

**Monitoring Results of Natural Gas Wells
Near the Rulison, Colorado, Site
First Semiannual Monitoring Event – March 2016**

**U.S. Department of Energy Office of Legacy Management
Grand Junction, Colorado**

Date Sampled: March 16, 2016

Background

The Rulison, Colorado, Site is in the Piceance Basin of western Colorado, 40 miles northeast of Grand Junction. The site, identified as Lot 11 (Figure 1), was the location of an underground nuclear test conducted by the U.S. Atomic Energy Commission (a predecessor agency to the U.S. Department of Energy [DOE]) 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 gas production in a low permeability sandstone reservoir. It was the second natural gas reservoir stimulation experiment in the Plowshare Program, which was designed to develop peaceful uses for nuclear energy. The device was detonated in the emplacement well (R-E) at a depth of 8426 feet (ft) below ground surface on September 10, 1969. It had a reported yield of 40 kilotons and the detonation created a cavity, a collapse chimney, and a fractured zone surrounding the cavity (detonation zone). A sidetrack hole (reentry well) was drilled off the exploration well (R-Ex) into the chimney and tested to evaluate the success of the detonation at improving gas production. In 1976 the participating parties agreed that future gas production would not occur at the site, the wells (R-E and R-Ex) were abandoned, and a deed restriction was established for Lot 11. The deed restriction prohibits penetration or withdrawal of any material below 6000 ft within the boundary of Lot 11 unless authorized by the U.S. Government.

Purpose

Samples are collected from natural gas wells near the Rulison site to ensure public safety. The samples are analyzed for radionuclides that may be associated with the detonation. Tritium is the most abundant radionuclide remaining in the detonation zone that can be present in the gas and aqueous phases. Its presence in water vapor (a minor constituent of natural gas) is the primary concern because gas is more mobile than liquid in a gas reservoir. 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. Natural gas and produced water samples are collected for analysis. The Colorado Oil and Gas Conservation Commission requires that operators with gas wells within 3 miles of the Rulison site adhere to the *Rulison Sampling and Analysis Plan* developed by URS Corporation (URS 2010). The DOE Office of Legacy Management (LM), in a separate effort, has implemented the *Rulison Monitoring Plan*, which samples gas wells within 1 mile of the detonation zone (DOE 2010). The *Rulison Monitoring Plan* and analytical results from past monitoring activities are available on the LM website at <http://www.lm.doe.gov/Rulison/Documents.aspx>. Analytical results obtained from LM's March 16, 2016, monitoring event are summarized in the following sections.

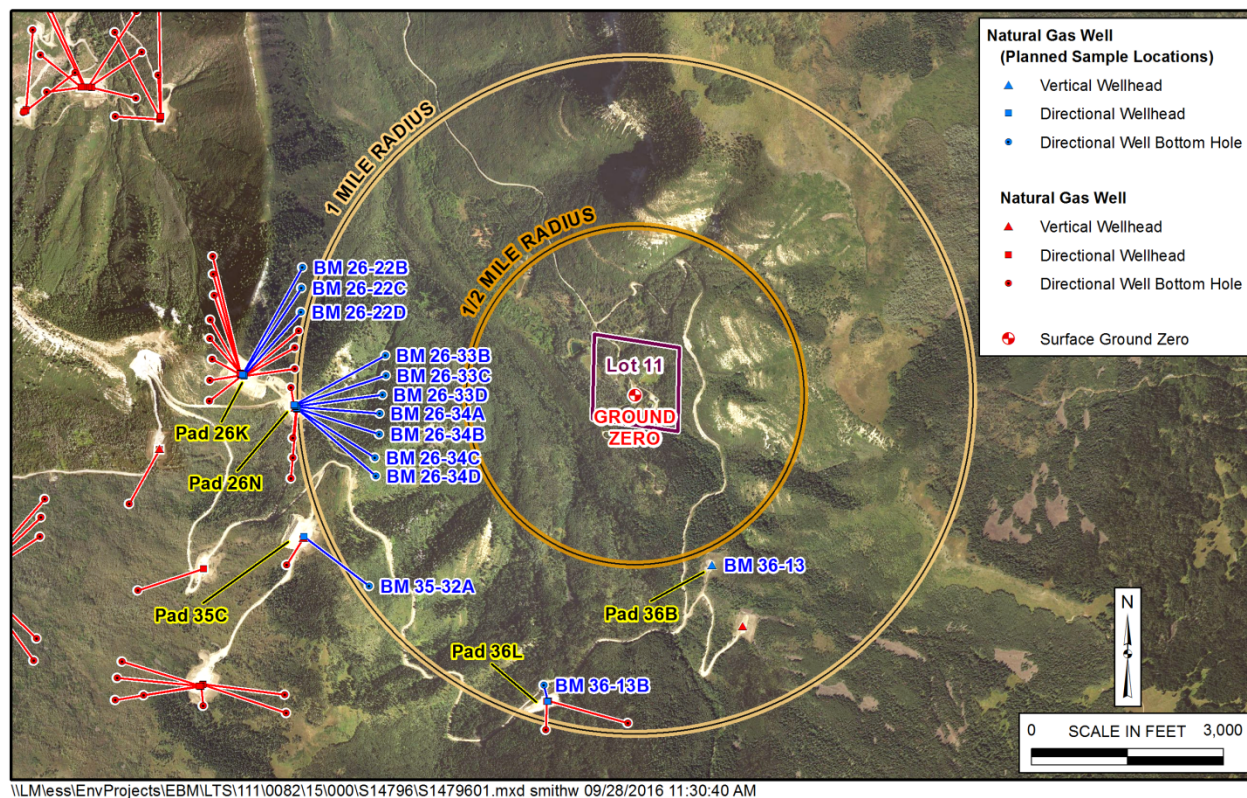


Figure 1. Rulison Site and Well Location Map

Monitoring Protocol

The *Rulison Monitoring Plan* provides guidance on the type of samples (natural gas or produced water) collected, laboratory analyses performed, and the frequency of sample collection as a function of distance and direction from the Rulison site. It also establishes screening levels or concentrations that, if exceeded in the sample results, require samples to be reanalyzed or additional sampling to be done. The natural gas and produced water samples are analyzed for tritium, which is the most mobile contaminant remaining in significant quantities in the detonation zone. Produced water samples are also analyzed for gross alpha/beta and gamma-emitting nuclides to obtain background information. Produced water samples are submitted to a commercial laboratory, which provides analytical services in accordance with the *Department of Defense (DoD) Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories* (updated annually) to ensure that data are of known, documented quality. 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). Table 1 provides the gas and produced water screening concentrations for tritium, gross alpha, gross beta, and gamma-emitting nuclides (specifically cesium-137). It should be noted that background concentrations for gross alpha/beta have not yet been established.

Table 1. Natural Gas and Produced Water Sample Screening Levels

Analyte	Sample Matrix	Laboratory Detection Limit	Screening Concentration	Action Concentration
Tritium	Natural Gas	10 TU ¹	19,293 TU ²	TBD ⁴
	Produced Water	400 pCi/L	800 pCi/L	TBD ⁴
Gross alpha	Produced Water	2 pCi/L	3 × background ³	TBD ⁴
Gross beta	Produced Water	4 pCi/L	3 × background ³	TBD ⁴
High-resolution gamma spectrometry (specifically cesium-137)	Produced Water	10 pCi/L	20 pCi/L	TBD ⁴

Notes:

The screening concentrations were obtained from the *Rulison Monitoring Plan* (DOE 2010).

¹ A tritium unit (TU) is equal to 3.19 picocuries per liter (pCi/L) in water.

² Natural gas screening concentration for tritium assumes a standard temperature (0 °C) and pressure (1 atmosphere).

³ Background concentrations have not been established for gross alpha/beta.

⁴ Action concentrations have not been established for the analytes of interest.

Abbreviations:

pCi/L = picocuries per liter

TBD = to be determined

TU = tritium unit (1 tritium atom in 1×10^{18} hydrogen atoms)

Monitoring Event and Sample Collection

The March 16, 2016, monitoring event included the collection of natural gas and produced water samples from nine natural gas wells. Four wells (BM 26-22B, BM 26-34D, BM36-13B, and BM 36-13) could not be sampled because the wells were not in production at the time of the monitoring event (Figure 1; Table 2). Samples of the produced water were collected from a tap on the dump line connecting the gas-liquid separators and accumulation tank. Prior to sample collection, the gas-liquid separators that share a dump line were isolated using valves and then purged of produced water and condensate. The samples were contained in 1-gallon plastic containers provided by the laboratory. The produced water samples were submitted to ALS Laboratory Group in Fort Collins, Colorado, for the determination of tritium, gross alpha/beta, and gamma-emitting nuclides.

Samples of the natural gas were collected from a tap on the production line downstream from the gas-liquid separator. Tubing used to connect the tap to the sample bottle was purged prior to sample collection. The natural gas samples were contained in an evacuated 18-liter propane bottle provided by the laboratory. The natural gas samples were submitted to Isotech Laboratories Inc. in Champaign, Illinois, for tritium and carbon-14 analysis. Carbon-14 was included in the natural gas analytical suite to get background levels to use in the future after tritium has decayed to insignificant levels. Carbon-14 is present in the gas phase. It is a longer-lived radionuclide with a half-life of 5700 years. The background data will be useful if gas production in the area continues beyond the next 80 years.

Table 2. Natural Gas Well Sample Locations

Well Name/Number	Well Pad	API # 05-045-	Sample Type	
			Gas	Liquid
BM 26-33B	26N	15743	Sampled	Sampled
BM 26-33C	26N	15742	Sampled	Sampled
BM 26-33D	26N	15739	Sampled	Sampled
BM 26-34A	26N	15744	Sampled	Sampled
BM 26-34B	26N	15745	Sampled	Sampled
BM 26-34C	26N	15741	Sampled	Sampled
BM 26-22C	26K	16087	Sampled	Sampled
BM 26-22D	26K	16074	Sampled	Sampled
BM 35-32A	35C	10919	Sampled	Sampled
BM 26-22B	26K	16086	Not Sampled	Not Sampled
BM 26-34D	26N	15748	Not Sampled	Not Sampled
BM 36-13B	36L	15469	Not Sampled	Not Sampled
BM 36-13	36B	10840	Not Sampled	Not Sampled

Abbreviations:

API = American Petroleum Institute

Sample Results

Analytical results of produced water and natural gas samples collected on March 16, 2016, are provided in Table 3. Tritium was not detected in the natural gas or produced water samples at concentrations that were above the laboratory minimum detectable concentration (MDC) for the specified analysis. Carbon-14 and cesium-137 were also not detected above their respective laboratory MDCs. Concentrations of gross alpha/beta were detected above the MDCs in select samples, but they were consistent with past sample results and within the expected range for background concentrations from naturally occurring radionuclides.

The analytical results were validated in accordance with the “Standard Practice for Validation of Environmental Data” section in the *Environmental Procedures Catalog*. All analyses were completed, and the samples were prepared and analyzed in accordance with accepted procedures that were based on the specified methods. The laboratory radiochemical MDC reported with these data is an a priori estimate of the detection capability of a given analytical procedure, not an absolute concentration that can or cannot be detected. A copy of the Data Validation Package is provided as Appendix A.

Table 3. Natural Gas and Produced Water Sample Analytical Results

Well Name/Number	API # 05-045-	Natural Gas ¹		Produced Water			
		Tritium (TU) ²	Carbon-14 (pMC) ³	Tritium (pCi/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Cesium-137 (pCi/L)
BM 26-33B	15743	<10	<0.4	<320	64.9	124	<4.2
BM 26-33B ⁴	15743	NA	NA	<320	63	117	<4.4
BM 26-33C	15742	<10	<0.4	<320	<73	112	<5.2
BM 26-33D	15739	<10	<0.4	<320	<50	130	<4.6
BM 26-34A	15744	<10	<0.4	<320	61.2	200	<3.7
BM 26-34B	15745	<10	<0.4	<330	61.9	93.2	<6.6
BM 26-34C	15741	<10	<0.4	<320	62.1	<72	<4.4
BM 26-22C	16087	<10	<0.4	<320	<56	180	<5.0
BM 26-22D	16074	<10	<0.4	<320	81.7	232	<6.9
BM 35-32A	10919	<10	<0.4	<320	<57	137	<4.0
BM 26-22B	16086	--	--	--	--	--	--
BM 26-34D	15748	--	--	--	--	--	--
BM 36-13B	15469	--	--	--	--	--	--
BM 36-13	10840	--	--	--	--	--	--
Screening Concentrations		19,293	TBD	800	3 × background ⁵	3 × background ⁵	20

Notes:

¹ The natural gas samples were initially analyzed by gas chromatography to determine the composition of the natural gas. The samples were then combusted and the resulting water was collected for tritium and carbon-14 analysis.

² A tritium unit (TU), 1 tritium atom in 1×10^{18} hydrogen atoms, is equal to 3.19 picocuries per liter (pCi/L) in water.

³ Percent modern carbon (pMC) is based on the International Radiocarbon Dating Standard, which is 1950 Before Present (BP).

⁴ Indicates that the sample was provided to the laboratory as a field duplicate.

⁵ Background concentrations have not yet been established for gross alpha/beta.

Abbreviations:

API = American Petroleum Institute

NA = not applicable

pCi/L = picocuries per liter

pMC = percent modern carbon

TBD = to be determined

TU = tritium unit (1 tritium atom in 1×10^{18} hydrogen atoms)

References

DOE (U.S. Department of Energy), 2010. *Rulison Monitoring Plan*, LMS/RUL/S06178, Office of Legacy Management, July.

Environmental Procedures Catalog, LMS/POL/S04325, continually updated, prepared by Navarro Research and Engineering, Inc., for the U.S. Department of Energy Office of Legacy Management.

URS (URS Corporation), 2010. *Rulison Sampling and Analysis Plan, Operational and Environmental Monitoring Within a Three-Mile Radius of Project Rulison, Revision 3*, July.

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Appendix A

Data Validation Package

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Data Validation Package

March 2016
Natural Gas and Produced Water
Sampling at the Rulison, Colorado, Site

July 2016



U.S. DEPARTMENT OF
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Attachment 1—Data Presentation

Produced Water Data
Natural Gas Data

Attachment 2—Trip Report

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Sampling Event Summary

Site: Rulison, Colorado, Site

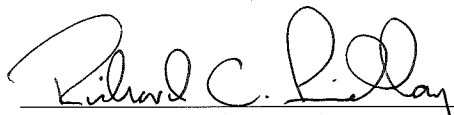
Sampling Period: March 16, 2016

The U.S. Department of Energy Office of Legacy Management conducted sampling at the Rulison, Colorado, Site on March 16, 2016, in accordance with the 2010 *Rulison Monitoring Plan*. The Monitoring Plan provides guidance regarding the type and frequency of sample collection as a function of distance and heading from the Rulison detonation point; it also specifies the types of analyses. Natural gas and produced water samples are analyzed for radionuclides to determine if contamination is migrating from the Rulison detonation zone to producing gas wells. Samples were submitted for analysis as follows:

- Natural gas samples were submitted under requisition 16037678 to Isotech Laboratories in Champaign, Illinois, for the determination of carbon-14 and tritium.
- Produced water samples were submitted under requisition 16037698 to ALS Laboratory Group in Fort Collins, Colorado, for the determination of gross alpha/beta, gamma-emitting nuclides, and tritium.

Sampling and analyses were conducted as specified in the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PRO/S04351, continually updated). A duplicate sample of produced water was collected at location BM 26-33B (05-045-15739).

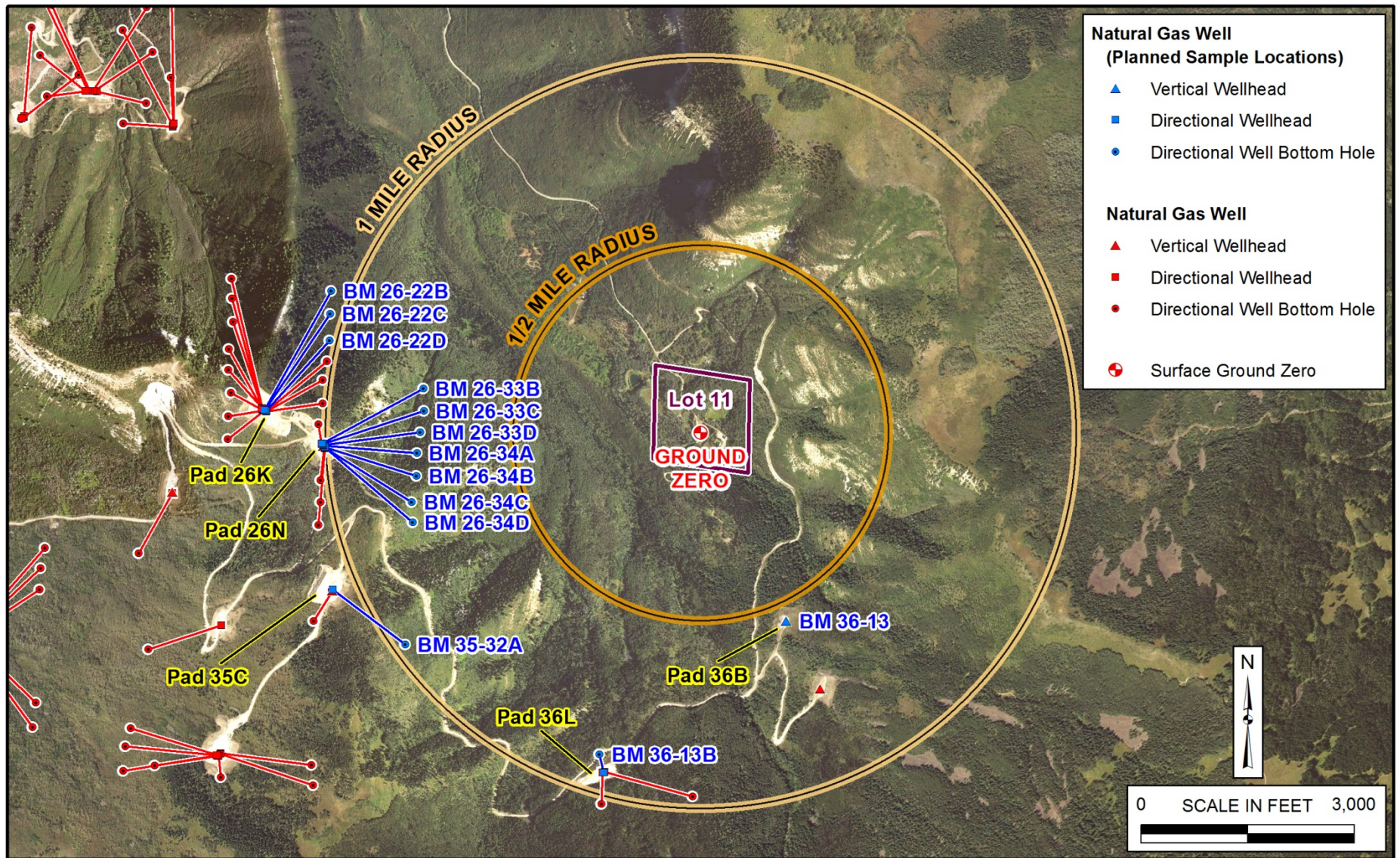
Sample radionuclide results for gamma-emitting nuclides and tritium are compared to the screening levels listed in the Monitoring Plan to determine if any further action is merited. Screening levels have not been determined for gross alpha and gross beta. None of the results for the 9 wells sampled during this event exceeded the screening levels specified in the Monitoring Plan. The natural gas and produced water sample results are presented in Attachment 1.



Rick Findlay, Site Lead
Navarro Research and Engineering, Inc.

10-6-2016

Date



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Rulison, Colorado, Site, Sample Location Map

Data Assessment Summary

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Water Sampling Field Activities Verification Checklist

Project	Rulison, Colorado	Date(s) of Water Sampling	March 16, 2016
Date(s) of Verification	May 26, 2016	Name of Verifier	Stephen Donovan

	Response (Yes, No, NA)	Comments
1. Is the SAP the primary document directing field procedures? List any Program Directives or other documents, SOPs, instructions.	Yes	Program Directive RUL-2015-01.
2. Were the sampling locations specified in the planning documents sampled?	No	The natural gas wells BM 26-34D, BM 26-22B, BM 36-13B, and BM 36-13 were not in production at the time of sampling.
3. Were field equipment calibrations conducted as specified in the above-named documents?	NA	Field measurements were not required.
4. Was an operational check of the field equipment conducted daily? Did the operational checks meet criteria?	NA	
5. Were the number and types (alkalinity, temperature, specific conductance, pH, turbidity, DO, ORP) of field measurements taken as specified?	NA	
6. Were wells categorized correctly?	NA	This sampling event did not include groundwater.
7. Were the following conditions met when purging a Category I well: Was one pump/tubing volume purged prior to sampling? Did the water level stabilize prior to sampling? Did pH, specific conductance, and turbidity measurements meet criteria prior to sampling? Was the flow rate less than 500 mL/min?	NA	This sampling event did not include groundwater.

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	This sampling event did not include groundwater.
Was one pump/tubing volume removed prior to sampling?		
9. Were duplicates taken at a frequency of one per 20 samples?	Yes	A duplicate sample of produced water was collected at location BM 26-33B (05-045-15739).
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?	NA	

Laboratory Performance Assessment

General Information

Requisition (RIN): 16037678
Sample Event: March 16, 2016
Site(s): Rulison, Colorado
Laboratory: Isotech Laboratories
Work Order No.: 31614
Analysis: Radiochemistry
Validator: Stephen Donovan
Review Date: May 26, 2016

This validation was performed according to the *Environmental Procedures Catalog*, (LMS/POL/S04325, continually updated) “Standard Practice for Validation of Environmental Data.” The procedure was applied at Level 1, Data Deliverables Examination. The data were examined to assess the completeness of the deliverables, identify any reporting errors, and assess the usability of the data based the laboratory’s evaluation of their data, as described in the narrative provided. The data are acceptable as received. The samples were prepared and analyzed using accepted procedures based on methods specified by line item code, which are listed in Table 1.

Table 1. Analytes and Methods

Analyte	Line Item Code	Prep Method	Analytical Method
Natural Gas Analysis	LMG-01	NA	Gas Chromatography
Carbon-14 and Tritium	LMG-03	Combustion	Liquid Scintillation Counting

Data Qualifier Summary

None of the analytical results required qualification.

Sample Shipping/Receiving

Isotech Laboratories received nine natural gas samples on March 22, 2016, 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. Copies of the shipping labels were included in the receiving documentation. The Chain of Custody form was complete with no errors or omissions.

Summary

Nine natural gas samples were received at Isotech Laboratories and analyzed by gas chromatography to determine the natural gas composition. The samples were then combusted with the resulting water collected for analysis. Carbon-14 and tritium were measured in the water

collected by liquid scintillation counting. There were no analytical difficulties noted by the laboratory.

Completeness

The results of the gas chromatography analysis were reported in volume percent showing the average sample composition of 90 percent methane.

The carbon-14 results were reported in percent modern carbon (pMC). The tritium results were reported in tritium units. Carbon-14 and tritium were not detected in any of the samples.

General Information

Requisition No. (RIN): 16037698
Sample Event: March 16, 2016
Site(s): Rulison Site
Laboratory: ALS Laboratory Group, Fort Collins, Colorado
Work Order No.: 1603341
Analysis: Radiochemistry
Validator: Stephen Donivan
Review Date: May 26, 2016

This validation was performed according to the *Environmental Procedures Catalog*, (LMS/POL/S04325, continually updated) “Standard Practice for Validation of Environmental Data.” The procedure was applied at Level 3, Data Validation. 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 2.

Table 2. Analytes and Methods

Analyte	Line Item Code	Prep Method	Analytical Method
Gamma Spectrometry	GAM-A-001	PA SOP713R11	PA SOP713R11
Gross Alpha/Beta	GPC-A-001	PA SOP702R19	PA SOP724R10
Tritium	LCS-A-001	PA SOP700R10	PA SOP704R9

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
1603341-1	BM 26-33B Duplicate	Actinium-228	U	Nuclide identification criteria
1603341-1	BM 26-33B Duplicate	Gross Alpha	J	Less than the determination limit
1603341-1	BM 26-33B Duplicate	Gross Beta	J	Less than the determination limit
1603341-2	BM 26-22C	Gross Beta	J	Less than the determination limit
1603341-3	BM 26-22D	Gross Alpha	J	Less than the determination limit
1603341-4	BM 26-33B	Actinium-228	U	Nuclide identification criteria
1603341-4	BM 26-33B	Gross Alpha	J	Less than the determination limit
1603341-4	BM 26-33B	Gross Beta	J	Less than the determination limit
1603341-5	BM 26-33C	Gross Beta	J	Less than the determination limit
1603341-6	BM 26-33D	Gross Beta	J	Less than the determination limit
1603341-7	BM 26-34A	Potassium-40	J	Less than the determination limit
1603341-7	BM 26-34A	Gross Alpha	J	Less than the determination limit

Table 3 (continued). Data Qualifier Summary

Sample Number	Location	Analyte	Flag	Reason
1603341-7	BM 26-34A	Gross Beta	J	Less than the determination limit
1603341-8	BM 26-34C	Gross Alpha	J	Less than the determination limit
1603341-9	BM 26-34B	Actinium-228	U	Nuclide identification criteria
1603341-9	BM 26-34B	Gross Alpha	J	Less than the determination limit
1603341-9	BM 26-34B	Gross Beta	J	Less than the determination limit
1603341-10	BM 35-32A	Yttrium-88	U	Nuclide identification criteria

Sample Shipping/Receiving

ALS Laboratory Group in Fort Collins, Colorado, received ten water samples on March 18, 2016, 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. Copies of the shipping labels were included in the receiving documentation. The Chain of Custody form was complete with no errors or omissions.

Preservation and Holding Times

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

Detection and Quantitation Limits

The method detection limit (MDL) was reported for all metal, organic, and wet chemical analytes as required. The MDL, as defined in 40 CFR 136, is the minimum concentration of an analyte that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero. The practical quantitation limit (PQL) for these analytes is the lowest concentration that can be reliably measured, and is defined as 5 times the MDL.

For radiochemical analytes (those measured by radiometric counting) the MDL and PQL are not applicable, and these 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 percent confidence that the analyte concentration is greater than zero, and is estimated as 3 times the one-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 met the detection limit requirements with the following exception. The required detection limits were not met for gross alpha and gross beta samples because of the elevated levels of dissolved solids in the samples.

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 verification 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 either one or both of the following criteria are not satisfied: one or more characteristic peaks for a nuclide must be identified above the critical level, 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 and Calibration Blanks

Method blanks are analyzed to assess any contamination that may have occurred during sample preparation. Calibration blanks are analyzed to assess instrument contamination prior to and during sample analysis. All radiochemical method blank results were below the Decision Level Concentration.

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.

Laboratory Replicate Analysis

Laboratory replicate sample results demonstrate acceptable laboratory precision. The relative percent difference value for the chloride matrix spike replicate met the acceptance criteria. The radiochemical relative error ratio (calculated using the one-sigma total propagated uncertainty) for the sample replicates was less than three for all duplicates.

Matrix Spike Analysis

Matrix spike and matrix spike duplicate (MS/MSD) samples are used to measure method performance in the sample matrix. The MS/MSD data are not evaluated when the concentration of the unspiked sample is greater than 5 times the spike concentration. The spike recoveries met the recovery and precision criteria for all analytes evaluated.

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 April 15, 2016. 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: 16037698 Lab Code: PAR Validator: Stephen Donovan Validation Date: 5/26/2016
Project: Rulison Site Analysis Type: ☐ Metals ☐ General Chem ☒ Rad ☐ Organics
of Samples: 10 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.

There was 1 duplicate evaluated.

SAMPLE MANAGEMENT SYSTEM

Radiochemistry Data Validation Worksheet

Page 1 of 2

RIN: 16037698 **Lab Code:** PAR **Date Due:** 4/15/2016
Matrix: Water **Site Code:** RUL01 **Date Completed:** 4/15/2016

Sample	Analyte	Date Analyzed	Result	Flag	Tracer %R	LCS %R	MS %R	Duplicate RER
BM 26-33B	Actinium-228	04/02/2016						0.20
BM 26-33B	Americium-241	04/02/2016						0.19
Blank_Spike	Americium-241	04/02/2016				103.00		
BM 26-33B	Antimony-125	04/02/2016						0.41
BM 26-33B	Cerium-144	04/02/2016						1.50
BM 26-33B	Cesium-134	04/02/2016						0.32
BM 26-33B	Cesium-137	04/02/2016						0.60
Blank_Spike	Cesium-137	04/02/2016				101.00		
Blank_Spike	Cobalt-60	04/02/2016				98.40		
BM 26-33B	Cobalt-60	04/02/2016						1.51
BM 26-33B	Europium-152	04/02/2016						1.95
BM 26-33B	Europium-154	04/02/2016						0.77
BM 26-33B	Europium-155	04/02/2016						0.70
Blank_Spike	GROSS ALPHA	04/07/2016				96.80		
BM 26-33C	GROSS ALPHA	04/07/2016						1.69
Blank	GROSS ALPHA	04/07/2016	0.1270	U				
BM 26-22C	GROSS ALPHA	04/07/2016					104.0	
Blank	GROSS BETA	04/07/2016	-0.0950	U				
BM 26-22C	GROSS BETA	04/07/2016					94.2	
Blank_Spike	GROSS BETA	04/07/2016				96.10		
BM 26-33C	GROSS BETA	04/07/2016						0.93
BM 26-34A	H-3	04/02/2016					87.7	
BM 26-33B	H-3	04/02/2016						0.48
Blank	H-3	04/04/2016	31.0000	U				
Blank_Spike	H-3	04/04/2016				107.00		
BM 26-33B	Lead-212	04/02/2016						0.62
BM 26-33B	Potassium-40	04/02/2016						0.51
BM 26-33B	Promethium-144	04/02/2016						0.50
BM 26-33B	Promethium-146	04/02/2016						0.16
BM 26-33B	Ruthenium-106	04/02/2016						0.21
BM 26-33B	Thorium-234	04/02/2016						0.47
BM 26-33B	Uranium-235	04/02/2016						1.79

SAMPLE MANAGEMENT SYSTEM
Radiochemistry Data Validation Worksheet

Page 2 of 2

RIN: 16037698 **Lab Code:** PAR **Date Due:** 4/15/2016
Matrix: Water **Site Code:** RUL01 **Date Completed:** 4/15/2016

Sample	Analyte	Date Analyzed	Result	Flag	Tracer %R	LCS %R	MS %R	Duplicate RER
BM 26-33B	Yttrium-88	04/02/2016						2.22

Sampling Quality Control Assessment

The following information summarizes and assesses quality control for this sampling event.

Sampling Protocol

The produced-water samples were collected from a tap on a common line connecting the output of two separators (each servicing a well) and the nearby accumulation tanks. The collected water sample from one separator was isolated from the other separator by valves. Lines from each of the two separators were purged before sample collection.

Natural gas samples were collected as specified in Program Directive RUL-2015-01 in an evacuated 17.8-liter gas cylinder provided by Isotech Laboratories, Inc. Each sampling container was filled to approximately 25 pounds per square inch with natural gas from each well.

Equipment Blank Assessment

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

Field Duplicate Assessment

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 BM 26-33B. 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

Page 1 of 1

RIN: 16037698 Lab Code: PAR Project: Rulison Site Validation Date: 5/26/2016

Duplicate: 2657

Sample: BM 26-33B

Analyte	Sample				Duplicate				RPD	RER	Units
	Result	Flag	Error	Dilution	Result	Flag	Error	Dilution			
Actinium-228	27.7		13.7	1	28.4		12.4	1		0.1	pCi/L
Americium-241	34.7	U	82.2	1	-69.6	U	66.1	1		1.9	pCi/L
Antimony-125	7.48	U	5.97	1	7.8	U	5.85	1		0.1	pCi/L
Cerium-144	-14.3	U	14.5	1	5.34	U	15.8	1		1.8	pCi/L
Cesium-134	-1.79	U	2.57	1	-3.34	U	2.87	1		0.8	pCi/L
Cesium-137	-2.58	U	2.39	1	-0.504	U	2.56	1		1.2	pCi/L
Cobalt-60	0.669	U	2.44	1	-2.02	U	2.8	1		1.4	pCi/L
Europium-152	-8.28	U	11.3	1	-3.67	U	13	1		0.5	pCi/L
Europium-154	-7.76	U	12.6	1	-7.15	U	20.4	1		0	pCi/L
Europium-155	6.39	U	10.2	1	2.04	U	10.2	1		0.6	pCi/L
GROSS ALPHA	64.9		40.1	1	63		39.8	1		0.1	pCi/L
GROSS BETA	124		48.9	1	117		47.3	1		0.2	pCi/L
H-3	-28.4	U	190	1	-62.4	U	188	1		0.2	pCi/L
Lead-212	5.75	U	7.94	1	7.51	U	8.28	1		0.3	pCi/L
Potassium-40	31.4	U	79.6	1	61.1	U	74.4	1		0.5	pCi/L
Promethium-144	0.276	U	2.67	1	1.78	U	2.69	1		0.8	pCi/L
Promethium-146	-1.46	U	2.88	1	0.563	U	2.98	1		1.0	pCi/L
Ruthenium-106	-2.36	U	21.6	1	-2.12	U	24.8	1		0	pCi/L
Thorium-234	18	U	141	1	40.7	U	133	1		0.2	pCi/L
Uranium-235	-21.2	U	33.4	1	7.18	U	15.1	1		1.5	pCi/L
Yttrium-88	-3.61	U	5.44	1	0.142	U	8.86	1		0.7	pCi/L

Certification

All laboratory analytical quality control criteria were met except as qualified in this report. The data qualifiers listed on the environmental database reports are defined on the last page of each report. All data in this package are considered validated and available for use.

Laboratory Coordinator:  7-26-2016
Stephen Donovan Date

Data Validation Lead:  7-26-2016
Stephen Donovan Date

Attachment 1

Data Presentation

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Produced Water Data

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General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-10919 WELL BM 35-32A

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Actinium-228	pCi/L	03/16/2016	N001	14.1	U		#	18	10.4
Americium-241	pCi/L	03/16/2016	N001	22.5	U		#	140	82.5
Antimony-125	pCi/L	03/16/2016	N001	-3.37	U		#	11	6
Cerium-144	pCi/L	03/16/2016	N001	6.03	U		#	24	14.7
Cesium-134	pCi/L	03/16/2016	N001	-4.08	U		#	4.4	2.54
Cesium-137	pCi/L	03/16/2016	N001	-0.046	U		#	4	2.33
Cobalt-60	pCi/L	03/16/2016	N001	0.602	U		#	4.2	2.49
Europium-152	pCi/L	03/16/2016	N001	5.63	U		#	20	11.9
Europium-154	pCi/L	03/16/2016	N001	-1.79	U		#	22	13
Europium-155	pCi/L	03/16/2016	N001	1.98	U		#	17	10.2
Gross Alpha	pCi/L	03/16/2016	N001	11.5	U		#	57	33.8
Gross Beta	pCi/L	03/16/2016	N001	137			#	68	48.3
Lead-212	pCi/L	03/16/2016	N001	2.94	U		#	13	8.14
Potassium-40	pCi/L	03/16/2016	N001	76.1	U		#	130	79.9
Promethium-144	pCi/L	03/16/2016	N001	1.36	U		#	4.4	2.67
Promethium-146	pCi/L	03/16/2016	N001	-2.21	U		#	4.9	2.88
Ruthenium-106	pCi/L	03/16/2016	N001	-16.2	U		#	38	22.1
Thorium-234	pCi/L	03/16/2016	N001	9.99	U		#	230	141

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site
REPORT DATE: 7/5/2016
Location: 05-045-10919 WELL BM 35-32A

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Tritium	pCi/L	03/16/2016	N001	12.7	U		#	320	193
Uranium-235	pCi/L	03/16/2016	N001	-12.6	U		#	56	33.6
Yttrium-88	pCi/L	03/16/2016	N001	5.01		U	#	4.6	2.95

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-15739 WELL BM 26-33D

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Actinium-228	pCi/L	03/16/2016	N001	27.4	U		#	32	13.9
Americium-241	pCi/L	03/16/2016	N001	2.29	U		#	26	15.7
Antimony-125	pCi/L	03/16/2016	N001	-2.61	U		#	10	6.04
Cerium-144	pCi/L	03/16/2016	N001	0.682	U		#	18	10.6
Cesium-134	pCi/L	03/16/2016	N001	-1.09	U		#	4.4	2.55
Cesium-137	pCi/L	03/16/2016	N001	-1.18	U		#	4.6	2.66
Cobalt-60	pCi/L	03/16/2016	N001	0.46	U		#	5.2	3.06
Europium-152	pCi/L	03/16/2016	N001	-0.38	U		#	27	15.9
Europium-154	pCi/L	03/16/2016	N001	-6.28	U		#	27	15.7
Europium-155	pCi/L	03/16/2016	N001	0.925	U		#	10	6.23
Gross Alpha	pCi/L	03/16/2016	N001	45.2	U		#	50	32.6
Gross Beta	pCi/L	03/16/2016	N001	130		J	#	71	49.4
Lead-212	pCi/L	03/16/2016	N001	-0.0945	U		#	11	6.72
Potassium-40	pCi/L	03/16/2016	N001	60.2	U		#	120	73.9
Promethium-144	pCi/L	03/16/2016	N001	-1.76	U		#	4.7	2.75
Promethium-146	pCi/L	03/16/2016	N001	-1.46	U		#	4.8	2.81
Ruthenium-106	pCi/L	03/16/2016	N001	-10.1	U		#	42	24.8
Thorium-234	pCi/L	03/16/2016	N001	-10	U		#	130	78.1

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site
REPORT DATE: 7/5/2016
Location: 05-045-15739 WELL BM 26-33D

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Tritium	pCi/L	03/16/2016	N001	-81	U		#	320	190
Uranium-235	pCi/L	03/16/2016	N001	-3.06	U		#	29	17.3
Yttrium-88	pCi/L	03/16/2016	N001	1.32	U		#	9.8	5.88

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-15741 WELL BM 26-34C

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Actinium-228	pCi/L	03/16/2016	N001	32.1	U		#	33	20.6
Americium-241	pCi/L	03/16/2016	N001	2.36	U		#	5	3.05
Antimony-125	pCi/L	03/16/2016	N001	2.62	U		#	9.7	5.08
Cerium-144	pCi/L	03/16/2016	N001	0.377	U		#	15	9.09
Cesium-134	pCi/L	03/16/2016	N001	-0.359	U		#	4.3	2.53
Cesium-137	pCi/L	03/16/2016	N001	-1.16	U		#	4.4	2.52
Cobalt-60	pCi/L	03/16/2016	N001	-1.82	U		#	5.2	2.88
Europium-152	pCi/L	03/16/2016	N001	-5.42	U		#	27	15.1
Europium-154	pCi/L	03/16/2016	N001	1.16	U		#	26	15
Europium-155	pCi/L	03/16/2016	N001	0.996	U		#	7.2	4.32
Gross Alpha	pCi/L	03/16/2016	N001	62.1		J	#	54	36.8
Gross Beta	pCi/L	03/16/2016	N001	46.8	U		#	72	44.4
Lead-212	pCi/L	03/16/2016	N001	2.42	U		#	12	7.5
Potassium-40	pCi/L	03/16/2016	N001	41.8	U		#	120	74.7
Promethium-144	pCi/L	03/16/2016	N001	0.467	U		#	4.8	2.88
Promethium-146	pCi/L	03/16/2016	N001	-2.46	U		#	8.1	4.77
Ruthenium-106	pCi/L	03/16/2016	N001	9.15	U		#	80	48.1
Thorium-234	pCi/L	03/16/2016	N001	-14.7	U		#	78	46.9

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site
REPORT DATE: 7/5/2016
Location: 05-045-15741 WELL BM 26-34C

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Tritium	pCi/L	03/16/2016	N001	-196	U		#	320	188
Uranium-235	pCi/L	03/16/2016	N001	7.01	U		#	26	11.8
Yttrium-88	pCi/L	03/16/2016	N001	-3.9	U		#	11	6.28

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-15742 WELL BM 26-33C

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Actinium-228	pCi/L	03/16/2016	N001	20.8	U		#	25	13.7
Americium-241	pCi/L	03/16/2016	N001	-4.81	U		#	26	15.6
Antimony-125	pCi/L	03/16/2016	N001	3.51	U		#	11	5.7
Cerium-144	pCi/L	03/16/2016	N001	-8.97	U		#	22	13.2
Cesium-134	pCi/L	03/16/2016	N001	-5.77	U		#	5.2	2.98
Cesium-137	pCi/L	03/16/2016	N001	-2.25	U		#	5.2	2.98
Cobalt-60	pCi/L	03/16/2016	N001	0.381	U		#	5.6	3.31
Europium-152	pCi/L	03/16/2016	N001	-5.93	U		#	29	16.5
Europium-154	pCi/L	03/16/2016	N001	-8.51	U		#	27	15.8
Europium-155	pCi/L	03/16/2016	N001	-0.322	U		#	12	7.49
Gross Alpha	pCi/L	03/16/2016	N001	0.252	U		#	73	42.5
Gross Beta	pCi/L	03/16/2016	N001	112		J	#	73	49.2
Lead-212	pCi/L	03/16/2016	N001	4.19	U		#	13	7.94
Potassium-40	pCi/L	03/16/2016	N001	115	U		#	130	79.5
Promethium-144	pCi/L	03/16/2016	N001	3.98	U		#	4.8	3.02
Promethium-146	pCi/L	03/16/2016	N001	1.62	U		#	4.9	2.94
Ruthenium-106	pCi/L	03/16/2016	N001	-4.56	U		#	46	27.3
Thorium-234	pCi/L	03/16/2016	N001	-2.63	U		#	130	79.2

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site
REPORT DATE: 7/5/2016
Location: 05-045-15742 WELL BM 26-33C

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Tritium	pCi/L	03/16/2016	N001	-56.5	U		#	320	186
Uranium-235	pCi/L	03/16/2016	N001	14.5	U		#	20	12.4
Yttrium-88	pCi/L	03/16/2016	N001	1.45	U		#	12	7.15

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site
REPORT DATE: 7/5/2016
Location: 05-045-15743 WELL BM 26-33B

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Actinium-228	pCi/L	03/16/2016	N001	27.7		U	#	25	13.7
Actinium-228	pCi/L	03/16/2016	N002	28.4		U	#	22	12.4
Americium-241	pCi/L	03/16/2016	N001	34.7	U		#	140	82.2
Americium-241	pCi/L	03/16/2016	N002	-69.6	U		#	110	66.1
Antimony-125	pCi/L	03/16/2016	N001	7.48	U		#	10	5.97
Antimony-125	pCi/L	03/16/2016	N002	7.8	U		#	11	5.85
Cerium-144	pCi/L	03/16/2016	N001	-14.3	U		#	25	14.5
Cerium-144	pCi/L	03/16/2016	N002	5.34	U		#	26	15.8
Cesium-134	pCi/L	03/16/2016	N001	-1.79	U		#	4.4	2.57
Cesium-134	pCi/L	03/16/2016	N002	-3.34	U		#	4.9	2.87
Cesium-137	pCi/L	03/16/2016	N001	-2.58	U		#	4.2	2.39
Cesium-137	pCi/L	03/16/2016	N002	-0.504	U		#	4.4	2.56
Cobalt-60	pCi/L	03/16/2016	N001	0.669	U		#	4.1	2.44
Cobalt-60	pCi/L	03/16/2016	N002	-2.02	U		#	4.9	2.8
Europium-152	pCi/L	03/16/2016	N001	-8.28	U		#	20	11.3
Europium-152	pCi/L	03/16/2016	N002	-3.67	U		#	23	13
Europium-154	pCi/L	03/16/2016	N001	-7.76	U		#	22	12.6
Europium-154	pCi/L	03/16/2016	N002	-7.15	U		#	35	20.4

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-15743 WELL BM 26-33B

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Europium-155	pCi/L	03/16/2016	N001	6.39	U		#	17	10.2
Europium-155	pCi/L	03/16/2016	N002	2.04	U		#	17	10.2
Gross Alpha	pCi/L	03/16/2016	N001	64.9		J	#	60	40.1
Gross Alpha	pCi/L	03/16/2016	N002	63		J	#	60	39.8
Gross Beta	pCi/L	03/16/2016	N001	124		J	#	71	48.9
Gross Beta	pCi/L	03/16/2016	N002	117		J	#	69	47.3
Lead-212	pCi/L	03/16/2016	N001	5.75	U		#	13	7.94
Lead-212	pCi/L	03/16/2016	N002	7.51	U		#	14	8.28
Potassium-40	pCi/L	03/16/2016	N001	31.4	U		#	130	79.6
Potassium-40	pCi/L	03/16/2016	N002	61.1	U		#	120	74.4
Promethium-144	pCi/L	03/16/2016	N001	0.276	U		#	4.5	2.67
Promethium-144	pCi/L	03/16/2016	N002	1.78	U		#	4.4	2.69
Promethium-146	pCi/L	03/16/2016	N001	-1.46	U		#	4.9	2.88
Promethium-146	pCi/L	03/16/2016	N002	0.563	U		#	5	2.98
Ruthenium-106	pCi/L	03/16/2016	N001	-2.36	U		#	37	21.6
Ruthenium-106	pCi/L	03/16/2016	N002	-2.12	U		#	42	24.8
Thorium-234	pCi/L	03/16/2016	N001	18	U		#	230	141
Thorium-234	pCi/L	03/16/2016	N002	40.7	U		#	220	133

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site
REPORT DATE: 7/5/2016
Location: 05-045-15743 WELL BM 26-33B

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Tritium	pCi/L	03/16/2016	N001	-28.4	U		#	320	190
Tritium	pCi/L	03/16/2016	N002	-62.4	U		#	320	188
Uranium-235	pCi/L	03/16/2016	N001	-21.2	U		#	56	33.4
Uranium-235	pCi/L	03/16/2016	N002	7.18	U		#	25	15.1
Yttrium-88	pCi/L	03/16/2016	N001	-3.61	U		#	9.2	5.44
Yttrium-88	pCi/L	03/16/2016	N002	0.142	U		#	15	8.86

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-15744 WELL BM 26-34A

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Actinium-228	pCi/L	03/16/2016	N001	27.4	U		#	29	13.7
Americium-241	pCi/L	03/16/2016	N001	0.246	U		#	4.1	2.45
Antimony-125	pCi/L	03/16/2016	N001	4.96	U		#	13	6.1
Cerium-144	pCi/L	03/16/2016	N001	-3.86	U		#	14	8.22
Cesium-134	pCi/L	03/16/2016	N001	0.56	U		#	3.5	1.54
Cesium-137	pCi/L	03/16/2016	N001	-0.524	U		#	3.7	2.16
Cobalt-60	pCi/L	03/16/2016	N001	0.272	U		#	4.2	2.46
Europium-152	pCi/L	03/16/2016	N001	-4.4	U		#	21	12.1
Europium-154	pCi/L	03/16/2016	N001	0.887	U		#	21	12.3
Europium-155	pCi/L	03/16/2016	N001	0.846	U		#	6.7	4.02
Gross Alpha	pCi/L	03/16/2016	N001	61.2		J	#	55	36.9
Gross Beta	pCi/L	03/16/2016	N001	200		J	#	70	55.3
Lead-212	pCi/L	03/16/2016	N001	5.17	U		#	10	6.35
Potassium-40	pCi/L	03/16/2016	N001	116		J	#	100	66.6
Promethium-144	pCi/L	03/16/2016	N001	1.54	U		#	3.7	2.26
Promethium-146	pCi/L	03/16/2016	N001	-1.92	U		#	4.2	2.44
Ruthenium-106	pCi/L	03/16/2016	N001	-20.7	U		#	36	20.7
Thorium-234	pCi/L	03/16/2016	N001	37.8	U		#	69	42.4

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site
REPORT DATE: 7/5/2016
Location: 05-045-15744 WELL BM 26-34A

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Tritium	pCi/L	03/16/2016	N001	-157	U		#	320	188
Uranium-235	pCi/L	03/16/2016	N001	6.13	U		#	14	7.85
Yttrium-88	pCi/L	03/16/2016	N001	-0.671	U		#	4.2	2.45

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-15745 WELL BM 26-34B

Parameter	Units	Sample Date	ID	Result	Qualifiers Lab	Data	QA	Detection Limit	Uncertainty
Actinium-228	pCi/L	03/16/2016	N001	32.8		U	#	26	11.4
Americium-241	pCi/L	03/16/2016	N001	-4.8	U		#	34	20.3
Antimony-125	pCi/L	03/16/2016	N001	5.94	U		#	13	7.47
Cerium-144	pCi/L	03/16/2016	N001	-7.6	U		#	26	15.4
Cesium-134	pCi/L	03/16/2016	N001	-1.24	U		#	10	5.92
Cesium-137	pCi/L	03/16/2016	N001	-1.61	U		#	6.6	3.86
Cobalt-60	pCi/L	03/16/2016	N001	-4.03	U		#	9.1	5.2
Europium-152	pCi/L	03/16/2016	N001	-9.16	U		#	42	24.4
Europium-154	pCi/L	03/16/2016	N001	-1.65	U		#	39	22.6
Europium-155	pCi/L	03/16/2016	N001	4.24	U		#	12	7.56
Gross Alpha	pCi/L	03/16/2016	N001	61.9		J	#	60	39.7
Gross Beta	pCi/L	03/16/2016	N001	93.2		J	#	71	46.6
Lead-212	pCi/L	03/16/2016	N001	2.48	U		#	13	7.79
Potassium-40	pCi/L	03/16/2016	N001	40.3	U		#	200	118
Promethium-144	pCi/L	03/16/2016	N001	4.98	U		#	6.5	4.08
Promethium-146	pCi/L	03/16/2016	N001	-1.62	U		#	6.9	4.04
Ruthenium-106	pCi/L	03/16/2016	N001	17.2	U		#	56	34
Thorium-234	pCi/L	03/16/2016	N001	-36	U		#	150	88.6

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site
REPORT DATE: 7/5/2016
Location: 05-045-15745 WELL BM 26-34B

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Tritium	pCi/L	03/16/2016	N001	130	U		#	330	198
Uranium-235	pCi/L	03/16/2016	N001	-9.5	U		#	40	23.8
Yttrium-88	pCi/L	03/16/2016	N001	2.72	U		#	7.9	4.77

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-16074 WELL BM 26-22D

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Actinium-228	pCi/L	03/16/2016	N001	27.1	U		#	33	13.9
Americium-241	pCi/L	03/16/2016	N001	-3.84	U		#	34	20.5
Antimony-125	pCi/L	03/16/2016	N001	7.64	U		#	13	7.63
Cerium-144	pCi/L	03/16/2016	N001	-4.82	U		#	26	15.6
Cesium-134	pCi/L	03/16/2016	N001	2.24	U		#	4.4	2.43
Cesium-137	pCi/L	03/16/2016	N001	-4.18	U		#	6.9	3.94
Cobalt-60	pCi/L	03/16/2016	N001	3.02	U		#	8.6	5.16
Europium-152	pCi/L	03/16/2016	N001	-2.07	U		#	42	24.2
Europium-154	pCi/L	03/16/2016	N001	2.29	U		#	41	24.1
Europium-155	pCi/L	03/16/2016	N001	-0.675	U		#	13	7.8
Gross Alpha	pCi/L	03/16/2016	N001	81.7		J	#	71	47.5
Gross Beta	pCi/L	03/16/2016	N001	232			#	75	61
Lead-212	pCi/L	03/16/2016	N001	0.764	U		#	13	7.74
Potassium-40	pCi/L	03/16/2016	N001	169	U		#	200	125
Promethium-144	pCi/L	03/16/2016	N001	0.409	U		#	6.8	4
Promethium-146	pCi/L	03/16/2016	N001	-3.86	U		#	7.3	4.26
Ruthenium-106	pCi/L	03/16/2016	N001	-20.5	U		#	61	35.6
Thorium-234	pCi/L	03/16/2016	N001	-7.36	U		#	150	88.2

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site
REPORT DATE: 7/5/2016
Location: 05-045-16074 WELL BM 26-22D

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Tritium	pCi/L	03/16/2016	N001	-32.8	U		#	320	192
Uranium-235	pCi/L	03/16/2016	N001	13.5	U		#	25	13.8
Yttrium-88	pCi/L	03/16/2016	N001	2.55	U		#	8.2	4.95

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-16087 WELL BM 26-22C

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Actinium-228	pCi/L	03/16/2016	N001	22.2	U		#	23	12.7
Americium-241	pCi/L	03/16/2016	N001	-7.23	U		#	33	19.4
Antimony-125	pCi/L	03/16/2016	N001	-5.28	U		#	12	6.7
Cerium-144	pCi/L	03/16/2016	N001	-15.8	U		#	22	12.9
Cesium-134	pCi/L	03/16/2016	N001	-2.51	U		#	5.2	2.99
Cesium-137	pCi/L	03/16/2016	N001	0.0575	U		#	5	2.97
Cobalt-60	pCi/L	03/16/2016	N001	-1.01	U		#	5.5	3.15
Europium-152	pCi/L	03/16/2016	N001	0.748	U		#	27	15.8
Europium-154	pCi/L	03/16/2016	N001	-10.7	U		#	28	15.9
Europium-155	pCi/L	03/16/2016	N001	-3.97	U		#	23	13.8
Gross Alpha	pCi/L	03/16/2016	N001	47.8	U		#	56	36
Gross Beta	pCi/L	03/16/2016	N001	180		J	#	71	54
Lead-212	pCi/L	03/16/2016	N001	3.37	U		#	15	9.16
Potassium-40	pCi/L	03/16/2016	N001	117	U		#	140	85.2
Promethium-144	pCi/L	03/16/2016	N001	3.08	U		#	5.1	3.13
Promethium-146	pCi/L	03/16/2016	N001	3.4	U		#	5.4	3.36
Ruthenium-106	pCi/L	03/16/2016	N001	-9.79	U		#	46	26.7
Thorium-234	pCi/L	03/16/2016	N001	17.4	U		#	150	92.7

General Water Quality Data by Location (USEE105) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-16087 WELL BM 26-22C

Parameter	Units	Sample Date	ID	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Tritium	pCi/L	03/16/2016	N001	16.1	U		#	320	187
Uranium-235	pCi/L	03/16/2016	N001	9.74	U		#	20	12.5
Yttrium-88	pCi/L	03/16/2016	N001	3.65	U		#	5.6	3.49

SAMPLE ID CODES: 000X = Filtered sample (0.45 µm). N00X = Unfiltered sample. X = replicate number.

LAB QUALIFIERS:

- * Replicate analysis not within control limits.
- > Result above upper detection limit.
- A TIC is a suspected aldol-condensation product.
- B Inorganic: Result is between the IDL and CRDL. Organic: Analyte also found in method blank.
- C Pesticide result confirmed by GC-MS.
- D Analyte determined in diluted sample.
- E Inorganic: Estimate value because of interference, see case narrative. Organic: Analyte exceeded calibration range of the GC-MS.
- H Holding time expired, value suspect.
- I Increased detection limit due to required dilution.
- J Estimated
- N Inorganic or radiochemical: Spike sample recovery not within control limits. Organic: Tentatively identified compound (TIC).
- P > 25% difference in detected pesticide or Aroclor concentrations between 2 columns.
- U Analytical result below detection limit.
- W Post-digestion spike outside control limits while sample absorbance < 50% of analytical spike absorbance.
- X,Y,Z Laboratory defined qualifier, see case narrative.

DATA QUALIFIERS:

- F Low flow sampling method used.
- L Less than 3 bore volumes purged prior to sampling.
- U Parameter analyzed for but was not detected.
- G Possible grout contamination, pH > 9.
- Q Qualitative result due to sampling technique.
- X Location is undefined.
- J Estimated value.
- R Unusable result.

QA QUALIFIER:

#Validated according to quality assurance guidelines.

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Natural Gas Data

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Gas Matrix Chemistry Data by Location (USEE510) FOR SITE RUL01, Rulison Site**REPORT DATE: 9/29/2016****Location: 05-045-10919 WELL, Natural Gas Well - Angle, BM 35-32A**

Parameter	Units	Sample Date	Sample ID	Ticket Number	Elev. Range (Ft)			Matrix Subtype	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Carbon-14	pMC	03/16/2016	0001	OEY 307	9236	-	9236	NATURAL GAS	0.4	U		#	0.4	
Tritium	pCi/L	03/16/2016	0001	OEY 307	9236	-	9236	NATURAL GAS	0.0514	U		#	0.0514	

Gas Matrix Chemistry Data by Location (USEE510) FOR SITE RUL01, Rulison Site**REPORT DATE: 7/5/2016****Location: 05-045-15739 WELL, Natural Gas Well - Angle, BM 26-33D**

Parameter	Units	Sample Date	Sample ID	Ticket Number	Elev. Range (Ft)			Matrix Subtype	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Carbon-14	pMC	03/16/2016	0001	OEY 300	8963.5	-	8963.5	NATURAL GAS	0.4	U		#	0.4	
Tritium	pCi/L	03/16/2016	0001	OEY 300	8963.5	-	8963.5	NATURAL GAS	0.0514	U		#	0.0514	

Gas Matrix Chemistry Data by Location (USEE510) FOR SITE RUL01, Rulison Site**REPORT DATE: 7/5/2016****Location: 05-045-15741 WELL, Natural Gas Well - Angle, BM 26-34C**

Parameter	Units	Sample Date	Sample ID	Ticket Number	Elev. Range (Ft)		Matrix Subtype	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Carbon-14	pMC	03/16/2016	0001	OEY 303	8963.5	-	8963.5	NATURAL GAS	0.4	U		#	0.4
Tritium	pCi/L	03/16/2016	0001	OEY 303	8963.5	-	8963.5	NATURAL GAS	0.0514	U		#	0.0514

Gas Matrix Chemistry Data by Location (USEE510) FOR SITE RUL01, Rulison Site**REPORT DATE: 7/5/2016****Location: 05-045-15742 WELL, Natural Gas Well - Angle, BM 26-33C**

Parameter	Units	Sample Date	Sample ID	Ticket Number	Elev. Range (Ft)			Matrix Subtype	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Carbon-14	pMC	03/16/2016	0001	OEY 299	8963.5	-	8963.5	NATURAL GAS	0.4	U		#	0.4	
Tritium	pCi/L	03/16/2016	0001	OEY 299	8963.5	-	8963.5	NATURAL GAS	0.0514	U		#	0.0514	

Gas Matrix Chemistry Data by Location (USEE510) FOR SITE RUL01, Rulison Site**REPORT DATE: 7/5/2016****Location: 05-045-15743 WELL, Natural Gas Well - Angle, BM 26-33B**

Parameter	Units	Sample Date	Sample ID	Ticket Number	Elev. Range (Ft)			Matrix Subtype	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Carbon-14	pMC	03/16/2016	0001	OEY 298	8963.5	-	8963.5	NATURAL GAS	0.4	U		#	0.4	
Tritium	pCi/L	03/16/2016	0001	OEY 298	8963.5	-	8963.5	NATURAL GAS	0.0514	U		#	0.0514	

Gas Matrix Chemistry Data by Location (USEE510) FOR SITE RUL01, Rulison Site**REPORT DATE: 7/5/2016****Location: 05-045-15744 WELL, Natural Gas Well - Angle, BM 26-34A**

Parameter	Units	Sample Date	Sample ID	Ticket Number	Elev. Range (Ft)			Matrix Subtype	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Carbon-14	pMC	03/16/2016	0001	OEY 301	8963.5	-	8963.5	NATURAL GAS	0.4	U		#	0.4	
Tritium	pCi/L	03/16/2016	0001	OEY 301	8963.5	-	8963.5	NATURAL GAS	0.0514	U		#	0.0514	

Gas Matrix Chemistry Data by Location (USEE510) FOR SITE RUL01, Rulison Site**REPORT DATE: 7/5/2016****Location: 05-045-15745 WELL, Natural Gas Well - Angle, BM 26-34B**

Parameter	Units	Sample Date	Sample ID	Ticket Number	Elev. Range (Ft)		Matrix Subtype	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Carbon-14	pMC	03/16/2016	0001	OEY 302	8963.5	- 8963.5	NATURAL GAS	0.4	U		#	0.4	
Tritium	pCi/L	03/16/2016	0001	OEY 302	8963.5	- 8963.5	NATURAL GAS	0.0514	U		#	0.0514	

Gas Matrix Chemistry Data by Location (USEE510) FOR SITE RUL01, Rulison Site**REPORT DATE: 7/5/2016****Location: 05-045-16074 WELL, Natural Gas Well - Angle, BM 26-22D**

Parameter	Units	Sample Date	Sample ID	Ticket Number	Elev. Range (Ft)			Matrix Subtype	Result	Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Carbon-14	pMC	03/16/2016	0001	OEY 306	8983.5	-	8983.5	NATURAL GAS	0.4	U		#	0.4	
Tritium	pCi/L	03/16/2016	0001	OEY 306	8983.5	-	8983.5	NATURAL GAS	0.0514	U		#	0.0514	

Gas Matrix Chemistry Data by Location (USEE510) FOR SITE RUL01, Rulison Site

REPORT DATE: 7/5/2016

Location: 05-045-16087 WELL, Natural Gas Well - Angle, BM 26-22C

Parameter	Units	Sample Date	Sample ID	Ticket Number	Elev. Range (Ft)	Matrix Subtype	Result	Qualifiers Lab	Qualifiers Data	QA	Detection Limit	Uncertainty
Carbon-14	pMC	03/16/2016	0001	OEY 310	8983.5 - 8983.5	NATURAL GAS	0.4	U		#	0.4	
Tritium	pCi/L	03/16/2016	0001	OEY 310	8983.5 - 8983.5	NATURAL GAS	0.0514	U		#	0.0514	

SAMPLE ID CODES: 000X = Filtered sample (0.45 µm). N00X = Unfiltered sample. X = replicate number.

LAB QUALIFIERS:

* Replicate analysis not within control limits.
 > Result above upper detection limit.
 A TIC is a suspected aldol-condensation product.
 B Inorganic: Result is between the IDL and CRDL. Organic: Analyte also found in method blank.
 C Pesticide result confirmed by GC-MS.
 D Analyte determined in diluted sample.
 E Inorganic: Estimate value because of interference, see case narrative. Organic: Analyte exceeded calibration range of the GC-MS.
 H Holding time expired, value suspect.
 I Increased detection limit due to required dilution.
 J Estimated
 N Inorganic or radiochemical: Spike sample recovery not within control limits. Organic: Tentatively identified compound (TIC).
 P > 25% difference in detected pesticide or Aroclor concentrations between 2 columns.
 U Analytical result below detection limit.
 W Post-digestion spike outside control limits while sample absorbance < 50% of analytical spike absorbance.
 X,Y,Z Laboratory defined qualifier, see case narrative.

DATA QUALIFIERS:

F Low flow sampling method used. G Possible grout contamination, pH > 9. J Estimated value.
 L Less than 3 bore volumes purged prior to sampling. Q Qualitative result due to sampling technique. R Unusable result.
 U Parameter analyzed for but was not detected. X Location is undefined.

QA QUALIFIER:

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Attachment 2

Trip Report

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Trip Report
Natural Gas Wells near Project Rulison
Semi-Annual, March 2016

U.S. Department of Energy Office of Legacy Management
Grand Junction, Colorado

Date Sampled

March 16, 2016

Background

Project Rulison was the second Plowshare Program test to investigate using a nuclear detonation to stimulate natural gas recovery from deep, low-permeability formations. On September 10, 1969, a 40-kiloton-yield nuclear device was detonated 8,426 feet (1.6 miles) below ground surface in the Williams Fork Formation, at what is now the Rulison, Colorado, Site. A series of production tests followed the detonation, and the site was subsequently shut down, the emplacement well (R-E) and reentry well (R-Ex) were plugged, and the surface soils were remediated.

Purpose

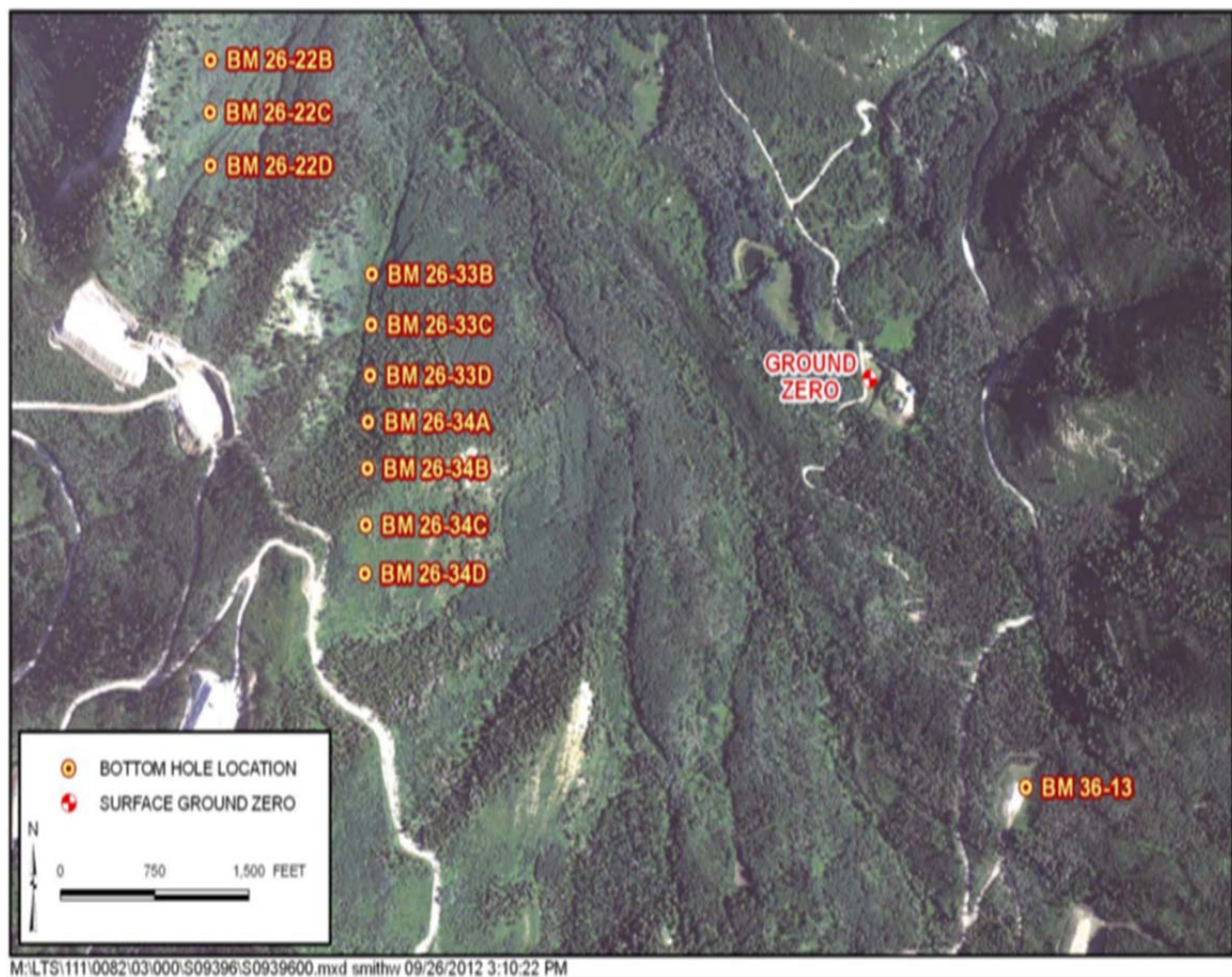
As part of the U.S. Department of Energy (DOE) Office of Legacy Management (LM) mission to protect human health and the environment, LM is monitoring natural gas wells near the Rulison site for radionuclides associated with the detonation. The very low permeability of the Williams Fork Formation limits contaminant migration in the subsurface and institutional controls limit subsurface access near the detonation zone. The Colorado Oil and Gas Conservation Commission notify DOE of any drilling permit activity within 3 miles of the site. The State and DOE review drilling permits and gas well development practices within this boundary to ensure that drilling activities maintain a safe distance from the detonation zone. The DOE *Rulison Monitoring Plan* (LMS/RUL/S06178) provides guidance for sample collection frequency based on distance from the Rulison detonation point, the types of analyses, and the reporting thresholds. The purpose of this trip was to collect natural gas and production water from producing natural gas wells in the Battlement Mesa (BM) field. The sampled wells collect natural gas from the formation horizon where the Project Rulison detonation occurred. The well locations are within 1.5 miles of the detonation location (surface ground zero on Figure 1).

Summary of Results

Due to economic factors the operator has shut-in four wells that are normally monitored for Rulison related contaminants. The water volume in the collection tanks was sufficient enough for collections of 1 gallon sample to be collected 8 of the 9 wells. A 1 gallon duplicate production water sample was collected during the March sampling event at well BM 26-33B. At well BM 26-22D approximately ½ gallon was collected which may provide enough sample for all scheduled analysis. The operator shut-in four wells (BM 26-34D, 22B, BM-13B, and BM-13) due to economic factors.

For the wells sampled on Pads 26N and 26K, the bottom-hole locations are between 0.76 mile and 1.1 miles from the Project Rulison vertical emplacement well 25-95 (R-E). Wells on

Pads 35C and 36L are approximately 0.95 mile from the detonation point. The well on Pad 36B is approximately 0.55 mile southeast of well 25-95 (R-E). Surface projections of the bottom-hole well locations and Project Rulison surface ground zero, at well 25-95 (R-E) (i.e., the detonation point), are shown in Figure 1.



Notes:

All wells sampled have been previously sampled by DOE.

The first two numerals in the well name designate the section number of the bottom-well location in the BM field.

The Project Rulison emplacement well, 25-95 (R-E) (i.e., ground zero), is located in Lot 11, Section 25.

Figure 1. Wells Sampled and Well 25-95 (R-E)

Table 1 lists the wells by sample-collection sequence. Before sample collection occurs at each well, each well's pressure and temperature (see Table 4) were read and recorded from surface transducers in the wells. Latitude and longitude values (not shown in Table 4) were compiled from survey plats included with the applications for permits to drill and from Colorado Oil and Gas Conservation Commission scout cards.

Except for the BM-13 well all other planned wellheads were available for sampling, and wellhead pressures and temperatures were within the normal range. At 9 of the 13 sampling locations plus a duplicate from BM 26-33C a 1 gallon container of production water was collected.

Table 4. Samples Collected

Sample Collection Sequence	Pad	Well Name	Location			Sample Phase		Well	
			API # 05-045-	Type	Subtype	Gas	Liquid	T (°F)	P (psi)
1	26N	BM 26-33B	15739	WL	NGSA	Yes	Yes	238	61
Duplicate	26N	BM 26-33B	15739	WL	NGSA	No	Yes	241	61
2	26N	BM 26-33C	15742	WL	NGSA	Yes	Yes	241	59
3	26N	BM 26-33D	15743	WL	NGSA	Yes	Yes	240	54.6
4	26N	BM 26-34A	15744	WL	NGSA	Yes	Yes	254	60
5	26N	BM 26-34B	15745	WL	NGSA	Yes	No	246	63
6	26N	BM 26-34C	15741	WL	NGSA	Yes	Yes	231	63
7	26K	BM 26-22C	16087	WL	NGSA	Yes	Yes	220	51
8	26K	BM 26-22D	16074	WL	NGSA	Yes	Yes ¹	243	60
9	35C	BM 35-32A	10919	WL	NGSV	Yes	Yes	245	66

Note:

¹ Approximately ½ gallon of production water was collected from the BM 26-22D well.

The operator has shut in wells BM 26-34D, 22B, BM 13B, and BM-13 for economic reasons.

Abbreviations:

API American Petroleum Institute

NGSA natural gas well–angle

NGSV natural gas well–vertical

P (psi) pressure in pounds per square inch

T (°F) temperature in degrees Fahrenheit

WL well

The produced-water samples were collected from a tap on a common line connecting the output of two separators (each servicing a well) and the nearby accumulation tanks. The collected water sample from one separator was isolated from the other separator by valves. Lines from each of the two separators were purged before sample collection.

The amount of water condensation in the condensation tank is variable and often not desired for the planned analytes. Collected sample volumes (Table 5) varied due to the water vapor concentration in the gas, temperature, age of the well, the cycle times of the well plunger, and transfer to the accumulation tank. Analysis priorities are tritium, gross alpha/beta, and high-resolution gamma spectrometry.

If condensate was collected with a sample, which happens for most samples, the condensate naturally separated from water after a short time in the sample bottle. The condensate was decanted in the field and returned to the operator. Table 5 lists the estimated sample volumes (including the condensate).

Table 5. Collected Water Sample Volumes (Before Decanting)

Sample Ticket	Well Name	Planned Analytes	Sample Volume
1	BM 26-33B	³ H, Gross α/β, Gamma spec	1 gallon
Duplicate	BM 26-33B	³ H, Gross α/β, Gamma spec	1 gallon
2	BM 26-33C	³ H, Gross α/β, Gamma spec	1 gallon
3	BM 26-33D	³ H, Gross α/β, Gamma spec	1 gallon
4	BM 26-34A	³ H, Gross α/β, Gamma spec	1 gallon
5	BM 26-34B	³ H, Gross α/β, Gamma spec	1 gallon
6	BM 26-34C	³ H, Gross α/β, Gamma spec	1 gallon
7	BM 26-22C	³ H, Gross α/β, Gamma spec	1 gallon
8	BM 26-22D	³ H, Gross α/β, Gamma spec	½ gallon
9	BM 35-32A	³ H, Gross α/β, Gamma spec	1 gallon

Notes:

Water sample information is listed in the order of collection.

Abbreviations:

Gamma spec high-resolution gamma spectrometry analysis

Gross α/β gross alpha and beta analyses

³H tritium

Equipment

Each produced-water sample was collected in a new, 1-gallon plastic bottle. After decanting, each water sample was poured into white, high-density polyethylene bottles of appropriate volumes for analysis.