-party validation. 100% of all analyses
Lab analysis - TPH Gasoline Range Organics	1.2	EA			52.17	$63	Standard TAT: EPA Method 8015A/B
Level IV validation - TPH Gasoline Range Organics	1	EA			78.26	$78	Third-party validation. 100% of all analyses

Lab analysis - High Explosive compounds	1.2	EA	160.21	$192	Standard TAT: EPA Method 8330B
Level IV validation - High Explosive compounds	1	EA	240.32	$240	Third-party validation. 100% of all analyses
Subtotal off-site services costs				$2,906	
Escalation from quotation to Base Year	1.00				
Subtotal off-site services costs with escalation				$2,906	
Subtotal equipment/supply costs + operational overhead	1.20			$3,487	
TOTAL COST				**$3,487**	

Source of Cost Data:

Analytical costs per analysis are based on GEL typical unit pricing in effect for Base Year 2022. The validation costs are estimated as actual costs and are formula based and affected by laboratory quality control data, batching, project specific requirements, etc. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.). Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases.

COST WORKSHEET

Well redevelopment Alternative 1 - LTM

Site: Burn Site Groundwater Area of Concern
Prepared by: Dept. 8888
Location: Sandia National Laboratories/New Mexico
Date: November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Drilling Company redevelops each of the 14 proposed sampling monitoring wells once (assumes redevelopment is done once per well at the half-way point of the 30-year remedy implementation). Well is surged and bailed, then pumped to obtain parameter stabilization. Health and safety protection is Level D. Fractured bedrock aquifer. Assume one day per well (setup, develop, containerize water) by the drilling company.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Subcontractor costs							
Mobe/demobe	1	EA				$6,785	Mobe/demobe to Burn Site
Well Development	140	HR	$345.00			$48,300	14 ten-hour days. Performed by drilling company using pump truck rig.
Subtotal contractor costs						$55,085	
Subtotal subcontractor costs + operational overhead	1.20					**$66,102**	Multiplier applied to outside contractors.
Contractor labor costs							
Staff Scientist/Engineer	162	HR	$205.00			$33,210	Coordination, oversight, and documentation. 4 office days plus 14 9-hour field days.
Contractor labor costs						**$33,210**	
Purge water analyses and validation	14	EVENT			$6,148	**$86,072**	Lab, validation, and data handling cost from other spreadsheet. POTW analytes plus
Purge water transport and disposal	14	EVENT			$3,228	**$45,192**	Labor for one event from other spreadsheet. 14 wells.
TOTAL COST						**$230,576**	

Source of Cost Data:

Hourly drilling company rate for well development based on Yellow Jacket quote (25 August 2021 for TA-V) adjusted to base year 2022.
Level of effort based on site-specific past experience. Operational overhead multiplier of 1.20 applied to subcontractor cost line items.

COST WORKSHEET

Five Year Performance Monitoring Report Alternative 1 - LTM

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

The five year performance monitoring report is a progress report with several elements: 1) description of work completed during the reporting period, 2) summary of all problems, potential problems, or delays encountered during the reporting period, 3) description of actions taken to eliminate or mitigate problems, potential problems, or delays, 4) discussion of work projected for next reporting period, including sampling, and 5) copies of results from monitoring, including sampling/analysis, and other data generated during the reporting period. Includes potentiometric-surface contour maps and isoconcentration maps. The report will be submitted to the NMED HWB.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Internal draft
Project Manager	120	HR	$251.00			$30,120	
Senior Scientist/Engineer	80	HR	$227.00			$18,160	Prepare text and review of figures, graphs, and appendices.
Staff Scientist/Engineer	40	HR	$205.00			$8,200	Draft figures. Update water level and concentration trend graphs.
Field Technician	40	HR	$168.00			$6,720	Assemble field data form appendices and files.
Graphics Technician	40	HR	$179.00			$7,160	Up to ten figures at four hours each. Mostly updating of AGMR figures.
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	40	HR	$168.00			$6,720	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							Internal draft
Project Manager	40	HR	$251.00			$10,040	
Senior Scientist/Engineer	20	HR	$227.00			$4,540	
Staff Scientist/Engineer	10	HR	$205.00			$2,050	
Field Technician	20	HR	$168.00			$3,360	
Graphics Technician	20	HR	$179.00			$3,580	
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	8	HR	$168.00			$1,344	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final for submittal to NMED HWB
Project Manager	32	HR	$251.00			$8,032	
Senior Scientist/Engineer	16	HR	$227.00			$3,632	
Staff Scientist/Engineer	8	HR	$205.00			$1,640	
Field Technician	10	HR	$168.00			$1,680	
Graphics Technician	10	HR	$179.00			$1,790	
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	4	HR	$168.00			$672	

Production Supplies/Distribution costs	1	LS	$500	$500
TOTAL COST				**$140,260**

Source of Cost Data:

Based on estimated level of estimate for onsite contractor staff to produce report.

COST WORKSHEET

Corrective Measures Implementation Report **Alternative 1 - LTM**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Prepare Corrective Measure Implementation Report: Includes 1) summary of work completed during implementation of the remedy. Also includes a request for Certificate of Corrective Action Complete from NMED HWB. CMI Report summarizes the Five Year Performance Monitoring Reports. A request for plugging and abandoning wells will be included.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Internal draft
Project Manager	160	HR	$251.00			$40,160	
Sr. Geologist/Engineer/Scientist	160	HR	$227.00			$36,320	
Staff Geologist/Engineer/Scientist	160	HR	$205.00			$32,800	
Technician	0	HR	$168.00			$0	
Graphics	80	HR	$179.00			$14,320	
Technical Editor/Production	80	HR	$169.00			$13,520	
Analytical Data Administrator	40	HR	$168.00			$6,720	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							Internal draft
Project Manager	80	HR	$251.00			$20,080	
Sr. Geologist/Engineer/Scientist	80	HR	$227.00			$18,160	
Staff Geologist/Engineer/Scientist	80	HR	$205.00			$16,400	
Technician	0	HR	$168.00			$0	
Graphics	40	HR	$179.00			$7,160	
Technical Editor/Production	80	HR	$169.00			$13,520	
Analytical Data Administrator	10	HR	$168.00			$1,680	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final for submittal to NMED HWB
Project Manager	40	HR	$251.00			$10,040	
Sr. Geologist/Engineer/Scientist	40	HR	$227.00			$9,080	
Staff Geologist/Engineer/Scientist	40	HR	$205.00			$8,200	
Technician	0	HR	$168.00			$0	
Graphics	20	HR	$179.00			$3,580	
Technical Editor/Production	80	HR	$169.00			$13,520	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$500	$500	
TOTAL COST						**$265,800**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report. Used projected TAG hours.

COST WORKSHEET

Well plugging and abandonment Alternative 1 - LTM

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 2, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Plug and abandon (P&A) fourteen 5-in diameter PVC monitoring wells. Remove wellhead completions. Install monuments. Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Subcontractor costs								
Mobe/Demobe	1	EA				$6,785	$6,785	Mobe/demode to Burn Site.
Well pad demolition	14	EA				$500	$7,000	Demolish well pad and bollards.
Grout well to ground surface	3,537	FT				$9	$31,833	Sum of total depths for the 14 monitor wells.
Concrete monument	14	EA				$800	$11,200	Placed at location of abandoned well.
Subtotal contractor costs							$56,818	
Subtotal subcontractor costs + operational overhead	1.20						**$68,182**	Multiplier applied to outside contractors.
Contractor labor costs								
Project Manager	2	HR	251.00			$502	$502	
Senior Scientist/Engineer	8	HR	227.00			$1,816	$1,816	
Staff Scientist/Engineer	140	HR	205.00			$28,700	$28,700	14 days with 10 hour shift
Field Technician	4	HR	168.00			$672	$672	Onsite handling/disposal of IDW water under site-wide POTW permit.
Graphics Technician	0	HR	179.00			$0	$0	
Technical Editor/ Word Processor	4	HR	169.00			$676	$676	
Analytical Data Administrator	0	HR	168.00			$0	$0	
Production Supplies/Distribution costs	0	EA	0.00			$0	$0	
Subtotal contractor labor costs							$32,366	
TOTAL COST							**$100,548**	

Source of Cost Data:

Hourly drilling company rate for well decommissioning based on Yellow Jacket quote (25 August 2021 for TA-V) adjusted for inflation to base year 2022. Level of effort based on site-specific past experience. Operational overhead multiplier of 1.20 applied to outside contractor cost line items based on funding under Long-Term Stewardship (LTS).

COST WORKSHEET

Well plugging and abandonment report **Alternative 1 - LTM**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Prepare well Plugging and Abandonment Report. Includes summary of work completed and field forms. Includes forms submittal to NMOSE.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							internal draft
Project Manager	20	HR	$251.00			$5,020	
Sr. Geologist/Engineer/Scientist	160	HR	$227.00			$36,320	
Staff Geologist/Engineer/Scientist	20	HR	$205.00			$4,100	
Technician	0	HR	$168.00			$0	
Graphics	20	HR	$179.00			$3,580	
Technical Editor/Production	80	HR	$169.00			$13,520	
Production Supplies/Distribution costs	1	LS				$0	
Prepare Draft Final							internal draft
Project Manager	10	HR	$251.00			$2,510	
Sr. Geologist/Engineer/Scientist	60	HR	$227.00			$13,620	
Staff Geologist/Engineer/Scientist	10	HR	$205.00			$2,050	
Technician	0	HR	$168.00			$0	
Graphics	10	HR	$179.00			$1,790	
Technical Editor/Production	40	HR	$169.00			$6,760	
Production Supplies/Distribution costs	1	LS				$0	
Prepare Final							Final report version for submittal to NMED HWB. Forms to NMOSE.
Project Manager	5	HR	$251.00			$1,255	
Sr. Geologist/Engineer/Scientist	20	HR	$227.00			$4,540	
Staff Geologist/Engineer/Scientist	5	HR	$205.00			$1,025	
Technician	0	HR	$168.00			$0	
Graphics	5	HR	$179.00			$895	
Technical Editor/Production	40	HR	$169.00			$6,760	
Production Supplies/Distribution costs	1	LS			$2,000	$2,000	
TOTAL COST						**$105,745**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

APPENDIX K-2
COST ESTIMATE WORK SHEETS FOR THE MONITORED NATURAL ATTENUATION ALTERNATIVE

Monitored Natural Attenuation - Cost Work Sheets	Cost, Base Year 2022	Year(s) Activity Occurs	Present Value
Corrective Measures Implementation Plan	$118,857	2026	$118,857
Corrective Measures Design for CMI Plan	$80,514	2026	$80,514
Contingency Plan for CMI Plan	$71,458	2026	$71,458
Depth to water measurements	$15,656	2027 through 2060	$532,304
Groundwater well sampling	$39,504	2027 through 2060	$1,343,136
Groundwater laboratory analysis and validation NPN	$456	2027 through 2060	$15,960
Groundwater laboratory analysis and validation MNA List	$9,944	2027 through 2061	$348,040
Groundwater analytical data handling	$2,548	2027 through 2061	$89,180
Purge water transport and disposal	$7,036	2027 through 2061	$246,260
Purge water laboratory analysis and validation	$27,896	2027 through 2061	$976,360
Well redevelopment	$138,410	2042	$138,410
Five Year Performance Monitoring Report	$541,560	2032, 2037, 2042, 2047, 2052, 2057	$3,249,360
Corrective Measures Implementation Report	$267,480	2058	$267,480
Well plugging and abandonment	$100,548	2062	$100,548
Well plugging and abandonment report	$105,745	2063	$105,745
Totals, for Alternative 2: MNA	**Not applicable**	**2026 through 2063**	**$7,683,612**

COST WORKSHEET

Corrective Measures Implementation Plan Alternative 2 - MNA

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Prepare Corrective Measure Implementation Plan with Sampling and Analysis Plan and a Land Use Controls Plan. Preparation of the CMI Plan is a one-year effort. Community Relations Plan is not listed below because SNL already submits an updated version to NMED annually.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Corrective Measures Implementation Plan							
Prepare Draft							internal draft
Project Manager	32	HR	$251.00			$8,032	
Senior Scientist/Engineer	8	HR	$227.00			$1,816	
Staff Scientist/Engineer	4	HR	$205.00			$820	
Field Technician	4	HR	$168.00			$672	
Graphics Technician	16	HR	$179.00			$2,864	
Technical Editor/ Word Processor	12	HR	$169.00			$2,028	
Analytical Data Administrator	8	HR	$168.00			$1,344	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							internal draft
Project Manager	16	HR	$251.00			$4,016	
Senior Scientist/Engineer	4	HR	$227.00			$908	
Staff Scientist/Engineer	2	HR	$205.00			$410	
Field Technician	2	HR	$168.00			$336	
Graphics Technician	8	HR	$179.00			$1,432	
Technical Editor/ Word Processor	12	HR	$169.00			$2,028	
Analytical Data Administrator	1	HR	$168.00			$168	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final for submittal to regulatory agencies.
Project Manager	16	HR	$251.00			$4,016	
Senior Scientist/Engineer	4	HR	$227.00			$908	
Staff Scientist/Engineer	2	HR	$205.00			$410	
Field Technician	1	HR	$168.00			$168	
Graphics Technician	4	HR	$179.00			$716	
Technical Editor/ Word Processor	12	HR	$169.00			$2,028	
Analytical Data Administrator	0	HR	$168.00			$0	

Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL					**$35,660**	
Sampling and Analysis Plan						
Prepare Draft						internal draft
Project Manager	40	HR	$251.00		$10,040	
Senior Scientist/Engineer	40	HR	$227.00		$9,080	
Staff Scientist/Engineer	8	HR	$205.00		$1,640	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	32	HR	$179.00		$5,728	
Technical Editor/ Word Processor	24	HR	$169.00		$4,056	
Analytical Data Administrator	8	HR	$168.00		$1,344	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Draft Final						internal draft
Project Manager	8	HR	$251.00		$2,008	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	16	HR	$179.00		$2,864	
Technical Editor/ Word Processor	12	HR	$169.00		$2,028	
Analytical Data Administrator	4	HR	$168.00		$672	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Final						Final will be an Appendix in the CMI Plan.
Project Manager	8	HR	$169.00		$1,352	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	2	HR	$205.00		$410	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	8	HR	$179.00		$1,432	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	1	HR	$168.00		$168	
Production Supplies/Distribution costs	1	LS		$20	$20	
SUBTOTAL					**$48,686**	

Land Use Controls Plan						
Prepare Draft						internal draft
Project Manager	12	HR	$251.00		$3,012	
Senior Scientist/Engineer	40	HR	$227.00		$9,080	
Staff Scientist/Engineer	8	HR	$205.00		$1,640	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	16	HR	$179.00		$2,864	
Technical Editor/ Word Processor	16	HR	$169.00		$2,704	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Draft Final						internal draft
Project Manager	6	HR	$251.00		$1,506	
Senior Scientist/Engineer	20	HR	$227.00		$4,540	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	8	HR	$179.00		$1,432	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Final						Final will be an Appendix in the CMI Plan.
Project Manager	3	HR	$251.00		$753	
Senior Scientist/Engineer	10	HR	$227.00		$2,270	
Staff Scientist/Engineer	2	HR	$205.00		$410	
Field Technician	0	4	$168.00		$0	
Graphics Technician	4	HR	$179.00		$716	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
SUBTOTAL					**$34,511**	
CMI PLAN TOTAL COST					**$118,857**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

COST WORKSHEET

Corrective Measures Design for CMI Plan Alternative 2 - MNA

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Prepare Corrective Measure Design in support of CMI Plan. Includes O&M plan, Waste Management Plan, and the internal and Health and Safety Plan. No Design Plans/Specifications/associated construction schedule or Construction Quality Assurance Plan, are necessary. Includes NEPA Checklist.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Operation and Maintenance Plan							Prepare strategy for mini-SAPs and bottle orders.
Prepare Draft							Internal draft
Project Manager	24	HR	$251.00			$6,024	
Senior Scientist/Engineer	8	HR	$227.00			$1,816	
Staff Scientist/Engineer	4	HR	$205.00			$820	
Field Technician	4	HR	$168.00			$672	
Graphics Technician	8	HR	$179.00			$1,432	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	8	HR	$168.00			$1,344	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							Internal draft
Project Manager	8	HR	$251.00			$2,008	
Senior Scientist/Engineer	4	HR	$227.00			$908	
Staff Scientist/Engineer	2	HR	$205.00			$410	
Field Technician	2	HR	$168.00			$336	
Graphics Technician	4	HR	$179.00			$716	
Technical Editor/ Word Processor	8	HR	$169.00			$1,352	
Analytical Data Administrator	2	HR	$168.00			$336	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final will be an Appendix to the CMI Plan.
Project Manager	8	HR	$251.00			$2,008	
Senior Scientist/Engineer	2	HR	$227.00			$454	
Staff Scientist/Engineer	1	HR	$205.00			$205	
Field Technician	1	HR	$168.00			$168	
Graphics Technician	2	HR	$179.00			$358	
Technical Editor/ Word Processor	8	HR	$169.00			$1,352	
Analytical Data Administrator	0	HR	$168.00			$0	

Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL Operation and Maintenance Plan					**$25,963**	

Waste Management Plan

Prepare Draft						
Project Manager	4	HR	$251.00		$1,004	Internal draft.
Senior Scientist/Engineer	16	HR	$227.00		$3,632	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	4	HR	$168.00		$672	
Graphics Technician	4	HR	$179.00		$716	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	4	HR	$168.00		$672	
Production Supplies/Distribution costs	0	LS		$20	$20	
Prepare Draft Final						Internal draft.
Project Manager	2	HR	$251.00		$502	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	2	HR	$179.00		$358	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	0	LS		$20	$20	
Prepare Final						Final will be an Appendix to the CMI Plan.
Project Manager	2	HR	$251.00		$502	
Senior Scientist/Engineer	2	HR	$227.00		$454	
Staff Scientist/Engineer	0	HR	$205.00		$0	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	0	HR	$179.00		$0	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$100	$100	
SUBTOTAL Schedule WMP					**$16,164**	

Health and Safety Plan

Prepare Draft						Internal draft. Not submitted to regulators.
Project Manager	8	HR	$251.00		$2,008	
Senior Scientist/Engineer	24	HR	$227.00		$5,448	
Staff Scientist/Engineer	8	HR	$205.00		$1,640	
Field Technician	4	HR	$168.00		$672	
Graphics Technician	4	HR	$179.00		$716	

Technical Editor/ Word Processor	8		$169.00		$1,352	
Analytical Data Administrator	4	HR	$168.00		$672	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Draft Final						Internal draft. Not submitted to regulators.
Project Manager	4	HR	$251.00		$1,004	
Senior Scientist/Engineer	12	HR	$227.00		$2,724	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	2	HR	$168.00		$336	
Graphics Technician	2	HR	$179.00		$358	
Technical Editor/ Word Processor	4	HR	$169.00		$676	
Analytical Data Administrator	0		$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Final						Internal draft for review and approval. Not submitted to regulators.
Project Manager	2	HR	$251.00		$502	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	2	HR	$205.00		$410	
Field Technician	1	HR	$168.00		$168	
Graphics Technician	1	HR	$179.00		$179	
Technical Editor/ Word Processor	4	HR	$169.00		$676	
Analytical Data Administrator	0		$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
SUBTOTAL Health and Safety Plan					**$22,237**	
NEPA Checklist						Submit internal National Environmental Protection Act (NEPA) Checklist to DOE SFO. May require multiple cycles for approval. Not submitted to regulators.
Project Manager	40	HR	$251.00		$10,040	
Senior Scientist/Engineer	10	HR	$227.00		$2,270	
Staff Scientist/Engineer	10	HR	$205.00		$2,050	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	10	HR	$179.00		$1,790	Field GPS work and prepare figures.
Technical Editor/ Word Processor	0	HR	$169.00		$0	
Analytical Data Administrator	0	HR	$168.00		$0	
SUBTOTAL NEPA					**$16,150**	
CORRECTIVE MEASURE DESIGN TOTAL COST					**$80,514**	

Source of Cost Data:

Based on estimated level of effort for onsite staff to produce documents.

COST WORKSHEET

Contingency Plan for CMI Plan Alternative 2 - MNA

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Prepare Contingency Plan to be submitted along with Corrective Measures Implementation Plan.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							internal draft
Project Manager	80	HR	$251.00			$20,080	
Senior Scientist/Engineer	24	HR	$227.00			$5,448	
Staff Scientist/Engineer	40	HR	$205.00			$8,200	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	16	HR	$179.00			$2,864	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							internal draft
Project Manager	40	HR	$251.00			$10,040	
Senior Scientist/Engineer	12	HR	$227.00			$2,724	
Staff Scientist/Engineer	20	HR	$205.00			$4,100	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	8	HR	$179.00			$1,432	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final will be an Appendix to the CMI Plan.
Project Manager	20	HR	$251.00			$5,020	
Senior Scientist/Engineer	6	HR	$227.00			$1,362	
Staff Scientist/Engineer	4	HR	$205.00			$820	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	4	HR	$179.00			$716	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$500	$500	
TOTAL COST						**$71,458**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

COST WORKSHEET

Depth to water measurements Alternative 2 - MNA

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Depth-to-water measurement for 14 monitoring wells. Includes submittal of field data, QC, and database entry. Health and safety protection is Level D. Assume one day of field work.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	2	HR	$227.00			$454	Data QA.
Staff Scientist/Engineer	0	HR	$205.00			$0	
Field Technician	18	HR	$168.00			$3,024	DTW measurement at 14 monitoring wells including transportation to/from Burn Site from field office. Two technicians working together at remote site. 9-hour work day.
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	2	HR	$168.00			$336	Data entry.
GSA pickup truck	1					$100	Assumed day charge.
TOTAL COST						**$3,914**	

Source of Cost Data:

Practical knowledge from SNL projects.

COST WORKSHEET

Groundwater well sampling Alternative 2 - MNA

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Groundwater sample collection from one monitoring well. Assumes well is sampled using a portable Bennett pump. Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	2	HR	$227.00			$454	Coordination of sampling task.
Staff Scientist/Engineer	2	HR	$205.00			$410	Coordination of sampling task.
Field Technician	18	HR	$168.00			$3,024	Groundwater sample collection requires a nine-hour workday for two technicians per well. Sample collection using portable pump system at a remote location. Includes equipment calibration and decontamination. Includes sample handling and delivery to SNL sample management office.
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	2	HR	$168.00			$336	
COST						**$4,224**	
Consumables Costs:	1	EA			$500.00	$500	Sample containers, ice packs, DI water, calibration fluids for field instruments.
Vehicles	1			$214.00		$214	Two vehicles: sampling van and pickup truck (4x4 with Tommy gate). Prorated $3,000.
TOTAL COST						**$4,938**	

Source of Cost Data:

Practical knowledge from SNL projects.

COST WORKSHEET

Groundwater laboratory analysis and validation NPN Alternative 2 - LTM

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Analytical costs for one suite of groundwater sample analysis, and independent third party validation from one groundwater monitoring well for purposes of monitoring COC (Nitrate). GEL actual lab costs for August 2022. Quantity of 1.2 accounts for 20% QC samples (duplicates, equipment decontamination, etc.) samples.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - NPN as nitrogen	1.2	EA			$15.81	$19	Standard turn around time: EPA Method 353.2.
Level IV validation - NPN as nitrogen	1	EA			$23.72	$24	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Shipping	1	EA			$5.00	$5	FedEx overnight shipping charge per sample (prorated from shipping a cooler)
Subtotal off-site services costs						$48	
Subtotal equipment/supply costs + operational overhead						**$57**	
TOTAL COST						**$57**	

Source of Cost Data:

Analytical costs per analysis based on typical unit pricing in effect for Base Year 2022. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.). Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases.

COST WORKSHEET

Groundwater laboratory MNA list analysis and validation Alternative 2 - MNA

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Analytical costs for one suite of groundwater sample analysis, and independent third party validation from one groundwater monitoring well for purposes of monitoring the seven MNA parameters). Quantity of 1.2 accounts for 20% QC samples (duplicates, equipment decontamination, etc.) samples.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - total dissolved carbon	1.2	EA			$24.24	$29.09	Standard turn around time: EPA Method SW846-9060A. GEL lab cost.
Level IV validation - total dissolved carbon	1	EA			$36.36	$36.36	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Lab analysis - dissolved gas argon	1.2	EA			$100.00	$120.00	Standard turn around time: Assumed Eurofins lab cost.
Level IV validation - dissolved gas argon	1	EA			$150.00	$150.00	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Lab analysis - dissolved gas nitrogen	1.2	EA			$100.00	$150.00	Standard turn around time: Assumed Eurofins lab cost.
Level IV validation - dissolved gas nitrogen2	1	EA			$150.00	$150.00	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Lab analysis - water delta18oxygen	1.2	EA			$27.00	$32.40	Standard turn around time: UC Davis lab, "Oxygen and Hydrogen of Water" tab.
Level IV validation - water delta18oxygen	1	EA			$40.50	$40.50	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Lab analysis - water delta2hydrogen	1.2	EA			$22.50	$27.00	Standard turn around time: UC Davis lab, "Oxygen and Hydrogen of Water" tab.
Level IV validation - water delta2hydrogen	1	EA			$40.50	$40.50	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Lab analysis - nitrate18oxygen	1.2	EA			$45.29	$54.35	Standard turn around time. UC Davis lab, "Nitrate (NO3) in Water" tab.
Level IV validation - nitrate18oxygen	1	EA			$67.94	$67.94	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Lab analysis - nitrate delta15nitrogen	1.2	EA			$45.29	$54.35	Standard turn around time. UC Davis lab, "Nitrate (NO3) in Water" tab.
Level IV validation - nitrate delta15nitrogen	1	EA			$67.90	$67.90	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Shipping	3	EA			$5.00	$15.00	FedEx overnight shipping charge per sample (prorated for shipping a cooler to the 3 labs).
Subtotal off-site services costs						$1,035.38	
Subtotal equipment/supply costs + operational overhead						**$1,242.46**	
TOTAL COST						**$1,242.46**	

Source of Cost Data:

Analytical costs per analysis based on typical unit pricing in effect for Base Year 2022. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.). Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases. GEL 2022 lab costs from TJ. Isotope analyses costs from the University of California Davis lab at https://stableisotopefacility.ucdavis.edu/analytical-services. UC Davis website accessed 28 Sept 2022.

COST WORKSHEET

Groundwater analytical data handling **Alternative 2 - MNA**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Receive and verify laboratory Electronic Data Deliverables (EDDs) analytical report. Upload validated data to database for one sampling event.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	4	HR	$227.00			$908	
Staff Scientist/Engineer	8	HR	$205.00			$1,640	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	8	HR	$168.00			$1,344	
TOTAL COST						**$2,548**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff for one sampling event (8 wells).

COST WORKSHEET

Purge water transport and disposal Alternative 2 - MNA

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Disposal of 55-gallon drums of purge water generated while sampling or redeveloping a monitoring well. Wastewater is transported from Burn Site to ERFO storage yard. After analytical results are reviewed, the drums are discharged to a sanitary sewer access point at ERFO. Disposed of using the 2022 POTW requirements. Health and safety protection is Level D. Assume three drums per monitoring well per event.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	0	HR	$227.00			$0	
Staff Scientist/Engineer	4	HR	$205.00			$820	Reviews analytical data. Prepares memorandum.
Field Technician	36	HR	$168.00			$6,048	Two technicians for 9 hours each to pick up and transport drums from Burn Site to ERFO. Includes completing related documentation. Drums moved later to nearby sewer manhole; two technicians for one day.
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	1	HR	$168.00			$168	
TOTAL COST						**$7,036**	

Source of Cost Data:

Based on current onsite contractor staff typical level of effort for similar onsite operations.

COST WORKSHEET

Purge water laboratory analysis and validation Alternative 2 - LTM

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Analytical costs for one suite of groundwater sample analyses to ensure compliance with requirements for discharge of purge water to the POTW. Third-party validation is required. Sample are collected from the sampling manifold in the ERFO sampling van while collecting environmental samples. Laboratory standard TAT (turn around time) is 30 days. Analytical results from each sampled well are used for POTW compliance purposes.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - VOCs	1.2	EA			128.06	$154	Standard TAT: SW846-8260D
Level IV validation - VOCs	1	EA			192.09	$192	Third-party validation. 100% of all analyses
Lab analysis - Unfiltered TAL Metals plus Uranium	1.2	EA			201.31	$242	Standard TAT: SW846-6020B/7470A
Level IV validation - TAL Metals incl. Uranium	1	EA			301.97	$302	Third-party validation. 100% of all analyses
Lab analysis - Gamma spec (short list: Am241, Cs137, Co60, K40)	1.2	EA			93.81	$113	Standard TAT: EPA Method 901.1
Level IV validation - Gamma spec (short list)	1	EA			140.72	$141	Third-party validation. 100% of all analyses
Lab analysis - Gross Alpha/Beta	1.2	EA			68.52	$82	Standard TAT: EPA 900.0
Level IV validation - Gross Alpha/Beta	1	EA			102.78	$103	Third-party validation. 100% of all analyses
Lab analysis - Tritium	1.2	EA			55.34	$66	Standard TAT: EPA Method 906.0M
Level IV validation - Tritium	1	EA			83.01	$83	Third-party validation. 100% of all analyses
Lab analysis - Isotopic Uranium	1.2	EA			132.28	$159	Standard TAT: HASL 300
Level IV validation - Isotopic Uranium	1	EA			198.42	$198	Third-party validation. 100% of all analyses
Lab analysis - Alkalinity	1.2	EA			36.36	$44	Standard TAT: SM2320B
Level IV validation - Alkalinity	1	EA			54.54	$55	Third-party validation. 100% of all analyses
Lab analysis - Anions (Bromide, Chloride, Fluoride, Sulfate)	1.2	EA			80.12	$96	Standard TAT: SW846-9056A
Level IV validation - Anions (Bromide, Chloride, Fluoride, Sulfate)	1	EA			120.18	$120	Third-party validation. 100% of all analyses
Lab analysis - TPH Diesel Range Organics	1.2	EA			67.98	$82	Standard TAT: EPA Method 8015D
Level IV validation - TPH Diesel Range Organics	1	EA			101.97	$102	Third-party validation. 100% of all analyses
Lab analysis - TPH Gasoline Range Organics	1.2	EA			52.17	$63	Standard TAT: EPA Method 8015A/B
Level IV validation - TPH Gasoline Range Organics	1	EA			78.26	$78	Third-party validation. 100% of all analyses

Lab analysis - High Explosive compounds	1.2	EA	160.21	$192	Standard TAT: EPA Method 8330B
Level IV validation - High Explosive compounds	1	EA	240.32	$240	Third-party validation. 100% of all analyses
Subtotal off-site services costs				$2,906	
Escalation from quotation to Base Year	1.00				
Subtotal off-site services costs with escalation				$2,906	
Subtotal equipment/supply costs + operational overhead	1.20			$3,487	
TOTAL COST				**$3,487**	

Source of Cost Data:

Analytical costs per analysis are based on GEL typical unit pricing in effect for Base Year 2022. The validation costs are estimated as actual costs and are formula based and affected by laboratory quality control data, batching, project specific requirements, etc. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.). Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases.

COST WORKSHEET

Well redevelopment **Alternative 2 - MNA**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Drilling Company redevelops each of the 8 proposed sampling monitoring wells once (assumes redevelopment is done once per well at the half-way point of the 30-year remedy). Well is surged and bailed, then pumped to obtain parameter stabilization. Health and safety protection is Level D. Fractured bedrock aquifer. Assume one day per well (setup, develop, containerize water) by the drilling company.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Subcontractor costs							
Mobe/demobe	1	EA				$6,785	mobe/demobe to Burn Site
Well Development	80	HR	$345.00			$27,600	Eight 10-hour days. Performed by drilling company using pump truck rig. Eight wells.
Subtotal contractor costs						$34,385	
Subtotal subcontractor costs + operational overhead	1.20					**$41,262**	Multiplier applied to outside contractors.
Contractor labor costs							
Staff Scientist/Engineer	108	HR	$205.00			$22,140	Coordination, oversight, and documentation. Four office days plus eight 9-hour field days.
Contractor labor costs						**$22,140**	
Purge water analyses and validation	8	EVENT			$6,148	**$49,184**	Lab, validation, and data handling cost from other spreadsheet. POTW analytes plus NPN.
Purge water transport and disposal	8	EVENT			$3,228	**$25,824**	Labor for one event from other spreadsheet. 8 wells.
TOTAL COST						**$138,410**	

Source of Cost Data:

Hourly drilling company rate for well development based on Yellow Jacket quote (25 August 2021 for TA-V) adjusted to base year 2022. Level of effort based on site-specific past experience. Operational overhead multiplier of 1.20 applied to subcontractor cost line items.

COST WORKSHEET

Five Year Performance Monitoring Report   Alternative 2 - MNA

Site: Burn Site Groundwater Area of Concern   **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico   **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Five Year Performance Monitoring Report is a progress report with several elements: 1) description of work completed during the reporting period, 2) summary of all problems, potential problems, or delays encountered during the reporting period, 3) description of actions taken to eliminate or mitigate problems, potential problems, or delays, 4) discussion of work projected for next reporting period, including sampling, and 5) copies of results from monitoring, including sampling/analysis, and other data generated during the reporting period. Includes potentiometric-surface contour maps and isoconcentration maps. Report will be submitted to NMED HWB.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Internal draft
Project Manager	120	HR	$251.00			$30,120	
Senior Scientist/Engineer	80	HR	$227.00			$18,160	Prepare text and review of figures, graphs, and appendices.
Staff Scientist/Engineer	40	HR	$205.00			$8,200	Draft figures. Update water level and concentration trend graphs.
Field Technician	40	HR	$168.00			$6,720	Assemble field data form appendices and files.
Graphics Technician	40	HR	$179.00			$7,160	Up to ten figures at four hours each. Mostly updating of AGMR figures.
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	40	HR	$168.00			$6,720	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							Internal draft
Project Manager	40	HR	$251.00			$10,040	
Senior Scientist/Engineer	20	HR	$227.00			$4,540	
Staff Scientist/Engineer	10	HR	$205.00			$2,050	
Field Technician	20	HR	$168.00			$3,360	
Graphics Technician	20	HR	$179.00			$3,580	
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	8	HR	$168.00			$1,344	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final for submittal to NMED HWB.
Project Manager	32	HR	$251.00			$8,032	
Senior Scientist/Engineer	16	HR	$227.00			$3,632	
Staff Scientist/Engineer	8	HR	$205.00			$1,640	
Field Technician	10	HR	$168.00			$1,680	
Graphics Technician	10	HR	$179.00			$1,790	
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	4	HR	$168.00			$672	

Production Supplies/Distribution costs	1	LS	$500	$500
TOTAL COST				**$140,260**

Source of Cost Data:

Based on estimated level of estimate for onsite contractor staff to produce report.

COST WORKSHEET

Corrective Measures Implementation Report **Alternative 2 - MNA**

Site: Burn Site Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Prepared by: Dept. 8888
Date: November 4, 2022

Work Statement:

Prepare Corrective Measure Implementation Report: Includes 1) summary of work completed during implementation of the remedy. Also includes a request for Certificate of Corrective Action Complete from NMED HWB. CMI Report summarizes the Five Year Performance Monitoring Reports. A request for plugging and abandoning wells will be included.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Internal draft
Project Manager	160	HR	$251.00			$40,160	
Sr. Geologist/Engineer/Scientist	160	HR	$227.00			$36,320	
Staff Geologist/Engineer/Scientist	160	HR	$205.00			$32,800	
Technician	0	HR	$168.00			$0	
Graphics	80	HR	$179.00			$14,320	
Technical Editor/Production	80	HR	$169.00			$13,520	
Analytical Data Administrator	40	HR	$168.00			$6,720	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							Internal draft
Project Manager	80	HR	$251.00			$20,080	
Sr. Geologist/Engineer/Scientist	80	HR	$227.00			$18,160	
Staff Geologist/Engineer/Scientist	80	HR	$205.00			$16,400	
Technician	0	HR	$168.00			$0	
Graphics	40	HR	$179.00			$7,160	
Technical Editor/Production	80	HR	$169.00			$13,520	
Analytical Data Administrator	20	HR	$168.00			$3,360	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final for submittal to NMED HWB
Project Manager	40	HR	$251.00			$10,040	
Sr. Geologist/Engineer/Scientist	40	HR	$227.00			$9,080	
Staff Geologist/Engineer/Scientist	40	HR	$205.00			$8,200	
Technician	0	HR	$168.00			$0	
Graphics	20	HR	$179.00			$3,580	
Technical Editor/Production	80	HR	$169.00			$13,520	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$500	$500	
TOTAL COST						**$267,480**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report. Used projected TAG hours.

COST WORKSHEET

Well plugging and abandonment Alternative 2 - MNA

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Plug and abandon (P&A) 14 5-in diameter PVC monitoring wells. Remove wellhead completions. Install monuments. Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Subcontractor costs								
Mobe/Demobe	1	EA				$6,785	$6,785	Mobe/demode to Burn Site.
Well pad demolition	14	EA				$500	$7,000	Demolish well pad and bollards.
Grout well to ground surface	3,537	FT				$9	$31,833	Sum of total depths for the 14 monitor wells.
Concrete monument	14	EA				$800	$11,200	Placed at location of abandoned well.
Subtotal contractor costs							$56,818	
Subtotal subcontractor costs + operational overhead	1.20						**$68,182**	Multiplier applied to outside contractors.
Contractor labor costs								
Project Manager	2	HR	251.00			$502	$502	
Senior Scientist/Engineer	8	HR	227.00			$1,816	$1,816	
Staff Scientist/Engineer	140	HR	205.00			$28,700	$28,700	14 days with 10 hour shift
Field Technician	4	HR	168.00			$672	$672	Onsite handling/disposal of IDW water under site-wide POTW permit.
Graphics Technician	0	HR	179.00			$0	$0	
Technical Editor/ Word Processor	4	HR	169.00			$676	$676	
Analytical Data Administrator	0	HR	168.00			$0	$0	
Production Supplies/Distribution costs	0	EA	0.00			$0	$0	
Subtotal contractor labor costs							$32,366	
TOTAL COST							**$100,548**	

Source of Cost Data:

Hourly drilling company rate for well decommissioning based on Yellow Jacket quote (25 August 2021 for TA-V) adjusted for inflation to base year 2022. Level of effort based on site-specific past experience. Operational overhead multiplier of 1.20 applied to outside contractor cost line items.

COST WORKSHEET

Well plugging and abandonment Report **Alternative 2 - MNA**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -25% to +25%)
Base Year: 2022

Work Statement:

Prepare Plugging and Abandonment Report. Includes summary of work completed and field forms for submittal to NMED HWB. Forms to NMOSE.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							
Project Manager	20	HR	$251.00			$5,020	
Sr. Geologist/Engineer/Scientist	160	HR	$227.00			$36,320	
Staff Geologist/Engineer/Scientist	20	HR	$205.00			$4,100	
Technician	0	HR	$168.00			$0	
Graphics	20	HR	$179.00			$3,580	
Technical Editor/Production	80	HR	$169.00			$13,520	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS				$0	
Prepare Draft Final							
Project Manager	10	HR	$251.00			$2,510	
Sr. Geologist/Engineer/Scientist	60	HR	$227.00			$13,620	
Staff Geologist/Engineer/Scientist	10	HR	$205.00			$2,050	
Technician	0	HR	$168.00			$0	
Graphics	10	HR	$179.00			$1,790	
Analytical Data Administrator	0	HR	$168.00			$0	
Technical Editor/Production	40	HR	$169.00			$6,760	
Production Supplies/Distribution costs	1	LS				$0	
Prepare Final							Final version for submittal to NMED HWB. Forms sent to NMOSE.
Project Manager	5	HR	$251.00			$1,255	
Sr. Geologist/Engineer/Scientist	20	HR	$227.00			$4,540	
Staff Geologist/Engineer/Scientist	5	HR	$205.00			$1,025	
Technician	0	HR	$168.00			$0	
Graphics	5	HR	$179.00			$895	
Analytical Data Administrator	0	HR	$168.00			$0	
Technical Editor/Production	40	HR	$169.00			$6,760	
Production Supplies/Distribution costs	1	LS			$2,000	$2,000	
TOTAL COST						**$105,745**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

APPENDIX K-3
COST ESTIMATE WORK SHEETS FOR THE GROUNDWATER EXTRACTION, TREATMENT, AND REINJECTION ALTERNATIVE

Groundwater Extraction, Treatment and Reinjection - Cost Work Sheets	Cost, Base Year 2022	Year(s) Activity Occurs	Present Value
Corrective Measures Implementation Plan	$133,172	2026	$133,172
Corrective Measures Design for CMI Plan	$426,565	2026	$426,565
Contingency Plan for CMI Plan	$72,298	2026	$72,298
Discharge Permit	$255,090	2027	$255,090
Well installation	$3,259,032	2028	$3,259,032
Well Installation Report	$105,578	2029	$105,578
Groundwater conveyance for eastern plume	$382,234	2029	$382,234
Groundwater conveyance for western plume	$316,454	2029	$316,454
Groundwater treatment systems (2)	$802,828	2029	$802,828
Operation and maintenance - Eastern plume	$324,975	2030 through 2049	$6,499,500
Operation and maintenance - Western plume	$217,604	2030-2034	$1,088,020
Depth to water measurements	$16,076	2027 through 2053	$434,052
Groundwater well sampling	$61,432	2027 through 2053	$1,658,664
Groundwater laboratory analysis and validation NPN	$798	2027 through 2054	$22,344
Groundwater analytical data handling	$2,548	2027 through 2054	$71,344
Purge water transport and disposal	$98,504	2027 through 2054	$2,758,112
Purge water lab analysis and validation	$45,192	2027 through 2054	$1,265,376
Well redevelopment	$149,352	2040	$149,352
Quarterly discharge permit report	$128,128	2030 through 2050	$2,690,688
Five Year Performance Monitoring Report	$782,608	2035, 2040, 2045, 2050	$3,130,432
Corrective Measures Implementation Report	$397,960	2052	$397,960
Well plugging and abandonment	$532,950	2055	$532,950
Well plugging and abandonment Report	$200,705	2056	$200,705
Dismantle groundwater conveyances and treatment systems	$140,926	2055	$140,926
Totals, Alternative 3: GETR	**Not applicable**	**2026 through 2056**	**$26,793,676**

COST WORKSHEET

Corrective Measures Implementation Plan Alternative 3 - GETR

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Prepare Corrective Measure Implementation Plan including Sampling and Analysis Plan, and Land Use Controls Plan. A Community Relations Plan is not listed below because SNL already submits an updated version to NMED HWB annually.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Corrective Measures Implementation Plan							
Prepare Draft							Internal draft
Project Manager	56	HR	$251.00			$14,056	
Senior Scientist/Engineer	8	HR	$227.00			$1,816	
Staff Scientist/Engineer	4	HR	$205.00			$820	
Field Technician	4	HR	$168.00			$672	
Graphics Technician	16	HR	$179.00			$2,864	
Technical Editor/ Word Processor	12	HR	$169.00			$2,028	
Analytical Data Administrator	8	HR	$168.00			$1,344	
Production Supplies/Distribution costs	1	LS			$50	$50	
Prepare Draft Final							Internal draft
Project Manager	28	HR	$251.00			$7,028	
Senior Scientist/Engineer	4	HR	$227.00			$908	
Staff Scientist/Engineer	2	HR	$205.00			$410	
Field Technician	2	HR	$168.00			$336	
Graphics Technician	8	HR	$179.00			$1,432	
Technical Editor/ Word Processor	12	HR	$169.00			$2,028	
Analytical Data Administrator	1	HR	$168.00			$168	
Production Supplies/Distribution costs	1	LS			$50	$50	
Prepare Final							Final for submittal to regulatory agencies.
Project Manager	14	HR	$251.00			$3,514	
Senior Scientist/Engineer	2	HR	$227.00			$454	
Staff Scientist/Engineer	1	HR	$205.00			$205	
Field Technician	1	HR	$168.00			$168	
Graphics Technician	4	HR	$179.00			$716	
Technical Editor/ Word Processor	12	HR	$169.00			$2,028	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
SUBTOTAL						**$44,095**	

Sampling and Analysis Plan

Prepare Draft						Internal draft
Project Manager	40	HR	$251.00		$10,040	
Senior Scientist/Engineer	40	HR	$227.00		$9,080	
Staff Scientist/Engineer	8	HR	$205.00		$1,640	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	32	HR	$179.00		$5,728	
Technical Editor/ Word Processor	24	HR	$169.00		$4,056	
Analytical Data Administrator	8	HR	$168.00		$1,344	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Draft Final						Internal draft
Project Manager	8	HR	$251.00		$2,008	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	16	HR	$179.00		$2,864	
Technical Editor/ Word Processor	12	HR	$169.00		$2,028	
Analytical Data Administrator	4	HR	$168.00		$672	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Final						Final will be an Appendix to the CMI Plan.
Project Manager	8	HR	$169.00		$1,352	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	2	HR	$205.00		$410	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	8	HR	$179.00		$1,432	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	1	HR	$168.00		$168	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
SUBTOTAL					**$51,626**	

Land Use Controls Plan

Prepare Draft						Internal draft
Project Manager	12	HR	$251.00		$3,012	
Senior Scientist/Engineer	40	HR	$227.00		$9,080	
Staff Scientist/Engineer	8	HR	$205.00		$1,640	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	16	HR	$179.00		$2,864	
Technical Editor/ Word Processor	16	HR	$169.00		$2,704	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Draft Final						Internal draft
Project Manager	6	HR	$251.00		$1,506	
Senior Scientist/Engineer	20	HR	$227.00		$4,540	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	8	HR	$179.00		$1,432	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Final						Final will be an Appendix to the CMI Plan. Land use controls are not specified in the Consent Order.
Project Manager	3	HR	$251.00		$753	
Senior Scientist/Engineer	10	HR	$227.00		$2,270	
Staff Scientist/Engineer	2	HR	$205.00		$410	
Field Technician	0	4	$168.00		$0	
Graphics Technician	4	HR	$179.00		$716	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
SUBTOTAL					**$37,451**	
CMI PLAN TOTAL COST					**$133,172**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

COST WORKSHEET

Corrective Measures Design for CMI Plan **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Prepare Corrective Measure Design as an Appendix to the CMI Plan. Includes Operation and Maintenance Plan, Waste Management Plan, and internal Health and Safety Plan. Includes computer (MODFLOW) modeling to optimize well placements. Also includes preparation of Design Plans/Specifications/associated construction schedule, and Construction Quality Assurance Plan. NEPA Checklist listed below.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Design Plans and Specifications							Used TAG Alt 3 CM Design hours
Prepare Draft							
Project Manager	40	HR	$251.00			$10,040	Internal version
Senior Scientist/Engineer	160	HR	$227.00			$36,320	
Staff Scientist/Engineer	240	HR	$205.00			$49,200	
Field Technician	80	HR	$168.00			$13,440	
Graphics Technician	80	HR	$179.00			$14,320	
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	8	HR	$168.00			$1,344	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							
Project Manager	20	HR	$251.00			$5,020	Internal version
Senior Scientist/Engineer	80	HR	$227.00			$18,160	
Staff Scientist/Engineer	120	HR	$205.00			$24,600	
Field Technician	40	HR	$168.00			$6,720	
Graphics Technician	40	HR	$179.00			$7,160	
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	4	HR	$168.00			$672	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final will be an Appendix in the CMI Plan.
Project Manager	10	HR	$251.00			$2,510	
Senior Scientist/Engineer	40	HR	$227.00			$9,080	
Staff Scientist/Engineer	60	HR	$205.00			$12,300	
Field Technician	20	HR	$168.00			$3,360	
Graphics Technician	10	HR	$179.00			$1,790	
Technical Editor/ Word Processor	20	HR	$169.00			$3,380	

Analytical Data Administrator	2	HR	$168.00		$336	
Production Supplies/Distribution costs	1	LS		$20	$20	
SUBTOTAL Design Plans and Specifications					**$233,332**	
Waste Management Plan						
Prepare Draft						
Project Manager	10	HR	$251.00		$2,510	Internal version
Senior Scientist/Engineer	40	HR	$227.00		$9,080	
Staff Scientist/Engineer	20	HR	$205.00		$4,100	
Field Technician	4	HR	$168.00		$672	
Graphics Technician	4	HR	$179.00		$716	
Technical Editor/ Word Processor	20	HR	$169.00		$3,380	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Draft Final						
Project Manager	20	HR	$251.00		$5,020	Internal version
Senior Scientist/Engineer	20	HR	$227.00		$4,540	
Staff Scientist/Engineer	10	HR	$205.00		$2,050	
Field Technician	2	HR	$168.00		$336	
Graphics Technician	2	HR	$179.00		$358	
Technical Editor/ Word Processor	40	HR	$169.00		$6,760	
Analytical Data Administrator	4	HR	$168.00		$672	
Production Supplies/Distribution costs	1	LS		$500	$500	
Prepare Final						Final will be an Appendix in the CMI Plan.
Project Manager	16	HR	$251.00		$4,016	
Senior Scientist/Engineer	32	HR	$227.00		$7,264	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	4	HR	$168.00		$672	
Graphics Technician	8	HR	$179.00		$1,432	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	4	HR	$168.00		$672	
Production Supplies/Distribution costs	1	LS		$20	$20	
SUBTOTAL WMP					**$56,962**	Includes draft and final versions for internal use.
Construction Quality Assurance Plan						Used TAG Alt 3 Construction QAP hours
Prepare Draft						
Project Manager	8	HR	$251.00		$2,008	Internal version
Senior Scientist/Engineer	40	HR	$227.00		$9,080	
Staff Scientist/Engineer	60	HR	$205.00		$12,300	
Field Technician	8	HR	$168.00		$1,344	

Graphics Technician	16	HR	$179.00		$2,864	
Technical Editor/ Word Processor	16	HR	$169.00		$2,704	
Analytical Data Administrator	2	HR	$168.00		$336	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Draft Final						
Project Manager	4	HR	$251.00		$1,004	Internal version
Senior Scientist/Engineer	20	HR	$227.00		$4,540	
Staff Scientist/Engineer	30	HR	$205.00		$6,150	
Field Technician	4	HR	$168.00		$672	
Graphics Technician	8	HR	$179.00		$1,432	
Technical Editor/ Word Processor	16	HR	$169.00		$2,704	
Analytical Data Administrator	2	HR	$168.00		$336	
Production Supplies/Distribution costs	1	LS		$20	$20	
Prepare Final						Final will be an Appendix in the CMI Plan.
Project Manager	2	HR	$251.00		$502	
Senior Scientist/Engineer	10	HR	$227.00		$2,270	
Staff Scientist/Engineer	15	HR	$205.00		$3,075	
Field Technician	2	HR	$168.00		$336	
Graphics Technician	4	HR	$179.00		$716	
Technical Editor/ Word Processor	16	HR	$169.00		$2,704	
Analytical Data Administrator	2	HR	$168.00		$336	
Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL Construction QAP					**$57,953**	
Health and Safety Plan						
Prepare Draft						Internal review
Project Manager	16	HR	$251.00		$4,016	
Senior Scientist/Engineer	40	HR	$227.00		$9,080	
Staff Scientist/Engineer	8	HR	$205.00		$1,640	
Field Technician	4	HR	$168.00		$672	
Graphics Technician	16	HR	$179.00		$2,864	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	4	HR	$168.00		$672	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Draft Final						Internal review
Project Manager	8	HR	$251.00		$2,008	
Senior Scientist/Engineer	20	HR	$227.00		$4,540	
Staff Scientist/Engineer	4	HR	$205.00		$820	
Field Technician	2	HR	$168.00		$336	
Graphics Technician	8	HR	$179.00		$1,432	

Technical Editor/ Word Processor	4	HR	$169.00		$676	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Final						HASP will not be submitted to regulators.
Project Manager	4	HR	$251.00		$1,004	
Senior Scientist/Engineer	8	HR	$227.00		$1,816	
Staff Scientist/Engineer	2	HR	$205.00		$410	
Field Technician	1	HR	$168.00		$168	
Graphics Technician	4	HR	$179.00		$716	
Technical Editor/ Word Processor	4	HR	$169.00		$676	
Analytical Data Administrator	0	HR	$168.00		$0	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
SUBTOTAL Health and Safety Plan					**$37,898**	
NEPA Checklist						Submit internal National Environmental Protection Act (NEPA) Checklist to DOE SFO.
Project Manager	80	HR	$251.00		$20,080	May require multiple cycles for approval. Not submitted to regulators.
Senior Scientist/Engineer	40	HR	$227.00		$9,080	
Staff Scientist/Engineer	20	HR	$205.00		$4,100	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	40	HR	$179.00		$7,160	Field GPS work and prepare figures.
Technical Editor/ Word Processor	0	HR	$169.00		$0	
Analytical Data Administrator	0	HR	$168.00		$0	
SUBTOTAL NEPA					**$40,420**	
CORRECTIVE MEASURE DESIGN TOTAL COST					**$426,565**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

COST WORKSHEET

Contingency Plan for CMI Plan   Alternative 3 - GETR

Site: Burn Site Groundwater Area of Concern   **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico   **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Prepare Contingency Plan to be submitted along with Corrective Measures Implementation Plan.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Internal draft
Project Manager	80	HR	$251.00			$20,080	
Senior Scientist/Engineer	24	HR	$227.00			$5,448	
Staff Scientist/Engineer	40	HR	$205.00			$8,200	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	16	HR	$179.00			$2,864	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$50	$50	
Prepare Draft Final							Internal draft
Project Manager	40	HR	$251.00			$10,040	
Senior Scientist/Engineer	12	HR	$227.00			$2,724	
Staff Scientist/Engineer	20	HR	$205.00			$4,100	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	8	HR	$179.00			$1,432	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$50	$50	
Prepare Final							Final will be an Appendix to the CMI Plan.
Project Manager	20	HR	$251.00			$5,020	
Senior Scientist/Engineer	6	HR	$227.00			$1,362	
Staff Scientist/Engineer	10	HR	$205.00			$2,050	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	4	HR	$179.00			$716	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$50	$50	
TOTAL COST						**$72,298**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report. Used projected TAG hours.

COST WORKSHEET

Discharge Permit — Alternative 3 - GETR

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Prepare and submit a discharge permit application to the New Mexico Environment Department (NMED) Groundwater Quality Bureau for discharge (reinjection) of treated groundwater.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare draft NMED Discharge Permit Application							Internal draft
Project Manager	40	HR	$251.00			$10,040	
Senior Scientist/Engineer	80	HR	$227.00			$18,160	
Staff Scientist/Engineer	10	HR	$205.00			$2,050	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	20	HR	$179.00			$3,580	
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	4	HR	$168.00			$672	
Production Supplies/Distribution costs	1	LS			$50	$50	
Draft Total						$41,312	
Prepare draft final NMED Discharge Permit Application							Internal draft
Project Manager	10	HR	$251.00			$2,510	
Senior Scientist/Engineer	20	HR	$227.00			$4,540	
Staff Scientist/Engineer	4	HR	$205.00			$820	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	8	HR	$179.00			$1,432	
Technical Editor/ Word Processor	16	HR	$169.00			$2,704	
Analytical Data Administrator	2	HR	$168.00			$336	
Production Supplies/Distribution costs	1	LS			$50	$50	
Draft Final Total						$12,392	
Prepare draft NMED Discharge Permit Application							Final sent to NMED GWQB
Project Manager	10	HR	$251.00			$10,040	
Senior Scientist/Engineer	20	HR	$227.00			$36,320	
Staff Scientist/Engineer	4	HR	$205.00			$4,100	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	4	HR	$179.00			$7,160	
Technical Editor/ Word Processor	16	HR	$169.00			$6,760	

Analytical Data Administrator	0	HR	$168.00		$672	
Permit application fees	1	EA		$4,400	$4,400	Filing ($100) fee, Class III injection well fee ($1,700), and GW abatement fee ($2,600) paid to NMED GWQB. From 20.6.2.3114 NMAC Table 1. (DT's email 14 July 2022).
Production Supplies/Distribution costs	1	LS		$2,000	$2,000	
Final Total					$71,452	
Public Notification						Publish notices in local newspapers. Includes internal draft for review. Submittal to regulatory agencies.
Project Manager	2	HR	$251.00		$502	
Senior Scientist/Engineer	12	HR	$227.00		$2,724	
Staff Scientist/Engineer	0	HR	$205.00		$0	
Field Technician	0	HR	$168.00		$0	
Graphics Technician	0	HR	$179.00		$0	
Technical Editor/ Word Processor	8	HR	$169.00		$1,352	
Analytical Data Administrator	0	HR	$168.00		$0	
Newspaper placement costs	1	LS		$200	$200	
TOTAL COST					**$255,090**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

COST WORKSHEET

Well installation **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 2, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Install 28 wells (12 extraction wells, 12 reinjection wells, and 4 hydraulic-communication test wells) to an average total depth of 250 feet, with 20 feet of 0.020-inch factory-slotted screen. Installation uses a combination of Air-Rotary Casing-Hammer (ARCH) and Air-Rotary drilling methods, installation of nominal 5-inch diameter flush-threaded Schedule 80 PVC blank and screen with filter pack and grout seal. Includes setup and decontamination, and wellhead completion (stovepipe with hinged lid, concrete pad, 3 steel bollards). Includes logging and location/elevation surveying. Health and safety protection is Level D. Geophysical logging is not required. Video logging of borehole conducted by SNL personnel with driller's assistance. Cuttings will be spread on the ground surface in the vicinity of each well. No performance monitoring wells will be installed. Assumes one mobe each for drill rig and development rig.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Subcontractor costs							
Drill rig mobilization/demobilization	1	LS				$32,373	Mobe/demobe once to ERFO for initial decon.
Mobe to next well at Burn Site.	28				$4,715	$132,020	Set up rig at each well.
Rig Decon at ERFO	28	EA			$4,715	$132,020	Decon for each well. Roundtrip to ERFO.
Polyethylene plastic under rig	14	EA			$184	$2,576	used twice before disposal
Borehole drilling	7,000	LF		$161.00		$1,127,000	Average depth of wells is assumed to be 250 feet. Total of 28 wells for both plumes.
Well installation - blank casing	6,440	LF		$51.75		$333,270	230 feet times 28 wells
Well installation - screen	560	LF		$74.75		$41,860	20 feet times 28 wells
Well installation - sump	140	LF		$51.75		$7,245	5 feet times 28 wells
Well installation - centralizers	84	EA		$70.15		$5,893	3 per well
Well installation - silica sand	840	LF		$20.70		$17,388	30 feet per well annulus
Well installation - bentonite chips	5,880	LF		$25.30		$148,764	210 feet per well annulus
Well installation - bentonite chips	280	LF		$20.00		$5,600	10 feet per well annulus
Standby	280	HR	$345.00			$96,600	10 hours per well. Video logging assistance and grout setup time.
Wellhead completion	28	LS			$4,140	$115,920	Well pad and bollards/installation. 24 wells.
NMOSE permit filing fee	28	EA			$5	$140	needed for each new well.
Development rig mobilization/demobilization	1	EA			$6,785	$6,785	Smaller rig
Well development	280	HR	$345.00			$96,600	Average depth of extraction and reinjection wells is assumed to be 250 feet. Total of 28 wells for both plumes. Assume one 10-hour day per well. Setup, develop, containerize water.
Land Surveying	28	EA	$200.00			$5,600	Surveying horizontal coordinates and vertical elevations under one mobilization. Prorated cost. Includes field work, data processing and report preparation. Estimated surveyor cost.
Subtotal onsite contractor costs						$2,307,653	

Subtotal subcontractor costs + operational overhead	1.20			**$2,769,184**	Multiplier applied to "outside" contractors.
Contractor labor costs					
Project Manager	40	HR	$251.00	$10,040	Drilling and facilities/safety logistical coordination. Review of driller's safety plan.
Senior Scientist/Scientist	1,400	HR	$227.00	$317,800	Onsite drilling, well installation, logging, and well development oversight. Five 10-hour days per well.
Staff Geologist/Engineer	56	HR	$205.00	$11,480	Drill site assistance. Two hours per well.
Field Technician	896	HR	$168.00	$150,528	Site setup, site maintenance, video logging of borehole to determine screen depth for intercepting bedrock fracture. Two technicians, 16 hours per well.
Graphics Technician	0	HR	$179.00	$0	
Technical Editor/Word Processor	0	HR	$169.00	$0	
Analytical Data Administrator	0	HR	$168.00	$0	
Subtotal contractor labor costs				**$489,848**	
WELL INSTALL TOTAL COST				**$3,259,032**	

Source of Cost Data:

Well installation costs based on Yellow Jacket quote (25 August 2022 for TA-V) adjusted to base year of 2022. Operational overhead multiplier of 1.20 applied to outside contractor cost line items.

COST WORKSHEET

Well Installation Report **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measure Evaluation (-30% to +50%)
Base Year: 2022

Prepared by: Dept. 8888
Date: November 4, 2022

Work Statement:

Well installation report. Includes tabulated information on multiple new well installations (extraction and reinjection wells). Surveyor cost listed below.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	8	HR	$251.00			$2,008	
Senior Scientist/Engineer	160	HR	$227.00			$36,320	
Staff Scientist/Engineer	8	HR	$205.00			$1,640	
Field Technician	8	HR	$168.00			$1,344	
Graphics Technician	80	HR	$179.00			$14,320	
Technical Editor/ Word Processor	20	HR	$169.00			$3,380	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$10	$0	
Prepare Draft Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	4	HR	$251.00			$1,004	
Senior Scientist/Engineer	80	HR	$227.00			$18,160	
Staff Scientist/Engineer	4	HR	$205.00			$820	
Field Technician	4	HR	$168.00			$672	
Graphics Technician	40	HR	$179.00			$7,160	
Technical Editor/ Word Processor	8	HR	$169.00			$1,352	
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$10	$10	
Prepare Final							Final report version will be submitted to NMED HWB. Forms to NMOSE.
Project Manager	2	HR	$251.00			$502	
Senior Scientist/Engineer	40	HR	$227.00			$9,080	
Staff Scientist/Engineer	2	HR	$205.00			$410	
Field Technician	2	HR	$168.00			$336	
Graphics Technician	20	HR	$179.00			$3,580	
Technical Editor/ Word Processor	20	HR	$169.00			$3,380	
Analytical Data Administrator	0	HR	$268.00				
Production Supplies/Distribution costs	1	LS			$100	$100	
Surveyor	40	HR	$200.00			$8,000	Surveyor cost estimate for 20 wells (3 days) field work plus compiling a report.
TOTAL COST						**$105,578**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce recent reports.

COST WORKSHEET

Groundwater conveyance system for eastern plume **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Eastern Plume. Install equipment and materials to convey groundwater from extraction wells to the eastern treatment system, and convey treated water from the treatment system to the reinjection wells. Includes submersible pumps, manifold, piping, valves, primary and secondary containment, electrical wiring, conduit, and water-level controls. Work also includes trenching, backfilling, and compacting for the piping and wiring. Average depth of the extraction wells and reinjection wells assumed to be 250 feet. Conveyance involves 6 extraction wells and 6 reinjection wells at eastern plume.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Extraction pump assemblies								
Extraction wellhead fittings	6	EA			$325.00	$325	$1,950	Fittings, sampling port, pressure gauge, valves, and totalizing flow meter.
Extraction pumps	6	EA			$910.00	$910	$5,460	Electric submersible pump (up to 5 gpm), downhole wiring, fittings, riser pipe/tubing.
Downhole pipe, wire, fittings	1,500	FT			$1.95	$1.95	$2,925	Assumed depth of 250 feet per well.
Safety cable	1,500	FT			$0.98	$ 0.98	$1,470	Stainless steel (7 × 19 strand).
Extraction pump controller	6	EA			$910.00	$910	$5,460	Pump controller and high/low water level switching.
Hi/Lo level sensor and cabling	6	EA			$585.00	$585	$3,510	
Hi/Lo level sensor controller	6	EA			$357.00	$357	$2,142	
Install assemblies	108		$200.00				$21,600	Labor. Two technicians. Requires six 9-hour days.
Subtotal extraction pump assemblies							**$44,517**	
Subtotal subcontractor costs + operational overhead	1.20						**$53,420**	Multiplier applied to "outside" contractors.
Trenching, backfill, and compaction								
Trenching, backfilling, compaction	3,200	LF				$48.89	$156,448	1.5 ft wide, approximately 2 ft deep (piping not included). Total length includes trenches for (a) manifold along extraction wells [800 ft], (b) piping from extraction manifold to treatment system [900 ft], and (c) piping from treatment system to reinjection manifold [800 ft], and manifold along the reinjection wells [700 ft]. Includes labor and equipment rental.
Subtotal trenching, backfill, and compaction.							**$156,448**	
Subtotal subcontractor costs + operational overhead	1.20						**$187,738**	Multiplier applied to "outside" contractors.

Primary conveyance tubing						
Groundwater conveyance tubing (wellhead to manifold along extraction wells)	120	LF		$0.87	$104	1/2-in ID PVC tubing with polyester braiding. Individual lines for each of the extraction wells. Connector fittings included. 20 ft per well.
Groundwater conveyance (manifold along extraction wells)	800	LF		$3.50	$2,800	2-in ID flexible PVC pipe, 100 ft lengths with couplings cost $350 each. Actual 2022 cost.
Groundwater conveyance tubing (manifold to treatment system)	900	LF		$3.50	$3,150	2-in ID flexible PVC pipe, 100 ft lengths with couplings cost $350 each. Actual 2022 cost.
Treated water conveyance tubing (treatment system to manifold along reinjection wells)	800	LF		$3.50	$2,800	2-in ID flexible PVC pipe, 100 ft lengths with couplings cost $350 each. Actual 2022 cost.
Treated water conveyance (manifold along reinjection wells)	700	LF		$3.50	$2,450	2-in ID flexible PVC pipe, 100 ft lengths with couplings cost $350 each. Actual 2022 cost.
Treated water conveyance tubing (manifold to reinjection well)	120	LF				20 feet per well head
Install primary conveyance tubing. Labor cost.	3,200	LF	$1.46		$4,672	Assumes tubing is pulled through secondary containment piping in 200 ft sections (between pull boxes). Two technicians, two hours each/600 LF of tubing.
Subtotal primary conveyance tubing					**$15,976**	
Subtotal subcontractor costs + operational overhead	1.20				**$19,172**	Multiplier applied to "outside" contractors.
Secondary containment pipe						
Containment pipe (wellhead to manifold along extraction wells)	120	LF		$4.03	$484	4-in ID Sched 40 PVC pipe.
Containment pipe (manifold along extraction wells)	800	LF		$4.03	$3,224	4-in ID Sched 40 PVC pipe.
Containment pipe (manifold to treatment system)	900	LF		$4.03	$3,627	4-in ID Sched 40 PVC pipe.
Containment pipe (treatment system to manifold along reinjection wells)	800	LF		$4.03	$3,224	4-in ID Sched 40 PVC pipe.
Containment pipe (manifold along reinjection wells)	700	LF		$4.03	$2,821	4-in ID Sched 40 PVC pipe.
Containment pipe (manifold to wellhead)	120	LF		$4.03	$484	4-in ID Sched 40 PVC pipe.
Containment couplings	100	EA		$5.28	$528	4-in ID Sched 40 PVC pipe. 3-4 tubing lines per piping run.
Install secondary containment pipe. Labor cost.	3,200	LF	$8.74		$27,968	Assumes two technicians can install 50 ft of piping (five, 10-ft sections) per hour.
Subtotal secondary containment					**$42,359**	

Subtotal subcontractor costs + operational overhead	1.20					**$50,831**	Multiplier applied to "outside" contractors.
Electrical conduit, wiring, and control panels for extraction and transfer pumps. Main control panel at treatment system building.							
Electrical conduit (treatment system to extraction wellheads)	1,700	LF		$0.94		$1,598	2-in ID Sched 40 PVC pipe, integral belled couplings, installed parallel to secondary containment piping. Each conduit contains power lines for pumps and associated level controls.
Install electrical conduit (treatment system to extraction wells). Labor cost.	1,700	LF	$8.74			$14,858	2-in ID PVC pipe installed in 10-ft sections with cemented bell couplings. Assumes two technicians can install 50 ft of conduit (five, 10-ft sections) per hour.
Electrical wire (treatment system to extraction wellheads)	1,700	LF		$0.39		$663	2-wire, sheathed Romex (or functional equivalent). Miscellaneous connectors are nominal cost. Total equals primary tubing length plus distance from nearest electrical drop/control panel.
Install electrical wiring and connect at extraction wellheads. Labor cost.	1,700	LF	$1.46			$2,482	Assumes wiring is pulled through electrical conduit in 200 ft sections (between pull boxes) containing three bundled 200 ft lengths of wire (total of 600 LF). Two technicians, two hours each/600 LF of wire.
Electrical conduit (treatment system to reinjection wellheads)	1,500	LF		$0.94		$1,410	2-in ID Sched 40 PVC pipe, integral belled couplings, installed parallel to secondary containment piping. Each conduit contains power lines for pumps and associated level controls.
Install electrical conduit (treatment system to reinjection wells). Labor cost.	1,500	LF	$8.74			$13,110	2-in ID PVC pipe installed in 10-ft sections with cemented bell couplings. Assumes two technicians can install 50 ft of conduit (five, 10-ft sections) per hour.
Electrical wire to reinjection wells	1,500	LF		$0.39		$585	2-wire, sheathed Romex (or functional equivalent). Miscellaneous connectors are nominal cost. Total equals primary tubing length plus distance from nearest electrical drop/control panel.
Hi/Lo level sensor	6	EA		$585.00	$585	$3,510	At reinjection wells
Hi/Lo level sensor controller	6	EA		$357.00	$357	$2,142	At reinjection wells
Install electrical wiring and connect at reinjection wellheads. Labor cost.	1,500	LF	$2.18			$3,270	Assumes wiring is pulled through electrical conduit in 200 ft sections (between pull boxes) containing one wire. Two technicians, one hour each/200 LF of wire.
Electrical control panel	2	EA		$7,800	$7,800	$15,600	Master pump control panel for each transect (A and B). Includes controls for transfer pumps. Includes $1,000 each for installation labor.
Subtotal electrical conduit, wiring, and control panels for extraction and transfer pumps						**$59,228**	
Subtotal subcontractor costs + operational overhead	1.20					**$71,074**	Multiplier applied to "outside" contractors.
GW EASTERN CONVEYANCE TOTAL COST						**$382,234**	

Source of Cost Data:

Cost rates for labor, equipment, and material are assumed to be 130% of the respective costs used for the Tijeras Arroyo Groundwater AOC CCM/CME Report (SNL February 2018), except where noted as actual 2022 cost. Operational overhead multiplier of 1.20 applied to outside contractor cost line items.

COST WORKSHEET

Groundwater conveyance system for western plume **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Western Plume. Install equipment and materials to convey groundwater from the extraction wells to the western treatment system, and convey treated water from the treatment system to the reinjection wells. Includes submersible pumps, manifold, piping, valves, primary and secondary containment, electrical wiring, conduit, and water-level controls. Work also includes trenching, backfilling, and compacting for the piping and wiring. Average depth of the extraction wells and reinjection wells assumed to be 250 feet. Conveyance involves 6 extraction wells and 6 reinjection wells at western plume.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Extraction pump assemblies								
Extraction wellhead fittings	6	EA			$325.00	$325	$1,950	Fittings, sampling port, pressure gauge, valves, and totalizing flow meter.
Extraction pumps	6	EA			$910.00	$910	$5,460	Electric submersible pump (up to 5 gpm), downhole wiring, fittings, riser pipe/tubing.
Downhole pipe, wire, fittings	1,500	FT			$1.95	$1.95	$2,925	Assumed depth of 250 feet per well, based on maximum depth of modeled fractures.
Safety cable	1,500	FT			$0.98	$ 0.98	$1,470	Stainless steel (7 × 19 strand).
Extraction pump controller	6	EA			$910.00	$910	$5,460	Pump controller and high/low level switching.
Hi/Lo level sensor and cabling	6	EA			$585.00	$585	$3,510	
Hi/Lo level sensor controller	6	EA			$357.00	$357	$2,142	
Install assemblies	108		$200.00				$21,600	Labor. Two technicians. Requires six 9-hour days.
Subtotal extraction pump assemblies							**$44,517**	
Subtotal subcontractor costs + operational overhead	1.20						**$53,420**	Multiplier applied to "outside" contractors.
Trenching, backfill, and compaction								
Trenching, backfilling, compaction	2,500	LF				$48.89	$122,225	1.5 ft wide, approximately 2 ft deep (piping not included). Total length includes trenches for (a) manifold along extraction wells [800 ft], (b) piping from extraction manifold to treatment system [500 ft], and (c) piping from treatment system to reinjection manifold [500 ft], and manifold along the reinjection wells [700 ft].
Subtotal trenching, backfill, and compaction.							**$122,225**	
Subtotal subcontractor costs + operational overhead	1.20						**$146,670**	Multiplier applied to "outside" contractors.
Primary conveyance tubing								

Groundwater conveyance tubing (wellhead to manifold along extraction wells)	120	LF		$0.87	$104	1/2-in ID PVC tubing with polyester braiding. Individual lines for each of the extraction wells. Connector fittings included. 20 ft per well.
Groundwater conveyance (manifold along extraction wells)	800	LF		$3.50	$2,800	2-in ID flexible PVC pipe, 100 ft lengths with couplings cost $350 each. Actual 2022 cost.
Groundwater conveyance tubing (manifold to treatment system)	500	LF		$3.50	$1,750	2-in ID flexible PVC pipe, 100 ft lengths with couplings cost $350 each. Actual 2022 cost.
Treated water conveyance tubing (treatment system to manifold along reinjection wells)	500	LF		$3.50	$1,750	2-in ID flexible PVC pipe, 100 ft lengths with couplings cost $350 each. Actual 2022 cost.
Treated water conveyance (manifold along reinjection wells)	700	LF		$3.50	$2,450	2-in ID flexible PVC pipe, 100 ft lengths with couplings cost $350 each. Actual 2022 cost.
Treated water conveyance tubing (manifold to reinjection well)	120	LF		$0.87	$104	20 feet per well head
Install primary conveyance tubing.. Labor cost.	2,500	LF	$1.46		$3,650	Assumes tubing is pulled through secondary containment piping in 200 ft sections (between pull boxes). Two technicians, two hours each/600 LF of tubing.
Subtotal primary conveyance tubing					**$12,609**	
Subtotal subcontractor costs + operational overhead	1.20				**$15,131**	Multiplier applied to "outside" contractors.
Secondary containment pipe						
Containment pipe (wellhead to manifold along extraction wells)	120	LF		$4.03	$484	4-in ID Sched 40 PVC pipe.
Containment pipe (manifold along extraction wells)	800	LF		$4.03	$3,224	4-in ID Sched 40 PVC pipe.
Containment pipe (manifold to treatment system)	500	LF		$4.03	$2,015	4-in ID Sched 40 PVC pipe.
Containment pipe (treatment system to manifold along reinjection wells)	500	LF		$4.03	$2,015	4-in ID Sched 40 PVC pipe.
Containment pipe (manifold along reinjection wells)	700	LF		$4.03	$2,821	4-in ID Sched 40 PVC pipe.
Containment pipe (manifold to wellhead)	120	LF		$4.03	$484	4-in ID Sched 40 PVC pipe.
Containment couplings	100	EA		$5.28	$528	4-in ID Sched 40 PVC pipe.
Install secondary containment pipe. Labor cost.	2,500	LF	$8.74		$21,850	Assumes two technicians can install 50 ft of piping (five, 10-ft sections) per hour.
Subtotal secondary containment					**$33,420**	
Subtotal subcontractor costs + operational overhead	1.20				**$40,104**	Multiplier applied to "outside" contractors.

Electrical conduit, wiring, and control panels for extraction and transfer pumps. Main control panel at treatment system building.

Electrical wire conduit (treatment system to extraction wellheads)	1,300	LF		$0.94		$1,222	2-in ID Sched 40 PVC pipe, integral belled couplings, installed parallel to secondary containment piping. Each conduit contains power lines for pumps and associated level controls.
Install electrical conduit (treatment system to extraction wells). Labor cost.	1,300	LF	$8.74			$11,362	2-in ID PVC pipe installed in 10-ft sections with cemented bell couplings. Assumes two technicians can install 50 ft of conduit (five, 10-ft sections) per hour.
Electrical wire (treatment system to extraction wellheads)	1,300	LF		$0.39		$507	2-wire, sheathed Romex (or functional equivalent). Miscellaneous connectors are nominal cost. Total equals primary tubing length plus distance from nearest electrical drop/control panel.
Install electrical wiring and connect at extraction wellheads. Labor cost.	1,300	LF	$1.46			$1,898	Assumes wiring is pulled through electrical conduit in 200 ft sections (between pull boxes) containing three bundled 200 ft lengths of wire (total of 600 LF). Two technicians, two hours each/600 LF of wire.
Electrical wire conduit (treatment system to reinjection wellheads)	1,200	LF		$0.94		$1,128	2-in ID Sched 40 PVC pipe, integral belled couplings, installed parallel to secondary containment piping. Each conduit contains power lines for pumps and associated level controls.
Install electrical wire conduit (treatment system to reinjection wells). Labor cost.	1,200	LF	$8.74			$10,488	2-in ID PVC pipe installed in 10-ft sections with cemented bell couplings. Assumes two technicians can install 50 ft of conduit (five, 10-ft sections) per hour.
Electrical wire to reinjection wells	1,200	LF		$0.39		$468	2-wire, sheathed Romex (or functional equivalent). Miscellaneous connectors are nominal cost. Total equals primary tubing length plus distance from nearest electrical drop/control panel.
Hi/Lo level sensor	6	EA		$585.00	$585	$3,510	
Hi/Lo level sensor controller	6	EA		$357.00	$357	$2,142	
Install electrical wiring and connect at reinjection wellheads. Labor cost.	1,200	LF	$2.18			$2,616	Assumes wiring is pulled through electrical conduit in 200 ft sections (between pull boxes) containing one wire. Two technicians, one hour each/200 LF of wire.
Electrical control panel	2	EA		$7,800	$7,800	$15,600	Master pump control panel for each of the two manifolds. Includes controls for transfer pumps. Includes $1,000 each for installation labor.
Subtotal electrical conduit, wiring, and control panels for extraction and transfer pumps						**$50,941**	
Subtotal subcontractor costs + operational overhead	1.20					**$61,129**	Multiplier applied to "outside" contractors.
GW WESTERN CONVEYANCE TOTAL COST						**$316,454**	

Source of Cost Data:

Cost rates for labor, equipment, and material are assumed to be 130% of the respective costs used for the Tijeras Arroyo Groundwater AOC CCM/CME Report (SNL February 2018), except where actual 2022 costs are noted. Operational overhead multiplier of 1.20 applied to outside contractor cost line items.

COST WORKSHEET

Groundwater treatment systems **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Costs for installing two treatment systems and conducting optimization/shakedown. Both plumes need a treatment system. Purchase and install groundwater treatment systems including particulate filtration and nitrate treatment with ion exchange resin. Assumes total influent 10 gpm total flow rate with basis of 70% treated flow to 30% bypass flow. Blended effluent flow of 10 gpm at less than nitrate MCL. Analytes are assumed requirements for the NMED GWQB discharge permit based on recent TA-V treatability study.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Equipment/supply costs							
Construction of heated portable building	1	EA			$20,000	$20,000	Tuff Shed. In 2021, a 120 square foot shed cost $6,800 constructed in Albuquerque using pre-fab parts. No heat. $57 per square foot. Assume 200 square foot for the Burn Site with 30% inflation is $15,000. Add insulation and heaters assume $5,000 more.
Ion exchange resin canisters	3	EA			$18,500	$55,500	Ion-exchange system consists of: 24 vessels (8 plumbed in series: 4 lead and 4 lag) with 8 spare onsite and 8 "float" being in transit to/from the regeneration facility. Each canister has a 60 cu ft resin capacity. (TAG estimate was 100 gpm. BSG quantity estimated at 10% of TAG estimate.)
Ion exchange resin	144	CU FT			$146	$21,024	Strong base anion (SBA) resin. 60 cu ft/canister. (TAG estimate was 100 gpm. BSG quantity estimated at 10% of TAG estimate.)
Additional system equipment/materials	1	LS			$113,750	$113,750	Particulate prefilters, hose and connectors, nitrate analyzer and other controls, freight. TAG estimate escalated 130%.
Water Storage Tank	1				$3,000	$3,000	Assumed cost.
Mileage	1,680	MI			$0.625	$1,050	Mileage for subcontractor's construction/testing activities at the remote Burn Site. Assume four standard work weeks and three pickup trucks. Distance from Eubank Gate to Burn Site (14 miles one way). GSA vehicle rate, Sept. 2022, $0.625 per mile.
Subtotal equipment/supply costs						$214,324	
Subtotal equipment/supply costs + operational overhead	1.20					**$257,189**	
Off-site services costs							
Lab analysis - NPN as nitrogen	20	EA			$15.81	$316	Standard turn around time: EPA Method 353.2.
Level IV validation - NPN as nitrogen	20	EA			$23.72	$474	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Lab analysis - VOCs	4	EA			128.06	$512	Standard TAT: SW846-8260B
Level IV validation - VOCs	4	EA			192.09	$768	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Lab analysis - Unfiltered TAL Metals plus Uranium	4	EA			201.31	$805	Standard TAT: SW846-6020B/7470A
Level IV validation - TAL Metals incl. Uranium	4	EA			301.97	$1,208	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Lab analysis - Anions (Bromide, Chloride, Fluoride, Sulfate)	10	EA			80.12	$801	Standard TAT: SW846-9056A

Level IV validation - Anions (Bromide, Chloride, Fluoride, Sulfate)	10	EA		120.18	$1,202	Validation is assumed to be 1.5 times the lab cost (TJ guidance).
Shipping and misc. costs	20	EA		5.00	$100	
Subtotal					$6,187	
Subtotal, expedited	1.5				$9,281	Used an assumed rate to expedite analyses and validation during period of system shakedown
Subtotal equipment/supply costs + operational overhead	1.2				**$11,137**	
Contractor labor costs						
Sr. Geologist/Engineer/Scientist	160	HR	$227.00		**$36,320**	Coordination, oversight, and documentation. 40 hours/week × 4 weeks during construction.
Subcontractor labor costs						
Technician	160	HR	$168.00		$26,880	System installation (40 hour work week; four weeks).
Technician/Electrician/Plumber	160	HR	$168.00		$26,880	System installation (40 hour work week; four weeks).
Technician/Electrician/Plumber assistant	160	HR	$168.00		$26,880	System installation (40 hour work week; four weeks).
Subtotal					$80,640	
Overhead multiplier	1.2				$96,768	Overhead multiplier 120%.
Total subcontractor labor cost					**$96,768**	
COST FOR ONE SYSTEM					**$401,414**	
TOTAL COST FOR TWO SYSTEMS					**$802,828**	

Source of Cost Data:

BSG ion-exchange system equipment costs are based on the Evoqua Water Technologies email estimate (11/12/2017) for the Tijeras Arroyo Groundwater project. BSG facility installation and onsite contractor level of effort based on SNL professional judgment. Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases. Analytical costs are 2022 GEL unit rates. Factor of 1.2 for QC samples not applied.

COST WORKSHEET

Operations & Maintenance Cost - Eastern Plume **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Annual costs for operating and maintaining the Eastern groundwater extraction and treatment system (six extraction wells, six reinjection wells, one treatment system). Includes inspections, sampling, and water level measurements of wells. Treatment system operating and maintenance cost included. Well redevelopment cost on other spreadsheet.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Sampling port sample collection at treatment system during full-scale operation	216	HR	$168	$36,288		$36,288	2 technicians at remote site, 9 hours each. Monthly sampling of treatment system influent and effluent. Includes recording totalizing flow meter readings and basic system inspection.
Treatment system discharge lab analysis	12	SAMPLES		$1,282		$15,384	Monthly sample analyses for the four assumed Discharge Plan requirements ($1068). Standard turn around time: Rate includes factor of 1.2 to account for duplicates. Includes level IV validation. Includes shipping and misc. costs.
Analytical data handling	24	HR	$168	$4,032		$4,032	Upload EDD and related analytical data into database, review analytical reports/perform verification. Monthly samples. Data administrator.
Biweekly inspection of well field and treatment system	468	HR	$168	$78,624		$78,624	Two technicians at remote site. 9 hour days for 26 weeks equals 468 hours.
Quarterly measurement of water levels at 12 eastern monitoring wells during extraction phase	72	HR	$168	$12,096		$12,096	One day per quarter for two technicians, 9 hour days. Quarterly.
Quarterly sampling of 6 extraction wells during extraction phase. Performance monitoring.	72	HR	$168	$12,096		$12,096	One day per quarter for two technicians, 9 hour days. Access sampling ports at wellheads.
Analyses of quarterly extraction well water	24	SAMPLES	$57	$1,368		$1,368	Nitrate analyses. Standard turn around time: EPA Method 353.2. Rate includes factor of 1.2 to account for duplicates. Includes level IV validation. Quarterly samples for each of 6 wells. Includes shipping and misc. costs.
Analytical data handling, quarterly	8	HR	$168	$1,344		$1,344	Upload EDD and related analytical data into database, review analytical reports/perform verification. Quarterly samples. Data administrator.

Annual sampling of 9 monitoring wells (CYN-MW3, CYN-MW6, CYN-MW9, CYN-10, CYN-11, CYN-12, CYN-14A, CYN-15, and CYN-MW18) at eastern plume during extraction phase	162	HR	$168	$27,216	$27,216	Two technicians one a year: 9 hour days for each of 9 wells.
Analyses for monitoring well samples during extraction phase	9	SAMPLES	$57	$513	$513	Nitrate analyses. Standard turn around time: EPA Method 353.2. Rate includes factor of 1.2 to account for duplicates. Includes level IV validation. Includes shipping and misc. costs.
Analytical data handling	4	HR	$168	$672	$672	Upload EDD and related analytical data into database, review analytical reports/perform verification. Semiannual samples. Data administrator.
Annual sampling of two upgradient monitoring wells (CYN-MW4 and CYN-MW19) wells during extraction phase	36	HR	$168	$6,048	$6,048	Two days for two technicians, 9 hour days.
Analyses of annual monitoring well samples	2	SAMPLES	$57	$114	$114	Nitrate analyses. Standard turn around time: EPA Method 353.2. Rate includes factor of 1.2 to account for duplicates. Includes level IV validation. Monthly sample for each of 6 wells. Includes shipping and misc. costs.
Analytical data handling, annual	4	HR	$168.00	$672	$672	Upload EDD and related analytical data into database, review analytical reports/perform verification. Annual samples. Data administrator.
Subtotal Sampling and Inspection Cost					**$196,467**	
Particulate filter replacement	120	EA		$50	$6,000	Replace particulate filters every two months for twenty years. Assumed cost rate.
Strong base anion ion-exchange resin offsite regeneration	4	EVENTS		$22,100	$88,400	Offsite transportation and regeneration of canisters. Based upon 10% of the regeneration rate for 2018 TAG estimate. Cost rate escalated 130%.
Resin loss/replacement	7	CU FT		$190	$1,330	5% resin loss per year based on 2018 TAG estimate. Cost rate increased 130%
Piping and electrical repairs	1	PARTS		$100	$100	Assumed cost. As needed basis. Labor included in weekly inspections.
Wellhead maintenance	12	PARTS		$25	$300	General maintenance of extraction and reinjection well heads. Assume $25/well/year. Labor included in weekly inspections.
Electricity for pumps	188,000	KWH		$0.0583	$10,960	Six submersible pumps and 2 transfer pumps cycling 50% time $0.0583 kwh (industrial rate) escalated 130%.
Subtotal material and subcontractor costs					$107,090	Multiplier applied to outside contractors.
Subtotal subcontractor costs + operational overhead	1.2				$128,508	

TOTAL COST O&M EASTERN PLUME	**$324,975**

Source of Cost Data:

Labor based on estimated level of effort for onsite contractor staff. Analytical costs from spreadsheet: CostWS Alt 1 Lab GW analysis with validation LTM BSG. Strong ion exchange (IX) base resin. Industrial electricity rate from www.electricitylocal.com accessed 21 September 2022.

COST WORKSHEET

Operations & Maintenance Cost - Western Plume **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Annual costs for operating and maintaining the Western groundwater extraction and treatment system (six extraction wells, six reinjection wells, one treatment system). Includes inspections, sampling, and water level measurements of wells. Treatment system operating and maintenance cost included. Well redevelopment cost on other spreadsheet.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Sampling port sample collection at treatment system during full-scale operation	216	HR	$168	$36,288		$36,288	2 technicians at remote site, 9 hours each. Monthly sampling of treatment system influent and effluent. Includes recording totalizing flow meter readings and basic system inspection.
Treatment system discharge lab analysis	12	SAMPLES		$1,282		$15,384	Monthly sample analyses for the four assumed Discharge Plan requirements ($1068). Standard turn around time: Rate includes factor of 1.2 to account for duplicates. Includes level IV validation. Includes shipping and misc. costs.
Analytical data handling	24	HR	$168	$4,032		$4,032	Upload EDD and related analytical data into database, review analytical reports/perform verification. Monthly samples. Data administrator.
Biweekly inspection of well field and treatment system	468	HR	$168	$78,624		$78,624	Two technicians at remote site. 9 hour days for 26 weeks equals 468 hours.
Quarterly measurement of water levels at 12 eastern monitoring wells during extraction phase	72	HR	$168	$12,096		$12,096	One day per quarter for two technicians, 9 hour days. Quarterly.
Quarterly sampling of 6 extraction wells during extraction phase. Performance monitoring.	72	HR	$168	$12,096		$12,096	One day per quarter for two technicians, 9 hour days. Access sampling ports at wellheads.
Analyses of quarterly extraction well water	24	SAMPLES	$57	$1,368		$1,368	Nitrate analyses. Standard turn around time: EPA Method 353.2. Rate includes factor of 1.2 to account for duplicates. Includes level IV validation. Quarterly samples for each of 6 wells. Includes shipping and misc. costs.
Analytical data handling, quarterly	8	HR	$168	$1,344		$1,344	Upload EDD and related analytical data into database, review analytical reports/perform verification. Quarterly samples. Data administrator.
Annual sampling of 4 monitoring wells (CYN-MW7, CYN-MW8, CYN-MW13, and CYN-MW16) at the western plume during extraction phase	72	HR	$168	$12,096		$12,096	Two technicians twice a year. 9 hour days. 4 wells.
Analyses of monitoring well samples during extraction phase	8	SAMPLES	$57	$456		$456	Nitrate analyses. Standard turn around time: EPA Method 353.2. Rate includes factor of 1.2 to account for duplicates. Includes level IV validation. Includes shipping and misc. costs.
Analytical data handling	2	HR	$168	$336		$336	Upload EDD and related analytical data into database, review analytical reports/perform verification. Data administrator.
Annual sampling of one upgradient monitoring wells (CYN-MW17) wells during extraction phase	18	HR	$168	$3,024		$3,024	One days for two technicians, 9 hour days. Once annually.
Analyses of annual monitoring well samples	1	SAMPLES	$57	$57		$57	Nitrate analyses. Standard turn around time: EPA Method 353.2. Rate includes factor of 1.2 to account for duplicates. Includes level IV validation. Monthly sample for each of 6 wells. Includes shipping and misc. costs.
Analytical data handling, annual	4	HR	$168.00	$672		$672	Upload EDD and related analytical data into database, review analytical reports/perform verification. Annual samples. Data administrator.

Subtotal Sampling and Inspection Cost				**$177,873**	
Particulate filter replacement	48	EA	$50	$2,400	Replace particulate filters every two months for ten years. Assumed cost rate.
Strong base anion ion-exchange resin offsite regeneration	1	EVENTS	$22,100	$22,100	Offsite transportation and regeneration of canisters. Based upon 10% of the regeneration rate for 2018 TAG estimate. Cost rate escalated 130%.
Resin loss/replacement	7	CU FT	$190	$1,330	5% resin loss per year based on 2018 TAG estimate. Cost rate increased 130%
Piping and electrical repairs	1	PARTS	$100	$100	Assumed cost. As needed basis. Labor included in weekly inspections.
Wellhead maintenance	12	PARTS	$25	$300	General maintenance of extraction and reinjection well heads. Assume $25/well/year. Labor included in weekly inspections.
Electricity for pumps	118,000	KWH	$0.0583	$6,879	6 submersible pumps and 2 transfer pumps cycling 50% time $0.0583 kwh (industrial rate).
Subtotal material and subcontractor costs				$33,109	Multiplier applied to outside contractors.
Subtotal subcontractor costs + operational overhead	1.2			$39,731	
TOTAL COST O&M WESTERN PLUME				**$217,604**	

Source of Cost Data:

Labor based on estimated level of effort for onsite contractor staff. Analytical costs from spreadsheet: CostWS Alt 1 Lab GW analysis with validation LTM BSG. Strong ion exchange (IX) base resin. Industrial electricity rate from www.electricitylocal.com accessed 21 September 2022.

COST WORKSHEET

Depth to water measurements **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Prepared by: John Copland, SNL
Date: November 4, 2022

Work Statement:

One year of quarterly depth-to-water measurement for 17 AGMR monitoring wells. Includes submittal of field data, QC, and database entry. Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	8	HR	$227.00			$1,816	Data QA
Staff Scientist/Engineer	4	HR	$205.00			$820	
Field Technician	72	HR	$168.00			$12,096	DTW measurement at 17 monitoring wells. Four events. Includes transportation to/from Burn Site from field office. Two technicians working together at remote site, 9-hour days.
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	8	HR	$168.00			$1,344	Data entry
TOTAL COST						**$16,076**	

Source of Cost Data:

Practical knowledge at SNL.

COST WORKSHEET

Groundwater well sampling Alternative 3 - GETR

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Groundwater sample collection from one well. Assumes well is sampled using a portable Bennett pump. Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	2	HR	$227.00			$454	Coordination of sampling task.
Staff Scientist/Engineer	2	HR	$205.00			$410	Coordination of sampling task.
Field Technician	18	HR	$168.00			$3,024	Groundwater sample collection requires a nine-hour workday for two technicians per well. Sample collection using portable pump system at a remote location. Includes equipment calibration and decontamination. Includes sample handling and delivery to SNL sample management office.
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	0	HR	$168.00			$0	
COST						**$3,888**	
Consumables Costs:	1	EA			$500.00	$500	Sample containers, ice packs, DI water, calibration fluids for field instruments.
TOTAL COST						**$4,388**	

Source of Cost Data:

Practical experience at SNL.

COST WORKSHEET

Groundwater laboratory analysis and validation Alternative 3 - GETR

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Analytical costs for one suite of groundwater sample analysis, and independent third party validation from one groundwater monitoring well for purposes of monitoring the COC (nitrate).

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - NPN as nitrogen	1.2	EA			$15.81	$19	Standard turn around time: EPA Method 353.2.
Level IV validation	1				$23.72	$24	Third-part validation assumed to be 1.5 times unit lab cost (TJ guidance).
Shipping	1	EA			$5.00	$5	FedEx overnight shipping charge per sample (prorated from shipping a cooler)
Subtotal off-site services costs						$48	
Subtotal equipment/supply costs + operational overhead						**$57**	
TOTAL COST						**$57**	

Source of Cost Data:

Analytical costs per analysis based on 2022 unit pricing from GEL. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.) for a sampling event. Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases.

COST WORKSHEET

Groundwater analytical data handling Alternative 3 - GETR

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Receive and verify laboratory Electronic Data Deliverables (EDDs) analytical report. Upload validated data to database for one annual sampling event.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	4	HR	$227.00			$908	
Staff Scientist/Engineer	8	HR	$205.00			$1,640	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	8	HR	$168.00			$1,344	
TOTAL COST						**$2,548**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff for one sampling event.

COST WORKSHEET

Purge water transport and disposal Alternative 3 - GETR

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Disposal of 55-gallon drums of purge water generated while sampling or redeveloping a monitoring well. Wastewater is transported from Burn Site to ERFO storage yard. After analytical results are reviewed, the drums are discharged to a sanitary sewer access point at ERFO. Disposed of using the 2022 POTW requirements. Health and safety protection is Level D. Assume three drums per monitoring well per event.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	0	HR	$251.00			$0	
Senior Scientist/Engineer	0	HR	$227.00			$0	
Staff Scientist/Engineer	4	HR	$205.00			$820	Reviews analytical data. Prepares memorandum.
Field Technician	36	HR	$168.00			$6,048	Two technicians for 9 hours each to pick up and transport drums from Burn Site to ERFO. Includes completing related documentation. Drums moved later to nearby sewer manhole; two technicians for one day.
Graphics Technician	0	HR	$179.00			$0	
Technical Editor/Production	0	HR	$169.00			$0	
Analytical Data Administrator	1	HR	$168.00			$168	
TOTAL COST						**$7,036**	

Source of Cost Data:

Based on current onsite contractor staff typical level of effort for similar onsite operations.

COST WORKSHEET

Purge Water laboratory analysis and validation Alternative 3 - GETR

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Analytical costs for one suite of groundwater sample analyses to ensure compliance with requirements for discharge of purge water to the POTW. (NPN costs are on other spreadsheet). Third-party validation is required. Sample are collected from the sampling manifold in the ERFO sampling van while collecting environmental samples. Laboratory standard TAT (turn around time) is 30 days. Analytical results from each sampled well are used for POTW compliance purposes.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - VOCs	1.2	EA			128.06	$154	Standard TAT: SW846-8260D
Level IV validation - VOCs	1	EA			192.09	$192	Third-party validation. 100% of all analyses
Lab analysis - Unfiltered TAL Metals plus Uranium	1.2	EA			201.31	$242	Standard TAT: SW846-6020B/7470A
Level IV validation - TAL Metals incl. Uranium	1	EA			301.97	$302	Third-party validation. 100% of all analyses
Lab analysis - Gamma spec (short list: Am241, Cs137, Co60, K40)	1.2	EA			93.81	$113	Standard TAT: EPA Method 901.1
Level IV validation - Gamma spec (short list)	1	EA			140.72	$141	Third-party validation. 100% of all analyses
Lab analysis - Gross Alpha/Beta	1.2	EA			68.52	$82	Standard TAT: EPA 900.0
Level IV validation - Gross Alpha/Beta	1	EA			102.78	$103	Third-party validation. 100% of all analyses
Lab analysis - Tritium	1.2	EA			55.34	$66	Standard TAT: EPA Method 906.0M
Level IV validation - Tritium	1	EA			83.01	$83	Third-party validation. 100% of all analyses
Lab analysis - Isotopic Uranium	1.2	EA			132.28	$159	Standard TAT: HASL 300
Level IV validation - Isotopic Uranium	1	EA			198.42	$198	Third-party validation. 100% of all analyses
Lab analysis - Alkalinity	1.2	EA			36.36	$44	Standard TAT: SM2320B
Level IV validation - Alkalinity	1	EA			54.54	$55	Third-party validation. 100% of all analyses
Lab analysis - Anions (Bromide, Chloride, Fluoride, Sulfate)	1.2	EA			80.12	$96	Standard TAT: SW846-9056A
Level IV validation - Anions (Bromide, Chloride, Fluoride, Sulfate)	1	EA			120.18	$120	Third-party validation. 100% of all analyses
Lab analysis - TPH Diesel Range Organics	1.2	EA			67.98	$82	Standard TAT: EPA Method 8015D
Level IV validation - TPH Diesel Range Organics	1	EA			101.97	$102	Third-party validation. 100% of all analyses
Lab analysis - TPH Gasoline Range Organics	1.2	EA			52.17	$63	Standard TAT: EPA Method 8015A/B

Level IV validation - TPH Gasoline Range Organics	1	EA	78.26	$78	Third-party validation. 100% of all analyses
Lab analysis - High Explosive compounds	1.2	EA	160.21	$192	Standard TAT: EPA Method 8330B
Level IV validation - High Explosive compounds	1	EA	240.32	$240	Third-party validation. 100% of all analyses
Subtotal off-site services costs				$2,906	
Escalation from quotation to Base Year	1.00				
Subtotal off-site services costs with escalation				$2,906	
Subtotal equipment/supply costs + operational overhead	1.20			$3,487	
TOTAL COST				**$3,487**	

Source of Cost Data:

Analytical costs per analysis based on GEL unit pricing in effect for Base Year 2022, from TJ. The validation costs are estimated as actual costs and are formula based and affected by laboratory quality control data, batching, project specific requirements, etc. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.). Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases.

COST WORKSHEET

Well redevelopment Alternative 3 - MNA

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Drilling contractor redevelops monitoring, extraction, or reinjection well. Well is surged and bailed, then pumped to obtain parameter stabilization. Includes setup and decontamination, containerization of water, Health and safety protection is Level D. Assumes one day per well. Fractured bedrock aquifer. Assume 25 percent of the 41 wells (both plumes) will require redevelopment during the 10-year remedy. For costing, the redevelopment occurs at the mid-point of the extraction/reinjection phase.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Subcontractor costs							
Mobe/demobe	1	EA				$6,785	Mobe/demobe to Burn Site
Well Development	100	HR	$345.00			$34,500	Performed by drilling company using pump truck rig. Ten wells. One day per well. Ten 10-hour days. Decon of bailer and pump at ERFO.
Subtotal contractor costs						$41,285	
Subtotal subcontractor costs + operational overhead	1.20					**$49,542**	Multiplier applied to outside contractors.
Contractor labor costs							
Staff Scientist/Engineer	150	HR	$205.00			$30,750	Coordination, oversight, and documentation. Ten field days plus 5 days office.
Contractor labor costs						**$30,750**	
Purge water analyses and validation	10	EVENT			$6,626	**$66,260**	Lab, validation, and data handling cost from other spreadsheet. POTW analytes plus
Purge water transport and disposal	10	EVENT			$3,228	**$32,280**	Labor for one event from other spreadsheet. 10 wells.
TOTAL COST						**$178,832**	

Source of Cost Data:

Hourly drilling company rate for well development based on Yellow Jacket quote (25 August 2021) adjusted to base year 2022. Level of effort based on site-specific past experience. Operational overhead multiplier of 1.20 applied to subcontractor cost line items.

COST WORKSHEET

Quarterly discharge permit report **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Quarterly discharge compliance reporting to NMED Groundwater Quality Bureau for one year. Four reports submitted per year. Includes total volume discharged, flow rates, treatment system influent and effluent analytical results, and summarized narrative of operational maintenance.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Discharge compliance report							
Prepare Draft							Internal review
Project Manager	8	HR	$251.00			$2,008	
Senior Scientist/Engineer	40	HR	$227.00			$9,080	
Staff Scientist/Engineer	8	HR	$205.00			$1,640	
Field Technician	8	HR	$168.00			$1,344	
Graphics Technician	8	HR	$179.00			$1,432	
Technical Editor/Production	16	HR	$169.00			$2,704	
Analytical Data Administrator	8	HR	$168.00			$1,344	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							Internal review
Project Manager	4	HR	$251.00			$1,004	
Senior Scientist/Engineer	8	HR	$227.00			$1,816	
Staff Scientist/Engineer	2	HR	$205.00			$410	
Field Technician	2	HR	$168.00			$336	
Graphics Technician	4	HR	$179.00			$716	
Technical Editor/Production	8	HR	$169.00			$1,352	
Analytical Data Administrator	2	HR	$168.00			$336	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final is submitted to NMED GWQB on quarterly basis.
Project Manager	4	HR	$251.00			$1,004	
Senior Scientist/Engineer	8	HR	$227.00			$1,816	
Staff Scientist/Engineer	2	HR	$205.00			$410	
Field Technician	2	HR	$168.00			$336	
Graphics Technician	4	HR	$179.00			$716	
Technical Editor/Production	8	HR	$169.00			$1,352	
Analytical Data Administrator	2	HR	$168.00			$336	
Production Supplies/Distribution costs	1	LS			$500	$500	

Subtotal		**$32,032**	
Four quarterly reports per year	4		Four reports submitted each year.
TOTAL COST		**$128,128**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

COST WORKSHEET

Five Year Performance Monitoring Report Alternative 3 - GETR

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Five Year Performance Monitoring Report: 1) description of work completed during the reporting period, 2) summary of all problems, potential problems, or delays encountered during the reporting period, 3) description of actions taken to eliminate or mitigate problems, potential problems, or delays, 4) discussion of work projected for next reporting period, including sampling, 5) copies of results from monitoring, including sampling/analysis, and other data generated during the reporting period, and 6) copies of waste disposal records generated during the reporting period. Includes potentiometric surface contour maps and isoconcentration maps. Includes water volumes and system operation & maintenance, and discharge compliance results. Report submitted to NMED HWB.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Internal draft
Project Manager	240	HR	$251.00			$60,240	
Senior Scientist/Engineer	80	HR	$227.00			$18,160	Prepare text and review of figures, graphs, and appendices.
Staff Scientist/Engineer	40	HR	$205.00			$8,200	Draft figures. Update water level and concentration trend graphs.
Field Technician	16	HR	$168.00			$2,688	Assemble field data form appendices and files.
Graphics Technician	40	HR	$179.00			$7,160	Up to ten figures at four hours each. Mostly updating AGMR figures.
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	20	HR	$168.00			$3,360	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							Internal draft
Project Manager	120	HR	$251.00			$30,120	
Senior Scientist/Engineer	40	HR	$227.00			$9,080	
Staff Scientist/Engineer	20	HR	$205.00			$4,100	
Field Technician	8	HR	$168.00			$1,344	
Graphics Technician	20	HR	$179.00			$3,580	
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	
Analytical Data Administrator	20	HR	$168.00			$3,360	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final for submittal to NMED HWB.
Project Manager	60	HR	$251.00			$15,060	
Senior Scientist/Engineer	20	HR	$227.00			$4,540	
Staff Scientist/Engineer	10	HR	$205.00			$2,050	
Field Technician	0	HR	$168.00			$0	
Graphics Technician	10	HR	$179.00			$1,790	
Technical Editor/ Word Processor	40	HR	$169.00			$6,760	

Analytical Data Administrator	0	HR	$168.00		$0
Production Supplies/Distribution costs	1	LS		$500	$500
TOTAL COST					**$195,652**

Source of Cost Data:

Based on estimated level of estimate for onsite contractor staff to produce report.

COST WORKSHEET

Corrective Measures Implementation Report **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measures Evaluation (cost estimate range -30% to +50%)
Base Year: 2022

Prepared by: Dept. 8888
Date: November 4, 2022

Work Statement:

Prepare Corrective Measure Implementation Report: Includes 1) summary of work completed, 2) as-built drawings, 3) copies of monitoring results and other data from Five-Year Performance Monitoring Reports. Also includes a request for Certificate of Corrective Action Complete from NMED HWB and associated supporting information.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Internal draft
Project Manager	320	HR	$251.00			$80,320	
Sr. Geologist/Engineer/Scientist	320	HR	$227.00			$72,640	
Staff Geologist/Engineer/Scientist	160	HR	$205.00			$32,800	
Technician	0	HR	$168.00			$0	
Graphics	80	HR	$179.00			$14,320	
Technical Editor/Production	80	HR	$169.00			$13,520	
Analytical Data Administrator	40	HR	$168.00			$6,720	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Draft Final							Internal draft
Project Manager	160	HR	$251.00			$40,160	
Sr. Geologist/Engineer/Scientist	160	HR	$227.00			$36,320	
Staff Geologist/Engineer/Scientist	80	HR	$205.00			$16,400	
Technician	0	HR	$168.00			$0	
Graphics	40	HR	$179.00			$7,160	
Technical Editor/Production	80	HR	$169.00			$13,520	
Analytical Data Administrator		HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$20	$20	
Prepare Final							Final for submittal to NMED HWB
Project Manager	80	HR	$251.00			$20,080	
Sr. Geologist/Engineer/Scientist	80	HR	$227.00			$18,160	
Staff Geologist/Engineer/Scientist	40	HR	$205.00			$8,200	
Technician	0	HR	$168.00			$0	
Graphics	20	HR	$179.00			$3,580	
Technical Editor/Production	80	HR	$169.00			$13,520	
Analytical Data Administrator		HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$500	$500	
TOTAL COST						**$397,960**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

COST WORKSHEET

Well plugging and abandonment **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 2, 2022
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Plug and abandon (P&A) 5-inch diameter PVC monitoring, extraction, reinjection, or test well. Remove wellhead completion. Health and safety protection is Level D. Total of 42 wells. SNL will haul off and dispose of waste (broken concrete, stovepipes, bollards, empty grout sacks). Cost for writing the plugging and abandoning report is on other spreadsheet.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Subcontractor costs								
Drilling contractor Mobe/Demobe	1	EA				$6,785	$6,785	One time.
Well pad demolition	42	EA				$500	$21,000	Demolish well pad. Remove stovepipe and bollards.
Grout monitoring well to ground surface	3,537	FT				$9.20	$32,540	Total of casing lengths for 14 monitoring wells. (3 sentry wells will not be plugged.)
Grout extraction, reinjection, or test well to the ground surface	7,000	FT				$9.20	$64,400	Assume 250 foot casing length for each of the 28 other wells.
Concrete monument	42	EA				$800	$33,600	Construct concrete pad with marker at each plugged well.
Drilling contractor costs							$158,325	
Subtotal subcontractor costs + operational overhead	1.20						**$189,990**	Multiplier applied to outside contractors.
Contractor labor costs								
Project Manager	20	HR	251.00			$5,020	$5,020	Coordination.
Senior Scientist/Engineer	40	HR	227.00			$9,080	$9,080	Coordination.
Staff Scientist/Engineer	1,260	HR	205.00			$258,300	$258,300	Three days for each of the 42 wells. 10-hour days.
Field Technician	420	HR	168.00			$70,560	$70,560	One day for each of the 42 wells. 10-hour days.
Graphics Technician	0	HR	179.00			$0	$0	
Technical Editor/ Word Processor	0	HR	169.00			$0	$0	
Analytical Data Administrator	0	HR	168.00			$0	$0	
Production Supplies/Distribution costs	0	EA	0.00			$0	$0	
Subtotal contractor labor costs							$342,960	
TOTAL COST							**$532,950**	

Source of Cost Data:

Hourly drilling company rate for well decommissioning based on Yellow Jacket quote (25 August 2021) for TA-V adjusted for inflation to base year 2022. Level of effort based on site-specific past experience. Operational overhead multiplier of 1.20 applied to outside contractor cost line items.

COST WORKSHEET

Well plugging and abandonment Report **Alternative 3 - GETR**

Site: Burn Site Groundwater Area of Concern **Prepared by:** Dept. 8888
Location: Sandia National Laboratories/New Mexico **Date:** November 4, 2022
Phase: Corrective Measures Evaluation (cost estimate range -30% to +50%)
Base Year: 2022

Work Statement:

Prepare Well Plugging and Abandonment Report. Includes summary of work completed and field forms.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							
Project Manager	20	HR	$251.00			$5,020	
Sr. Geologist/Engineer/Scientist	320	HR	$227.00			$72,640	50% more than Alt 1 and Alt 2
Staff Geologist/Engineer/Scientist	40	HR	$205.00			$8,200	50% more than Alt 1 and Alt 2
Technician	0	HR	$168.00			$0	
Graphics	40	HR	$179.00			$7,160	50% more than Alt 1 and Alt 2
Technical Editor/Production	160	HR	$169.00			$27,040	50% more than Alt 1 and Alt 2
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS				$0	
Prepare Draft Final							
Project Manager	10	HR	$251.00			$2,510	
Sr. Geologist/Engineer/Scientist	120	HR	$227.00			$27,240	50% more than Alt 1 and Alt 2
Staff Geologist/Engineer/Scientist	20	HR	$205.00			$4,100	
Technician	0	HR	$168.00			$0	
Graphics	20	HR	$179.00			$3,580	
Technical Editor/Production	80	HR	$169.00			$13,520	50% more than Alt 1 and Alt 2
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS				$0	
Prepare Final							Final version for submittal to NMED HWB. Forms to NMOSE.
Project Manager	5	HR	$251.00			$1,255	
Sr. Geologist/Engineer/Scientist	40	HR	$227.00			$9,080	50% more than Alt 1 and Alt 2
Staff Geologist/Engineer/Scientist	10	HR	$205.00			$2,050	
Technician	0	HR	$168.00			$0	
Graphics	10	HR	$179.00			$1,790	
Technical Editor/Production	80	HR	$169.00			$13,520	50% more than Alt 1 and Alt 2
Analytical Data Administrator	0	HR	$168.00			$0	
Production Supplies/Distribution costs	1	LS			$2,000	$2,000	
TOTAL COST						**$200,705**	

Source of Cost Data:

Estimate based on recent level of effort for onsite contractor staff to produce SNL report.

COST WORKSHEET

Dismantle groundwater conveyances and treatment systems **Alternative 3 GETR**

Site: Burn Site Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measure Evaluation (-30% to +50%)
Base Year: 2022

Prepared by: Dept. 8888
Date: November 4, 2022

Work Statement:

Remove and dispose of extraction pumps, piping, wiring, treatment systems, concrete pads, and controls. As much material as possible will be hauled to SNL Reapplication. Trash and debris hauled to KAFB C&D Landfill. Concrete rubble hauled to TA-III recycling pile. Electrical wiring hauled to recycling center.

- Pull out and dispose of all buried electrical wiring and water conveyance tubing out of the PVC conduit and secondary containment.
- Cap and abandon in place all buried electrical conduit and piping (not filling them with grout or excavating).
- Remove and dispose of all electrical pull-box vaults – spaced every 200 feet. Backfill, compact, and pave as necessary to match.
- Remove and dispose of all treatment system equipment, except as noted below.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Subcontractor costs								
Remove extraction pumps, downhole piping and wiring, level controls, and wellhead fixtures.	70	HRS	$98				$6,860	Total of labor hours is 25 percent of TAG hours. TAG labor rate was increased 30 percent.
Remove buried primary conveyance tubing and electrical wiring	75	HRS	$98				$7,350	Total of labor hours is 25 percent of TAG hours. TAG labor rate was increased 30 percent.
Pull box removal, cap ends of conduit and pipe	100	EA	$98				$9,800	Total of labor hours is 25 percent of TAG hours. TAG labor rate was increased 30 percent.
Remove transfer tanks, transfer pumps, and controls	100	EA	$98				$9,800	Total of labor hours is 25 percent of TAG hours. TAG labor rate was increased 30 percent.
Dispose of remaining ion exchange resin		CF					$0	Remaining onsite resin taken by resin servicing vendor during last servicing trip (covered under annual O&M).
Portable treatment system buildings (2)	40	HR	$98				$3,920	Tuff Sheds hauled to SNL reapplication. Two laborers plus truck and trailer.
Misc. materials hauling and disposal fees	1	LS					$0	Used equipment, tubing, building materials. No disposal fee for KAFB C&D Landfill.
Hauling of materials to landfill, reapplication, or recycling.	200	EA	$98				$19,600	Labor
Equipment rental and mileage	1	EA					$8,000	trucks, trailers, forklift, jackhammer
Subtotal contractor costs							$65,330	
Subtotal subcontractor costs + operational overhead	1.20						**$78,396**	Multiplier applied to outside contractors.
Contractor labor costs								
Sr. Geologist/Engineer/Scientist	140	HR	227.00			$227	$31,780	Coordination, oversight, and documentation. 20 hours/week during demo. 3 weeks for demo. 80 hours for prep.
Staff Geologist/Engineer/Scientist	150	HR	205.00			$205	$30,750	On-site supervision for 3 weeks (50 hours/week).
Subtotal SNL labor costs							**$62,530**	
TOTAL COST							**$140,926**	

Source of Cost Data:

Professional judgment from other SNL projects. Operational overhead multiplier of 1.20 applied to outside contractor cost line items.

Appendix L
Cost Estimate Design Assumptions for the Remedial Alternatives

Cost Estimate Design Assumptions for the Remedial Alternatives

Chapter 7 summarizes the cost estimates prepared to support evaluation of the three remedial alternatives. The cost estimates (worksheets) are presented in Appendix K. The assumptions discussed below are based on the conceptual scope of the alternatives presented in Sections 7.2.1 (Alternative 1: Long-Term Monitoring), 7.2.2 (Alternative 2: Monitored Natural Attenuation), and 7.2.3 (Alternative 3: Groundwater Extraction, Treatment, and Reinjection). Specific details concerning the various tasks in the three alternatives are presented on the worksheets (Appendix K). The following discussion summarizes the tasks.

These costs may be subject to:

- Changes in regulatory requirements,
- Variations in specific assumptions such as timing and duration of alternative implementation and associated effectiveness of the remedy,
- Changes in dollar value at the time of implementation,
- Changes in the assumed discount rate used in present-value calculations,
- Uncertainties associated with the hydrogeologic characteristics, subsurface heterogeneities, and extent of contaminant distribution, and
- Impact from potential offsite sources of contamination.

Costing Assumptions

The timeframe for all three alternatives assumes a Base Year of 2022 also referred to as Year 1. Costs are presented in three categories:

1. Capital Costs

   This includes costs for preparing planning documents, obtaining permits, preparing designs, equipment and materials procurement, remediation system installation, and the deployment of remedial measures.

   Alternatives 1 and 2 have no capital costs other than planning documents and this work is assumed to be done in parallel with groundwater monitoring currently ongoing at the Burn Site Groundwater (BSG) Area of Concern (AOC).

   Alternative 3 capital costs include installation of extraction wells, reinjection wells, treatment systems, and associated infrastructure (piping, electric power, and control cables).

2. Annual Operation and Maintenance, Monitoring, and Reporting

   This includes costs for water level measurements, groundwater sample collection, laboratory analysis, data validation, purge water handling, data processing, reporting, and an allowance for routine wellhead maintenance.

Alternative 3 also includes cost items for operation and maintenance of the groundwater extraction and treatment systems including electricity, ion-exchange resin regeneration and replacement. Costs also include discharge permit compliance sampling.

3. Periodic Costs

   This category includes costs assumed to be incurred one or more times after initial implementation but not less frequently than annually during the corrective action timeframe. Examples of such costs include Five-year Performance Review Reports and an allowance for as-needed well redevelopment to address potential biofouling and/or silting of well screens.

General Assumptions

Several costing assumptions are applicable across the three costing categories. These include:

- Cost estimates for each alternative are based on the outlined conceptual scope of work for the projected timeline from a base year of 2022. For Alternatives 1 and 2, the estimated cost accuracy is -25 percent to +25 percent. Due to its greater complexity, the estimated cost accuracy for Alternative 3 is -30 percent to +50 percent. The range of cost accuracies includes contingency.

- Labor rates used for cost estimating tasks to be performed by onsite contractors (National Technology & Engineering Solutions of Sandia, LLC [NTESS] personnel) are based on anticipated fully burdened costs for Fiscal Year 2022. These rates are obtained from the current Resource Loaded Baseline. Standard Labor Rates are based on the mid-point of each salary band then increased to recover overtime, allowances, and fringe benefits. The Total Burdened Labor Rate is the Standard Labor Rate (with fringe) increased by a multiplier for the recovery of Division Support, Program Management, Corporate Taxes, New Mexico Site Support, Strategic Partnership Projects Office Support, General & Administrative, and Research & Development.

- Subcontractors will perform laboratory analyses, third-party validation, well installation, treatment system installation, and well development. Analytical costs for routine groundwater samples shipped to the offsite commercial GEL laboratory were obtained from the Sandia National Laboratories, New Mexico (SNL/NM) Sample Management Office (SMO) for unit pricing, effective in 2022 and are valid for Base Year 2022. Costs for unique other groundwater analyses are noted on the spreadsheets. Validation costs for all analyses are estimated per SMO guidance because actual costs are formula based and affected by laboratory quality control data, batching, project-specific requirements, and other variable factors. Well installation and development cost estimates are from on recently performed work at SNL/NM as noted on the respective spreadsheets.

- Costs for documents (for example, plans and reports) include three preparation steps to allow for applicable review: Draft (peer), Draft Final (technical editor) and Final (management, legal, and DOE). Draft Final and Final labor are typically assigned costs of 50 percent and 25 percent of the Draft, respectively, except for technical editor/production costs that are assumed to be equal for each preparation step. Some documents have several components, each of which are prepared separately, but are summed in the cost estimate to simplify cost presentation.

Implementation Planning

The scope for implementation planning includes:

- A Corrective Measure Implementation Plan (CMIP) that contains a Sampling and Analysis Plan, a Land Use Controls Plan, and a Contingency Plan.
- A Corrective Measure Design to be appended to the CMIP. This includes a Waste Management Plan, National Environmental Policy Act (NEPA) Checklist, and a Health and Safety Plan.
- The design for Alternative 3 also includes a Construction Quality Assurance Plan.

Annual Monitoring

Annual monitoring costs for all three alternatives also include:

- Laboratory analysis for nitrate and third-party validation,
- Analytical data handling and verification,
- An allowance for wellhead maintenance,
- Analysis of purge water and decontamination water to meet Albuquerque Bernalillo County Water Utility Authority Publicly Owned Treatment Works (POTW) discharge permit requirement before disposal to the sanitary sewer, and
- Labor for transport and disposal of purge water and decontamination water to the onsite permitted sanitary sewer discharge point.

Periodic Costs

The periodic costs include:

- Preparation of Five-year Performance Monitoring Report (identified in the Consent Order as “Progress Reports”) for submittal to the New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB). The reports will include potentiometric surface contour figures, nitrate isoconcentration contour figures, hydrographs, nitrate concentration trend graphs, extraction volumes, and an evaluation of remedy performance.

- Preparation of Quarterly Discharge Reports to the NMED (Ground Water Quality Bureau (GWQB). The reports will discussion extraction/reinjection volumes, rates, and analytical results.

- For Alternative 3, costs include ion exchange resin replacement and offsite regeneration servicing. Assumptions include an allowance for 5 percent new resin replacement during each year of operation, and an allowance for as-needed replacement of tubing used for conveying extracted groundwater from the extraction wells to the treatment systems.

One-time Costs

Certain documents will be prepared one time, and revised if necessary. These one-time documents are:

- A Corrective Measures Implementation Report that will be submitted to NMED HWB after completion of the remedy.

- For Alternative 3, a well installation report will be prepared. After completion of this remedy. A well plugging and abandonment report will be prepared.

One-time field tasks include:

- Redeveloping Alternatives 1 and 2 wells that become biofouled or silted up hindering collection of representative groundwater samples. The cost estimates for Alternatives 1 and 2 assumes that each monitoring well will need to be redeveloped once during the 30-year duration of the remedies. For costing purposes, redevelopment is scheduled at year 15.

  Redeveloping Alternative 3 wells that become biofouled or silted up. Redevelopment is assumed to occur at the midway point of the active portion of the remedy for each monitoring, extraction, or reinjection well.

- As noted above, decommissioning (plugging and abandonment) of wells after completion of the Alternative 3 remedy. The actual schedule of well decommissioning would be dependent on receiving final Corrective Action Complete approval from NMED HWB. Dismantlement of the Alternative 3 remedial is also considered.

Present Value Analysis

Total costs are estimated in 2022 dollars (Total Cost) by applying Present Value analysis. Per U.S. Environmental Protection Agency (EPA) guidance (EPA July 2000), “Present value analysis is a method to evaluate expenditures, either capital or Operations & Maintenance (O&M), which occur over different time periods. This standard methodology allows for cost comparisons of different remedial alternatives based on a single cost figure for each alternative. This single number, referred to as the present value, is the amount needed to be set aside at the initial point in time (base year) to assure that funds will be available in the future as they are needed, assuming certain economic conditions.”

Present Value costs were calculated using the real discount rate of 0.70 percent for federal facilities based on the 2017 Discount Rates for Office of Management and Budget (OMB) Circular A-94 (OMB December 2016). EPA guidance indicates that the same discount rate should be used for all evaluated alternatives based on the alternative with the longest timeframe (EPA July 2000). A remedy that is less costly, but does not sacrifice protection of health and the environment, shall be preferred.

References Cited in the Cost Estimate Design Assumptions for the Remedial Alternatives

Office of Management and Budget (OMB), December 2016. “Memorandum for the Heads of Departments and Agencies M-17-10, 2017 Discount Rates for OMB Circular A-94.” Executive Office of the President, Office of Management and Budget, Washington, D.C., December 12.

U.S. Environmental Protection Agency (EPA), July 2000. “A Guide to Developing and Documenting Cost Estimates During the Feasibility Study,” EPA 540-R-00-002. OSWER 9355.0-75.

Attachment 1
Groundwater Investigation
Canyons Test Area, Operable Unit
1333 Burn Site, Lurance Canyon
November 2001

Sandia National Laboratories/New Mexico

GROUNDWATER INVESTIGATION CANYONS TEST AREA, OPERABLE UNIT 1333 BURN SITE, LURANCE CANYON

November 2001

Pgs. 108

Environmental
Restoration
Project

United States Department of Energy
Albuquerque Operations Office

EXECUTIVE SUMMARY

This investigation was performed to determine the role that bedrock plays in the movement of groundwater and contaminants at the Burn Site. The Burn Site is located within the Canyons Test Area, Operable Unit 1333, in Lurance Canyon. Fifteen Solid Waste Management Units (SWMUs) are located at the site, each of which is associated with high-explosives testing and burn testing. Groundwater beneath the site has been contaminated by volatile organic compounds (VOCs), diesel-range organic (DRO) compounds, and nitrate. The VOC and DRO compounds are attributed to spills of jet fuel. The source of the nitrate is unknown.

The saturated zone beneath the Burn Site is contained within an assemblage of fractured, Precambrian igneous and metamorphic rocks. These rocks occur on the north flank of the granitic Manzanita pluton, which was intruded 1.65 billion years ago (Ga) into a sequence of 1.7-Ga volcanics, shales, and sandstones during a northwest-directed, regional compressive and metamorphic event. The entire sequence was further deformed and metamorphosed during a second northwest-directed compressive event at 1.4 Ga. Erosion during the next billion years removed some 4 to 9 miles of rock and produced a beveled surface of low elevation. Regional subsidence 300 million years ago (Ma) permitted Pennsylvanian seas to transgress the terrain and deposit the Sandia Formation (mainly sandstone) and Madera Group (mainly limestone and sandstone) on the beveled Precambrian surface. Early Tertiary, Laramide northeast-directed compression and uplift at >40 Ma had an effect on the rocks but to an unknown extent. Regional late Tertiary, west-east tension beginning about 26 Ma opened the Rio Grande rift and developed a sequence of generally north-trending normal faults in the Burn Site area. Cliff retreat from west to east and entrenchment and partial backfilling of canyons resulted in the present topography of the Manzanita Mountains and the Burn Site.

Since 1986, one water supply well (Burn Site Well), three groundwater monitoring wells (CYN-MW1D, CYN-MW3, and CYN-MW4), and two piezometers (12AUP01 and CYN-MW2S) have been installed at the Burn Site. A surface spring (Burn Site Spring) and a probably obliterated spring ("Hidden Spring") complete the groundwater data set.

The subsurface data indicate that the groundwater system at the Burn Site is confined by an aquitard of Precambrian rocks characterized by healed fractures. It is speculated that the sealing occurred during a period when the groundwater flowed at a higher elevation, prior to incision of the Rio Grande sometime before 620 thousand years ago.

Because the aquifer is confined, contaminants must reach the groundwater via a breach or breaches in the aquitard. Surface geologic mapping indicates that a north-south, down-to-the-east normal fault passes a short distance west of the Burn Site Well and CYN-MW4. Stratigraphic evidence suggests that the fault cuts both wells. This "Burn Site fault" and its splays are interpreted to provide the conduits through which surface contamination reaches the aquifer.

Groundwater at the Burn Site generally flows to the west. Trace amounts of ethylbenzene, toluene, and xylene were encountered in CYN-MW1D, the most downgradient well. Its source is believed to be SWMU 94F, an unlined open pit located west of the Burn Site fault, used to collect wastewater from burn tests of jet fuel composition 4. A probable splay of the Burn Site fault passes through the Precambrian bedrock at the base of the pit. Each of the three monitoring wells encountered DRO compounds. The source is interpreted to be leaking underground piping of jet fuel composition 4 at SWMU 94F, located just west of the Burn Site fault. Three of the four wells encountered nitrate in excess of the drinking-water standard of 10 milligrams per liter. The conduit is interpreted to be the Burn Site fault but the source of the nitrate is unknown.

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ACRONYMS AND ABBREVIATIONS

ARCH	air-rotary casing-hammer
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylene
DOE	U.S. Department of Energy
DRO	diesel-range organics
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ERCL	ER Chemistry Laboratory
FY	fiscal year
Ga	billion years
GEL	General Engineering Laboratory
GWQB	Ground Water Quality Bureau
JP-4	jet fuel composition 4
JP-8	jet fuel composition 8
Ka	thousand years
L	liter(s)
LAARC	Light Airtransport Accident Resistant Container
µg	microgram(s)
Ma	million years
MCL	Maximum Contaminant Level
mg	milligram(s)
MNA	monitored natural attenuation
NMED	New Mexico Environment Department
OU	Operable Unit
pCi	picocurie(s)
ppm	part(s) per million
QC	Quality Control
SNL/NM	Sandia National Laboratories/New Mexico
SWMU	Solid Waste Management Unit
TD	total depth
USGS	U.S. Geological Survey
VCA	Voluntary Corrective Action
VOC	volatile organic compound

1.0 INTRODUCTION

This report describes the role that the bedrock plays in the movement of groundwater and contaminants in the subsurface of the Canyons Test Area, Operable Unit (OU) 1333 at Sandia National Laboratories/New Mexico (SNL/NM). This study avoids the type of operational and surface-analysis detail presented in the other reports and focuses instead on surface and subsurface hydrogeological data. Site-specific information can be found in the following reports: SNL/NM September 1999 and SNL/NM March 2001. The published geological literature, some of very recent vintage, provides adequate source material for the generation of bedrock-geologic and groundwater-flow conceptual models (e.g., Brown et al. 1999, Cavin et al. 1982, Karlstrom et al. 1994, Myers and McKay 1970, and Titus 1980).

The Canyons Test Area embraces three large canyons in the Manzanita Mountains (Madera Canyon from the north, Sol se Mete Canyon from the south, and Lurance Canyon from the east) (Figure 1-1). The canyons channel the headwaters of the Arroyo del Coyote. The land has been withdrawn from the U.S. Forest Service and permitted to the U.S. Department of Energy (DOE). The Burn Site is located in OU 1333 within Lurance Canyon (Figure 1-2). Coyote Springs Road follows the drainage of Arroyo del Coyote and provides access through Lurance Canyon to the Burn Site. The Burn Site is located on the alluvial and colluvial fill of the narrow canyon. The canyon walls are moderately steep and consist of Precambrian metamorphics and igneous rocks to the north and south and Pennsylvanian sedimentary rocks to the east.

The Burn Site is one of six test sites and is considered a potential source for groundwater contamination known to be present at the Burn Site and at the eastern portion of Lurance Canyon. There are 18 SWMUs at the Burn Site: SWMU 65 "A" through "F," and SWMU 94 "A" through "H," 10, 12A, 12B, and 13 (Figure 1-2). Each SWMU is associated with high-explosives testing and burn testing.

Open, high-explosives testing mainly took place between 1967 and 1975 and was completely phased out by the early 1980s. Burn testing began in the early 1970s. The early tests were conducted in open excavated pits, and by 1975 portable burn pans were used for open burning with jet fuel composition 4 (JP-4). SWMU 94F (the Light Airtransport Accident Resistant Container, or LAARC Unit), was constructed around 1980 and engineered burns were conducted until 1983 (Figure 1-2). Wastewater discharge from the LAARC into an unlined pit (SWMU 94F) is suspected to be a source of groundwater contamination at the Burn Site. In August 2000, a spill-site of jet fuel composition 8 (JP-8), SWMU 94H, was discovered (Figure 1-2). Samples were collected from the base of the excavation during a piping upgrade in October 2000 that verified contamination in the soil from leaking underground pipes. However, soil samples collected from the excavation showed that the fuel contamination was of limited extent and did not reach the underlying bedrock.

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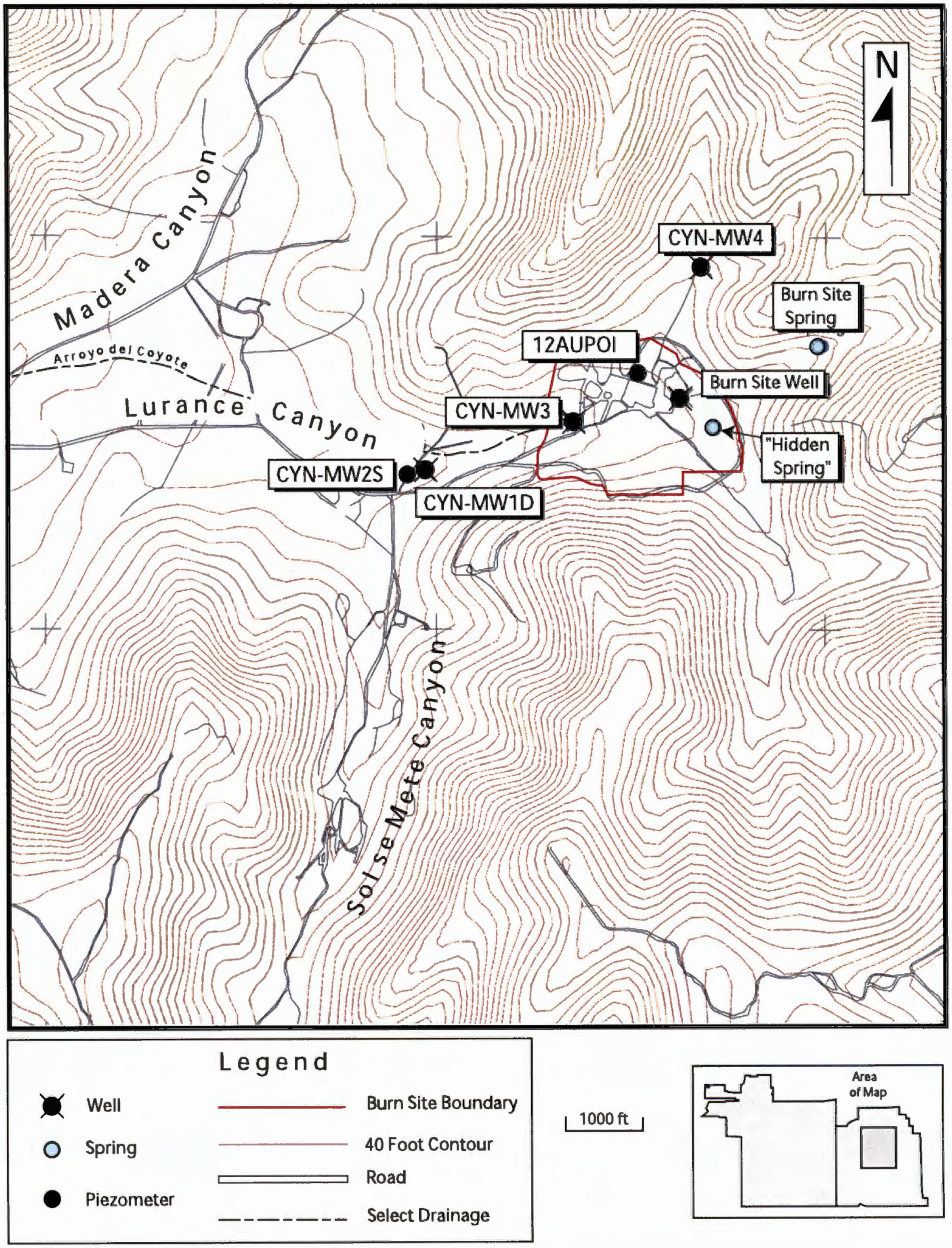

Figure 1-1. Index Map of Canyons Test Area

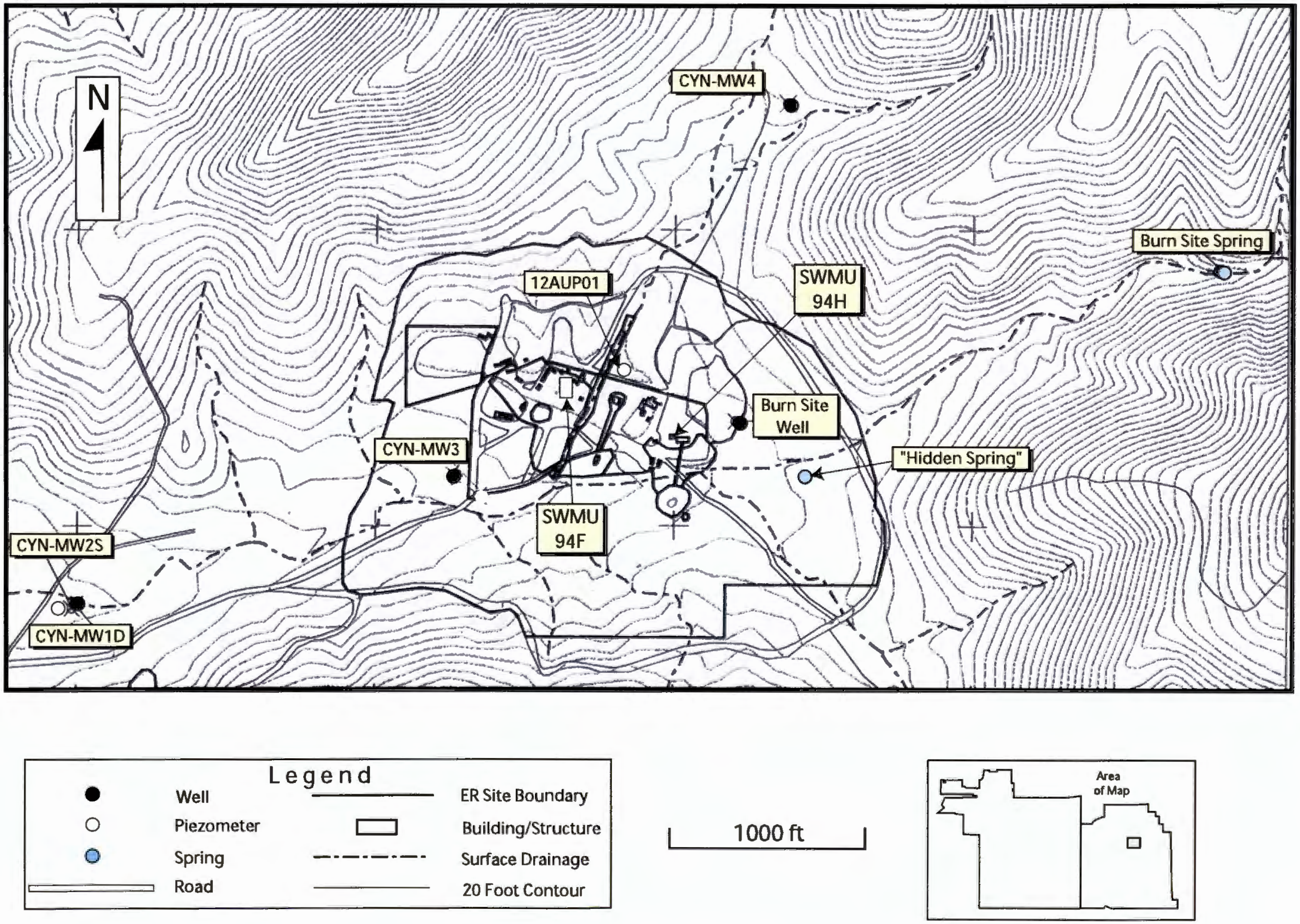

Figure1-2. Index Map of Burn Site

2.0 BEDROCK GEOLOGY

2.1 Bedrock Control

Surface bedrock control is documented on the geologic map of the Tijeras Quadrangle recently published by the New Mexico Bureau of Mines and Mineral Resources (Karlstrom et al. 1994, modified in 1999). This map has replaced the geologic map of portions of the Tijeras and Sedillo Quadrangle by Myers and McKay (1976). The Burn Site is located near the southeastern corner of the Tijeras Quadrangle. Geologic context south of the Burn Site is provided by the geologic map of the Mount Washington Quadrangle (Myers and McKay 1970). A conceptual geologic model of the Precambrian geology is provided by Brown et al. (1999). Subsurface geologic control was determined from data collected during installation and sampling of four wells and two piezometers (Figure 1-1).

2.2 Bedrock Units

The Manzanita Mountains are underlain by a complex sequence of Precambrian igneous and metamorphic rocks, unconformably capped by Pennsylvanian-age sedimentary rocks. The basal Pennsylvanian unit is the Sandia Formation, a slope-forming sequence of olive-drab micaceous siltstone, sandstone, and conglomerate. It ranges in thickness from 100 to 320 feet and averages about 200 feet (Myers 1982). Lying conformably above the Sandia is the Madera Group. The lowermost formation of the group (Los Moyos Formation) is a 350-foot-thick sequence of cliff-forming beds of gray limestone, which forms the heights to the north, east, and south of the site. The highest elevations of the Manzanita Mountains are underlain by younger formations of the Madera Group, which consist of sandstones, siltstones, shales, and limestone. Fractured Precambrian rocks contain the groundwater aquifers at the Burn Site and these units are therefore the focus of this report.

2.3 Precambrian Bedrock Conceptual Model

The model adhered to in this report is that of Brown et al. (1999). Their paper resolved a dilemma produced by the earlier map of Myers and McKay (1970). The 1970 map described most of the Precambrian igneous rocks cropping out south of Arroyo del Coyote as a 14,000-foot-thick sequence of schistose to gneissic metarhyolite. Brown et al. (1999), however, reinterpreted the "metarhyolite" as a strongly deformed granite, the "Manzanita pluton," and devised an emplacement and regional deformation model to embrace the entire Precambrian sequence of the Manzanita Mountains.

Karlstrom et al. (1994) differentiate between the Manzanita granite and the much less voluminous, Cibola granite. The latter is in part intimately associated with the north and south margins of the Manzanita granite and is coeval with it. This investigation includes the two as one granite body in the area of the Burn Site and the Cibola granite as a separate, discrete unit only to the north where it is more extensive.

Figure 2.3-1 is a simplified geologic map of the bedrock exposures relevant to the Burn Site that surround the northern and northeastern part of the Hubbell Bench, a structural level intermediate between the Manzanita Mountains to the east and the Albuquerque basin to the west. In order to illustrate the Precambrian geology, it is necessary to "remove" the Pennsylvanian and alluvial cover. This step (Figure 2.3-2) requires considerable interpretation

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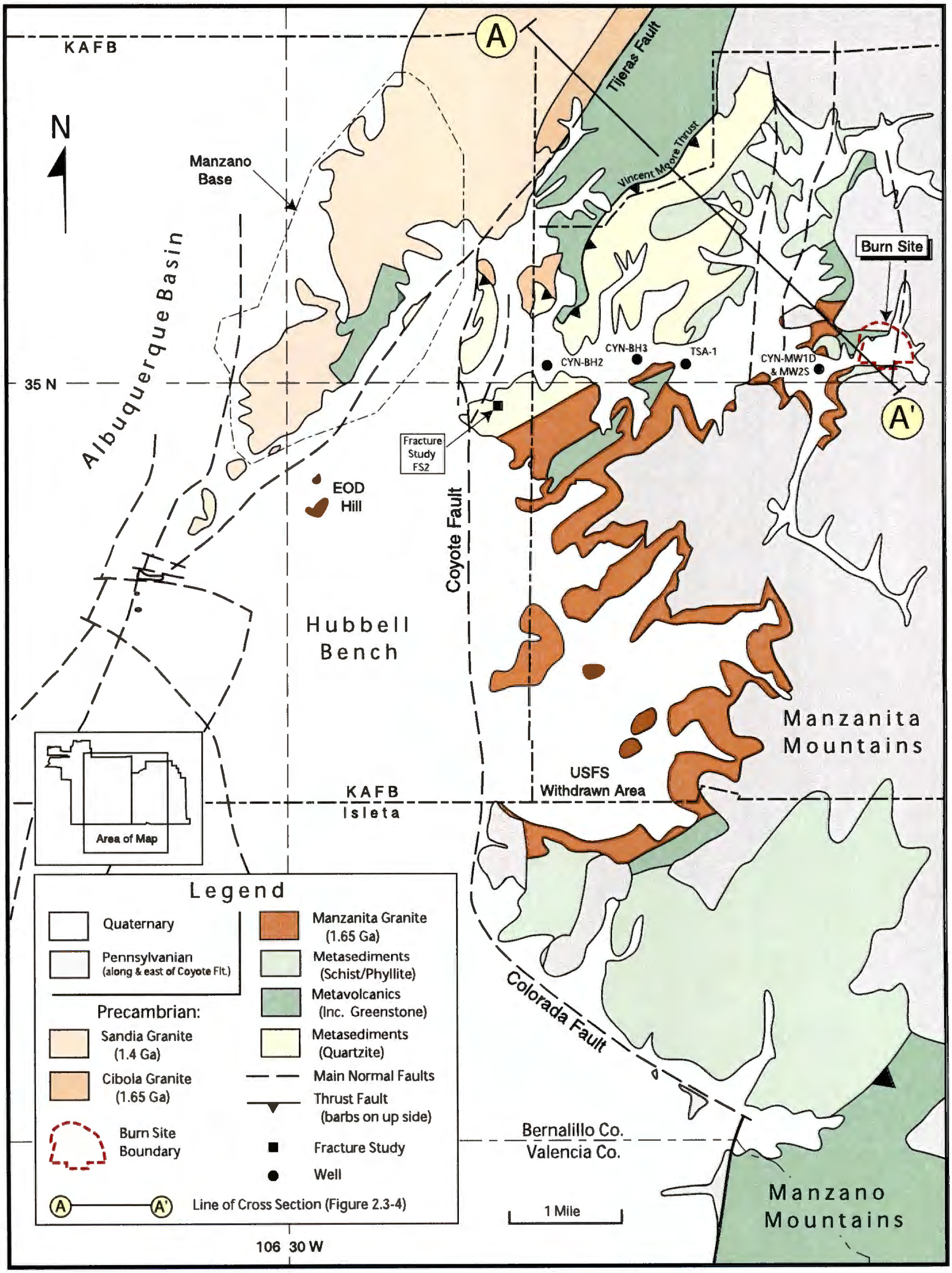

Figure 2.3-1. Simplified Geologic Map, Northern Part of Hubbell Bench
(modified from Karlstrom et al. 1994; Myers & McKay 1970)

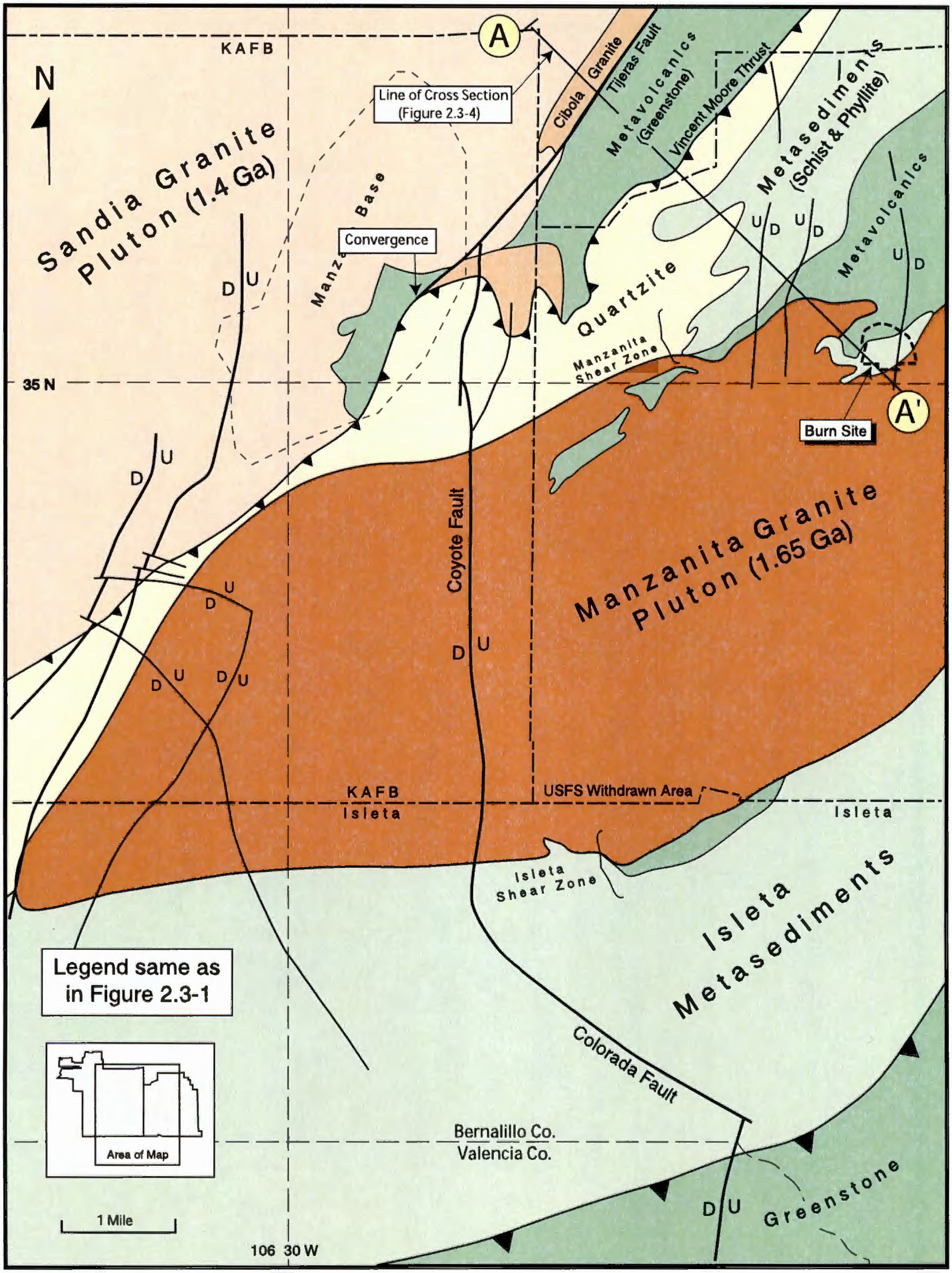

Figure 2.3-2. Interpreted Precambrian Geology

but the task is guided by the Brown et al. (1999) conceptual model. The Tijeras fault and the Vincent Moore thrust are shown to occupy the same trace to the west in Figure 2.3-2. This is highly speculative and based upon the apparent convergence of the two to the southwest in Figure 2.3-2.

Figure 2.3-3 (A-C) is a modification of the Brown et al. (1999) model. It depicts three stages of Precambrian structural deformation. First (Figure 2.3-3A), a 1.7-billion-year- (Ga-) old sequence of sedimentary and volcanic rocks was deformed via compression and overthrusting of about 1.65 Ga, followed by continued deformation and regional metamorphism. The northwest-directed compression created a component of relative low confining pressure normal (southwest-northeast) to the principal stress axis. This permitted magma to intrude the zone at a depth of some 4 to 9 miles below ground surface (bgs) (Figure 2.3-3B). Deformation intensified as intrusion of the pluton progressed and the surrounding country rocks were thermally softened. About 1.4 Ga, a second northwest-directed compressive event resulted in renewed thrusting and emplacement of the Sandia pluton to the north, in a manner similar to that of the Manzanita pluton 250 million years (Ma) earlier (Figure 2.3-3C).

The multiple tectonic events have highly deformed the northern and southern margins of the Manzanita pluton and the surrounding rock. These "shear zones" are up to a mile wide and are termed the Manzanita and Isleta shear zones, respectively. In the Manzanita shear zone the granite has in places suffered a significant reduction in grain size and has understandably been described as metarhyolite (Myers and McKay 1970), and in places has a flow-banded gneissic fabric. The gross nature of the zone is that of a complex contact between the Manzanita granite and country rock and is characterized by masses of greenstone and metasediments (e.g., schist and phyllite) that are completely enveloped by the granite (Brown et al. 1999). In short, the Manzanita pluton and its enclosing rocks collectively constitute part of an exhumed mid-crustal, ductile mega-shear zone.

A billion years of uplift and erosion resulted in a beveled surface of low elevation. Regional subsidence about 300 Ma allowed the Pennsylvanian seas to transgress over the low-relief Precambrian terrain and to deposit an epicontinental sedimentary sequence. The area was uplifted again during the northeast-directed Laramide compressive event >40 Ma (May et al. 1994). Figure 2.3-4 is a northwest-southeast cross section from the Sandia granite outcrop to the Burn Site area, showing the nature of the Precambrian structure surrounding the site.

By 26 Ma, regional tension was initiated by plate-tectonic effects propagating eastward from the western margin of the North American continent. The tension was accommodated in New Mexico by clockwise rotation of the Colorado Plateau away from the Stable Interior, the resultant opening of the Rio Grande rift, and the lowering of erosional base level for the flanking uplands. Subsequent cliff retreat to the east across the Hubbell Bench resulted in the present architecture of the Manzanita Mountains. The geometry of the west-east rift-related foundering of the Precambrian basement and its Phanerozoic cover was in part influenced by the Precambrian and Laramide structural grains, but many north-south trending normal faults sliced across the grain of diverse rock suites at high angles (Figure 2.3-2). Figure 2.3-5 is a portion of the most recent published geologic map (Karlstrom et al. 1994), and Figure 2.3-6 is the derivative interpreted bedrock geologic map, with the Pennsylvanian and Quaternary units removed. The site outline, wells, and Burn Site Spring have been superimposed onto the geologic map.

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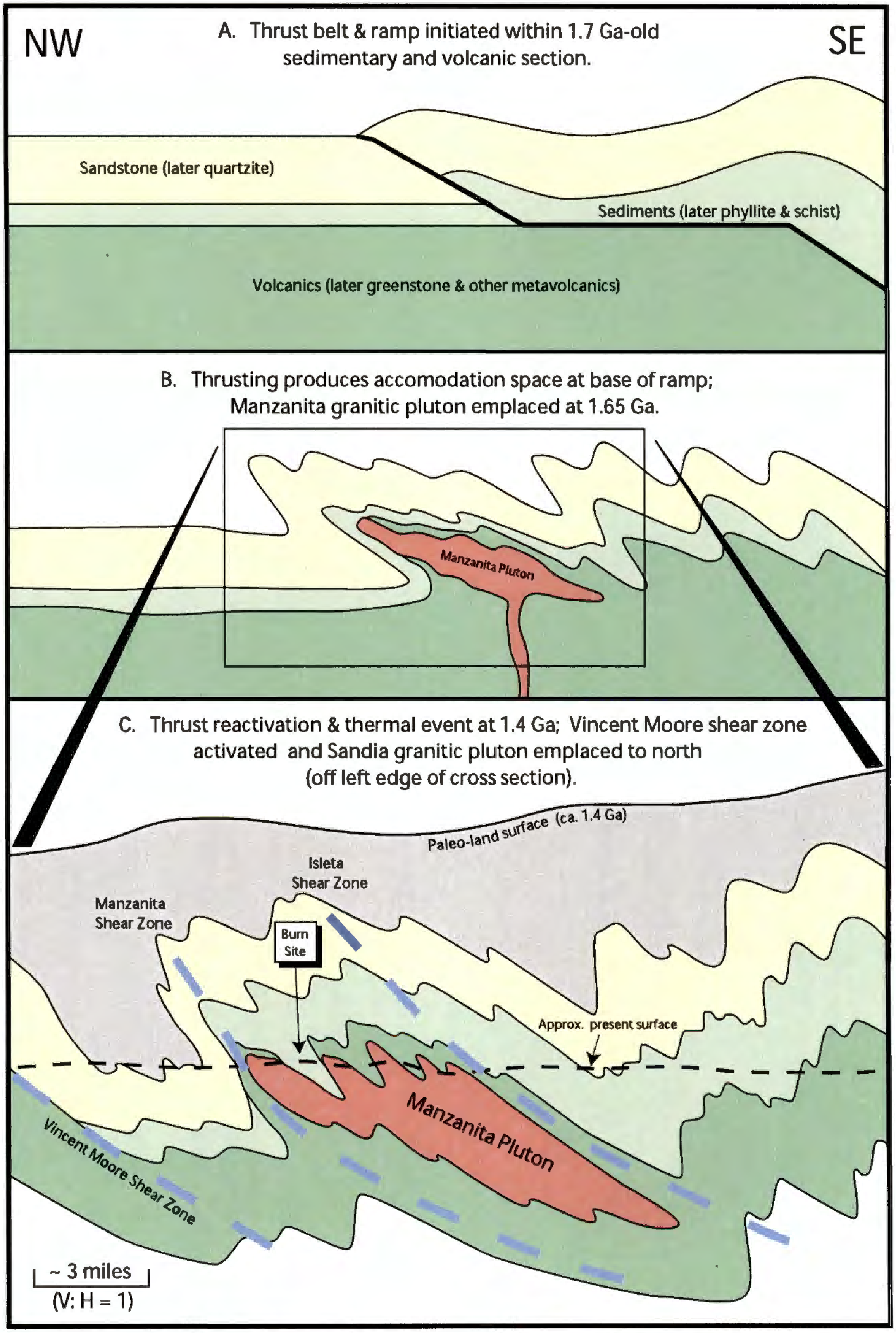

Figure 2.3-3. Schematic Summary of Precambrian Tectonic Events, Manzanita Mountain Area (modified from Brown et al. 1999)

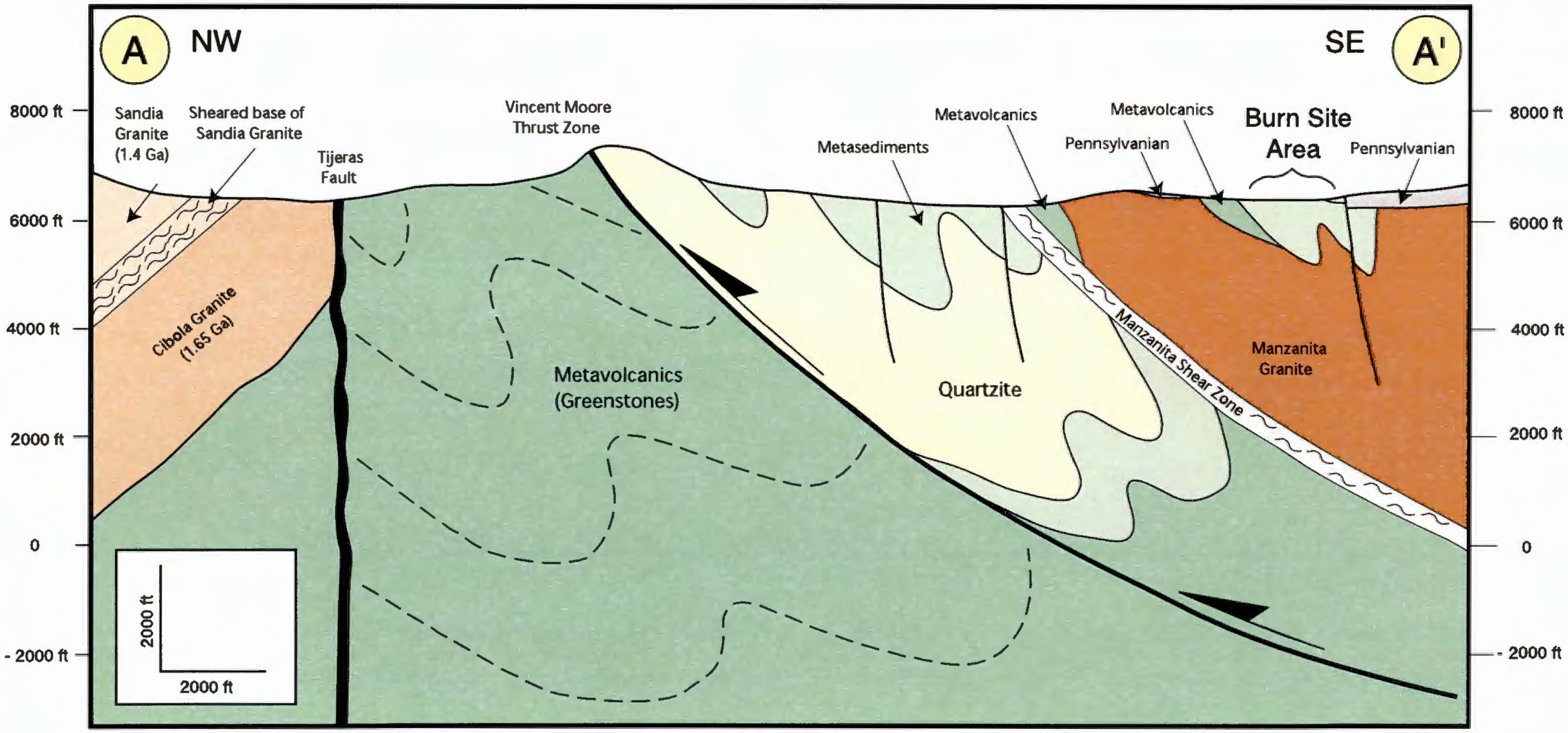

Figure 2.3-4. Regional Northwest-Southeast Cross Section A-A'

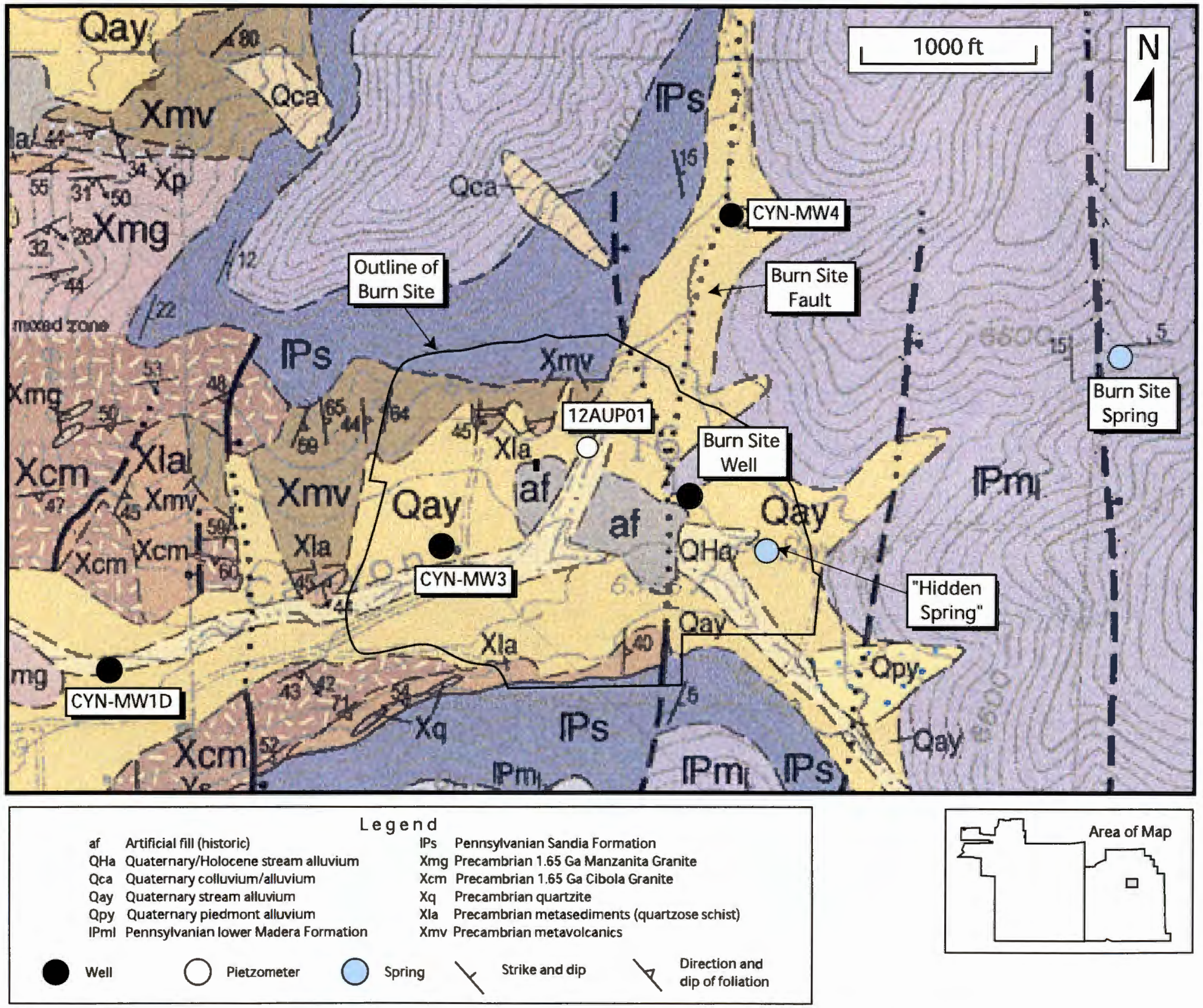

Figure 2.3-5. Surface Geology of the Burn Site (from Karlstrom et al. 1994)

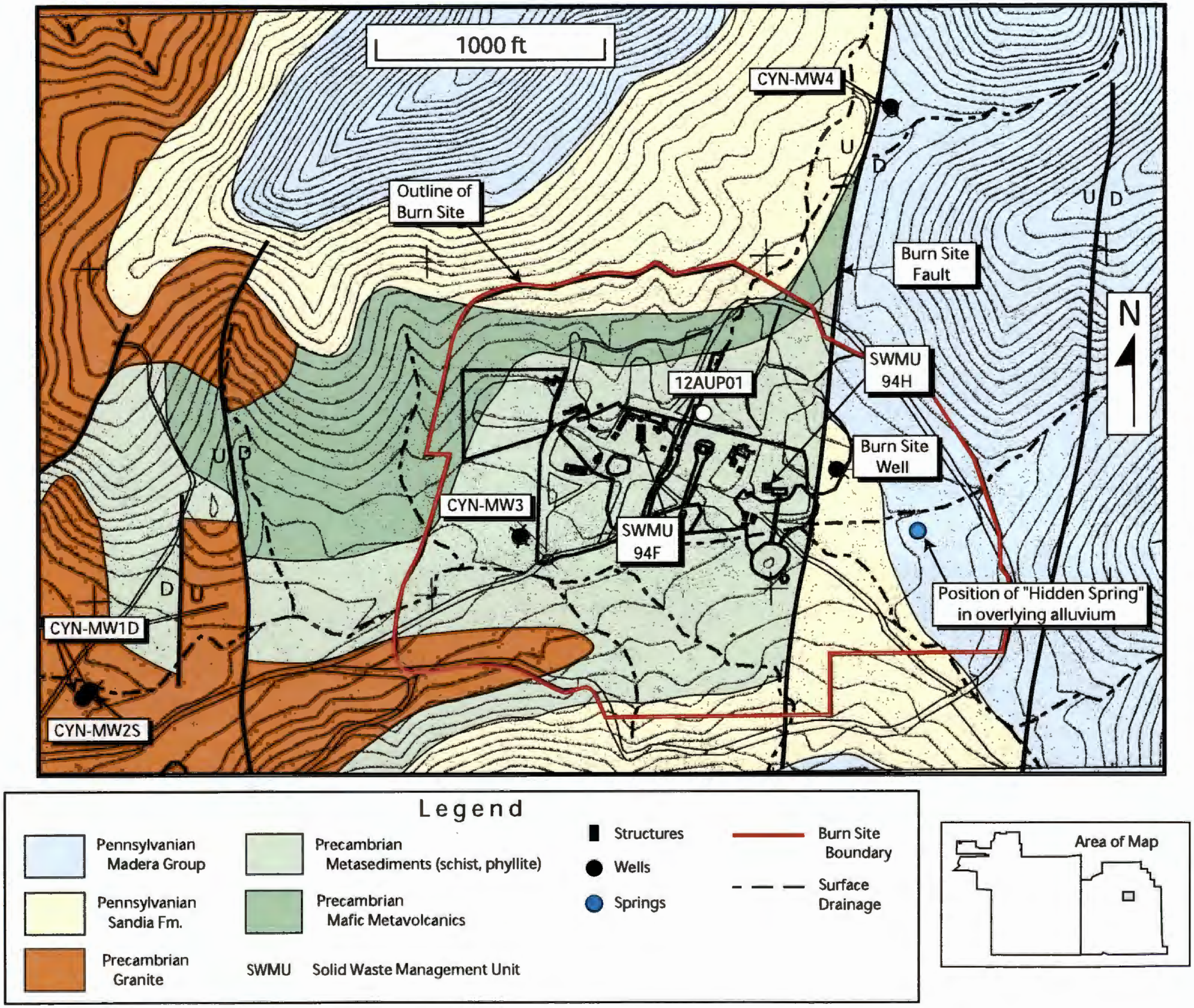

Figure 2.3-6. Bedrock Geology of the Burn Site (based on Karlstrom et al. 1994)

2.4 Bedrock Geologic Control Points in the Burn Site Area

Six subsurface groundwater control points, and at least one and probably two surface control points, exist in the vicinity of the Burn Site. The subsurface points include four wells (Figure 1-2 and Figure 2.4-1): 1) the Burn Site well installed in 1986 for fire control; 2) monitoring well CYN-MW1D, a downgradient long-stepout (1500 feet) from the Burn Site Well, installed in 1997; 3) monitoring well CYN-MW3, a downgradient short-stepout from the Burn Site Well, installed in 1999; and 4) monitoring well CYN-MW4, an upgradient "background" well, also installed in 1999. The subsurface control also includes two piezometers: 1) 12AUP01 installed in 1996, a short distance WNW of the Burn Site Well; and 2) CYN-MW2S, installed in 1997, a few feet from the CYN-MW1D well (Figure 1-2). The piezometers were intended to detect any groundwater flow at the alluvium/Precambrian bedrock interface. One surface groundwater control point is Burn Site Spring, located up in the hills about 2,500 feet east of the Burn Site Well (Figures 1-2 and 2.3-5).

In 1996, elevated nitrate readings of about 25 milligrams (mg) per liter (L) were first encountered in the Burn Site Well. CYN-MW1D was installed late the next year to determine the extent of the potential contamination. This monitoring well found nitrate levels up to 20 mg/L and detectable levels of petroleum hydrocarbons. The downgradient well CYN-MW3 and upgradient well CYN-MW4 were installed in 1999 to better define the nature and extent of the contamination at the site.

The following sections provide more details of individual control points and data collected from these wells.

2.4.1 Burn Site Well

The Burn Site Well was drilled in February 1986 in the drainage of the Arroyo del Coyote by Rodgers and Company Inc. to a total depth of 350 feet bgs (Figure 2.4-1). The purpose of the Burn Site Well was to provide a source of nonpotable water for fire suppression during burn tests. The base of the alluvium occurs at 29 feet. The rocks between 29 and 74 feet were logged as light red shale, brown siltstone, and soft gray shale, quite unlike Precambrian lithologies. Below 74 feet, the rocks are undoubtedly Precambrian and consist mainly of gray mica schist to 178 feet, gray granite to 199 feet, mainly gray mica schist to 222 feet, hard, fractured schist to 260 feet, and fractured granite to total depth (TD) of 350 feet bgs. The geologic map (Karlstrom et al. 1994) shows an unnamed, north-trending, down-to-the-east normal fault that is partly obscured by alluvium and passes approximately through the well site (Figure 2.3-5). (Note: this fault is interpreted to be important in understanding the Burn Site and it is cited several times in this report. For convenience, it will be referred to as the Burn Site fault.)

Bedrock mapping (Figure 2.3-6) indicates that Pennsylvanian-age sedimentary rocks and Precambrian phyllite/schist should exist on the eastern, downthrown and the western, upthrown blocks, respectively. Furthermore, the well site appears to be located very close to the base Madera Group/top Sandia Formation contact. The average thickness of the Sandia Formation in the area is about 170 feet in the Tijeras Quadrangle (Karlstrom et al. 1994) to 200 feet in the general Manzanita Mountain area (Myers 1982). Based upon these figures, the interpretation is that the sedimentary rocks between 29 and 74 feet belong to the Sandia Formation in the downthrown block (east), part of the Madera Group and all of the Sandia Formation are faulted out at 74 feet, and the Precambrian rocks from 74 feet to TD are in the upthrown block (west).

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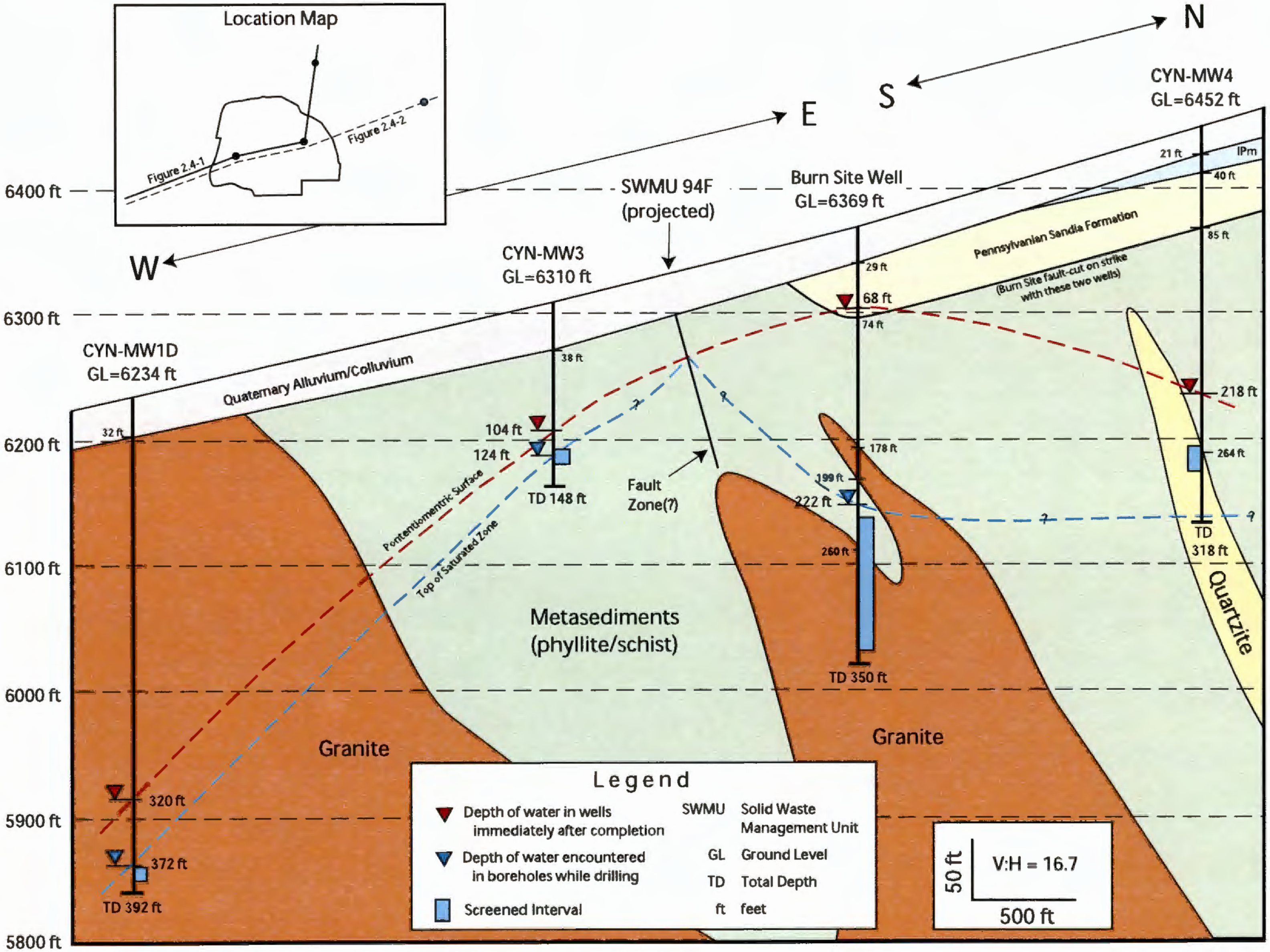

Figure 2.4-1. Schematic Groundwater Control-Point Comparison Across Burn Site: CYN-MW1D to CYN-MW4

Water-bearing fractures were encountered from 222 feet to 350 feet (TD). Prior to completion on February 20, 1986, groundwater had risen to a depth of 68 feet in the borehole, indicating confined conditions and, more importantly, that the section between 29 and 222 feet acts as an aquitard. The interval 231–341 feet (110 feet) was screened. Lack of an access port for the water-level sounder has precluded any subsequent water-level measurements in this well.

2.4.2 CYN-MW1D

Two attempts were made to install a 5-inch monitoring well about 3400 feet downgradient (south southwest) from the Burn Site Well. The objective of the well was to determine the extent of the potential contamination (volatile organic compounds [VOCs], diesel-range organics [DRO], and nitrates). Steward Bros., Inc. drilled the well using the air-rotary casing-hammer (ARCH) method. The first attempt in November 1997 met drive-casing refusal at 25 feet. The bit was advanced to 50 feet but serious borehole deviation forced abandonment of the hole. The second attempt in December encountered the base alluvium/top Precambrian "granite gneiss" at 32 feet (Figure 2.4-1). Brown et al. (1999) state that at least the northwestern part of the 1.65 Ga Manzanita pluton in the Lurance Canyon area is indeed granite that has experienced a significant reduction in grain size via crushing after emplacement. The well was drilled to a TD of 392 feet bgs in granite. Groundwater was encountered while drilling at 372 feet. The water level subsequently rose to a level of 320 feet. A 10-foot screen was placed over the interval 372-382 feet.

2.4.3 CYN-MW3

This 5-inch monitoring well was installed in June 1999 about 1400 feet downgradient (south southwest) from the Burn Site Well and 2000 feet upgradient from CWN-MW1D (Figure 2.4-1). It was drilled by Water Development Co. via the air-rotary/Strat-X method. The base alluvium/top Precambrian was logged at 38 feet and casing refusal occurred at 40 feet. The well was drilled to a total depth of 148 feet in phyllite schist. Groundwater was encountered while drilling fractured schist at 124 feet. The water level subsequently rose to 104 feet in the well. A 10-foot screen was placed over the interval 120-130 feet.

2.4.4 CYN-MW4

The final 5-inch monitoring well was also installed in June 1999 about 1,650 feet upslope (north northeast) from the Burn Site Well and was intended to be an upgradient, "background" well (Figure 2.4-1). It was drilled by Water Development Co. via the Strat-X method. The base of the alluvium was encountered at a depth of 21 feet. Pennsylvanian Madera Group limestones and sandstones occur below the alluvium from a depth of 21 to 40 feet, Pennsylvanian Sandia Formation sandstones from 40 to 85 feet, Precambrian "schist" and "schist/phyllite" from 85 to 264 feet, and fractured, brittle Precambrian quartzite from 264 to TD of 318 feet bgs. As in CYN-MW3, the Precambrian schistose rocks are likely equivalent to the gray schist seen in the bottom of SWMU 94F. The well was drilled to TD without indications of saturated conditions. However, after overnight shutdown, the water level rose to a depth of 218 feet in the borehole. The degree of fracturing in the bedrock was significantly less than in CYN-MW3; it is plausible that the top of the saturated zone was above 318 feet but that the small amount of water flowing into the borehole was not detectable while drilling. The placement of the 20-foot well screen (depth interval 260–280 feet) was based on the location of the maximum water-producing zone and prevalence of fractures within the quartzite.

The Sandia Formation is anomalously thin in Well CYN-MW4, 45 feet versus a normal of 170 to 200 feet (Karlstrom et al. 1994, Myers 1982). When CYN-MW4 is plotted on the published geologic map (Karlstrom et al. 1994) it is evident that this well, like the Burn Site Well to the south, is located just to east of the same normal, down-to-the-east Burn Site fault cited above in 2.4.1 (Figure 2.3-5). The fault is interpreted to pass through the CYN-MW4 well bore at 85 feet and to cut out 125 to 155 feet of lower Sandia Formation at the Sandia/Precambrian "contact."

2.4.5 Piezometers

Two 2-inch piezometers were installed to monitor possible groundwater flow along the sediment/bedrock interface as a possible pathway from surface-water recharge (Figures 1-2 and 2.3-6). The first, 12AUP01 (Alluvium Underflow Piezometer #01 located in SWMU 12A), was located about 750 feet WNW of the Burn Site Well. It was drilled by Stewart Bros., Inc. with a hollow-stem auger to TD of 58 feet in November 1996. The borehole encountered alluvium from the surface to a depth of 55 feet and Precambrian metasediments from 55 to 57.5 feet bgs (TD). A 5-foot screen was placed between 52.5 and 57.5 feet. No water has ever been detected in this piezometer.

The second piezometer, CYN-MW2S, was installed in December 1997 approximately 23 feet WSW of the CYN-MW1D well (Figures 1-2 and 2.3-6). It was drilled by Stewart Bros, Inc. using the ARCH method. The sediment/bedrock interface was encountered at a depth of 27.6 feet and the well was drilled to a TD of 35 feet bgs. A 5-foot screen was placed at the top of the granite over the interval of 23.6 to 28.6 feet. No water has ever been detected in this piezometer.

2.4.6 Burn Site Spring

The 1961 U.S. Geological Survey (USGS) Tijeras Quadrangle topographic 7.5-minute map shows the Burn Site Spring located up in the hills about 2500 feet east northeast from the Burn Site Well at an elevation of 6,545 feet (Figures 2.3-5 and 2.4-2). The 1990 USGS Tijeras map shows the spring at the same location but with another name, "Lurance Spring." For convenience, this feature will be referred to as the "Burn Site Spring" in this report. A small volume of water issues from this ephemeral spring from bedding planes in the limestones of the Pennsylvanian Madera Group along the flanks of the drainage course. On the north side a 1-foot square concrete cistern is filled with 2 feet of water that sometimes overflows the rim of the cistern at a low rate. An adjacent clump of wet soil is thickly grassed over. About 25 feet up the bank slope north of the cistern is an outcropping ledge of Madera limestone, about 15 feet high, with a section of overhang perhaps 15 feet wide from west to east. The roof of the overhang is thoroughly blackened by countless fires and the spring has evidently been accessed for a very long time. On the south side, a short distance downstream, a derelict pair of pipes embedded in a clump of wet soil once fed a concrete trough and a few low areas in the stream bed, all of which at one time provided water for wildlife, but not anymore.

A normal, north-south, down-to-the-east fault occurs about 200 feet west of the spring. It is not known if the fault plays a role in producing the spring. The published geologic map (Figure 2.3-5) suggests that the amount of throw is minor and the fault is therefore not shown on the cross section (Figure 2.4-2).

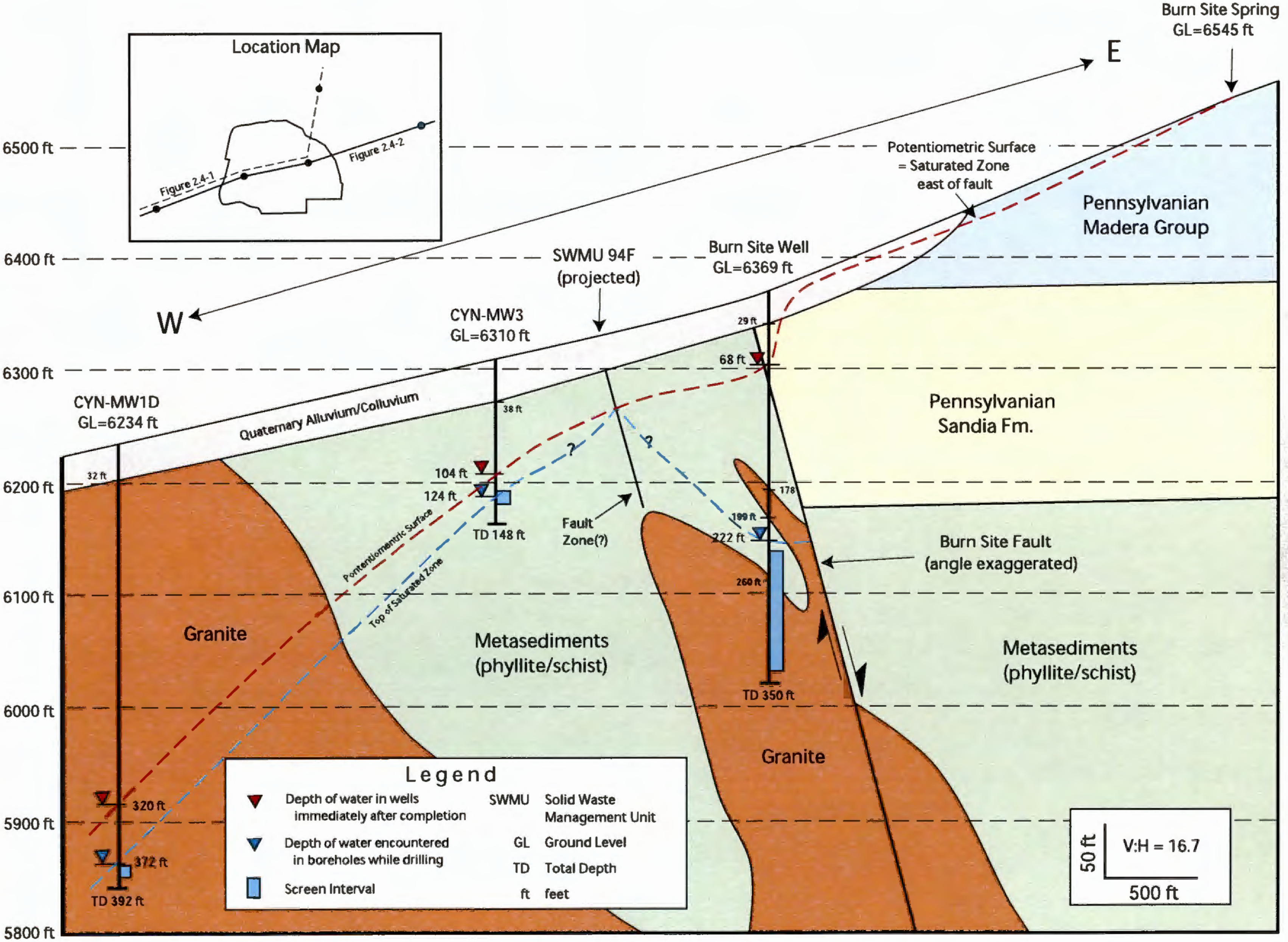

Figure 2.4-2. Schematic Groundwater Control-Point Comparison Across Burn Site: CYN-MW1D to Burn Site Spring

2.4.7 "Hidden Spring" (former spring near Burn Site Well)

The USGS Tijeras map also depicts a spring located near the present site of the Burn Site Well (Figure 2.4-3). The map shows the area prior to the construction of the Burn Site facility in 1967. The spring apparently seeped from alluvium. A comparison of the 1961 and present site maps indicates that the spring was located about 500 feet southeast of the well (Figure 2.4-3). For convenience, this feature will be referred to as "Hidden Spring" in this report.

2.5 Geologic Discussion

To understand this situation, it is necessary to place Lurance Canyon in its regional context. Pazzaglia et al. (1999) explain the origin of the piedmont on the west flank of the Sandia Mountains and their ideas are relevant to the stream courses and piedmont of the Manzanitas. The Sandia piedmont owes its origin to both tectonic and climatic events. The Sandias, however, are a Miocene-Pliocene uplift. The Manzanitas, on the other hand, were last uplifted during the Laramide about 40 Ma (May et al. 1994), and its piedmont is likely more the result of nontectonic, hydrologic, and climatic changes. Pazzaglia et al. (1999) propose that the first critical event occurred about 800 thousand years (Ka) ago during the middle Pleistocene. That point marks the onset of large-scale glaciation in North America and the beginning of large-amplitude, 100 Ka glacial-interglacial cycles. Prior to that time, the mountain slopes were subject to a greater degree of weathering than today. The hillslopes were blanketed by a significant thickness of soil and deeply weathered bedrock. The weathered material remained on the slopes and supported perennial streams draining the heights, and the sediment-limited streams cut valleys into the bedrock.

After about 800 Ka, the 100 Ka glacial-interglacial climate cycles and monsoonal rains limited deep weathering and favored stripping of the soil cover. As soil was removed, the mode of water runoff changed from subsurface to overland flow. The increased sediment supply allowed stream courses to become backfilled, and the increasingly ephemeral drainage caused alluvial fans to be deposited on the piedmont. As the soil was stripped down to the bedrock roots of the pre-middle Pleistocene weathering profile, the sediment supply became coarser, thus explaining the upward-coarsening profiles commonly seen in the piedmont deposits.

A second crucial, hydrologic event accelerated the above changes taking place. At about 620 Ka, the Ancestral Rio Grande captured the drainage of the San Luis basin of northern New Mexico and southern Colorado. The addition of the Colorado mountain runoff vastly increased the Rio Grande's discharge and promoted the incision of the valley and the resulting dramatic lowering of base level. Added to these events was the local drying-out of the climate during the 10 Ka of the Holocene.

With this setting in mind, Figure 2.4-1 is presented as a cross section that connects the four groundwater wells in the order of increasing surface elevation, and Figure 2.4-2 is a cross section that ties three of the four wells to the Burn Site Spring. The figures reveal two highly significant facts:

1. The difference between the top of the current potentiometric surface and top of the groundwater encountered during drilling (saturated zone) represents an interval that can be interpreted as a nonpermeable aquitard due to lack of fractures or to healed fractures.

   A preliminary characterization of surface fractures was performed at several sites in 1994/95 during the Site-Wide Hydrogeologic Characterization Project

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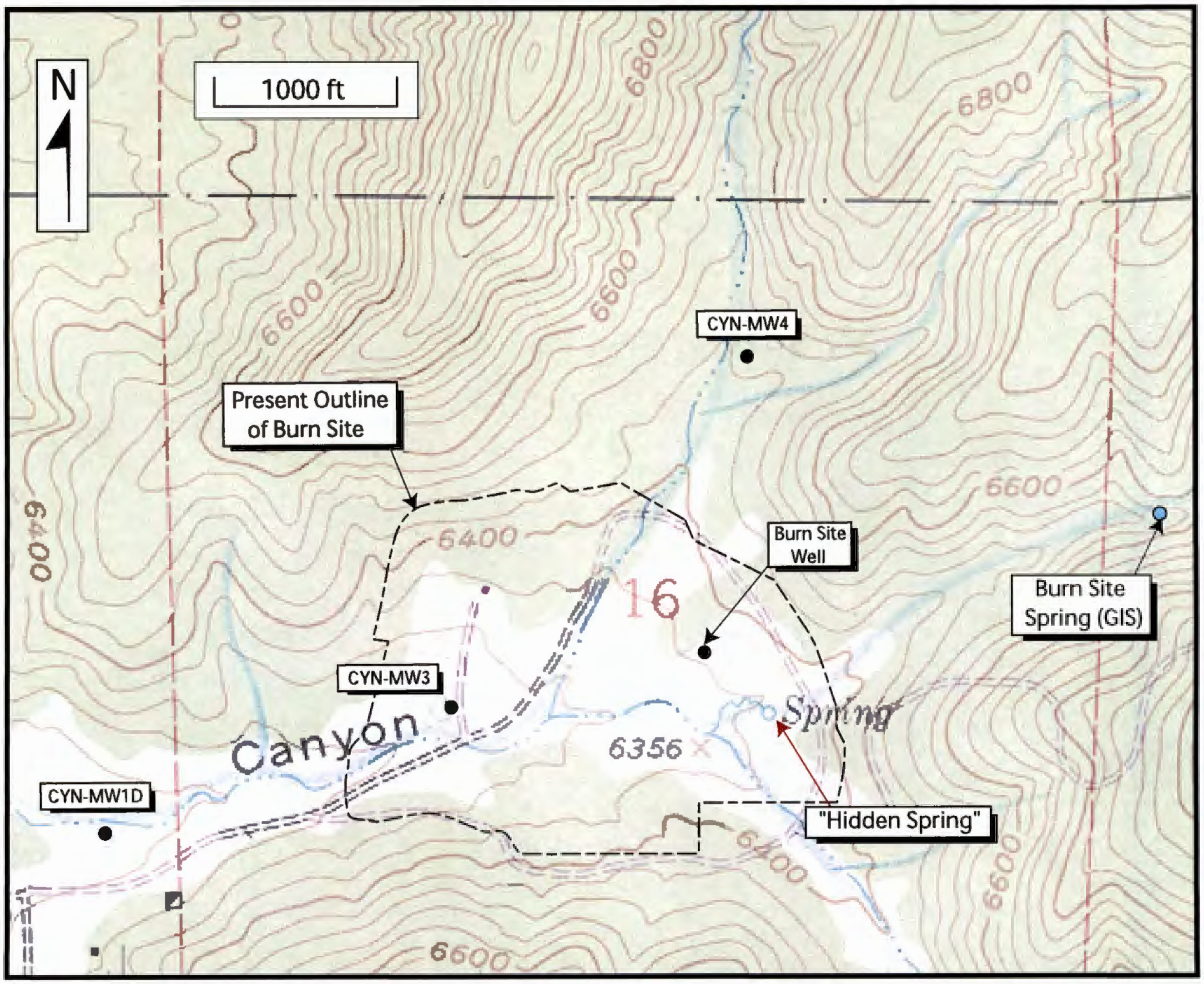

Figure 2.4-3. Portion of 1961 USGS Tijeras Quadrangle 7.5' Topographic Map Showing Location of Spring (red arrow) near Burn Site Well
(referred to as "Hidden Spring" in this report)

(SNL/NM 1996, p. 2-108). The nearest locality to the Burn Site was in a Precambrian quartzite outcrop near the mouth of Lurance Canyon (Figure 2.3-1). The outcrop had two fracture orientations, northwest and northeast, and all were open and uncemented by calcium carbonate. However, this outcrop is more than 10 feet higher than the active Arroyo del Coyote and the degree of noncementing is probably not representative of subsurface conditions.

The top of the saturated zone today is below the base of the alluvium that fills the stream courses in Lurance Canyon (CYN-BH2, CYN-BH3, TSA-1, CYN-MW1D, CYN-MW2S, and 12AUP01, Figure 2.3-1). (Coyote Springs, where groundwater issues from alluvium, is located west of the mouth of the canyon and water probably rises up along a splay of the Coyote fault.)

As mentioned earlier, groundwater flow prior to the Holocene was at a shallower level than today and calcium-rich groundwater had ample opportunity to cement shut the upper zone of bedrock fractures, thus producing an effective aquitard for the present system.

Given that the aquitard interval is capable of confining water under pressure, it is unlikely to allow contaminants to penetrate through it to the saturated zone. It follows that, assuming that groundwater samples were not contaminated during the sampling process, the contaminants reached the groundwater via a breach in the aquitard.

On April 20, 2000, a preliminary inspection of the excavated SWMU 94F was made (Figure 2.4-4). A zone of crushing, trending roughly north-south and dipping east at a high angle (>60°) and indicating a possible fault zone, was visible near the bottom of the excavation, which may have compromised the integrity of the aquitard. The zone was friable and the bedrock was contaminated (>1000 parts per million [ppm] total petroleum hydrocarbons). Prior to removal of approximately 1000 cubic yards of petroleum-contaminated soil from SWMU 94F, this conduit could have allowed contaminants to migrate to groundwater and to flow downgradient to CYN-MW3 and CYN-MW1D. The current conceptual model hypothesizes that if this potential conduit connects to groundwater, the potentiometric surface and the saturated zone must come together at this point. This possibility is schematically shown on Figures 2.4-1 and 2.4-2.

2. CYN-MW4, although topographically updrainage from the Burn Site Well, is downgradient on the potentiometric surface (Figure 2.4-1). The elevation of the saturated zone in the Burn Site Well is +6147 feet (222 feet bgs). CYN-MW4 was drilled to total depth of 318 feet bgs, an elevation of +6134 feet, with no trace of groundwater. However, as noted previously, the water rose in the hole overnight to a depth of 218 feet bgs. The quartzite (264 to 318 feet TD) exhibited a very low degree of fracturing and the unit simply might have been unable to yield water from the saturated zone in detectable amounts while drilling. It is difficult to accept the notion that the zone of saturation occurred exactly at the bottom of the hole but it could be close. In either case, the saturated zone in CYN-MW4 could be lower or nearly level with that in the Burn Site Well, despite the former's topographically upslope position.

In summary, Figures 2.4-1 and 2.4-2 show what is known, what is unknown, and what must be conjectured about the water levels in the Burn Site area.

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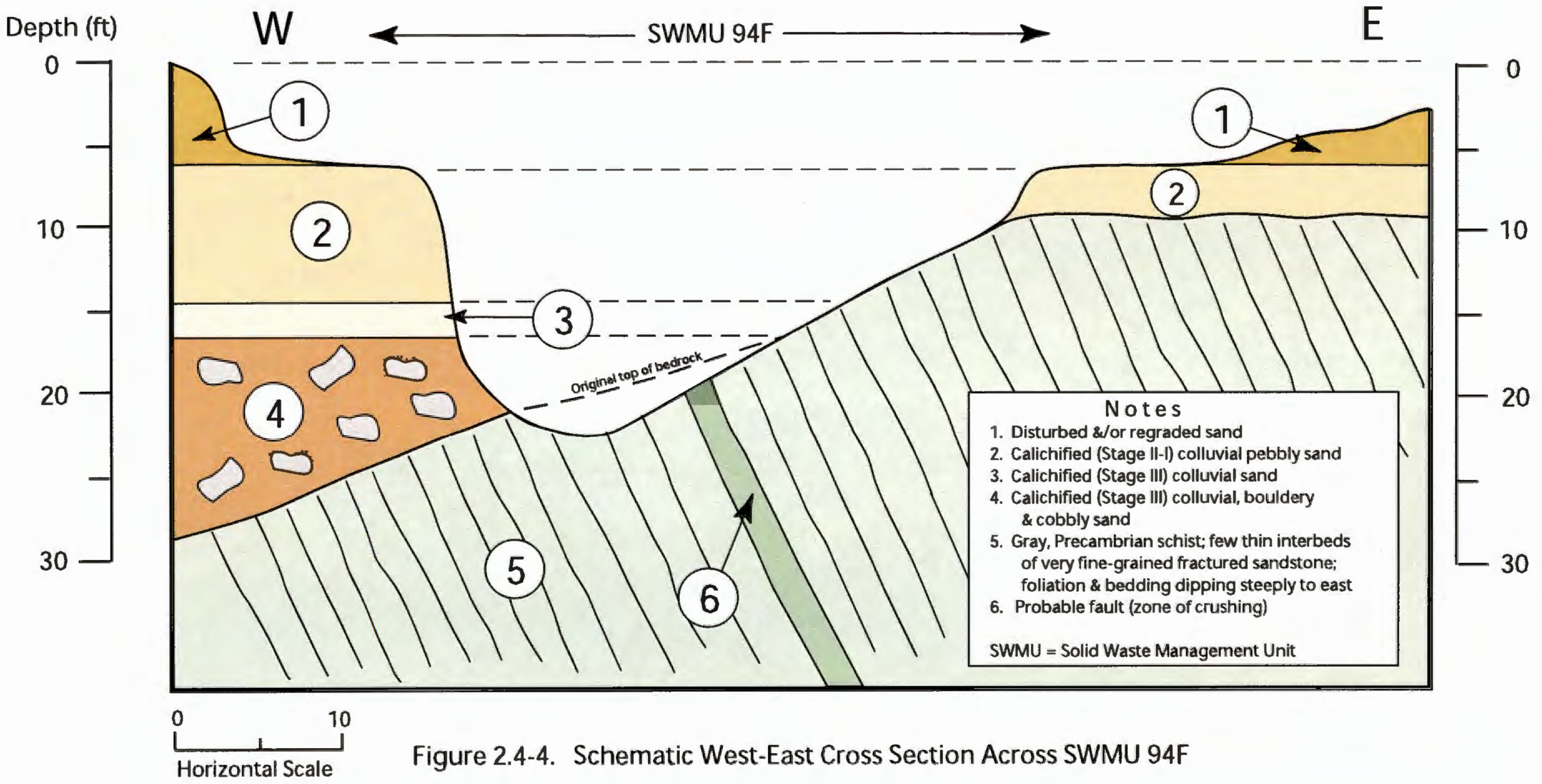

Notes
1. Disturbed &/or regraded sand
2. Calichified (Stage II-I) colluvial pebbly sand
3. Calichified (Stage III) colluvial sand
4. Calichified (Stage III) colluvial, bouldery & cobbly sand
5. Gray, Precambrian schist; few thin interbeds of very fine-grained fractured sandstone; foliation & bedding dipping steeply to east
6. Probable fault (zone of crushing)

SWMU = Solid Waste Management Unit

Figure 2.4-4. Schematic West-East Cross Section Across SWMU 94F

3.0 GROUNDWATER

3.1 Potentiometric Surface

Figure 3.1-1 is a map of the generalized, regional potentiometric surface. The figure ties the Burn Site to the regional picture to the west in Arroyo del Coyote (SNL/NM 1996), to the east along NM-337 (formerly "South 14"), and north along Tijeras Arroyo (Titus 1980). The figure also shows that the general western groundwater gradient ramps down from a closed high of 7,500 feet that straddles NM Route 337 about four miles east southeast of the Burn Site.

Of particular interest in Titus (1980) is the potentiometric surface's apparent disregard for Cedro Peak (elevation 7,767 feet), about 2 miles southeast of the village of Tijeras. This seems to defy the conventional wisdom that the potentiometric surface follows the topography. It also underscores the fact that the Manzanita Mountains are a water-starved hydrologic system, that effective recharge areas are of limited extent, and that deep underflow from a central recharge area is the norm.

Figure 3.1-2 is a map of the generalized potentiometric surface in the vicinity of the Burn Site, based upon the five groundwater control points. As previously stated, due to well construction the only water level reading available for the Burn Site Well was that taken just after the well's completion in 1986. The groundwater gradient at the Burn Site is to the west northwest at about 95 feet/1000 feet or about 500 feet/mile.

3.2 Groundwater Levels at Burn Site

The groundwater elevations for fiscal year (FY) 1998 through the latest measurements available in FY 2001 are listed in Table 3.2-1. Readings are generally taken each month but there are gaps in the data set. Figure 3.2-1 is a plot of hydrographs for the three monitoring wells in the Burn Site area. The figure illustrates the net changes in water levels for CYN-MW1D relative to April 1998 (installed December 1997) and for the first readings for CYN-MW3 and CYN-MW4 for July 1999 (installed June 1999). The potentiometric surface in CYN-MW1D has gradually risen about 2.4 feet in almost three years, while the potentiometric surface in CYN-MW4 rose about 2.8 feet in 1.5 years. Taken together, the two suggest an increase in average precipitation in the Manzanita Mountains. CYN-MW3 is anomalous. Between August 1999 and November 1999 the water level gained about 4 feet, remained fairly constant for three additional months during the winter of 1999/2000, and then gradually declined to a level about 0.5 foot below the initial value. This well is completed in a highly transmissive zone of the aquifer and appears to be more responsive to changes in the water budget.

Figure 3.1-2 shows an increased spacing and westward bulging in the pontentiometric contours over the Burn Site. The resulting ridge crosses the center of the site near CYN-MW3. Some correlation may exist between this ridge and the anomalous behavior of CYN-MW3, but the relationship is not understood. The strike of the Precambrian structure is generally northeast-southwest (Figure 2.3-2) but the Rio Grande extensional structures trend north-south to north northeast-south southwest and cut across the Precambrian trends at a high angle (Figure 2.3-1). The intersection of these faults with varying Precambrian rock types undoubtedly produces a complicated fracture network, which is currently not fully understood

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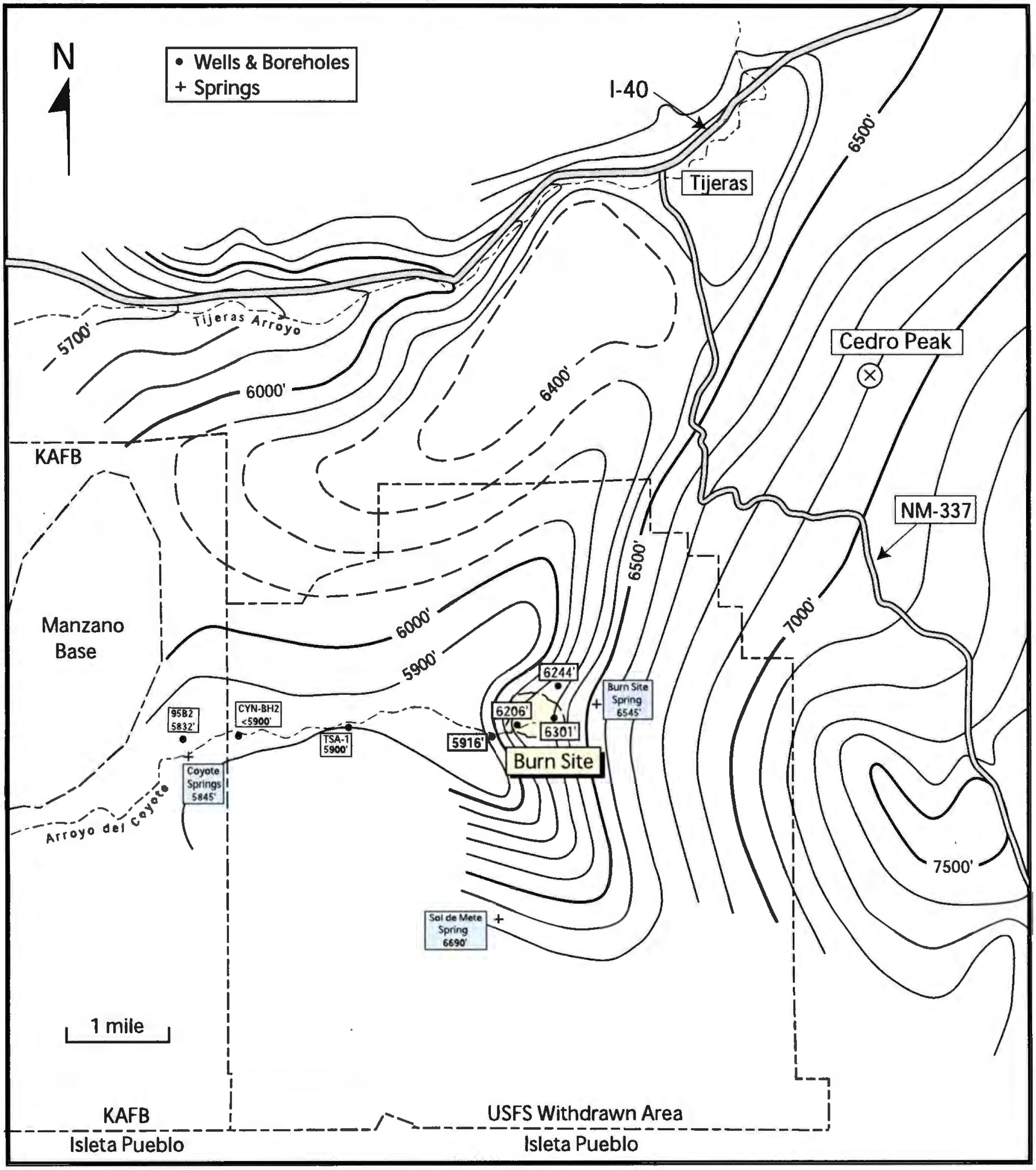

Figure 3.1-1. Generalized Regional Potentiometric Surface Map (C.I. = 100 ft)
(northern & eastern parts taken from Titus 1980)

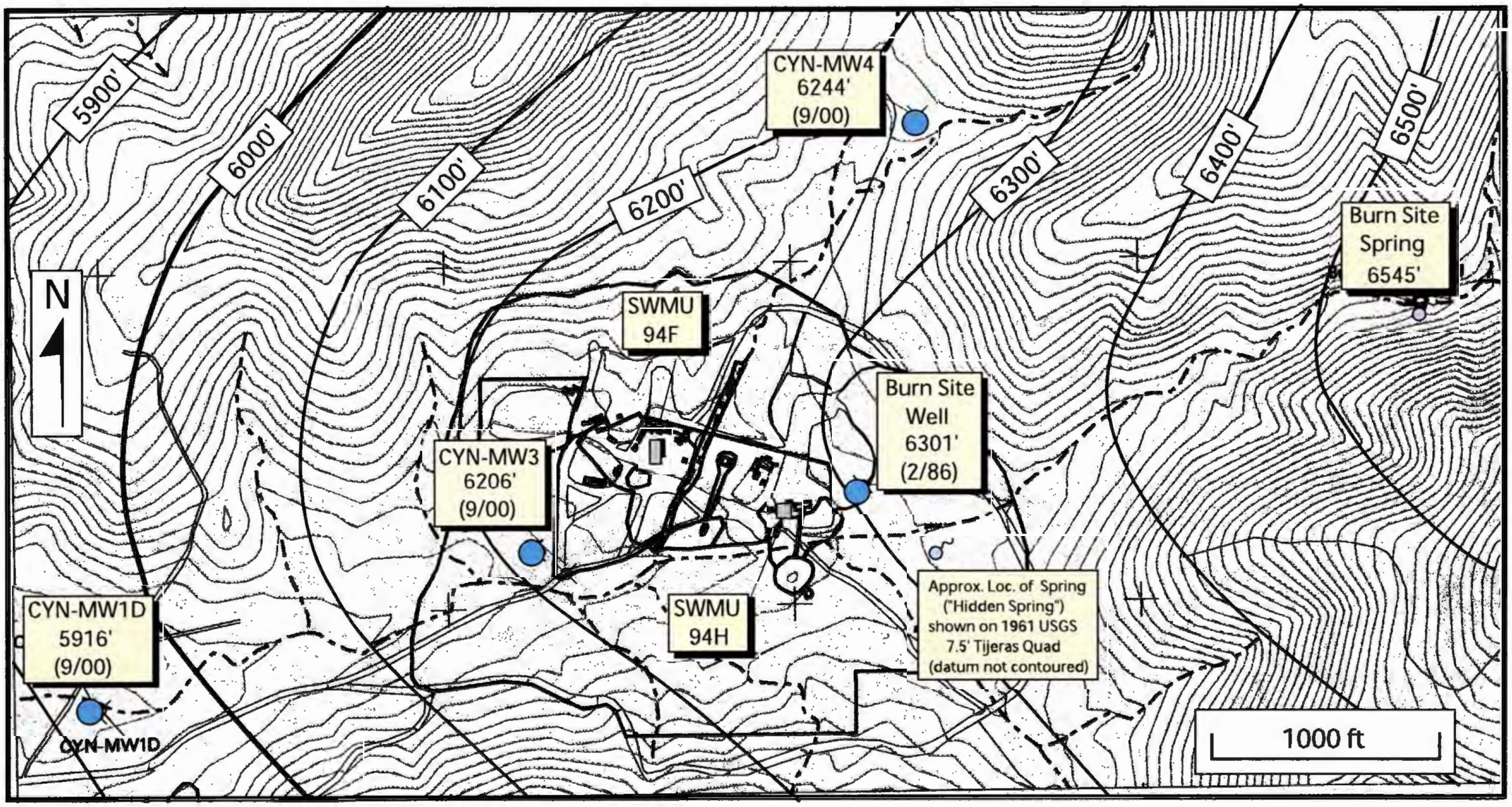

Figure 3.1-2. Generalized Potentiometric Surface Map, Burn Site Area (C.I. = 100 ft)
(Note: 20-ft topographic contours in background)

Table 3.2-1
Burn Site Groundwater Monitoring
Water-Level Measurements: Depths and Elevations (fbgs)
FY 1998 through FY 2001

Date of Measurement	CYN-MW1D (MD = 6236.92')	CYN-MW3 (MD = 6310.91')	CYN-MW4 (MD = 6452.81')
April 1, 1998	322.78 (5914.14)	No data. Wells installed June 1999	
June 1, 1998	322.34 (5914.58)		
June 30, 1998	322.72 (5914.70)		
April 1, 1999	336.25 (5900.67)[a]		
May 7, 1999	321.50 (5915.42)		
June 11, 1999	321.92 (5915.00)		
July 2, 1999	321.42 (5915.50)	108.45 (6202.46)	210.47 (6242.34)
August 2, 1999	321.49 (5915.43)	108.90 (6202.01)	211.75 (6241.06)
August 10, 1999	No measurement taken	No measurement taken	211.17 (6241.64')
August 16, 1999	No measurement taken	108.66 (6202.25)	No measurement taken
August 17, 1999	321.22 (5915.70)	No measurement taken	No measurement taken
November 2, 1999	320.67 (5916.31)	104.32 (6206.59)	210.26 (6242.55)
December 2, 1999	320.76 (5916.16)	104.50 (6206.41)	209.72 (6243.09)
January 3, 2000	321.75 (5915.17)	104.23 (6206.68)	209.45 (6243.36)
February 2, 2000	320.67 (5916.25)	104.51 (6206.40)	209.20 (6243.61)
March 3, 2000	320.60 (5916.32)	104.81 (6206.10)	208.91 (6243.90)
September 5, 2000	320.49 (5916.43)	107.65 (6203.26)	207.88 (6244.93)
October 4, 2000	320.43 (5916.49)	108.04 (6202.87)	207.65 (6245.16)
November 6, 2000	320.35 (5916.57)	108.45 (6202.46)	207.35 (6245.46)
December 1, 2000	320.53 (5916.39)	108.68 (6202.23)	207.71 (6245.10)
January 8, 2001	320.33 (5916.59)	108.80 (6202.11)	207.48 (6245.33)
February 2, 2001	320.37 (5916.55)	108.92 (6201.99)	207.65 (6245.16)

[a] Anomalous value as per ERFO field report.

ERFO = Environmental Restoration Field Office.
fbgs = Feet below ground surface.
FY = Fiscal year.
MD = Elevation of measurement datum.

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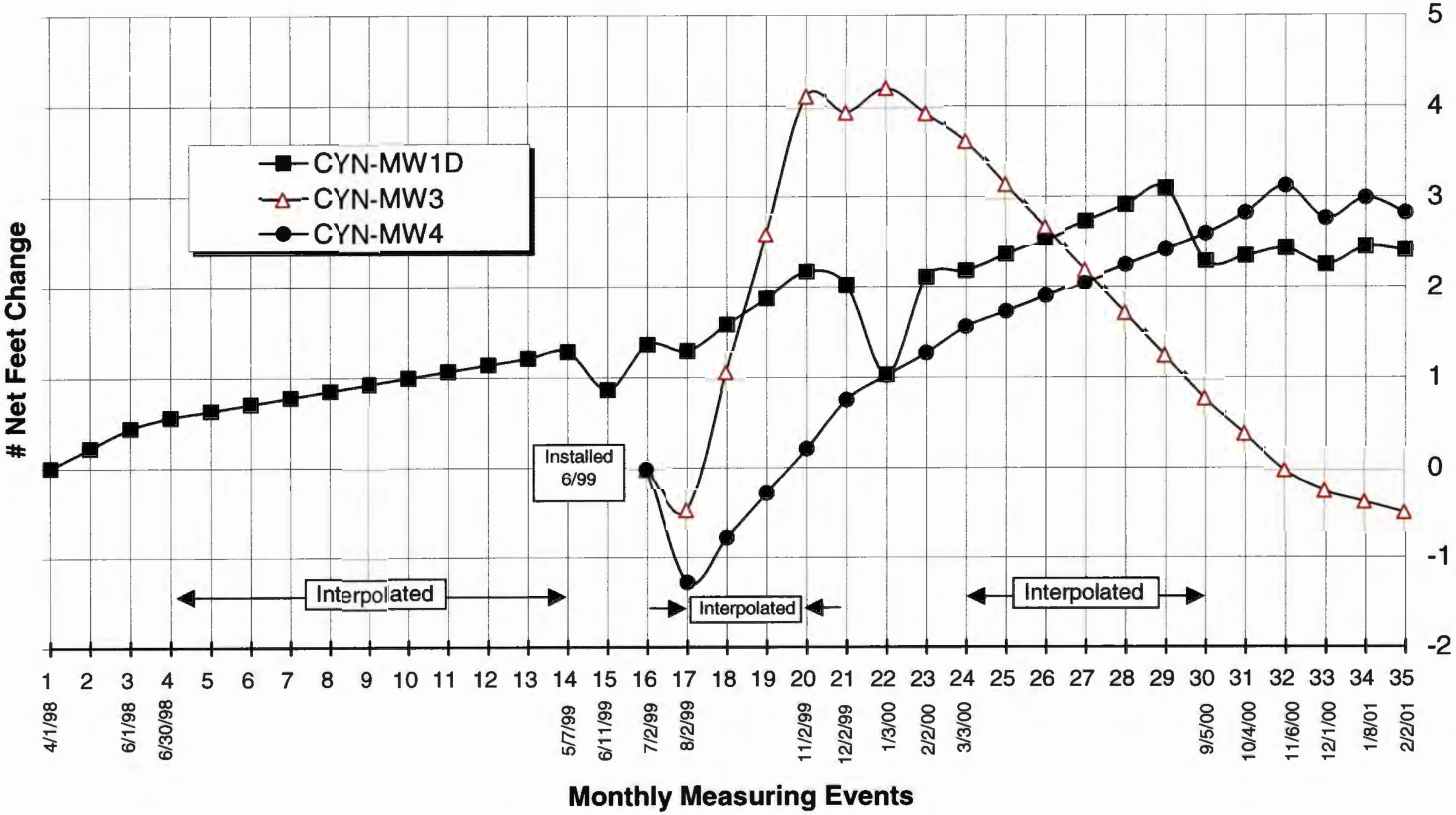


Figure 3.2-1. Hydrographs Showing Net Changes of Water Levels in Monitor Wells: Burn Site
April 1998 through February 2000

with the available data. However, evidence about the preferred direction of groundwater movement within the fracture network is embedded in the groundwater- sampling and chemical-analysis data set.

3.3 Groundwater Sampling and Analysis

Environmental Restoration (ER) Field Office personnel generally sample groundwater from the monitoring wells quarterly (Table 3.3-1). The Burn Site Well is not routinely sampled as part of the program. Due to budgetary constraints, the sampling effort was cut back in the third quarter of FY 1999 when only CYN-MW3 was sampled, and was cut out completely in the fourth quarter of FY 2000.

In the second and third quarters of FY 1998, chemical analyses were performed off site by Core Laboratories, Inc., of Casper, Wyoming, and on site by the ER Chemistry Laboratory (ERCL). Beginning in the fourth quarter of FY 1998, the off-site analyses were done by General Engineering Laboratory (GEL) of Charleston, South Carolina, and on site by ERCL. Radioisotope analyses are done off site by GEL and on site by the Radiation Protection Sample Diagnostic Laboratory. Quality assurance was provided by duplicate and split samples. Table 3.3-2 summarizes the analytical methods used by the labs, and the tables in Annex A list the results.

3.4 Contamination in Groundwater at the Burn Site

As previously mentioned in Section 2.4, groundwater samples taken in 1996 from the Burn Site Well contained elevated nitrate levels of about 25 mg/L, well above the U.S. Environmental Protection Agency's Maximum Contaminant Level (MCL) of 10 mg/L for drinking water. In the latter half of 1997, the New Mexico Environment Department (NMED), the DOE, and SNL/NM agreed to investigate the source of the contamination. In December 1997, the CYN-MW1D (the "Narrows") well was installed downgradient to the west. Samples from the well indicated nitrate concentrations slightly above the MCL and trace levels of fuel-related VOCs. Continuing the investigation, two more wells, CYN-MW3 and CYN-MW4, were installed in June 1999.

The contaminants of concern at the Burn Site are the VOCs toluene, ethylbenzene, and xylenes, DRO compounds, and nitrate. The occurrences of the detections are detailed by Table 3.4-1 and summarized by Figure 3.4-1(A-C).

3.4.1 Volatile Organic Compounds

Table 3.4-1, and Figure 3.4-1A list the detections of VOCs by sampling event during FY 1999 and FY 2000 (Tables A-1 through A-4 in Annex A). In this report, "total BTEX" refers to the total benzene, toluene, ethylbenzene, and xylenes, although benzene has never been detected at the Burn Site. Trace amounts of total BTEX were encountered in samples from well CYN-MW1D and have decreased with time. Well CYN-MW3, the closest downgradient well near the suspected source (SWMU 94F), never detected VOCs during the five sampling episodes since the well was completed. CYN-MW4 recorded a one-time trace of toluene followed by three nondetects, which indicates that the detection may have been anomalous.

Table 3.3-1
Burn Site Groundwater Monitoring Sampling Schedule FY 1998 through FY 2000

Well	Analytes	FY 1998			FY 1999				FY 2000			
		4/98	6/98	8/98	12/99	4/99	8/99	10/99[a]	12/99	3/00	5/00	8/00
Burn Site Well (installed 2/86)	VOCs								✓[b]			
	Phenolics											
	Gasoline-range organics								✓			
	Diesel-range organics						✓		✓	✓		
	Inorganics								✓			
	Metals								✓			
	Radioisotopes								✓			
CYN-MW1D (installed 12/97)	VOCs	✓	✓	✓	✓	✓	✓	✓	✓	✓		
	Phenolics				✓	✓	✓	✓	✓	✓		
	Gasoline-range organics	✓		✓			✓	✓	✓	✓		
	Diesel-range organics			✓			✓	✓	✓	✓		
	Inorganics	✓	✓		✓	✓	✓	✓	✓	✓		
	Metals	✓	✓	✓	✓	✓	✓	✓	✓	✓		
	Radioisotopes						✓		✓	✓		
CYN-MW3 (installed 6/99)	VOCs	No data. Wells installed June 1999					✓[b]	✓[b]	✓[b]	✓[b]	✓[b]	
	Phenolics						✓	✓	✓	✓	✓	
	Gasoline-range organics						✓	✓	✓	✓		
	Diesel-range organics						✓	✓	✓	✓		
	Inorganics						✓	✓	✓	✓	✓	
	Metals							✓	✓	✓	✓	
	Radioisotopes								✓	✓	✓	
CYN-MW4 (installed 6/99)	VOCs						✓	✓[b]	✓[b]	✓[b]		
	Phenolics						✓	✓	✓	✓		
	Gasoline-range organics							✓	✓	✓		
	Diesel-range							✓	✓	✓		
	Inorganics						✓	✓	✓	✓		
	Metals						✓	✓	✓	✓		
	Radioisotopes								✓	✓		

[a] Early October 1999 sampling attributed to fourth quarter FY 99.

[b] Samples analyzed for VOCs but no detections encountered. Not included in database tables.

FY = Fiscal year.
VOC = Volatile organic compound.
✓ = Analysis performed.

Table 3.3-2
Burn Site Groundwater Monitoring
Summary of Analytical Methods

Analyte	Analytical Method[a]
Organics:	
VOC	8260
Phenol	8270; 8270C
Gasoline-range organics	8015; 8015A/B
Diesel-range organics	8015; 8015A/B; 8015G
TOC	9060; 415.1
Inorganics:	
Alkalinity (as calcium carbonate)	HACH_ALK; 310.1
Bromide, chloride, fluoride, sulfate	Anions_CE; 300.0
Nitrate as N	HACH_NO3; 353.1
TOX	9020B
Metals:	
Total metals	6010; 6010B; 6020
Mercury	7470; 7470A
Thallium	6020
Radioisotopes:	
Gross alpha and beta	900.0
Radium	Gamma; 903.1; 904.0
Uranium	Gamma; DOE EML HASL 300

[a] U.S. Environmental Protection Agency, 1986, "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," SW-846, 3rd ed.

ALK = Alkalinity.
DOE = U.S. Department of Energy.
EML HASL = Environmental Measurements Laboratory/Health and Safety Laboratory.
HACH = Hach Company, Loveland, Colorado.
NO3 = Nitrate.
TOC = Total organic carbon.
TOX = Total organic halogens.
VOC = Volatile organic compound.

Table 3.4-1
Burn Site Groundwater Monitoring
VOCs, DRO Compounds, and Nitrate
FY 1999 and FY 2000

	FY 99				FY 00		
	12/98	4/99	8/99	10/99	12/99	3/00	5/00
Total BTEX (µg/L; MCL ≥ 700)							
Burn Site Well	NA	NA	NA	NA	ND	NA	NA
CYN-MW1D	6.51	5.8	3.89	5.11	3.29	1.64	NA
CYN-MW1D Split	6.55	5.24	NA	3.34	2.65	3.49	—
CYN-MW3	No data. Wells installed June 1999		ND	ND	ND	ND	ND
CYN-MW4			6.1 (toluene)	ND	ND	ND	NA
Ethylbenzene (µg/L; MCL = 700)							
CYN-MW1D	0.91	1.0	0.59	0.81	0.54	0.31	NA
CYN-MW1D Split	0.95	0.88	NA	0.55	0.46	0.56	—
Toluene (µg/L; MCL = 1000)							
CYN-MW1D	1.8	1.2	1.1	1.2	0.75	0.51	NA
CYN-MW1D Split	2.0	1.2	NA	0.99	0.66	0.74	—
CYN-MW4	NA	NA	6.1	NA	NA	NA	NA
Total Xylene (µg/L; MCL = 10,000)							
CYN-MW1D	3.8	3.6	2.2	3.1	2.0	0.81	NA
CYN-MW1D Split	3.6	3.2	NA	1.8	1.5	2.2	—
DRO (µg/L; MCL not established)							
Burn Site Well	NA	NA	NA	NA	ND	NA	NA
CYN-MW1D[a]	NA	NA	170[b]	160[c]	177	147[c]	
CYN-MW3	No data. Wells installed June 1999		15	ND	ND	ND	
CYN-MW-3 Duplicate			15	ND	ND	ND	
CYN-MW4			NA	20	28.2	37.7[c]	
Nitrate (mg/L; MCL = 10)							
Burn Site Well	NA	NA	NA	NA	9.2	NA	NA
Burn Site Well Split	NA	NA	NA	NA	**15**	NA	—
CYN-MW1D	NA	**11.7–19.6**	**15.8**	**15.7**	**16.9**	**16.9**	NA
CYN-MW1D Split	**11**	**13.9**	NA	**22**	**23**	**20**	—
CYN-MW3	No data. Wells installed June 1999		**13.3**	**12.1**	9.8	**13**	**12.5**
CYN-MW3 Split			**17–18**	3.3	**17**	**11**	NA
CYN-MW3 Duplicate			**13–16**	3.4–**12.3**	9.7–**18**	NA	**12.6**
CYN-MW4			0.05–0.22	0.12	0.01	0.06	NA
CYN-MW4 Split			0.4	0.3	0.2	0.65	—

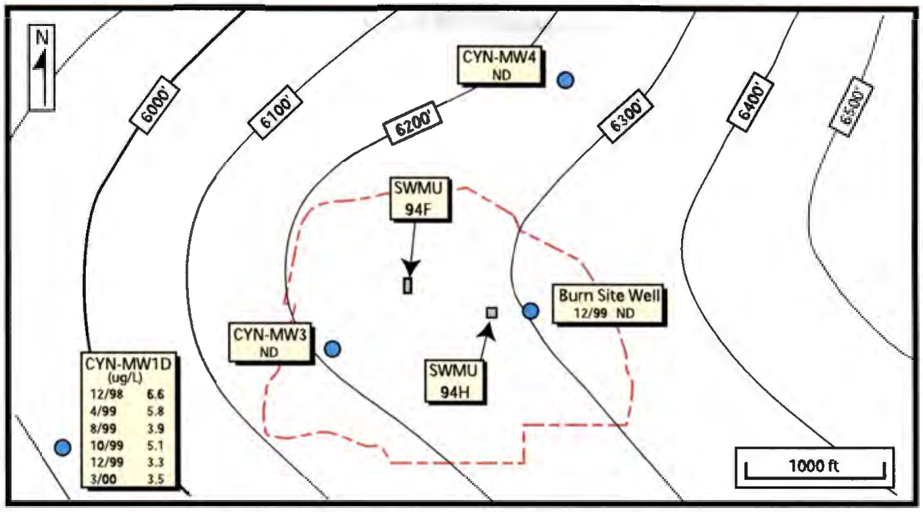
Note: Values in **bold** exceed the associated MCL.

[a] Well had questionable detection of 330 µg/L of DRO in 8/98; next reading was in 8/99.

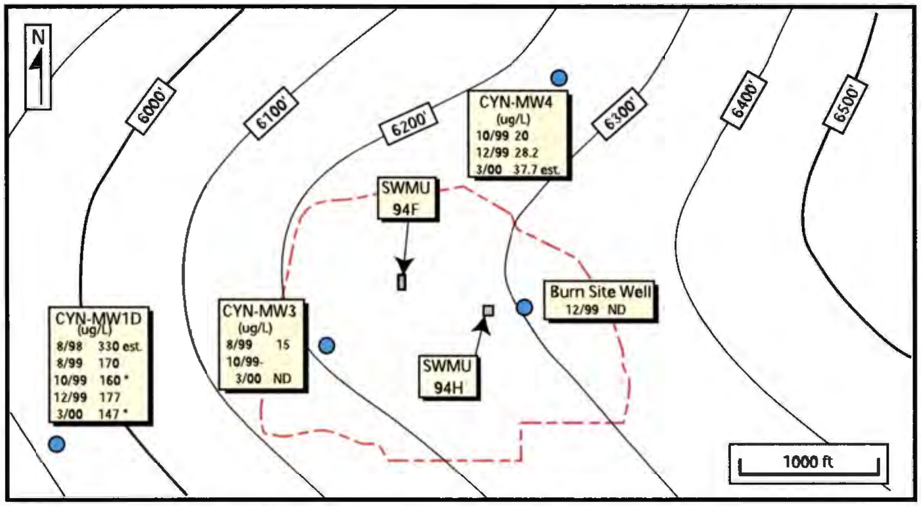
[b] Estimated value.

[c] Analyte also present in QC blank.

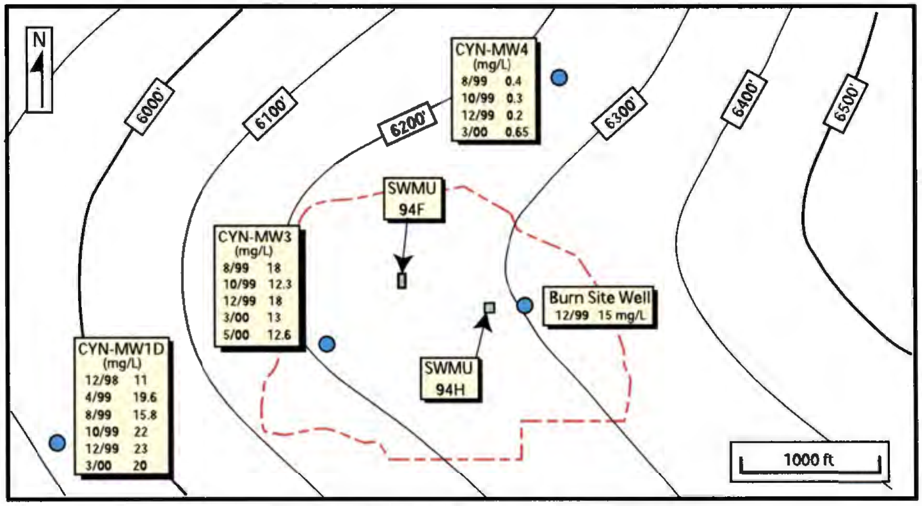
BTEX = Benzene, toluene, ethylbenzene, and xylene.
DRO = Diesel range organics.
FY = Fiscal year.
µg/L = Microgram(s) per liter.
MCL = Maximum Contaminant Level for drinking water.
NA = No sample analyzed.
ND = Analyzed but analyte not detected above MCL.
QC = Quality control.
VOC = Volatile organic compounds.
— = No split or duplicate sample collected.



A. Total BTEX Detections (MCL = >700 ug/L)



B. Total Diesel-Range Organics (MCL not determined)



C. Total Nitrate (MCL = 10 mg/L)

mg/L = milligrams/liter
ug/L = micrograms/liter
est. = estimated; ND = not detected
MCL = maximum contaminant level
SWMU = solid waste management unit
* amount questionable -- analyte also present in quality-control blank

Figure 3.4-1. Detections of Contaminants of Concern in Burn Site Area
(Note: Contours on top of generalized potentiometric surface from Figure 3.1-2)

Groundwater was analyzed for gasoline-range organics (volatile petroleum hydrocarbons) from all four wells (Table 3.3-1). No detections were ever encountered.

3.4.2 Semivolatile Organic Compounds

There were no detections of phenol in the groundwater from the Burn Site (Tables A-5 through A-6 in Annex A).

3.4.3 Diesel-Range Organics

Figure 3.4-1B and Table 3.4-1 show that all three monitoring wells detected low concentrations of DRO (Table A-7 in Annex A). CYN-MW1D, the most downgradient well, had a questionable estimate of 330 micrograms (µg)/L in August 1998, an estimated concentration of 170 µg/L in August 1999 (not listed in Table 3.4-1), a questionable estimate of 160 µg/L in October 1999, 177 µg/L in December 1999, and an questionable concentration of 147 µg/L in March 2000. The questionable values had detections in the Quality Control (QC) sample blanks. CYN-MW3, the closest downgradient well, detected DRO at 15 µg/L in August 1999 and has had no detections in the three subsequent analysis rounds. Groundwater from the Burn Site Well was analyzed once (December 1999) for DRO, which was not detected.

The most anomalous occurrence of DRO in groundwater is at CYN-MW4. This well detected increasing concentrations, 20, 28.2, and 37.7 µg/L, during three consecutive quarters (October 1999, December 1999, and March 2000, respectively). The validity of the last detection is questionable because the contaminant was also encountered in the QC blank. No known upgradient source of DRO contamination exists to the east or southeast of CYN-MW4 (Figures 3.1-2 and 3.2-1).

However, in August 2000, a spill-site of JP-8 fuel, SWMU 94H, was discovered just to the south and west of the Burn Site Well (Figure 2.3-6). In October 2000, a piping upgrade was performed. During the work, samples were collected from the base of the excavation that verified contamination in the soil from leaking underground pipes and the need for a Voluntary Corrective Action (VCA). Approximately 300 cubic yards of petroleum-contaminated soil were removed and disposed of at an off-site disposal facility. Visual inspection of the excavation indicated that bedrock is shallow (10-20 feet) in the area of the site. Additional investigation/VCA is scheduled for July through August 2001.

In order to explain the anomalous occurrence of DRO in CYN-MW4, a conduit or conduits must exist to allow contaminants spilled at the surface to penetrate the aquitard and access the saturated zone. The best available candidate is the Burn Site fault, which is interpreted to pass through both the Burn Site Well and CYN-MW4 (Figures 2.3-5, 2.3-6, and 2.4-1). The fault could well be a zone consisting of a series of splays rather than a simple fault. The occurrence of a possible fault (splay?) in the excavation at SWMU 94F supports the former concept.

3.4.4 Nitrate

Table 3.4-1 and Figure 3.4-1C show that three of the four wells have detected nitrate in excess of the MCL of 10 mg/L for drinking water (Tables A-8 through A-14 in Annex A). As mentioned previously, the Burn Site Well detected a concentration of about 25 mg/L in 1996. CYN-MW1D detected 11 mg/L in December 1998, which increased to about 20 mg/L the next quarter and held approximately constant for an additional four quarters, suggesting continuous sourcing. CYN-MW3 and CYN-MW4 were installed in June 1999. CYN-MW3 detected a range of nitrate concentrations in August 1999 from 13.3 to 18 mg/L. Subsequent quarters had concentrations ranging from 3.3 to 12.3 mg/L (October 1999), 9.7 to 18 mg/L (December 1999), 11 to 13 mg/L in March 2000, and 12.5 to 12.6 mg/L in May 2000, the last sample taken. CYN-MW4 had detections of very low concentrations below the MCL, ranging from 0.01 to 0.22 mg/L. The nitrate concentrations in these two wells lack a clear trend. The source of the nitrate is unknown.

3.4.5 Other Detections

Table 3.4-2 lists the detections of chloride, fluoride, and sulfate (Tables A-8 through A-14 in Annex A), Table 3.4-3 the detections of metals (Tables A-15 through A-24 in Annex A), and Table 3.4-4 the detections of radioisotopes (Tables A-25 through A-27 in Annex A).

3.4.5.1 Chloride

The most striking characteristic of the chloride concentrations is the range of values. The only apparent variable is the depth of completion (Figure 2.4-1) The chloride concentrations generally decrease with depth bgs. Average values at the four wells from all types of samples (including production and purge water, excerpted from the basewide tabulation of chloride concentrations from all wells, dated December 20, 2000), compared to the screen-midpoint depths are:

Well	Screen (Midpoint), in feet	Average chloride (# Values), in mg/L
CYN-MW3	120–130 (125)	62.2 (11)
CYN-MW4	260–280 (270)	44.8 (6)
Burn Site Well	231–341 (286)	59.4 (3)
CYN-MW1D	372–382 (377)	27.4 (15)

3.4.5.2 Fluoride

Fluoride was detected at levels below the MCL of 4 mg/L. Values ranging from 1.9 to 2.4 mg/L were encountered in CYN-MW1D and at trace levels of 0.5 to 0.9 mg/L in the other two monitoring wells, but the levels appear to be stable. An average fluoride concentration taken from 29 wells and springs elsewhere in the Sandia and Manzanita Mountains is about 0.5 mg/L, but some samples taken from Madera Group and Precambrian bedrock had fluoride concentrations greater than 1.0 mg/L (Titus 1980, p. 36).

Table 3.4-2
Burn Site Groundwater Monitoring
Select Inorganic Compounds: Chloride, Fluoride, and Sulfate
FY 1999 and FY 2000

	FY 99				FY 00		
	12/98	4/99	8/99	10/99	12/99	3/00	5/00
Chloride (mg/L; MCL not established)[a]							
Burn Site Well	NA	NA	NA	NA	NA	NA	NA
CYN-MW1D	29.9	28.7	27.4	27.6	29.3	25.7	NA
CYN-MW1D Split	24	21	—	NA	NA	NA	—
CYN-MW3	No data. Wells installed June 1999		66.8	67.9	58.5	61.4	NA
CYN-MW3 Duplicate			NA	NA	61.7	NA	—
CYN-MW4			43.6	45.9	45.2	45.7	NA
Fluoride (mg/L; MCL = 4)[b]							
Burn Site Well	NA	NA	NA	NA	NA	NA	NA
CYN-MW1D	NA	2.2-2.4	1.92	2.06	2.17	2.11	NA
CYN-MW1D Split	2.1	2.2	—	—	—	—	—
CYN-MW3	No data. Wells installed June 1999		0.53	0.54	0.57	0.56	NA
CYN-MW-3 Duplicate			—	—	0.54	—	—
CYN-MW4			0.91	0.885	0.93	0.93	NA
Sulfate (mg/L; MCL not established)[a,c]							
Burn Site Well	NA	NA	NA	NA	NA	NA	NA
CYN-MW1D	128	120	116	117	115	111	NA
CYN-MW1D Split	130	110	—	NA	NA	NA	—
CYN-MW3	No data. Wells installed June 1999		184	186	167	181	NA
CYN-MW-3 Duplicate			NA	NA	175	NA	NA
CYN-MW4			154	166	161	155	NA

[a] No MCL for chloride or sulfate, but there are National Secondary Drinking Water Regulations. Both chloride and sulfate are 250 mg/L.

[b] 29 of 48 wells and springs in Sandia and Manzanita Mountains had values < 0.5 mg/L (Titus 1980, p. 36).

[c] Average sulfate from 7 wells and springs in Precambrian of Sandia and Manzanita Mountains = 110 mg/L (Titus 1980, p. 29).

FY = Fiscal year.
MCL = Maximum Contaminant Level in drinking water.
mg/L = Milligram(s) per liter.
NA = No sample analyzed.
— = No split or duplicate sample collected.

Table 3.4-3
Burn Site Groundwater Monitoring
Select RCRA Metals: Arsenic, Barium, Cadmium, Selenium, and Silver
FY 1999 and FY 2000

	FY 99				FY 00		
	12/98	4/99	8/99	10/99	12/99	3/00	5/00
Arsenic (µg/L; MCL = 50)							
Burn Site Well	NA	NA	NA	NA	ND	NA	NA
CYN-MW1D	NA	NA	ND	ND	ND	ND	NA
CYN-MW1D Split	ND	ND	—	—	—	—	—
CYN-MW3	No data.		NA	ND	ND	ND	3.96
CYN-MW3 Duplicate	Wells installed		—	—	ND	—	ND
CYN-MW4	June 1999		NA	ND	ND	ND	NA
Barium (µg/L; MCL = 2000)							
Burn Site Well	NA	NA	NA	NA	65.5	NA	NA
CYN-MW1D	NA	NA	39.2	32.3	37.9	38.1	NA
CYN-MW1D Split	42	41–49	—	—	—	—	—
CYN-MW3	No data.		NA	56	53.9	51.6	48.8
CYN-MW-3 Duplicate	Wells installed		—	—	50.6	—	50.7
CYN-MW4	June 1999		NA	87.5	81.9	72.6	NA
Cadmium (µg/L; MCL = 5)							
Burn Site Well	NA	NA	NA	NA	0.97	NA	NA
CYN-MW1D	NA	NA	ND	ND	ND	ND	NA
CYN-MW1D Split	ND	ND	—	—	ND	—	—
CYN-MW3	No data.		NA	ND	ND	ND	0.22
CYN-MW3 Duplicate	Wells installed		—	—	—	—	0.25
CYN-MW4	June 1999		NA	ND	ND	ND	NA
Selenium (µg/L; MCL = 50)							
Burn Site Well	NA	NA	NA	NA	2.86	NA	NA
CYN-MW1D	NA	NA	ND	ND	ND	ND	NA
CYN-MW1D Split	3.6	3.6–4.7	—	—	—	—	—
CYN-MW3	No data.		NA	9.13	8.5	6.3	5.54
CYN-MW3 Duplicate	Wells installed		—	—	6.47	—	5.46
CYN-MW4	June 1999		NA	3.88	ND	ND	NA
Silver (µg/L; MCL = 50)							
Burn Site Well	NA	NA	NA	NA	ND	NA	NA
CYN-MW1D	ND	NA	ND	ND	0.66	0.65	NA
CYN-MW1D Split	—	ND	—	—	—	—	—
CYN-MW3	No data.		NA	2.1	ND	0.96	ND
CYN-MW3 Duplicate	Wells installed		—	—	ND	—	ND
CYN-MW4	June 1999		NA	4.08[a]	ND	1.7	NA

[a] Analyte also present in QC blank.

FY = Fiscal year.
MCL = Maximum Contaminant Level in drinking water.
µg/L = Microgram(s) per liter.
NA = No sample analyzed.
ND = Sample analyzed but analyte not detected.
QC = Quality control.
RCRA = Resource Conservation and Recovery Act.
— = No split or duplicate sample collected.

Table 3.4-4
Burn Site Groundwater Monitoring Radioisotopes FY 1999 and FY 2000

	FY 99		FY 00		
	8/99	10/99[a]	12/99	3/00	5/00
Gross Alpha (pCi/L; MCL = 15)					
Burn Site Well	NA	NA	8.48 ± 2.17	NA	NA
CYN-MW1D	0.81 ± 0.705		0.483 ± 0.63	0.651 ± 0.509	
CYN-MW3	NA		10.8 ± 2.69	5.68 ± 1.44	
CYN-MW3 Duplicate			12.8 ± 3.1	—	
CYN-MW4			23.6 ± 3.4	24.5 ± 2.35	
Gross Beta (mR/yr; MCL = 4)					
Burn Site Well	NA	NA	5.66 ± 2.51	NA	NA
CYN-MW1D	4.53 ± 0.996		4.9 ± 1.34	3.63 ± 1.3	
CYN-MW3	NA		7.69 ± 2.49	4.81 ± 1.4	
CYN-MW-3 Duplicate			3.6 ± 2.45	—	
CYN-MW4			11 ± 3.05	9.58 ± 1.5	
Radium-226 + Radium-228 (pCi/L; MCL = 5)					
Burn Site Well	NA	NA	ND	NA	NA
CYN-MW1D				ND	
CYN-MW3					0.66 ± 0.666
CYN-MW-3 Duplicate					0.894 ± 0.701
CYN-MW4					NA
Uranium-233/234 (pCi/L; MCL not established)					
Burn Site Well	NA	NA	NA	NA	NA
CYN-MW1D					
CYN-MW3					7.49 ± 1.36
CYN-MW-3 Duplicate					6.66 ± 1.21
CYN-MW4					NA
Uranium-238 (pCi/L; MCL not established)					
Burn Site Well	NA	NA	ND	NA	NA
CYN-MW1D				ND	
CYN-MW3					2.55 ± 0.656
CYN-MW-3 Duplicate					1.92 ± 0.531
CYN-MW4					NA

[a] Early October sampling attributed to fourth quarter FY 99.

FY = Fiscal year.
MCL = Maximum Contaminant Level in drinking water.
mR/yr = Millirem(s) per year.
NA = No sample analyzed.
ND = Sample analyzed but analyte not detected.
pCi/L = Picocurie(s) per liter.
— = No split or duplicate sample collected.

3.4.5.3 Sulfate

Sulfate values ranged from 110 to 130 mg/L in CYN-MW1D, 167 to 186 mg/L in CYN-MW3, and 155 to 166 mg/L in CYN-MW4. These values are not particularly high compared to those from groundwaters in gypsum-rich Mesozoic-age aquifers east of the Manzanita Mountains, which start at about 300 mg/L and exceed 1000 mg/L (Titus 1980). However, no gypsiferous formations are known to exist upgradient from the site.

3.4.5.4 Resource Conservation and Recovery Act Metals

No detections of Resource Conservation and Recovery Act metals were recorded above the MCLs.

3.4.5.5 Radioisotopes

Gross alpha above the MCL of 15 picocuries (pCi)/L was detected in CYN-MW4 (Table 3.4-4). In December 1999 and March 2000, the readings were 23.6 ± 3.4 pCi/L and 24.5 ± 2.35 pCi/L, respectively. The other three wells had detections, but all were below the MCL. Gross beta was detected in all four wells, but at low concentrations. Only CYN-MW3 was analyzed for radium 226 plus radium 228, uranium 233/234, and uranium 238. All were detected at very low levels. The well was tested for radium in the previous two quarters, with no detections.

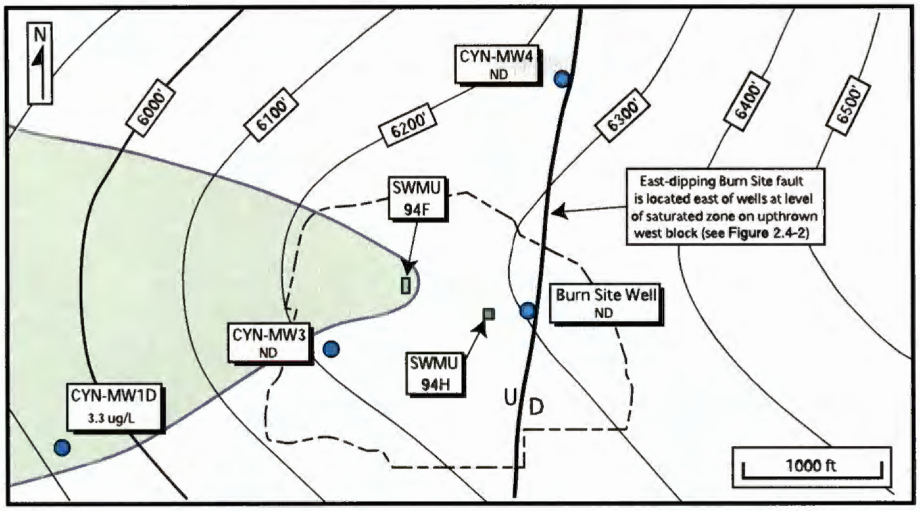
3.5 Proposed Contaminant-Flow Model

Figure 3.5-1(A-C) illustrates the estimated plume configurations for the three contaminants of concern at the Burn Site. The three plots all assume that the axis of maximum groundwater movement is along the crest of the groundwater ridge that passes through the site (Figure 3.1-2). Figure 3.5-1A clearly suggests that the principal source of the total BTEX contamination is SWMU 94F.

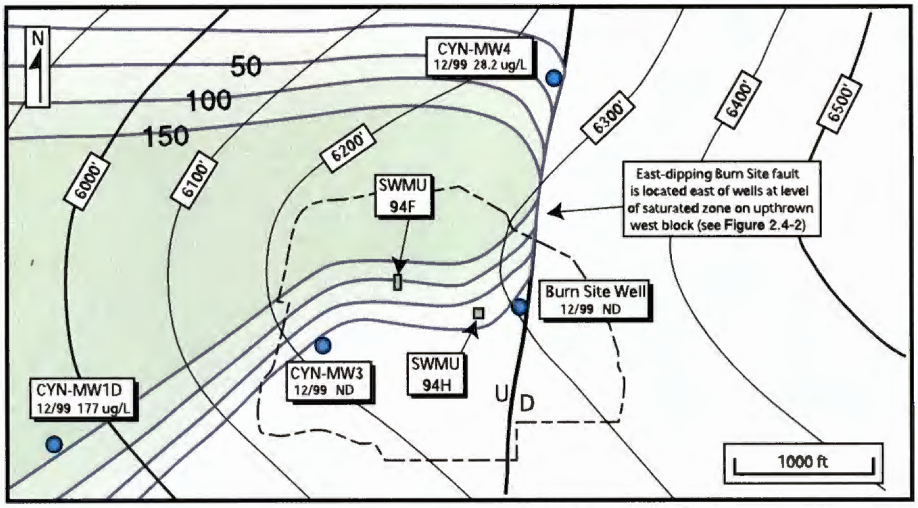
DRO and nitrate contamination are a more complicated matter. If the assumption is made that no sources of these contaminants exist in the hills east of the site, a model needs to be constructed that permits transport of these contaminants northward and down to the confined aquifer at CYN-MW4. DRO and nitrate concentrations therefore serve as a forensic constraint for the design of the groundwater flow model. Attention needs to focus on:

- The north-trending Burn Site fault (Figure 2.3-6)
- The possible Hidden Spring near the Burn Site Well (Figure 2.4-2)
- The groundwater ridge passing through the site (Figure 3.1-2)
- The observed concentrations of DRO (Figure 3.5-1B) and nitrates (Figure 3.5-1C)

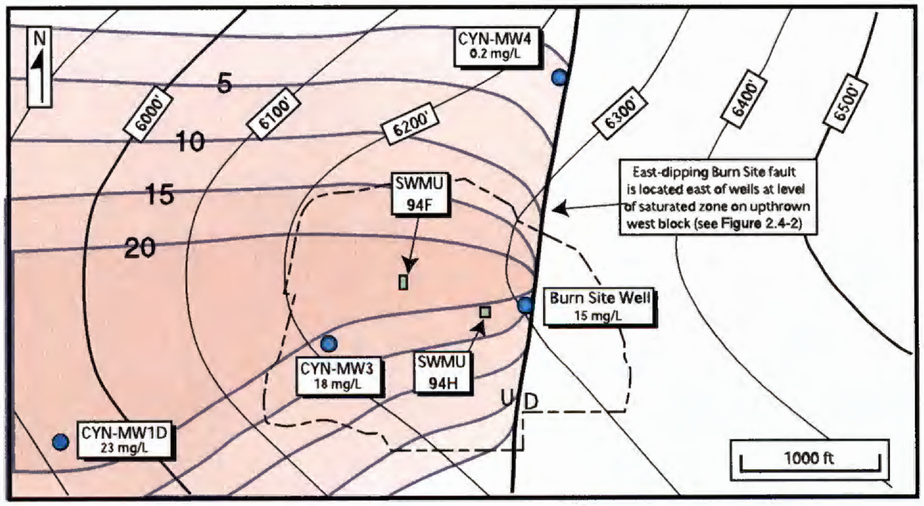
The Burn Site fault is an obvious, and the only known, candidate to provide a conduit to the north. Faults are known to act as both barriers and as flow paths. Kirtland Air Force Base already has an excellent example of such an ambivalent feature with its Hubbell Springs fault



A. Total BTEX (December 1999)



B. Diesel-Range Organics (December 1999; C.I. = 50 ug/L)



C. Total Nitrate (December 1999; C.I. = 5 mg/L))

mg/L = milligrams/liter; ug/L = micrograms/liter; ND = not detected; SWMU = Solid Waste Management Unit

Figure 3.5-1. Contaminant Plumes in Burn Site Area
(Note: Also shown are 1) Burn Site fault at its position at top of saturated zone, & 2) generalized potentiometric-surface contours from **Figure 3.1-2**)

(Haneberg 1995, SNL/NM 1996, Reiter 1999). Segments of the Hubbell Springs normal fault zone transmit fluid downgradient to the west in a stair-step pattern, and presumably laterally north and south as well, if a downward gradient exists in those directions. As a working hypothesis, therefore, it will be assumed that the Burn Site fault performs a similar transmissive role at the Burn Site. Most likely the fault is not a dimensionless horizon but rather a crushed zone of finite thickness with numerous splays.

It is hypothesized that DRO and nitrate infiltrate down through the alluvium to the Burn Site fault and/or its associated splays somewhere near the crest of the groundwater ridge near the Burn Site Well. The two SWMUs in this area, SWMU 94F (the LAARC Unit) and SWMU 94H, are the likely sources of the DRO. It is possible that the fault seen in the bottom of SWMU 94F is a splay of the Burn Site fault and is continuous with it. Contaminant flow downward to the saturated zone and downgradient along the fault zone(s) in groundwater to the north and possibly south may be responsible for the plume geometry suggested by Figures 3.5-1B and 3.5-1C.

Table 3.4-1 and Figure 3.5-1B show that groundwater from three of the four wells had detections of DRO. The Burn Site Well was sampled only once (December 1999) and no detection was recorded at that time. Figure 3.5-1B is a map of the interpreted plume during December 1999.

Table 3.4-1 and Figure 3.5-1C is a map of the interpreted nitrate plume during December 1999. The map shows a geometry suggesting that the source was located between the Burn Site Well and CYN-MW4.

The plume geometries from Figures 3.5-1B and 3.5-1C provide an interpretive feedback loop to the generalized site potentiometric-surface map (Figure 3.1-2). The generalized map requires fine-tuning and reconfiguration to produce a conceptual model capable of permitting the transport of DRO and nitrate from their possible surface sources to their subsurface plumes in the groundwater. The resultant conceptual potentiometric-surface map (Figure 3.5-2) incorporates the measured water levels (Table 3.2-1), Hidden Spring (Figure 2.4-3), the mid-site groundwater ridge (Figure 3.1-2), and a transmissive role for the Burn Site fault.

3.6 Monitored Natural Attenuation

According to the U.S. Environmental Protection Agency (EPA), monitored natural attenuation (MNA) is the "reliance on natural attenuation processes (within the context of a carefully controlled and monitored approach to site cleanup) to achieve site-specific remediation objectives within a time frame that is reasonable compared with that offered by more active methods" (EPA 1999). Monitoring, therefore, is the critical component of any remediation by natural attenuation. Although MNA is not a default option or a presumptive remedy, it is recognized by the EPA as a viable method of remediation for soil and groundwater that can be evaluated and compared to other methods.

VCAs were performed at two of the Burn Site SWMUs (94F and 94H) to remove petroleum-contaminated soil believed to have been the primary sources of contamination in groundwater at the Lurance Canyon Burn Site. The VCA at SWMU 94H confirmed that petroleum contamination did not reach the overburden/bedrock interface and did not infiltrate into the underlying bedrock and groundwater. However, petroleum contamination

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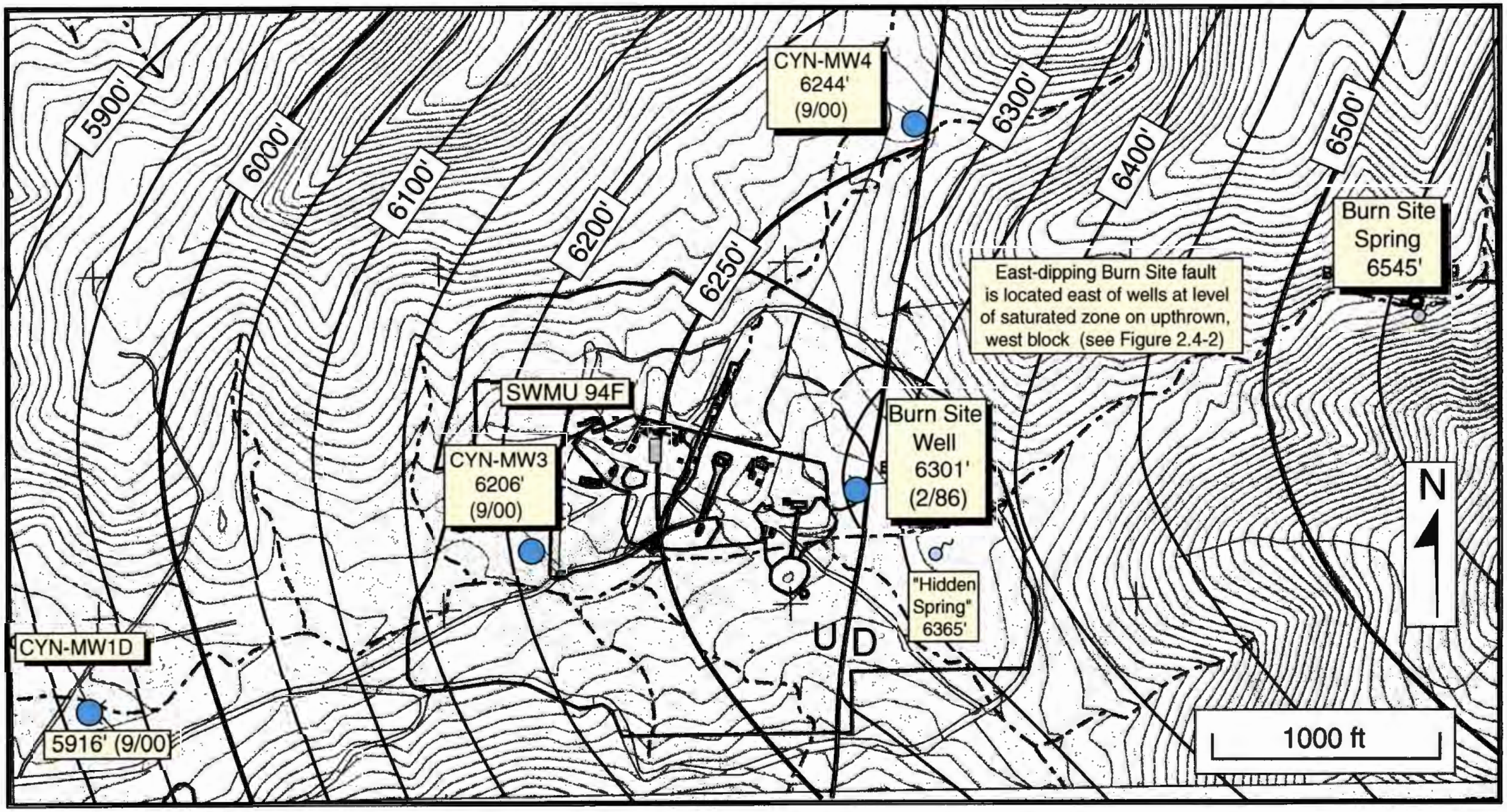

Figure 3.5-2. Conceptual Potentiometric-Surface Map, Burn Site Area (C.I. = 50 ft)
(Note: 20-ft topographic contours in background)

did infiltrate into the underlying bedrock at SWMU 94F. The porosity of soil at both sites appears to be much greater than the underlying bedrock. Typical porosity values range from 25 to 50 percent for unconsolidated sediments (silts and sands) and 0 to 10 percent for fractured rock and shales (Driscoll 1986). Therefore, the majority of contaminants released from both SWMUs were bound to the soil underlying the site and were eliminated as a continuing source of groundwater contamination. Some residual contamination remains in the bedrock underlying SWMU 94F, however, it was not technically practical to remove all of the contaminated bedrock.

A preliminary assessment of potential remedial technologies was conducted to address the small amount of contamination remaining in the bedrock at SWMU 94F. Soil vapor extraction and bioventing were deemed impractical to implement in the fractured bedrock system because they would not greatly enhance airflow rates for the removal of the contaminants from the bedrock medium. Biological treatments work well in soil but maintaining the necessary moisture content and nutrient levels required to stimulate respiration rates, which would effectively decrease contaminant levels, is not achievable in bedrock. It was determined that continued monitoring and evaluation of contaminant concentrations in groundwater would be the most effective method of determining if the source removals at 94F and 94H were adequate remedial measures.

The NMED Groundwater Quality Bureau (GWQB) Draft Monitored Natural Attenuation Policy for Abatement of Ground Water Pollution (NMED GWQB October 2000) provides criteria for a site to be eligible for MNA and provides minimum requirements for an MNA Plan. SWMU 94F meets the eligibility criteria for using MNA as a remedial strategy. The policy requirements will be used in an MNA Plan for the Burn Site groundwater-monitoring program that will be developed in conjunction with the NMED. Some of the requirements have already been met: a site investigation and source removal have been conducted, and the levels of organics detected in the groundwater have been decreasing over time. When approved, the MNA Plan will be implemented and results from the MNA program at the Burn Site will be presented in annual reports submitted to the NMED. Monitoring the levels of contaminants in the groundwater over time and determining if contaminant concentrations continue to decrease will be used to evaluate the effectiveness of the VCAs and the MNA.

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4.0 SUMMARY AND CONCLUSIONS

The Burn Site is contained within the Canyons Test Area (OU 1333) and was used for a high-explosives testing mainly between 1967 and 1975 and for open burn-testing from the early 1970s to 1983. The site is still active.

Groundwater at the Burn Site is contained in fractured, Precambrian bedrock aquifers. Lithologies include granite, quartzite, and schists. These were formed about 1.65 Ga during a regional, northwest-directed compression event with the associated intrusion of a granitic pluton, and were later (about 1.4 Ga) further deformed and metamorphosed. During the next billion years this Precambrian assemblage was uplifted from mid-crustal levels, beveled almost flat to near sea level, and then submerged and overlain by Pennsylvanian sedimentary rocks of the Sandia Formation and the Madera Group. The area was uplifted during the northeast-directed Laramide, compressive event, culminating about 40 Ma, and broken by normal faults during the west-east tensional, Rio Grande rifting event during the late Tertiary. The geometry of the fracture-porosity regime is poorly understood. The Burn Site fault and/or its splays cross through the site from north to south, may contribute significantly to the fracture regime, and may provide conduits from the surface to the fractured aquifer.

Four subsurface groundwater control points exist at the Burn Site: the Burn Site water supply well, installed in 1986, CYN-MW1D installed in 1997, and CYN-MW3 and CYN-MW4, installed in June 1999. A fifth control point, Burn Site Spring, is located in the hills east of the site. A buried spring located about 500 feet southeast of the Burn Site Well is a possible sixth control point.

The contaminants of concern at the Burn Site are VOCs, DRO, and nitrate. The VOCs toluene, ethylbenzene, and xylenes were detected in trace amounts, all below the MCLs, and appear to be naturally attenuating. No benzene has been detected. The source of the VOCs is likely the petroleum hydrocarbons discharged into an unlined pit, SWMU 94F, which probably infiltrated downward to the aquifer through a possible fault in the bedrock at the bottom of the pit. The contaminated soils and several feet of bedrock have since been removed.

Low concentrations of DRO were detected in the three monitoring wells. The main sources of the DRO are likely SWMU 94F (the LAARC unit) and SWMU 94H. The former was an unlined pit that received wastewater contaminated with residual JP-4 jet fuel. A VCA in 2000 removed approximately 1200 cubic yards of fuel-contaminated soil. After removal, a visual inspection revealed a possible fault in the fractured bedrock at the base of the excavation. This feature may be a splay of the Burn Site fault. SWMU 94F is probably the principal source of DRO contamination at the Burn Site. A VCA in 2001 removed approximately 880 cubic yards of JP-8 fuel-contaminated soil from SWMU 94H. Verification samples showed that the fuel contamination was of limited extent and did not reach the underlying bedrock.

Nitrate concentrations in excess of the MCL were detected in the Burn Site Well and in CYN-MW1D and CYN-MW3. The specific source of nitrate is unknown, but the distribution of the contaminant, like DRO, suggests downward movement through the Burn Site fault to the saturated zone.

There are no receptors downgradient of the Burn Site. The Burn Site Well provides a supply of nonpotable water and it is the only such well in the Canyons Test Area. Other facilities in the area depend on bottled water.

Continuous monitoring of the groundwater from the Burn Site Well and the three monitoring wells should, in time, establish clear trends in the contaminant concentrations.

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Attachment 2
Aquifer Pumping Test Report for the Burn Site Groundwater Area of Concern
December 2017

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

SANDIA NATIONAL LABORATORIES, NEW MEXICO
ENVIRONMENTAL RESTORATION OPERATIONS

DECEMBER 2017

United States Department of Energy
Sandia Field Office

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525.

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 conclusions 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.

- Based on the identification of unconfined conditions in several wells, infiltration of nitrate-contaminated water (from past testing activities) could have occurred during historical operations.

- There is no conclusive evidence that nitrate contamination (in excess of background) found in groundwater is from natural or off-site sources.

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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

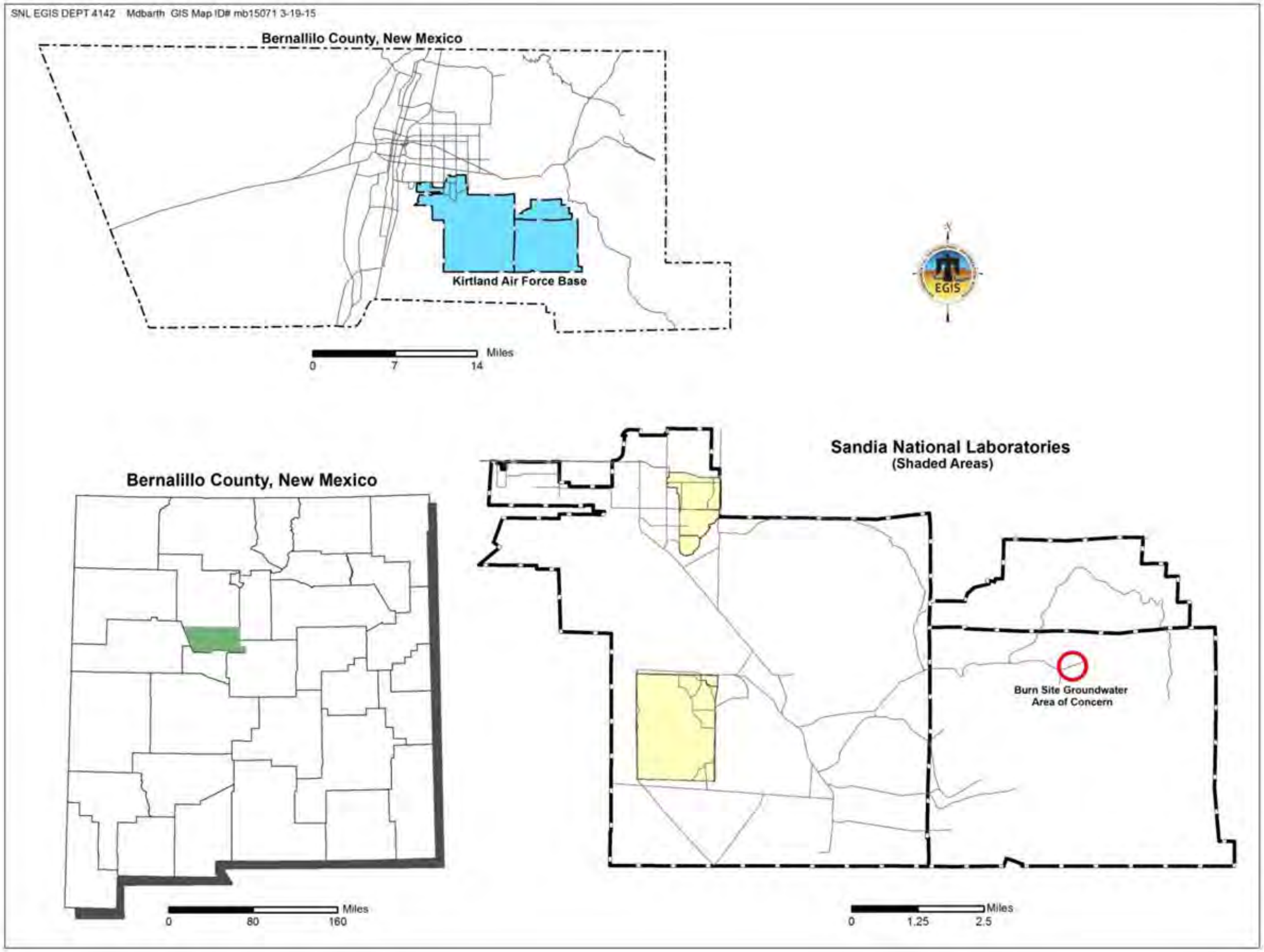

Figure 1-1
Location of the Burn Site Groundwater Area of Concern

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.

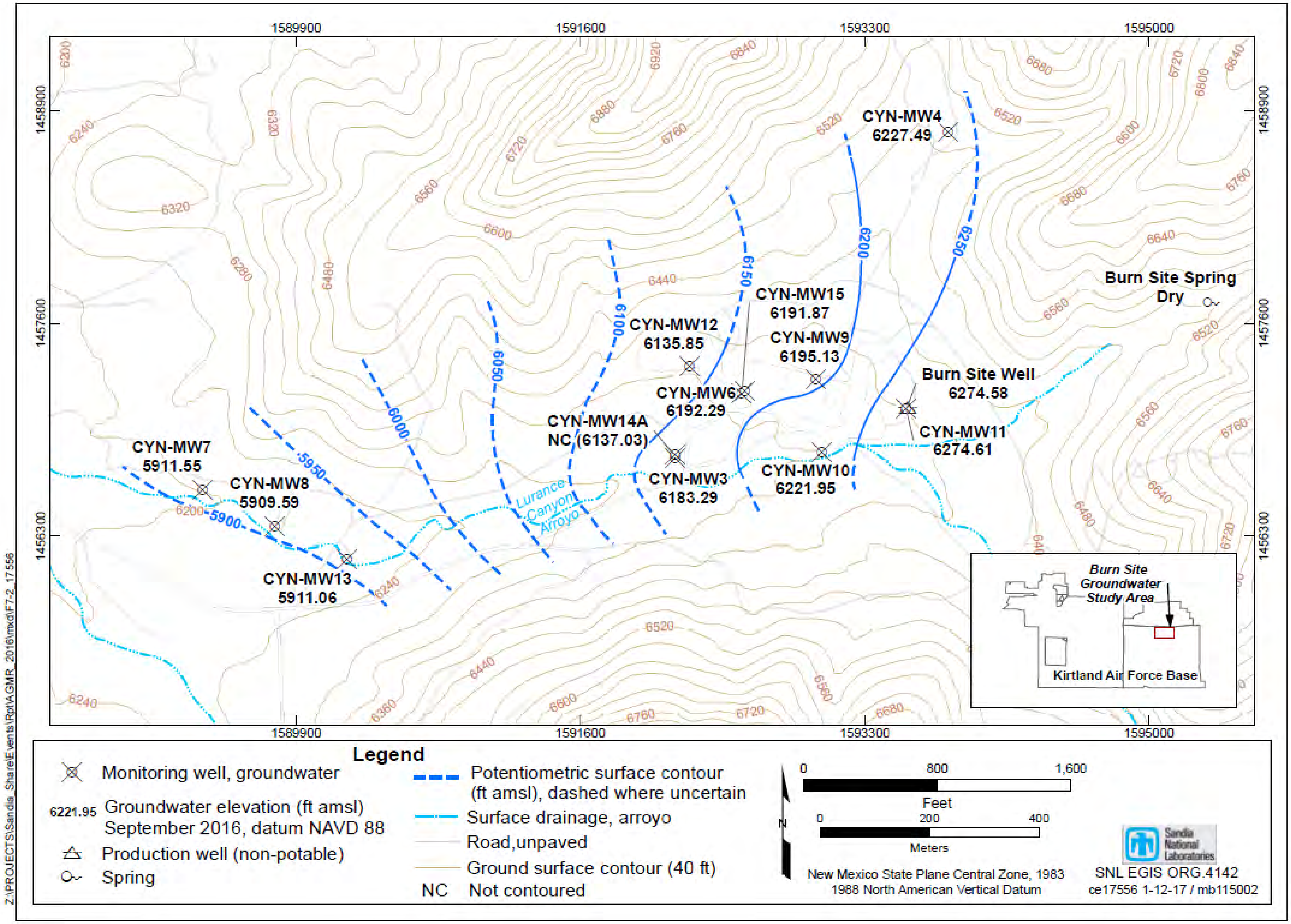

Figure 1-2
Localized Potentiometric Surface of the Burn Site Groundwater Area of Concern (September 2016)

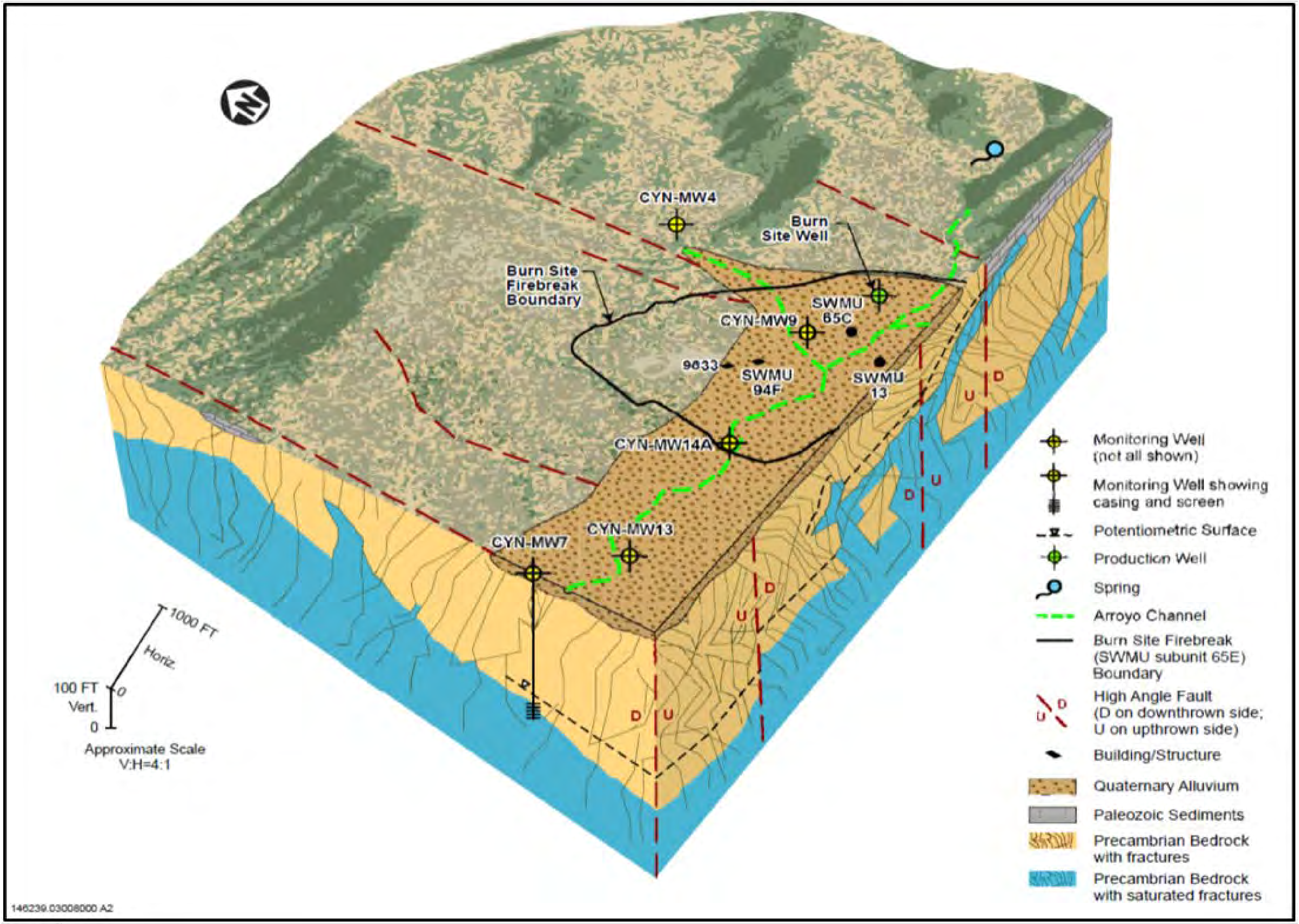

Figure 1-3
Site Conceptual Model of the Burn Site Groundwater Area of Concern

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).

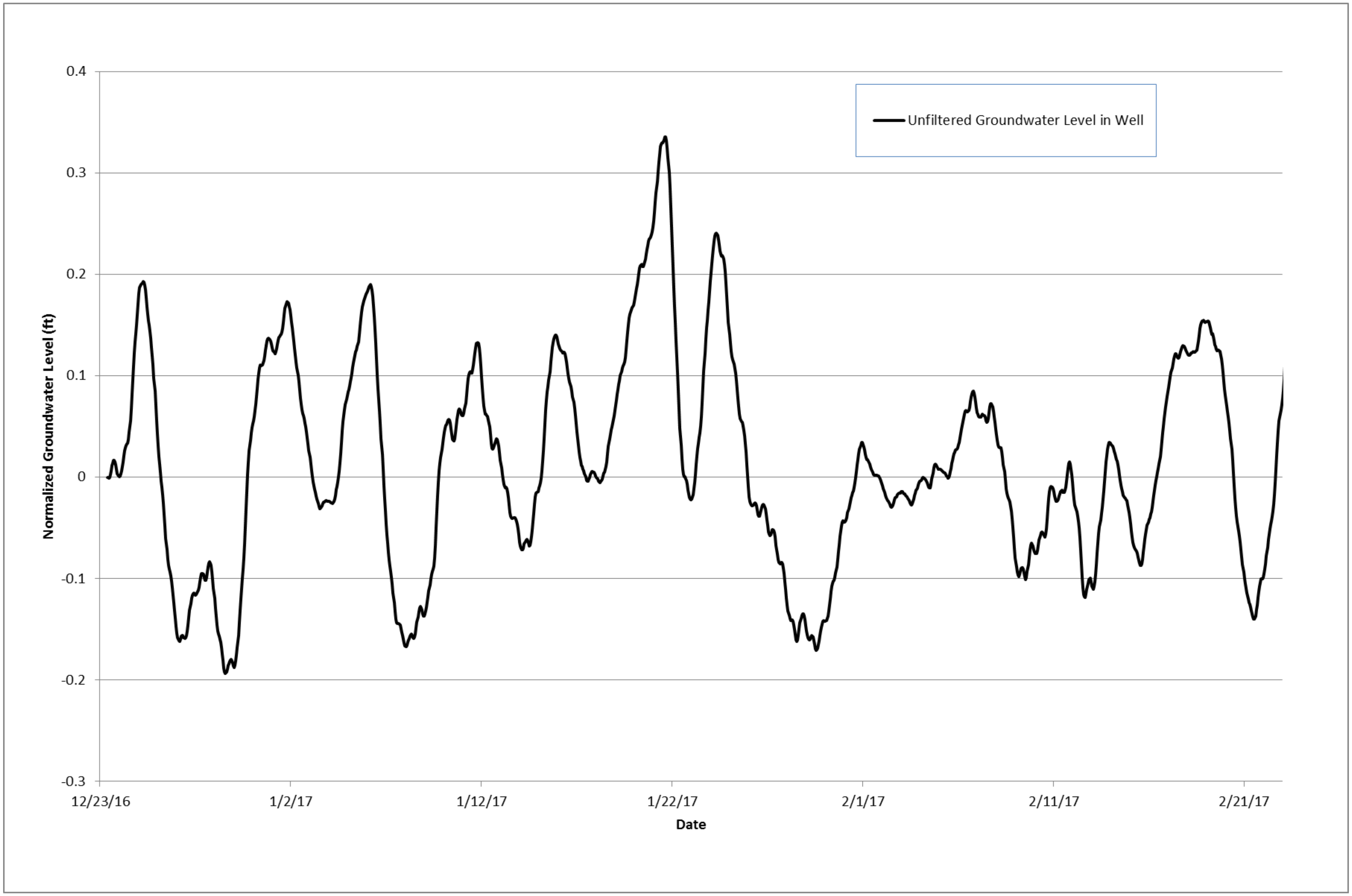


Figure 2-1
Unfiltered Groundwater Level in Well CYN-MW4

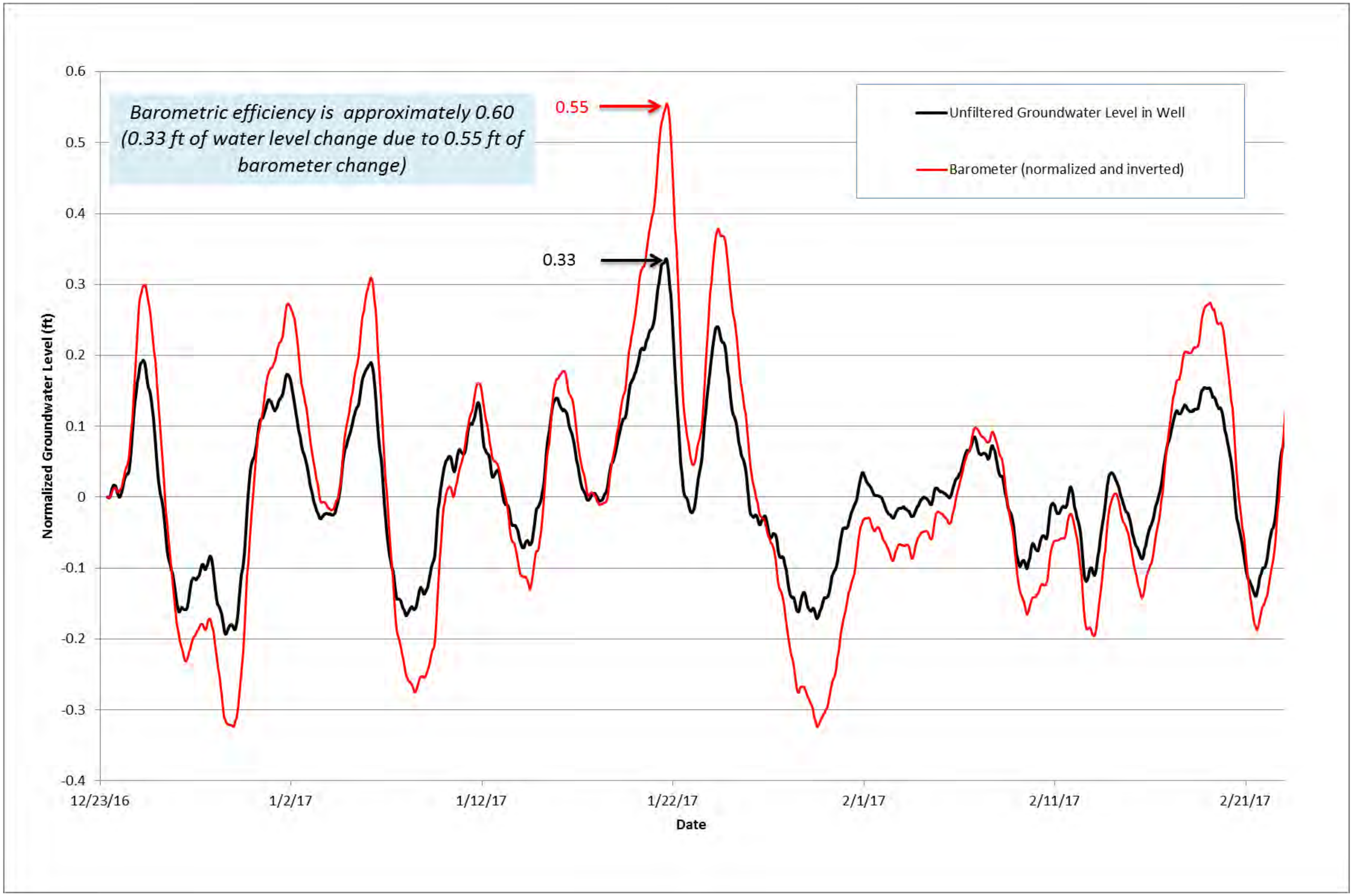


Figure 2-2
Groundwater Level and Barometric Pressure in Well CYN-MW4

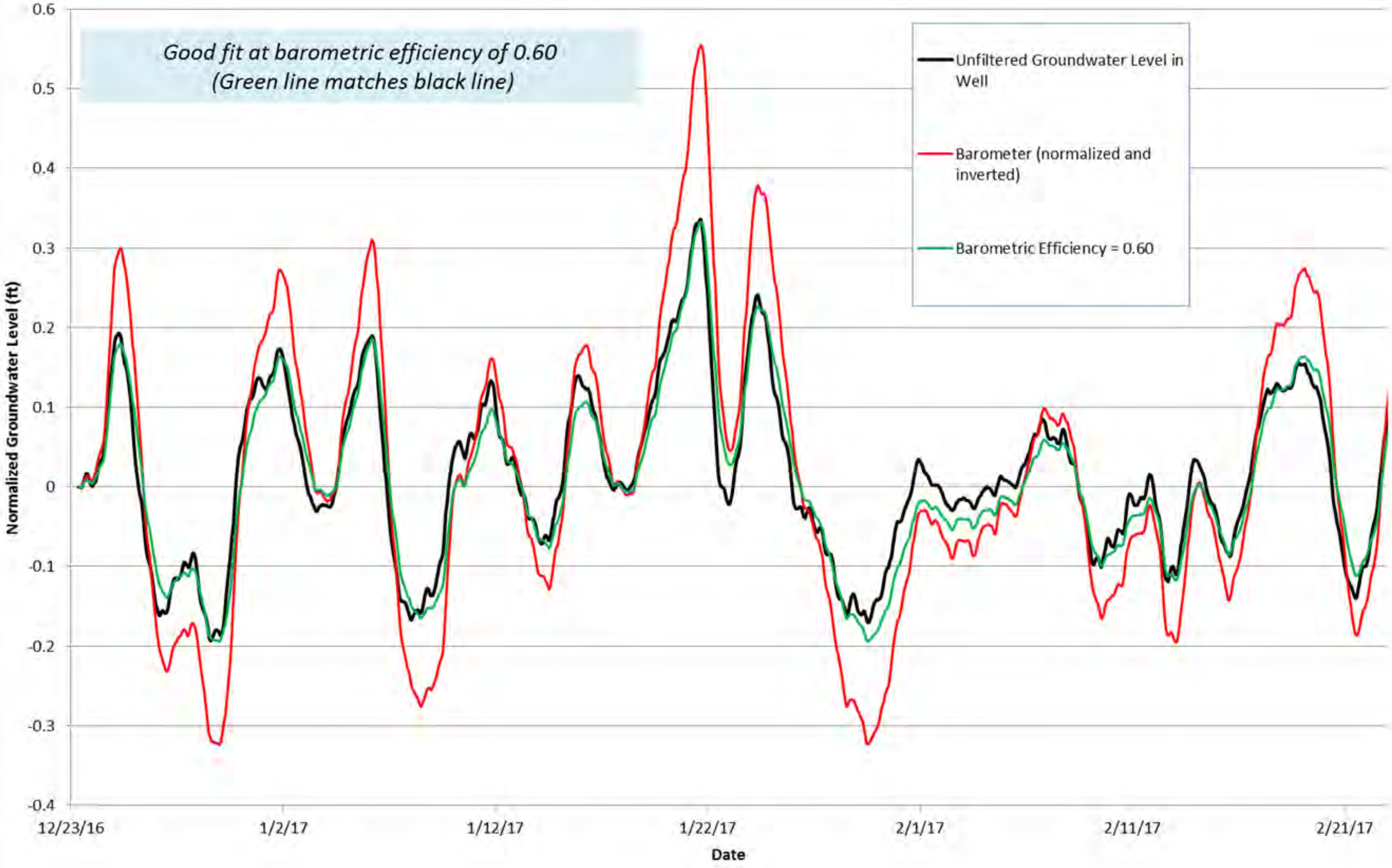


Figure 2-3
Barometric Efficiency in Well CYN-MW4

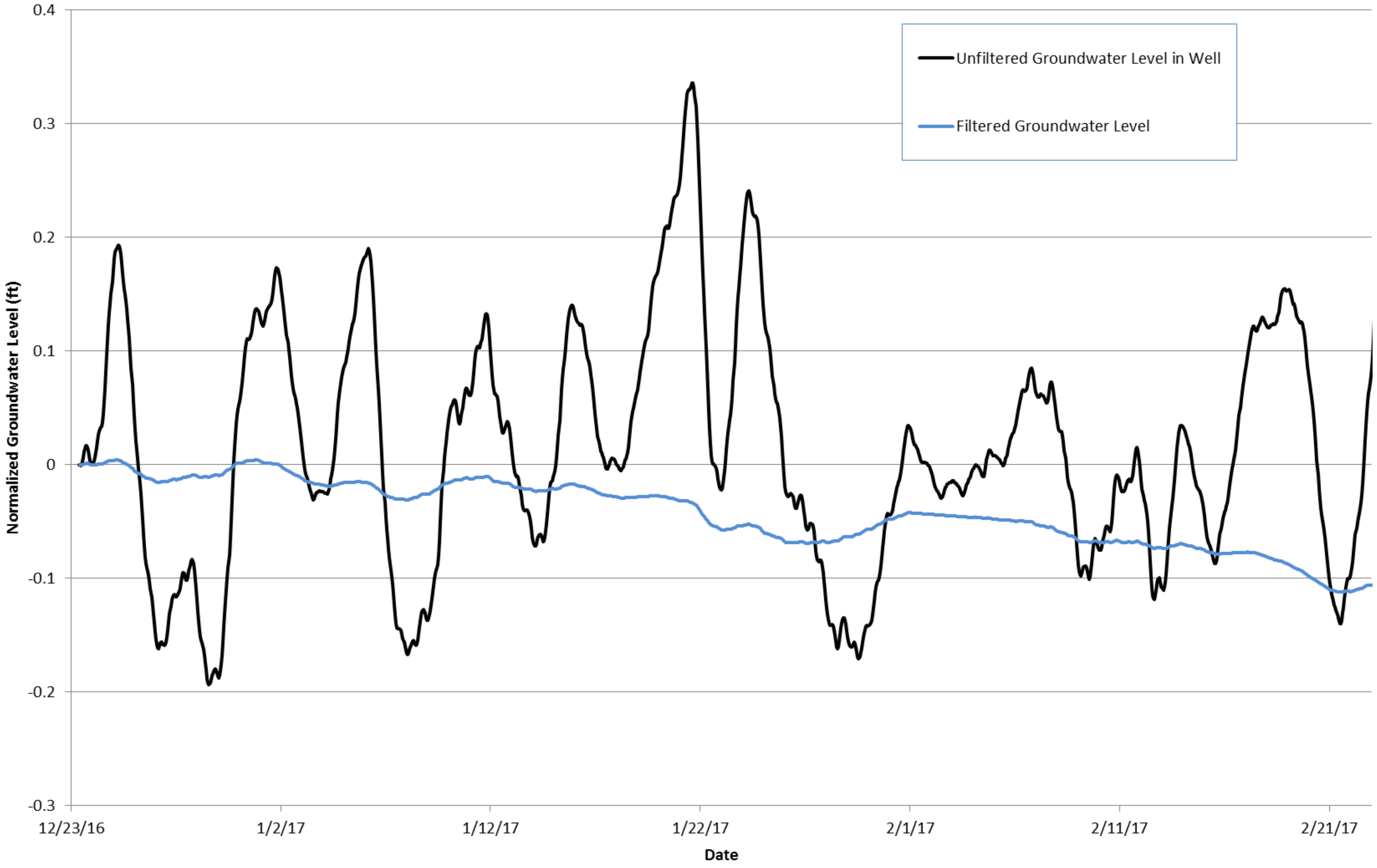


Figure 2-4
Unfiltered and Filtered Groundwater Levels in Well CYN-MW4

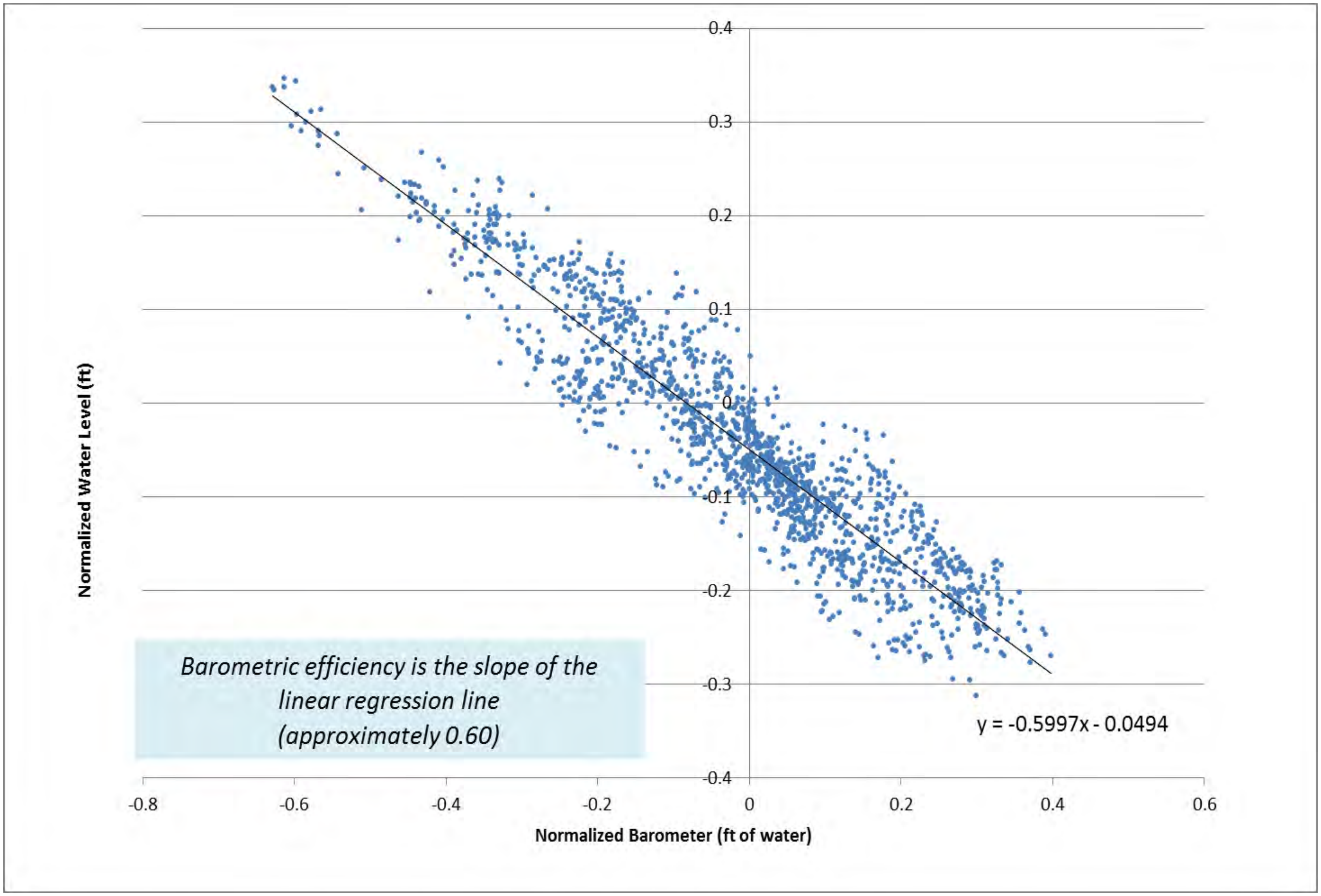


Figure 2-5
Slope Method for Determining Barometric Efficiency in Well CYN-MW4

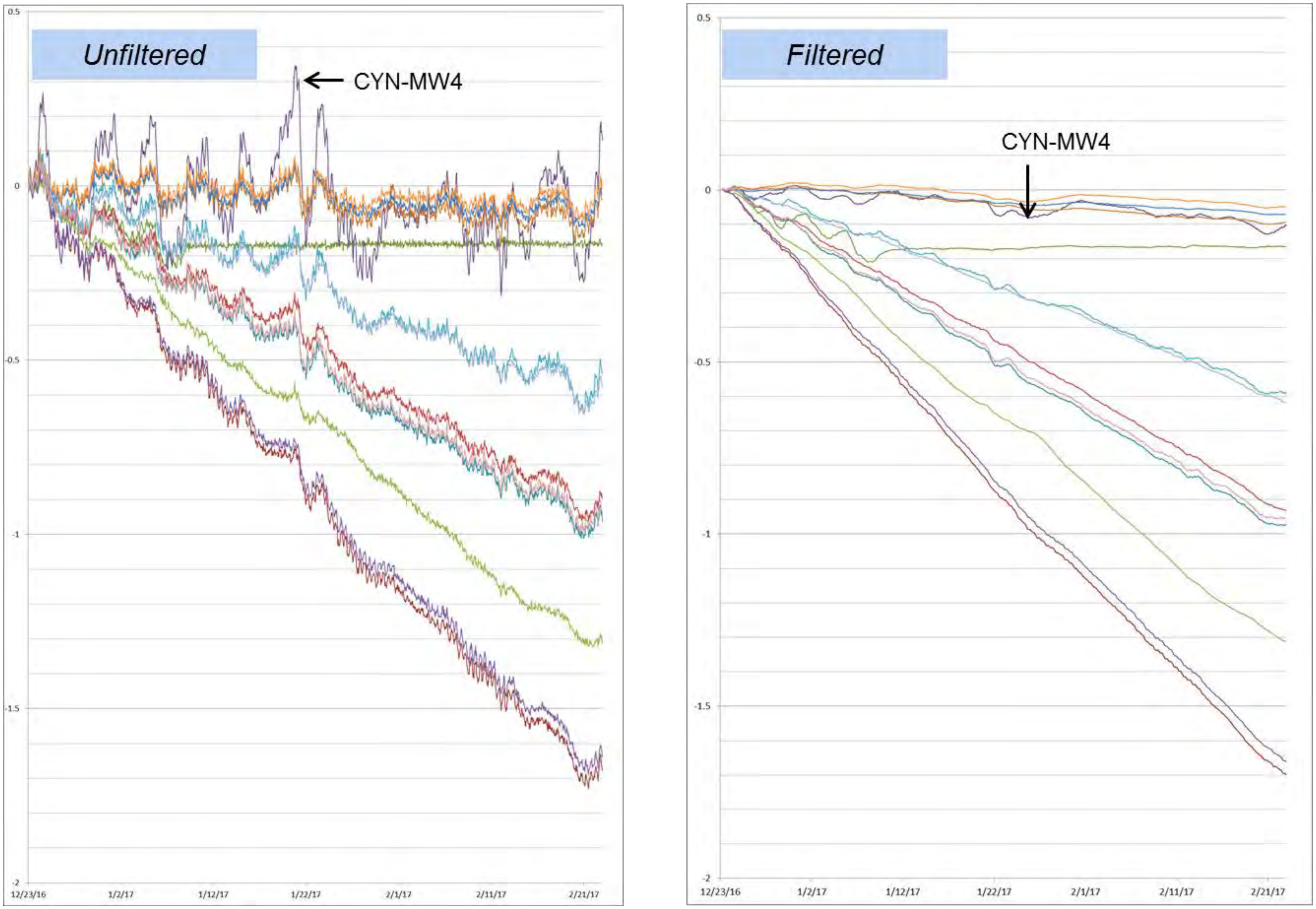


Figure 2-6
Comparison of Unfiltered and Barometrically Filtered Groundwater Levels in Burn Site Groundwater Wells
(well color coding described in Figure 2-7)

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.

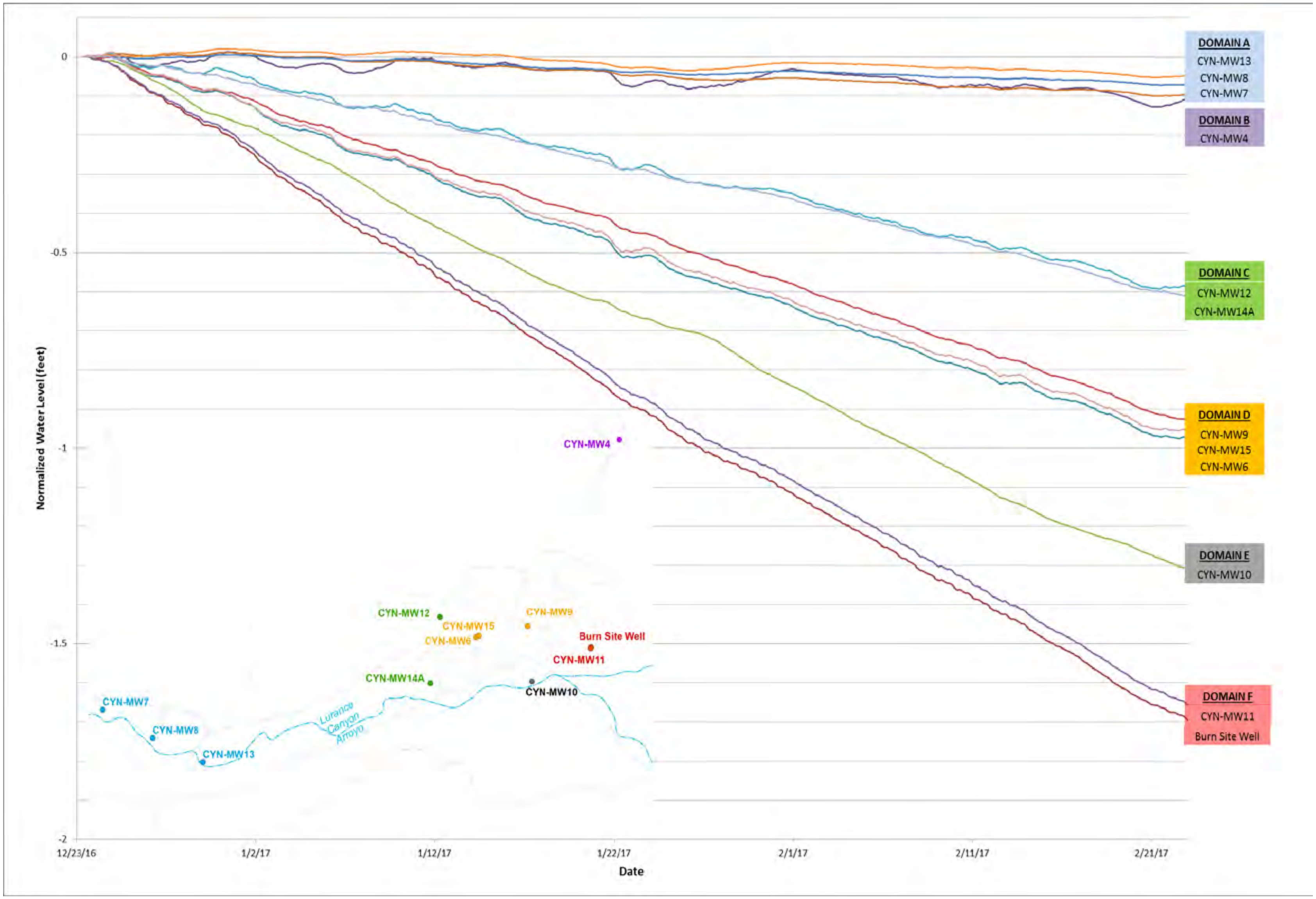


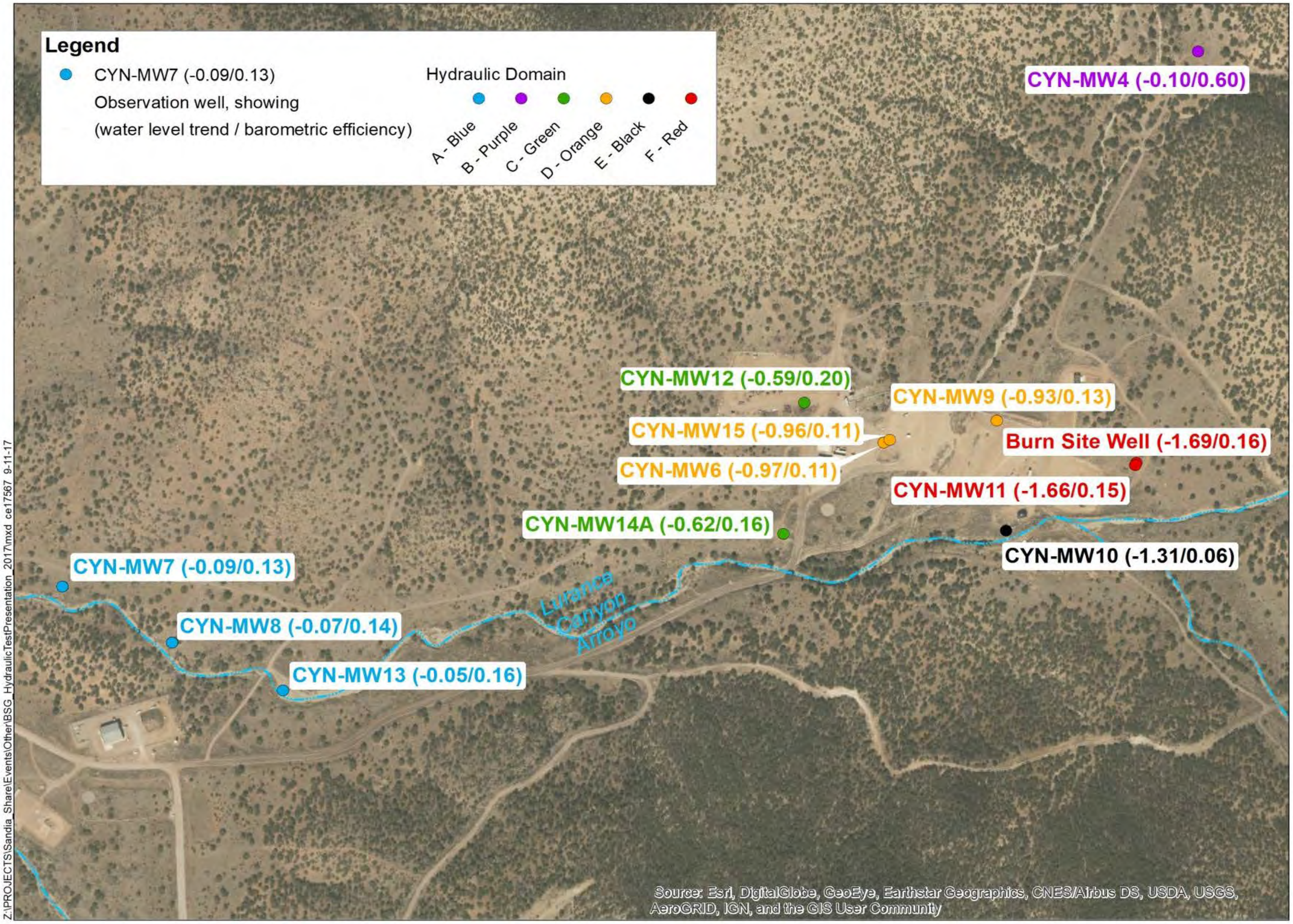
Figure 2-7
Groundwater Level Trends and Hydraulic Domains

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.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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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.

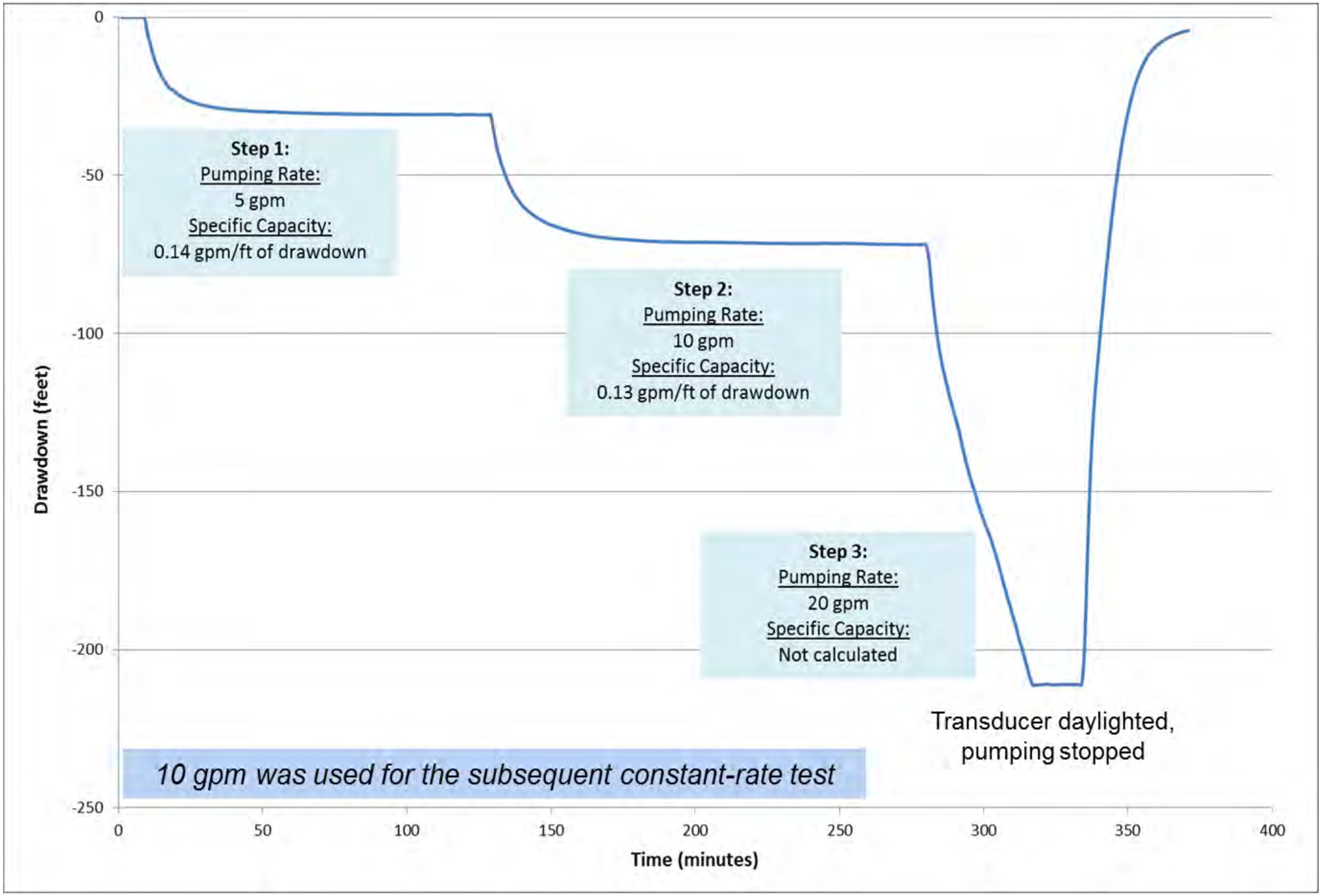

Figure 3-1
Burn Site Well Step-Drawdown Test Hydrograph

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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.

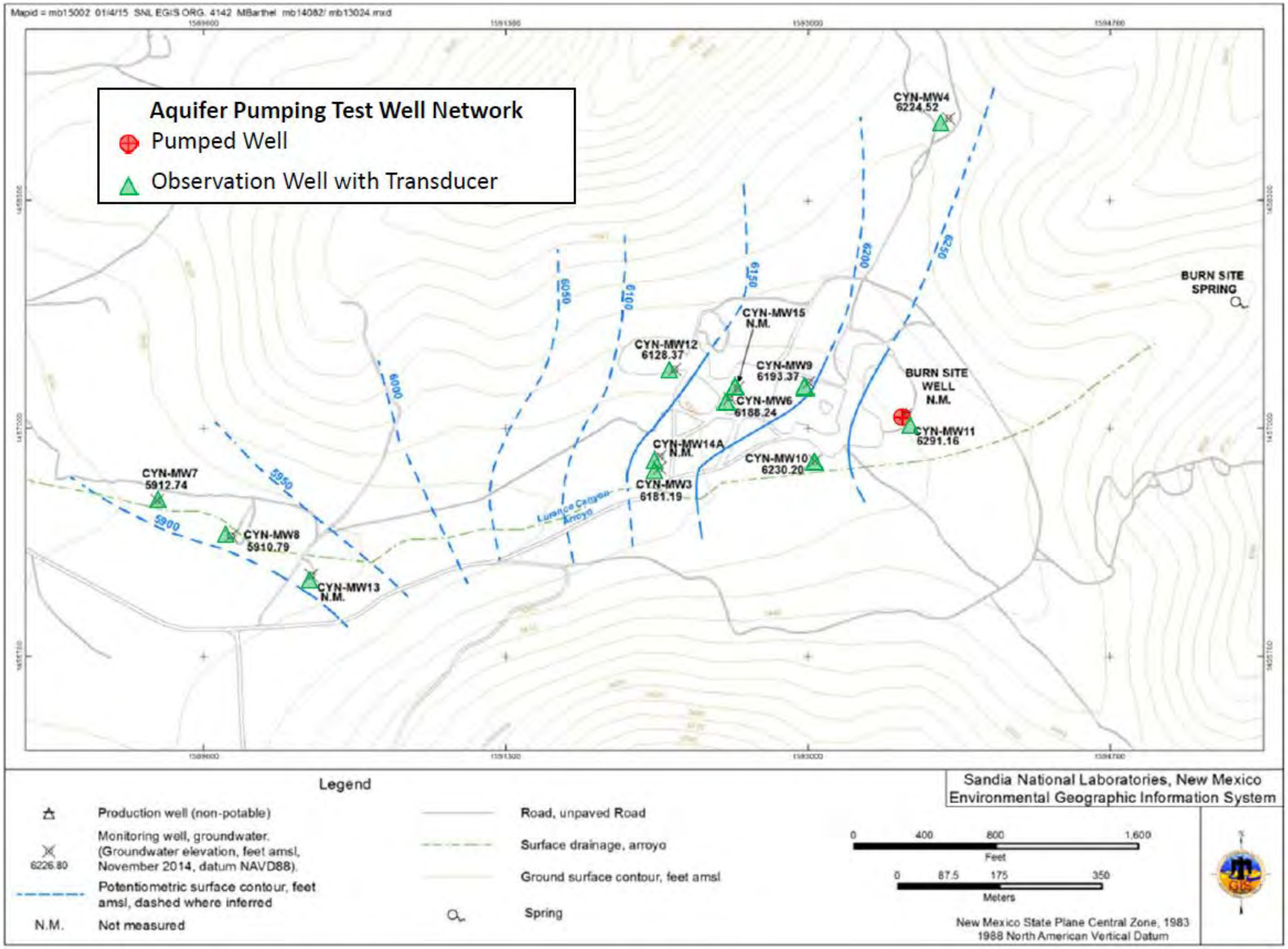

Figure 4-1
Burn Site Groundwater Aquifer Pumping Test Monitoring Well Network

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.

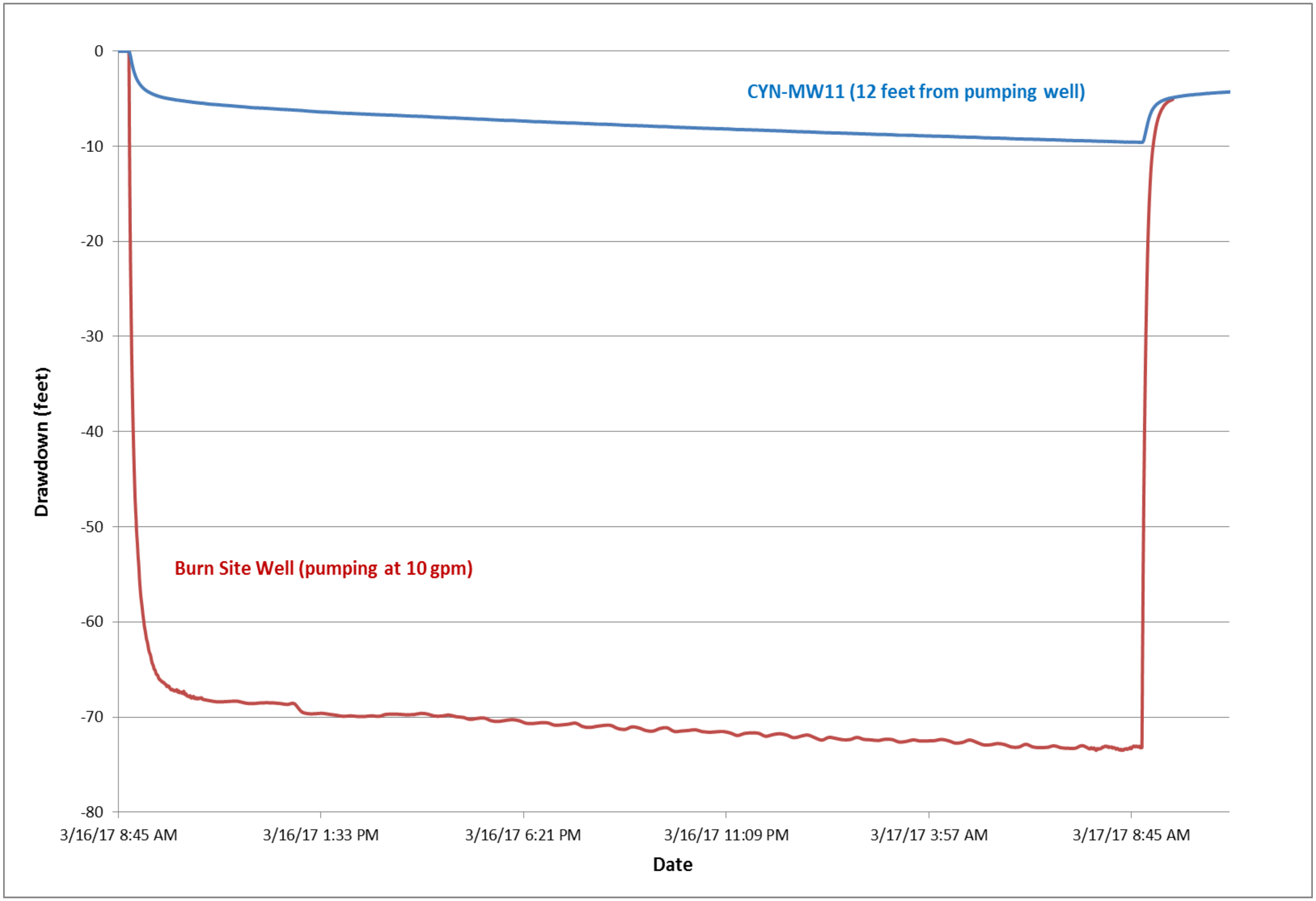

Figure 4-2
Constant-Rate Test Hydrographs for the Burn Site Well and Well CYN-MW11

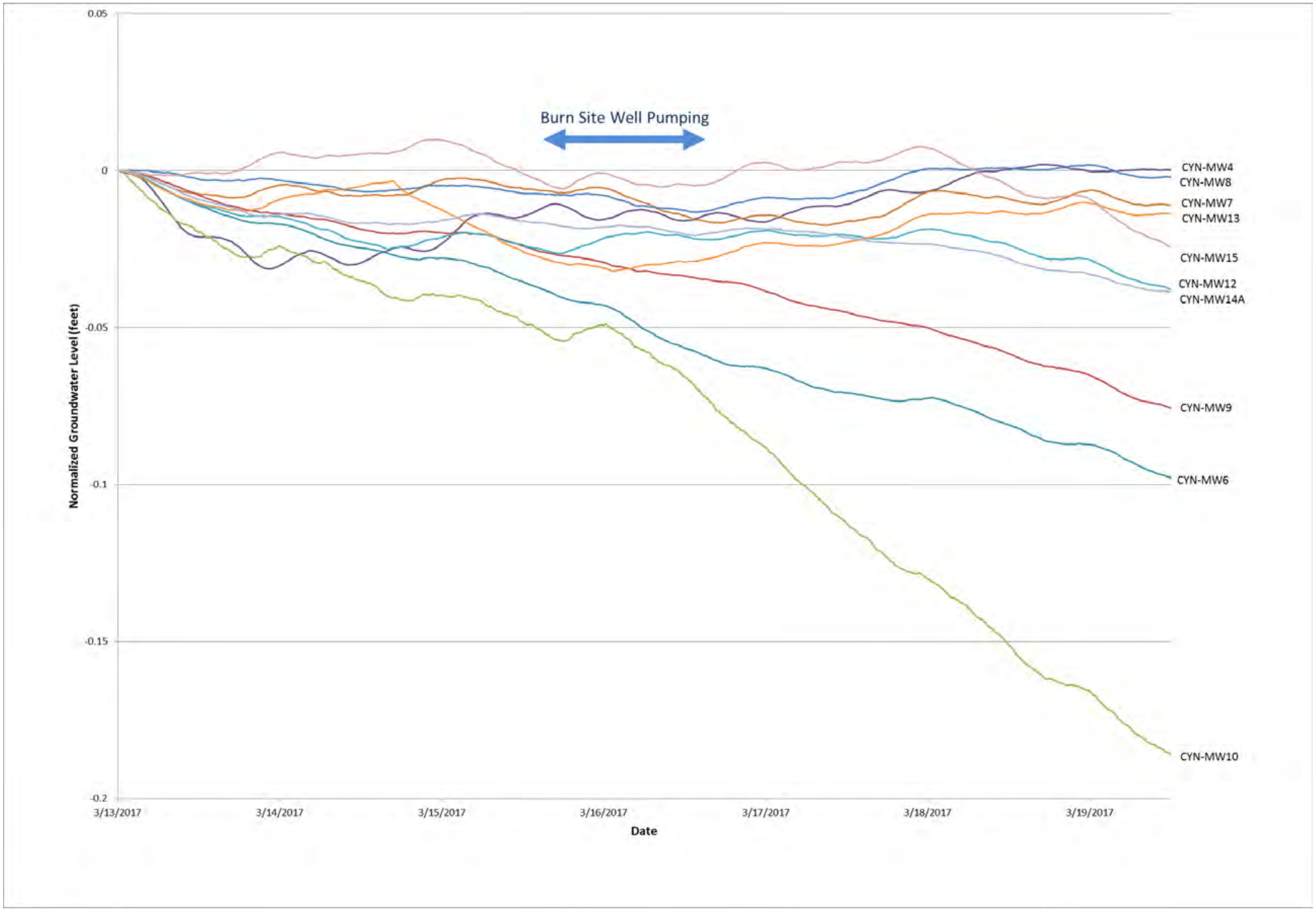

Figure 4-3
Constant-Rate Test Hydrographs for Observation Wells

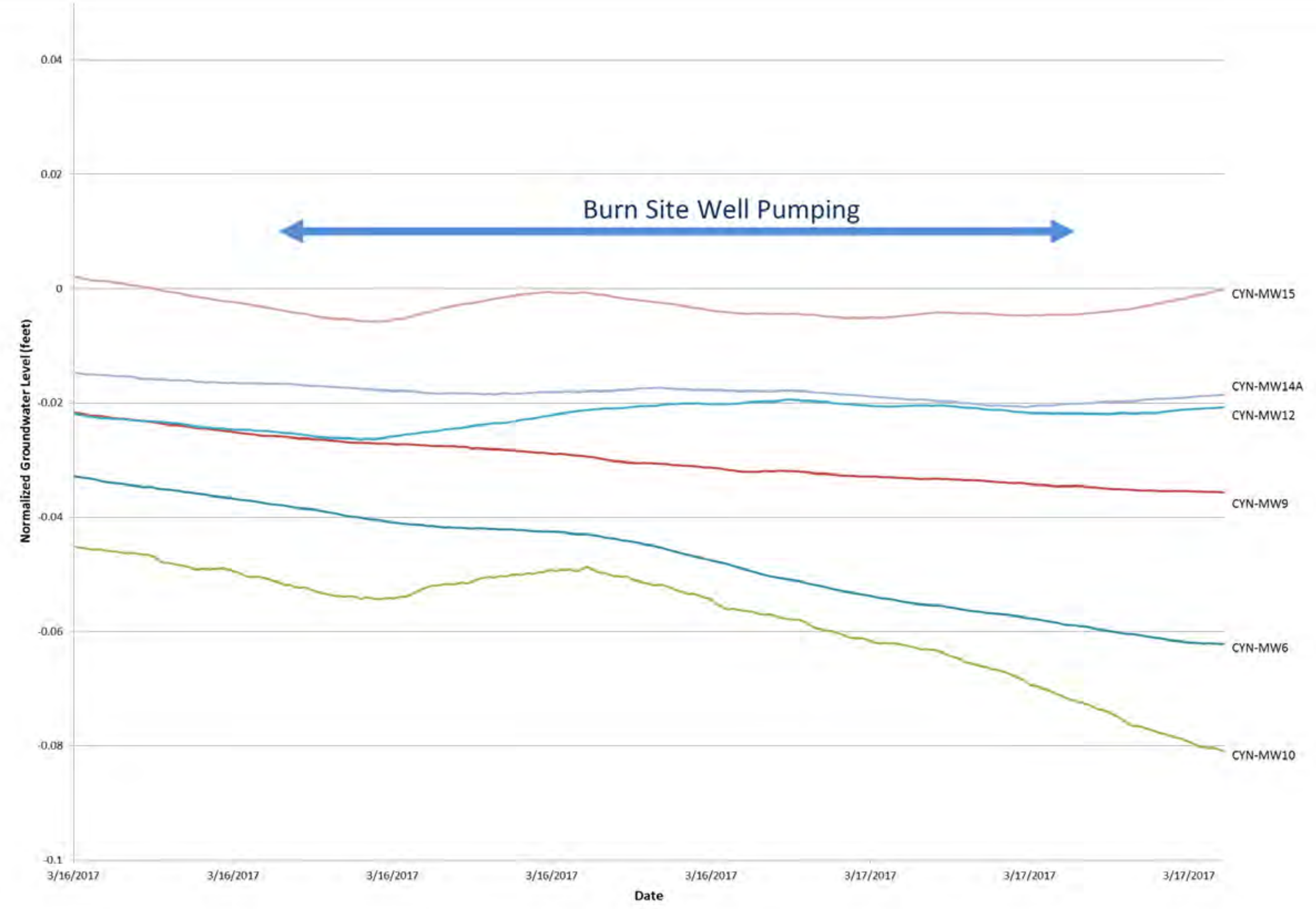

Figure 4-4
Constant-Rate Test Hydrographs for Selected Observation Wells (Detailed View)

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.

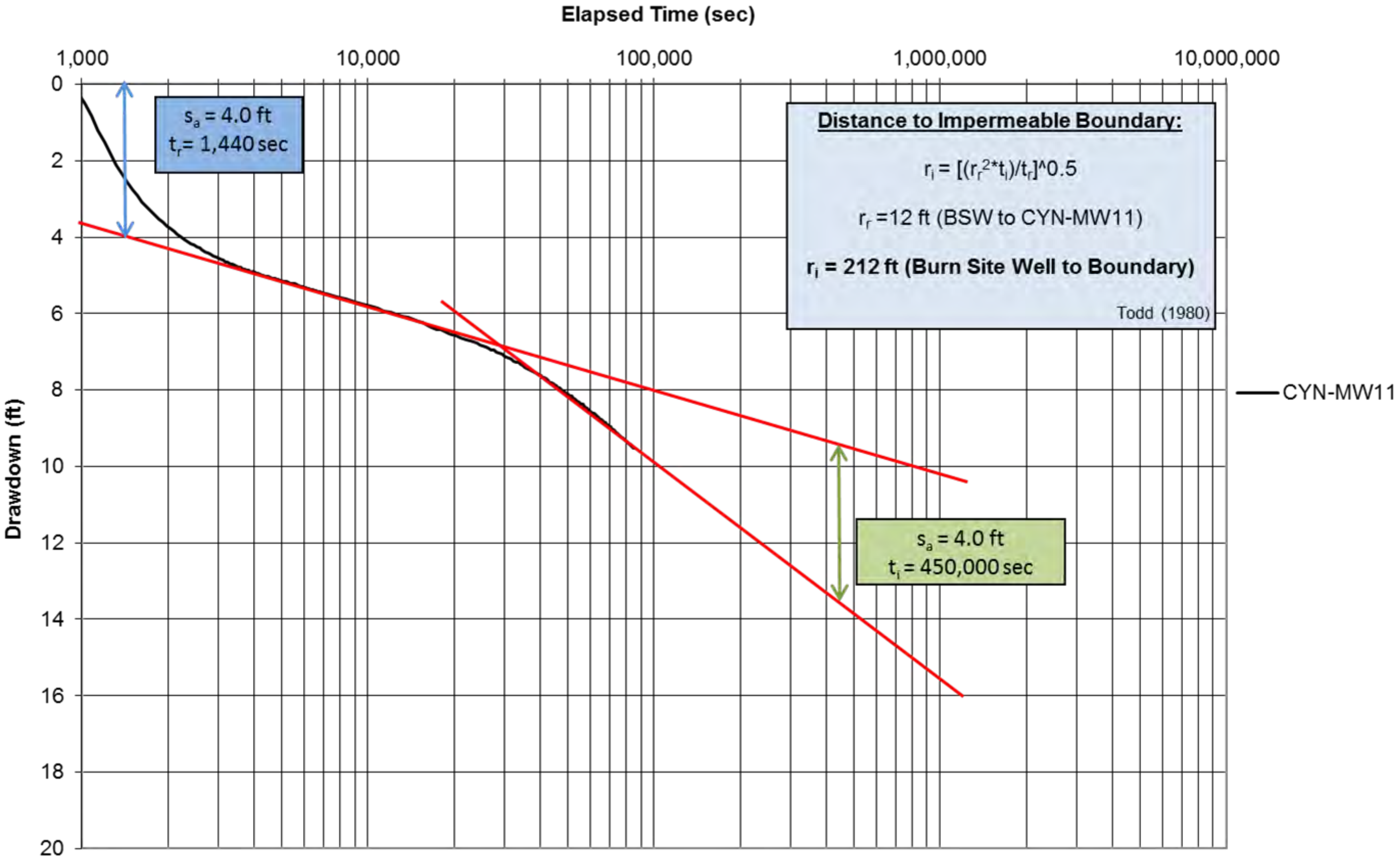

Figure 4-5
Distance to Impermeable Boundary Calculation

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.

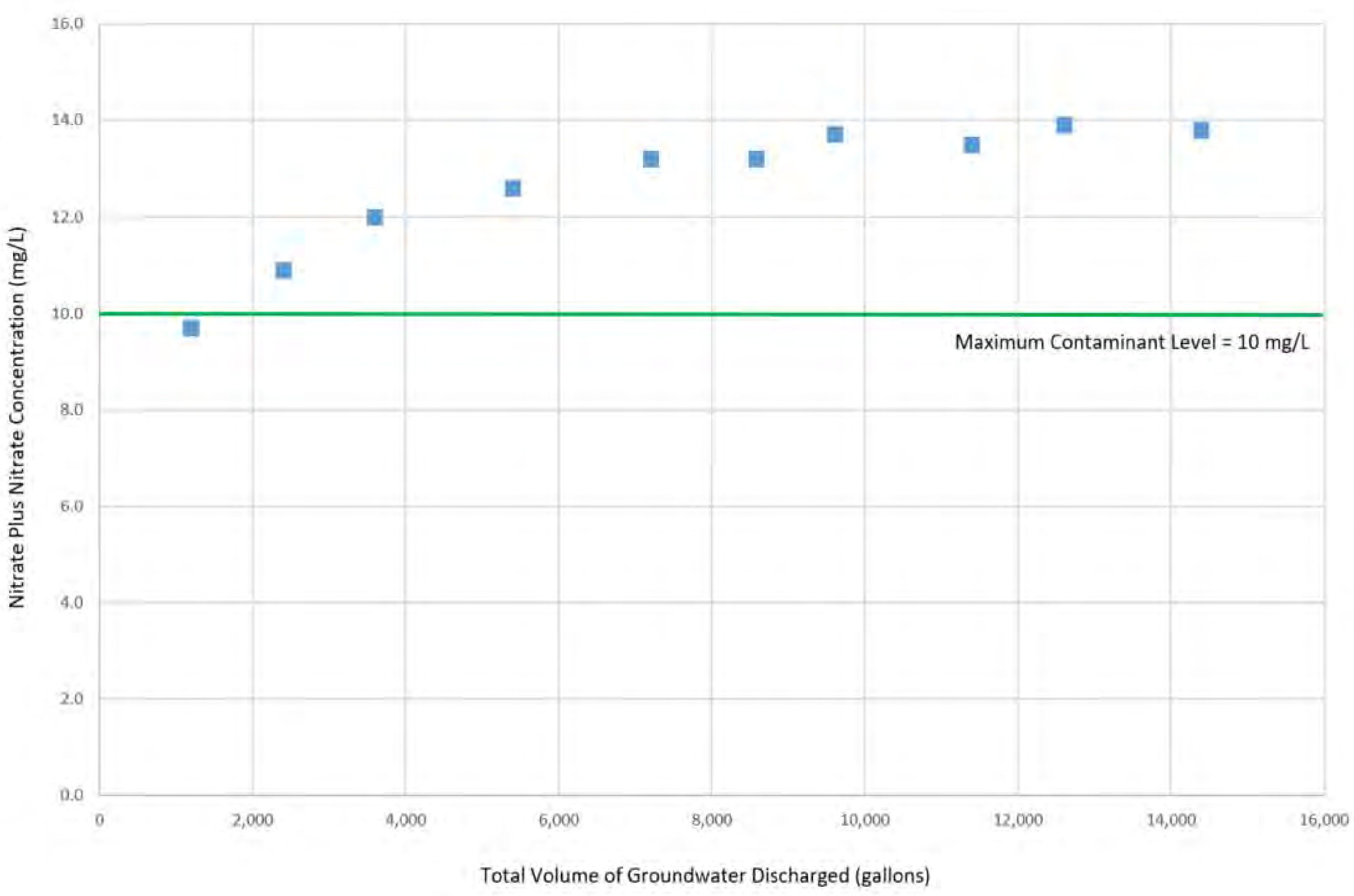

Figure 5-1
Nitrate plus Nitrite (NPN) Concentrations (mg/L) in Discharged Groundwater

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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, there does not appear to be a natural source of nitrate in the area surrounding or upgradient of the BSG AOC.

- Based on 20+ years of hydrologic and analytical data and verified by the barometric efficiency calculations, there is a strong temporal correlation between elevated nitrate concentrations in wells that have precipitation responses during intense thunderstorms, and lower initial hydraulic heads encountered during well drilling.

- There is a strong spatial correlation between elevated nitrate concentrations and the areas where the majority of the outdoor testing (explosives and burning) was conducted, and areas where wastewater discharges occurred during historical operations. Current SNL/NM operational procedures and Best Management Practices do not allow for contaminant releases to the environment.

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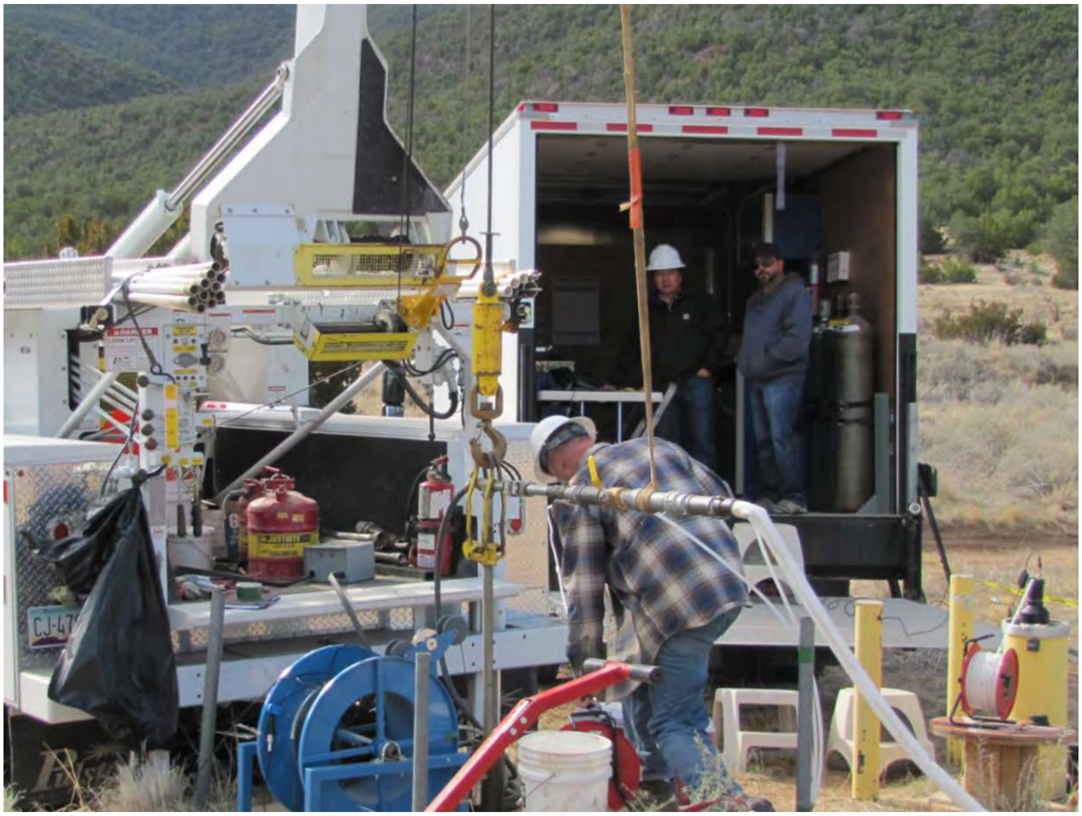
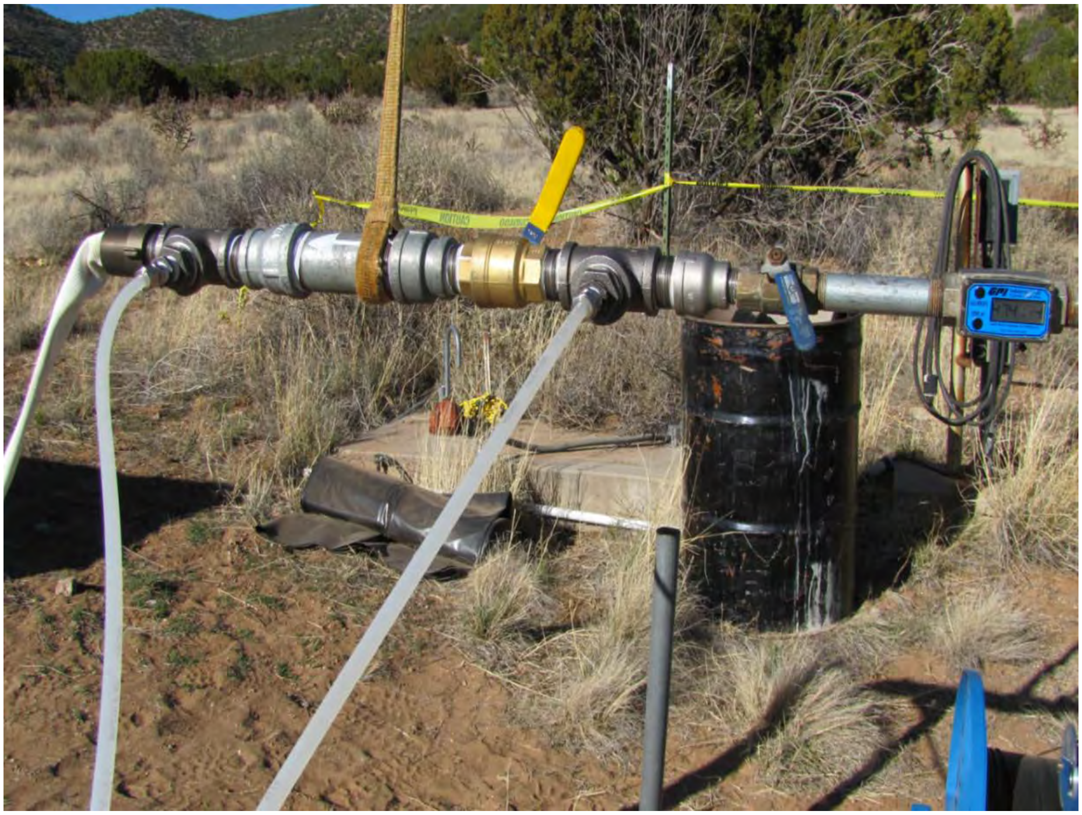
APPENDIX A
Field Photos from the Aquifer Pumping Test at Burn Site Groundwater Area of Concern, March 2017

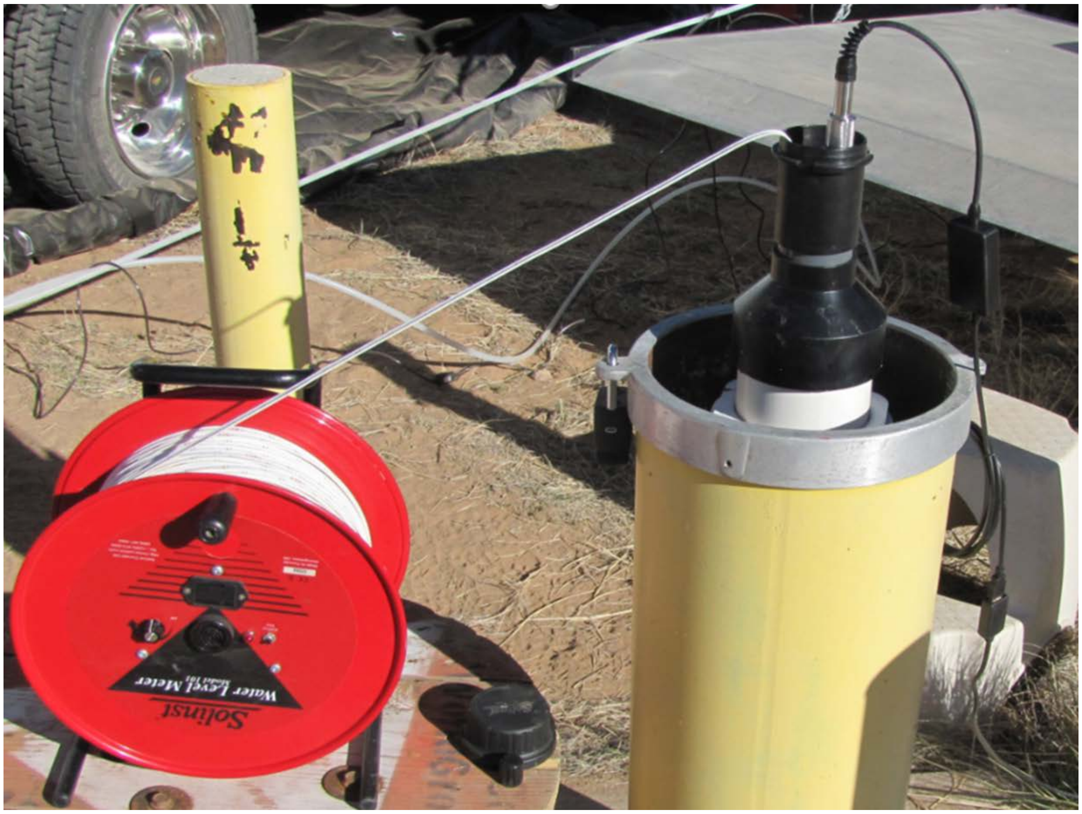


View to the Southeast. Pump Puller Rig (left) and Water Sampling Truck (right) set up over the Burn Site Well, and Monitoring Well CYN-MW11 with Water Level Sounder and Transducer (far right).

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).

Attachment 3
Interpretation of Stable Isotope, Denitrification, and Groundwater Age Data for Samples Collected from Sandia National Laboratories/New Mexico (SNL/NM) Burn Site Groundwater Area of Concern
July 2016

LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-TR-694041

Interpretation of stable isotope, denitrification, and groundwater age data for samples collected from Sandia National Laboratories/New Mexico (SNL/NM) Burn Site Groundwater Area of Concern

Vic Madrid, Michael J. Singleton,
Ate Visser and Bradley K. Esser
Lawrence Livermore National Laboratory

July 11, 2016

Report to Sandia National Laboratories/New Mexico
(WFO Project D20024)

Disclaimer

Auspices Statement

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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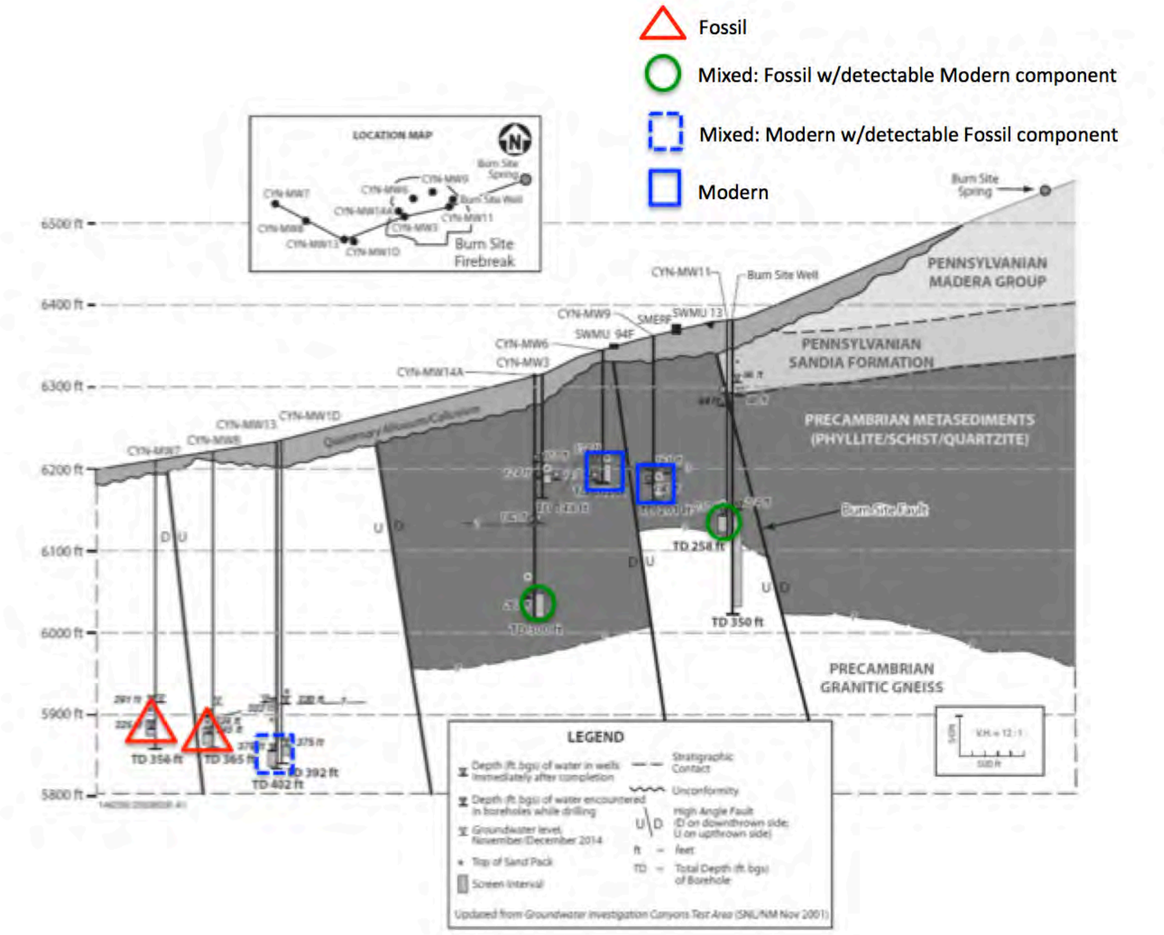
A report to Sandia National Laboratory
LLNL-TR-694041

2016



Suggested citation:

Interpretation of stable isotope, denitrification, and groundwater age data for samples from the Sandia National Laboratories/New Mexico (SNL/NM) Burn Site Groundwater Area of Concern **(LLNL-TR-694041)**

Vic Madrid, Michael J. Singleton, Ate Visser and Bradley K. Esser:

Lawrence Livermore National Laboratory

Prepared in cooperation with Sandia National Laboratory

1 INTRODUCTION

This report combines and summarizes results for two groundwater-sampling events (October 2012 and October/November 2015) from the Sandia National Laboratories/New Mexico (SNL/NM) Burn Site Groundwater (BSG) Area of Concern (AOC) located in the Lurance Canyon Arroyo southeast of Albuquerque, NM in the Manzanita Mountains. The first phase of groundwater sampling occurred in October 2012 including samples from 19 wells at three separate sites that were analyzed by the Environmental Radiochemistry Laboratory at Lawrence Livermore National Laboratory (LLNL, Madrid et al., 2013) as part of a nitrate Monitored Natural Attenuation (MNA) evaluation. The three sites (BSG, Technical Area-V, and Tijeras Arroyo) are shown on the regional hydrogeologic map (Figure 1) and described in the Sandia *Annual Groundwater Monitoring Report* (Jackson et al., 2011). The first phase of groundwater sampling included six monitoring wells at the Burn Site, eight monitoring wells at Technical Area-V, and five monitoring wells at Tijeras Arroyo. Each groundwater sample was analyzed using the two specialized analytical methods, age-dating and denitrification suites (Table 1). In September 2015, a second phase of groundwater sampling took place at the Burn Site including 10 wells sampled and analyzed by the same two analytical suites. Five of the six wells sampled in 2012 were resampled in 2015 (Figure 2).

Table 1. Constituents in the Age-Dating and Denitrification Suites

Age-Dating Suite	Denitrification Suite
• Tritium • $^3He/^4He$ • Noble gases (Helium, Neon, Argon, Krypton, and Xenon)	• Stable isotopes of water: $^{18}O/^{16}O$, $^2H/^1H$ • Stable isotopes of nitrate in samples containing >1 mg/L-NO3 nitrate: $^{15}N/^{14}N$, $^{18}O/^{16}O$ • Dissolved nitrogen and argon gas concentrations • Total Organic Carbon

Groundwater age dating can be used to evaluate the degree to which groundwater at a particular monitoring well is derived from pre-modern and/or modern sources. More specifically, this analysis can be used to assess the timing and contribution of seasonal recharge to the groundwater beneath the BSG AOC relative to recent anthropogenic activities such as high explosives (HE) detonation and burning. Additionally, the data can be used to rule out the possibility that groundwater in some areas exhibits no evidence of recharge in modern times (i.e., during the last 50 years).

The analytical data from the denitrification suite can be used to evaluate the presence and magnitude of *in situ* nitrate reduction by detecting the presence of excess dissolved nitrogen gas and any enrichment in the ^{15}N and ^{18}O of nitrate. Denitrification is a microbially facilitated process that reduces nitrate to molecular nitrogen (N_2) through a series of intermediate products. Denitrification typically occurs in oxygen-depleted, redox negative groundwater systems. If present, the degree of denitrification in groundwater is expected to increase along a groundwater flow path as the residual nitrate concentrations decrease with the isotopic composition, enriched in the heavier ^{15}N and ^{18}O isotopes and depleted in the ^{14}N and ^{16}O isotopes, relative to the original source nitrate. The ratio of the isotopic enrichment of nitrogen to oxygen is consistent across environmental settings, and has been empirically determined to be roughly 2:1 (Kendall, 1998). As a result of denitrification, the concentration of dissolved N_2 gas also increases.

Note that a key factor in any evaluation of natural attenuation of a natural inorganic constituent of groundwater such as nitrate, is an understanding of the: a) extent and magnitude of natural and anthropogenic nitrate source(s), b) aquifer recharge and discharge mechanisms, and 3) the continuity of groundwater flow pathways. As shown in the Burn Site Conceptual Hydrogeologic Model (Figure 3), the subsurface beneath the BSG AOC is complex due to variable bedrock stratigraphy and structure, and the presence of fractures and faults with unknown hydraulic connectivity. An understanding of the major processes that influence natural attenuation of nitrate in such a complex hydrogeologic setting requires the integration of several independent data sets (e.g., geochemistry, long-term spatial and temporal nitrate trends, hydraulic response under natural recharge and stress conditions, etc.) that are not part of this evaluation. In this report, LLNL summarizes results from two sampling events in order to evaluate evidence for *in situ* denitrification, the average age of the groundwater, and the extent of recent recharge of the bedrock fracture system beneath the BSG AOC.

2 ANALYTICAL METHODS

All analyses listed in Tables 1 and 2 were performed at Lawrence Livermore National Laboratory. Data quality objectives and reporting standards for the stable isotope analyses are summarized in Table 2. Stable isotopic analyses were determined using an IsoPrime gas source isotope ratio mass spectrometer (IRMS) in continuous flow mode. Molecules of interest are first converted to a simple gas prior to determining their stable isotope compositions. Oxygen isotope compositions in water are determined using an automated carbon dioxide equilibration method for $^{18}O/^{16}O$ based on the procedure of (Epstein and Mayeda, 1953). The hydrogen stable isotope compositions of water samples are determined by the high-temperature chromium reduction technique (Morrison et al., 2001). A small volume of water (~0.4μL) is injected by an autosampler into an elemental analyzer containing chromium metal. The sample oxygen bonds with the chromium and the resulting H_2 gas is carried in a stream of helium to the IRMS.

Table 2: Data Quality Objectives and Reporting for Stable Isotope Analysis

Parameter	Method/ Range	Units	Reference	External Precision[1]	Instrumental Precision[2]
Nitrate $\delta^{18}O$ **Nitrate $\delta^{15}N$**	Continuous Flow Mass Spectrometry	Per mil (‰)	$\delta^{15}N$: Air $\delta^{18}O$: VSMOW	$\delta^{15}N$ ± 0.3 ‰ $\delta^{18}O$ ± 0.8 ‰	$\delta^{15}N$ ± 0.2 ‰ $\delta^{18}O$ ± 0.5 ‰
Water $\delta^{18}O$ **Water $\delta^{2}H$**	Dual Inlet and/or Continuous Flow Mass Spectrometry	Per mil (‰)	$\delta^{18}O$: VSMOW $\delta^{2}H$: VSMOW	$\delta^{18}O$ ± 0.3 ‰ $\delta^{2}H$ ± 2 ‰	± 0.15 ‰ ± 1 ‰

1. External (1 sigma) precision objectives apply to replicate analyses of a single sample.
2. Instrumental precision (1 sigma) applies to calibration check samples, laboratory control samples and other measurements of samples of known concentration and isotopic composition where the known value is compared to the measured value.
3. VSMOW = Vienna Standard Mean Ocean Water.

Samples for isotopic analysis of nitrate ($\delta^{15}N-NO_3$ and $\delta^{18}O-NO_3$) were analyzed following a version of the denitrifier method (Casciotti et al., 2002; Sigman et al., 2001; Singleton et al., 2005). In this method, a strain of denitrifying bacteria is used to reduce dissolved nitrate in water samples to N_2O gas that can be analyzed for N and O isotopic composition on the IRMS. The denitrifier method provides the results of the combined nitrate and nitrite signatures (Wankel et al., 2009).

In order to detect excess dissolved nitrogen produced by denitrification, dissolved concentrations of N_2 and Ar for this study were analyzed by Membrane Inlet Mass Spectrometry (MIMS) as described in (Kana et al., 1994). The gas abundances are calibrated using water equilibrated with air under known conditions of temperature, altitude, and humidity (typically 25 °C, 183 m, and 100% relative humidity). Typical sample size is 5 mL, and each analysis takes approximately 3 minutes. Samples are collected for MIMS analysis in 40 mL amber glass VOA vials, with no headspace.

Excess N_2 was calculated by subtracting the nitrogen present in the water due to equilibration with the atmosphere and assimilation of excess air, similar to the method in (Beller et al., 2004). For the Burn Site wells, recharge temperature was determined based on dissolved xenon concentrations, and excess air was determined based on the concentration of neon. For wells where noble gases were not measured, the recharge temperature is assumed to be equal to the discharge temperature at the well, and argon was used to correct for excess air. Recharge elevations were assumed to be at the surface elevation of the well.

The decay of tritium (^3H) in groundwater and the subsequent accumulation of its daughter product, helium-3 (^3He), can be used to determine the age of a groundwater sample, i.e. the time since last equilibration of groundwater helium with atmospheric helium at recharge. The primary source of tritium in groundwater is recharging precipitation. Sources of helium in groundwater include equilibration with the atmosphere (for both ^3He and ^4He), the alpha decay of uranium and thorium (for ^{4}He), and the beta decay of tritium (for ^{3}He). Distinguishing tritiogenic ^{3}He from non-tritiogenic ^{3}He in a groundwater sample typically requires the determination of other noble gases in the groundwater sample.

The Noble Gas Mass Spectrometer facility at LLNL has been operational for over fifteen years. The collection and analysis of samples is described in two SOPs (Visser et al., 2013a; Visser et al., 2013b). A groundwater sample for analysis of dissolved noble gases is collected by pumping water through a soft copper tubing (0.95 cm diameter, 35 cm length) that is subsequently sealed under back-pressure with steel pinch clamps to create a gas-tight cold weld. The cold-welded copper tube typically contains 9.75 grams of water, determined accurately by weighing tube and clamps before and after analysis. The helium isotope ratio and abundances of all noble gases (He, Ne, Ar, Kr, and Xe) are measured in groundwater samples in the laboratory by mass spectrometry techniques using a VG5400 noble gas mass spectrometer. The gas samples are prepared for mass spectrometric analysis using a combination of chemical gettering and cryogenic separations. Tritium concentrations were determined on 500 g sub-samples by the ^{3}He in-growth method (approximately 25 day accumulation time). Analytical uncertainties are approximately 1% for ^{3}He/^{4}He, 2% for He, Ne, and Ar, and 3% for Kr and Xe. Errors for derived parameters such as groundwater age and recharge temperature are propagated using analytical errors for the individual measured quantities. Accurate ^{3}H/^{3}He ages can be determined if a samples contains more than 1 pCi/L of ^{3}H.

3 RESULTS

To date, eleven different wells have been sampled in the Burn Site area for analyses of groundwater age (Table 3a) and denitrification (Table 4). Depending on location, the wells are screened in Precambrian metasediments (phyllite and schist). Of the six wells that were sampled in 2012, all were resampled in 2015 with the exception of CYN-MW6 (Figure 2). Well CYN-MW15, located adjacent to CYN-MW6 but screened slightly deeper, was sampled in 2015 rather than CYN-MW6. Of the ten wells sampled in 2015, seven (CYN-MW9, CYN-MW10, CYN-MW11, CYN-MW12, CYN-MW13, CYN-MW14A, and CYN-MW15) contained groundwater with nitrate exceeding the 10 mg/L (as N) maximum concentration limit (MCL). Six of the seven wells with elevated nitrate are located in the central test area of the Burn Site and one well (CYN-MW13) is located approximately 2,000 feet west-southwest in the Lurance Canyon Arroyo. The groundwater age and nitrate isotope data are plotted on Figures 4 and 5, respectively.

The ^{3}H/^{3}He age-dating results indicate that the age of groundwater recharge varies across the study area. The two monitoring wells (CYN-MW9 and CYN-MW10) located near the Burn Site central test area that contain the highest nitrate concentrations (> 20 mg/L as N) also sample exclusively modern groundwater (< 50 years). Additionally, groundwater samples collected from wells CYN-MW9 exhibited a significant increase in the amount of tritium detected in 2015 compared to 2012 (Figure 4). The apparent ^{3}H/^{3}He age of the modern water in this well is less than 10 years. The increase in tritium concentration indicates an increase in the relative contribution of recent recharge. Wells CYN-MW11 and CYN-MW12 sampled predominantly fossil water with a small (< 1 pCi/L) but detectable modern component in 2012. However, samples collected in 2015 contained significantly higher tritium concentrations, indicating a significant fraction of modern water. The other monitoring well (CYN-MW-13) that contains elevated nitrate (> 20 mg/L as N) also samples predominantly modern groundwater, in which a component of fossil water is also detected. All other groundwater monitoring wells that were sampled either contain exclusively fossil water or predominantly fossil water with a detectable modern component. Note that CYN-MW6, which was sampled in 2012 but not in 2015, contains predominantly modern water. As mentioned above, this well is located adjacent to CYN-MW15 but screened slightly shallower.

The $^3H/^3He$ method can only determine the average age of the groundwater and does not directly trace the source or age of the dissolved nitrate. In groundwater with a specific age (not-mixed) the age of the nitrate and the water are likely the same. In mixed-age groundwater, the age of the water and the mass-weighted age of the nitrate need not be the same. The results of a $^3H/^3He$ on a single mixed-age well cannot distinguish whether the high nitrate is associated with modern recharge. Monitoring wells CYN-MW11 and CYN-MW12, also located near the Burn Site central test area, contained very low but detectable amounts of modern recharge (< 1 pCi/L of ^3H). The farthest up gradient (CYN-MW4) and farthest down gradient monitoring wells (CYN-MW7 and CYN-MW8) contained pre-modern to fossil waters with no evidence of modern recharge and no detectable tritium (< 0.5 pCi/L). Although no $^3H/^3He$ ages could be calculated from these low-level tritium wells, the tritium data are supported by helium isotope ($^3He/^4He$) analyses. The monitoring wells with the lowest tritium concentrations also had the highest radiogenic ^4He concentrations. Based on the presence of radiogenic ^4He that accumulated in these samples from the decay of natural uranium and thorium, water from monitoring well CYN-MW4 is estimated to be on the order of several thousand years old, water from monitoring well CYN-MW7 is over 1,000 years old and CYN-MW8 is at least several hundred years old.

Denitrification in Burn Site groundwater is evaluated based on the presence of detectable excess nitrogen gas (N_2) and the isotopic composition of the nitrate. Although all six BSG AOC monitoring wells sampled in 2012 contained low but detectable levels of excess N_2, only one well (CYN-MW11) contained detectable excess N_2 (4 +/-3 mg/L as N equivalent) in the 2015 groundwater sample. All 2012 detections of excess N_2 were close to the 2 mg/L as N equivalent detection limit, whereas the 2012 and 2015 results overlap within the uncertainty of this measurement. Additionally, ^{15}N and ^{18}O isotopes of nitrate were not significantly enriched in any of the groundwater samples collected in 2012 or 2015, with the exception of up gradient well CYN-MW4, which samples fossil water as shown in Figure 6 where nitrate concentration is plotted against $\delta^{15}N\text{-}NO_3$. Apparently, the fossil water in this well contained a low concentration of natural nitrate that has been almost completely denitrified. Although wells CYN-MW7 and CYN-MW8 contain low concentrations of nitrate (<10 mg/L as N) and CYN-MW7 contained detectable excess N_2 equivalent to 3 mg/L as N in the 2012 sample, the 2015 sample from CYN-MW7 did not contain detectable excess N_2. Furthermore, neither well exhibits any evidence of isotopic enrichment indicative of denitrification.

The denitrification of nitrate in groundwater is typically favorable in oxygen-depleted groundwater systems with less than 2 mg/L of dissolved oxygen (DO). Groundwater from three monitoring wells (CYN-MW6, CYN-MW11, and CYN-MW12) have historically contained DO concentrations < 2 mg/L as measured in a flow cell during well purging for routine semiannual sampling events. Groundwater monitoring wells CYN-MW4, CYN-MW7, and CYN-MW9 contained DO concentrations > 2 mg/L.

The isotopic composition of dissolved groundwater nitrate at the Burn Site for both 2012 and 2015 samples shown in Figures 5a and 5b indicate that most samples have isotopic compositions that fall within or close to the "Soil" source field, which represents nitrified soil nitrogen. The sample that falls furthest from the Soil source field is from the farthest up-gradient well, CYN-MW4, although the nitrate concentrations in well CYN-MW4 are very low and may be perturbed by small changes in to the nitrate isotopic composition during sample collection or transport. In Figure 6 nitrate concentration is plotted aganst $\delta^{15}N\text{-}NO_3$ and symbolized by groundwater age. Excluding CYN-MW4, the trend indicates wells that sample modern groundwater also contain the highest nitrate concentrations. The range of $^{15}N\text{-}NO_3$ is consistent with nitrate soil sources and exhibits little evidence of isotopic enrichment related to dentrification. Although CYN-MW4 contains fossil groundwater slightly enriched in $\delta^{15}N\text{-}NO_3$, it is located up gradient of the Burn Site central test area and appears to be hydraulically isolated from modern recharge.

The stable isotopic composition of water was measured in all samples and plotted in Figure 7. Samples from all monitoring wells fall on or close to the Global Meteoric Water Line (GMWL) and do not show evidence for significant evaporation under hot arid conditions. The oxygen and hydrogen isotope compositions of CYN-MW9 changed significantly in the 2015 sample, consistent with modern recharge of isotopically distinct water.

Noble gas recharge temperatures (Table 3B) were calculated using a ground-surface elevation of 6,300 feet above mean sea level (Figure 6). Recharge temperatures of samples collected in 2015 agree well with 2012 results.

Figure 8 is a plot of $^{18}O\text{-}NO_3$ isotopic composition plotted against $^{18}O\text{-}H_2O$ isotopic composition. Nitrate produced by nitrification typically derives two oxygen atoms from air (which is isotopically uniform) and one oxygen atom from water (which varies). If nitrate is produced by nitrification with local water, then $^{18}O\text{-}NO_3$ will fall on or close to a local water nitrification line. As shown in Figures 8, 11 of the 14 samples fall within two-sigma analytical uncertainty of the nitrification line and all but 3 of the samples fall with five-sigma analytical uncertainty of the nitrification line. Note that CYN-MW4 is not plotted on Figure 8.

4 CONCLUSIONS

Data from both the 2012 and 2015 sampling events are presented in Tables 3, 4, and 5. The interpreted groundwater age for each well is plotted on the BSG AOC map in Figure 9.

Based on these results, the conclusions of this groundwater denitrification and age dating study are:

- The highest NO_3 concentrations at the Burn Site (CYN-MW6, CYN-MW9, CYN-MW10) exhibit the youngest $^3H/^3He$ groundwater ages and the lowest tritiogenic ^3He and radiogenic ^{4}He concentrations. These wells sample water that is predominantly to exclusively modern (< 10 years).

- Groundwater from wells CYN-MW9, CYN-MW11, and CYN-MW12 collected in 2015 exhibited significant increases in the amount of tritium detected and changes in the oxygen and hydrogen isotope compositions when compared to the 2012 results. CYN-MW11 and CYN-MW12 sampled predominantly fossil water with a detectable modern component in 2012. The 2015 tritium concentrations in these wells indicate a significant increase in the relative contribution from recent recharge.
- The spatial and temporal correlation between modern groundwater and elevated nitrate suggest a significant vertical pathway for recharge that is likely co-located with an elevated nitrate source. The nitrate source could be natural, anthropogenic, or mixed. Given the complex hydrogeologic setting, the recharge pathway could be associated with faults or fracture corridors that act as vertical conduits for recharge to the deep bedrock aquifers. It is also possible that the annular seal(s) in one or more of the Burn Site wells have degraded and may be acting as vertical conduits for deep recharge.
- The lowest nitrate concentration wells (i.e., < 10 mg/L as N [the MCL]), CYN-MW4, CYN-MW7 and CYN-MW8, have the most radiogenic ^{4}He. These wells sample very old fossil water and represent levels that are indicative of natural background nitrate levels under past climatic and environmental conditions including water-rock interaction for at least several hundred years.
- The increased tritium concentrations in 2015, with respect to 2012, are evidence for recharge pathways at the Burn Site that are active under present day conditions.
- The combined results of the denitrification suite (i.e., low to non-detectable excess N_2 and no significant enrichment in nitrate isotopic composition) are not supportive of any significant natural attenuation of groundwater nitrate in the Burn Site monitoring wells.

Table 3A Groundwater Age Data

n.s. = not sampled

Well ID	Tritium pCi/L 2012	+/-	Terrigenic He 10^{-9} cm^3 STP/g 2012	+/-	Tritium pCi/L 2015	+/-	Terrigenic He 10^{-9} cm^3 STP/g 2015	+/-	Interpreted Groundwater Age 2012	Interpreted Groundwater Age 2015
CYN-MW4	< 0.5	0.14	326.7	8.5	< 0.5	0.07	140.5	4.3	Fossil	Fossil
CYN-MW6	3.49	0.87	< 3	1.5	n.s.		n.s.		Modern	n.s.
CYN-MW7	< 0.5	0.60	149.6	4.4	< 0.5	0.09	121.3	3.8	Fossil	Fossil
CYN-MW8	n.s.		n.s.		< 0.5	0.32	50.3	4.4	n.s.	Fossil
CYN-MW9	3.26	0.24	7.4	1.7	10.7	0.59	< 3.2	1.6	Modern w/det Fossil	Modern
CYN-MW10	n.s.		n.s.		3.1	0.34	< 3.2	1.6	n.s.	Modern
CYN-MW11	0.30	0.79	41.4	2	1.7	0.29	35.2	2	Fossil w/det Modern	Fossil w/det Modern
CYN-MW12	0.46	0.89	40.6	2.3	4.7	0.24	31.7	2.1	Fossil w/det Modern	Fossil w/det Modern
CYN-MW13	n.s.		n.s.		6.2	0.30	6.2	1.7	n.s.	Modern w/det Fossil
CYN-MW13 (dup)	n.s.		n.s.		6.0	0.28	8.2	1.6	n.s.	Modern w/det Fossil
CYN-MW14A	n.s.		n.s.		2.1	0.20	15.3	1.9	n.s.	Fossil w/det Modern
CYN-MW15	n.s.		n.s.		2.5	0.31	69	2.9	n.s.	Fossil w/det Modern

Table 3B Noble Gas Recharge Temperatures

Burn Site Well	NGRT °C 2012	+/-	NGRT °C 2015	+/-
CYN-MW4	12.7	1.0	12.9	1.0
CYN-MW6	19.4	1.1	21.4	1.2
CYN-MW7			18.5	1.3
CYN-MW8	17.6	1.1	16.5	1.1
CYN-MW9			16.0	1.1
CYN-MW10	17.9	1.1	15.7	1.0
CYN-MW11	15.5	1.1	16.1	1.1
CYN-MW12			19.0	1.1
CYN-MW13			18.3	1.1
CYN-MW13 (dup)			17.9	1.1
CYN-MW14A			16.0	1.1
CYN-MW15	12.7	1.0	12.9	1.0

Table 4 Denitrification Data

Well ID	$\delta^{15}N-NO_3$ air 2012	$\delta^{18}O-NO_3$ SMOW 2012	$\delta^{15}N-NO_3$ air 2015	$\delta^{18}O-NO_3$ SMOW 2015	Excess N_2 (as N) 2012	+/-	Excess N_2 (as N) 2015	+/-
CYN-MW4	12.3	17.6	10.4	-6.6	3	2	< 2	4
CYN-MW6	5.9	-0.4	n.s.	n.s.	5	3	n.s.	
CYN-MW7	5.2	0.7	5.1	1.4	3	3	< 2	3
CYN-MW8	n.s.	n.s.	4.9	1.8	n.s.		< 2	7
CYN-MW9	2.1	0.0	2.4	-1.7	3	1	< 2	3
CYN-MW10	n.s.	n.s.	2.4	0.7	n.s.		< 2	3
CYN-MW11	5.9	3.4	3.7	2.2	4	1	4	3
CYN-MW12	5.0	1.6	4.7	2.9	3	1	< 2	3
CYN-MW13	n.s.	n.s.	3.7	2.4	n.s.		< 2	3
CYN-MW13 (dup)	n.s.	n.s.	3.1	3.0	n.s.		< 2	3
CYN-MW14A	n.s.	n.s.	4.6	1.8	n.s.		< 2	3
CYN-MW15	n.s.	n.s.	4.7	2.9	n.s.		< 2	3

Table 5 Water Isotope Data

Burn Site Well	$\delta^{18}O$-H_20 2012	δD-H_20 2012	$\delta^{18}O$-H_20 2015	δD-H_20 2015
CYN-MW4	-11.6	-83	-11.2	-83
CYN-MW6	-9.9	-71	n.s.	n.s.
CYN-MW7	-10.7	-77	-10.1	-77
CYN-MW8	n.s.	n.s.	-10.1	-78
CYN-MW9	-10.8	-74	-9.2	-65
CYN-MW10	n.s.	n.s.	-10.6	-78
CYN-MW11	-11.0	-78	-10.5	-77
CYN-MW12	-11.0	-77	-10.4	-78
CYN-MW13	n.s.	n.s.	-9.1	-66
CYN-MW13 (dup)	n.s.	n.s.	-9.1	-63
CYN-MW14A	n.s.	n.s.	-10.4	-78
CYN-MW15	n.s.	n.s.	-10.4	-76

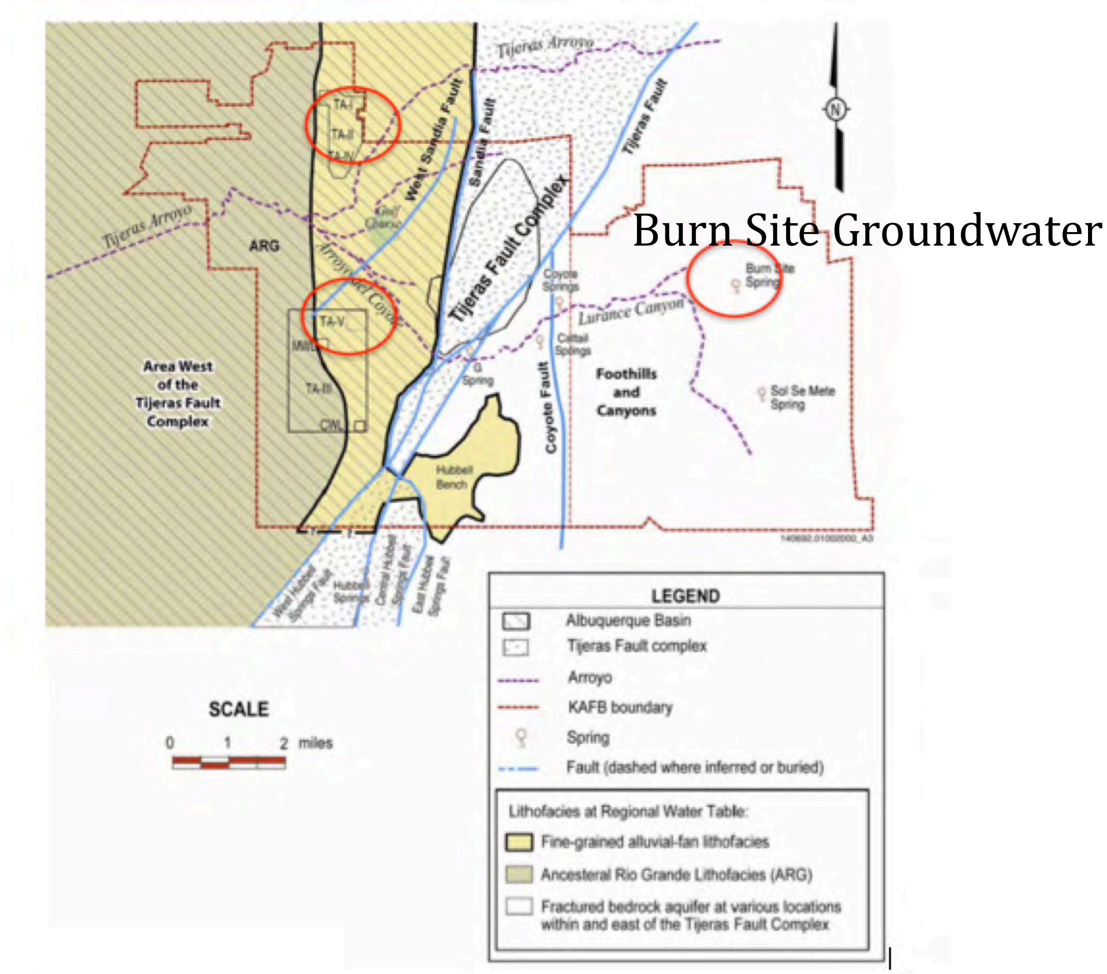


FIGURE 1. Generalized hydrogeologic map of the Albuquerque area showing the three Sandia National Laboratories/New Mexico Areas of Concern sampled in 2012. In 2015 groundwater samples were collected from the BSG AOC only.

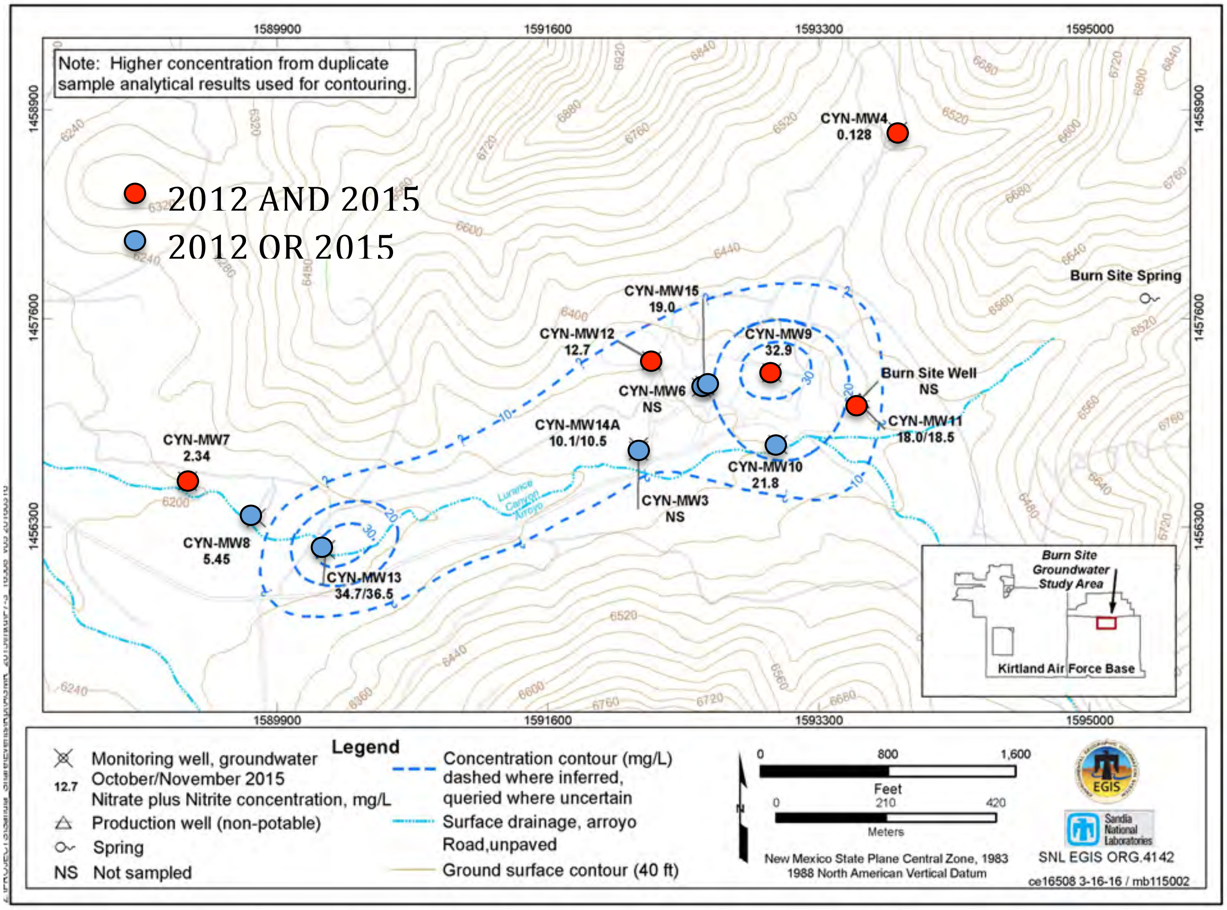


FIGURE 2. Site map showing all wells sampled at the BSG AOCand annotated to indicate which wells were sampled in 2012 and 2015.

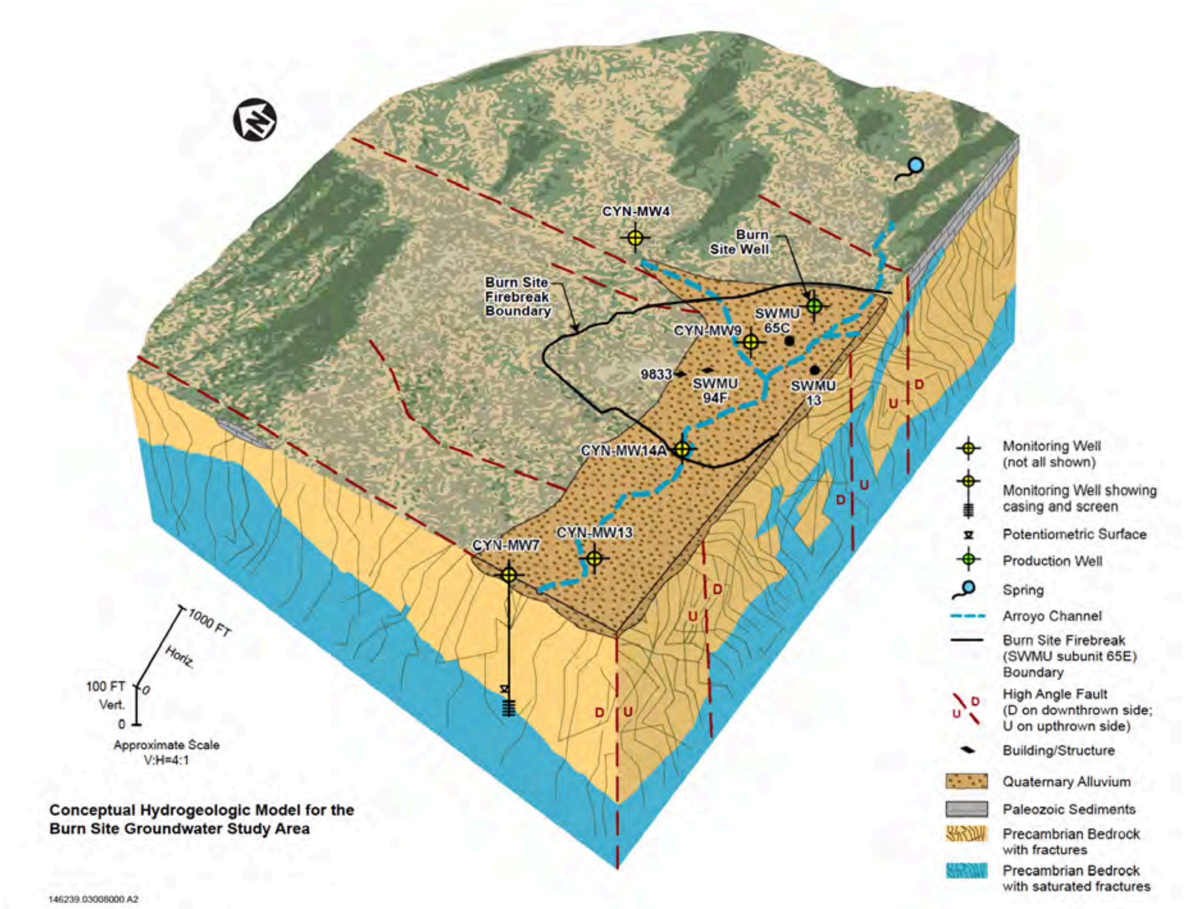


FIGURE 3. Sandia National Laboratories/New Mexico Conceptual Hydrogeologic Model for the BSG AOC.

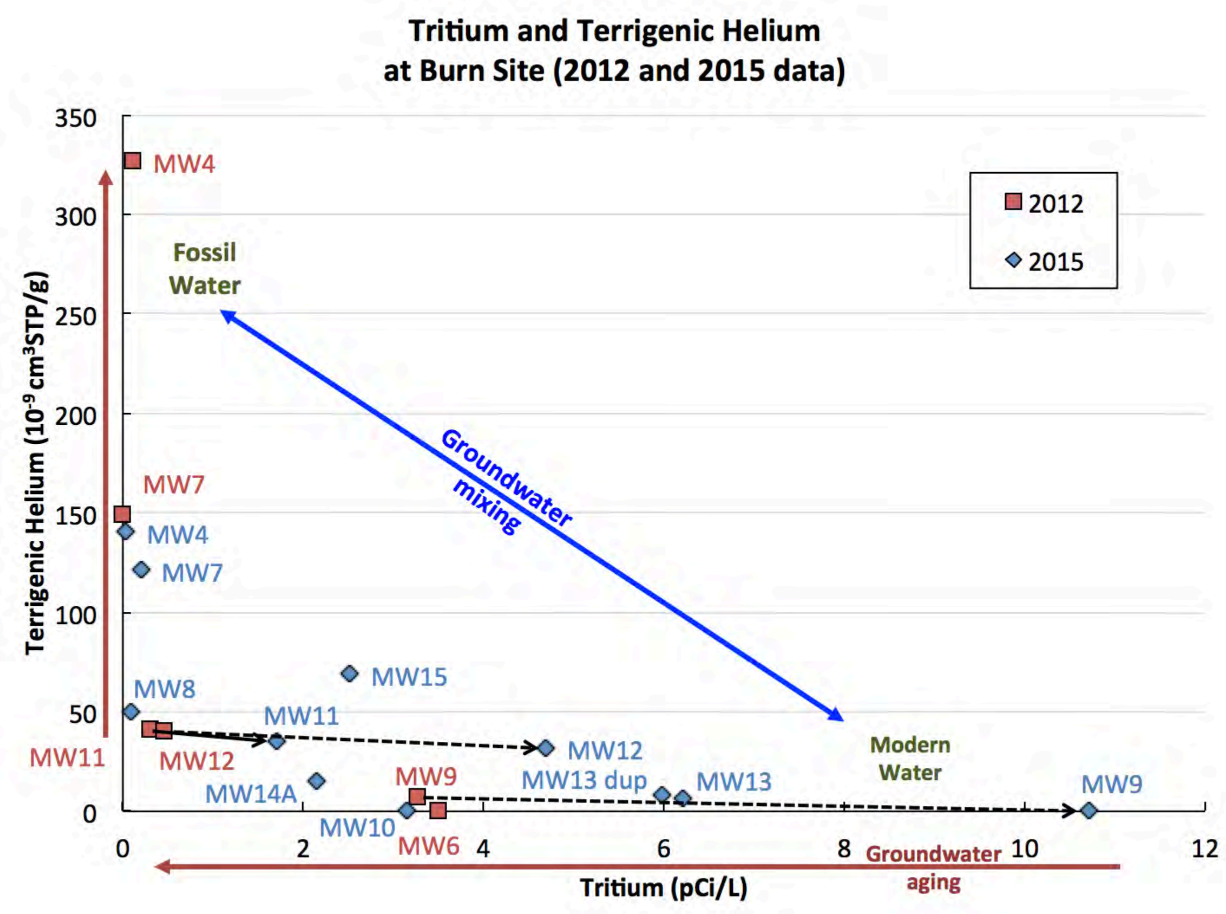


FIGURE 4. Plot of Terrigenic Helium versus Tritium for all BSG AOC groundwater samples collected in 2012 and 2015. The well prefix CYN- is not shown for spacing considerations.

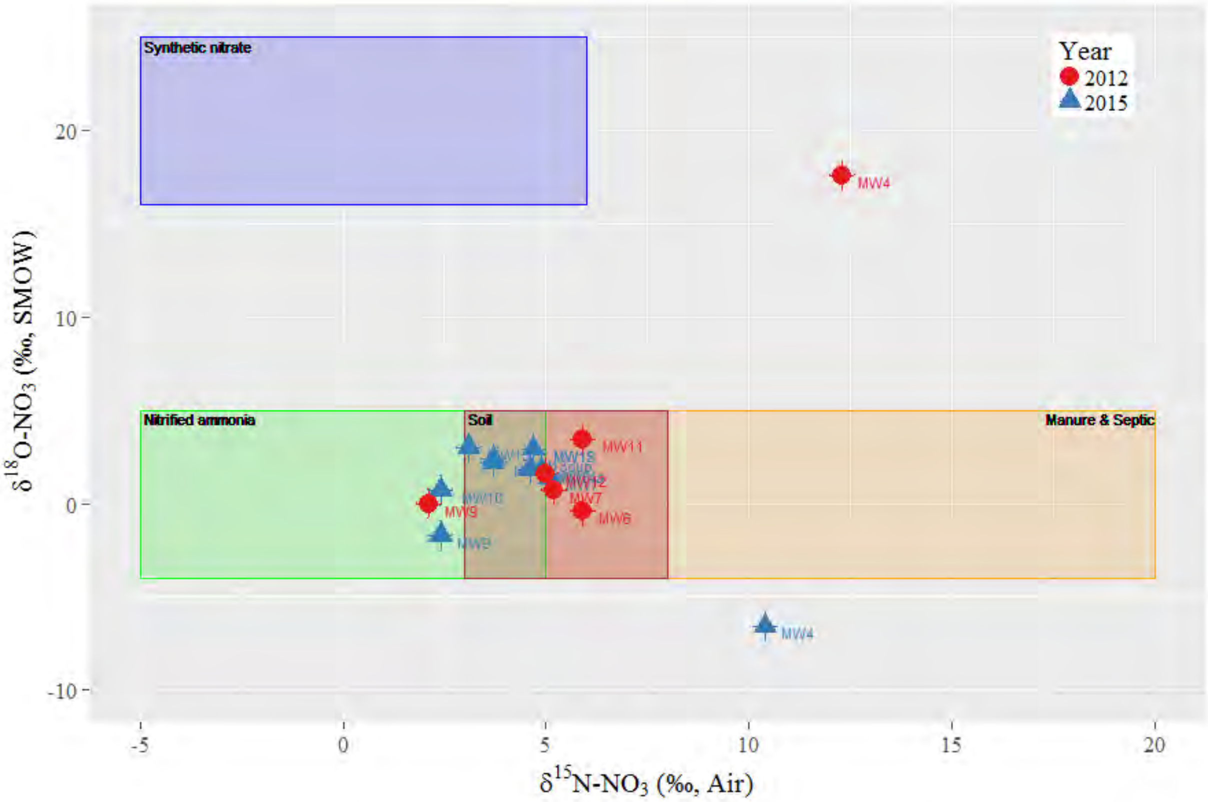


FIGURE 5a. Plot of δ^{15}N-NO$_3$ vs δ^{18}O-NO$_3$ for all BSG AOC groundwater samples collected in 2012 and 2015. Source fields (boxes) derived from Kendall (1998).

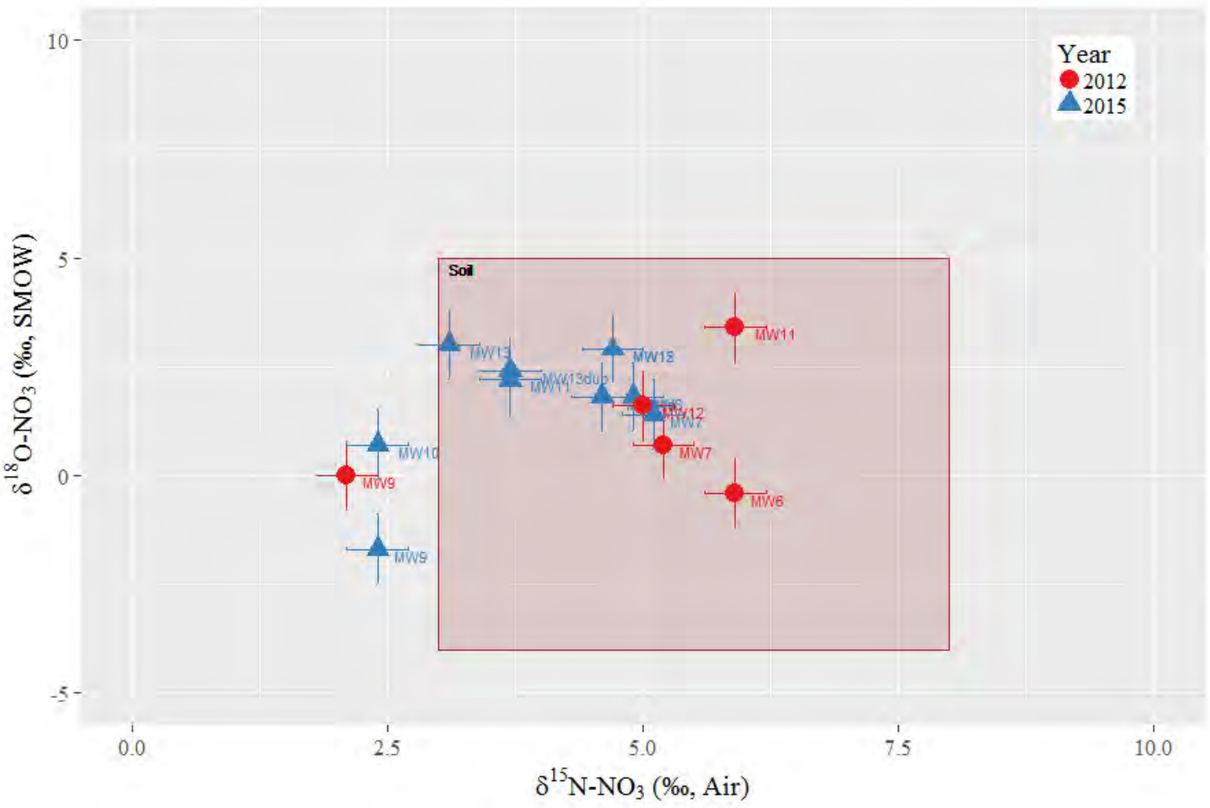


FIGURE 5b. Expanded plot of δ^{15}N-NO$_3$ vs δ^{18}O-NO$_3$ for BSG AOC groundwater samples collected in 2012 and 2015. Soil source field derived from Kendall (1998).

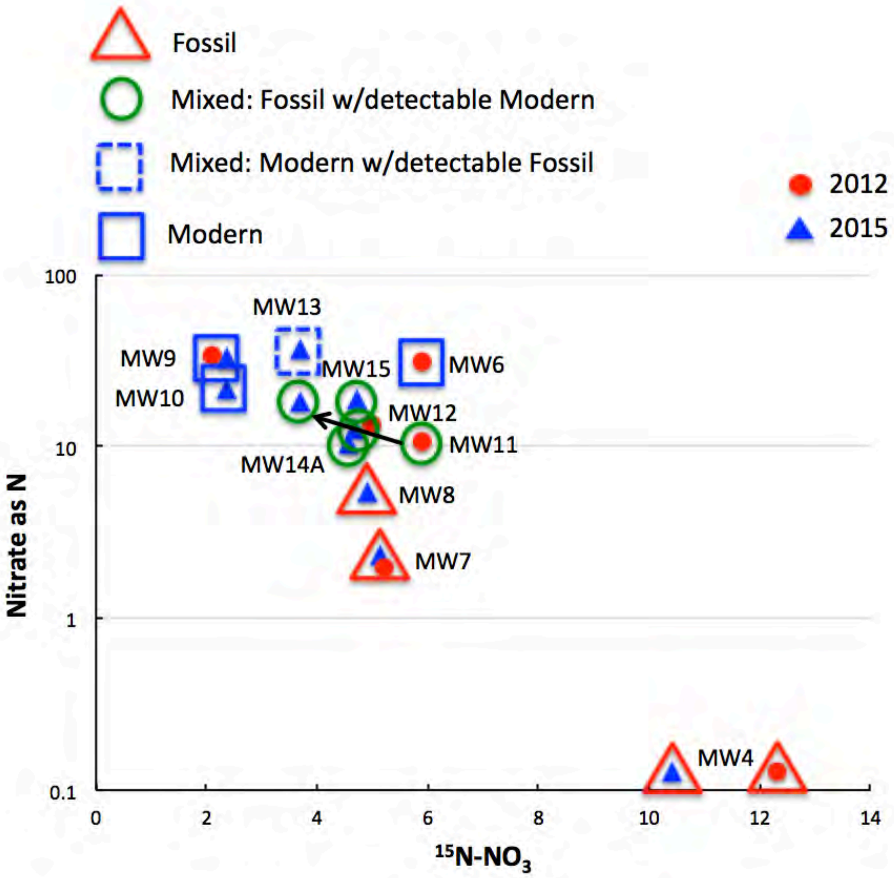


FIGURE 6. Plot of Nitrate in mg/L as N vs ^{15}N-NO$_3$ annotated with groundwater age for all BSG AOC samples collected in 2012 and 2015.

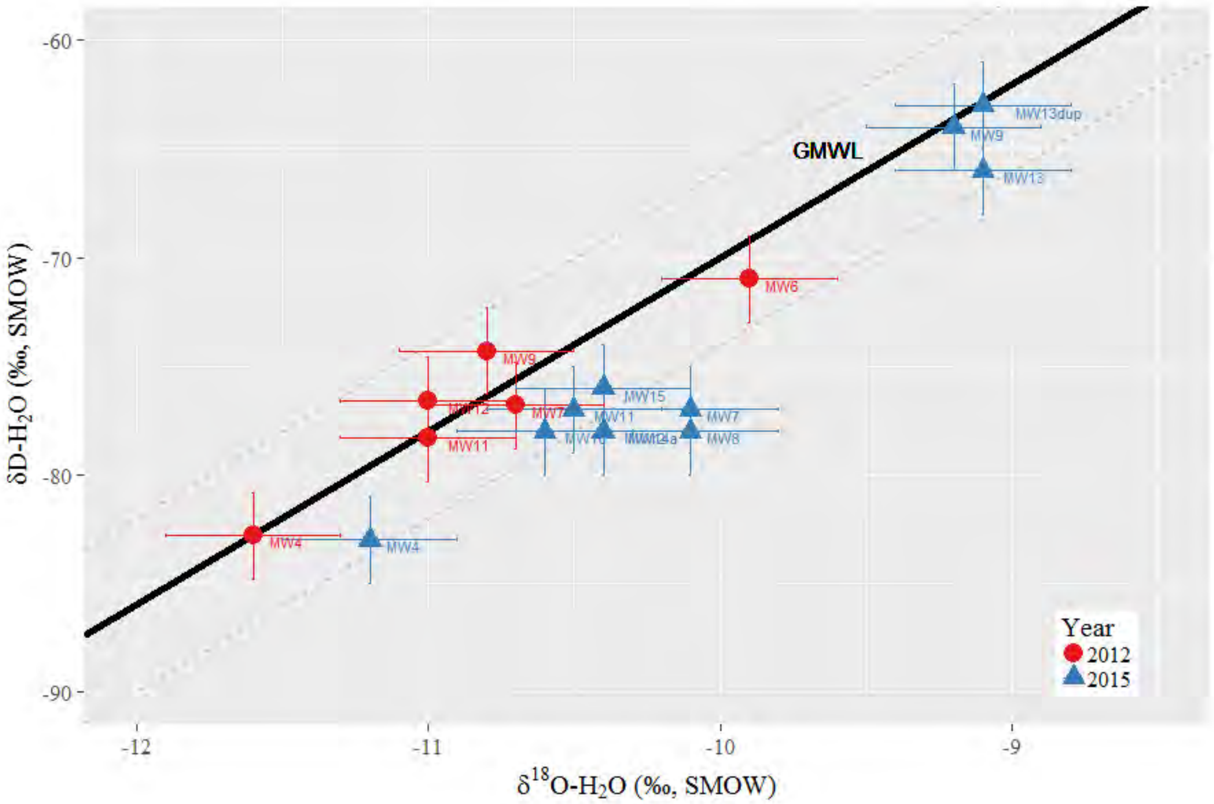


FIGURE 7. Isotopic composition of water with Global Meteoric Water Line (GMWL) from BSG AOC groundwater samples collected in 2012 and 2015. Note CYN-MW4 is not shown on the plot.

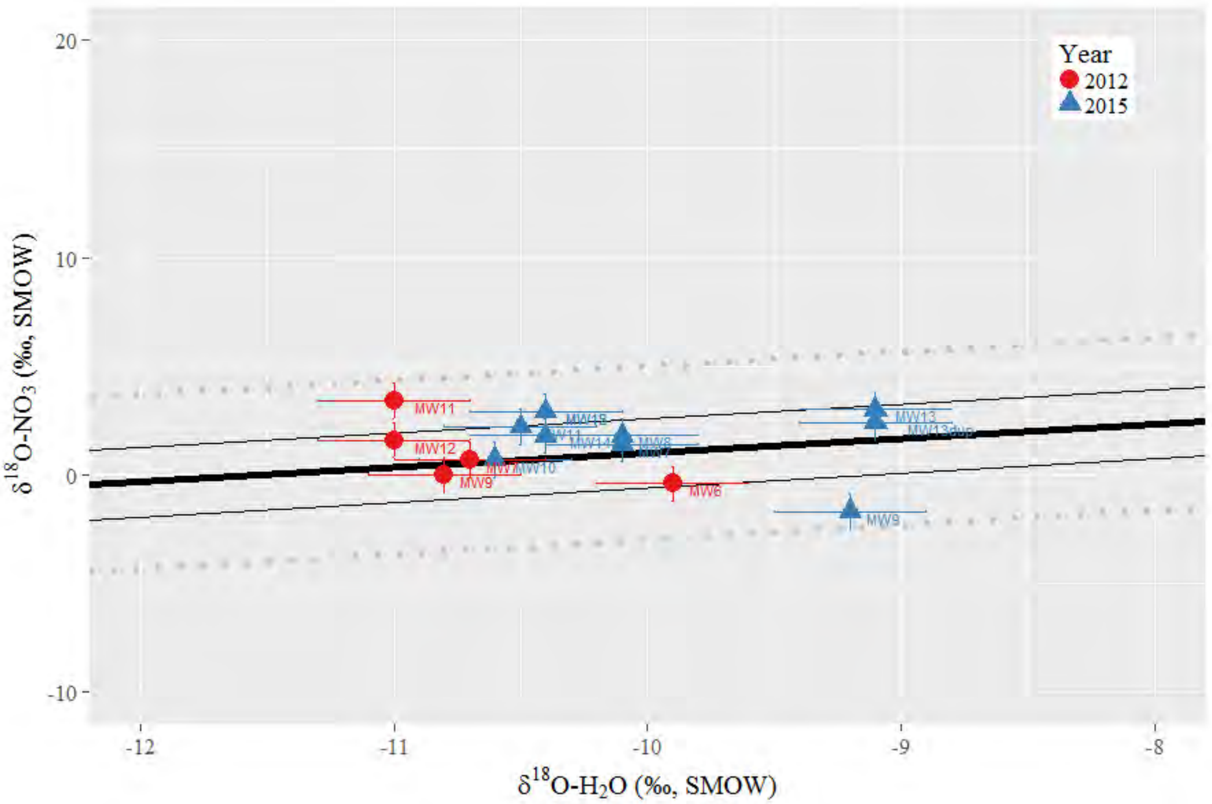


FIGURE 8. Isotopic composition of δ^{18}O-NO$_3$ plotted against isotopic composition of δ^{18}O-H$_2$O for BSG AOC groundwater samples. The expected correlation for nitrification with local water is shown as a thick black line with two-sigma (thin black lines) and five-sigma (dotted lines) analytical uncertainty. This correlation assumes that two of the three oxygen atoms in the nitrate molecule come from air and one comes from local water. Note CYN-MW4 is not shown on the plot.

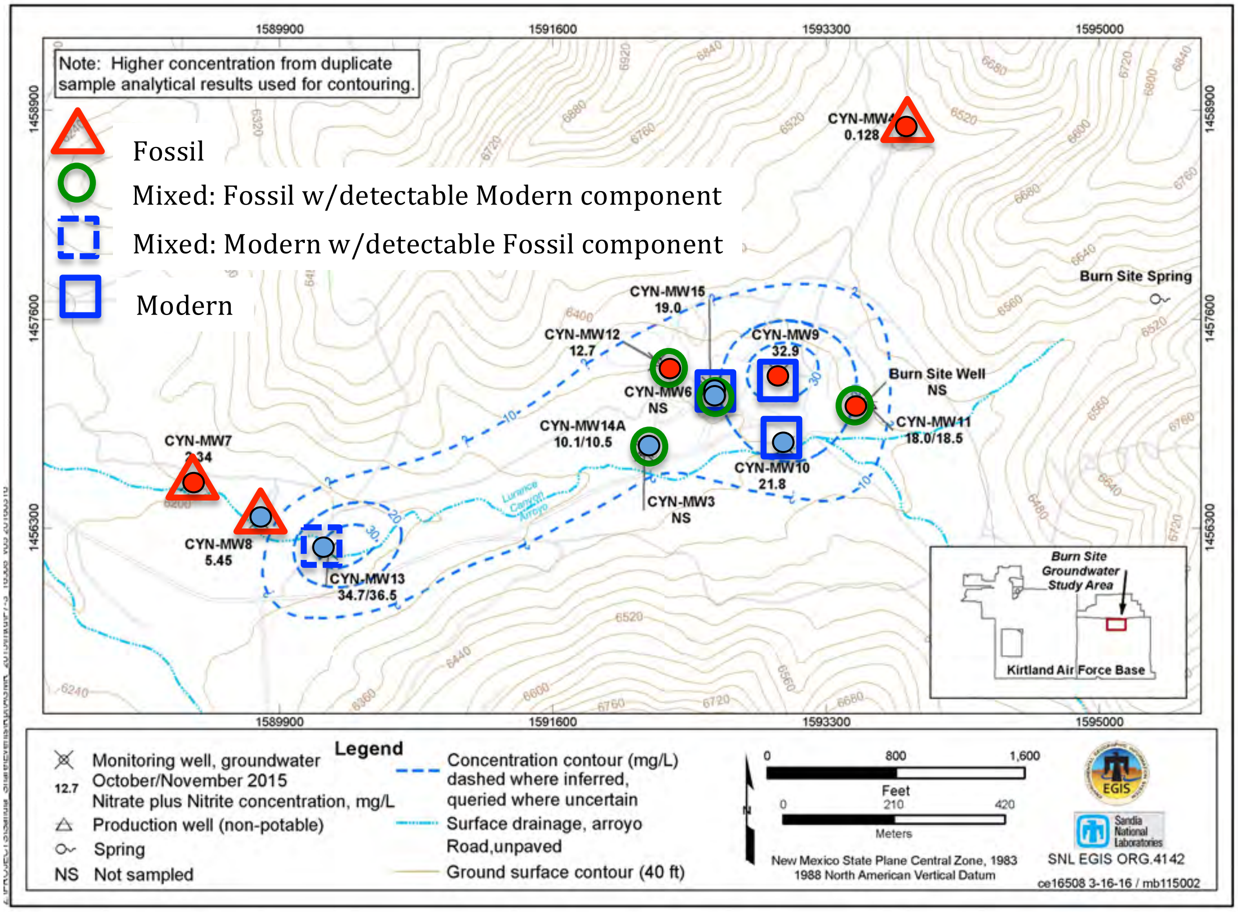


FIGURE 9. Summary map showing groundwater age on the 2015 BSG AOC nitrate distribution.

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