

## **Monitoring Results of Natural Gas Wells near the Rulison, Colorado, Site April and July 2018 Monitoring Events**

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

**Date Sampled:** April 12 and July 26, 2018

#### **Background**

The Rulison, Colorado, Site is in the Piceance Basin of western Colorado, 40 miles northeast of Grand Junction. 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, conducted an underground nuclear test at the site, identified as Lot 11 (Figure 1), on September 10, 1969. The test, known as Project Rulison, was designed to evaluate the use of a nuclear detonation to enhance gas production in a low-permeability sandstone reservoir. This was the second natural gas reservoir stimulation experiment in the Plowshare Program, which was initiated to develop peaceful uses for nuclear energy. The device was detonated in the emplacement well (R-E) at a depth of 8425 feet (ft) and had a reported yield of 40 kilotons (DOE 2015). It created a temporary cavity, a collapse chimney, and a fractured zone surrounding the cavity (collectively known as the detonation zone). Prior to the detonation, an exploration well (R-Ex) was drilled near the R-E well. A sidetrack hole (a reentry well, known as well R-En) was drilled from well R-Ex into the chimney of well R-E in October 1970 to allow testing to evaluate the success of the detonation at improving gas production. The production testing produced 455 million cubic feet (MMCF) of gas in 107 days of testing that took place from October 1970 through April 1971 (Reynolds 1971). Production testing data indicated that essentially all tritiated methane was removed from the detonation zone, but that tritium likely remained as tritiated liquid water (that can exchange into the gas-phase as water vapor) and in minerals that make up the melt rock. In 1976, the participating parties agreed there would be no gas production at the site in the future, the R-E and R-Ex wells 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**

DOE's Office of Legacy Management (LM) collects samples (natural gas and produced water) from producing natural gas wells near the Rulison site to verify that residual radiological contamination has not migrated from the detonation zone to those locations. The samples are analyzed for radionuclides that are associated with a nuclear detonation. Tritium is the most abundant radionuclide remaining in the detonation zone that can be present in both 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. Almost all tritiated methane was removed and flared during the production testing (Smith 1971).

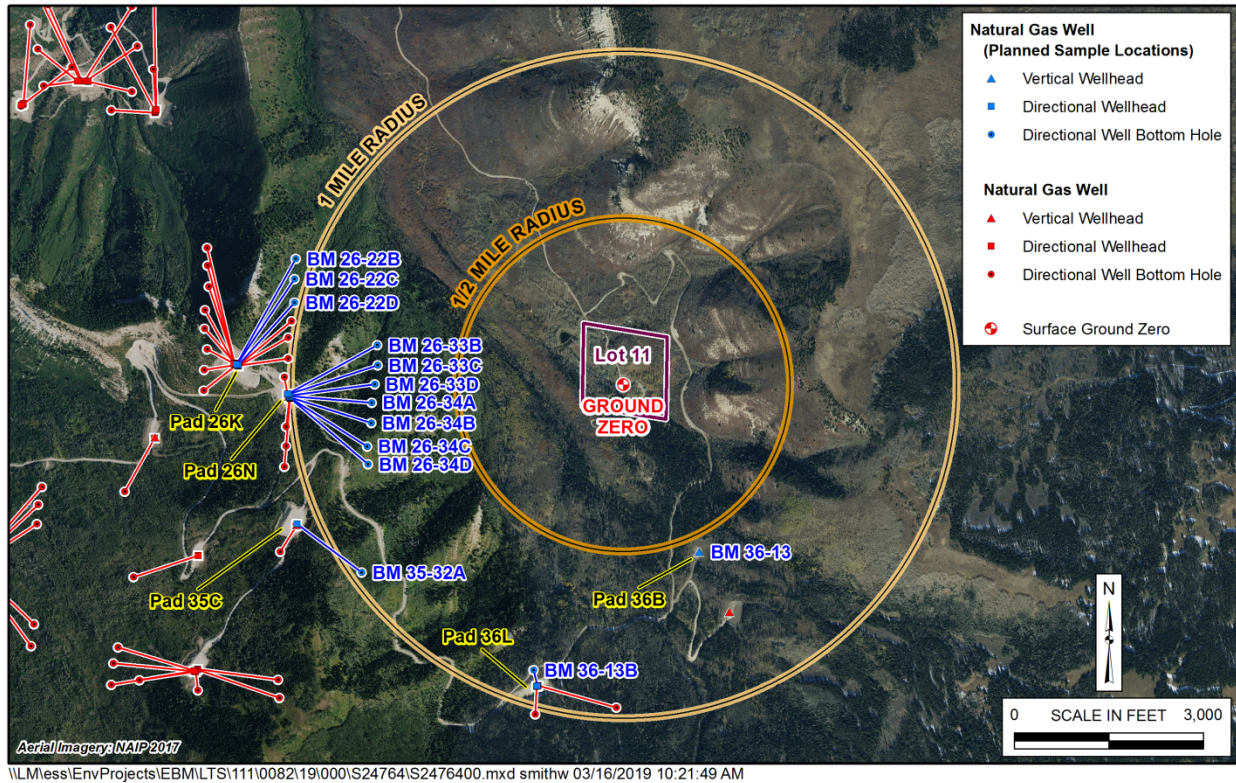


Figure 1. Rulison, Colorado, Site and Well Location Map

The natural gas wells produce some liquids (produced water and hydrocarbon condensate) along with natural gas; these liquids are brought to the surface with the natural gas and are 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 (COGCC) requires that operators with gas wells within approximately 2 miles of the Rulison site adhere to the COGCC’s *Rulison Sampling and Analysis Plan for Operational and Environmental Radiological Monitoring Near Project Rulison, Revision 4* (COGCC 2017). LM, in a separate effort, has implemented the *Rulison Monitoring Plan* (DOE 2010), also called the Monitoring Plan, which outlines a strategy for sampling gas wells within 1 mile of the detonation zone. The Monitoring Plan and analytical results from past monitoring activities are available on the LM public website at <https://www.lm.doe.gov/Rulison/Documents.aspx>. Analytical results obtained from LM’s April and July 2018 monitoring events are summarized in the following sections.

### Monitoring Protocol

The Monitoring Plan provides guidance on the type of samples collected (natural gas or produced water), the laboratory analyses performed, and the frequency of sample collection that is based on the amount of gas produced and the distance and direction of the well from the Rulison site. It also establishes screening levels or concentrations that, if exceeded in the sample results, require that samples be reanalyzed or additional sampling 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. In addition, natural gas samples are analyzed for carbon-14, and produced water samples are analyzed for gross alpha and beta radiation and gamma-emitting nuclides, to obtain background information.

Produced water samples are submitted to a commercial laboratory that provides analytical services in accordance with the *Department of Defense (DoD) Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories* (DoD/DOE 2017) to ensure that data are of known, documented quality. These laboratory analytical results are validated according to Section 5.0, “Validation of Environmental Data,” in the *Environmental Data Validation Procedure* (LMS/PRO/S15870). Table 1 provides the gas and produced water screening activities (concentrations) for tritium, gross alpha and gross beta radiation, and gamma-emitting nuclides (specifically cesium-137 [<sup>137</sup>Cs]). Background concentrations for gross alpha and gross beta have not been established.

Table 1. Rulison Area Natural Gas and Produced Water Sample Screening Levels

Analyte	Sample Matrix	Laboratory Detection Limit	Screening Concentration	Action Concentration
Tritium	Natural gas	10 TU <sup>a</sup>	19,293 TU <sup>b</sup>	TBD <sup>d</sup>
	Produced water	400 pCi/L	800 pCi/L	TBD <sup>d</sup>
Gross alpha radiation	Produced water	2 pCi/L	3 × background <sup>c</sup>	TBD <sup>d</sup>
Gross beta radiation	Produced water	4 pCi/L	3 × background <sup>c</sup>	TBD <sup>d</sup>
<sup>137</sup> Cs (high-resolution gamma spectrometry)	Produced water	10 pCi/L	20 pCi/L	TBD <sup>d</sup>

**Notes:**

The laboratory detection limits are an estimate of the laboratories capability of a given analytical procedure, which are reported by the laboratory as a minimum detectable concentration (MDC) that is often lower than the detection limit. The screening activities (concentrations) were obtained from the *Rulison Monitoring Plan* (DOE 2010).

<sup>a</sup> A tritium unit (TU) is equal to 3.19 picocuries per liter in water.

<sup>b</sup> The natural gas screening concentration for tritium assumes a standard temperature (0 °C) and pressure (1 atmosphere).

<sup>c</sup> Background concentrations have not been established for gross alpha and beta radiation.

<sup>d</sup> 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<sup>18</sup> hydrogen atoms)

**Sample Collection of Produced Water and Natural Gas**

Samples of the produced water and natural gas were collected from the gas wells operating near the site on April 12 and July 26, 2018. The second sampling event in July was conducted because wells BM 36-13B and BM 36-13 could not be accessed during the April sampling event. Samples of the produced water could not be collected from wells BM 26-22B, BM 26-22D, BM 35-32A, and BM 36-13 during these sampling events because the wells had not produced enough water for sampling (Figure 1 and Table 2). Only a partial sample was collected from well BM 26-34A because of the limited water produced by the well. Samples of the produced water were collected from a tap on the dump line connecting the gas–liquid separators and accumulation tank. Before 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 and beta radiation, and gamma-emitting radionuclides. The amount of produced water collected from well BM 26-34A was insufficient for gross alpha/beta radiation and gamma-emitting radionuclide analysis.

Table 2. Rulison Area Natural Gas Well Sample Locations for April and July 2018

Well ID	Well Pad	API No. 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 <sup>a</sup>
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	Not Sampled
BM 35-32A	35C	10919	Sampled	Not Sampled
BM 26-22B	26K	16086	Sampled	Not Sampled
BM 26-34D	26N	15748	Sampled	Sampled
BM 36-13B	36L	15469	Sampled	Sampled
BM 36-13	36B	10840	Sampled	Not Sampled

**Note:**

<sup>a</sup> Sample collected, but its limited volume allowed for tritium sampling only

**Abbreviation:**

API = American Petroleum Institute

The samples of the natural gas taken on April 12 and July 26, 2018, were collected from taps on the production lines downstream from the gas-liquid separators. For each sample, the tubing used to connect the tap to the sample bottle was purged prior to sample collection. The natural gas samples were contained in evacuated 18-liter propane bottles 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 and 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. Appendix A includes a chart for each well showing the monthly and cumulative gas production volumes in MMCF.

**Results for Produced Water and Natural Gas Samples**

The produced water samples had no detections of tritium or cesium-137 above their respective laboratory minimum detectable concentrations (MDCs). Concentrations of gross alpha and beta radiation were 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 natural gas samples also had no detections of tritium or carbon-14 above their respective laboratory MDCs (Table 3). The laboratory results were validated in accordance with Section 5.0, "Validation of Laboratory Data," in the *Environmental Data Validation Procedure*. All analyses were completed, and the samples were prepared and analyzed in accordance with accepted procedures for 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. Laboratory results for produced water and natural gas samples collected in April and July 2018 are also provided in Table 3. A copy of the Data Validation Memo is provided as Appendix B.

Table 3. Produced Water and Natural Gas Sample Results for April and July 2018

Well ID	API No. 05-045-	Natural Gas <sup>a</sup>		Produced Water			
		Tritium (TU) <sup>b</sup>	Carbon-14 (pMC) <sup>c</sup>	Tritium (pCi/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	<sup>137</sup> Cs (pCi/L)
BM 26-33B <sup>d</sup>	15743	<9.70	<0.5	<290	<57	79	<5.5
		NS	NS	<290	<36	58.7	<5.3
BM 26-33C	15742	<9.76	<0.5	<270	<56	142	<4.5
BM 26-33D	15739	<9.92	<0.5	<300	<52	101	<5.3
BM 26-34A	15744	<9.94	<0.5	<290	NA <sup>e</sup>	NA <sup>e</sup>	NA <sup>e</sup>
BM 26-34B	15745	<9.78	<0.5	<290	<63	82.2	<5.9
BM 26-34C	15741	<9.76	<0.5	<300	66.1	91.6	<4.4
BM 26-22C	16087	<9.92	<0.5	<290	69.6	178	<4.8
BM 26-22D	16074	<10.80	<0.5	NS	NS	NS	NS
BM 35-32A	10919	<9.85	<0.5	NS	NS	NS	NS
BM 26-22B	16086	<10.90	<0.5	NS	NS	NS	NS
BM 26-34D	15748	<9.91	<0.5	<280	127	140	<4.0
BM 36-13B	15469	<13.3	<0.5	<360	<55	229	<6.1
BM 36-13	10840	<12.6	<0.5	NS	NS	NS	NS
Screening concentrations		19,293	TBD	800	3 × background <sup>f</sup>	3 × background <sup>f</sup>	20

**Notes:**

<sup>a</sup> 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.

<sup>b</sup> A tritium unit (TU), 1 tritium atom in  $1 \times 10^{18}$  hydrogen atoms, is equal to 3.19 pCi/L in water.

<sup>c</sup> pMC is based on the International Radiocarbon Dating Standard, which is 1950 before present.

<sup>d</sup> Indicates that the sample was provided to the laboratory as a field duplicate.

<sup>e</sup> Sample not analyzed, because of limited sample volume.

<sup>f</sup> Background activities (concentrations) have not been established for gross alpha and beta radiation.

**Abbreviations:**

API = American Petroleum Institute

NA = not analyzed

NS = not sampled

pCi/L = picocuries per liter

pMC = percent modern carbon

TBD = to be determined

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

## Conclusion

Laboratory results obtained from this monitoring event continue to indicate that tritium has not been detected above the screening levels established for produced water or natural gas in the wells within 1 mile of the site. Natural gas wells near the Rulison site have not been impacted by detonation-related contaminants. This report is available on the LM public website at <https://www.lm.doe.gov/rulison/Sites.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>.

## References

COGCC (Colorado Oil and Gas Conservation Commission), 2017. *Rulison Sampling and Analysis Plan for Operational and Environmental Radiological Monitoring Near Project Rulison, Revision 4*, July.

DoD/DOE (Department of Defense/Department of Energy), 2017. *Department of Defense (DoD) Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories*, Version 5.1, January.

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

DOE (U.S. Department of Energy), 2015. *United States Nuclear Tests, July 1945 through September 1992*, DOE/NV--209-Rev 16, National Nuclear Security Administration, September.

*Environmental Data Validation Procedure*, LMS/PRO/S15870, continually updated, prepared by Navarro Research and Engineering, Inc., for the U.S. Department of Energy Office of Legacy Management.

Reynolds, Miles, 1971. *Project Rulison—Summary of Results and Analyses*, American Nuclear Society Winter Meeting, October.

Smith, C.F., 1971. *Gas Analysis Results for Project Rulison Production Testing Samples*, Lawrence Livermore Laboratories, UCRL-51153, November.

## **Appendix A**

### **Gas Well Production Data**

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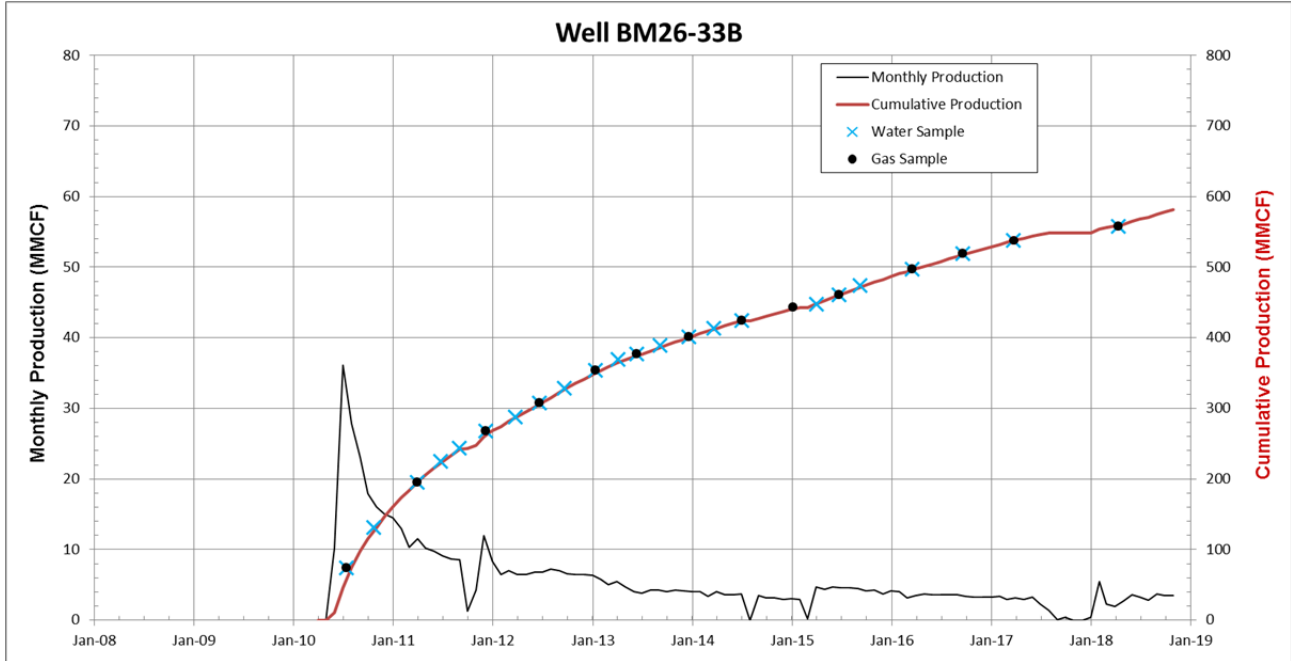


Figure A-1. Frequency of Sampling with Gas Production Data for Well BM26-33B

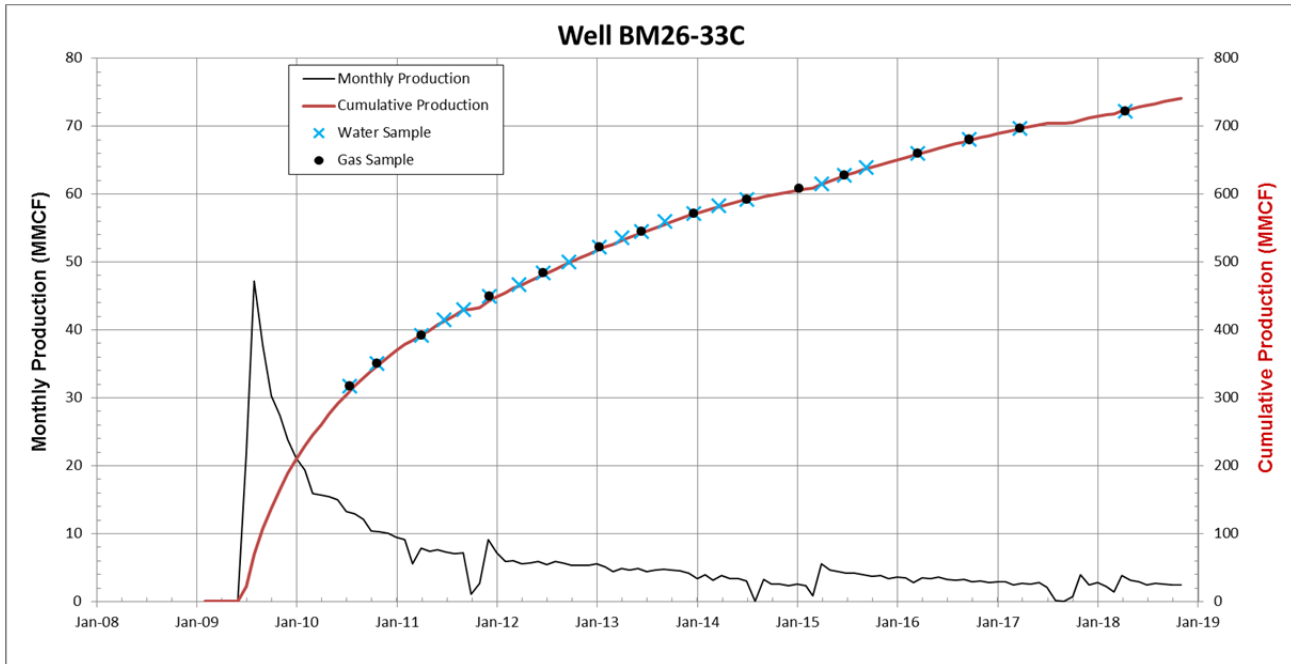


Figure A-2. Frequency of Sampling with Gas Production Data for Well BM26-33C

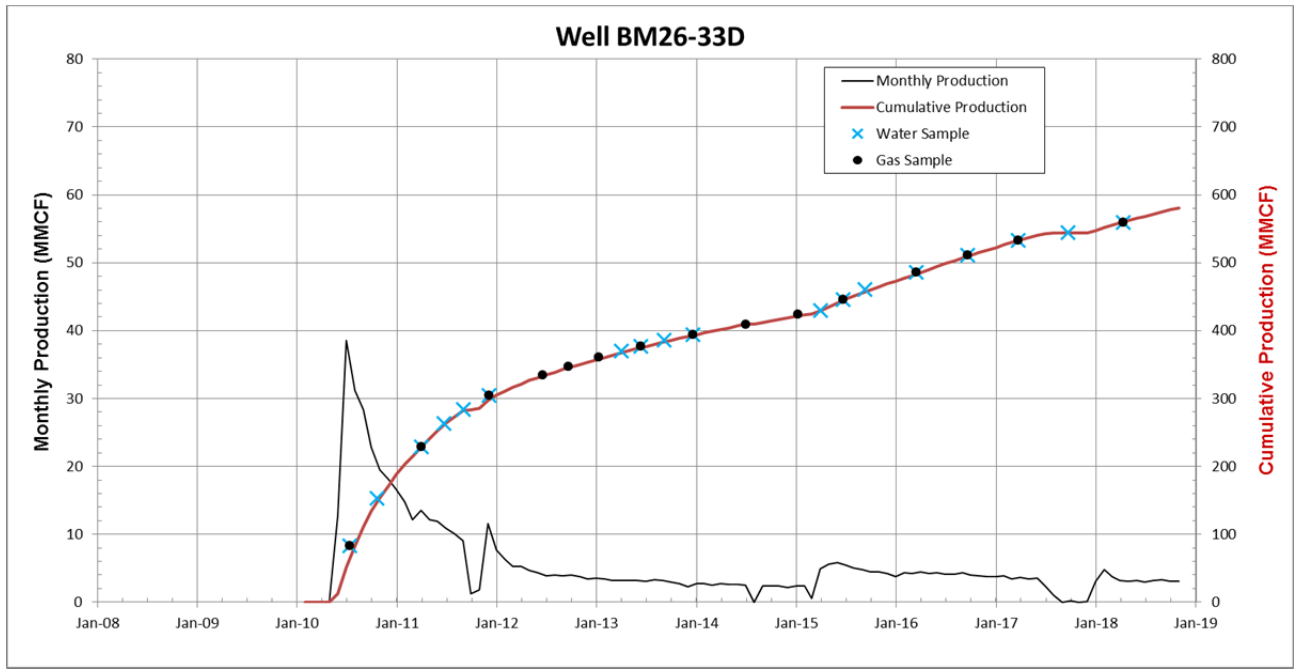


Figure A-3. Frequency of Sampling with Gas Production Data for Well BM26-33D

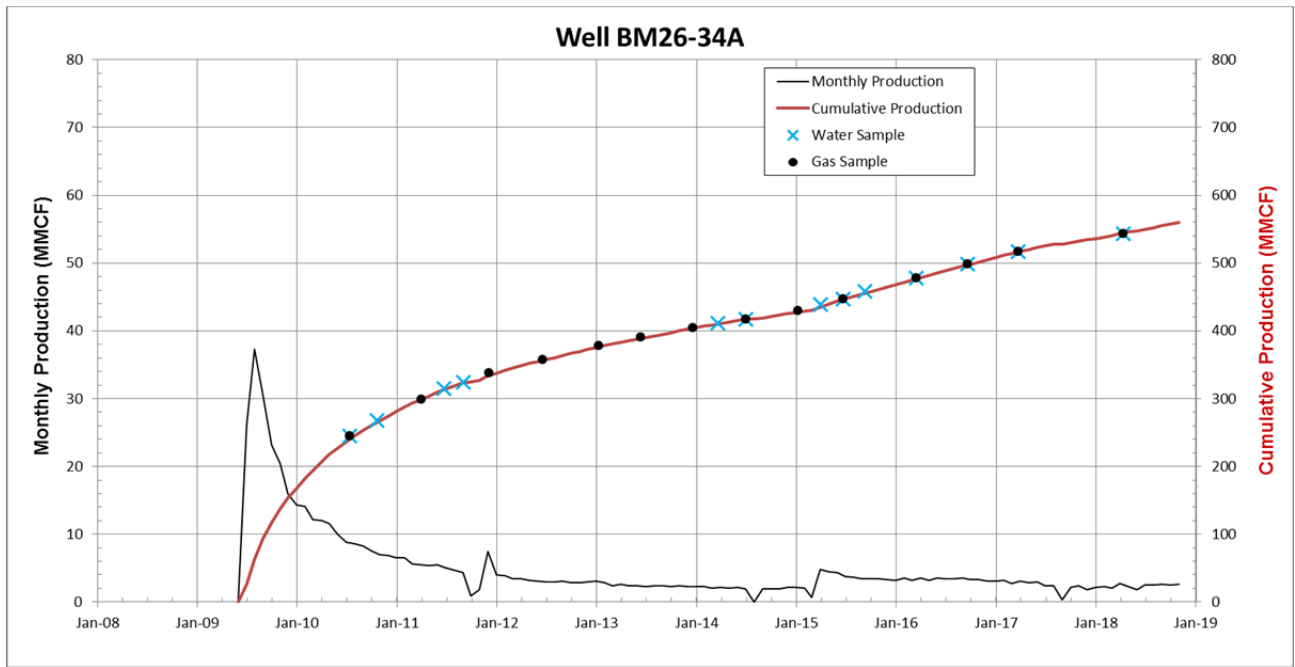


Figure A-4. Frequency of Sampling with Gas Production Data for Well BM26-34A

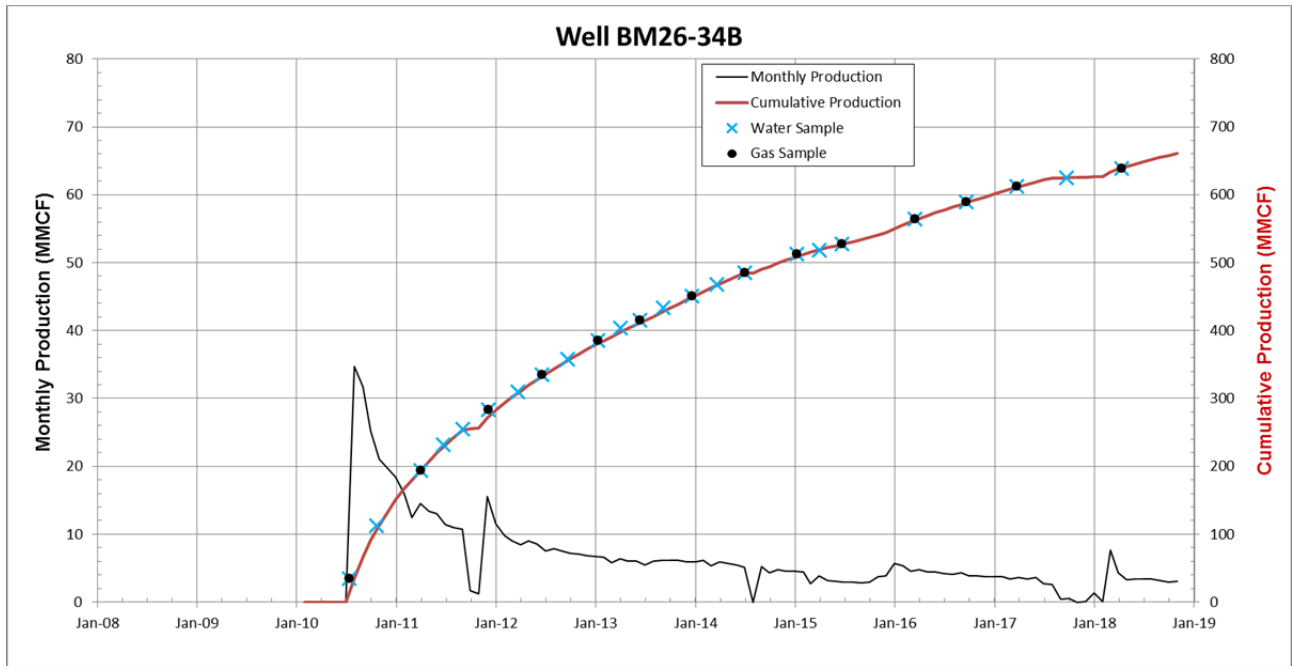


Figure A-5. Frequency of Sampling with Gas Production Data for Well BM26-34B

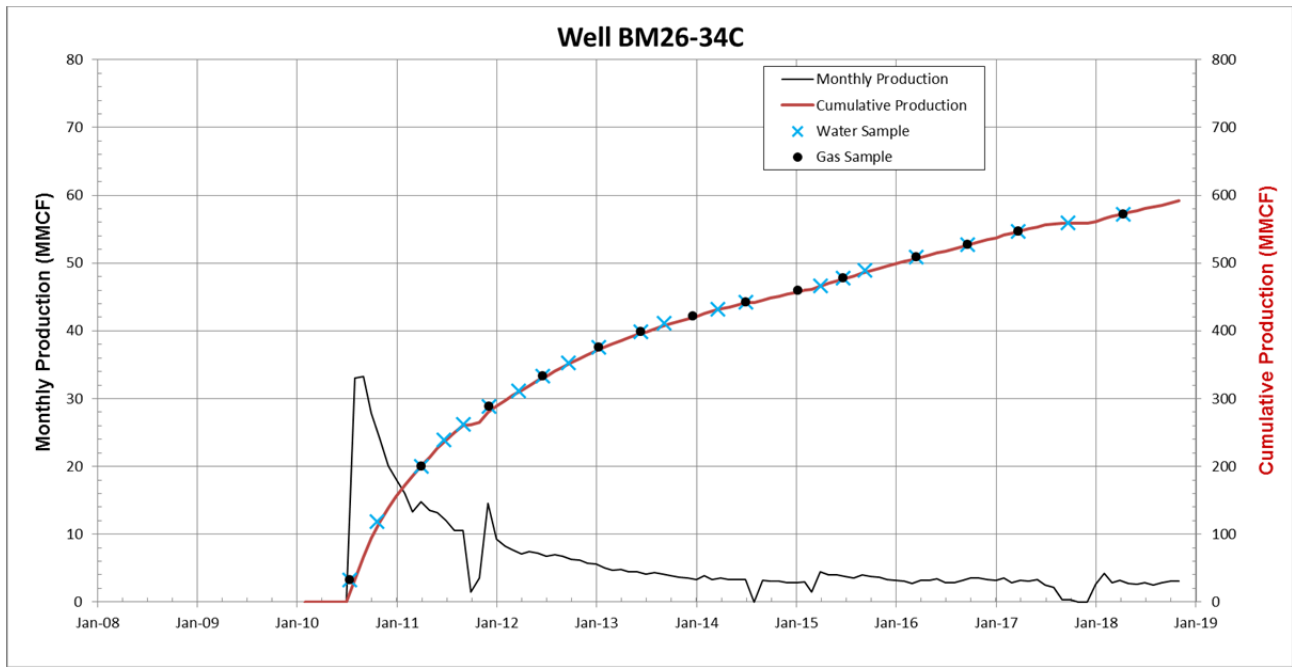


Figure A-6. Frequency of Sampling with Gas Production Data for Well BM26-34C

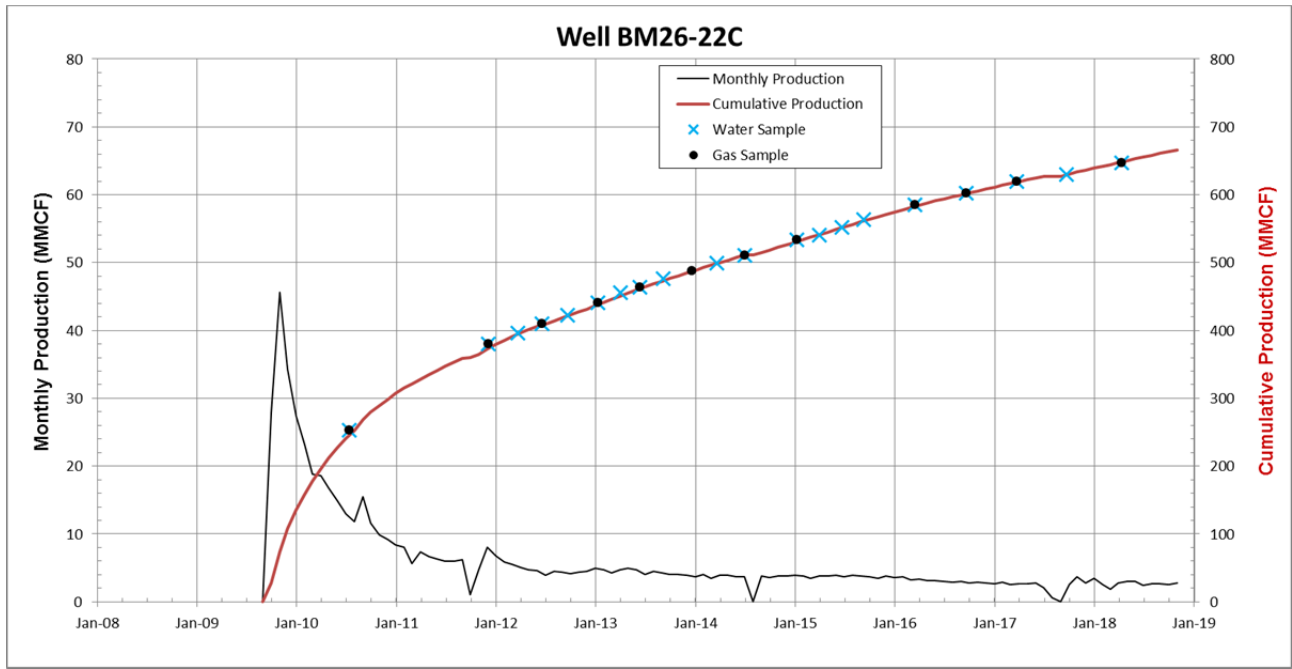


Figure A-7. Frequency of Sampling with Gas Production Data for Well BM26-22C

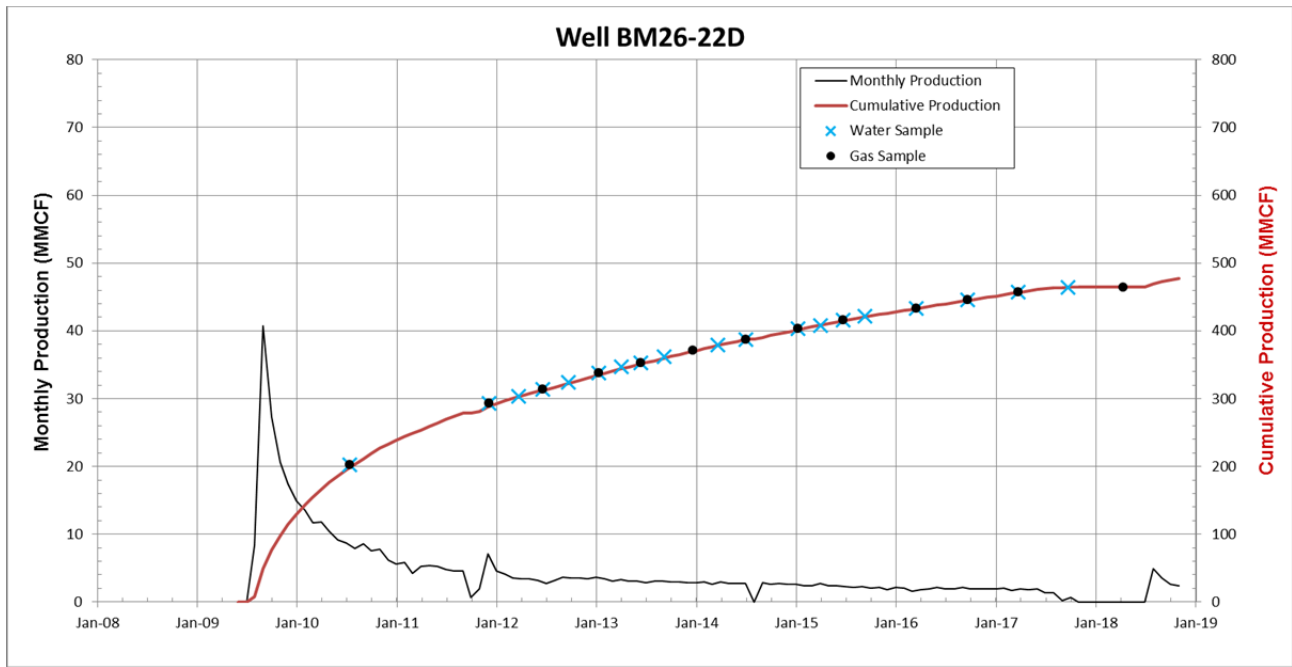


Figure A-8. Frequency of Sampling with Gas Production Data for Well BM26-22D

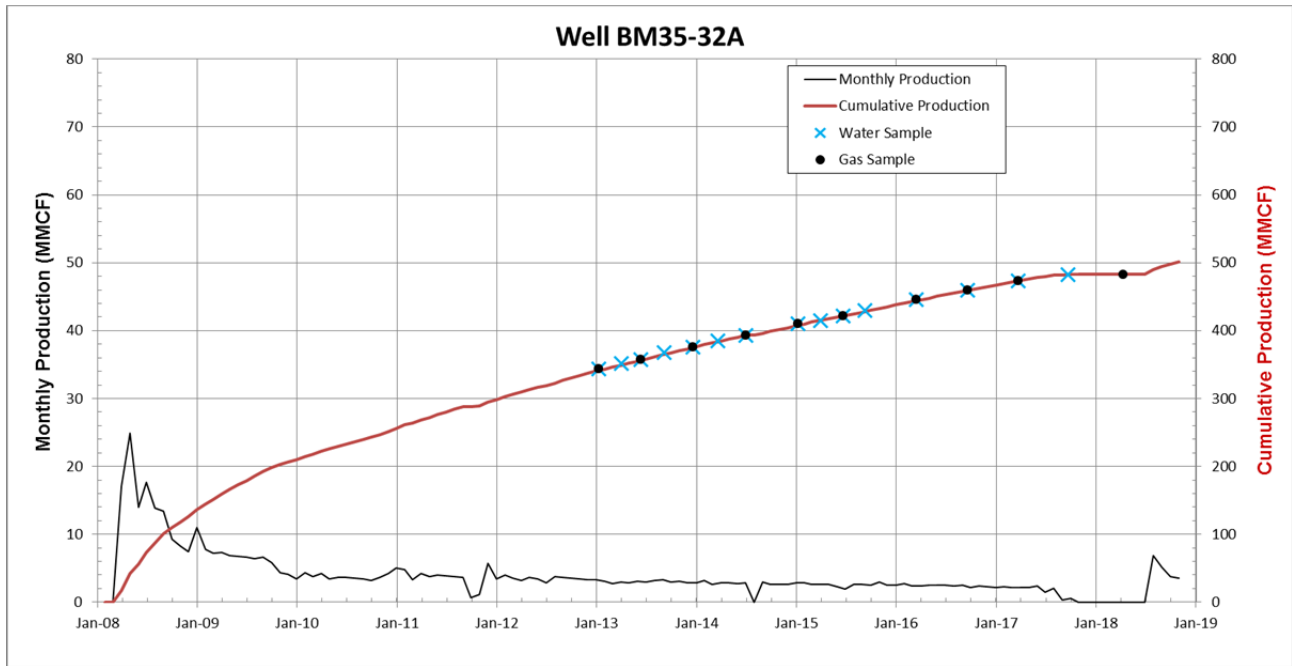


Figure A-9. Frequency of Sampling with Gas Production Data for Well BM35-32A

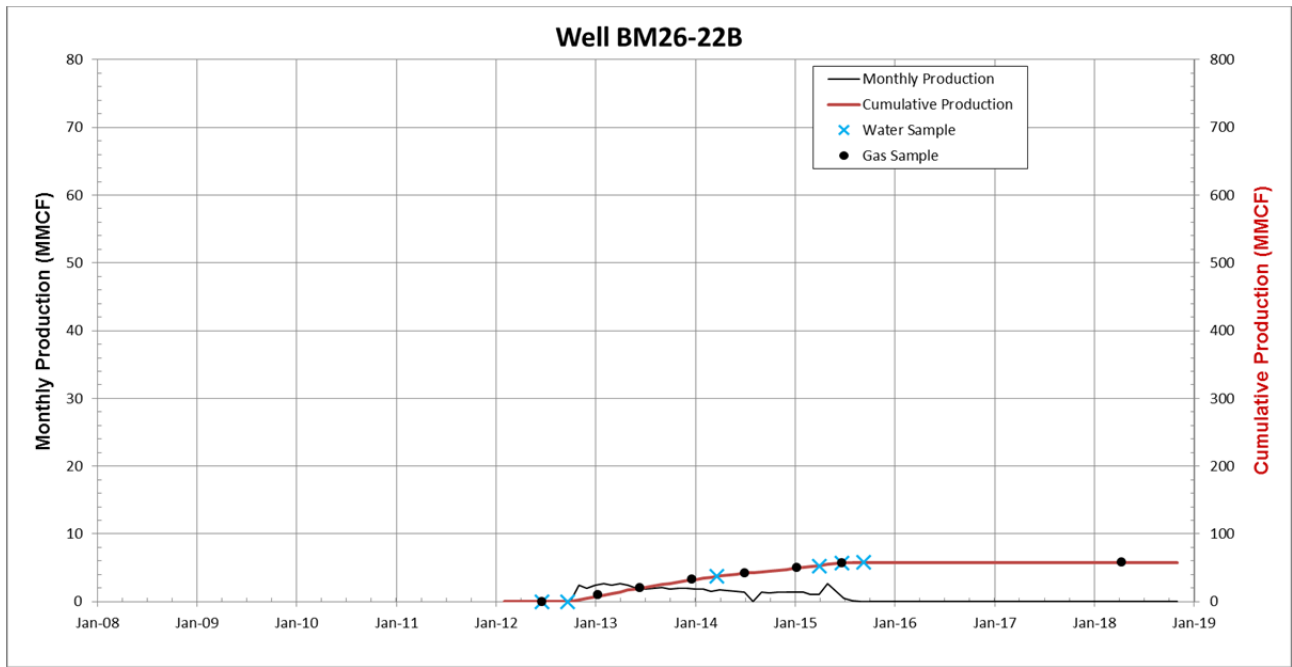


Figure A-10. Frequency of Sampling with Gas Production Data for Well BM26-22B

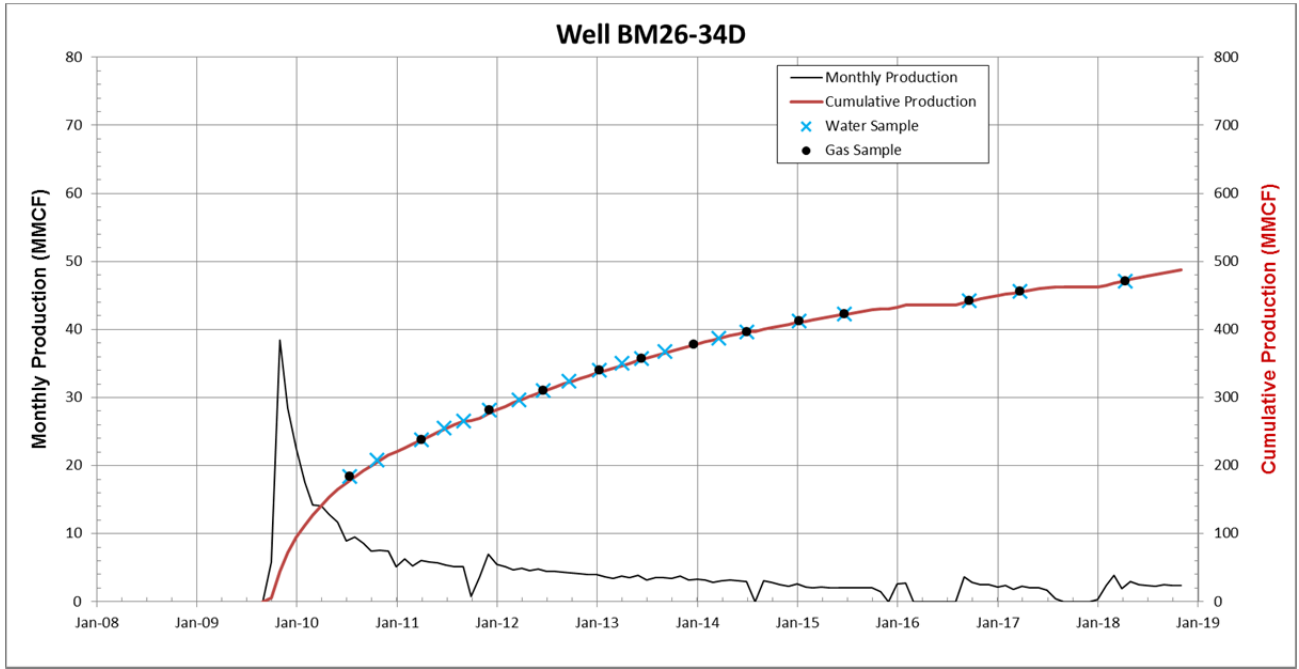


Figure A-11. Frequency of Sampling with Gas Production Data for Well BM26-34D

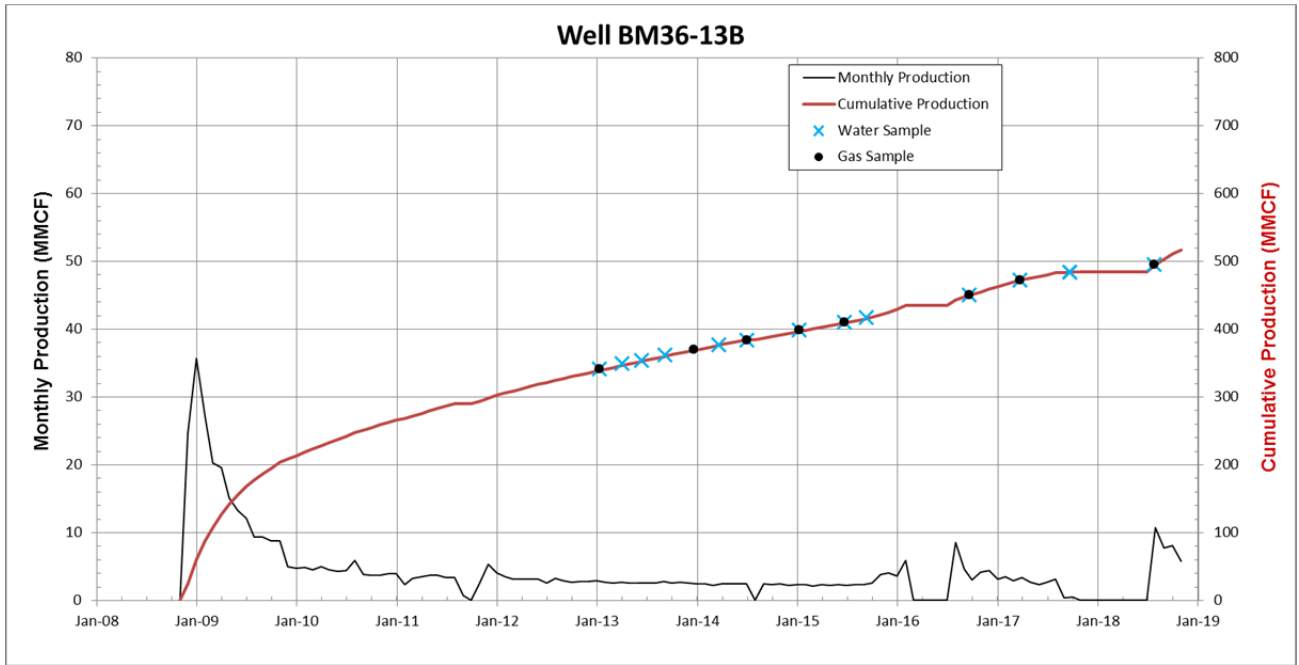


Figure A-12. Frequency of Sampling with Gas Production Data for Well BM36-13B

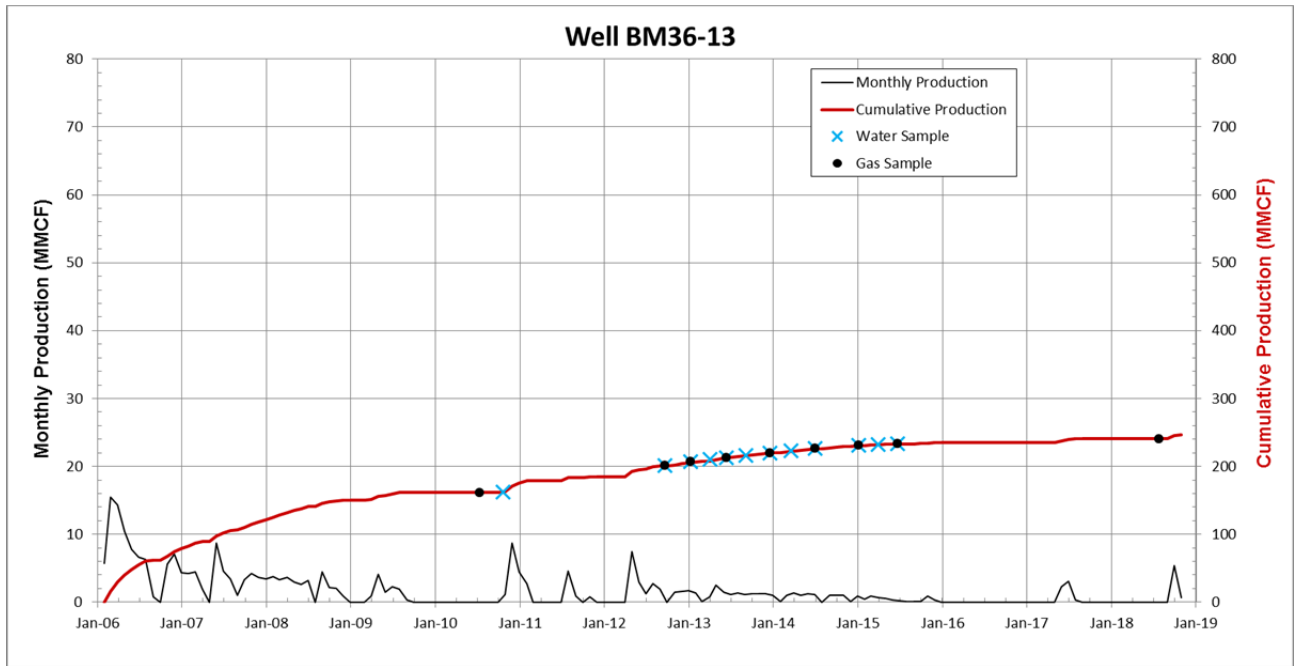


Figure A-13. Frequency of Sampling with Gas Production Data for Well BM36-13

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**Appendix B**  
**Data Validation Memo**

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memo



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To: Rick Findlay, Navarro  
From: Stephen Donovan, Navarro  
CC: Janice McDonald, Navarro  
Date: October 16, 2018  
Re: Validation of April and July 2018 Natural Gas and Produced Water Data from the Rulison Site

Validation of data generated from the April and July 2018 natural gas and produced water sampling events at the Rulison, Colorado, Site has been completed. This Level 2 validation was conducted according to the “Environmental Data Validation Procedure” (LMS/PRO/S15870).

The samples were submitted for analysis identified by Task Codes RUL01-02.1804002 (water), RUL01-03.1804002 (gas), RUL01-02.1807003 (water), and RUL01-03.1807003 (gas). Planned monitoring locations are shown in the Sampling and Analysis Work Order (Enclosure 1). Produced water samples were collected from 9 of the 13 planned sample locations; gas samples were collected from 13 of the 13 planned sample locations. See the Trip Reports (Enclosure 2) for additional details.

All environmental data from this sampling event are considered validated and available for use. Site data will be available for viewing with dynamic mapping via the GEMS (Geospatial Environmental Mapping System) website at <http://gems.lm.doe.gov/#> after transition to the new EQuIS database is complete. The Field Data Assessment (Enclosure 3) includes discussion of the field data and field quality control samples. The Laboratory Performance Assessments (Enclosure 4) documents the review of the laboratory data. Summaries of Enclosures 3, 4, and 5 are presented below.

**Sampling and Analysis Work** (Enclosure 1)

**Trip Reports** (Enclosure 2)

**Field Data Assessment** (Enclosure 3)

*Verification of Field Activities*

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

*Assessment of Field Quality Control Samples*

A duplicate sample was collected from location 05-045-15743. All duplicate results met the acceptance criteria, demonstrating acceptable precision.

**Laboratory Performance Assessments** (Enclosure 4)

All laboratory analytical quality control criteria were met. As shown in the Laboratory Performance Assessments, several analytical results were qualified as estimated values based on the low concentrations observed. Analytical data and the associated qualifiers can be viewed in reports from the environmental database.

Enclosures (4)

**Enclosure 1**  
**Sampling and Analysis Work**

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**Navarro Research and Engineering, Inc.**

March 30, 2018

Task Assignment 104  
Control Number 18-0590

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

SUBJECT: Contract No. DE-LM0000421, Navarro Research and Engineering, Inc.  
(Navarro)  
Task Assignment 104 LTS&M - Nevada Off Sites and Monticello Site  
April 2018 Environmental Sampling at the Rulison, Colorado, Site

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

Dear Mr. Kleinrath:

The purpose of this letter is to inform you of the upcoming sampling event at the Rulison, Colorado, site. Enclosed are the map and tables specifying sample locations and analytes for gas and produced water monitoring at the site. Data will be collected at this site as part of the routine gas well sampling currently scheduled for the week of April 9, 2018.

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

**GAS AND PRODUCED WATER MONITORING WELLS**

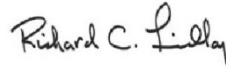
BM 26-22B (05-045-16086)	BM 26-34C (05-045-15741)
BM 26-22C (05-045-16087)	BM 26-34D (05-045-15748)
BM 26-22D (05-045-16074)	BM 35-32A (05-045-10919)
BM 26-33B (05-045-15743)	BM 36-13 (05-045-10840)
BM 26-33C (05-045-15742)	BM 36-13A (if available)
BM 26-33D (05-045-15739)	BM 36-13B (05-045-15469)
BM 26-34A (05-045-15744)	BM 36-13C (if available)
BM 26-34B (05-045-15745)	

All samples will be collected as directed in the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites*.

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

Art Kleinrath  
18-0590  
Page 2

Sincerely,

 2018.03.30  
11:38:28 -06'00'

Richard C. Findlay  
LMS Site Lead

RCF/bkb

Enclosures

cc: (electronic)

Jeanie Gueretta, DOE  
Marie Sepe, PhD, DOE  
Beverly Cook, Navarro  
Steve Donovan, Navarro  
Rick Findlay, Navarro  
Lauren Goodknight, Navarro  
Kenneth Karp, Navarro  
Sam Marutzky, Navarro  
Diana Osborne, Navarro  
EDD Delivery  
Document Determination  
Records  
File: CNT 400.02





Navarro Research and Engineering, Inc.

March 30, 2018

Task Assignment 104  
Control Number 18-0590

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

SUBJECT: Contract No. DE-LM0000421, Navarro Research and Engineering, Inc.  
(Navarro)  
Task Assignment 104 LTS&M - Nevada Off Sites and Monticello Site  
April 2018 Environmental Sampling at the Rulison, Colorado, Site

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

Dear Mr. Kleinrath:

The purpose of this letter is to inform you of the upcoming sampling event at the Rulison, Colorado, site. Enclosed are the map and tables specifying sample locations and analytes for gas and produced water monitoring at the site. Data will be collected at this site as part of the routine gas well sampling currently scheduled for the week of April 9, 2018.

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

**GAS AND PRODUCED WATER MONITORING WELLS**

BM 26-22B (05-045-16086)	BM 26-34C (05-045-15741)
BM 26-22C (05-045-16087)	BM 26-34D (05-045-15748)
BM 26-22D (05-045-16074)	BM 35-32A (05-045-10919)
BM 26-33B (05-045-15743)	BM 36-13 (05-045-10840)
BM 26-33C (05-045-15742)	BM 36-13A (if available)
BM 26-33D (05-045-15739)	BM 36-13B (05-045-15469)
BM 26-34A (05-045-15744)	BM 36-13C (if available)
BM 26-34B (05-045-15745)	

All samples will be collected as directed in the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites*.

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

**Sampling Frequencies for Locations at  
Rulison, Colorado**

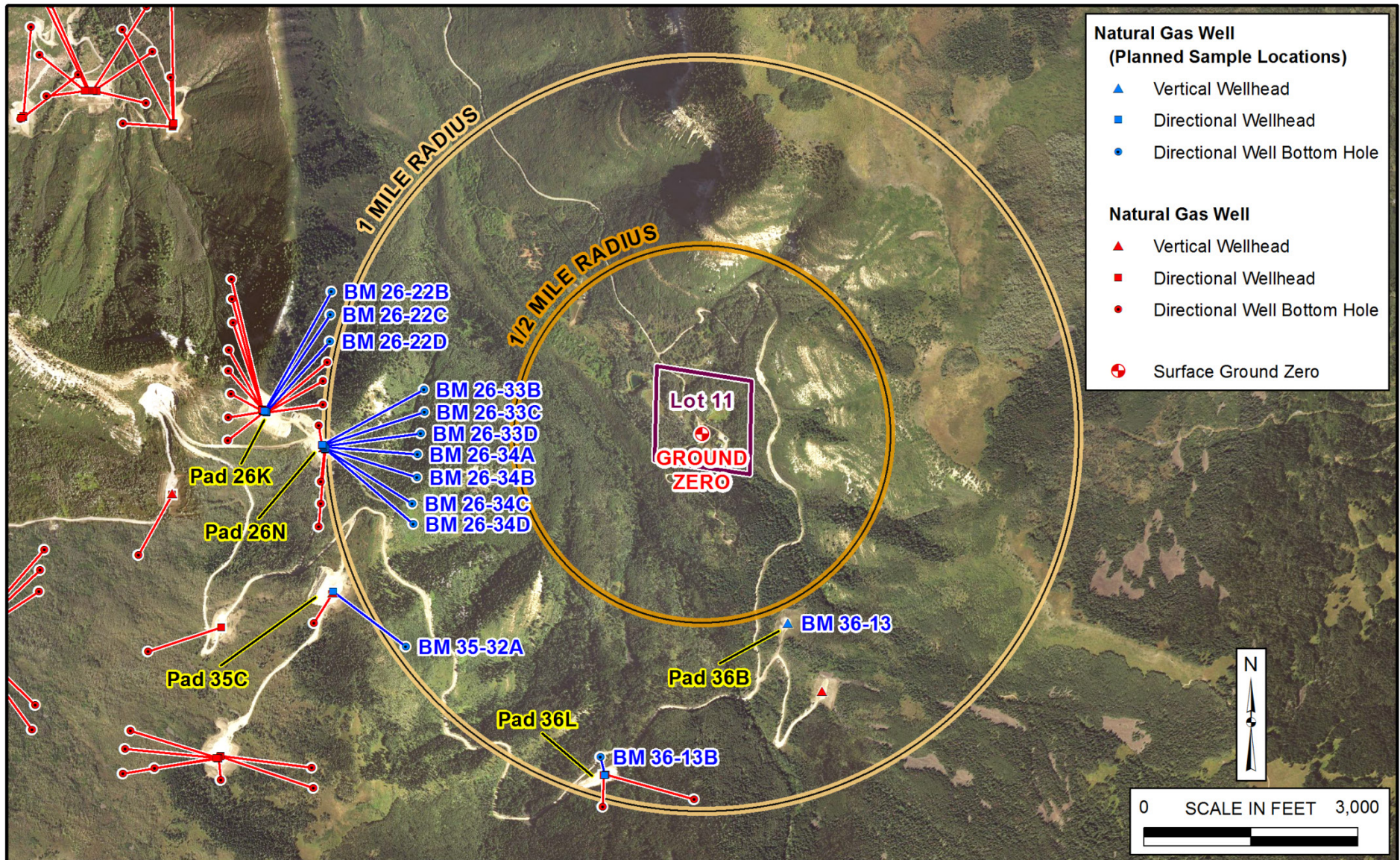
Location ID	Quarterly	Semiannually	Annually	Biennially	Not Sampled	Notes
<b>Gas and Produced Water Wells</b>						
BM 26-22B		X				05-045-16086
BM 26-22C		X				05-045-16087
BM 26-22D		X				05-045-16074
BM 26-33B		X				05-045-15743
BM 26-33C		X				05-045-15742
BM 26-33D		X				05-045-15739
BM 26-34A		X				05-045-15744
BM 26-34B		X				05-045-15745
BM 26-34C		X				05-045-15741
BM 26-34D		X				05-045-15748
BM 35-32A		X				05-045-10919
BM 36-13		X				05-045-10840
BM 36-13A		X				If available
BM 36-13B		X				05-045-15469
BM 36-13C		X				If available

Sampling conducted in April and September

### Constituent Sampling Breakdown

Site	Rulison		Required Detection Limit (mg/L)	Analytical Method	Line Item Code
Analyte	Gas	Produced Water			
Approx. No. Samples/yr	30	30			
<b>Field Measurements</b>					
Total Alkalinity					
Dissolved Oxygen					
Redox Potential					
pH					
Specific Conductance					
Turbidity					
Temperature					
<b>Laboratory Measurements</b>					
Aluminum					
Ammonia as N (NH3-N)					
Calcium					
Chloride					
Chromium					
Gamma Spec		X	10 pCi/L	Gamma Spectrometry	GAM-A-001
Gross Alpha		X	2 pCi/L	EPA 900.0	GPC-A-001
Gross Beta		X	4 pCi/L	EPA 900.0	GPC-A-001
Iron					
Lead					
Magnesium					
Manganese					
Molybdenum					
Nickel					
Nickel-63					
Nitrate + Nitrite as N(NO3+NO2)-N					
Potassium					
Radium-228					
Radium-226					
Selenium					
Silica					
Sodium					
Strontium					
Sulfate					
Sulfide					
Total Organic Carbon					
Tritium (liquids)	X	X	400 pCi/L	Liquid Scintillation	LSC-A-001
Tritium, enriched					
Uranium					
Vanadium					
Zinc					
<b>Total No. of Analytes</b>	<b>1</b>	<b>4</b>			

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.



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**Enclosure 2**  
**Trip Reports**

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memo



To: Rick Findlay, Navarro  
 From: Jeff Price, Navarro  
 Date: April 27, 2018  
 CC: Steve Donovan, Navarro  
 Rex Hodges, Navarro  
 EDD Delivery  
 Re: Trip Report – 1<sup>st</sup> Semiannual Gas Well Sampling Event 2018

**Site:** Rulison, Colorado, Site

**Date of Event:** April 12, 2018

**Team Members:** Rick Findlay, Jeff Price, and Tony Franzone, all from Navarro.

**Number of Locations Sampled:** Produced water samples were collected from 8 of the 13 planned sample locations (with one duplicate); gas samples were collected from 11 of the 13 planned sample locations.

**Locations Not Sampled/Reason:** Two gas wells (BM 36-13B and BM 36-13) could not be sampled because the road to the wells had not been cleared of snow and the wells were not in production at the time of the sampling event.

**Quality Control Sample Cross Reference:** Table 1 provides the false identification assigned to the quality control sample.

*Table 1. Quality Control Sample Summary*

False Location	False Sample ID	Parent Location	Parent Sample ID	Sample Type	Associated Matrix
2487	RUL01-02.1804002-012	BM 26-33B	RUL01-02.1804002-002	Duplicate	Produced Water

**Task Code Assigned:** Samples were assigned to Task Codes RUL01-02.1804002 (produced water), RUL01-03.1804002 (gas). Field data sheets can be found at <\\crow\SMS\RUL01-02.1804002\RECORDS\FieldData> and <\\crow\SMS\RUL01-03.1804002\RECORDS\FieldData>.

**Sample Shipment:** The samples (produced water and natural gas) were shipped via FedEx from Grand Junction, Colorado, on April 16, 2018. The produced water samples were sent to ALS Laboratory Group in Fort Collins, CO, and the natural gas samples were sent to Isotech Laboratories in Champaign, Illinois.

**Well Inspection Summary:** No issues were identified.

Rick Findlay  
April 27, 2018  
Page 2

**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)* and Program Directive RUL-2015-01.

**Field Variance:** None.

**Equipment:** All equipment functioned properly.

**Stakeholder/Regulatory/DOE:** Ken Kreie (DOE) was onsite to observe the sampling activities. Ryan Birdsey with Caerus Oil and Gas provided access to the natural gas wells.

**Safety Issues:** None.

**Access Issues:** None.

**General Information:** Nothing to note.

**Immediate Actions Taken:** None.

**Future Actions Required or Suggested:** Request the gas well production data from Caerus prior to sampling to obtain the volume of gas removed since the last sampling event. This will help identify wells for sampling, because the gas well production data on the Colorado Oil and Gas Conservation Commission web site is not current (usually out of date by 4 to 6 months).



memo



To: Rick Findlay, Navarro  
From: Jeff Price, Navarro  
Date: August 2, 2018  
CC: Steve Donovan, Navarro  
Rex Hodges, Navarro  
EDD Delivery  
Re: Trip Report – Follow-Up to the 1<sup>st</sup> Semiannual Gas Well Sampling Event 2018

**Site:** Rulison, Colorado, Site

**Date of Event:** July 26, 2018

**Team Members:** Jeff Price and Tony Franzone (Navarro).

**Number of Locations Sampled:** Gas wells (BM 36-13B and BM 36-13) were not sampled in April 2018 because the wells were shut off. These wells were re-visited and sampled on July 31. Gas samples were collected from both locations, produced water was collected only from BM 36-13B. Although well BM 36-13 was producing gas, there was no associated produced water.

**Locations Not Sampled/Reason:** See above discussion.

**Quality Control Sample Cross Reference:** None taken.

**Task Code Assigned:** Samples were assigned to Task Codes RUL01-02.1807003 (produced water), RUL01-03.1807003 (gas). Field data sheets can be found at <\\crow\SMS\RUL01-02.1807003\RECORDS\FieldData> and <\\crow\SMS\RUL01-03.1807003\RECORDS\FieldData>.

**Sample Shipment:** The produced water sample was shipped via FedEx from Grand Junction on July 26, 2018, to ALS Laboratory Group in Fort Collins, CO. The gas samples were shipped via FedEx from Grand Junction on July 31, 2018, to Isotech Laboratories in Champaign, Illinois.

**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)* and Program Directive RUL-2015-01.

**Field Variance:** None.

**Equipment:** All equipment functioned properly.

**Stakeholder/Regulatory/DOE:** R. Birdsey with Caerus Oil and Gas provided access to the natural gas wells.

Rick Findlay  
August 2, 2018  
Page 2

**Safety Issues:** None.

**Access Issues:** None.

**General Information:** Nothing to note.

**Immediate Actions Taken:** None.

**Future Actions Required or Suggested:** None.

## **Enclosure 3**

# **Field Data Assessment**

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### Water Sampling Field Activities Verification Checklist

<b>Project</b>	Rulison, Colorado	<b>Date(s) of Water Sampling</b>	April 12, 2018 and July 26, 2018
<b>Date(s) of Verification</b>	October 11, 2018	<b>Name of Verifier</b>	Stephen Donovan

	<b>Response (Yes, No, NA)</b>	<b>Comments</b>
1. Is the SAP the primary document directing field procedures?  List any Program Directives or other documents, SOPs, instructions.	Yes	
2. Were the sampling locations specified in the planning documents sampled?	No	Wells 05-045-15469 and 05-045-10840 could not be sampled in April because the road to the wells had not been cleared of snow. These wells were sampled in July.
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)**

	<b>Response (Yes, No, NA)</b>	<b>Comments</b>
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 was collected at location 05-045-15743.
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	

### Data Qualifier Summary

None of the analytical results were qualified based on field quality control.

### 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 05-045-15743. 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

Page 1 of 2  
25-Jun-2018

**Project:** Rulison Produced Water **Task Code:** RUL01-02.1804002 **Lab Code:** PAR

Analyte	Duplicate: RUL01-02.1804002-012				Sample: RUL01-02.1804002-002 05-045-15743				RPD	RER	Units
	Result	Qualifiers	Uncert	Dilution	Result	Qualifiers	Uncert.	Dilution			
Actinium-228	12.2	U	25.7	1	17.5	U	12.4	1		-0.4	pCi/L
Americium-241	-3.09	U	21.6	1	-8.44	U	28.4	1		0.3	pCi/L
Antimony-125	8.42	U	7	1	4.43	U	5.87	1		0.9	pCi/L
Cerium-144	-7.09	U	14	1	-2.53	U	13.8	1		-0.5	pCi/L
Cesium-134	-1.97	U	4.35	1	-1.72	U	3.01	1		-0.1	pCi/L
Cesium-137	-0.429	U	3.13	1	-2.68	U	3.15	1		1.0	pCi/L
Cobalt-60	0.206	U	3.59	1	-0.0944	U	3.12	1		0.1	pCi/L
Europium-152	7.59	U	18.3	1	-18.4	U	15.4	1		2.1	pCi/L
Europium-154	8.38	U	17.5	1	-3.29	U	15.7	1		1.0	pCi/L
Europium-155	0.794	U	8.05	1	8.05	U	8.03	1		-1.3	pCi/L
Gross Alpha	-5.75	U	20.3	1	27.6	U	34.7	1		-1.6	pCi/L
Gross Beta	58.7		17.1	1	79		45.4	1		-0.8	pCi/L
Lead-212	7.68	U	8.97	1	2.14	U	8.05	1		0.9	pCi/L
Potassium-40	145		87.1	1	6.82	U	104	1		2.0	pCi/L
Promethium-144	3.51	U	3.41	1	-0.479	U	3.44	1		1.6	pCi/L
Promethium-146	-1.59	U	3.33	1	0.766	U	3.08	1		-1.0	pCi/L
Ruthenium-106	-11.4	U	28.6	1	20.2	U	26.9	1		-1.6	pCi/L
Thorium-234	41.2	U	96.9	1	97.1	NQ	41.3	1		-1.0	pCi/L

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



### Validation Report: Field Duplicates

Page 2 of 2  
25-Jun-2018

**Project:** Rulison Produced Water    **Task Code:** RUL01-02.1804002    Lab Code: PAR

Analyte	Duplicate: RUL01-02.1804002-012				Sample: RUL01-02.1804002-002 05-045-15743				RPD	RER	Units
	Result	Qualifiers	Uncert	Dilution	Result	Qualifiers	Uncert.	Dilution			
Tritium	-97.9	U	172	1	-1.02	U	173	1		-0.8	pCi/L
Uranium-235	-1.63	U	26	1	0.144	U	12.9	1		-0.1	pCi/L
Yttrium-88	2.98	U	4.14	1	1.16	U	3.79	1		0.6	pCi/L

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

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**Enclosure 4**  
**Laboratory Performance Assessments**

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General Information

Task ID: RUL01-02.1804002  
 Sample Event: April 12, 2018  
 Site(s): Rulison Site  
 Laboratory: ALS Laboratory Group, Fort Collins, Colorado  
 Work Order No.: 1804413  
 Analysis: Radiochemistry  
 Validator: Stephen Donivan  
 Review Date: June 26, 2018

This validation was performed according to the “Environmental Data Validation Procedure” (LMS/PRO/S15870, draft). The procedure was applied at Level 2, Data Verification. See attached Data Validation Worksheets for supporting documentation on the data review and validation. All analyses were successfully completed. The samples were prepared and analyzed using accepted procedures based on methods specified by line item code, which are listed in Table 1.

*Table 1. 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 2. Refer to the sections below for an explanation of the data qualifiers applied.

*Table 2. Data Qualifier Summary*

Sample Number	Location	Analyte	Flag	Reason
RUL01-02.1804002-002	05-045-15743	Gross Beta	J	Less than the determination limit
RUL01-02.1804002-002	05-045-15743	Thorium-234	U	Nuclide identification criteria
RUL01-02.1804002-003	05-045-15742	Gross Beta	J	Less than the determination limit
RUL01-02.1804002-003	05-045-15742	Potassium-40	J	Less than the determination limit
RUL01-02.1804002-004	05-045-15739	Gross Beta	J	Less than the determination limit
RUL01-02.1804002-006	05-045-15745	Gross Beta	J	Less than the determination limit
RUL01-02.1804002-007	05-045-15741	Gross Alpha	J	Less than the determination limit
RUL01-02.1804002-007	05-045-15741	Gross Beta	J	Less than the determination limit
RUL01-02.1804002-008	05-045-15748	Gross Alpha	J	Less than the determination limit
RUL01-02.1804002-008	05-045-15748	Gross Beta	J	Less than the determination limit
RUL01-02.1804002-008	05-045-15748	Yttrium-88	U	Nuclide identification criteria
RUL01-02.1804002-011	05-045-16087	Gross Alpha	J	Less than the determination limit
RUL01-02.1804002-011	05-045-16087	Gross Beta	J	Less than the determination limit
RUL01-02.1804002-012	05-045-15743	Gross Beta	J	Less than the determination limit
RUL01-02.1804002-012	05-045-15743	Potassium-40	J	Less than the determination limit

### Sample Shipping/Receiving

ALS Laboratory Group in Fort Collins, Colorado, received nine water samples on April 19, 2018, 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% 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 is calculated and reported as specified in *Quality Systems for Analytical Services*. The DLC is the minimum concentration of an analyte that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, and is estimated as 3 times the 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 replicates.

### 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 four times the spike concentration. The spike recoveries were acceptable for all analytes.

### 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 May 25, 2018. The EDD was examined to verify that the file was complete and in compliance with requirements. The contents of the file were compared 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.

# General Data Validation Report

Page 1 of 1

**Task Code:** RUL01-02.1804002    **Lab Code:** PAR    **Validator:** Stephen Donivan    **Validation Date:** 06-25-2018

**Project:** Rulison Produced Water

**# Samples:** 14

**Analysis Type:**  General Chemistry     Metals     Organics     Radiochemistry

**Chain of Custody**

**Sample**

Present: <u>OK</u>	Signed: <u>OK</u>	Dated: <u>OK</u>
--------------------	-------------------	------------------

Integrity: <u>OK</u>	Preservation: <u>OK</u>	Temperature: <u>OK</u>
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**Check**

**Summary**

<b>Holding Times:</b>	All analyses were completed within the applicable holding times.
<b>Detection Limits:</b>	There were 7 detection limits above the contract required limits.
<b>Field Duplicates:</b>	There was 1 duplicate evaluated.



## Radiochemistry Data Validation Worksheet

Page 1 of 3

26-Jun-2018

**Project:** Rulison Produced Water

**Task Code:** RUL01-02.1804002

**Lab Code:** PAR

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
	Actinium-228	05-17-2018	MB	TRG	24.90	NQ	14.8								
	Americium-241	05-17-2018	LCS	SC	100000.00		11700	98.80		85	115				
	Americium-241	05-17-2018	MB	TRG	6.71	U	19.4								
	Antimony-125	05-17-2018	MB	TRG	1.42	U	7.48								
	Cerium-144	05-17-2018	MB	TRG	-16.00	U	14.9								
	Cesium-134	05-17-2018	MB	TRG	-2.75	U	3.46								
	Cesium-137	05-17-2018	LCS	SC	38300.00		4500	98.40		85	115				
	Cesium-137	05-17-2018	MB	TRG	0.31	U	3.66								
	Cobalt-60	05-17-2018	LCS	SC	43200.00		5070	99.50		85	115				
	Cobalt-60	05-17-2018	MB	TRG	1.03	U	4.59								
	Europium-152	05-17-2018	MB	TRG	4.04	U	22.8								
	Europium-154	05-17-2018	MB	TRG	7.54	U	20.8								
	Europium-155	05-17-2018	MB	TRG	-5.54	U	7.64								
	Gross Alpha	05-17-2018	LCS	SC	228.00		41.3	101.00		75	125				
	Gross Alpha	05-20-2018	MB	TRG	0.48	U	0.497								
	Gross Beta	05-17-2018	LCS	SC	207.00		35.9	96.50		75	125				
	Gross Beta	05-20-2018	MB	TRG	-0.60	U	0.646								
	Lead-212	05-17-2018	MB	TRG	-2.21	U	9.11								
	Potassium-40	05-17-2018	MB	TRG	-15.20	U	122								
	Promethium-144	05-17-2018	MB	TRG	-5.47	U	5.8								
	Promethium-146	05-17-2018	MB	TRG	-0.19	U	3.65								

**QC Types:** LCS: Laboratory Control Sample    LCSLD: 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

Page 2 of 3

26-Jun-2018

**Project:** Rulison Produced Water

**Task Code:** RUL01-02.1804002

**Lab Code:** PAR

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
	Ruthenium-106	05-17-2018	MB	TRG	4.01	U	30.3								
	Thorium-234	05-17-2018	MB	TRG	44.60	U	83.3								
	Tritium	04-30-2018	LCS	SC	18500.00		2840	103.00		85	115				
	Tritium	04-30-2018	MB	TRG	64.20	U	173								
	Uranium-235	05-17-2018	MB	TRG	-2.71	U	25.4								
	Yttrium-88	05-17-2018	MB	TRG	2.80	U	4.03								
RUL01-02.1804002-002	Tritium	04-28-2018	MS	SC	19600.00		3000	109.00		85	115				
RUL01-02.1804002-008	Actinium-228	05-15-2018	R	TRG	24.50		8.24							0.951	
RUL01-02.1804002-008	Americium-241	05-15-2018	R	TRG	10.10	U	11.3							1.59	
RUL01-02.1804002-008	Antimony-125	05-15-2018	R	TRG	0.76	U	3.03							1.06	
RUL01-02.1804002-008	Cerium-144	05-15-2018	R	TRG	-10.90	U	9.88							2.7	
RUL01-02.1804002-008	Cesium-134	05-15-2018	R	TRG	0.66	U	0.887							1.55	
RUL01-02.1804002-008	Cesium-137	05-15-2018	R	TRG	-0.65	U	1.32							0.183	
RUL01-02.1804002-008	Cobalt-60	05-15-2018	R	TRG	-0.52	U	1.37							1.21	
RUL01-02.1804002-008	Europium-152	05-15-2018	R	TRG	6.59	U	6.38							2.49	
RUL01-02.1804002-008	Europium-154	05-15-2018	R	TRG	1.62	U	6.89							1	
RUL01-02.1804002-008	Europium-155	05-15-2018	R	TRG	3.85	U	5.4							0.395	
RUL01-02.1804002-008	Lead-212	05-15-2018	R	TRG	-0.15	U	5.15							0.263	
RUL01-02.1804002-008	Potassium-40	05-15-2018	R	TRG	53.90	U	40							0.184	

**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

Page 3 of 3

26-Jun-2018

**Project:** Rulison Produced Water

**Task Code:** RUL01-02.1804002

**Lab Code:** PAR

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
RUL01-02.1804002-008	Promethium-144	05-15-2018	R	TRG	-0.27	U	1.41							0.362	
RUL01-02.1804002-008	Promethium-146	05-15-2018	R	TRG	-2.00	U	1.58							0.229	
RUL01-02.1804002-008	Ruthenium-106	05-15-2018	R	TRG	-18.30	U	13.5							1.68	
RUL01-02.1804002-008	Thorium-234	05-15-2018	R	TRG	-47.40	U	66.5							1.65	
RUL01-02.1804002-008	Tritium	04-29-2018	R	TRG	-35.60	U	172							1.43	
RUL01-02.1804002-008	Uranium-235	05-15-2018	R	TRG	18.10	NQ	9.19							0.804	
RUL01-02.1804002-008	Yttrium-88	05-15-2018	R	TRG	2.92	NQ	1.68							1.28	
RUL01-02.1804002-011	Gross Alpha	05-17-2018	MS	SC	18800.00		3470	124.00		60	140				
RUL01-02.1804002-011	Gross Beta	05-17-2018	MS	SC	14500.00		2490	99.90		60	140				
RUL01-02.1804002-012	Gross Alpha	05-19-2018	R	TRG	13.90	U	18.7							1.42	
RUL01-02.1804002-012	Gross Beta	05-19-2018	R	TRG	48.70		15.9							0.859	

**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

General Information

Task Code: RUL01-03.1804002  
 Sample Event: April 12, 2018  
 Site(s): Rulison, Colorado, Site  
 Laboratory: Isotech Laboratories  
 Work Order No.: 38063  
 Analysis: Radiochemistry  
 Validator: Stephen Donivan  
 Review Date: June 25, 2018

This validation was performed according to the “Environmental Data Validation Procedure” (LMS/PRO/S15870, draft). 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 3.

*Table 3. 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 11 natural gas samples on April 19, 2018, 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

Eleven 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 89% 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.

Electronic Data Deliverable (EDD) File

The EDD file arrived on June 5, 2018. The EDD was examined to verify that the file was complete and in compliance with requirements. The contents of the file were compared 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.

General Information

Task ID: RUL01-02.1807003  
 Sample Event: July 26, 2018  
 Site(s): Rulison, Colorado, Site  
 Laboratory: ALS Laboratory Group, Fort Collins, Colorado  
 Work Order No.: 1807568  
 Analysis: Radiochemistry  
 Validator: Stephen Donivan  
 Review Date: October 11, 2018

This validation was performed according to the “Environmental Data Validation Procedure” (LMS/PRO/S15870, draft). The procedure was applied at Level 2, Data Verification. See attached Data Validation Worksheets for supporting documentation on the data review and validation. All analyses were successfully completed. The samples were prepared and analyzed using accepted procedures based on methods specified by line item code, which are listed in Table 4.

*Table 4. 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 5. Refer to the sections below for an explanation of the data qualifiers applied.

*Table 5. Data Qualifier Summary*

Sample Number	Location	Analyte	Flag	Reason
RUL01-02.1807003-010	05-045-15469	Potassium-40	J	Less than the determination limit

Sample Shipping/Receiving

ALS Laboratory Group in Fort Collins, Colorado, received one water sample on July 27, 2018, accompanied by a Chain of Custody form. The Chain of Custody form was checked to confirm that the sample was 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% 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% 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 limits requirements with the following exception. The required detection limits were not met for the gross alpha result 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 replicates.

### 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 four times the spike concentration. The spike recoveries were acceptable for all analytes.

### 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 September 15, 2018. The EDD was examined to verify that the file was complete and in compliance with requirements. The contents of the file were compared 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.



# General Data Validation Report

**Task Code:** RUL01-02.1807003    **Lab Code:** PAR    **Validator:** Stephen Donivan    **Validation Date:** 10-11-2018

**Project:** Rulison Produced Water

**# Samples:** 2

**Analysis Type:**  General Chemistry     Metals     Organics     Radiochemistry

**Chain of Custody**

**Sample**

Present: <u>OK</u> Signed: <u>OK</u> Dated: <u>OK</u>	Integrity: <u>OK</u> Preservation: <u>OK</u> Temperature: <u>OK</u>
---	---

**Check**

**Summary**

<b>Holding Times:</b>	All analyses were completed within the applicable holding times.
<b>Detection Limits:</b>	There was 1 detection limit above the contract required limits.

## Radiochemistry Data Validation Worksheet

Page 1 of 3

11-Oct-2018

**Project:** Rulison Produced Water

**Task Code:** RUL01-02.1807003

**Lab Code:** PAR

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
	Actinium-228	09-07-2018	MB	TRG	-2.53	U	10.4								
	Americium-241	09-07-2018	LCS	SC	104000.00		12500	103.00		85	115				
	Americium-241	09-07-2018	MB	TRG	10.20	U	11.1								
	Antimony-125	09-07-2018	MB	TRG	3.57	U	3.21								
	Cerium-144	09-07-2018	MB	TRG	2.60	U	8.7								
	Cesium-134	09-07-2018	MB	TRG	0.16	U	0.941								
	Cesium-137	09-07-2018	LCS	SC	38200.00		4500	99.00		85	115				
	Cesium-137	09-07-2018	MB	TRG	-1.57	U	1.28								
	Cobalt-60	09-07-2018	LCS	SC	41300.00		4850	99.00		85	115				
	Cobalt-60	09-07-2018	MB	TRG	-1.04	U	1.31								
	Europium-152	09-07-2018	MB	TRG	8.08	U	6.23								
	Europium-154	09-07-2018	MB	TRG	1.07	U	6.62								
	Europium-155	09-07-2018	MB	TRG	-3.71	U	5.17								
	Gross Alpha	08-27-2018	LCS	SC	209.00		39.5	89.80		75	125				
	Gross Alpha	08-27-2018	MB	TRG	0.29	U	0.464								
	Gross Beta	08-27-2018	LCS	SC	197.00		34	92.30		75	125				
	Gross Beta	08-27-2018	MB	TRG	0.33	U	0.616								
	Lead-212	09-07-2018	MB	TRG	-2.97	U	4.81								
	Potassium-40	09-07-2018	MB	TRG	14.70	U	36.7								
	Promethium-144	09-07-2018	MB	TRG	1.28	NQ	0.679								
	Promethium-146	09-07-2018	MB	TRG	0.33	U	1.5								

**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

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11-Oct-2018

**Project:** Rulison Produced Water

**Task Code:** RUL01-02.1807003

**Lab Code:** PAR

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
	Ruthenium-106	09-07-2018	MB	TRG	20.20	NQ	12								
	Thorium-234	09-07-2018	MB	TRG	50.30	U	55								
	Tritium	08-22-2018	LCS	SC	16900.00		2730	96.19		85	115				
	Tritium	08-22-2018	MB	TRG	104.00	U	217								
	Uranium-235	09-07-2018	MB	TRG	6.65	U	22.8								
	Yttrium-88	09-07-2018	MB	TRG	0.10	U	3.23								
RUL01-02.1807003-010	Actinium-228	09-06-2018	R	TRG	-1.06	U	23.1							0.0283	
RUL01-02.1807003-010	Americium-241	09-06-2018	R	TRG	0.79	U	3.91							0.509	
RUL01-02.1807003-010	Antimony-125	09-06-2018	R	TRG	-1.90	U	6.73							0.0525	
RUL01-02.1807003-010	Cerium-144	09-06-2018	R	TRG	-1.72	U	12.9							0.435	
RUL01-02.1807003-010	Cesium-134	09-06-2018	R	TRG	0.73	U	3.13							0.235	
RUL01-02.1807003-010	Cesium-137	09-06-2018	R	TRG	-3.62	U	3.47							1.56	
RUL01-02.1807003-010	Cobalt-60	09-06-2018	R	TRG	-1.67	U	3.53							1.07	
RUL01-02.1807003-010	Europium-152	09-06-2018	R	TRG	8.94	U	16.8							0.139	
RUL01-02.1807003-010	Europium-154	09-06-2018	R	TRG	7.86	U	18.9							1.01	
RUL01-02.1807003-010	Europium-155	09-06-2018	R	TRG	-2.21	U	5.76							0.148	
RUL01-02.1807003-010	Gross Alpha	08-27-2018	MS	SC	10100.00		2160	86.50		60	140				
RUL01-02.1807003-010	Gross Alpha	08-27-2018	R	TRG	-8.94	U	29.5							0.784	
RUL01-02.1807003-010	Gross Beta	08-27-2018	MS	SC	10300.00		1770	94.09		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

## Radiochemistry Data Validation Worksheet

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11-Oct-2018

**Project:** Rulison Produced Water

**Task Code:** RUL01-02.1807003

**Lab Code:** PAR

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
RUL01-02.1807003-010	Gross Beta	08-27-2018	R	TRG	186.00		44.8							1.27	
RUL01-02.1807003-010	Lead-212	09-06-2018	R	TRG	0.39	U	6.91							0.083	
RUL01-02.1807003-010	Potassium-40	09-06-2018	R	TRG	159.00		75.2							0.0915	
RUL01-02.1807003-010	Promethium-144	09-06-2018	R	TRG	-0.11	U	3.84							0.115	
RUL01-02.1807003-010	Promethium-146	09-06-2018	R	TRG	-0.20	U	3.27							1.18	
RUL01-02.1807003-010	Ruthenium-106	09-06-2018	R	TRG	-13.30	U	30.9							1.45	
RUL01-02.1807003-010	Thorium-234	09-06-2018	R	TRG	-4.71	U	44.7							0.384	
RUL01-02.1807003-010	Tritium	08-22-2018	MS	SC	16900.00		2730	95.09		85	115				
RUL01-02.1807003-010	Tritium	08-22-2018	R	TRG	-122.00	U	207							1.31	
RUL01-02.1807003-010	Uranium-235	09-06-2018	R	TRG	-7.07	U	19.2							0.276	
RUL01-02.1807003-010	Yttrium-88	09-06-2018	R	TRG	-0.27	U	4.71							0.551	

**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

General Information

Task Code: RUL01-03.1807003  
 Sample Event: July 26, 2018  
 Site(s): Rulison, Colorado  
 Laboratory: Isotech Laboratories  
 Work Order No.: 39100  
 Analysis: Radiochemistry  
 Validator: Stephen Donivan  
 Review Date: October 11, 2018

This validation was performed according to the “Environmental Data Validation Procedure” (LMS/PRO/S15870, draft). 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 6.

*Table 6. 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 2 natural gas samples on August 1, 2018, 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

Two 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 91% 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.

Electronic Data Deliverable (EDD) File

The EDD file arrived on September 26, 2018. The EDD was examined to verify that the file was complete and in compliance with requirements. 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 reflect the data contained in the sample data package.

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