LMS/RUL/S17304

2017 Long-Term Hydrologic Monitoring Program Report for Rulison, Colorado, Site

March 2019

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Contents

Figures

Table

Appendix

Abbreviations

CDPHE	Colorado Department of Public Health and Environment
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	feet
GEMS	Geospatial Environmental Mapping System
LM	Office of Legacy Management
LTHMP	Long-Term Hydrologic Monitoring Program
pCi/L	picocuries per liter
SGZ	surface ground zero

1.0 Introduction

This report presents the monitoring data collected by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) at the Rulison, Colorado, Site (Figure 1). The Rulison site was the location of an underground nuclear test in 1969. The test resulted in residual radionuclide contamination at the depth of the detonation, which was approximately 8400 feet (ft) below ground surface. Monitoring includes the collection of samples from shallow groundwater wells, surface water locations, and producing natural gas wells near the site to assess for any potential impacts that may be attributed to the nuclear test. This report summarizes the laboratory analytical results obtained from the 2017 annual sampling of shallow groundwater wells and surface water locations near the site. Laboratory analytical results from the sampling of natural gas wells are summarized in a separate report. This annual report and the natural gas well monitoring reports are available on the LM public website at https://www.lm.doe.gov/Rulison/Documents.aspx. Data collected during this and previous monitoring events are available on the Geospatial Environmental Mapping System (GEMS) website at https://gems.lm.doe.gov/#site=RUL.

2.0 Site Location and Background

The Rulison site is in the Piceance Basin of western Colorado and is 40 miles northeast of Grand Junction, Colorado (Figure 1). The U.S. Atomic Energy Commission (a predecessor agency to DOE) conducted the underground nuclear test in partnership with the Austral Oil Company Inc. and the nuclear engineering firm CER Geonuclear Corporation. The test was called Project Rulison, and it was designed to evaluate the use of a nuclear detonation to enhance natural gas production in the low-permeability, gas-bearing sandstone of the Williams Fork Formation. This was the second natural gas stimulation experiment in the Plowshare Program, which was a program to develop peaceful uses for nuclear energy. The nuclear device used at the Rulison site was detonated in the emplacement hole (R-E) at a depth of approximately 8400 ft on September 10, 1969. The device had a reported yield of 40 kilotons (DOE 2015), which produced extremely high temperatures that vaporized a volume of rock, temporarily creating a cavity surrounded by a fractured area extending outward from the detonation point (AEC 1973). Shortly after the detonation, the overlying fractured rock collapsed into the void space, creating a rubble-filled collapse chimney that extends above the detonation point. The former cavity, now the lower part of the collapse chimney, and the surrounding fractured rock are together referred to as the detonation zone. A reentry well (R-En) was drilled as a sidetrack hole off the exploration well (R-Ex) into the collapse chimney and tested to evaluate the success of the detonation at improving gas production in the low-permeability sandstone reservoir. Results of this testing are summarized in the *Modeling of Flow and Transport Induced by Gas Production Wells near the Project Rulison Site, Piceance Basin, Colorado* (DOE 2013).

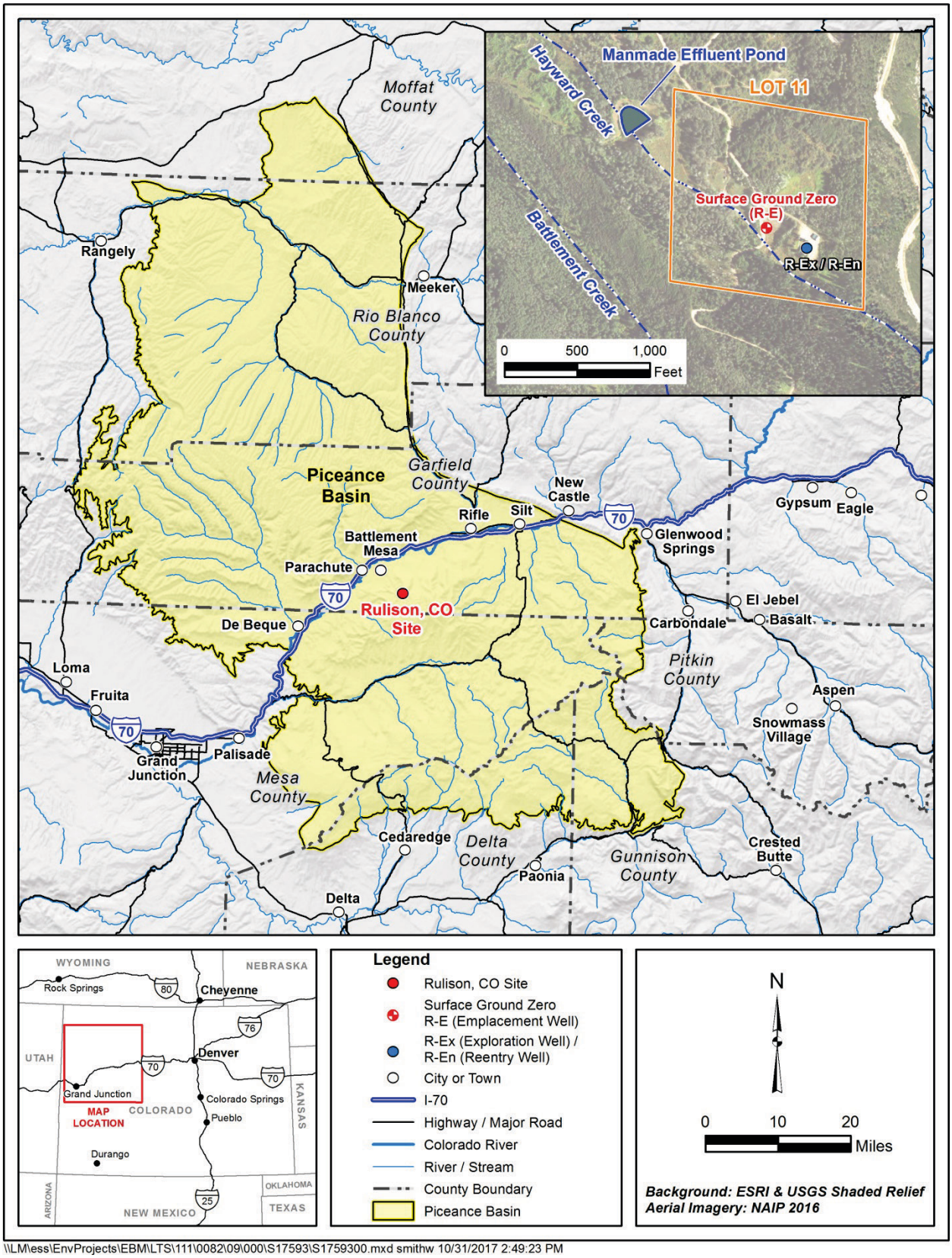

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Figure 1. Site Location Map, Rulison Site

Site decommissioning and cleanup activities were initiated in July 1972. This included collecting soil and vegetation samples to be analyzed for radiological contaminants, decontaminating equipment, and removing equipment and material not needed for future gas production activities (AEC 1973). The "final" decommissioning and cleanup occurred in 1976 after the participating parties agreed that future gas production would not occur at the site (ERDA 1977). Remaining equipment and material were removed; the mud pits adjacent to the R-Ex (now referred to as R-En) well were backfilled; tritium-contaminated soils were removed; and the radiological condition of the site was further characterized through extensive surficial soil sampling. At the request of the landowner, the effluent pond used to store drilling fluids during the installation of the R-E emplacement hole was left in place. As part of this cleanup, the R-E and R-En wells were abandoned and a deed restriction was established for the site (ERDA 1977). The deed restriction prohibits the penetration or withdrawal of any material below 6000 ft within Lot 11 (also referred to as the site boundary) unless authorized by the U.S. government.

In 1994 and 1995, soil and sediment samples were collected from the former effluent pond and areas near the former R-E and R-En wells. Samples were analyzed for chemical and radiological contaminants to assess the completeness of past cleanup operations (IT 1996). Corrective action consisted of draining the effluent pond and removing contaminated sediments that exceeded State of Colorado regulatory limits. Shallow groundwater monitoring wells were also installed near the effluent pond and monitored to verify that the remedial actions had been complete. In 1998, DOE provided Colorado regulators with a Surface Closure Report and recommended closure of the site surface with no further action (DOE 1998). The Colorado Department of Public Health and Environment (CDPHE) reviewed the report, agreed with the recommendation, and approved the surface closure activities (CDPHE 1998). The shallow monitoring wells were abandoned in 1999.

2.1 Source of Contamination

Surface and subsurface contamination resulted from the underground nuclear test at Rulison. The surface contamination was excavated and removed in 1996, and CDPHE approved closure of the surface with no further actions in 1998. Subsurface contamination remains in the detonation zone near the R-E emplacement hole, which includes the former cavity, collapse chimney, and fractured rock surrounding the former cavity. The detonation zone is contaminated by residual radioactive isotopes, with the high-melting-point radionuclides trapped in the solidified melt rock (often referred to as melt glass due to its glassy texture) at the bottom of the former cavity. The radionuclides incorporated in the melt rock can only be released to groundwater very slowly through dissolution of the melt rock (e.g., Tompson et al. 1999, Pawloski et al. 2001). Though dissolution of radionuclides from melt rock can represent a long-term source of subsurface contamination, dissolved-phase transport of radionuclides away from the detonation zone is considered insignificant, because the rock surrounding the former cavity and collapse chimney is unsaturated with respect to water. The presence of gas in the surrounding Williams Fork Formation also severely limits liquid movement (if present), making any solidified radionuclides that may have dissolved in the former cavity essentially immobile.

The primary contaminants of concern are expected to be those radionuclides that can exist in the gas phase, because the gas phase is much more mobile than liquids in the gas-producing reservoirs of the Williams Fork Formation. Of the radionuclides that can exist

in the gas phase, tritium and krypton-85 are expected to constitute most of the radioactivity (Smith 1971). Samples collected during production testing in 1970 and 1971 indicated that most of the krypton-85 was removed and flared but that tritium remained (DOE 2013). Since tritium is the most abundant radionuclide remaining in the detonation zone that can be present in the gas and aqueous phases, it is the main radionuclide of concern at the Rulison site.

2.2 Geologic Setting

The Williams Fork Formation of the Mesaverde Group is the primary gas-producing zone within the Piceance Basin. The Piceance Basin is a northwest-southeast-oriented structure about 100 miles long and 40−50 miles wide (Figure 2). The bedding on the western flank of the basin dips gently to the east, and the bedding on the eastern flank of the basin dips steeply to the west, causing the basin to be asymmetrical and deepest along its eastern edge, where more than 20,000 ft of sedimentary rocks were deposited. The Williams Fork Formation is encountered between the depths of approximately 6500 and 9000 ft near the site and is overlain by the Ohio Creek Conglomerate and the Wasatch and Green River formations. The Colorado River divides the Piceance Basin into a northern and southern province. The southern province, which includes the Rulison site, is marked by two significant erosional remnants, Grand Mesa and Battlement Mesa.

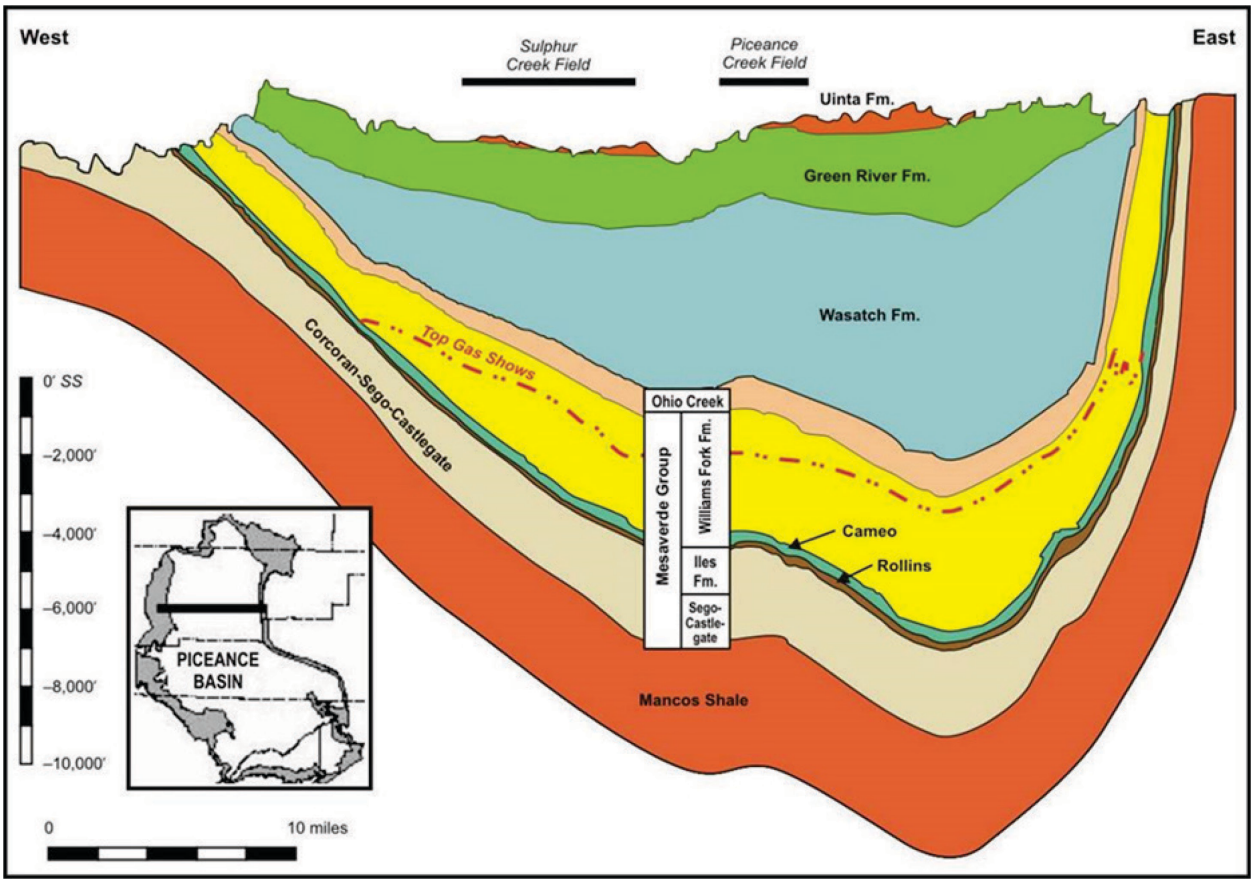

Figure 2. Piceance Basin Cross Section

The Williams Fork Formation is composed of low-permeability, discontinuous, interbedded fluviodeltaic sandstones and shales. These sandstones vary in clay content; the cleaner sandstones (less clay) in the lower two-thirds of the formation are the main targets for hydrofracturing and natural gas production. Sandstones in the upper one-third of the Williams Fork are not production targets because of their higher water content, which lowers the relative permeability of the gas phase and causes water production to be excessive compared to the amount of gas that can be produced. Despite improvements in hydrofracturing technology, formation properties greatly inhibit fluid migration outside the extent of the hydrofractures. Wells near the Rulison site are being spaced relatively close (located on 10-acre centers), about 400 ft north/south and about 1320 ft east/west of adjacent wells. The east-west trend of natural fractures in the Williams Fork causes the hydrofracturing and drainage patters to be elongated in that direction (DOE 2013). A more-detailed description of the hydrofracturing and drainage patters at Rulison is provided in the *Modeling of Flow and Transport Induced by Gas Production Wells near the Project Rulison Site, Piceance Basin, Colorado* (DOE 2013).

2.2.1 Site Hydrology

There are three surface water features at the site (Lot 11). They include Battlement Creek, a smaller, spring-fed tributary of Battlement Creek (locally known as Hayward Creek), and a man-made effluent pond (Figure 1). Battlement Creek is a perennial stream that flows through the southwest corner of the site and discharges to the Colorado River. The flow in Battlement Creek is regulated by Battlement Reservoir and is primarily fed by snow melt, shallow groundwater, and springs. The smaller, spring-fed tributary of Battlement Creek flows across the site east of Battlement Creek. The man-made pond covers a surface area of approximately 1 acre and is approximately 1300 ft northwest of the R-E emplacement borehole (also referred to as surface ground zero [SGZ]). During the surface restoration, at the request of the land owner, DOE constructed the pond from the drilling effluent pond. Battlement Creek and its tributaries flow in a generally northwesterly direction toward the Colorado River (USGS 1969).

Groundwater is encountered in the surficial deposits (shallow alluvium <200 ft thick) near the site, with recharge to this aquifer occurring from the infiltration of snowmelt. The wells used by local residents are completed in this shallow alluvial aquifer (<200 ft thick). The next possible groundwater source would be a few sandy zones in the lower part of the underlying Green River Formation (1700 ft thick) capable of yielding minor quantities of water. The Wasatch and Fort Union formations and Ohio Creek Conglomerate extend from a depth of approximately 1700 to 6500 ft and are generally not a source of groundwater in the Rulison area. They effectively separate the overlying water-bearing aquifers from the gas-producing zones in the Mesaverde Group. The natural gas wells produce some liquids along with natural gas. The liquids (produced water and hydrocarbon condensate) are brought to the surface with the natural gas and mechanically separated at the wellhead. Produced water is a mixture of water vapor in the natural gas that condenses at the surface, formation water, and remnant water from hydrofracturing well development. The produced water is high in total dissolved solids and is not a usable water source.

2.3 Previous Monitoring Programs

Shallow groundwater and surface water surrounding the Rulison site has been monitored to ensure public safety under the Long-Term Hydrologic Monitoring Program (LTHMP) since 1972. The U.S. Environmental Protection Agency (EPA) performed the LTHMP sampling from

the program's inception in 1972 through 2007. In 2008, LM assumed responsibility for the sampling and conducted a review of all previous LTHMP data to evaluate the effectiveness of the monitoring program. Analytical results show that nuclear-test-related contamination has not impacted groundwater or surface water at the sample locations. The evaluation considered the depth of the detonation and the potential transport pathways for contaminant migration from the detonation zone. It was concluded that the most likely contaminant transport pathway from the detonation zone to the surface is through a gas production well drilled near enough to the site to allow hydrofractures from the well to interact with nuclear fractures of the detonation. Based on the findings of that evaluation, a new monitoring program was implemented to emphasize the sampling of natural gas production wells near the site. Although gas production wells are the most likely transport path for detonation-related contaminants, LM has continued the sampling of shallow groundwater and surface water at several nearby locations.

3.0 Monitoring Program

The monitoring program for the Rulison site includes the collection of samples from shallow groundwater wells, surface water locations, and producing natural gas wells near the site to assess for any potential impacts that may be attributed to the Rulison nuclear test. Laboratory analytical results from the sampling of natural gas wells are summarized in a separate report. A summary of the shallow groundwater and surface water sampling is provided with the laboratory analytical results in the following sections.

3.1 Groundwater and Surface Water Monitoring

LM has continued the yearly sampling of shallow groundwater wells and surface water locations near the site that was initiated in 1972 as part of the LTHMP. The sampling has continued to assure the public that no radiological contamination associated with the Rulison nuclear test has impacted the sample locations near the site. The annual monitoring event conducted on May 18 and June 8, 2017, included the collection of samples from 13 locations (Figure 3). The sampled locations are a combination of shallow groundwater wells (<200 ft deep) and surface water locations. Four of the locations (two surface and two shallow groundwater wells) are within the site boundary (Lot 11). The remaining nine locations (three surface and six shallow groundwater wells) are offsite, with these locations ranging from 2 to 6 miles from the former R-E emplacement well that signifies surface ground zero at the site (Figure 3). Samples are collected according to the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PRO/S04351). The Sampling and Analysis Plan can be accessed on the LM public website at https://energy.gov/lm/downloads/sampling-and-analysis-plan-us-department-energy-office-legacy-management-sites.

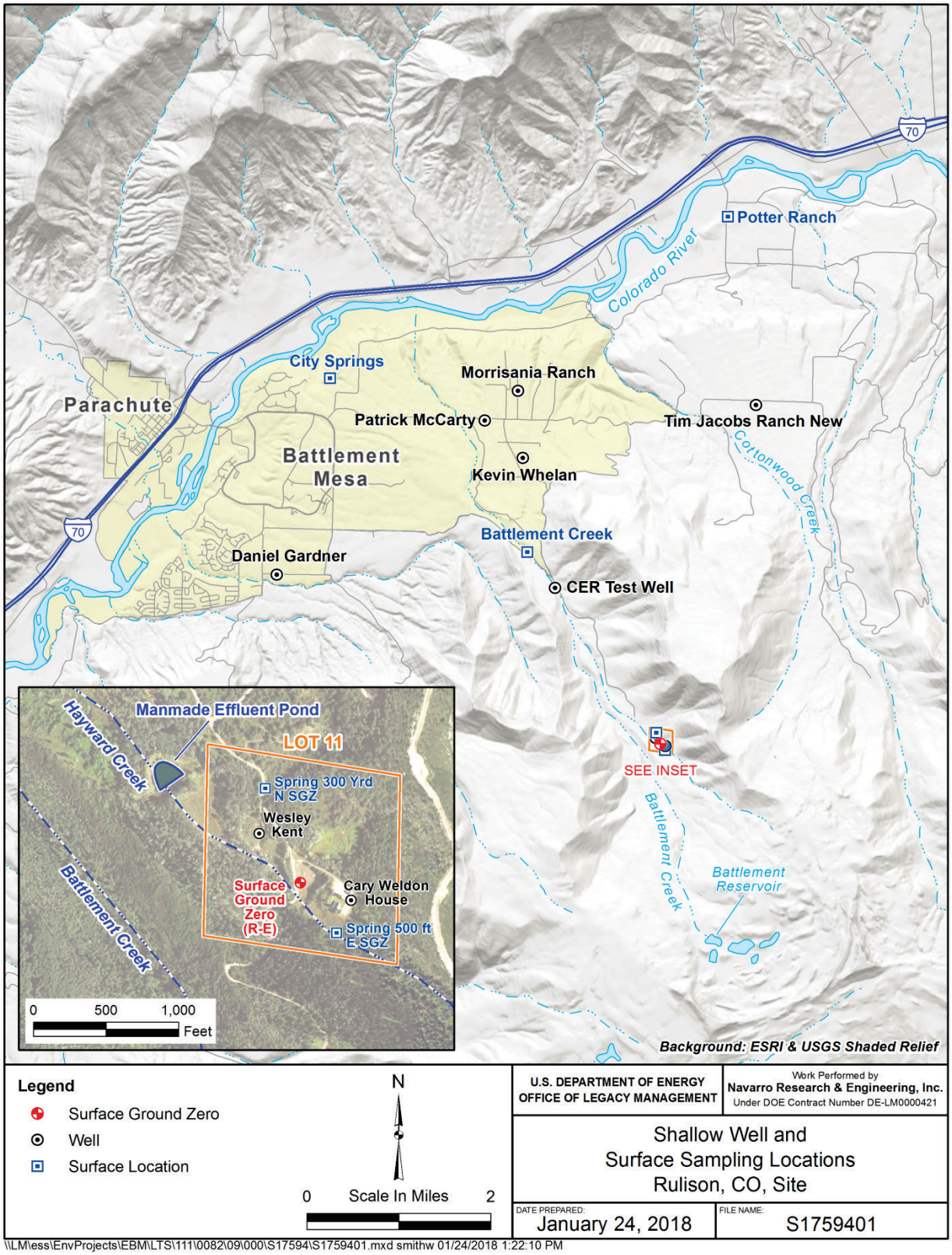

Figure 3. Shallow Groundwater and Surface Sampling Location Map, Rulison Site

Samples collected during the annual sampling were analyzed for tritium, because it is the most mobile contaminant remaining in significant quantities in the detonation zone. Some of these samples were analyzed for tritium using the electrolytic enrichment method, which allows the laboratory to provide a minimum detectable concentration that is approximately 2 orders of magnitude lower than the conventional method. Samples were also analyzed for gamma-emitting radionuclides (using high-resolution gamma spectrometry) that may be associated with the nuclear detonation. The samples were submitted to GEL Laboratories in Charleston, South Carolina, and were analyzed using accepted procedures based on specified methods. The laboratory minimum detectable concentration reported with these data is an estimate of the predicted detection capability of a given analytical procedure, not an absolute concentration that can or cannot be detected. These laboratory analytical data are validated according to the "Standard Practice for Validation of Environmental Data" section in the *Environmental Procedures Catalog* (LMS/POL/S04325). A summary of the laboratory analytical results is provided in the following section.

3.2 Groundwater and Surface Water Sample Results

The 2017 laboratory results continue to demonstrate that no detonation-related contaminants have impacted the sampled locations. Tritium was not detected above the laboratory minimum detectable concentration using the conventional laboratory method. The two samples analyzed using the enrichment method detected tritium above the laboratory minimum detectable concentration (Table 1). The detection of tritium using this method is consistent with historical LTHMP results and with the worldwide tritium distribution in precipitation that resulted from aboveground nuclear tests during the 1950s and early 1960s (Brown 1995). Aboveground tests conducted by the United States and Soviet Union ended with the test ban treaty in 1963. The tritium results obtained using the enrichment method are shown with the plot of tritium in precipitation (Figure 4 and Figure 5) at Ottawa, Canada (Brown 1995), which is the longest record of tritium in precipitation in the Northern Hemisphere (Brown 1995). The natural decay rate for tritium (12.3 years) is also included in the figures for comparison. The similarity of the tritium levels obtained from the enrichment laboratory method to tritium levels in precipitation indicates that the wells and surface locations are supplied by recent infiltration of water from rain or snowmelt. These results are much lower than the EPA drinking water standard for tritium of 20,000 picocuries per liter (pCi/L) (Title 40 *Code of Federal Regulations* Part 141.16). No other radionuclides were detected by high-resolution gamma spectrometry analysis. Specific radionuclides that are included in gamma spectrometry analysis are listed in the data validation memo provided as Appendix A. Table 1 shows the 2017 laboratory results.

Table 1. Shallow Groundwater and Surface Water Sample Results, Rulison Site

Sample Location	Sample Location Type	Date Collected	Tritium by Conventional Method (pCi/L)	Tritium by Enrichment Method (pCi/L)	Gamma-Emitting Radionuclides[a] (pCi/L)
Cary Weldon House (private well)	Groundwater	6/08/2017	<344	NA	ND
CER Test Well (private well)		6/08/2017	<343	NA	ND[b]
Daniel Gardner (private well)		5/18/2017	<294	NA	ND
Kevin Whelan (private well)		5/18/2017	<293	NA	ND
Morrisania Ranch (private well)		5/18/2017	NA	16.3	ND
Patrick McCarty (private well)		5/18/2017	NA	18.8	ND
			<288[c]	NA	ND[c]
Tim Jacobs Ranch (private well)		5/18/2017	<293	NA	ND
Wesley Kent House (private well)[d]		6/08/2017	<347	NA	ND
City Springs (spring)	Surface water	5/18/2017	<290	NA	ND
Spring 300 yrd N SGZ (spring)		6/08/2017	<343	NA	ND
Spring 500 ft E SGZ (spring)		6/08/2017	<340	NA	ND
Battlement Creek (creek)		5/18/2017	<324	NA	ND
Potter Ranch (spring)		5/18/2017	<292	NA	ND

Notes:
[a] See data validation memo (Appendix A, Enclosure 3) for a list of radionuclides included in this analysis.
[b] The sample was filtered because the turbidity requirements were not met per the Sampling and Analysis Plan.
[c] Field duplicate sample.
[d] Well water is derived from a gravity-fed line from the spring (500 ft east of SGZ).

Abbreviations:
ft = feet
NA = not analyzed
ND = not detected
SGZ = surface ground zero
yrd = yards

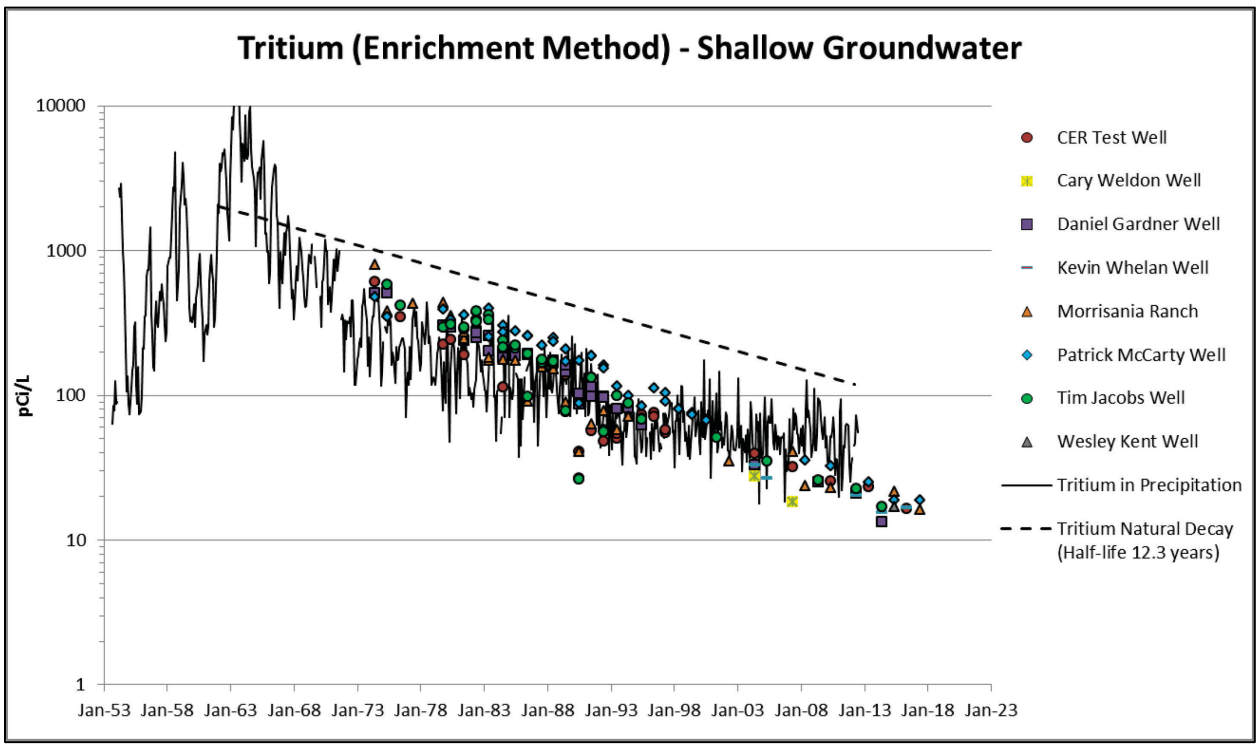

Figure 4. Comparison of Tritium in Shallow Wells near the Rulison Site with Tritium in Precipitation at Ottawa, Canada (site with longest historical tritium record [Brown 1995])

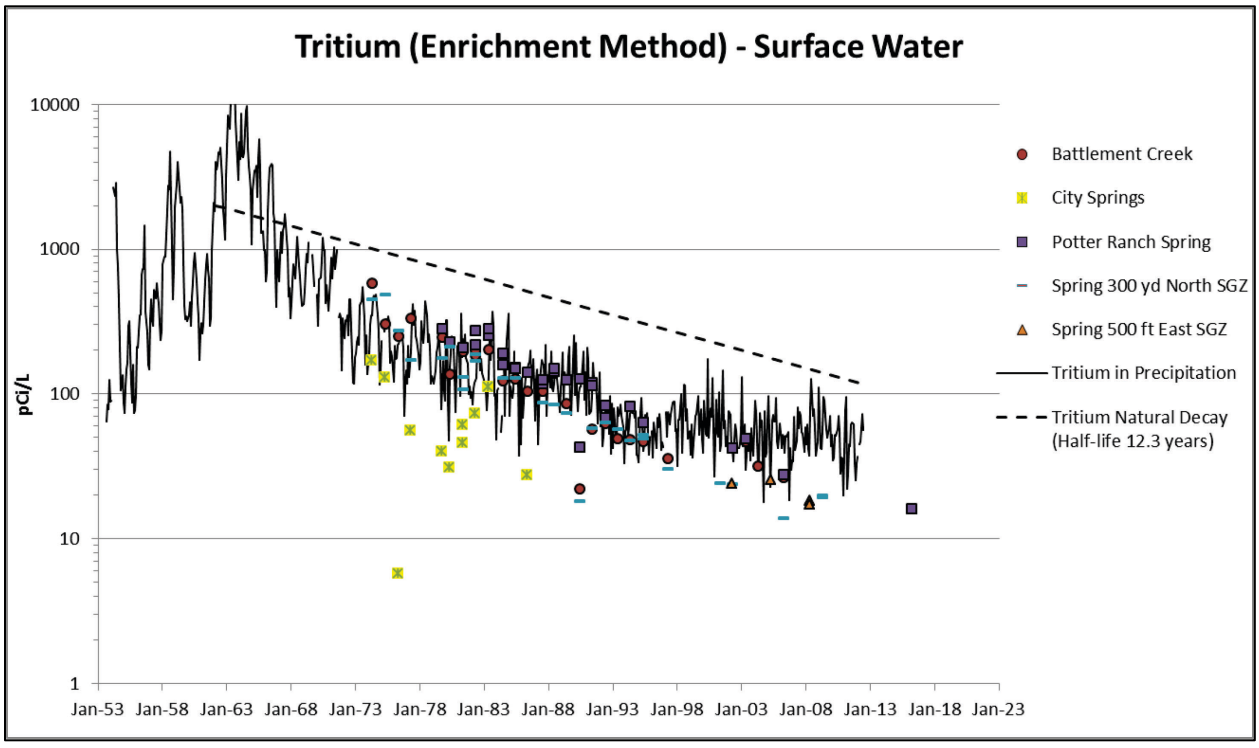

Figure 5. Comparison of Tritium in Surface Water near the Rulison Site with Tritium in Precipitation at Ottawa, Canada (site with longest historical tritium record [Brown 1995])

4.0 Conclusions

The laboratory results obtained from this monitoring event continue to demonstrate that no Rulison detonation-related contaminants have impacted the shallow groundwater or surface water locations near the site. This report is available on the LM public website at https://www.lm.doe.gov/Rulison/Documents.aspx. Data collected during this and previous monitoring events are available on the GEMS website at https://gems.lm.doe.gov/#site=RUL.

5.0 References

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Appendix A

2017 Data Validation Memo

(May–June 2017 Groundwater and Surface Water Data from the Rulison, Colorado, Site)

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memo

To:	Rick Findlay, Navarro
From:	Stephen Donivan, Navarro
CC:	Stephen Donivan, Navarro Janice MacDonald, Navarro
Date:	October 13, 2017
Re:	Validation of May–June 2017 Groundwater and Surface Water Data from the Rulison, Colorado, Site.

Validation of data generated from the May–June 2017 Groundwater and Surface Water Data from the Rulison, Colorado, Site has been completed. This Level 2 validation was conducted according to the Standard Practice for Validation of Environmental Data (*Environmental Procedures Catalog*, LMS/POL/S04325, continually updated).

The samples were submitted for analysis identified by requisition index numbers (RIN) 17058484 and 17068565. Planned monitoring locations are shown in the Sampling and Analysis Work Order (Enclosure 1). Samples were collected at all of the 13 planned locations. See the Trip Report (Enclosure 2) for additional details.

All environmental data from this sampling event are considered validated and available for use. Site data are available for viewing with dynamic mapping via the GEMS (Geospatial Environmental Mapping System) website at https://gems.lm.doe.gov/#. The Data Assessment Summary (Enclosure 3) includes documentation of the validation. An assessment of anomalous data is included in Enclosure 4. Summaries of Enclosures 3 and 4 are presented below.

Sampling and Analysis Work Order (Enclosure 1)

Trip Report (Enclosure 2)

Data Assessment Summary (Enclosure 3)

Verification of Field Activities

A Water Sampling Field Activities Verification Checklist was completed with no issues identified.

Laboratory Performance Assessment

The results of all laboratory analytical quality control samples met the acceptance criteria. Analytical data and the associated qualifiers can be viewed in reports from the environmental database.

Assessment of Field Quality Control Samples

Assessment of field quality control samples was conducted. An equipment blank was not required. A duplicate sample was collected from location Patrick McCarty with acceptable results.

Assessment of Anomalous Data (Enclosure 4)

Assessment of anomalous data is documented in Enclosure 4.

Enclosures (4)

Enclosure 1
Sampling and Analysis Work Order

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May 1, 2017

Task Assignment 104
Control Number 17-0472

U.S. Department of Energy
Office of Legacy Management
ATTN: Art Kleinrath
Site Manager
2597 Legacy Way
Grand Junction, CO 81503

SUBJECT: Contract No. DE-LM0000421, Navarro Research and Engineering, Inc. (Navarro)
Task Assignment 104 LTS&M-Nevada Off Sites and Monticello Site
May 2017 Environmental Sampling at the Rulison, Colorado, Site

REFERENCE: Task Assignment 104, 1-104-1-04-619, Rulison, Colorado, Site

Dear Mr. Kleinrath:

The purpose of this letter is to inform you of the upcoming sampling event at the Rulison, Colorado, Site. Enclosed are the map and tables specifying sample locations and analytes for monitoring at the site. Water quality data will be collected at this site as part of the routine environmental sampling currently scheduled to begin the week of May 15, 2017.

The following lists show the locations scheduled for sampling during this event.

GROUNDWATER WELLS

Off-Site

CER Test Well	Daniel Gardener	Kevin Whelan	Morrissania Ranch
Patrick McCarty	Tim Jacobs Ranch New		

On-Site

Cary Weldon House W	Wesley Kent House W

SURFACE WATER

On-Site

Spr 300 Yrd N of GZ	Sprg 500ft E of GZ

Off-Site

Battlement Creek	City Springs	Potter Ranch

2597 Legacy Way - Grand Junction, CO 81503-1789 -Telephone (970) 248-6000 - Fax (970) 248-6040

All samples will be collected as directed in the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites*. Notification for access to locations on private property will be conducted prior to the beginning of fieldwork.

Please contact me at (970) 248-6419 if you have any questions.

Sincerely,

Rick C. Findlay
2017.05.01 13:26:47
-06'00'

Richard C. Findlay
LMS Site Lead

RCF/lcg/bkb

Enclosures

cc: (electronic)
Christine Hopper, DOE
Christina Pennal, DOE
Bev Cook, Navarro
Steve Donivan, Navarro
Rick Findlay, Navarro
Lauren Goodknight, Navarro
Kenneth Karp, Navarro
Sam Marutzky, Navarro
Diana Osborne, Navarro
EDD Delivery
Document Determination
Records
File: RUL 0400.02

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Sampling Frequencies for Locations at Rulison, Colorado

Location ID	Quarterly	Semiannually	Annually	Biennially	Not Sampled	Notes
Monitoring Wells						
Off-Site						
CER Test Well			X			
Daniel Gardener			X			
Kevin Whelan			X			
Morrissania Ranch			X			
Patrick McCarty			X			
Tim Jacobs Ranch New			X			
On-Site						
Cary Weldon House W			X			
Wesley Kent House W			X			
Surface Locations						
On-Site						
Spr 300 Yrd N Of GZ			X			
Sprg 500ft E of GZ			X			
Off-Site						
Battlement Creek			X			
City Springs			X			
Potter Ranch			X			

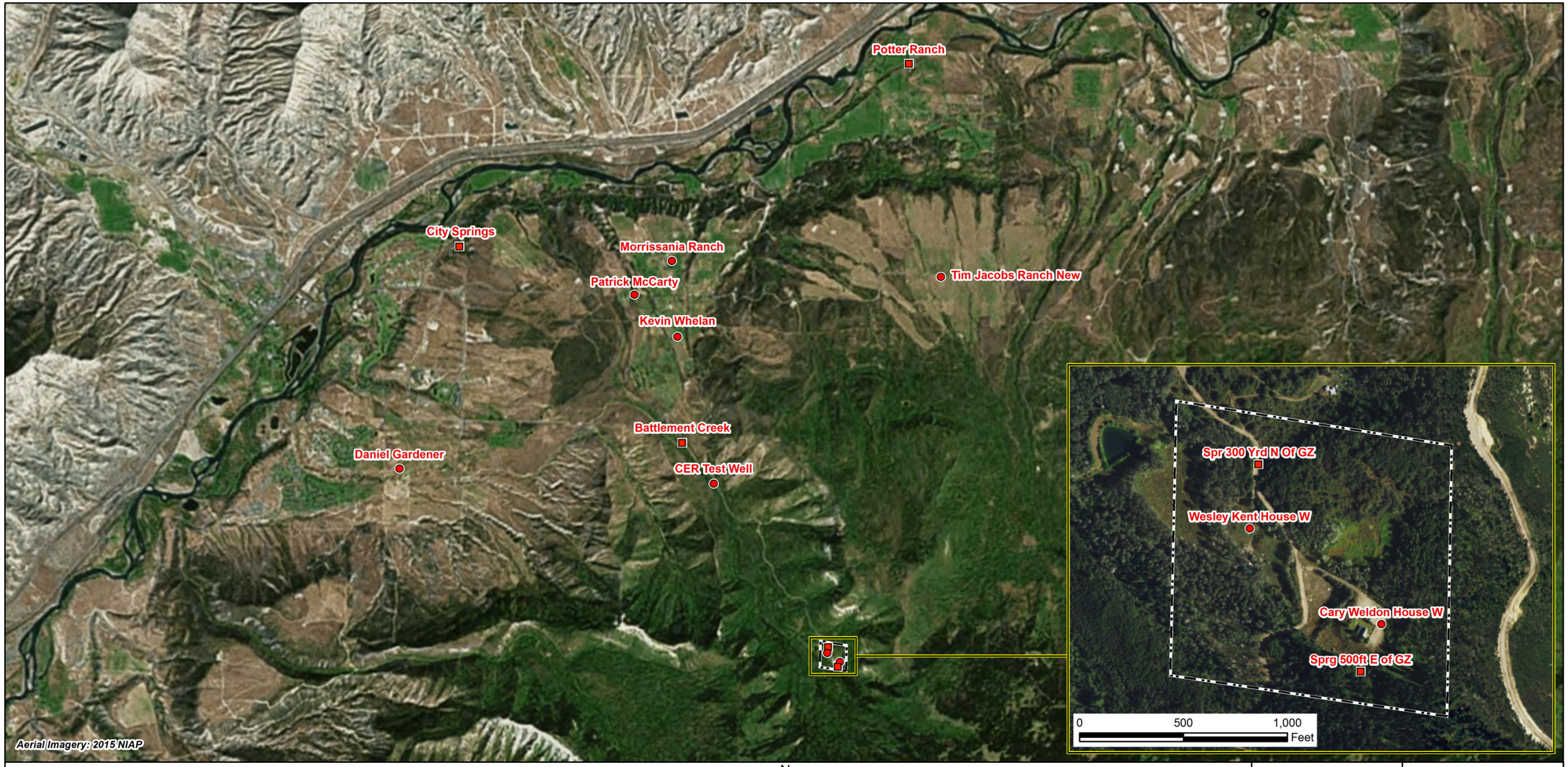
Sampling conducted in May

Be sure to pick different locations from last year for enriched tritium.

Constituent Sampling Breakdown

Site	Rulison				
Analyte	Groundwater	Surface Water	Required Detection Limit (mg/L)	Analytical Method	Line Item Code
Approx. No. Samples/yr	9	4			
Field Measurements					
Total Alkalinity					
Dissolved Oxygen					
Redox Potential					
pH	X	X			
Specific Conductance	X	X			
Turbidity	X				
Temperature	X	X			
Laboratory Measurements					
Aluminum					
Ammonia as N (NH3-N)					
Calcium					
Chloride					
Chromium					
Gamma Spec	X	X	10 pCi/L	Gamma Spectrometry	GAM-A-001
Gross Alpha					
Gross Beta					
Iron					
Lead					
Magnesium					
Manganese					
Molybdenum					
Nickel					
Nickel-63					
Nitrate + Nitrite as N (NO3+NO2)-N					
Potassium					
Radium-226					
Radium-228					
Selenium					
Silica					
Sodium					
Strontium					
Sulfate					
Sulfide					
Total Dissolved Solids					
Total Organic Carbon					
Tritium	X	X	400 pCi/L	Liquid Scintillation	LSC-A-001
Tritium, enriched	25% of the samples	25% of the samples	10 pCi/L	Liquid Scintillation	LMR-15
Uranium					
Vanadium					
Zinc					
Total No. of Analytes	3	3			

Note: All private well samples are to be unfiltered. The total number of analytes does not include field parameters.



LEGEND

- WELL TO BE SAMPLED
- SURFACE LOCATION TO BE SAMPLED
- SITE BOUNDARY

N

0 1 2 Miles

U.S. DEPARTMENT OF ENERGY
OFFICE OF LEGACY MANAGEMENT

Work Performed by
Navarro Research & Engineering, Inc.
Under DOE Contract Number DE-LM0000421

Planned Sample Locations
Rulison, CO, Site
May 2017

DATE PREPARED: March 22, 2017

FILE NAME: S1587700-11x17

\\LM\ess\EnvProjects\EBM\LTS\111\0001\16\004\S15877\S1587700-11x17.mxd smithw 03/22/2017 11:05:21 AM

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Enclosure 2
Trip Report

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memo

To:	Rick Findlay, Navarro
From:	Tony Franzone, Navarro
Date:	July 7, 2017
CC:	Art Kleinrath, DOE Steve Donivan, Navarro Rex Hodges, Navarro EDD Delivery
Re:	Sampling Trip report

Site: Rulison, Colorado, Site.

Date of Event: May 18 and June 8, 2017.

Team Members: Dan Sellers and Tony Franzone, Navarro.

Number of Locations Sampled: Samples were collected from all 13 of the locations identified on the sampling notification letter.

Locations Not Sampled/Reason: All scheduled locations were sampled.

Location-Specific Information: Table 1 provides location-specific information.

Table 1. Location-Specific Information

Location IDs	Comments
CER Test Well	Turbidity was not met. Samples for gamma spectrometry and tritium were filtered.
Morrisania Ranch, Patrick McCarty, Wesley Kent House W	Enriched tritium samples were collected at these locations.

Quality Control Sample Cross Reference: Table 2 provides the false identification assigned to the quality control sample.

Table 2. Quality Control Sample Summary

False ID	Ticket Number	True ID	Sample Type	Associated Matrix
2487	PGV 142	Patrick McCarty	Duplicate	Groundwater

Requisition Index Number (RIN) Assigned: Samples were assigned to RIN numbers 17058484 and 17068565. Field data sheets can be found in \\crow\SMS\17058484\FieldData and \\crow\SMS\17068565\FieldData.

Sample Shipment: Samples were shipped overnight via FedEx from Grand Junction, CO, to GEL Laboratories in Charleston, SC, on May 22 and June 12, 2017.

Water-Level Measurements: Water levels were measured in all sampled wells.

Well Inspection Summary: No issues were identified.

Sampling Method: Samples were collected according to the *Sampling and Analysis Plan for the U.S. Department of Energy Office of Legacy Management Sites* (SAP) (LMS/PRO/S04351, continually updated). FDCS software was used to collect field data for this event.

Field Variance: Filtered tritium samples were collected at the CER Test Well because turbidity less than 10 nephelometric turbidity units (NTUs) could not be attained.

Equipment: All equipment functioned properly.

Stakeholder/Regulatory/DOE: Nothing to note.

Institutional Controls:

Fences, Gates, and Locks: All property owner gates were left as found.
Signs: No issues were observed.
Trespassing/Site Disturbances: None observed.
Disposal Cell/Drainage Structure Integrity: N/A

Safety Issues: None.

Access Issues: None.

General Information: None.

Immediate Actions Taken: None.

Future Actions Required or Suggested: None.

Enclosure 3
Data Assessment Summary

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Water Sampling Field Activities Verification Checklist

Project	Rulison, Colorado, Site	**Date(s) of Water Sampling**	May 18 and June 8, 2017
Date(s) of Verification	September 29, 2017	**Name of Verifier**	Stephen Donivan

	Response (Yes, No, NA)	Comments
1. Is the SAP the primary document directing field procedures?	Yes	
List any Program Directives or other documents, SOPs, instructions.		Work Order letter dated May 1, 2017
2. Were the sampling locations specified in the planning documents sampled?	Yes	
3. Were field equipment calibrations conducted as specified in the above-named documents?	Yes	Calibrations were performed on May 15 and 17 and June 8, 2017
4. Was an operational check of the field equipment conducted daily?	Yes	
Did the operational checks meet criteria?	Yes	
5. Were the number and types (alkalinity, temperature, specific conductance, pH, turbidity, DO, ORP) of field measurements taken as specified?	Yes	
6. Were wells categorized correctly?	Yes	
7. Were the following conditions met when purging a Category I well:		
Was one pump/tubing volume purged prior to sampling?	NA	There were no Category I wells.
Did the water level stabilize prior to sampling?	NA	
Did pH, specific conductance, and turbidity measurements meet criteria prior to sampling?	NA	
Was the flow rate less than 500 mL/min?	NA	

Water Sampling Field Activities Verification Checklist (continued)

	Response (Yes, No, NA)	Comments
8. Were the following conditions met when purging a Category II well:		
Was the flow rate less than 500 mL/min?	Yes	
Was one pump/tubing volume removed prior to sampling?	Yes	
9. Were duplicates taken at a frequency of one per 20 samples?	Yes	A duplicate sample was collected from location Patrick McCarty.
10. Were equipment blanks taken at a frequency of one per 20 samples that were collected with non-dedicated equipment?	NA	An equipment blank was not required.
11. Were trip blanks prepared and included with each shipment of VOC samples?	NA	
12. Were the true identities of the QC samples documented?	Yes	
13. Were samples collected in the containers specified?	Yes	
14. Were samples filtered and preserved as specified?	Yes	
15. Were the number and types of samples collected as specified?	Yes	
16. Were chain of custody records completed and was sample custody maintained?	Yes	
17. Was all pertinent information documented on the field data sheets?	Yes	
18. Was the presence or absence of ice in the cooler documented at every sample location?	NA	Sample cooling was not required.
19. Were water levels measured at the locations specified in the planning documents?	Yes	

Laboratory Performance Assessment

General Information

Report Number (RIN):	17058484, 17068565
Sample Event:	May 18 and June 8, 2017
Site(s):	Rulison, Colorado, Site
Laboratory:	GEL Laboratories, Charleston, South Carolina
Work Order No.:	423943, 425402
Analysis:	Radiochemistry
Validator:	Stephen Donivan
Review Date:	September 29, 2017

This validation was performed according to the *Environmental Procedures Catalog* (LMS/PRO/S04325, continually updated) "Standard Practice for Validation of Laboratory Data." The procedure was applied at Level 2, Data Verification. See attached Data Validation Worksheets for supporting documentation on the data review and validation. All analyses were successfully completed. The samples were prepared and analyzed using accepted procedures based on methods specified by line item code, which are listed in Table 1. Samples Morrisania Ranch and Patrick McCarty were subcontracted to ARS International for tritium analysis using the enrichment method.

Table 1. Analytes and Methods

Analyte	Line Item Code	Prep Method	Analytical Method
Gamma spectrometry	GAM-A-001	EPA 901.1	EPA 901.1
Tritium, enrichment method	LMR-17	DOE HASL 300	DOE HASL 300
Tritium	LSC-A-001	EPA 906.0m	EPA 906.0m

Data Qualifier Summary

None of the analytical results required qualification.

Sample Shipping/Receiving

GEL Laboratories in Charleston, South Carolina, received nine water samples on May 24, 2017, and five water samples on June 14, 2017, accompanied by Chain of Custody forms. The Chain of Custody forms were checked to confirm that all of the samples were listed with sample collection dates and times and that signatures and dates were present indicating sample relinquishment and receipt. The Chain of Custody forms had no errors or omissions.

Preservation and Holding Times

The sample shipment was received intact at ambient temperature, which complies with requirements. The sample aliquots were received in the correct container types and had been preserved correctly for the requested analyses. All analyses were completed within the applicable holding times.

Detection and Quantitation Limits

Radiochemical results are evaluated using the minimum detectable concentration (MDC), decision-level concentration (DLC), and determination limit (DL). The MDC is a measure of radiochemical method performance and was calculated and reported as specified in *Quality Systems for Analytical Services*. The DLC is the minimum concentration of an analyte that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, and is estimated as 3 times the 1-sigma total propagated uncertainty. Results that are greater than the MDC, but less than the DLC, are qualified with a "U" flag (not detected). The DL for radiochemical results is the lowest concentration that can be reliably measured and is defined as 3 times the MDC. Results not previously "U" qualified that are less than the DL are qualified with a "J" flag as estimated values.

The reported MDCs for radiochemical analytes demonstrate compliance with contractual requirements.

Laboratory Instrument Calibration

Compliance requirements for satisfactory instrument calibration are established to ensure that the instrument is capable of producing acceptable qualitative and quantitative data for all analytes. Initial calibration demonstrates that the instrument is capable of acceptable performance in the beginning of the analytical run. Compliance requirements for continuing calibration checks are established to ensure that the instrument continues to be capable of producing acceptable qualitative and quantitative data. All laboratory instrument calibrations were performed correctly in accordance with the cited methods. All calibration and laboratory spike standards were prepared from independent sources.

Method Blanks

Method blanks are analyzed to assess any contamination that may have occurred during sample preparation. All method blank results associated with the samples were below the DLC for all analytes.

Matrix Spike Analysis

Matrix spike and matrix spike duplicate samples were analyzed for tritium as a measure of method performance in the sample matrix. All spike results were within the acceptance range.

Laboratory Replicate Analysis

Laboratory replicate analyses are used to determine laboratory precision for each sample matrix. The relative error ratio for radiochemical replicate results (calculated using the 1-sigma total propagated uncertainty) was less than 3, indicating acceptable precision.

Laboratory Control Sample

Laboratory control samples were analyzed at the correct frequency to provide information on the accuracy of the analytical method and the overall laboratory performance, including sample preparation. All control sample results were acceptable.

Completeness

Results were reported in the correct units for all analytes requested using contract-required laboratory qualifiers.

Electronic Data Deliverable (EDD) File

The EDD file arrived on August 21, 2017. The Sample Management System EDD validation module was used to verify that the EDD files were complete and in compliance with requirements. The module compares the contents of the file to the requested analyses to ensure all and only the requested data are delivered. The contents of the EDD were manually examined to verify that the sample results accurately reflect the data contained in the sample data package.

SAMPLE MANAGEMENT SYSTEM

General Data Validation Report

RIN: 17058484 **Lab Code:** GEN **Validator:** Stephen Donivan **Validation Date:** 9/29/2017

Project: Rulison Site **Analysis Type:** ☐ Metals ☐ General Chem ☑ Rad ☐ Organics

# of Samples: 9 **Matrix:** Water **Requested Analysis Completed:** Yes

Chain of Custody

Present: OK **Signed:** OK **Dated:** OK

Sample

Integrity: OK **Preservation:** OK **Temperature:** OK

Select Quality Parameters

☑ Holding Times	All analyses were completed within the applicable holding times.
☑ Detection Limits	The reported detection limits are equal to or below contract requirements.
☐ Field/Trip Blanks	
☑ Field Duplicates	There was 1 duplicate evaluated.

SAMPLE MANAGEMENT SYSTEM

General Data Validation Report

RIN: 17068565 **Lab Code:** GEN **Validator:** Stephen Donivan **Validation Date:** 9/29/2017

Project: Rulison Site **Analysis Type:** ☐ Metals ☐ General Chem ☑ Rad ☐ Organics

# of Samples: 5 **Matrix:** Water **Requested Analysis Completed:** Yes

Chain of Custody

Present: OK **Signed:** OK **Dated:** OK

Sample

Integrity: OK **Preservation:** OK **Temperature:** OK

Select Quality Parameters

- ☑ Holding Times
- ☑ Detection Limits
- ☐ Field/Trip Blanks
- ☐ Field Duplicates

All analyses were completed within the applicable holding times.

The reported detection limits are equal to or below contract requirements.

SAMPLE MANAGEMENT SYSTEM
Radiochemistry Data Validation Worksheet

RIN: 17058484 **Lab Code:** GEN **Date Due:** 8/22/2017

Matrix: Water **Site Code:** RUL01 **Date Completed:** 8/23/2017

Sample	Analyte	Date Analyzed	Result	Flag	Tracer %R	LCS %R	MS %R	Duplicate RER
2487	Actinium-228	07/18/2017						1.40
2487	Americium-241	07/18/2017						0.99
2487	Antimony-125	07/18/2017						0.43
2487	Cerium-144	07/18/2017						0.91
2487	Cesium-134	07/18/2017						0.26
2487	Cesium-137	07/18/2017						0.88
2487	Cobalt-60	07/18/2017						0.50
2487	Europium-152	07/18/2017						0.37
2487	Europium-154	07/18/2017						0.86
2487	Europium-155	07/18/2017						0.29
2487	Lead-212	07/18/2017						0.87
2487	Potassium-40	07/18/2017						0.58
2487	Promethium-144	07/18/2017						2.21
2487	Promethium-146	07/18/2017						1.02
2487	Ruthenium-106	07/18/2017						0.09
2487	Thorium-234	07/18/2017						0.79
2487	Uranium-235	07/18/2017						1.32
2487	Uranium-238	07/18/2017						0.79
2487	Yttrium-88	07/18/2017						2.15
Blank_Spike	Americium-241	07/18/2017				99.10		
Blank_Spike	Cesium-137	07/18/2017				103.00		
Blank_Spike	Cobalt-60	07/18/2017				106.00		
Blank_Spike	Enriched Tritium	08/02/2017				90.00		
Blank_Spike	Tritium	08/07/2017				96.30		
Blank_Spike_Du	Enriched Tritium	08/02/2017				93.00		
Fawn Creek 500	Enriched Tritium	08/04/2017					113.0	
RB-D-03	Tritium	08/07/2017					107.0	

SAMPLE MANAGEMENT SYSTEM
Radiochemistry Data Validation Worksheet

RIN: 17068565 **Lab Code:** GEN **Date Due:** 7/12/2017

Matrix: Water **Site Code:** RUL01 **Date Completed:** 7/10/2017

Sample	Analyte	Date Analyzed	Result	Flag	Tracer %R	LCS %R	MS %R	Duplicate RER
Blank_Spike	Americium-241	06/28/2017				104.00		
Blank_Spike	Cesium-137	06/28/2017				104.00		
Blank_Spike	Cobalt-60	06/28/2017				101.00		
Blank_Spike	Tritium	07/03/2017				75.00		
Cary Weldon Ho	Actinium-228	06/28/2017						0.46
Cary Weldon Ho	Americium-241	06/28/2017						0.49
Cary Weldon Ho	Antimony-125	06/28/2017						0.49
Cary Weldon Ho	Cerium-144	06/28/2017						0.65
Cary Weldon Ho	Cesium-134	06/28/2017						1.17
Cary Weldon Ho	Cesium-137	06/28/2017						0.46
Cary Weldon Ho	Cobalt-60	06/28/2017						0.16
Cary Weldon Ho	Europium-152	06/28/2017						0.62
Cary Weldon Ho	Europium-154	06/28/2017						0.95
Cary Weldon Ho	Europium-155	06/28/2017						0.33
Cary Weldon Ho	Lead-212	06/28/2017						1.03
Cary Weldon Ho	Potassium-40	06/28/2017						0.42
Cary Weldon Ho	Promethium-144	06/28/2017						0.97
Cary Weldon Ho	Promethium-146	06/28/2017						0.48
Cary Weldon Ho	Ruthenium-106	06/28/2017						0.04
Cary Weldon Ho	Thorium-234	06/28/2017						0.02
Cary Weldon Ho	Tritium	07/03/2017					80.1	
Cary Weldon Ho	Tritium	07/03/2017						0.40
Cary Weldon Ho	Uranium-235	06/28/2017						0.58
Cary Weldon Ho	Uranium-238	06/28/2017						0.02
Cary Weldon Ho	Yttrium-88	06/28/2017						0.30

Assessment of Field Quality Control Samples

Sampling Protocol

Well CER Test Well was sampled using a dedicated bladder pump. Data from this well is qualified with an "F" flag in the database, indicating the well was purged and sampled using the low-flow sampling method and further qualified with a "Q" flag because this well was classified as Category II. All other sample locations were domestic wells or surface water locations.

Equipment Blank

Equipment blanks are prepared and analyzed to document contamination attributable to the sample collection process. An equipment blank was not required during this sampling event.

Field Duplicate Analysis

Field duplicate samples are collected and analyzed as an indication of overall precision of the measurement process. The precision observed includes both field and laboratory precision and has more variability than laboratory duplicates, which measure only laboratory performance. A duplicate sample was collected from location Patrick McCarty. For radiochemical measurements, the relative error ratio (the ratio of the absolute difference between the sample and duplicate results and the sum of the 1-sigma uncertainties) is used to evaluate duplicate results and should be less than 3. All duplicate results met this criteria demonstrating acceptable precision.

SAMPLE MANAGEMENT SYSTEM

Validation Report: Field Duplicates

RIN: 17058484 **Lab Code:** GEN **Project:** Rulison Site **Validation Date:** 9/29/2017

Duplicate: 2487 **Sample:** Patrick McCarty

Analyte	Sample				Duplicate				RPD	RER	Units
	Result	Flag	Error	Dilution	Result	Flag	Error	Dilution			
Actinium-228	-12.3	U	9.12	1.00	7.65	U	13.6	1.00		2.4	pCi/L
Americium-241	1.60	U	6.62	1.00	-1.22	U	15.6	1.00		0.3	pCi/L
Antimony-125	-1.75	U	4.08	1.00	2.65	U	4.26	1.00		1.5	pCi/L
Cerium-144	3.82	U	9.54	1.00	3.27	U	13.3	1.00		0.1	pCi/L
Cesium-134	0.398	U	1.51	1.00	0.789	U	1.63	1.00		0.3	pCi/L
Cesium-137	-0.625	U	1.35	1.00	0.143	U	1.36	1.00		0.8	pCi/L
Cobalt-60	0.0849	U	1.18	1.00	0.533	U	1.50	1.00		0.5	pCi/L
Europium-152	-2.21	U	3.87	1.00	0.547	U	4.88	1.00		0.9	pCi/L
Europium-154	-0.805	U	4.17	1.00	-4.51	U	5.19	1.00		1.1	pCi/L
Europium-155	2.61	U	4.77	1.00	0.116	U	6.40	1.00		0.6	pCi/L
Lead-212	0.00	UI	6.67	1.00	1.41	U	6.97	1.00		0.3	pCi/L
Potassium-40	0.00	UI	32.3	1.00	-18.9	U	26.1	1.00		0.9	pCi/L
Promethium-144	0.547	U	1.36	1.00	0.164	U	1.74	1.00		0.3	pCi/L
Promethium-146	-0.711	U	1.54	1.00	2.77	U	2.44	1.00		2.4	pCi/L
Ruthenium-106	22.0	U	31.3	1.00	4.53	U	16.8	1.00		1.0	pCi/L
Thorium-234	31.7	U	115	1.00	-3.41	U	183	1.00		0.3	pCi/L
Tritium					72.7	U	167	1.00			pCi/L
Uranium-235	-2.56	U	11.7	1.00	1.92	U	14.6	1.00		0.5	pCi/L
Uranium-238	31.7	U	115	1.00	-3.41	U	183	1.00		0.3	pCi/L
Yttrium-88	-0.155	U	2.20	1.00	2.13	U	2.47	1.00		1.4	pCi/L

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Enclosure 4
Assessment of Anomalous Data

Potential Outliers Report

Potential outliers are measurements that are extremely large or small relative to the rest of the data and, therefore, are suspected of misrepresenting the population from which they were collected. Potential outliers can result from transcription errors, data-coding errors, or measurement system problems. However, outliers can also represent true extreme values of a distribution and can indicate more variability in the population than was expected.

Statistical outlier tests give probabilistic evidence that an extreme value does not "fit" with the distribution of the remainder of the data and is therefore a statistical outlier. These tests should only be used to identify data points that require further investigation. The tests alone cannot determine whether a statistical outlier should be discarded or corrected within a data set.

There are three steps involved in identifying extreme values or outliers:

1. **Identify extreme values that may be potential outliers.** Do this by generating the Outliers Report using the Sample Management System from data in the environmental database. The application compares the new data set (in standard environmental database units) with historical data and lists the new data that fall outside the historical data range. A determination is also made as to whether the data are normally distributed using the Shapiro-Wilk Test.
2. **Apply the appropriate statistical test.** Dixon's Test for extreme values is used to test for statistical outliers when the sample size is less than or equal to 25. This test considers both extreme values that are much smaller than the rest of the data (case 1) and extreme values that are much larger than the rest of the data (case 2). This test is valid only if the data without the suspected outlier are normally distributed. Rosner's Test is a parametric test that is used to detect outliers for sample sizes of 25 or more. This test also assumes that the data without the suspected outliers are normally distributed.
3. **Scientifically review statistical outliers and decide on their disposition.** The review should include an evaluation of any notable trends in the data that may indicate the outliers represent true extreme values.

None of the data were identified as potentially anomalous.