LMS/RUL/S27939

2019 Long-Term Hydrologic Monitoring Program Report for Rulison, Colorado, Site

May 2020

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Appendix

Appendix A 2019 Data Validation Memo (*May 2019 Groundwater and Surface Water Data from the Rulison, Colorado, Site*)

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 detonation depth of 8425 feet (ft). Monitoring includes the collection of samples from shallow groundwater wells, surface water locations, and producing natural gas wells near the site to monitor for any potential contamination that may be attributed to the nuclear test. This report summarizes the laboratory analytical results from the 2019 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 (identified as Lot 11) 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 8425 ft on September 10, 1969 (DOE 2015). 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 the gas well production 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).

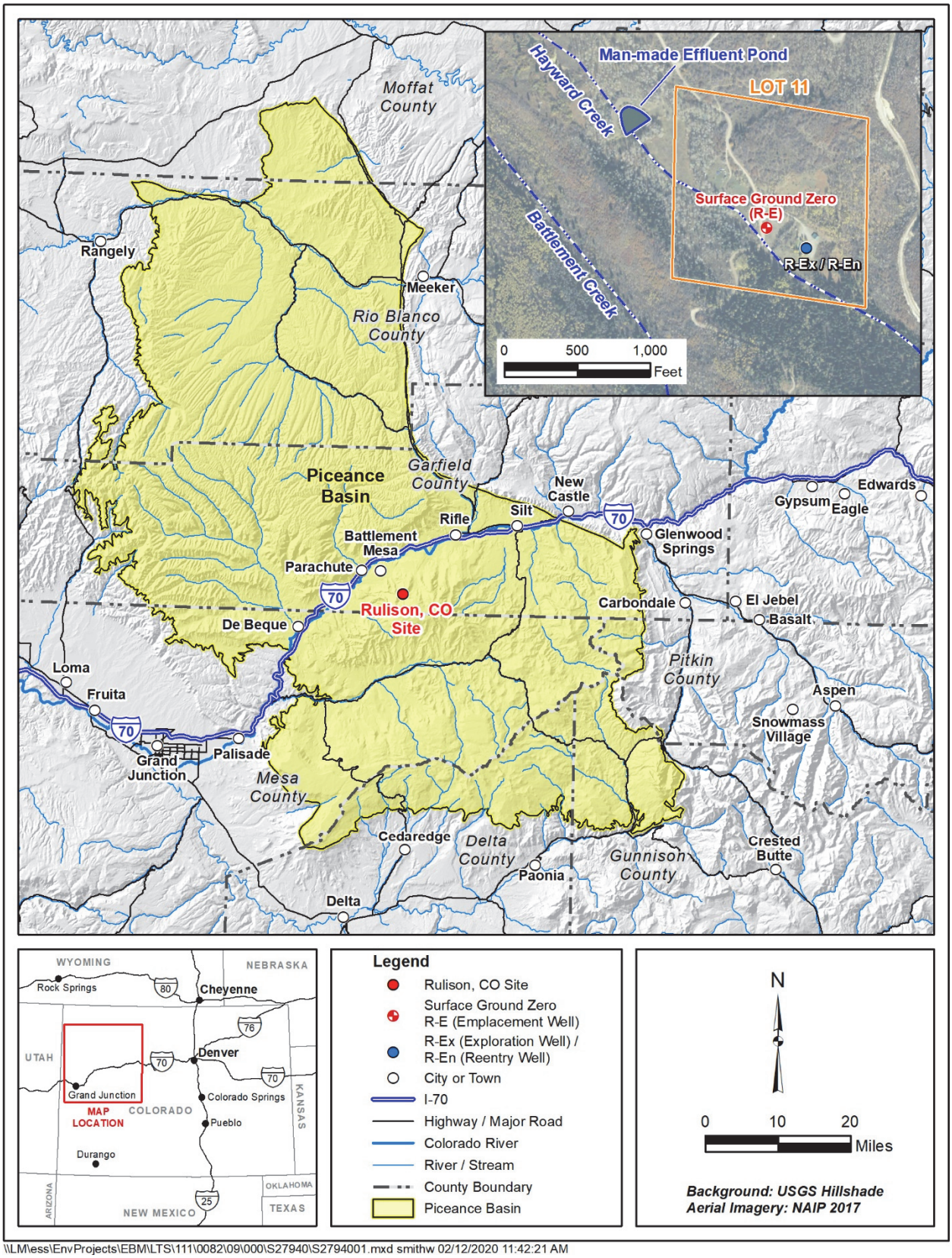

Figure 1. Site Location Map, Rulison Site

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 well (now referred to as R-En) 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 the 40 acres of 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 at a depth of 8425 ft 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. Liquid movement in the formation is severely limited by the low permeability of the formation (only a few microdarcies) and the presence of gas that makes the relative permeability of liquids even less. Due to these factors, radionuclides in the solidified melt rock are 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 is a cross section of the Piceance Basin.

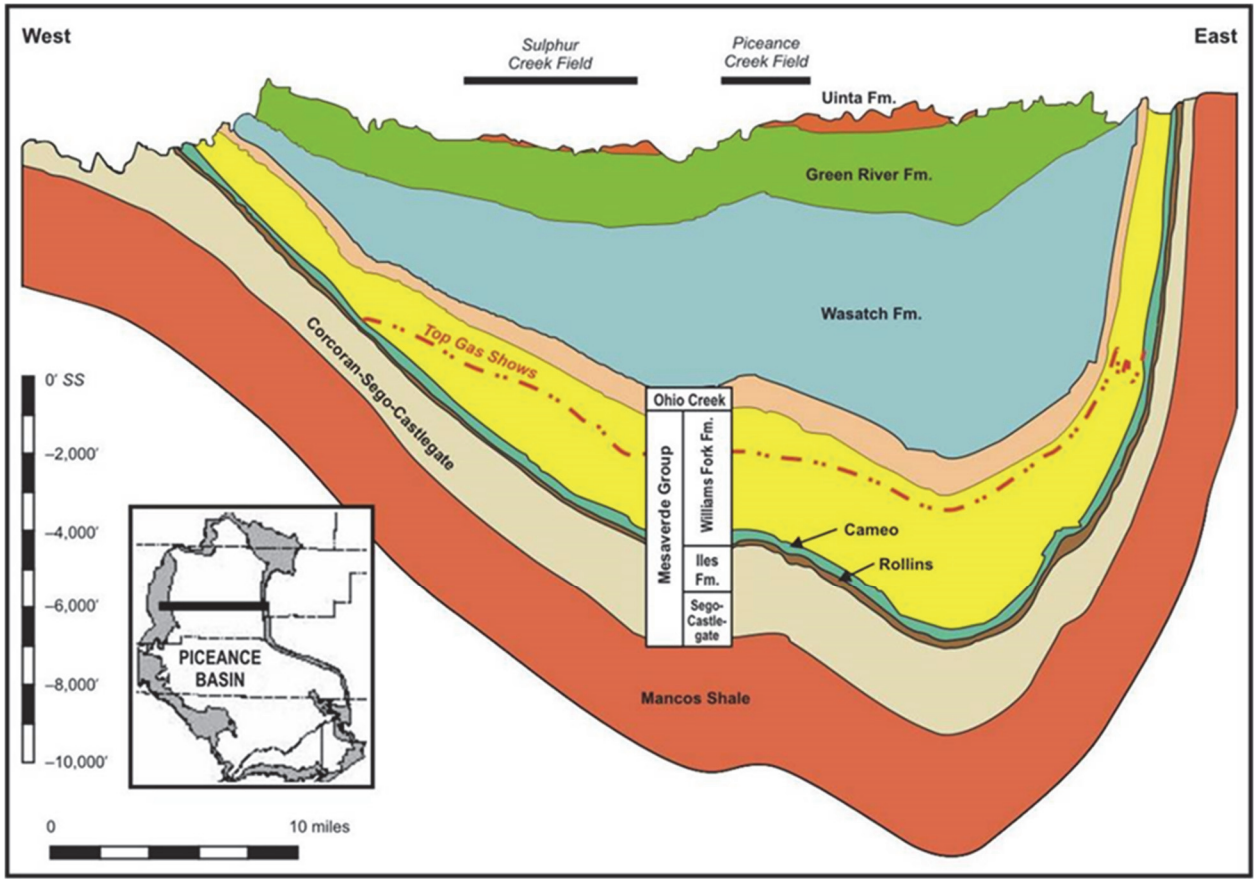

Figure 2. Piceance Basin Cross Section (modified from Yurewicz et al. 2003)

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 patterns to be elongated in that direction (DOE 2013). A more-detailed description of the hydrofracturing and drainage patterns 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 near 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, primarily 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) that are 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 sampled 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 would be 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 there are no reasonable pathways for detonation-related contaminants to impact the near-surface water, 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 monitor for any potential contamination 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 29, 2019, 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 (three surface and one shallow groundwater well) are within the site boundary. In past reports, the Wesley Kent sample location was identified as a shallow well, but it has been determined that water at this location is derived from a spring 500 ft east of SGZ and not a well registered with the Colorado Division of Water Resources (DWR 2019) based on a review of the website. The remaining nine locations (three surface and six shallow groundwater wells) are offsite, with these locations ranging from 2 to 6 miles from SGZ (Figure 3). Samples were collected according to the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PRO/S04351) (Sampling and Analysis Plan). The Sampling and Analysis Plan can be accessed on the LM public website at https://www.energy.gov/sites/prod/files/2019/01/f58/SAP%20Rev%2015.2.pdf.

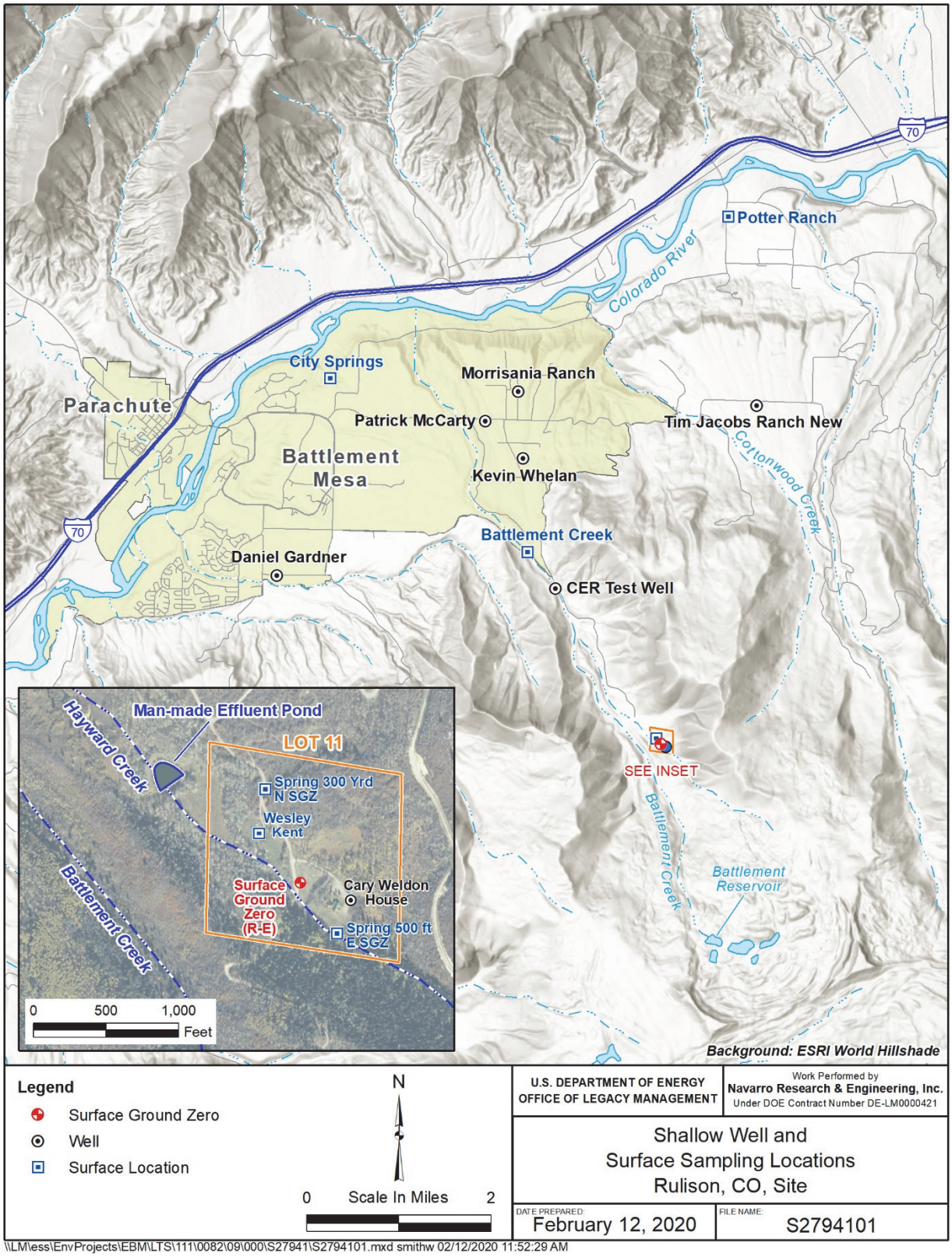

Figure 3. Shallow Groundwater and Surface Water Sampling Location Map, Rulison Site

Samples collected during the annual sampling event were analyzed for tritium because it is the most mobile contaminant remaining in significant quantities in the detonation zone. Samples from 11 locations were analyzed using the conventional method. Samples from three locations (three shallow well locations) 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. All samples were submitted to ARS Aleut Analytical, which analyzed the samples using accepted procedures that are based on specified methods in accordance with the *Department of Defense (DoD) Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories* (DOD and DOE 2017) to ensure that data are of known, documented quality. 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 results were validated in accordance with Section 5.0, "Validation of Environmental Data," in the *Environmental Data Validation Procedure* (LMS/PRO/S15870).

3.2 Groundwater and Surface Water Sample Results

The 2019 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. Three samples (three shallow well locations) were analyzed using the enrichment method. These samples (Daniel Gardner, Patrick McCarty, and Tim Jacobs Ranch) had 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 above-ground nuclear testing during the 1950s and early 1960s (Brown 1995). Above-ground 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* Section 141.16). No other detonation-related 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 provides the 2019 sample 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	5/29/2019	<295	NA	ND
CER Test Well (private well)		5/29/2019	<300	NA	ND[c]
Daniel Gardner (private well)		5/29/2019	NA	15.9	ND
Kevin Whelan (private well)		5/29/2019	<293	NA	ND
Morrisania Ranch (private well)		5/29/2019	<294	NA	ND
Patrick McCarty (private well)		5/29/2019	NA	20.2	ND
Tim Jacobs Ranch (private well)		5/29/2019	NA	18.5	ND
Battlement Creek (creek)	Surface water	5/29/2019	<294	NA	ND
City Springs (spring)		5/29/2019	<295	NA	ND
Potter Ranch (spring)		5/29/2019	<294	NA	ND
Spring 300 yrd N SGZ (spring)		5/29/2019	<298	NA	ND
Spring 500 ft E SGZ (spring)		5/29/2019	<295	NA	ND
Wesley Kent House (spring)[d]		5/29/2019	<295	NA	ND
			<287[b]	NA	ND[b]

Notes:
[a] See data validation memo (Appendix A, Enclosure 3) for a list of radionuclides included in this analysis.
[b] Field duplicate sample.
[c] The sample was filtered because the turbidity requirements were not met per the Sampling and Analysis Plan.
[d] 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

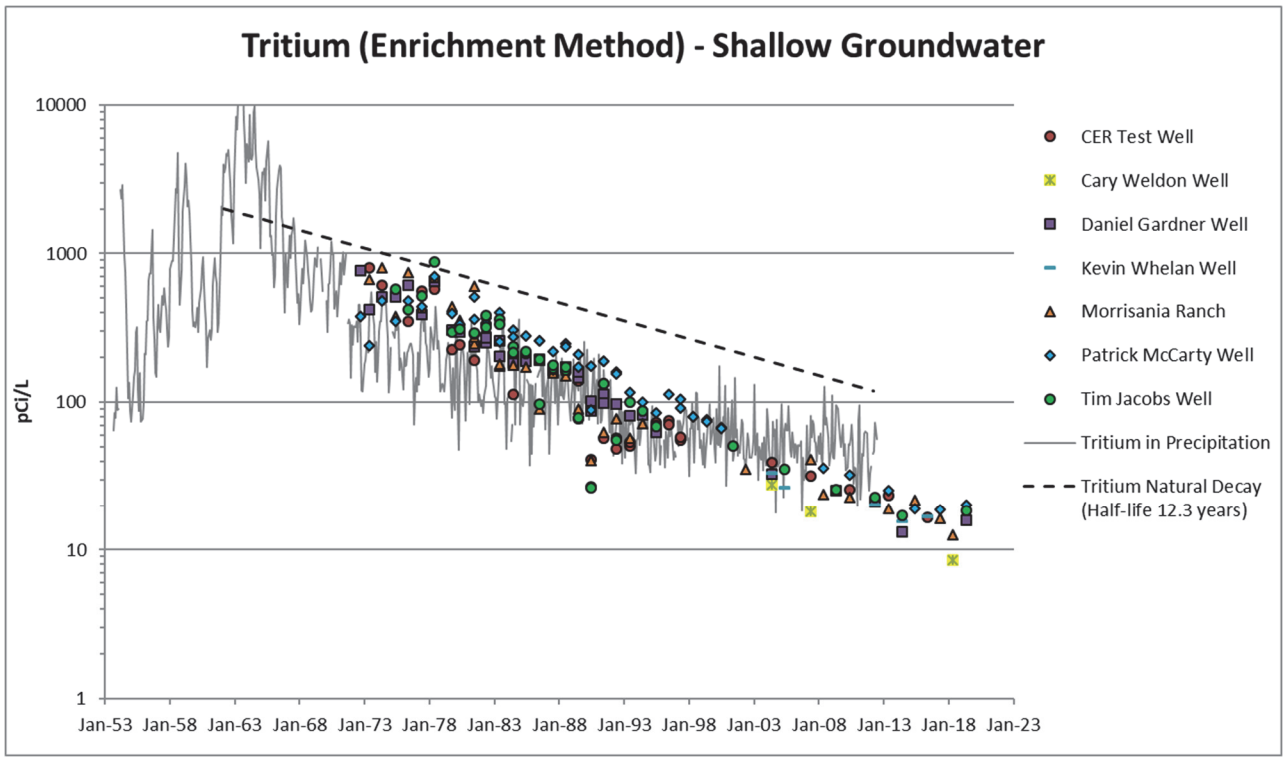

Figure 4. Comparison of Tritium in Shallow Wells near the Rulison Site with Tritium in Precipitation at Ottawa, Canada (site with longest historical tritium record [Brown 1995])

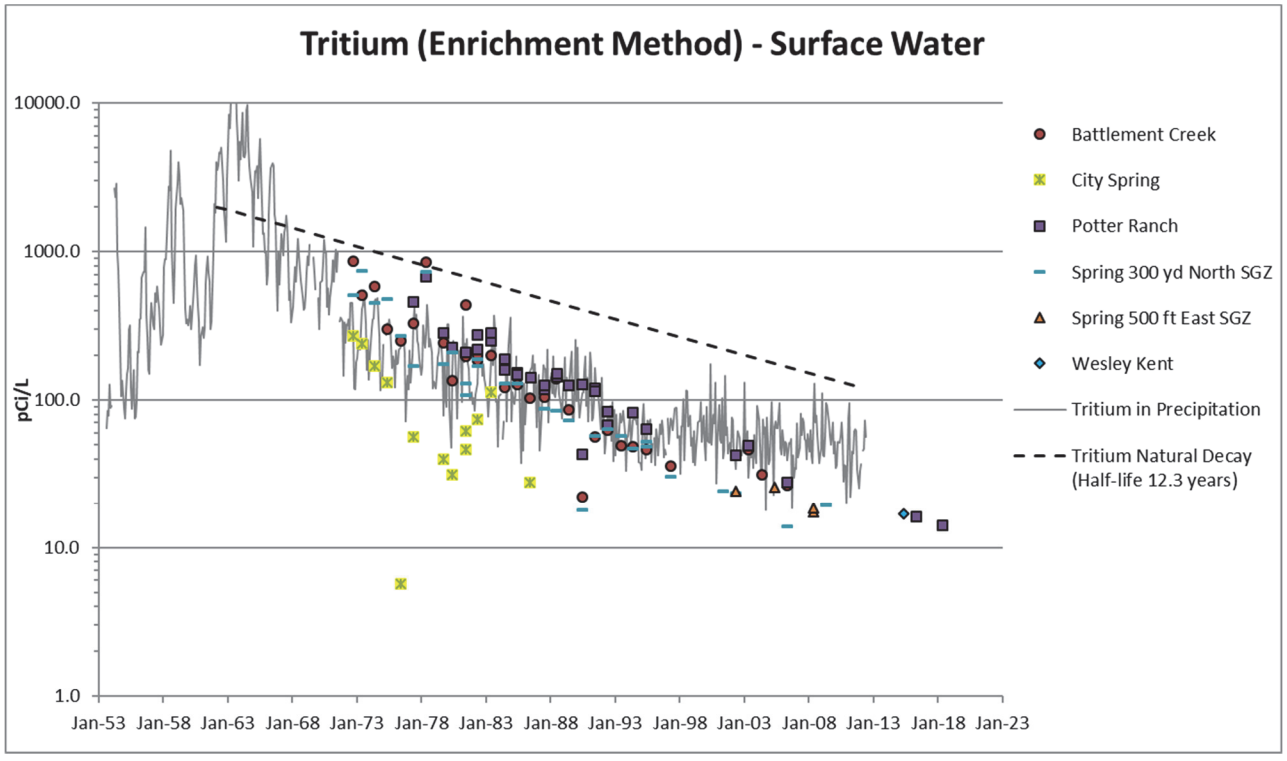

Figure 5. Comparison of Tritium in Surface Water near the Rulison Site with Tritium in Precipitation at Ottawa, Canada (site with longest historical tritium record [Brown 1995])

4.0 Conclusions

The laboratory results from the 2019 monitoring event continue to indicate that no Rulison site detonation-related contaminants have impacted the shallow groundwater or surface water locations near the site. The detection of tritium at concentrations of 15.9, 20.2, and 18.5 pCi/L in the samples collected from the Daniel Gardner, Patrick McCarty, and Tim Jacobs Ranch locations, respectively, is normal background tritium concentrations in precipitation that resulted from above-ground nuclear tests conducted at different global locations. Based on these results, the sampling planned for 2020 will be reduced to focus on the onsite well and two offsite well locations. This report and previous 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 GEMS website at https://gems.lm.doe.gov/#site=RUL.

5.0 References

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Appendix A

2019 Data Validation Memo

(May 2019 Groundwater and Surface Water Data from the Rulison, Colorado, Site)

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memo

To:	Rick Findlay, Navarro
From:	Stephen Donivan, Navarro
CC:	Janice McDonald, Navarro
Date:	September 24, 2019
Re:	Validation of May 2019 Groundwater and Surface Water Data from the Rulison, Colorado, Site

Validation of data generated from the May 2019 groundwater and surface water sampling event at the Rulison, Colorado, Site has been completed. This Level 3 validation was conducted according to the *Environmental Data Validation Procedure* (LMS/PRO/S15870).

The samples were submitted for analysis identified by Task Code RUL01-01.1905002. Planned monitoring locations are shown in the Sampling and Analysis Work Order (Enclosure 1). Samples were collected at 13 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 http://gems.lm.doe.gov/#. The Field Data Assessment (Enclosure 3) includes discussion of the field data and field quality control samples. The Laboratory Performance Assessment (Enclosure 4) documents the review of the laboratory data. An assessment of anomalous data is included in Enclosure 5. Summaries of Enclosures 3, 4, and 5 are presented below.

Sampling and Analysis Work Order (Enclosure 1)

Trip Report (Enclosure 2)

Field Data Assessment (Enclosure 3)

Verification of Field Activities

A Field Activities Verification Checklist was completed. There were no significant issues with the field activities.

Assessment of Field Quality Control Samples

Assessment of field quality control samples was conducted. A duplicate sample was collected from location Wesley Kent House W. The duplicate results met all applicable criteria, demonstrating acceptable overall precision of the measurement process.

Laboratory Performance Assessment (Enclosure 4)

Laboratory analytical quality control criteria were met. Analytical data and the associated qualifiers can be viewed in reports from the environmental database.

Assessment of Anomalous Data (Enclosure 5)

Assessment of anomalous data is documented in Enclosure 5. There were no outliers identified.

Enclosures (5)

Enclosure 1
Sampling and Analysis Work Order

May 1, 2019

Task Assignment 104
Control Number 19-1036

U.S. Department of Energy
Office of Legacy Management
ATTN: Ms. Jalena Dayvault
LM 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 2019 Environmental Sampling at the Rulison, Colorado, Site

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

Dear Ms. Dayvault:

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 as part of the routine environmental sampling currently scheduled to begin the week of May 27, 2019.

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

MONITORING WELLS

Off-Site

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

On-Site

Cary Weldon House	Wesley Kent House

SURFACE WATER

On-Site

Spring 300 yrd N SGZ	Spring 500 ft E SGZ

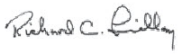
Off-Site

Battlement Creek	City Springs	Potter Ranch

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,



RICHARD FINDLAY
(Affiliate)
2019.05.01 12:30:17 -06'00'

Richard C. Findlay
LMS Site Lead

RCF/lcg/ks

Enclosures

cc: (electronic)
Bari Brooks, DOE
Darryl Groves, DOE
Jeanie Gueretta, DOE
Paul Kerl, DOE
Art Kleinrath, DOE
Ken Kreie, DOE
Stephen Browning, Navarro
Steve Donivan, Navarro
Richard Findlay, Navarro
Lauren Goodknight, Navarro
Deana Guzman, Navarro
Kenneth Karp, Navarro
Sam Marutzky, Navarro
Diana Osborne, Navarro
LM Admin Support
Document Determination
EDD Delivery
Records
File: LM 0610.10
RUL 0410.02

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 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 analyte samples are considered unfiltered unless stated otherwise. All private well samples are to be unfiltered. The total number of analytes does not include field parameters.

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 Gardner			X			
Kevin Whelan			X			
Morrisania 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						
Spring 300 Yrd N SGZ			X			
Spring 500 ft E SGZ			X			
Off-Site						
Battlement Creek			X			
City Springs			X			
Potter Ranch			X			

Sampling conducted in May

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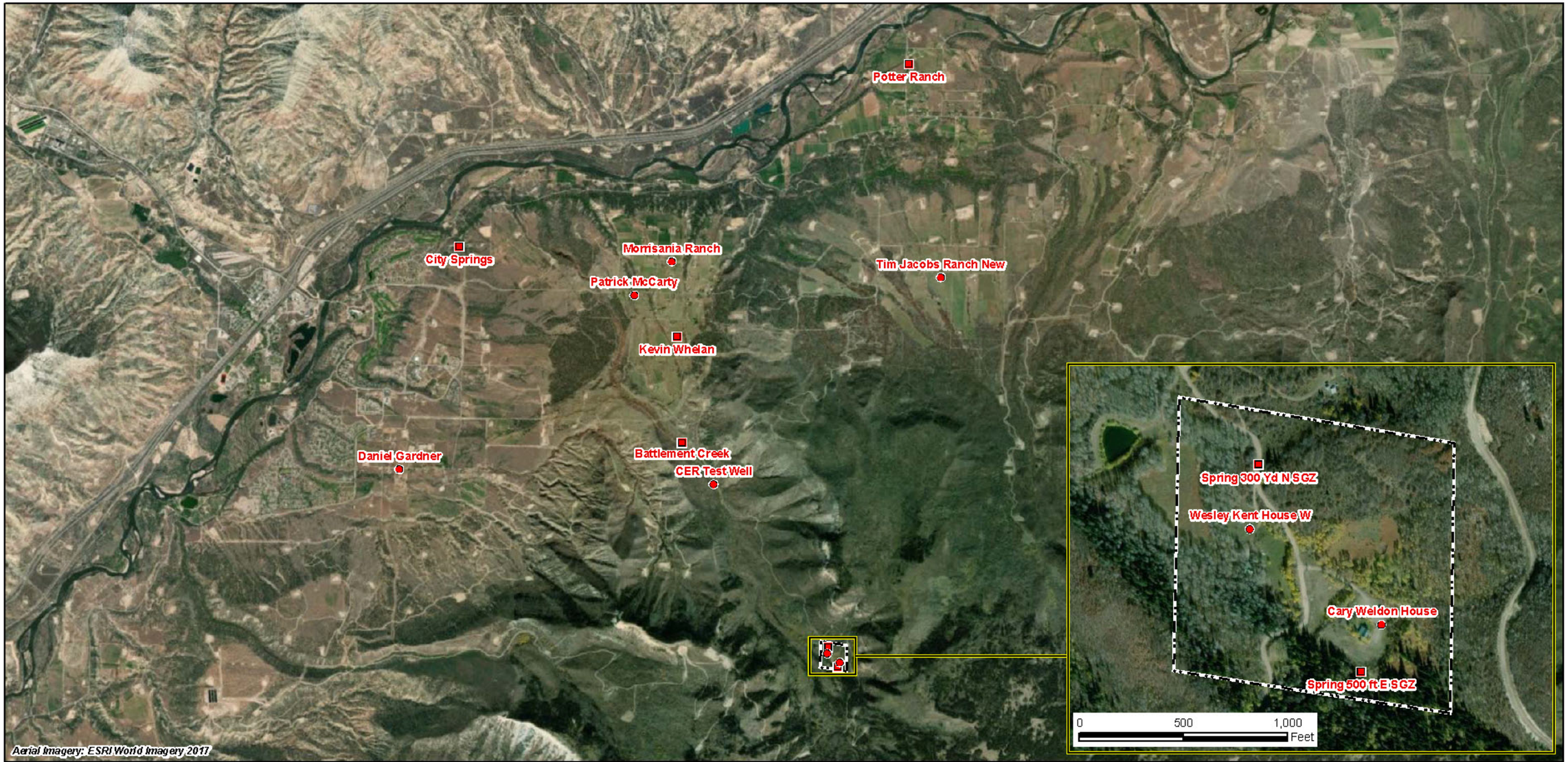

LEGEND

- 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 2018

DATE PREPARED: March 25, 2019

FILE NAME: S2481900-11x17

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Enclosure 2
Trip Report

memo

NAVARRO

To: Rick Findlay, Navarro

From: Samantha Tigar, Navarro

Date: June 3, 2019

CC: Steve Donivan, Navarro
Rex Hodges, Navarro
Janice McDonald, Navarro
EDD Delivery

Re: Sampling Trip report

Site: Rulison, Colorado, Site

Date of Event: May 30, 2019

Team Members: Jennifer Graham and Samantha Tigar, 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, Spring 500 ft E SGZ	Turbidity was greater than 10 NTUS at these locations. The samples for gamma spectrometry were filtered; tritium samples were not filtered.
Daniel Gardner, Tim Jacobs Ranch New, Patrick McCarty	Samples for enriched tritium analysis 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	Sample ID	Location ID	Parent Sample ID	Sample Type	Associated Matrix
2487	RUL01-01.1905002-013	Wesley Kent House W	RUL01-01.1905002-005	Duplicate	Groundwater

Task Code Assigned: All samples were assigned to RUL01-01.1905002. Field data sheets can be found in \\crow\SMS\RUL01-01.1905002\RECORDS\FieldData

Sample Shipment: Samples were shipped overnight via FedEx from Grand Junction, CO to ARS International in Port Allen, LA, on May 30, 2019.

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

Well Inspection Summary: No issues were identified.

Sampling Method: Samples were collected according to the *Sampling and Analysis Plan (SAP) for the U. S. Department of Energy Office of Legacy Management Sites* (LMS/PRO/S04351, continually updated).

Field Variance: None.

Equipment: All equipment functioned properly.

Stakeholder/Regulatory/DOE: R. Findlay, J. Trnka, D. Riddle, R. Rowsam (Navarro) and J. Dayvault (DOE) were present to observe sampling activities.

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: A camper was parked near the CER Test Well, on public land. The well was accessed and sampled without disrupting the campsite.

General Information: New owners have constructed a new house at the Patrick McCarty location.

Immediate Actions Taken: None.

Future Actions Required or Suggested: None.

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Enclosure 3
Field Data Assessment

Water Sampling Field Activities Verification Checklist

Project	Rulison, Colorado, Site	**Date(s) of Water Sampling**	May 29, 2019
Date(s) of Verification	September 12, 2019	**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, 2019
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 May 28, 2019
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?	NA	
Was one pump/tubing volume removed prior to sampling?	NA	
9. Were duplicates taken at a frequency of one per 20 samples?	Yes	One duplicate was collected from location Wesley Kent House W
10. Were equipment blanks taken at a frequency of one per 20 samples that were collected with non-dedicated equipment?	No	An equipment blank was not required.
11. Were trip blanks prepared and included with each shipment of VOC samples?	NA	VOC samples were not collected.
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 chilling was not required.
19. Were water levels measured at the locations specified in the planning documents?	Yes	

Data Qualifier Summary – Sampling Protocol and Field Measurements

Analytical results and field measurements were qualified as listed in the following table. Refer to the sections below for an explanation of the data qualifiers applied.

Table 1. Data Qualifiers for Sampling Protocol and Field Measurements

Location	Analyte(s)	Flag	Reason
CER Test Well	All analytical results and field measurements	FQ	Category II low-flow sampling

Sampling Protocol

Well CER Test Well was sampled using 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.

Field Measurements

No issues associated with the field measurements were noted.

Equipment Blanks

Equipment blanks are prepared and analyzed to document contamination attributable to the sample collection process. Dedicated equipment was used for all sampling and an equipment blank was not required.

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 Wesley Kent House W. 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 these criteria demonstrating acceptable precision.

Validation Report: Field Duplicates

12-Sep-2019

Project: Rulison Site Monitoring **Task Code:** RUL01-01.1905002 Lab Code: ARS

	Duplicate: RUL01-01.1905002-013				Sample: RUL01-01.1905002-005 Wesley Kent House W						
Analyte	**Result**	**Qualifiers**	**Uncert.**	**Dilution**	**Result**	**Qualifiers**	**Uncert.**	**Dilution**	**RPD**	**RER**	**Units**
Actinium-228	-9.075	U	21.527	1	5.980	U	4.679	1		1.3	pCi/L
Americium-241	-0.857	U	2.897	1	-0.857	U	2.981	1		0.0	pCi/L
Antimony-125	-0.122	U	7.755	1	1.552	U	4.109	1		0.4	pCi/L
Cerium-144	1.332	U	7.512	1	-2.469	U	8.899	1		0.6	pCi/L
Cesium-134	0.548	U	1.538	1	1.089	U	1.575	1		0.5	pCi/L
Cesium-137	-0.399	U	2.604	1	0.661	U	1.602	1		0.7	pCi/L
Cobalt-60	-0.275	U	2.427	1	0.160	U	1.431	1		0.3	pCi/L
Europium-152	-3.472	U	12.134	1	1.246	U	4.769	1		0.7	pCi/L
Europium-154	-0.690	U	2.010	1	2.619	U	1.693	1		2.5	pCi/L
Europium-155	-1.711	U	2.237	1	2.532	U	1.638	1		2.9	pCi/L
Lead-212	1.440	U	2.609	1	3.616	U	2.834	1		1.1	pCi/L
Potassium-40	-14.271	U	37.910	1	36.498		25.740	1		2.2	pCi/L
Promethium-144	-1.263	U	7.566	1	-0.551	U	8.993	1		0.1	pCi/L
Promethium-146	-1.311	U	1.976	1	0.157	U	1.837	1		1.1	pCi/L
Ruthenium-106	0.008	U	12.625	1	-14.012	U	25.513	1		1.0	pCi/L
Thorium-234	-34.310	U	46.269	1	8.055	U	5.985	1		1.8	pCi/L
Tritium	-90.512	U	165.604	1	16.445	U	172.665	1		0.9	pCi/L
Uranium-235	6.789	U	8.764	1	10.063	U	9.430	1		0.5	pCi/L

QC Checks: RPD: Relative Percent Difference RER: Relative Error Ratio

Validation Report: Field Duplicates

12-Sep-2019

Project: Rulison Site Monitoring **Task Code:** RUL01-01.1905002 Lab Code: ARS

	Duplicate: RUL01-01.1905002-013				Sample: RUL01-01.1905002-005 Wesley Kent House W						
Analyte	**Result**	**Qualifiers**	**Uncert.**	**Dilution**	**Result**	**Qualifiers**	**Uncert.**	**Dilution**	**RPD**	**RER**	**Units**
Uranium-238	-34.310	U	46.269	1	8.055	U	5.985	1		1.8	pCi/L
Yttrium-88	0.610	U	1.565	1	1.049	U	1.723	1		0.4	pCi/L

QC Checks: RPD: Relative Percent Difference RER: Relative Error Ratio

Enclosure 4
Laboratory Performance Assessment

General Information

Task Code:	RUL01-01.1905002
Sample Event:	May 29, 2019
Site(s):	Rulison, Colorado, Site
Laboratory:	ARS Aleut Analytical, Port Allen, Louisiana
Work Order No.:	ARS-19-01361
Analysis:	Radiochemistry
Validator:	Stephen Donivan
Review Date:	September 12, 2019

This validation was performed according to the *Environmental Data Validation Procedure* (LMS/PRO/S15870). The procedure was applied at Level 3, Data Validation.

This validation includes the evaluation of data quality indicators (DQIs) associated with the data. DQIs are the quantitative and qualitative descriptors that are used to interpret the degree of acceptability or utility of data. Indicators of data quality include the analysis of laboratory control samples to assess accuracy; duplicates and replicates to assess precision; and interference check samples to assess bias (see attached Data Validation Worksheets). The comparability, completeness, and sensitivity of the data are also evaluated in the sections to follow.

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 2.

Table 2. 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

Analytical results were qualified as listed in Table 3. Refer to the sections below for an explanation of the data qualifiers applied.

Table 3. Data Qualifier Summary

Sample Number	Location	Analyte	Flag	Reason
RUL01-01.1905002-005	Wesley Kent House	Potassium-40	U	Less than the Decision Level
RUL01-01.1905002-007	Spr 300 Yrd N Of SGZ	Potassium-40	U	Less than the Decision Level
RUL01-01.1905002-008	Spr 500 ft E Of SGZ	Uranium-235	U	Less than the Decision Level

Sample Shipping/Receiving

ARS Aleut Analytical in Port Allen, Louisiana, received 14 water samples on May 31, 2019, accompanied by a Chain of Custody form. The Chain of Custody form was 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 form was

complete with no errors or omissions. Copies of the air waybill labels were included with the receiving documentation.

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 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 as 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 that were not previously U qualified and 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.

Gamma Spectrometry

Activity concentrations above the MDC were reported in some instances where minimum nuclide identification criteria were not met. Such tentative identifications result when the software attempts to calculate net activity concentrations for analytes where any of the following criteria are not satisfied: one or more characteristic peaks for a nuclide must be identified above the critical level, peak shape meets acceptance criteria, or the minimum library peak abundance must be attained. Sample results for gamma-emitting radionuclides that do not meet the identification criteria are qualified with a U flag as not detected.

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 one-sigma total propagated uncertainty) was less than three, 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 29, 2019. The contents of the file were compared to the requested analyses to ensure all and only the requested data were delivered. The contents of the EDD were manually examined to verify that the sample results accurately reflected the data contained in the sample data package.

Radiochemistry Data Validation Worksheet

12-Sep-2019

Project: Rulison Site Monitoring **Task Code:** RUL01-01.1905002 **Lab Code:** ARS

Sample ID	Analyte	Analysis Date	QC Type	Result Type	Result	Flag	TPU	Spike Recovery	Spike Dup Recovery	Lower Limit	Upper Limit	RPD	RPD Limit	RER	Comments
ARS1-B19-01073-01	Enriched Tritium	07-31-2019	LCS	TRG	41.237		12.924	101		75	125				
ARS1-B19-01073-02	Enriched Tritium	07-31-2019	LCSD	TRG	41.775		12.991	102		75	125	1	25		
ARS1-B19-01073-03	Enriched Tritium	07-31-2019	MB	TRG	1.266	U	2.879								
ARS1-B19-01091-01	Americium-241	06-10-2019	LCS	TRG	43364.000		3376.500	99		75	125				
ARS1-B19-01091-01	Cesium-137	06-10-2019	LCS	TRG	53491.000		2472.600	103		75	125				
ARS1-B19-01091-01	Cobalt-60	06-10-2019	LCS	TRG	69556.000		2881.900	102		75	125				
ARS1-B19-01091-02	Americium-241	06-10-2019	LCSD	TRG	41684.000		3001.000	95		75	125	3	25		
ARS1-B19-01091-02	Cesium-137	06-10-2019	LCSD	TRG	52876.000		2333.100	102		75	125	1	25		
ARS1-B19-01091-02	Cobalt-60	06-10-2019	LCSD	TRG	67132.000		2913.500	98		75	125	3	25		
ARS1-B19-01091-03	Actinium-228	06-27-2019	MB	TRG	-1.493	U	7.653								
ARS1-B19-01091-03	Americium-241	06-27-2019	MB	TRG	-1.497	U	4.277								
ARS1-B19-01091-03	Cesium-134	06-27-2019	MB	TRG	-0.929	U	9.188								
ARS1-B19-01091-03	Cesium-137	06-27-2019	MB	TRG	0.568	U	1.346								
ARS1-B19-01091-03	Cobalt-60	06-27-2019	MB	TRG	0.038	U	1.286								
ARS1-B19-01091-03	Europium-152	06-27-2019	MB	TRG	-0.132	U	10.894								
ARS1-B19-01091-03	Lead-212	06-27-2019	MB	TRG	-4.017	U	8.605								
ARS1-B19-01091-03	Potassium-40	06-27-2019	MB	TRG	7.973	U	30.700								
ARS1-B19-01091-03	Ruthenium-106	06-27-2019	MB	TRG	1.412	U	11.713								
ARS1-B19-01091-03	Thorium-234	06-27-2019	MB	TRG	-33.617	U	88.592								
ARS1-B19-01091-03	Uranium-235	06-27-2019	MB	TRG	-0.103	U	1.731								

QC Types: LCS: Laboratory Control Sample LCSD: Laboratory Control Sample Duplicate MB: Method Blank MS: Matrix Spike MSD: Matrix Spike Duplicate R: Replicate

Result Types: IS: Internal Standard SC: Spike Analyte TRG: Target analyte

QC Checks: RPD: Relative Percent Difference RER: Relative Error Ratio TPU: Total Propagated Uncertainty

Radiochemistry Data Validation Worksheet

12-Sep-2019

Project: Rulison Site Monitoring **Task Code:** RUL01-01.1905002 **Lab Code:** ARS

Sample ID	Analyte	Analysis Date	QC Type	Result Type	Result	Flag	TPU	Spike Recovery	Spike Dup Recovery	Lower Limit	Upper Limit	RPD	RPD Limit	RER	Comments
ARS1-B19-01091-03	Uranium-238	06-27-2019	MB	TRG	-33.617	U	88.592								
ARS1-B19-01091-03	Yttrium-88	06-27-2019	MB	TRG	0.000	U	2.007								
ARS1-B19-01291-01	Tritium	07-18-2019	LCS	TRG	2639.490		352.315	94		75	125				
ARS1-B19-01291-02	Tritium	07-18-2019	LCSD	TRG	2796.936		366.815	99		75	125	5	25		
ARS1-B19-01291-03	Tritium	07-18-2019	MB	TRG	-47.358	U	171.786								
ARS1-B19-01291-15	Tritium	07-19-2019	MS	TRG	4805.992		559.918	103		60	140				

QC Types: LCS: Laboratory Control Sample LCSD: Laboratory Control Sample Duplicate MB: Method Blank MS: Matrix Spike MSD: Matrix Spike Duplicate R: Replicate

Result Types: IS: Internal Standard SC: Spike Analyte TRG: Target analyte

QC Checks: RPD: Relative Percent Difference RER: Relative Error Ratio TPU: Total Propagated Uncertainty

Enclosure 5
Assessment of Anomalous Data

Potential Outliers Report

Potential outliers are results that lie outside the historical range, possibly due to transcription errors, data calculation errors, or measurement system problems. However, outliers can also represent true values outside the historical range. Potential outliers are identified by generating the Data Validation Outliers Report from data in the environmental database. The new data are compared to historical values and data that fall outside the historical data range are listed on the report along with the historical minimum and maximum values. The potential outliers are further reviewed and may be subject to statistical evaluation using the ProUCL application developed by the EPA (https://www.epa.gov/land-research/proucl-software). The review also includes an evaluation of any notable trends in the data that may indicate the outliers represent true extreme values.

There were no potential outliers identified, and the data for this event are acceptable as qualified.