RULISON SAMPLING AND ANALYSIS PLAN

FOR

OPERATIONAL AND ENVIRONMENTAL

RADIOLOGICAL MONITORING

NEAR

PROJECT RULISON

REVISION 4

COGCC

COLORADO OIL AND GAS CONSERVATION COMMISSION

July, 2017

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LIST OF ACRONYMS

°C	degrees Celsius
<	less than
%	percent
±	plus or minus
^{3}H	tritium
^{14}C	carbon-14
^{36}Cl	chlorine-36
^{37}Ar	argon-37
^{39}Ar	argon-39
^{40}K	potassium-40
^{85}Kr	krypton-85
^{90}Sr	strontium-90
^{99}Tc	technetium-99
^{125}Sb	antimony-125
^{129}I	iodine-129
^{137}Cs	cesium-137
AEC	Atomic Energy Commission
ALARA	as low as reasonably achievable
APD	Application for Permit to Drill
API	American Petroleum Institute
C	Composite sample
CCR	Code of Colorado Regulations
CDPHE	Colorado Department of Public Health and Environment
CFR	Code of Federal Regulations
Ci	Curies
CL	critical level
COC	chain-of-custody
COGCC	Colorado Oil and Gas Conservation Commission
cpm	counts per minute
cps	counts per second
D	Duplicate sample
DF	Dissolved fraction
DC	drill cuttings
DER	duplicate error ratio
DMS	data management system
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DQI	data quality indicator
DQO	data quality objective
DRI	Desert Research Institute
DUP	duplicate
EDD	electronic data deliverable
EPA	U.S. Environmental Protection Agency
ERDA	U.S. Energy Research and Development Administration
FB	flowback fluids
ft msl	feet above mean sea level
FW	fracing fluids
G	Grab sample
gpm	gallons per minute
GPS	global positioning system

LIST OF ACRONYMS

GW	groundwater
IAEA/WMO	International Atomic Energy Agency/World Meteorological Organization
IATA	International Air Transportation Association
J	estimated data qualifier
keV	kilo electron volts
LCS	laboratory control sample
LIMS	Laboratory Information Management System
LP	liquid propane
LSC	liquid scintillation counter
MDA	minimum detectable activity
MeV	million electron volts
mg/L	milligram per liter
micro R/hr	micro Roentgen per hour
MMscf	million standard cubic feet
MS	matrix spike
MSD	matrix spike duplicate
mV	millivolt
N	tentatively identified data qualifier
NA	not applicable
NG	natural gas
NIST	National Institute of Standards and Technology
pCi/L	picocuries per liter
pMC	percent modern carbon
PPE	personnel protective equipment
PRG	preliminary remediation goal
psi	pounds per square inch
PW	produced water
QA	quality assurance
QC	quality control
R	unusable (rejected) data qualifier
R-E	device emplacement borehole
R-EX	pretest exploratory and re-entry borehole
RL	reporting limit
RPD	relative percent difference
RSAP	Rulison Sampling and Analysis Plan
RSO	Radiation Safety Officer
SD	standard deviation
SOP	standard operating procedure
SP	spring
SS	surface soils
SSO	Site Safety Officer
STP	standard temperature and pressure (20^{o}C and 1 atmosphere pressure)
SU	standard uncertainty
SW	surface water
TB	Trip blank
TEDE	total effective dose equivalent
TF	Total fraction
TIR	tentatively identified radionuclide
TLD	thermoluminescence dosimeter
TRL	target radionuclide list

LIST OF ACRONYMS

TU	tritium unit
U	not detected data qualifier
U.S.	United States
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator

1 INTRODUCTION

1.1 Sampling and Analysis Plan (RSAP) Overview

This Rulison Sampling and Analysis Plan (RSAP) defines the requirements for monitoring gas wells whose bottom-hole locations are within specified zones surrounding the site known as Project Rulison (Figure 1) in Garfield County, Colorado. Project Rulison is the site of a subsurface 43 kiloton (kT) (plus or minus 8 kT) nuclear detonation conducted at a depth of 8,426 feet below ground on September 10, 1969 by the Austral Oil Company and the Atomic Energy Commission (AEC) in an effort to increase natural gas production from low-permeability sandstones in the Williams Fork Formation. AEC is a predecessor agency to the United States Energy Research and Development Administration (ERDA) and the United States Department of Energy (DOE).

This RSAP is intended to be a Condition of Approval (COA) for Applications for Permit to Drill (APDs) issued for wells within the Tier I and Tier II zones defined in this plan. The companies (i.e., operators) who are issued APDs are referred to in the RSAP as the "Companies."

There are currently no gas wells within a half-mile radius of Project Rulison. Any APDs submitted within the half-mile radius of Project Rulison will require a COGCC hearing prior to approval. For RSAP implementation purposes, radial distances from Project Rulison are henceforth referenced to the Project Rulison device emplacement well R-E, also known as Hayward A 25-95.

The limitation on the number of drilling rigs concurrently operating within the Project Rulison monitoring zone has been eliminated in this revision because this has not been an administrative problem in recent years.

The monitoring program described in this RSAP is designed to provide radiological characterization of the area within the Tier I and II monitoring zones and to verify that natural gas operations near Project Rulison are conducted and monitored in a safe and responsible manner, reflective of the environmental health and safety needs of workers and the public. This RSAP revision is effective immediately upon approval by the COGCC.

A two-tiered operational and areal environmental monitoring program is presented in this RSAP. Two operational monitoring tiers, Tiers I and II (Figure 2), are defined based on distance from the Project Rulison device emplacement well R-E in Lot 11 in Section 25, Township

7 South, Range 95 West. Each tier zone is divided into 12 sectors surrounding Project Rulison. Tier I has a circular boundary set at the 1 mile radius which encloses an area of approximately 3.1 square miles. This boundary has not changed since the inception of the RSAP. The Tier II boundary has changed in this revision. Previously the circular boundary was set at a 3-mile radius, which enclosed an area (not including the Tier I area) of 25 square miles. In this version, the boundary is an ellipse aligned with the formation fracture pattern orientation in the area surrounding the Rulison site. The distance from the origin to the farthest point on the major axis of the Tier II boundary is 2 miles. The minor (short) axis of the ellipse is perpendicular to the long axis and the distance from the origin to boundary is 1.5 mile. The new Tier II boundary defines an area (not including the Tier I area) of 6.3 square miles. This change was made to remove controls on areas that present essentially no risk, as documented by years of monitoring data and extensive scientific evaluation of the subsurface environment by DOE.

The operational monitoring program is designed to screen gas drilling, completion, and production activities for the possibility of verified Project Rulison-related radionuclides within the Tier I and II monitoring zones (Figure 2) that might pose a threat to worker safety, public health, or the environment within that zone.

The areal environmental monitoring program has been deleted from this revision because there is no credible mechanism to transport Rulison-related activity to the surface except through natural gas production, which is covered in the operational monitoring portion of the RSAP.

While performing gas drilling operations within the Project Rulison monitoring zone (Tier I and II), the Companies shall comply with all provisions of the most recent COGCC approved revision of the RSAP. The Companies will also comply with all DOE Office of Legacy Management requests for sampling and analysis of natural gas and other materials associated with gas drilling, completion, and production.

The following sections of this RSAP define the monitoring requirements for the operational monitoring program and provide sampling procedures, analytical methods, data quality objectives (DQOs), and quality assurance (QA) and quality control (QC) measures for the analytes monitored. Appendix A also provides radiological incident mitigation, response, and recovery procedures for Tier I gas wells, in the unlikely event of a radiological release during gas drilling, completion, or production.

1.2 RSAP Organization

This RSAP is comprised of eleven sections, including this introduction. Section 2 provides an overview of the Project Rulison background, including a discussion of the more mobile or abundant radionuclides included in the monitoring program. Section 3 provides a summary of the historical and current environmental monitoring results. Section 4 summarizes the operational monitoring approach, including a description of the two-tiered, twelve-sector monitoring scheme designed for this RSAP. Section 5 describes the field sampling methods and procedures. Section 6 discusses the DQOs. Section 7 summarizes the sample handling and custody requirements. Section 8 provides the analytical methods and QC requirements. Section 9 describes the data validation and usability requirements. Section 10 lists the references cited in this RSAP. Appendix A provides a Tier I Radiological Incident Management Plan that discusses radiological incident mitigation, response, and recovery approaches. Appendices B, C, and D provide an example safe work plan, example field forms, and Radiological Equipment Information, respectively.

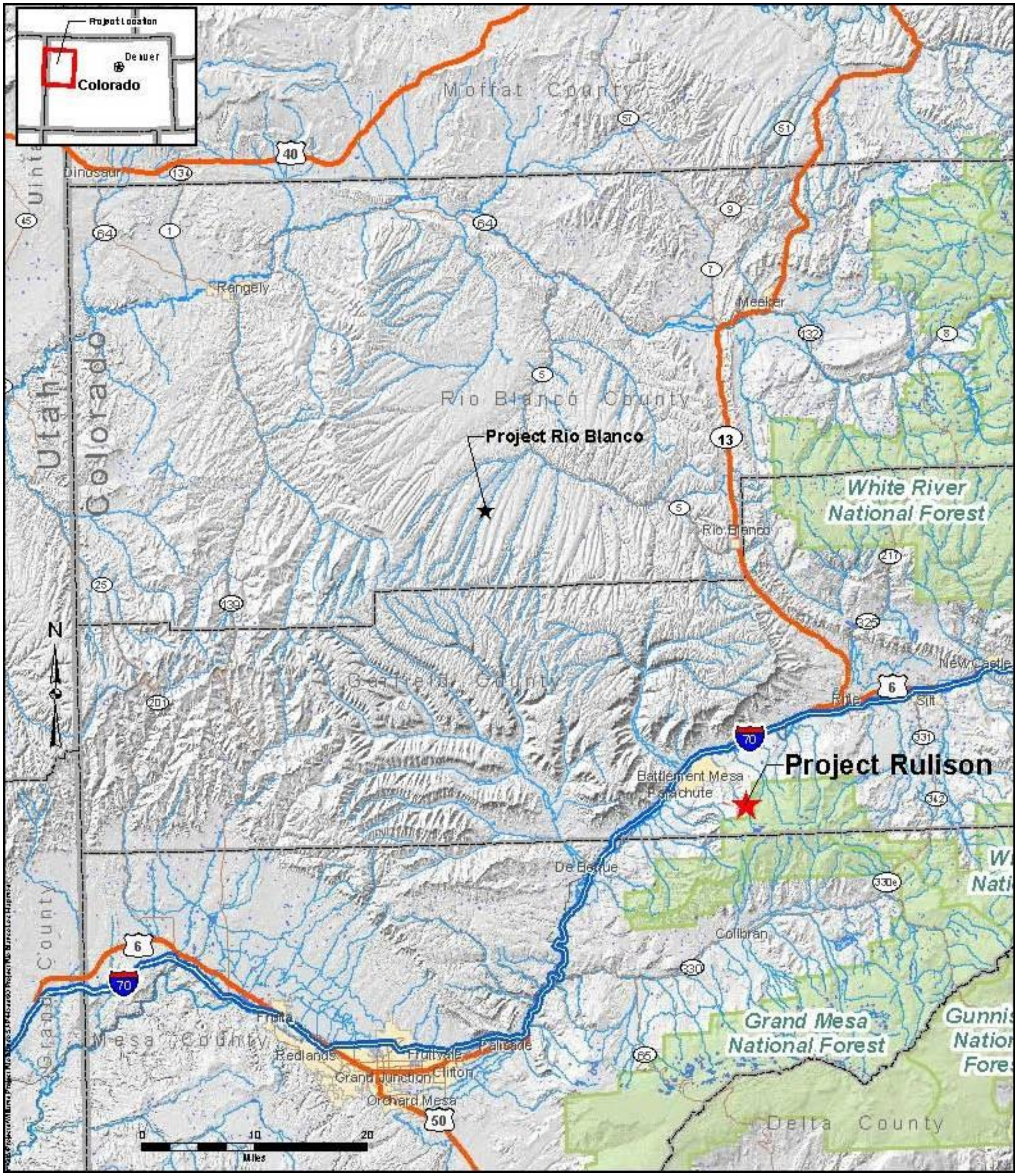

Figure 1. Project Rulison Location Map

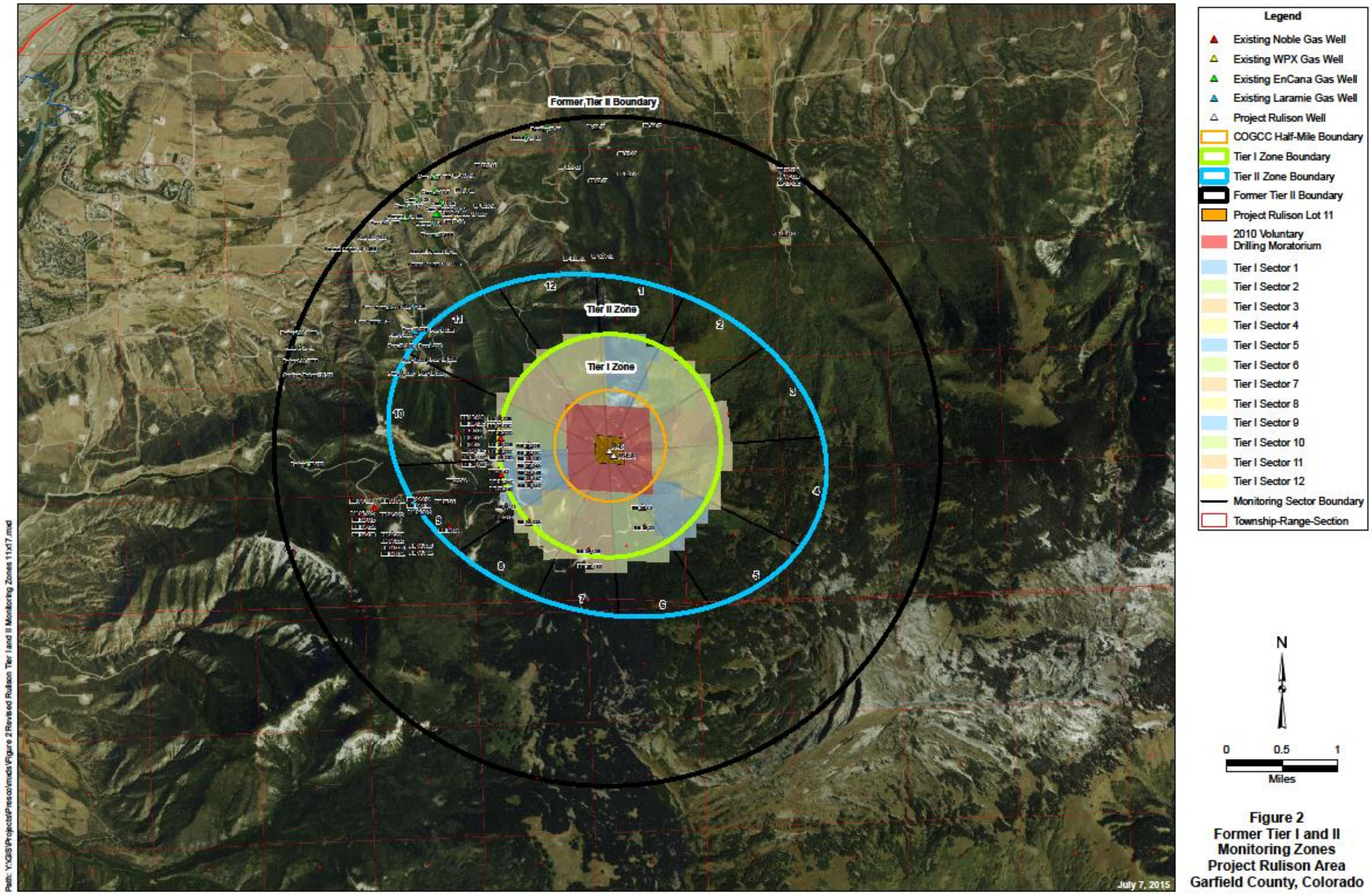

Figure 2. Tier I and II Monitoring Zones.

2 PROJECT RULISON BACKGROUND

Project Rulison was part of a program conducted by the AEC to pursue peaceful uses of nuclear explosives, sometimes referred to as the Plowshare Program. Multiple uses of these explosives were investigated, such as earth moving and excavation or stimulation of natural gas production from low-permeability reservoirs. The concept for gas stimulation was to exploit the large quantity of natural gas known to exist in very low-permeability reservoirs in sedimentary basins throughout the Rocky Mountain states. The creation of a large, effective wellbore and fractures in the adjacent formation using a nuclear explosive was proposed as possibly more efficient than using chemical explosives or hydraulic fracturing techniques (Rubin et al. 1972).

Three nuclear natural gas stimulation experiments were completed in the western U.S., with others in the planning stages before the end of the Plowshare Program in 1977. The first of the three experiments was the Gasbuggy test in the San Juan Basin in northwestern New Mexico. The second was the Rulison test in northwestern Colorado. The last was the Rio Blanco test, conducted north of Rulison, also located in northwestern Colorado. In all cases, gas production tests were conducted to evaluate the effectiveness of the stimulation, but the gas produced during these tests was flared (burned on site) and was not introduced into any gathering or distribution system or otherwise used.

Project Rulison was a joint industry-government partnership (AEC 1973a). The industry sponsor was Austral Oil Company, which acquired gas leases in the project area and conducted a feasibility study in cooperation with CER Geonuclear Corporation. Project Rulison was conducted in three phases:

- Phase I included drilling a pretest exploratory boring R-EX and the device emplacement well R-E; performing pretest gas production tests; and conducting geological, hydrological, and other studies for technical and safety considerations. Phase I activities were conducted between November 1967 and September 1969.
- Phase II focused on the emplacement, detonation, and immediate effects of the uranium fission nuclear device. The device was placed at a depth of 8,426 feet through a 10.75-inch steel casing that was then filled to the surface with stemming materials to isolate the detonation from the surface. The nuclear device was detonated on September 10, 1969. To protect workers, the public, and the environment, re-entry drilling occurred seven months

after the detonation so that the short-lived radionuclides had sufficient time to decay prior to re-entry. Phase II activities were conducted between August 1969 and March 1970.

- Phase III began in April 1970 and involved drilling a re-entry boring into the nuclear chimney created by the blast through the previously plugged R-EX boring, followed by gas flow testing to determine the cavity size and post-test production characteristics. Phase III activities were conducted between April 1970 and April 1971. The test site was placed on standby status in May 1971.

An underground nuclear explosion generates enormously high pressures and temperatures at the explosion source. The various nuclear explosion phases (Figure 3) occur rapidly over a few tens of milliseconds creating an initial cavity where the rocks are vaporized. As the explosion pressures rapidly subside, the rocks surrounding the cavity subsequently collapse into the underlying cavity and a chimney of rock rubble forms. Pore space within the chimney rubble is initially filled with gases generated during the explosion and is subsequently filled with formation waters and gases as hydrostatic pressures equilibrate over time.

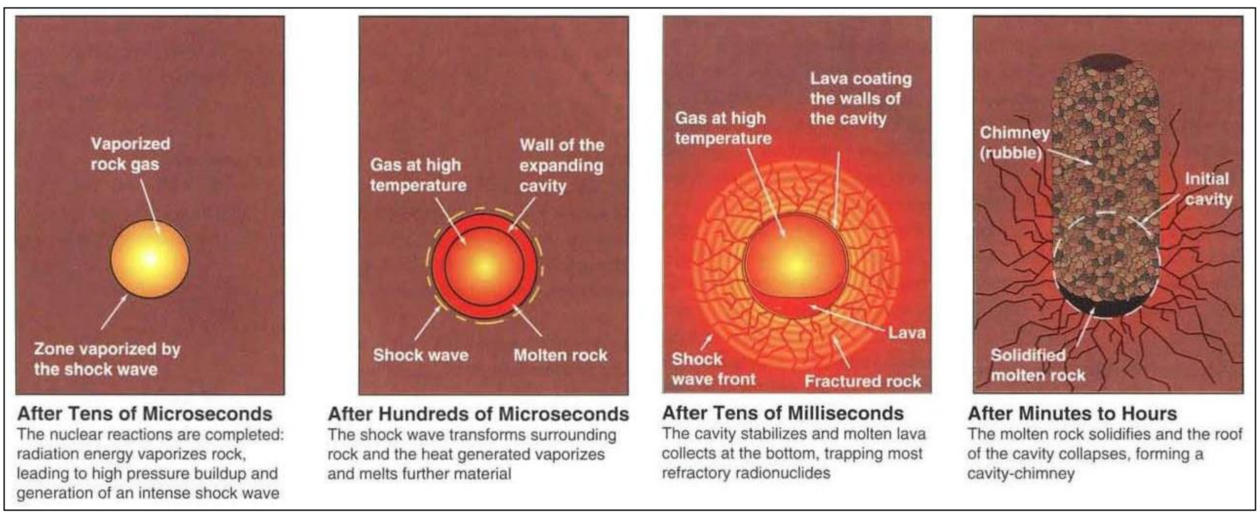

Figure 3. Sequence of Underground Nuclear Explosion Events (IAEA 1998).

A schematic cross-section of the Project Rulison detonation zone is shown as (Figure 4). The resulting chimney created by the Project Rulison nuclear explosion is reported to be up to 78 feet in radius based on equation of state calculations, krypton-85 (^{85}Kr) measurements, and pressure test analyses (AEC 1973a). The chimney height is estimated to be about 275 feet based on equation of state calculations and the depth of circulation loss (8,151 feet) encountered during re-entry drilling (AEC 1973a). Shear fractures were estimated to extend a radius of about 275 feet, with the maximum radius of fracturing estimated at about 433 feet (AEC 1973a). A high-permeability fractured region surrounds the cavity and chimney and extends an estimated 209 feet radially from the detonation (Cooper et al. 2009). The extent of the surrounding fractured zone is based on an analysis of data from the re-entry well production testing that indicated a 33-fold increase in permeability to a distance of 2.75 cavity radii (Montan 1971; Rubin et al. 1972). The postulated flow of gas and formation water in and around the chimney is discussed in Earman et al. (1996), Cooper (2004), DOE (2007a), and Cooper et al (2009).

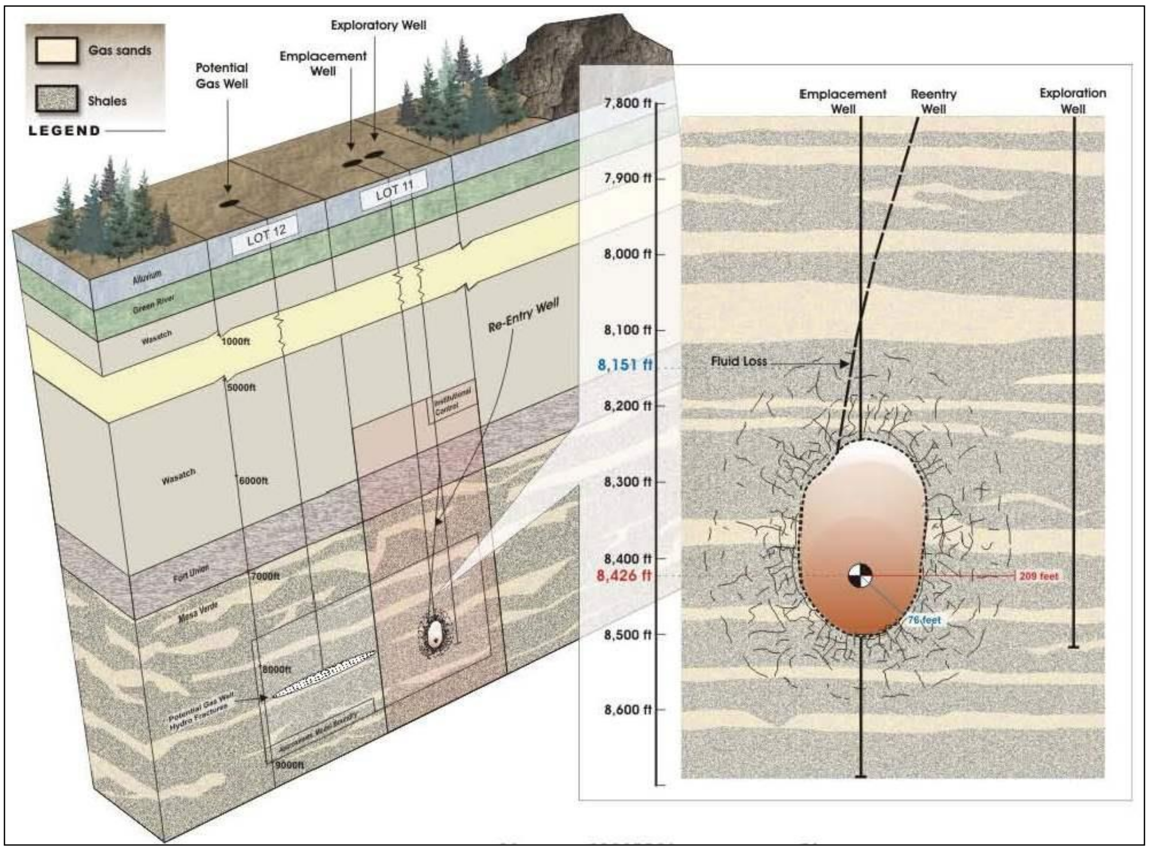

Figure 4. Schematic Cross-Section of the Project Rulison Detonation Zone (DOE 2009).

Gas was produced from the re-entry well drilled into the nuclear chimney during an initial short-term calibration test and three subsequent production tests. During all of these tests, the gas was flared (burned) to the atmosphere. Calibration flaring was conducted between October 4 and 7, 1970 and involved the production of 13 million standard cubic feet (MMscf) of gas. A high flow-rate production test occurred between October 26 and November 3, 1970, where a total of 109 MMscf of gas was produced. After a short build-up period, an intermediate flow-rate production test was conducted from December 1 to 20, 1970. This test flared 100 MMscf of gas. The final flow test ran from February 2 until April 23, 1971, and produced 234 MMscf of gas. In all, a total of 456 MMscf of gas was flared during the calibration-flaring and three production flow test periods.

Gas pressures in the nuclear cavity were measured during the production flow tests in the re-entry well (R-EX). Pressures showed a pattern of pressure reduction during the tests and modest pressure recovery during shut-in periods, imposed on an overall pressure decline in the cavity (Figure 5). The initial pressure in the well was 3,200 pounds per square inch (psi), which declined to about 400 psi over the calibration flaring and three production flow tests. The overall pressure decrease in the nuclear chimney during these tests reduced the natural migration potential of radioactive gases to the surrounding formation.

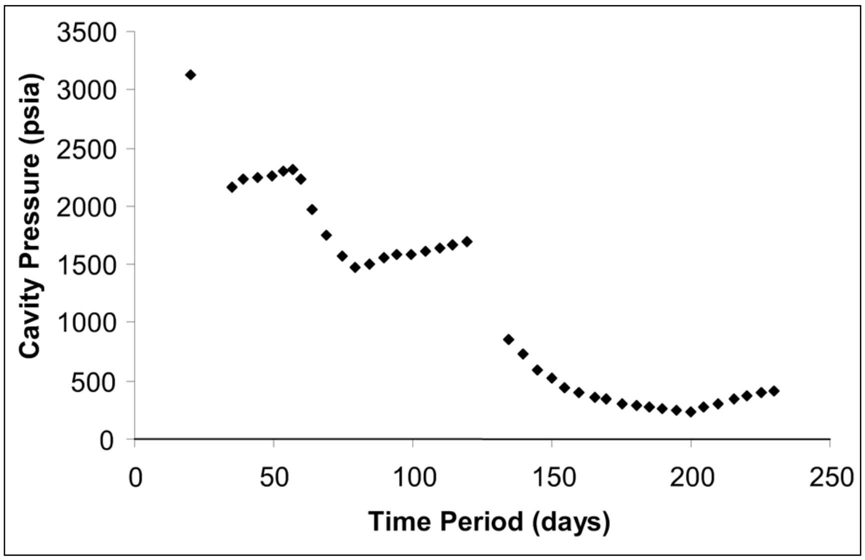

Figure 5. Nuclear Chimney Pressure Measurements during Re-Entry Testing (AEC 1973).

2.1 Project Rulison-Related Radionuclides

Based on the historic use of the site, and characterization at similar sites, the DOE Rulison Site Environmental Management End State Vision (DOE 2005) indicates that the radionuclides in the subsurface nuclear cavity are expected to include mixed radioactive fission products, plutonium, uranium, and gaseous radionuclides, tritium (^{3}H; as tritiated hydrogen gas [HT], methane [CH_3T], and/or water [HTO]), ^{85}Kr (an inert gas), and carbon-14 (^{14}C; as methane $^{14}CH_4$). The gas phase radionuclides are thought to be the most mobile in the subsurface environment. Radionuclide transport in the formation water is thought to be much less significant than gas phase transport because the relative permeability of water in the Williams Fork Formation is 3 to 4 times less than gas (Cooper et al. 2009). **Table 1** provides a summary of some of the more mobile or abundant Project Rulison-related radionuclides, their half lives, their estimated inventory in the cavity as of July 1, 2017, and the potential exposure medium. The radionuclides listed in (**Table 1**) are those whose half-life is greater than 10 years, are a significant inventory component (greater than 1 Curie), and may have the potential to migrate from the Project Rulison test cavity in either the gas or formation water.

Table 1 does not include any radionuclide whose half-life is less than 10 years, like antimony-125 (2.8 years) or argon-37 (35 days), because these short-lived radionuclides have decayed sufficiently since the Project Rulison test and no longer pose a threat to human health or the environment. A more exhaustive inventory of short- and long-lived radionuclides typically found in subsurface nuclear tests is provided as Table 1.1 in the Final Rulison Site Environmental Management End State Vision (DOE 2005).

Borg et al. (1976) reported that radionuclides in a below-ground nuclear cavity like Project Rulison may exist in one of four phases: 1) in the nuclear glass melt; 2) in surface deposits on rubble in the cavity chimney; 3) dissolved in water; or 4), or in the gas phase. Most of the fission and activation radionuclides from the detonation are not readily soluble in groundwater, as they are refractory (having low volatility) and are incorporated into the nuclear glass melt. Dissolution of the glass melt is an extremely slow process and any leached and dissolved radionuclides will tend to sorb to the formation rock.

Table 1. Potentially Mobile or Abundant Project Rulison-Related Radionuclides[1].

Radionuclide	Half-Life[2] (years)	Initial Activity (Curies)	Activity in 2017[3] (Curies)	Percent Initial Activity Remaining[4]	Potential Exposure Medium
Tritium (^{3}H)	12.33	7,800[5]	530	6.8	Gas and produced water
Cesium-137 (^{137}Cs)	30.07	7,500[6]	2490	33	Cuttings and produced water limited to inside the boundary of Lot 11
Strontium-90 (^{90}Sr)	28.79	5,900[7]	1865	32	Cuttings and produced water limited to inside the boundary of Lot 11
Krypton-85 (^{85}Kr)	10.76	1,100[6]	50	4.6	Gas
Argon-39 (^{39}Ar)	269	24.3[7]	21	88	Gas
Technetium-99 (^{99}Tc)	211,100	4.04[8]	4.04	100	Cuttings and produced Water
Chlorine-36 (^{36}Cl)	301,000	2.82[8]	2.82	100	Cuttings and produced water
Carbon-14 (^{14}C)	5730	2.20[8]	2.19	99.4	Gas and produced water

[1] A more exhaustive inventory of radionuclides found in subsurface nuclear tests is listed in Table 1.1 (DOE 2005).
[2] Half-lives from Lawrence Berkley National Laboratory Table of Isotopes, Version 2.1, January 2004.
[3] Activity in 2017 is referenced to July 1, 2017, and assumes a closed system (i.e., no loss of parent or daughter radionuclides).
[4] Unless otherwise specified, percent initial activity remaining does not account for radionuclide mass removed during gas production testing. Actual activities for ^{85}Kr, ^{39}Ar, and ^{14}C are likely less than those calculated because of removal of these isotopes during calibration and production testing.
[5] Initial activity in Rulison cavity from Reynolds (1971) was approximately 10,000 Ci. By April 1971 the activity was reduced to 7,000 Ci by production testing DOE (2010a). Regressing to detonation date, this equates to an initial inventory of 7,800 Ci.
[6] Initial activity in Rulison cavity from Nork and Fenske (1970).
[7] Initial activity in Rulison cavity from DOE (2005).
[8] Initial activity in Rulison cavity from Smith (1971); gaseous species only.

As a result, most of the radionuclides within the nuclear chimney are not likely to be transported in the subsurface water pathway (Borg et al. 1976). However, these contaminants could pose a risk if materials from the cavity were brought to the surface, necessitating the existing 40-acre drilling restriction in Lot 11 surrounding the nuclear cavity through perpetuity (DOE 2007a). This drilling restriction is a recorded right owned by the federal government for the subsurface, 6,000 feet and deeper, under Lot 11 (Garfield County Recorder, Book 490, pages 953-956, December 7, 1976).

Formation water in the Williams Fork Formation is thought to be much less mobile than the gas phase because of the low formation permeability and the significant gas-filled pore space which inhibits water flow. A detailed discussion of two-phase (i.e., gas and water) flow is presented in DOE (2007a) and Cooper et al (2009). However, considering that formation water is produced along with the gas and the general public perception that a release of radionuclides might occur as a result of gas production, transport of potentially mobile radionuclides in the gas phase and less mobile radionuclides in the liquid phase is considered in this RSAP. The radionuclides that could be dissolved and transported in subsurface formation water would likely include ^{3}H, ^{85}Kr, chlorine-36 (^{36}Cl), iodine-129 (^{129}I), technetium-99 (^{99}Tc), antimony-125 (^{125}Sb), cesium-137 (^{137}Cs), and strontium-90 (^{90}Sr) (Smith, Esser, and Thompson 1995). Radionuclides that would more likely be transported in the gas phase include ^{3}H, ^{85}Kr, ^{14}C, argon-37 (^{37}Ar), and argon-39 (^{39}Ar). Based on their initial estimated inventories, ^{3}H and ^{85}Kr are likely to be responsible for most of the radioactivity in the gas phase (Holzer 1970) and ^{3}H, ^{137}Cs, and ^{90}Sr are likely to be responsible for most of the potential Project Rulison-related radioactivity in formation water.

The re-entry well drilled into the nuclear chimney produced an estimated 455 million standard cubic feet (MMscf) of gas. The only gaseous radionuclides detected (Cooper et al. 2009) were ^{3}H, ^{85}Kr, ^{14}C, ^{37}Ar, ^{39}Ar, and mercury-203 (^{203}Hg). Analysis of gas produced during the tests (Smith 1971a; 1971b) indicates that the concentrations of ^{3}H, ^{85}Kr, and ^{14}C in the natural gas declined steadily throughout production testing, as shown in (Figure 6). These results indicate that some of the ^{3}H and the majority of the ^{85}Kr and ^{14}C produced during the explosion at Project Rulison were removed during the gas calibration flaring and production flow testing (AEC 1973), leaving ^{3}H as the most mobile radionuclide that remains in a sufficient quantity to pose a potential concern if released. ^{3}H occurs as both tritiated liquid water and water vapor which allows it to migrate as formation water or a gas phase. Comparison of the decay-corrected ^{3}H inventory (708 Curies [Ci]; (Table 1) with the decay-corrected inventories of ^{85}Kr (53 Ci) and ^{14}C (2.19 Ci) suggests that ^{3}H, if present in the chimney, is the most likely gaseous radionuclide that would be susceptible to transport from the cavity and detection during monitoring.

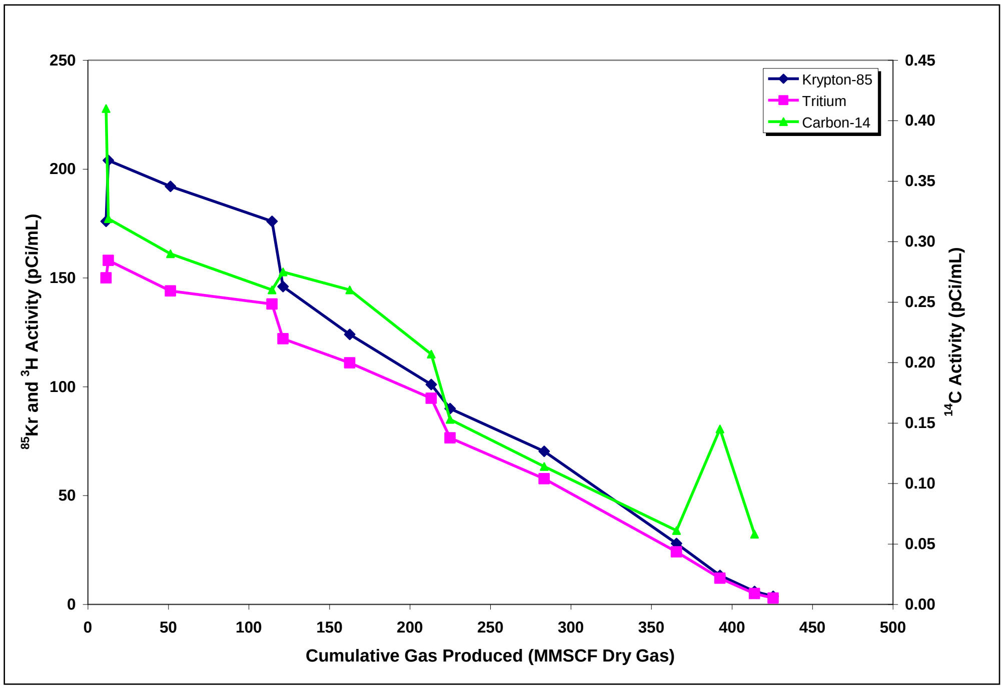

Figure 6. ^{3}H, ^{85}Kr, and ^{14}C Activities in Gas Produced from the Project Rulison Test Cavity.

The Project Rulison device emplacement well R-E and the re-entry well R-EX, were plugged and abandoned in September and October 1976 (IT Corporation 1996).

3 BASELINE ENVIRONMENTAL CONDITIONS

A review of both the historical and current environmental monitoring data developed as part of the many monitoring studies completed by the U.S. Geological Survey (USGS), AEC, DOE, the U.S. Environmental Protection Agency (EPA), the Colorado Department of Health, the Desert Research Institute (DRI), and operators prior to the RSAP (PRESCO) demonstrates that no release of radionuclides has occurred from Project Rulison, except during the natural gas calibration flaring and production tests following re-entry into the nuclear chimney in 1970 and 1971. A summary of some of these studies is provided below to define the historical and current environmental conditions near Project Rulison.

3.1 Historical Environmental Data

A number of historical Project Rulison environmental studies have been completed by the AEC (AEC 1973a; 1973b; 1977), DOE (DOE 1984; DOE 1994; IT 1996; DOE 2005; DOE 2007a and 2007b; DOE 2009 and 2010), ERDA (1977), EPA, and USGS (USGS 1969a; USGS 1969b; USGS 1970a; USGS 1970b; Classen 1971a; Classen 1971b; Classen and Voegeli 1971; Voegeli and Classen 1971a; and Voegeli and Classen 1971b). Past studies and evaluations have also been performed by the COGCC (COGCC 1998), the DRI (Earman, Chapman, and Andricevic 1996; Cooper 2004; Shirley 2005; Cooper et al. 2009), and energy companies working in the area (PRESCO 2006a; PRESCO 2006b; PRESCO 2007a; PRESCO 2007b; and PRESCO 2007c; URS 2008a; URS 2008b; URS 2009a; URS 2009b; URS 2009c; URS 2009d; URS 2010a; and URS 2010b). These studies have included the sampling and monitoring of environmental media (i.e., milk, air, soils, and water); characterization and cleanup of soils at the Project Rulison site; and radiation screening and sampling of drill cuttings and fluids, produced water, and natural gas from natural gas wells drilled within the area. A summary of these studies and their results is provided below.

3.1.1 USGS Studies

The USGS conducted a pre-shot inventory of wells and springs within a 6.2-mile radius of Project Rulison in May 1969 (USGS 1969b). A total of 29 wells or springs were sampled within this area and analyzed for background radionuclide activities. The USGS also established a network of 21 well, spring, or stream locations for post-shot monitoring of radioactivity. These post-shot locations were sampled ten days after the Project Rulison test; before, during, and after re-entry into the nuclear chimney; and following each of three gas production tests (USGS 1970a; Voegeli and Classen 1971a and 1971b; Classen and Voegeli 1971; Classen 1971a and 1971b). The pre-shot (background) results (USGS 1969; USGS 1970a; USGS 1970b) showed the following ranges of radionuclide activities in water in the Rulison area:

- Gross alpha – not detected (less than 0.4 pCi/L) to 18 picoCuries (pCi)/L (as natural uranium equivalent)
- Gross beta - not detected (less than 0.4 pCi/L) to 15 pCi/L (as strontium-90 (90Sr)-yttrium-90 (90Y) equivalent)
- 3H - not detected (less than 700 pCi/L) to 1,984 pCi/L.

The post-shot radionuclide activities in water were similar to the pre-shot results as shown below:

- Gross alpha - not detected (less than 0.4 pCi/L) to 15 pCi/L (as natural uranium equivalent)
- Gross beta - not detected (less than 0.4 pCi/L) to 31 pCi/L (as 90Sr-90Y equivalent)
- 3H - not detected (less than 700 pCi/L) to 2,100 pCi/L.

For comparison, present-day groundwater standards are 15 pCi/L (less the alpha contribution of natural uranium and radon) for gross alpha; 4 millirem per year (or a 50 pCi/L screening activity) for gross beta; and 20,000 pCi/L for ^{3}H.

The pre- and post-event water quality results confirmed that the Project Rulison test did not release any radionuclides to the environment that resulted in a significant increase in radioactivity in surface water or groundwater supplies (DOE 1984). The ^{3}H detected in groundwater and surface water prior to and after the Project Rulison test is largely the result of ^{3}H fallout from atmospheric thermonuclear bomb tests between 1950 and 1963 (Figure 7).

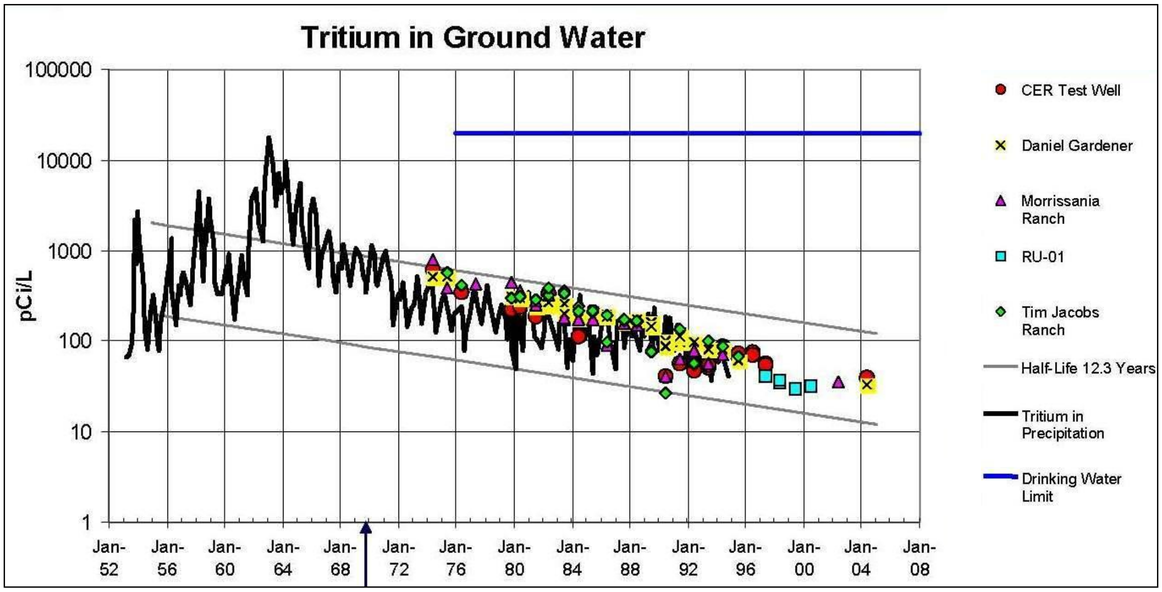

Figure 7. ^{3}H Activity in Precipitation at Ottawa, Ontario and in Water at Project Rulison (Ottawa ^{3}H data from IAEA/WMO 2004; graphic from DOE 2007b).

Most of the tritium found in present day groundwater and surface water is largely derived from the atmospheric testing of nuclear weapons in the 1950's and 1960's. (Figure 7) shows the ^{3}H activities in precipitation (black line) at Ottawa, Ontario, which are considered representative of general precipitation. A large increase of ^{3}H in precipitation occurred in 1963 because of the increase in atmospheric testing of nuclear weapons during this time. However, natural radioactive decay and a relatively short half-life for ^{3}H resulted in a decrease in ^{3}H activities after the cessation of most of the atmospheric testing of nuclear weapons in 1963 to the present-day activity of 50 pCi/L or less in waters. (Figure 7) also shows ^{3}H concentrations in water samples collected and analyzed by the DOE at some of the locations in the Rulison area after the detonation. These results are further discussed in Section 3.1.5.

^{3}H activities have also been monitored by the Companies in 2008 and 2009 in selected Rulison area water wells, springs, and streams. ^{3}H activities in these media have been less than the typical reporting concentration of 10 tritium units (TU; or approximately 32 pCi/L). The Colorado basic groundwater standard for ^{3}H is 20,000 pCi/L.

3.1.2 AEC and DOE Studies

Starting in 1969, environmental monitoring (air, soil, precipitation, groundwater, surface water, vegetation, and milk) was conducted by the AEC with support from the USGS and EPA prior to, during, and after the Project Rulison test. This monitoring included the following:

- Air monitoring was conducted at 22 air monitoring stations set up around Project Rulison
- An additional 25 air monitoring stations were set up during the calibration flaring test in 1970
- Monthly radiation exposures were measured at 20 thermoluminescence dosimeters (TLD) stations
- Fifteen milk- and eight vegetation- and fruit-sampling stations were established to determine if radiation was released into the ecosystem
- A 40-station water sampling network was monitored that included municipal supplies, private wells, reservoirs, springs, and streams to determine if radiation was released into the local water supply
- Natural gas samples were obtained from three producing wells within seven miles of the Project Rulison test and at the Project Rulison test well

The results of each of these monitoring studies demonstrated that no radioactive fission products attributable to Project Rulison were found in any of these media after the test (AEC 1973). The TLDs and film badges in the monitoring network showed no positive exposures. No radiation levels greater than background were detected at any of the off-site air-monitoring locations during calibration and gas production testing except for ^{3}H and ^{85}Kr, which were detected at activities above background but significantly below regulated levels. However, flow and pressure data collected during these tests suggest that most of the radioactive gas in the cavity was flared and that little or no radioactive gas remained in the cavity at the conclusion of testing.

Aerial monitoring of radioactivity was also performed during the detonation of the nuclear explosive, calibration flaring, and production testing to determine whether a release of

^{3}H or ^{85}Kr to the atmosphere occurred during the detonation. The results of the aerial monitoring indicated that no radioactivity was released directly from the cavity to the atmosphere during the detonation (AEC 1973). This monitoring also determined that the activities and rate of atmospheric dispersion of these radionuclides released during post-detonation calibration flaring and production testing posed no health threat (AEC 1973).

The AEC characterized, removed, and shipped 3,000 gallons of decontamination liquids and solids contaminated with ^{3}H from the Project Rulison site during an initial site cleanup in July 1972. These materials were shipped off-site to Beatty, Nevada for permanent disposal. Three liquid storage tanks, the wellhead and logging equipment, a separator, and two hydrocarbon storage tanks were left on-site for future production use. In September 1976, the R-E and R-EX wells were plugged and abandoned, and the remaining surface equipment was dismantled, decontaminated, and removed from the test site. Additional ^{3}H-contaminated soils and other solid waste were shipped off-site for permanent disposal during the final cleanup. No burial of radioactive solids occurred at the Project Rulison site. A final beta-gamma radiation survey was conducted at the site in 1976 and found no radioactivity above ambient background (DOE 1984; IT 1996).

The DOE initiated preliminary characterization studies at Project Rulison in 1994 to identify known or suspected areas of contamination in the drilling effluent pond and mud pits at the test site. The characterization results indicated that petroleum hydrocarbon- and chromium-contaminated soils existed in soils at the drilling effluent pond and mudpits used during the drilling operations. In 1996, DOE voluntarily cleaned up the contaminated effluent pond and mudpits at the historical drilling and production site. Its closure was subsequently approved by the CDPHE.

In August, 1997, the DOE collected natural gas samples from five producing gas wells near Project Rulison. The wells sampled were located between 3 and 7 miles from the Project Rulison site. The closest well sampled was Federal 28-95. The samples were analyzed at the Lawrence Livermore National Laboratory for ^{3}H, ^{85}Kr, and ^{14}C. The results of the analyses at all five producing wells were below the lower limit of detection for these analytes and confirmed that no Project Rulison-related radioactivity was present in the natural gas from these wells.

The DOE has also simulated the transport of ^3H from the nuclear cavity (Earman et al 1996; Cooper 2004; DOE 2007b; and Cooper et al. 2009). The modeling studies predicted that ^3H is not likely to migrate from the cavity to a hypothetical producing gas well at concentrations above any action level or standard.

DOE issued a Rulison path forward document (DOE 2010a) that discusses recommendations for natural gas development in the area. DOE recommends adoption of a conservative, staged drilling approach that will allow gas reserves near Project Rulison to be recovered in a manner that minimizes the likelihood of encountering radioactive contamination that may be present in the subsurface beneath Lot 11. The proposed path forward approach includes sampling and analysis of gas wells outside of the ½-mile monitoring radius to verify that Project Rulison-related radionuclides are not present, and a proposal that drilling and radiological testing proceed from beyond the ½-mile radius towards Project Rulison. DOE states that they do not encourage drilling within the ½-mile radius until sufficient radiological and other data have been collected outside the ½ -mile radius, particularly along the predominant east-west trending structural grain. DOE reported that microseismic mapping in a portion of the Rulison Field 6 to 8 miles northeast of the Rulison site revealed a fracture orientation of N75°W, with a local range of plus or minus 10 degrees (Wohlart et al. 2005). Other nearby data were consistent with this. DOE assumes that a fracture orientation of N75°W applies to the area surrounding the Rulison site.

The DOE conducts a monitoring program in accordance with a plan (DOE 2010b) for radionuclides in fluids from gas wells that would indicate contamination is migrating from the Rulison detonation zone into producing gas wells. This is designed to allow action to be taken before the contamination could pose a health risk. The plan lists the contaminants of concern, transport pathways, sample frequency, sample media and analytes. Results of monitoring program are routinely published and available on the DOE Legacy Management website (http://www.lm.doe.gov/rulison/Sites.aspx). No indication of release of Rulison-related radionuclides has been detected under this program.

DOE (2013) reported on updated numeric modeling of Project Rulison gas flow and contaminant transport to test past, current and future scenarios. New computational capability allowed the domain included in the model to be extended, including the existing gas production wells 0.75 mile west of the site. This study confirmed the results of the previous modeling efforts and predicts that the contamination, in the form of tritiated water, is contained with the boundary of Lot 11 and that future gas well production in adjacent areas will not change this.

3.1.3 Colorado Department of Health

The Colorado Department of Health, predecessor agency to the Colorado Department of Public Health and Environment (CDPHE), performed monitoring similar to that described in Section 3.1.2 prior to, during, and after the Project Rulison test. The Colorado Department of Health results for the various media were all within the range of background except for one atmospheric moisture sample collected during the second production test, which showed ^{3}H activities slightly above background.

3.1.4 DOE Studies (combined with Section 3.1.2 in this revision)

3.1.5 EPA Studies

Beginning in 1972, the EPA has been performing annual water sampling at 13 well, spring, or stream locations in the area of Project Rulison, on behalf of the DOE. These locations have typically included the Grand Valley municipal springs, eight ranch wells, one test well, two springs, and Battlement Creek. Water samples collected from these locations are routinely analyzed for ^{3}H and gamma-emitting radionuclides by spectroscopy. The EPA results have found measurable ^{3}H activities consistent with the activities found in worldwide precipitation (Figure 7) but have found no man-made, gamma-emitting radionuclides above their minimum detectable activity (MDA).

The EPA concluded in its 2004 report (EPA 2004a) that “Tritium concentrations in water samples collected onsite and offsite are consistent with those of past studies at the Project Rulison test site. In general, the current level of tritium in shallow wells at the Project Rulison site cannot be distinguished from the rain-out of naturally produced tritium augmented by, perhaps, a small amount of residual global ‘fallout tritium’ remaining from nuclear testing in the 1950s and 1960s.”

3.1.6 COGCC Studies and Policies

The COGCC collected water samples from Rulison area wells and springs in 1997 and 1998. These samples were analyzed for a variety of parameters including volatile organic compounds, inorganic compounds, and water quality parameters. The COGCC did not analyze any of the water samples for radiological parameters.

In 1998, the COGCC (COGCC 1998) reviewed the available information regarding Project Rulison to ensure that the COGCC's decisions regarding permitting of natural gas wells in the Battlement Mesa area near Project Rulison would be protective of public health, safety, and welfare. The COGCC concluded that there was an "extremely low probability of encountering gas with radiation activity due to the limited radius of the chimney cavity and fracture zone created by the nuclear detonation, the limited areal extent of the sandstone lenses within the Williams Fork Formation, and the lack of remaining contaminated gas following the extensive production testing of the re-entry well in 1970 and 1971." Based on its review, the COGCC stated that drilling of natural gas wells should not be permitted inside of Lot 11, but that natural gas drilling could be permitted outside of that area.

Although COGCC staff concluded that natural gas drilling could be permitted outside of Lot 11, the COGCC itself informally established a 3-mile radius zone, based on the fact that no existing gas well was closer than 3 miles. As part of this informal policy, DOE will receive a courtesy notification concerning any future APDs within 3 miles of the detonation site.

In 2004, COGCC Cause No.139-43 formally established the provision that any APD for a well within a half-mile of the detonation site would require a full COGCC hearing prior to issuance.

3.1.7 Desert Research Institute Studies

Desert Research Institute (DRI) sampled five producing gas wells near Project Rulison in May 2005 (Shirley 2005). The wells sampled (28-31 S. Parachute Federal, 15-34 Clem-Warren, 11-43 Bentley, 11-34 Bentley, and 10-11 Savage) are located about 3 miles west and northwest of the Rulison test site and are owned by EnCana. The gas samples collected were analyzed for ^{3}H and ^{14}C by Isotech Laboratories of Champaign, Illinois. The results of the analyses (DRI 2005) indicated that ^{3}H and ^{14}C in the gas samples were less than the MDAs (i.e., not detected). The MDA for ^{3}H was 10 tritium units (TU) or approximately 32 pCi/L. The ^{14}C detection limits ranged between 0.6 and 0.7 percent modern carbon (pMC).

The DOE sponsored DRI to a conduct a screening assessment of potential health risks from future natural gas drilling near Rulison (Daniels et al 2011). This assessment evaluated possible health risks from exposure to Rulison contaminants to inform decisions regarding institutional controls, appropriate monitoring of nearby natural-gas extraction activities, and appropriate action levels for contaminant monitoring to ensure protection of human health. Although no release of Rulison related radioactivity is expected, the health risk was evaluated assuming a hypothetical release. The exposure scenario for both workers and a nearby resident involves inhalation and dermal exposure of tritium in the form of tritiated water vapor. A worker could also experience occasional dermal exposure to liquid water containing tritium. A very conservation assumption was made that the tritiated water vapor concentrations in the vicinity would be the same as those observed in 1970 and 1971 when approximately 3000 Ci (DOE 2011b) of tritium (30% of the estimated 10,000 Ci) was removed during production testing. This is a conservative assumption because, as shown in (**Table 1**), only 760 Ci (7.6%) of the tritium present in 1970 still exists at the subsurface site. For workers the estimated excess risk of contracting fatal or non-fatal cancer due to this exposure is risk 3×10^{-8} (3 cases per 100,000,000 workers). For nearby residents the estimated excess risk of contracting fatal or non-fatal from cancer due to this exposure is risk 2×10^{-8} (2 cases per 100,000,000 people). These are exceptionally low risks when compared to risks that are routinely accepted in daily life. For comparison the National Safety Council (2015) reports that the lifetime risk of dying in a motor vehicle crash is 1 death per 112 people (8.83×10^{-3}).

3.1.8 PRESCO Studies

PRESCO Inc. (PRESCO), a former natural gas leaseholder in the area, performed baseline monitoring of water resources (e.g., springs, streams, and wells) in 2004, prior to the initiation of natural gas drilling near Project Rulison. Sampling was conducted by Cordilleran Compliance, and the samples were analyzed by Paragon Analytics, Isotech Laboratories, Evergreen Analytical Laboratory, Grand Junction Laboratories, Inc., and ACZ Laboratories. The annual water monitoring program consisted of 14 locations, some of which were previously sampled by the EPA, USGS, and COGCC. The samples were analyzed for petroleum hydrocarbons, water quality parameters, bacteria, and ^{3}H and gamma-emitting radionuclides. PRESCO sampled these same locations in 2005 and 2006 as part of its annual water quality evaluation. The results of these sampling events are presented and summarized in reports presented to the COGCC (PRESCO 2006a; 2006b; 2007a; 2007b; 2007c). The radionuclide results for all three sampling events indicated that ^{3}H and gamma-emitting radionuclides were less than their respective detection limits, except for naturally occurring radionuclide daughter products of uranium and thorium.

As part of its monitoring program, PRESCO also monitored its personnel and the ambient environment using TLDs while drilling new gas wells (i.e., BM26-42, BM36-13, BM36-23, and BM34-24) in the area. Drill cuttings obtained during drilling were also screened for evidence of Rulison-related radiation using hand-held radiation survey instruments. The TLD badges showed no positive radiation exposures. The radiation levels measured on drill cuttings obtained while drilling new gas wells was within background limits.

PRESCO also sampled three of its producing gas wells (i.e., BM26-42, BM27-44, and BM36-13; Figure 8) in December 2005 and January 2006. Gas wells BM 26-42 and 36-13 were sampled again in April and May 2006, respectively. The natural gas samples were analyzed for ^{3}H and ^{14}C. The produced water samples were analyzed for ^{3}H and gamma-emitting radionuclides. ^{3}H and ^{14}C were not detected in the gas samples. ^{3}H and gamma-emitting radionuclides were also not detected in the produced water samples, except for potassium-40 (^{40}K), which is a naturally occurring radionuclide.

3.2 Current Environmental Conditions

Noble acquired the PRESCO interest in 2007 and immediately sampled produced water and natural gas at seven of its producing gas wells in May 2007. The wells sampled included BM26-42, BM27-44, BM34-4, BM34-24, BM35-12, BM36-13, and BM36-23).

Figure 8. Initial Tier I Monitoring Zones. (Deleted)

These wells are located between approximately 0.7 and 1.7 miles from Project Rulison. Sampling was conducted by URS Corporation personnel, and the samples were analyzed by Paragon Analytics of Fort Collins, Colorado. The produced water samples were analyzed for ^{3}H, gross alpha, gross beta, and gamma-emitting radionuclides by spectroscopy, ^{129}I, and ^{99}Tc. The natural gas samples were analyzed for ^{3}H and ^{14}C.

Laboratory analytical results indicated no detections of ^{3}H, ^{99}Tc, ^{129}I, or Project Rulison-related gamma-emitting radionuclides in produced water at any of the gas wells. Gross alpha in the produced waters ranged between not detected and 29 pCi/L. Gross beta ranged between not detected and 82 pCi/L. ^{3}H was also not detected (< 48 pCi/L) in the methane component of the natural gas samples. Methane concentrations in the gas samples ranged between 88 and 93 percent. ^{14}C was also not detected in the natural gas samples; ^{14}C in all samples was less than the detection limit of 0.5 pMC. Noble also monitored the Williams Fork Formation interval for radiation on a 24-hour, seven-days-a-week basis while drilling two new gas wells (i.e., BM35-21D and BM35-32A) during the summer of 2007. The monitoring consisted of passive ambient radiation monitoring using environmental dosimeters; screening of the well pad area, drill rig work areas, and drill cuttings using hand-held radiation survey instruments; and screening of drilling fluids for ^{3}H using a portable field liquid scintillation counter. Composite drill cuttings and water samples were also submitted for laboratory analysis.

The results of these monitoring activities indicated that no confirmed radiation exposures above background occurred during drilling and that radiation screening and laboratory analysis of drill cuttings and fluids showed no evidence of Rulison-related radionuclides. Background levels of naturally occurring radionuclides were found in the well pad soils and in the drill cuttings and fluids at activities of no concern. The most abundant radionuclide found in site soils and drill cuttings was ^{40}K, with much lesser activities of radioactive daughter products of naturally occurring uranium-238 and thorium-232.

The Noble radionuclide monitoring plan evolved into the RSAP. Data on all samples that have been collected in accordance with the RSAP are available on line in the COGCC library which can be found at http://cogcc.state.co.us/library.html#/areareports.

The results of analyses conducted in accordance with the RSAP have not found any evidence of verified Project Rulison-related radionuclides in either the produced waters, natural gases, or drill cuttings from wells as close as ½- mile to the site.

3.3 Conclusions

Review of the results of the various monitoring studies completed by the USGS, AEC, DOE, EPA, DRI, PRESCO, and Noble shows that no known release of radionuclides has occurred from Project Rulison, except during the natural gas calibration flaring and production tests following re-entry into the nuclear chimney. Monitoring by the AEC and others during these test activities between 1969 and 1971 indicated that ^{3}H and ^{85}Kr were significantly below regulated levels during these periods. Residual radionuclides released during re-entry drilling were excavated and shipped off-site as part of the site cleanup efforts between 1972 and 1976. During early 1990s, the former mud pits were characterized and properly remediated and the closure was subsequently approved by the CDPHE. Overall, the monitoring performed prior to, during, and after the Project Rulison test has demonstrated that radionuclide activities in natural gas, produced water, drill cuttings and environmental media sampled over almost five decades since the test, are within background ranges or are naturally-occurring radionuclides that are found in the geologic formations. These monitoring studies have demonstrated that gas production has not resulted in the migration of Project Rulison-related radionuclides outside of the Project Rulison test cavity beneath Lot 11 to producing gas wells outside of Lot 11.

4 MONITORING APPROACH

A two-tiered (Tier I and II) operational and areal environmental monitoring program to support gas exploration and production within a 3-mile radius of the Project Rulison device emplacement well R-E has been implemented in prior versions of this plan. In this revision, the boundary of the Tier II zone has been adjusted to take advantage of knowledge regarding subsurface fracture patterns. The areal environmental monitoring program has been eliminated because there is no credible transport means, other than through natural gas production that can transport Rulison contaminants to the surface. The objectives of the operation monitoring program are to monitor the drilling, completion, and production operations and the local water supply quality so that workers, the public, and the environment are protected from an unlikely radiological release from gas drilling, completion, and production near Project Rulison.

The two operational monitoring tiers (Figure 2) are defined based on distance from the Project Rulison device emplacement well R-E. They are divided into 12 sectors. This RSAP defines the monitoring requirements for the operational monitoring program and provides sampling procedures, analytical methods, and QA/QC requirements for selected analytes that will be used to screen for potential Project Rulison-related radionuclides that may or may not be associated with Project Rulison. The specifics of each monitoring component are discussed below and summarized in (**Table 2**).

In this revision of the RSAP, Tier I boundary is unchanged. It is set at 1 mile radius from the Project Rulison device emplacement well R-E. The Tier II boundary is redefined to take advantage of knowledge of the fracture orientation pattern and insights from subsurface modelling (DOE 2010) that have developed since the RSAP was initially published. Tier II boundary now is elliptically shaped with the major (long) axis aligned with the average fracture orientation of N75°W. The distance from the origin (emplacement well R-E) to the farthest point on the major axis of the ellipse is 2 miles. The minor (short) axis of the ellipse is perpendicular to the long axis and the distance from the origin to boundary is 1.5 mile.

The operational monitoring program is designed to screen gas drilling, completion, and production activities for verified Project Rulison-related radionuclides within the Tier I and II monitoring zones (Figure 2) to protect workers, the public, and the environment. For the purposes of this RSAP, a verified Project Rulison-related radionuclide is a radionuclide that is:

- characteristic of a nuclear fission detonation
- whose half-life is greater than 10 years
- whose activity is above background
- whose presence is determined to be valid.

Because of its relative abundance, mobility in the environment and excellent detectability in laboratory samples, elevated tritium concentration in produced water or natural gas is expected to be the earliest and most sensitive indicator of a Rulison-related radionuclide release.

Table 2. Tier I and II Sampling and Analysis Scheme for Gas Wells Near Project Rulison.

Monitoring Activity	**Tier I Zone (Up to 1 Mile Radius from Project Rulison)**	**Tier II Zone (An elliptical region outside Tier I, aligned with fracture patterns of the formation)**
Drilling new wells	• Perform a one-time background radiation survey at the well pad after grading, but prior to drilling of the closest designated gas well within each Tier I monitoring sector. • Sampling and analysis of drilling mud for the radiological analytes listed in (Table 3) shall be performed prior to introduction into the well bore at the closest designated gas well within each Tier I monitoring sector. • Perform sampling and analysis of two composite samples of drill cuttings from intervals of the Williams Fork Formation equivalent to the Project Rulison test horizon at the closest new gas well within each monitoring sector, **except sectors 3 and 4 where Tier I monitoring will be implemented for the first four Tier I wells drilled within these sectors (Section 4.1.1)**. Samples shall be analyzed for the radiological analytes listed in (Table 3). Sample results shall be reviewed by a third-party consultant independent of the Companies. The cuttings can be transported, re-used, or disposed without approval from the COGCC if verified Project Rulison-related radionuclides are less than the screening levels (• • • Table 5). If verified Project Rulison-related radionuclides are equal to or greater than the screening levels, the cuttings cannot be transported, re-used, or disposed without prior written approval from the COGCC. A Notice of Intent to transport, re-use, or dispose of drill cuttings with verified Project Rulison-related radionuclides equal to or greater than the screening level shall be submitted to the COGCC for approval.	• If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), perform composite sampling and analysis of drill cuttings stored on the well pad from the closest designated well drilled within each monitoring sector. The sample shall be analyzed for the radiological analytes listed in Table 3. Sample results shall be reviewed by a third-party consultant independent of the Companies. The cuttings can be transported, re-used, or disposed without approval from the COGCC if verified Project Rulison-related radionuclides are less than the screening levels (Table 5). If verified Project Rulison-related radionuclides are equal to or greater than the screening levels, the cuttings cannot be transported, re-used, or disposed without prior written approval from the COGCC. A Notice of Intent to transport, re-use, or dispose of drill cuttings with verified Project Rulison-related radionuclides equal to or greater than the screening level shall be submitted to the COGCC for approval. • If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well) or is projected to be laterally within 200 feet of the Tier I boundary (1-mile radius), perform a high accuracy gyroscopic directional wellbore survey after reaching total well depth but prior to commencing perforation and completion activities for wells. Alternatively, a magnetic survey may be performed in lieu of a gyroscopic survey as long as Tier I monitoring is performed for the respective well(s). .

Table 2. Tier I and II Sampling and Analysis Scheme for Gas Wells within a Three-Mile Radius of Project Rulison.

Monitoring Activity	Tier I Zone (Up to 1 Mile Radius from Project Rulison)	Tier II Zone (An elliptical region outside Tier I, aligned with fracture patterns of the formation)
Drilling new wells (continued)	• Review open- or cased-hole gamma logs through the Williams Fork Formation for evidence of gamma radiation that might be related to Project Rulison. • Perform a high accuracy gyroscopic directional wellbore survey after reaching total well depth but prior to commencing perforating and completion activities for wells whose bottom-hole location is projected to be laterally within 200 feet of the ½-mile boundary to verify that the wellbore did not penetrate the ½-mile boundary. .	• If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), review open- or cased-hole gamma logs through the Williams Fork Formation for evidence of elevated gamma radiation that might be related to Project Rulison.
Completion of new wells	• Conduct sampling and analysis of fracing fluids at the closest designated gas well within each monitoring sector. Samples shall be analyzed for ^{3}H and reported to the COGCC in the quarterly monitoring reports. This provides a baseline for comparison to concentration of ^{3}H in flowback fluids. • Perform sampling and analysis of flowback fluids at the closest designated gas well within each monitoring sector. Samples shall be analyzed for ^{3}H. Flowback fluid results shall be reviewed by a third-party consultant independent of the Companies. Flowback fluids can be transported, re-used, or disposed without approval from the COGCC if ^{3}H is less than the screening level (• • • Table 5). If ^{3}H is equal to or greater than the screening level, flowback fluid results shall be reviewed and approved by the COGCC before the fluids can be transported, re-used, or disposed. A Notice of Intent to transport, re-use, or dispose of flowback fluid with ^{3}H equal to or greater than the screening level shall be submitted to the COGCC for approval.	• If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), perform sampling and analysis of fracing fluids prior to introduction into the well bore. Samples shall be analyzed for ^{3}H and reported to the COGCC in the quarterly monitoring reports. This provides a baseline for comparison to concentration of ^{3}H in flowback fluids • If a Tier II well is the closest designated gas well in a monitoring sector (i.e., no Tier I well), perform sampling and analysis of flowback fluids. Samples shall be analyzed for ^{3}H. Flowback fluid results shall be reviewed by a third-party consultant independent of the Companies. Flowback fluids can be transported, re-used, or disposed without approval from the COGCC if ^{3}H is less than the screening level (Table 5). If ^{3}H is equal to or greater than the screening level flowback fluid results shall be reviewed and approved by the COGCC before the fluids can be transported, re-used, or disposed. A Notice of Intent to transport, re-use, or dispose of flowback fluid with ^{3}H equal to or greater than the screening level shall be submitted to the COGCC for approval.

Table 2. Tier I and II Sampling and Analysis Scheme for Gas Wells within a Three-Mile Radius of Project Rulison.

Monitoring Activity	**Tier I Zone (Up to 1 Mile Radius from Project Rulison)**	**Tier II Zone (An elliptical region outside Tier I, aligned with fracture patterns of the formation)**
Production from new and existing wells	• Perform one-time sampling and analysis of produced water for radiological analytes in (Table 3) and natural gas for the radiological analytes listed in (Table 3) as soon as possible after fracing but no later than 30 days after the first gas delivery from a **new** well. • Perform quarterly sampling and analysis of produced water and natural gas at all **new** Tier I gas wells regardless of whether they are the closest designated well during Year 1 for the radiological analytes listed in (Table 3). • For the closest designated Tier I gas well in each monitoring sector, sample and analyze produced water and natural gas for the radiological analytes listed in (Table 3) quarterly during Year 1, semiannually during Years 2 and 3, and annually thereafter.	• If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), perform one-time sampling and analysis of produced water for the radiological analytes in (Table 3) and natural gas for the radiological analytes listed in Table 3 as soon as possible after fracing but no later than 30 days after the first gas delivery from a **new** gas well. • If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), produced water and natural gas shall be sampled and analyzed for the radiological analytes listed in Table 3 quarterly during Year 1, semiannually during Years 2 and 3, and annually thereafter. • Further testing contingent on the occurrence of verified Project Rulison-related radionuclide in Tier I gas wells.
Plugging and Abandonment of new and existing wells	• P&A monitoring requirements shall be determined on a case-by-case basis by the Companies and the COGCC based on available analytical data.	• P&A monitoring requirements will be determined on a case-by-case basis by the Companies and the COGCC based on available analytical data.

Table 3. Radiological Analyte List.

Sample Medium	Tritium (^{3}H)	Carbon-14 (^{14}C)
Natural Gas	yes	yes[2]
Produced Water	yes	no
Drilling Mud[1]	yes	no
Drill Cuttings or soil[1]	yes	no
Fracing Fluid	yes	no
Flowback Fluid	yes	no

Note 1: Water from this sample type is distilled and counted for tritium concentration using liquid scintillation methods. The results are reported in pCi/L in the distilled water.
Note 2: The methane analyzed is separated using molecular sieves from other hydrocarbon and gas (e.g., CO2) constituents that naturally occur in the natural gas. The separated methane is combusted to form carbon dioxide (CO2) that is captured for 14C analysis.

Table 4. Non-Radiological Analytes DELETED

4.1 Tier I Monitoring

Information in the section is summarized in (**Table 2**).

Tier I operational monitoring will be conducted at gas wells situated within the Tier I boundary. Tier I monitoring is designed to screen for the presence of verified Project Rulison-related radionuclides that may be encountered, regardless of how they are transported to a well, during gas drilling, completion, and production operations within the Tier I monitoring zone. The selected radionuclide analytes for various media are listed in (Table 3). The radiological analytes were selected because they provide radionuclide-specific data for the leading indicators (tritium and carbon-14) of Project Rulison-related radionuclides that might be transported in the subsurface fluids. Gross alpha/beta screening, which had been required in prior revisions, does not provide useful information because ubiquitous naturally-occurring radionuclides, such as uranium and thorium, produce positive results in this non-specific analysis method.

Tier I monitoring includes:

- Drilling monitoring
- Completion monitoring
- Production monitoring
- Plugging and Abandonment (P&A) monitoring.

Specifics of each of these monitoring activities are discussed below.

4.1.1 Tier I Drilling Monitoring

Tier I drilling monitoring shall be conducted **at the closest designated well in each Tier I monitoring sector, except sectors 3 and 4 (see below)**, to screen for the presence of verified Project Rulison-related radionuclides that might be encountered during gas drilling operations. The closest designated well is defined as the closest well within each Tier I monitoring sector whose bottom hole location is nearest to the Project Rulison device emplacement well R-E. If a new well is drilled within a Tier I monitoring sector whose bottom hole location is closer than a previously drilled well, then the new, closer well will be monitored.

Tier I drilling monitoring in monitor sectors 3 and 4 shall be implemented for the first four Tier I monitoring wells drilled within each sector regardless of whether they are the closest designated well. Tier I sectors 3 and 4 currently have no gas wells within them and are oriented along the predominant east-west trending geological structures in the area that would provide the most likely conduit for the migration of Project Rulison-related radionuclides. Once four Tier I wells have been completed in monitoring sectors 3 and 4, Tier I drilling monitoring shall only be conducted at the closest designated well in these sectors.

A 200-foot horizontal bottom hole location variance relative to the distance from the Project Rulison device emplacement well R-E is allowed in determining whether a well is deemed the closest designated well within each monitoring sector. Thus, if the bottom hole locations of two or more wells are within 200 horizontal feet or less relative to their distance from the Project Rulison device emplacement well R-E, the Companies can specify any one of these wells as the closest designated well to streamline regulatory responses and to minimize excessive submittals of laboratory data for wells whose bottom hole locations are a similar distance from the Project Rulison device emplacement well R-E and within the same monitoring sector.

To allow the Companies to streamline drilling operations, such as batch drilling and cementing surface casings prior to drilling a Tier I production hole, Tier I drilling monitoring shall be implemented during production drilling beneath the surface hole casing depth. This will facilitate establishing background radiation levels prior to entering the Williams Fork Formation while providing some degree of flexibility in planning drilling patterns. In practice, once production drilling is initiated, the Tier I monitoring activities discussed below will be implemented.

Tier I drilling monitoring activities include:

- A one-time background radiation survey shall be performed at each new Tier I well pad after it is graded but prior to drilling the first production hole on the well pad. The background radiation screening will be performed as described in Section 5.3.2.
- A closed loop mud system, or equivalent, shall be used to ensure containment of all drilling materials that have been in contact with downhole strata and fluids. All

drill cuttings, reserve, and fresh make-up water storage pits shall be lined to ensure containment. Stormwater best management practices (BMPs), such as surface contouring, drains, etc., shall be employed, as necessary, to ensure fluid containment and overall site integrity.

- Samples of drilling fluid (i.e., drilling mud) shall be collected prior to introduction into the borehole for laboratory analysis of selected radionuclides. The drilling fluid shall be analyzed for the radiological analytes listed in (Table 3). The results of these analyses will be used to determine whether any of the radiological constituents detected may have been introduced with the drilling fluid.
- Two composite samples of drill cuttings shall be collected and analyzed for the radiological analytes listed in (Table 3). The composite samples shall be collected from two intervals that are approximately equivalent (corrected for dip and distance) to the Project Rulison test interval by the Companies field representative in accordance with the procedures described in Section 5.7. The two intervals sampled shall include:

    An interval between about 750 feet (+478 ft msl) and 250 feet (-22 ft msl) above the approximate elevation of the Project Rulison test interval (approximately -272 ft msl)

    An interval between about 250 feet above (-22 ft msl]) and 250 feet below (-522 ft msl) the approximate elevation of the Project Rulison test interval (approximately -272 ft msl)

Drill cuttings from the closest designated well in each monitoring sector shall be analyzed for the radiological constituents listed in (Table 3) to confirm compliance with the RSAP. Sample results shall be reviewed by a third-party consultant independent of the Companies. The cuttings can be transported, re-used, or disposed without approval from the COGCC if verified Project Rulison-related radionuclides are less than the screening levels in (

- Table 5). A letter, including the data validation report and qualified data sheets, along with a Sundry Notice Form 4 shall be submitted to the COGCC to document the drill cuttings results and demonstrate compliance with the RSAP. If verified Project Rulison-related radionuclides are equal to or greater than the screening levels in (Table 5), the drill cuttings cannot be transported, re-used, or disposed without prior written approval from the COGCC. A Notice of Intent to transport, re-use, or dispose of drill cuttings with verified Project Rulison-related radionuclides equal to or greater than the screening level (Table 5) shall be submitted to the COGCC for approval. The Notice of Intent shall include a letter, including the data validation report and qualified data sheets, which summarizes and discusses the results as an attachment.

- Open- or cased-hole gamma-ray logs through the Williams Fork Formation interval shall be run after each hole is completed and reviewed to determine whether Project Rulison-related gamma radiation was encountered in the hole, its depth, and activity. A gamma radiation measurement greater than 500 American Petroleum Institute (API) gamma log units or any other gamma readings that appear to be anomalously high will be noted and immediately reported to Company management and the RSO for review and guidance. The Companies will immediately inform the COGCC, CDPHE, and DOE of any verified Project Rulison-related radiation incident.
- A high accuracy gyroscopic directional wellbore survey shall be performed after reaching the total wellbore depth but prior to commencing perforation and completion activities for wells whose bottom-hole location is projected to be laterally within 200 feet of the ½-mile monitoring radius to verify that the wellbore did not penetrate the ½-mile boundary. A copy of the directional drilling survey report, including a map view and a vertical profile view showing the wellbore trajectory and the distance from the ½ mile Project Rulison monitoring radius, along with a Sundry Notice Form 4 shall be submitted to the COGCC. The operator shall obtain approval in writing from the COGCC prior to commencing casing perforation and other completion activities.

4.1.2 Tier I Completion Monitoring

Tier I completion monitoring will be conducted **at the closest designated well in each Tier I monitoring sector** to screen for the presence of verified Project Rulison-related radionuclides that might be encountered in flowback fluids (i.e., produced waters) during gas well completion operations. The flowback fluids shall be contained in tanks only. The Companies shall submit a secondary and tertiary containment plan via Sundry Notice Form 4 for the tanks. If the COGCC has not objected to or requested additional information within 10 business days of a Company's filing of a Sundry Notice Form 4, the Company may proceed with fracing and flowback operations.

Ambient radiation monitoring shall be performed using dosimetry in personnel work areas to measure ambient radiation (other than ^{3}H) that could conceivably be released during fracing of the closest designated Tier I gas well in each monitoring sector. Passive or electronic radiation dosimeters shall be placed at the well pad prior to fracing and remain until flowback is completed. The dosimeters shall be placed near the well undergoing fracing and near fluid discharge locations on each well pad to measure cumulative radiation intensities to which personnel are exposed. One dosimeter shall be placed in a location away from the drilling activities on the well pad to measure the background radiation dose. The dosimetry shall be performed as discussed in Sections 4.1.1 and 5.4.

Samples of introduced fracing fluids (prior to use) and recovered flowback fluids shall be collected for laboratory analysis of selected radionuclides. The samples shall be collected in accordance with the procedures described in Section 5.8. The fracing and flowback fluids shall only be analyzed for ^{3}H to screen for the most likely verified Project Rulison-related radionuclide in these fluids. The results of the analyses shall be used to determine whether ^{3}H may have been introduced during fracing or to determine whether ^{3}H is present in the recovered flowback fluids.

Flowback fluid results shall be reviewed by a third-party consultant independent of the Companies, prior to transport, re-use, or disposal. Flowback fluids may be transported, re-used, or disposed without written approval from the COGCC if ^{3}H is less than the ^{3}H screening level provided in Table 5. A letter, including the data validation report and qualified data sheets, along with a Sundry Notice Form 4 shall be submitted to the COGCC to document the flowback fluid results and demonstrate compliance with the RSAP.

If ^{3}H is equal to or greater than the ^{3}H screening level (Table 5), flowback fluid results shall be reviewed and approved in writing by the COGCC before the flowback fluids can be transported, re-used, or disposed. A Notice of Intent to transport, re-use, or dispose of flowback fluids with verified Project Rulison-related radionuclides greater than the screening level (

Table 5) shall be submitted to the COGCC for approval. The Notice of Intent shall include a letter, including the data validation report and qualified data sheets that summarizes and discusses the results as an attachment. In either case, the ^{3}H results will be submitted to the COGCC to demonstrate compliance with the RSAP.

Once flowback fluids from the closest designated well have been demonstrated to contain ^{3}H at background concentrations or less, all subsequent flowback fluids generated in outlying wells in that monitoring sector can be transported, disposed, or re-used without additional laboratory analyses or COGCC approval.

4.1.3 Tier I Production Monitoring

Tier I production monitoring will be conducted to screen for the presence of verified Project Rulison-related radionuclides in natural gas or produced water in existing or new gas wells. Tier I production monitoring activities include:

- One-time sampling of produced water and natural gas shall be performed at all new Tier I gas wells as soon as possible after fracing, but no later than 30 days of the first gas delivery from a new well. Sampling of new gas wells within the first 30 days of delivery, rather than during the flowback period, provides a more representative sample of the actual formation water and gas, because the fracing fluid component remaining in the well will continue to decrease during the first 30 days of production. The produced water samples shall be analyzed for the radiological analytes listed in (Table 3). The natural gas samples shall be analyzed for the radiological analytes listed in (Table 3). For a new gas well that is the closest designated well within a Tier I monitoring sector, ^{3}H analyses of produced water samples shall be analyzed on a rapid turnaround basis (i.e., approximately 14 days or less). The samples will be submitted to an accredited laboratory for analysis. The samples shall be collected in accordance with the procedures described in Sections 5.9 and 5.10.

Following the initial (30 day) sampling, all new Tier I gas wells shall be sampled and analyzed quarterly for verified Project Rulison-related radionuclides (Table 3) during their first year (Year 1) of production **regardless of whether they are the closest designated well**.

- For the **closest designated gas well** to Project Rulison within each of the 12 Tier I sectors, sampling and analysis of produced water and natural gas shall be performed quarterly during Year 1 (as described above), semiannually during Years 2 and 3, and annually thereafter. The sampling frequency is based on the anticipated annual gas production at a well, which declines rapidly during the first few years of a well's life. The specified sampling frequency is essentially monitoring approximately 5-percent increments of cumulative gas production over a well's 20- to 30-year anticipated life span. Monitoring is more frequent on a time basis during the early years of production when gas volumes are larger. In the out years, monitoring is less frequent on a time basis but more frequent on a volume basis, because the gas volumes are considerably less. The produced water and natural gas samples shall be analyzed for the radiological analytes listed in (Table 3). The samples shall be collected in accordance with the procedures in Section 5.9 and 5.10.

4.1.4 Tier I Plugging and Abandonment Monitoring

Requests to abandon a well within the boundaries of the Project Rulison monitoring program shall be evaluated on a case by case basis, with specific requirements detailed as conditions of approval for the Form 6 (Notice of Intent to Abandon). Monitoring of fluids and/or solids may be required by COGCC during abandonment of a well if verified Project Rulison-related radionuclides were detected during drilling, completion and/or production monitoring. Similarly if drilling, completion and production activities at a well pre-date the monitoring requirements set forth in the RSAP, sampling of fluids and/or solids may be required by COGCC during abandonment activities to demonstrate that verified Project Rulison-related radionuclides are not present prior to disposal of any media derived from the subsurface during well abandonment.

4.2 Tier II Monitoring

Information in this section is summarized in (**Table 2**).

Tier II monitoring shall only be conducted at gas wells located in the Tier II zone (Figure 2) **if the well is the closest designated well (i.e., no Tier I well)** in a monitoring sector. Tier II monitoring is designed to collect a sample of produced water and natural gas to screen for the presence of verified Project Rulison-related radionuclides that may or may not be related to Project Rulison if the well is the closest designated well (i.e., no Tier I well) in a monitoring sector.

Tier II monitoring may include:

- Drilling monitoring
- Completion monitoring
- Production monitoring
- Plugging and Abandonment (P&A) monitoring.

4.2.1 Tier II Drilling Monitoring

Because existing sampling data indicate that verified Project Rulison-related radionuclides have not been encountered to date and recent DOE modeling suggests that radionuclides are not expected to be encountered outside of Lot 11, the Companies have established a limited Tier II drilling monitoring program to screen for verified Project Rulison-related radionuclides that might be unexpectedly encountered during gas drilling, completion, and production operations within the Tier II monitoring zone **if the well is the closest**

designated well (i.e., no Tier I well) in a monitoring sector. Tier II drilling monitoring activities include:

If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), composite sampling and analysis of drill cuttings stored on the well pad from the closest designated well drilled within each monitoring sector shall be performed. The sample shall be analyzed for the radiological analytes listed in (Table 3). Sample results shall be reviewed by a person with professional competence in radiological protection science who is able to evaluate the radiochemistry results and data quality. The drill cuttings can be transported, re-used, or disposed without approval from the COGCC if verified Project Rulison-related radionuclides are less than the screening level (

- Table 5). A letter, including the data validation report and qualified data sheets, along with a Sundry Notice Form 4 shall be submitted to the COGCC to document the drill cuttings results and demonstrate compliance with the RSAP. If verified Project Rulison-related radionuclides are equal to or greater than the screening level, the cuttings cannot be transported, re-used, or disposed without prior written approval from the COGCC. Notice of Intent to transport, re-use, or dispose of drill cuttings with verified Project Rulison-related radionuclides greater than the screening level shall be submitted to the COGCC for approval. The Notice of Intent shall include a letter, including the data validation report and qualified data sheets that summarizes and discusses the results as an attachment.
- If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), open- or cased-hole gamma-ray logs through the Williams Fork Formation interval shall be run after each hole is completed and reviewed to determine whether Project Rulison-related gamma radiation was encountered in the hole, its depth, and activity. A gamma radiation measurement greater than 500 American Petroleum Institute (API) gamma log units or any other gamma readings that

appear to be anomalously high shall be noted and immediately reported to Company management and the RSO for review and guidance. The Companies shall immediately inform the COGCC, CDPHE, and DOE of any verified Project Rulison-related radiation encountered.

- If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), a high accuracy gyroscopic directional wellbore survey shall be performed after reaching the total wellbore depth but prior to commencing perforation and completion activities for wells whose bottom-hole location is projected to be laterally within 200 feet of the 1-mile monitoring radius (Tier I) to verify that the wellbore did not penetrate the Tier I boundary. Alternatively, a magnetic survey may be performed in lieu of a gyroscopic survey as long as Tier I monitoring is performed for the respective well(s). In either case, a copy of the directional drilling survey report, including a map view and a vertical profile view showing the wellbore trajectory and the distance from the 1 mile Project Rulison monitoring radius, along with a Sundry Notice Form 4 shall be submitted to the COGCC to demonstrate compliance with the RSAP.

4.2.2 Tier II Completion Monitoring

If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), completion monitoring shall be conducted at the closest designated well in each Tier II sector to screen for the presence of verified Project Rulison-related radionuclides that might be encountered in flowback fluids during gas well completion operations. The flowback fluids shall be contained in tanks. The Companies shall submit a secondary and tertiary containment plan via Sundry Notice Form 4 for the tanks. If the COGCC has not objected to or requested additional information within 10 business days of a Company’s filing of a Sundry Notice Form 4, the Company may proceed with fracing and flowback operations.

If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), samples of introduced fracing fluids (prior to use) and recovered flowback fluids shall be collected for laboratory analysis of ^{3}H only. The fracing and flowback fluids shall only be analyzed for ^{3}H to screen for the most likely verified Project Rulison-related radionuclide in these fluids. The samples shall be collected in accordance with the procedure provided in Section

5.8. The results of the analyses shall be used to determine whether ^3H may have been introduced during fracing or to determine whether ^3H is present in the recovered flowback fluids.

Flowback fluid results shall be reviewed by a third-party consultant independent of the Companies, prior to transport, re-use, or disposal. Flowback fluids may be transported, re-used, or disposed without approval from the COGCC if ^3H is less than the screening level (Table 5). If ^3H is equal to or greater than the screening level, flowback fluid results shall be reviewed and approved in writing by the COGCC before the flowback fluids can be transported, re-used, or disposed. In either case, the ^3H results will be submitted to the COGCC to demonstrate compliance with the RSAP. Once flowback fluids from the closest designated well have been demonstrated to contain ^3H at background concentrations or less, all subsequent flowback fluids generated in outlying wells in that monitoring sector can be transported, disposed, or re-used without additional laboratory analyses or COGCC approval.

4.2.3 Tier II Production Monitoring

If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), Tier II production monitoring shall be conducted to screen for verified Project Rulison-related radionuclides in natural gas and produced water in existing and new gas wells. Tier II production monitoring activities include:

- If a Tier II well is the closest designated well in a monitoring sector (i.e., no Tier I well), one-time sampling of produced water and natural gas shall be performed as soon as possible after fracing but no later than 30 days after the first gas delivery from a new gas well. The produced water samples shall be analyzed for the radiological analytes listed in (Table 3). The natural gas samples shall be analyzed for the radiological analytes listed in (Table 3). The samples collected shall be submitted to an accredited laboratory for analysis. The samples shall be collected in accordance with the procedures in Sections 5.9 and 5.10.
- If a Tier II well is the closest designated well in a monitoring sector (i.e., no well within Tier I), sampling and analysis of produced water and natural gas shall be performed quarterly during Year 1, semiannually during Years 2 and 3, and annually thereafter. For a new Tier II well, that is the closest designated well within the sector, the first quarterly sample shall be collected approximately 180

days after initial gas delivery. The produced water and natural gas samples shall be analyzed for the radiological analytes listed in (Table 3). The samples shall be submitted to an accredited laboratory for radiochemical analysis. The samples shall be collected in accordance with the procedures in Section 5.9 and 5.10.

- If a verified Project Rulison-related radionuclide is detected in a Tier II well above its screening level, all Tier I and II wells within that sector shall be sampled to determine whether verified Project Rulison-related radionuclides exist in other wells. The well in question shall be temporarily shut-in pending further evaluation of the radionuclide activities and source.
- Additional radiological monitoring of produced water and natural gas within Tier II shall be contingent upon the detection of verified Project Rulison-related radionuclides within Tier I or Tier II zone gas wells, or as requested by the COGCC, CDPHE, or DOE.

4.3 Tier II Plugging and Abandonment Monitoring

Requests to abandon a well within the boundaries of the Project Rulison monitoring program shall be evaluated on a case by case basis, with specific requirements detailed as conditions of approval for the Form 6 (Notice of Intent to Abandon). Monitoring of fluids and/or solids may be required by COGCC during abandonment of a well if verified Project Rulison-related radionuclides were detected during drilling, completion and/or production monitoring. Similarly, if drilling, completion and production activities at a well pre-date the monitoring requirements set forth in the RSAP, sampling of fluids and/or solids may be required by COGCC during abandonment activities to demonstrate that verified Project Rulison-related radionuclides are not present prior to disposal of any media derived from the subsurface during well abandonment.

4.4 Areal Environmental Groundwater and Surface Water Monitoring (deleted)

4.5 Monitoring Schedule Variances

The COGCC expects the Companies to implement the RSAP version as approved while accounting for the safety of their personnel and equipment. COGCC understands that access to gas well sample sites during adverse weather conditions may not be safely accomplished, and in those situations, some of the schedules in this RSAP may not be met. Where a task cannot be safely completed as specified in the RSAP because of adverse weather conditions or any other conditions outside of the Company's control, the Company shall notify the COGCC and provide a written explanation which justifies the exception. COGCC expects the Companies to perform a postponed task as soon as it can be safely accomplished. Successive schedule extensions may be necessary and will be considered by the COGCC on a case-by-case basis.

New gas wells are occasionally brought on-line, and subsequently taken off-line within the 30-day first gas sales time period, to perform well workover activities, frac additional intervals within the well, or to frac other wells on the same pad. Where a task, such as 30-day first gas sales sampling, cannot be completed as specified in the RSAP because of these operational activities, the Company shall notify the COGCC and provide a written explanation which justifies the exception. COGCC expects the Companies to perform a postponed task as soon as it can be reasonably accomplished. Successive schedule extensions may be necessary and will be considered by the COGCC on a case-by-case basis.

4.6 Radionuclide Screening and Action Levels

Radionuclide screening and action levels for the various media and radionuclides of concern are listed in (

Table 5). These screening and action levels were developed to provide a measure against which radionuclide activities in natural gas, produced water, drill cuttings or soils, groundwater, and surface water can be compared to determine the exposure of workers, individual members of the public, or the environment to a potential release of verified Project Rulison-related radionuclides. In this revision, screening and action levels have, in some cases, been selected to be consistent with those used by the US Department of Energy as specified in the *Rulison Monitoring Plan* (DOE 2010b).

4.6.1 Development of Radionuclide Screening and Action Levels

The screening and action levels were developed based on an exposure scenarios to workers, individual members of the public, or the environment. Action levels are set to limit public dose and high enough so that the probability of false positive alarm is very low. Screening levels are selected to be lower than action levels, but substantially higher than the detection limit for the analysis. Tritium levels in recent North American atmospheric precipitation were considered when setting these values. Tritium activity measured in atmospheric precipitation at Ottawa, Canada between 2000 and 2012 have ranged between approximately 10 and 54 Tritium Units[9], which is equivalent to a range of 30 to 170 pCi/L. (The Tritium Unit concept is explained in the paragraph below.) The specific basis used to set the screening and action levels for each sample medium is discussed below.

Tritium in Natural Gas

Tritium in in the methane (C1) fraction of natural gas is analyzed by combusting natural gas and capturing the water of combustion which would contain the tritium fraction. This analysis is done by Isotech Laboratories. Isotech reports tritium concentration in "tritium units" (TU) which is a customary practice for laboratories that specialize in determining the geologic age of groundwater. One TU equals 1 tritium atom per 10^{18} hydrogen atoms or approximately 3.19 pCi/L in water (pCi/L_{water}) (Kazemi et al. 2006). To avoid confusion, screening and action levels for tritium in natural gas are provided in both TU and in units of pCi/L of combusted gas.

For ^{3}H analysis of natural gas, the water and water vapor in the gas is removed during sample preparation using a molecular sieve. The dry methane is combusted, resulting in carbon dioxide and water. At 20°C and one atmosphere, it takes approximately 621 liters of combusted methane to produce one liter of water. To convert the reported methane tritium results to pCi/L in methane gas ($pCi/L_{methane}$), a conversion factor of $1.61x\ 10^{-3}$ $L_{water}/L_{methane}$ is used. Thus, for a reported ^{3}H concentration of 10 TU in water (or approximately 32 pCi/L_{water}), the concentration of ^{3}H in the methane fraction of the natural gas would be approximately 0.05 $pCi/L_{methane}$.

The natural gas action level shown in (Table 5) is based on a DOE-sponsored screening assessment of potential health risks from future natural gas drilling near Rulison

[9] The data supporting this statement can be found at: http://www-naweb.iaea.org/napc/ih/IHS_resources_gnip.html

(Daniels et al 2011). The goal of the assessment was to ensure protection of human health. The assessment began with several assumptions:

- Exposure to tritiated water vapor occurs at the specified concentration for 30 days,
- Residents are present 24 hours per day,
- Breathing rate is 20 m3 per day,
- Airborne tritium concentration is 0.290 pCi/L.

Under these assumptions the study concluded that the risk of fatal and non-fatal cancer is 2×10^{-8}, which is extremely low. The total tritium intake during the 30-day period of exposure is 174,000 pCi. When the adult dose equivalent coefficient of 6.67×10^{-8} mrem/pCi for inhalation tritiated water vapor, which is published in ICRP 72 (ICRP 1995), is multiplied by the intake, the dose equivalent is determined to be 0.0116 mrem. So, for this continuous exposure scenario, a dosimetric relationship of 0.29 pCi/L per 0.0116 mrem is established. From this we estimate that an action level of 640 pCi/L (equivalent to 200 TU) would produce a dose to a nearby resident of 25 mrem. The screening level is set at 50% of the action level: 320 pCi/L (equivalent to 100 TU).

The nominal detection limit typically reported by Isotech is usually 10 TU, (approximately 32 pCi/L_{water}). This is far below the screening level.

<u>Carbon-14 in Natural Gas</u>

No exposure scenario exists that would define the basis for dose-based action levels. If an exposure scenario was defined there is no plausible situation in which public dose from ^{14}C emissions could approach 10 mrem per year. Nevertheless, ^{14}C in natural gas can provide a sensitive indicator that Rulison-related radionuclides are escaping from the blast chimney.

^{14}C in the methane fraction of natural gas is analyzed and reported by Isotech Laboratories as “percent modern carbon” (pMC). This unit is associated with radiocarbon dating analysis. Radiocarbon dating is normally used to determine how long it has been since a sample of organic material was alive and metabolizing CO_2. The method is normally assumed to be useful over the time frame of human civilization, more specifically 60,000 years ago until year

1950. Radiocarbon dating is based on the fact that a very small quantity ^{14}C is continuously and consistently created in the upper atmosphere by cosmic ray interactions, and this ^{14}C is incorporated into atmospheric CO_2. When a plant is growing it will have a ^{14}C activity concentration of 6.22 pCi/g of carbon (Currie 2004). As time passes the ^{14}C activity will decrease with a nominal half-life of 5568 years.

To perform the analysis, the laboratory cryogenically captures CO_2 from combustion of the methane sample then converts it to benzene through a series of reactions. The ^{14}C radioactivity concentration of the benzene is measured by liquid scintillation analysis. Since the methane in natural gas from the Williams Fork Formation was formed approximately 100 million years ago, the expected result for an unaffected sample is the method detection limit, which is 1 pMC or less. In theory, a result of 100 pMC would be expected from a sample dating to year 1950, but in this case the result would be interpreted to mean that the natural gas sample had been contaminated with ^{14}C that was produced in the Rulison test.

Considering this information, the action level for ^{14}C in natural gas is set at 20 pMC and the screening level is set at 2 pMC.

Produced Water

The radionuclide of interest in produced water is tritium.

The action level for tritium in produced water is set at 75% of the US EPA drinking water standard of 20,000 pCi/L, which is nominally equivalent to a dose of 4 mrem/year[10]. Therefore, the action level for tritium in produced water is 15,000 pCi/L. The screening level for tritium in produced waste is set much lower at 800 pCi/L. This value was selected in because tritium in produced water is the most important indicator a release from the Rulison Project and because low concentrations of tritium in water are readily detected.

Drill Cuttings and Soils

The radionuclide of interest in drill cutting and soil is tritium. The same criteria used for produced water apply to screening and action levels for tritium in drill cuttings and soil. The

[10] In 1991, EPA used improved calculations to conclude a tritium concentration of 60,900 pCi/L would yield a 4 mrem per year dose. However, EPA kept the 20,000 pCi/L value for tritium in its latest regulations. See http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/tritium-radiation-fs.html

laboratory is requested to distill the moisture from the soil and report the result in terms of activity per unit volume of water.

4.6.2 Application of Radionuclide Screening and Action Levels

Radionuclide screening and action levels (

Table 5) will be applied as described in the following table. If Rulison related radioactivity is equal to or greater than the action level, then required actions specified below and notification and actions consistent with the most recent edition of the COGCC Emergency Response Plan (COGCC 2015) are required.

Analyte Result	Required Action
Radionuclide analyte is not detected	No action required
Radionuclide analyte is detected but is less than the screening level	Verify the analytical result and determine its validity either through discussion with the analytical laboratory, re-analysis of existing sample, or resample and analyze; if verified, review previous and subsequent analytical results to determine if there is a statistically significant increasing trend; continue to monitor; if the radionuclide is verified and exhibits a statistically significant increasing trend, contact the COGCC, CDPHE, and DOE to discuss.
Radionuclide analyte is detected and its activity is equal to or greater than the screening level but less than the action level	Verify the analytical result and determine its validity either through discussion with the analytical laboratory, re-analysis of existing sample, or resample and analyze. If the radionuclide is verified, the closest wells within that sector and the two adjacent sectors shall be sampled to determine whether Project Rulison-related radionuclides exist in other

Analyte Result	Required Action
	wells. The well in question shall be temporarily shut-in pending further evaluation of the radionuclide activities. The Company shall contact the COGCC, CDPHE, and DOE within 1 week or less of the verified result and discuss subsequent actions.
Radionuclide analyte is detected and its activity is equal to or greater than the action level	Verify the analytical result and determine its validity either through discussion with analytical laboratory, re-analysis of existing sample, or resample and analyze. If the radionuclide is verified, the closest wells within that sector and the two adjacent sectors shall be sampled to determine whether Project Rulison-related radionuclides exist in other wells. The well in question shall be temporarily shut-in pending further evaluation of the radionuclide activities. The Company shall contact the COGCC, CDPHE, and DOE within 48 hours or less of the verified result and discuss subsequent actions.

4.7 Records Retention

Records, except for medical records, generated under this RSAP will be reported in the quarterly monitoring reports. An electronic copy of the data, in the form of a database or spreadsheet, will also be provided to COGCC. Personnel, field, and laboratory records will be retained for the life of the applicable oil and gas well or oil and gas location and for five (5) years after plugging and abandonment. After the retention date has passed, the records may continue to be retained or destroyed, depending on the Companies’ record retention policy. All non-personnel and non-proprietary records selected for disposal will first be offered to the COGCC for archiving.

4.8 Data Management

Operational and environmental monitoring field and analytical data will be stored and managed using an electronic format such as Microsoft Access® or equivalent.

4.9 Reporting

The results of the radiological monitoring will be reported to the COGCC on a quarterly, or more frequent basis, as necessary. The quarterly operational monitoring reports (as necessary) will include the results of monitoring and sampling activities conducted during each quarter. The annual environmental sampling results will be included in the fourth quarter report.

The quarterly reports will be submitted to the COGCC within approximately 90 days after the receipt of laboratory analytical results, including laboratory analytical results for verification samples if needed. It is anticipated that the quarterly reports will be submitted on or before the nearest business day to June 30 (First Quarter), September 30 (Second Quarter), December 31 (Third Quarter), or March 31 (Fourth Quarter). Once received and reviewed, the COGCC will post the quarterly reports on its website for public access. An electronic copy of the data, in the form of a database or spreadsheet, will also be provided to COGCC on the same schedule as the written reports.

Table 5. Radionuclide Screening and Action Levels

Radionuclide	Natural Gas		Produced Water		Drill Cuttings or Soil[2]	
	Screening Level	Action Level	Screening Level (pCi/L)	Action Level (pCi/L)	Screening Level (pCi/L)	Action Level (pCi/L)
Tritium	320 pCi/L in water of combustion	640 pCi/L in water of combustion	800	15,000	800	15,000
Tritium[1]	100 TU in water of combustion	200 TU in water of combustion	800	15,000	800	15,000
C-14	2 percent modern carbon (pMC)	20 pMC	N/A	N/A	N/A	N/A

Note 1: this line is a duplicate of the line above it. To avoid confusion the natural gas screening and action levels are presented in the alternative reporting system of Tritium Units.
Note 2: this refers to the water distilled by the laboratory out of the sample.

5 FIELD METHODS AND SAMPLING PROCEDURES

5.1 Site Access and Field Mobilization

5.1.1 Site Access

Prior to conducting any sampling activities, the Companies' designated representative will contact the Companies and other parties by phone, e-mail, or letter to obtain permission to sample as necessary. The Companies will provide escorted access and support, as necessary, for crews that will sample produced water and natural gas at the well sites.

5.1.2 Field Mobilization

Once site access permissions and the sampling events are scheduled, the field crews will call the analytical laboratories to notify them of the pending sampling event and to obtain the appropriate sampling bottles and containers. The field crews will also contact, as necessary, equipment vendors to rent or purchase the necessary field sampling equipment and supplies. All field equipment will be tested to make sure it is in working order before proceeding to the field. A list of the field equipment and supplies is provided in Section 5.2. All field personnel performing sampling will be trained on sampling procedures in the RSAP and the use of all field instruments prior to going in the field. An example Safe Work Plan (Appendix B) discusses the safety and health requirements for working around the drilling and production sites and performing field sampling. The attached Safe Work Plan, or an equivalent plan, will be used.

5.2 Field Equipment and Supplies

A list of the field equipment and supplies is provided below. The list is organized by field activity.

5.2.1 Personnel Protective Equipment

Personnel protective equipment (PPE) and supplies include:

- Hardhat
- Safety glasses
- Fluorescent safety vest
- Steel-toed boots

- Disposable, powderless, nitrile gloves
- Fire-retardant clothing as required

5.2.2 Sample Location Documentation

Sample location documentation equipment and supplies include:

- Field logbook
- Indelible pens
- Digital camera to photograph sampling site

5.2.3 Radiation Screening and Monitoring

Radiation screening equipment and supplies required only for Tier I drilling sites include:

- Fluke 451P Ion Chamber Survey Meter with microRoentgen per hour (microR/hr) meter face, or equivalent
- Fluke Advanced Survey Meter equipped with a Model 489-110 Geiger-Mueller pancake probe and a Model 489-55 NaI(Tl) gamma scintillator, or equivalent
- Check source (e.g., 137Cs) for performance testing of alpha, beta, and gamma radiation monitoring equipment

5.2.4 Water Sampling

Produced water sampling equipment and supplies include:

- Field sampling data sheets (example field forms are provided in Appendix C).
- Long-handled, disposable polyethylene dipper (for streams).
- Sample bottles (with preservative) from the analytical laboratory. Several extra sample bottles will be obtained in case of breakage and for QA/QC samples.
- Graduated 2- to 5-gallon bucket (for measuring spring flow rates).
- Stopwatch (for measuring stream or spring flow rates).
- Current velocity meter – optional (for measuring stream or spring flow rates).
- Electronic water level indicator - optional (for measuring water levels in wells).
- Garden hose (for plumbed well sampling).

- Disposable bailers and rope – optional (for sampling wells without pump).
- Submersible pump, portable generator (or battery) for submersible pump, and polyethylene and/or silicon discharge tubing – optional (for sampling wells without pump).
- 0.45-micron filter and filtering system for dissolved analytes (as needed).
- Decontamination equipment and supplies (e.g., wash/rinse tubs, brushes, Alconox®, plastic sheeting, paper towels, brushes, sponges, potable water, and deionized water).
- Large (30-gallon) trash bags.
- Assorted tools (knife, screwdriver, pliers, wrenches).

5.2.5 Drill Cuttings and Fluids Sampling

Drill cuttings and fluids sampling equipment and supplies include:

- Clean 1- and 5-gallon buckets with tight-fitting lid
- Shovel or sampling scoop

5.2.6 Natural Gas Sampling

Natural gas sampling equipment and supplies include:

- Laboratory-supplied evacuated 20-pound steel gas cylinders (gas cylinders supplied under vacuum from laboratory)
- Braided steel connector tubing (supplied by laboratory)
- Non-sparking (i.e., non-ferrous) adjustable wrench

5.2.7 Sample Shipping and Documentation

Sample shipping and documentation equipment and supplies include:

- Indelible pens and markers (e.g., Sharpie)
- Sample labels (pre-printed and/or blank)
- Chain-of-custody (COC) forms
- Clear plastic tape
- Fiber tape

- Custody seals
- 1-gallon Ziploc® freezer bags
- Coolers
- Shipping and handling labels (e.g., flammable gas, cargo aircraft only, this side up, etc.)
- Shipping documentation (e.g., laboratory address, FedEx number, dangerous goods paperwork, etc.)

5.3 Field Documentation and Measurements

5.3.1 Sample Location

Each sample site location will be initially documented, identifying its coordinates. The results will be recorded in a field logbook or on field sample forms (Appendix C).

5.3.2 Radiation Screening

5.3.2.1 Sample Site

Each sample site will be screened with hand-held radiation survey instruments prior to sampling, to measure background radiation activities. Background radiation screening will be performed using a Fluke Advanced Survey Meter equipped with a Model 489-110 Geiger-Mueller pancake probe, or equivalent. The background radiation measurements will be made by placing the detector probe within about 1 inch of the ground surface and recording the radiation response. A radiation measurement will also be collected by holding the detector probe about 3 feet (“waist high”) above the ground surface and recording the reading. The radiation measurements will be recorded in the field logbook or on field sample forms (Appendix C) as microR/hr and/or counts per minute (cpm). Radiation survey equipment will be operated and performance tested in accordance with the manufacturer’s instructions. Radiation survey instruments shall be calibrated by the manufacturer or a certified service center annually.

5.3.2.2 Tier I Well Pad

A background radiation survey will be performed at each new Tier I well after it is constructed. Existing Tier I well pads that have not been previously surveyed for background radiation will also be surveyed for background radiation prior to drilling a new well. Background radiation screening will be performed on a “9-point” grid over the area of the well pad. The 9 points will include measurements at each corner of the pad (4), at the midpoints of the sides of the pad (4), and at the center of the pad (1).

Alpha-beta-gamma radiation background will be measured using a Fluke Advanced Survey Meter equipped with a Model 489-110 Geiger-Mueller pancake probe. The background radiation measurements will be made by placing the detector probe within about 1 inch of the ground surface and recording the radiation response. A radiation measurement will also be collected by holding the detector probe about 3 feet (“waist high”) above the ground surface and recording the reading. The radiation measurements will be recorded in the field logbook or on field sample forms (Appendix C) as microR/hr and/or counts per minute (cpm). Radiation survey equipment will be operated and performance tested in accordance with the manufacturer’s instructions. Radiation survey instruments shall be calibrated by the manufacturer or a certified service center annually.

5.3.3 Field Parameters (deleted)

Field parameter measurements are non-radiological measurements and have been deleted in this revision

5.4 Dosimeters (deleted)

5.5 Surface Water Sampling (deleted)

5.6 Groundwater Sampling (deleted)

5.7 Drill Cuttings Sampling

Two composite samples of drill cuttings will be obtained from the closest designated well drilled to Project Rulison within each sector of Tier I. The composite samples will be analyzed for the radionuclides listed in (Table 3). The composite samples will be collected by the Companies’ field representative from two intervals that are approximately equivalent (corrected for dip and distance) to the Project Rulison test interval. The two 500-foot intervals sampled will include:

- An interval between about 750 feet (+478 ft msl) and 250 feet (-22 ft msl) above the approximate elevation of the Project Rulison test interval (approximately -272 ft msl)
- An interval between about 250 feet above (-22 ft msl]) and 250 feet below (-522 ft msl) the approximate elevation of the Project Rulison test interval (approximately -272 ft msl)

Each composite sample will be created by collecting approximately one-half gallon grab samples of drill cuttings at 50-foot frequencies over each 500-foot interval (i.e., 10 sample aliquots). The grab samples for each composite sample will be placed in a clean 5-gallon plastic bucket. Once the ten (10) drill cuttings aliquots have been placed in the bucket, the Companies' designated representative will process the composite sample by thoroughly mixing the drill cuttings and fluids with a clean stirring device. After the sample is thoroughly mixed, aliquots of the drill cuttings will be placed in the laboratory-supplied sample jars, capped, wiped clean, labeled, documented, stored in a cooler, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Drill cuttings analytes are listed in (Table 3).

The bucket containing the remaining portion of each composite sample will be closed with a tight-fitting lid, labeled, and stored off site until the laboratory results are received. Once the laboratory results are received, the sample can be discarded if additional analyses are not needed.

5.8 Fracing and Flowback Fluid Sampling

Composite samples of fracing and flowback fluids will be collected at the closest designated Tier I or Tier II gas well within each monitoring sector. Fracing fluid will be sampled and analyzed prior to introduction into the gas well. Flowback fluid will be sampled and analyzed once it is returned from the well. Fracing and flowback fluids will only be analyzed for ^{3}H.

Composite fracing and flowback fluid sampling will be accomplished by extracting one (1) liter or more aliquots of fluid from each frac tank using a bailer. The number of sample aliquots collected from each frac tank will vary and depends on the number of frac tanks sampled. A sufficient number of sample aliquots from each tank should be collected to create an approximate 5-gallon composite sample. For example, if there are 10 frac tanks, approximately 2 liters of fluid will be collected from each frac tank to create the composite sample.

The composite sample will be created by gently discharging each sample aliquot into a clean 5-gallon bucket to avoid agitating the sample. Once the appropriate number of aliquots have been collected from the various frac tanks to fill the 5-gallon bucket, any condensate that accumulates on the surface will be skimmed off and disposed in the frac tanks. Composite sample aliquots will then be taken from the 5-gallon bucket and placed in the laboratory-supplied 125 mL sample bottle. For laboratory-supplied, pre-preserved sample bottles, special care should be taken to avoid overfilling the bottle and diluting or rinsing out the preservative. Additional preservative may be added at the laboratory during sample receipt if it is needed to adjust the sample pH. Water samples will not be filtered in the field or laboratory prior to analysis of analytes that may be sorbed to suspended particulates. Water samples may be filtered in the field or laboratory for ^{3}H analysis if the sample contains suspended particulates.

Once filled, the sample bottle should be wiped dry, labeled, documented, stored in a cooler, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Fracing and flowback fluid analytes are listed in (Table 3).

Any unusual sample characteristics observed during sampling will be documented in the field logbook or on the field sample forms (Appendix C). Unusual sample characteristics might include noticeable discoloration of the water or fluid, precipitates (e.g., iron oxyhydroxides), surface sheen, condensate layer, petroleum hydrocarbon or other odor, or sample effervescence.

5.9 Produced Water Sampling

Produced water samples will be collected and analyzed as specified in Section 4. Produced water sampling will be accomplished with the assistance of the Companies' field staff. Sampling crews will not attempt to sample produced water without the presence of a Company representative. Preferably, the produced water samples will be collected from the line to the separator. If a well-specific sample cannot be collected at the separator, the produced water sample can be collected from the storage tanks at each well pad. If more than one gas well is plumbed to the separator, the Company field representative will close the appropriate valves to isolate the gas well that is being sampled. Any residual fluids in the line will be discharged so that a well-specific sampled is obtained.

The produced water will be collected by gently discharging the fluid into a clean 5-gallon bucket until approximately full. Sample aliquots will then be taken from the bucket and placed in the appropriately preserved laboratory-supplied sample bottles. For laboratory-supplied, pre-preserved sample bottles, special care should be taken to avoid overfilling the bottle and diluting or rinsing out the preservative. Additional preservative may be added at the laboratory during sample receipt if it is needed to adjust the sample pH. Water samples will not be filtered in the field or laboratory prior to analysis of analytes that may be sorbed to suspended particulates. Water samples may be filtered in the field or laboratory for ^{3}H analysis if the sample contains suspended particulates.

Once filled, the sample bottle should be wiped dry, labeled, documented, stored in a cooler, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Produced water analytes are listed in (Tables 3).

Any unusual sample characteristics observed during sampling will be documented in the field logbook or on the field sample forms (Appendix C). Unusual sample characteristics might include noticeable discoloration of the water or fluid, precipitates (e.g., iron oxyhydroxides), surface sheen, condensate layer, petroleum hydrocarbon or other odor, or sample effervescence.

5.10 Natural Gas Sampling

Natural gas samples will be collected and analyzed as specified in Section 4. Natural gas sampling will only be accomplished with the assistance of a Company field representative. Sampling crews will not attempt to sample natural gas without the assistance of a Company representative. The gas samples will be collected from the line to the separator or at the separator at each well pad so that a well-specific gas sample is obtained. If more than one gas well is plumbed to the separator, the Company field representative will close the appropriate valves to isolate the gas well that is being sampled. Any residual fluids in the line will be discharged prior to sampling so that a well-specific sample is obtained.

The samples will be collected in 20-pound (19-liter) steel gas canisters provided by Isotech Laboratories. The gas canisters are shipped under vacuum, so flushing of the gas canister prior to sampling is not necessary. To obtain a gas sample, the gas canister is connected to the gas sampling port using the braided steel connector tubing outfitted with a pressure regulator and flushing valve. Once the connector tubing is connected to the natural gas sampling port and the sampling canister, the connector tubing will be flushed with the flushing valve open to remove atmospheric gases from the line. Once flushing is complete and the flushing valve is closed, sampling can occur. The gas canister valve should not be opened until it is connected to the gas sampling port to avoid losing the vacuum in the canister and introducing atmospheric gases into the sample or while flushing the braided connector with natural gas.

To collect a gas sample, open the gas sampling canister valve. Gas will flow into the sample canister until it is full. Once the gas canister is full, tightly close its valve, then close the valve on the sampling port, open the flushing valve, and disconnect the braided connector tubing. Non-sparking (non-ferrous) tools should be used to connect the connector tubing to the gas sampling port. The Company representative will then return any manipulated valves to their original position.

Once filled, the sample tank should be labeled, documented, placed in a shipping carton, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Natural gas analytes are listed in (Table 3).

5.11 Decontamination Procedures

All sampling equipment will either be pre-cleaned, disposable equipment or cleaned using the procedures in this section. Pre-cleaned, disposable sampling equipment will be used to perform most of the sampling activities described in this RSAP. Pre-cleaned, disposable sampling equipment does not need to be decontaminated prior to use. However, it should remain in its sealed plastic bag until it is used to prevent cross-contamination.

Non-dedicated sampling equipment will be thoroughly cleaned prior to initiation of sampling activities and between each use at the site, to avoid cross-contamination. Decontamination of field instruments and sample containers will include an Alconox®, or equivalent, wash and scrubbing with a brush or sponge as appropriate to remove potential contaminants, followed by a deionized water rinse. Once cleaned, the decontaminated equipment will be stored in a manner to avoid subsequent contamination prior to next use.

6 DATA QUALITY ASSURANCE OBJECTIVES

6.1 Data Quality Objectives

The operational monitoring program in this RSAP is designed to detect an unanticipated migration of verified Rulison-related radionuclides from the subsurface nuclear cavity to producing gas wells. Operational monitoring data obtained to date have demonstrated that radionuclides have not migrated from the cavity to the currently producing gas wells within a 3-mile radius of Project Rulison. Environmental monitoring data collected since 1969 have also demonstrated that Project Rulison-related radionuclides have not migrated from the cavity to the surrounding environment.

Monitoring in this RSAP will provide the necessary field and laboratory data to track any changes in verified Project Rulison-related radionuclide activities over time in produced water and natural gas at existing and future gas wells. These monitoring data will provide an early warning of the potential migration of verified Project Rulison-related radionuclides to producing gas wells. Early detection of verified Project Rulison-related radionuclides will allow appropriate actions to be taken to avoid a radiological incident or introducing radioactively-contaminated gas into the gathering system at activity levels dangerous to health or to minimize their potential for an uncontrolled release to the environment.

Data collected under this RSAP will be used to satisfy the following DQOs:

- Radiologically characterize the area within Tier I and Tier II boundaries of the Project Rulison emplacement well R-E during drilling, completion, and production of natural gas.
- Screen for a subset of verified Project Rulison-related radionuclides in drill cuttings, produced water and natural gas at producing gas wells within Tier I and Tier II boundaries that are most likely to be transported in natural gas or formation water.
- Develop background activities for verified Project Rulison-related radionuclides in produced water, natural gas, or fluids introduced into the borehole that can be used to compare with future monitoring results.

- Determine whether the verified Project Rulison-related radionuclides detected are at or above activities that would exceed screening levels or action levels;
- Facilitate management of a radiological incident and determine a course of action if verified Project Rulison-radionuclides are detected above their action levels during drilling, completion, or production at a natural gas well.
- Manage worker and public health and safety in the unlikely event of a radionuclide release during drilling, completion, or production of natural gas.

Monitoring data collected under this RSAP will be of sufficient quality and analytical sensitivity to satisfy the above DQOs. To accomplish these objectives, data collected under this RSAP will be collected, handled, shipped, and analyzed using industry standard procedures and methods to ensure that the data are of known quality, consistent, comparable, usable, and defensible. QA objectives and approaches that will be implemented to support the above DQOs are discussed in Section 6.2 and Sections 7, 8, and 9.

6.2 Quality Assurance Objectives

The QA objectives established for this RSAP are listed below. The methods and procedures used to implement and accomplish these objectives are described in this RSAP and include.

- Implement standard procedures for sampling, sample custody, equipment operation and calibration, laboratory sample analysis, data reduction, and data reporting that will assure the consistency and thoroughness of data generation;
- Assess the quality of data generated to assure that all data are scientifically valid, of known and documented quality, and legally defensible, where appropriate. This is largely accomplished by establishing acceptance limits for parameters such as precision, accuracy, completeness, representativeness, comparability and sensitivity, and by testing generated data against acceptance criteria established for these parameters; and
- Achieve an acceptable level of confidence in the decisions that are made from data by using QC checks to control the degree of total error permitted in the data. Data that fail the QC checks or do not fall within the acceptance criteria

established will be evaluated for usability in meeting project objectives during data validation.

6.3 Data Quality Assessment

To support the DQOs of this monitoring program, data generated shall be of known and acceptable quality. To define acceptable quality for these data, data quality indicators (DQIs) were identified for each analytical parameter, and decisions were made regarding how each DQI would be assessed. The DQIs included precision, accuracy, completeness, representativeness, comparability, and sensitivity. These DQIs are briefly defined below, and the approach to assessing each DQI is specifically discussed in Section 9.

6.3.1 Precision

Precision is a measure of agreement among replicate (or between duplicate) or collocated sample measurements of the same analyte. The closer the numerical values of the measurements are to each other, the more precise the measurement. Precision for a single analyte will be expressed as a relative percent difference (RPD) between results of field replicate or laboratory duplicate samples, or matrix spike duplicates for cases where both results are sufficiently large (i.e., equal to or more than five times the reporting limit [RL]). Otherwise, the absolute difference between the results is compared to a factor of the RL (the RL is used for not detected results). However, to avoid this issue, the analytical laboratories will be instructed to provide a value for nondetects to minimize the need for using the RL in the RPD calculation. Precision will be determined for no less than 1 sample in 20 for field replicates and laboratory duplicates or 1 in 20 for laboratory matrix spike duplicates. In addition, precision will be maintained by conducting routine instrument checks to demonstrate that operating characteristics are within predetermined limits.

6.3.2 Accuracy

Accuracy is a measure of bias in a measurement system. The closer the value of the measurement agrees with the true value, the more accurate the measurement. This will be expressed as the percent recovery of a surrogate, laboratory control sample (LCS) matrix spike analyte, or of a standard reference sample. The samples having known constituent concentrations will be analyzed as unknowns in the analytical laboratory for comparison to true values. Accuracy of spiked sample analyses will be determined for no less than 1 sample in 20.

6.3.3 Completeness

Completeness is a measure of the number of valid measurements obtained in relation to the total number of measurements planned. The closer the numbers are, the more complete the measurement process. Completeness will be expressed as the percentage of valid or usable measurements to planned measurements. A high level of completeness will be achieved by obtaining samples for all types of analyses required at each individual location, a sufficient volume of sample material to complete the analyses, samples that represent all possible contaminant situations under investigation, and samples at critical data locations, such as background and control samples. The completeness goal for investigative activities is 80 percent for each sampling event. The completeness goal is intended to represent the percentage of planned measurements that are judged usable, including those qualified as estimated, during validation. Data that are qualified as estimated can be used if the uncertainty in the measurement is considered in the interpretation. Rejected values are not considered usable.

6.3.4 Representativeness

Representativeness is a qualitative parameter that expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. The design of and rationale for the sampling program (in terms of the purpose for sampling, selecting the sampling locations, the number of samples to be collected, the ambient conditions for sample collection, the frequencies and timing for sampling, and the sampling techniques) assure that the environmental condition has been sufficiently represented.

6.3.5 Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared to another. Data sets will be considered comparable only when precision and accuracy are considered acceptable during data validation. Sampling, analysis, and reporting will be conducted using procedures and protocols that are designed to produce data comparable to other measurement data for similar samples and analyses. This goal will be achieved by following standard procedures to collect and then analyze representative samples and by reporting analytical results in appropriate and consistent units. Each analytical procedure selected from among the acceptable options will be used for all monitoring analyses, unless rationale is provided for choosing an alternative method. Comparability will be maintained by consistency in sampling conditions, selection of sampling procedures, sample preservation methods, analytical methods, and data reporting units.

6.3.6 Sensitivity

Sensitivity is the ability of an analytical method to detect and quantify an analytical parameter at the concentration or activity of interest. Sensitivity is achieved by having the laboratory provide quantitation limits and detection limits that are lower than the respective action levels or standards identified for monitoring. For field measurements, the sensitivity is defined by the instrument manufacturer.

7 SAMPLE DOCUMENTATION AND HANDLING

The quality of data collected during any sampling effort is dependent upon the quality and thoroughness of field sampling activities. General field operations and practices and specific sample collection and inventory will be well planned and carefully implemented in accordance with the sampling procedures presented in Section 5. In addition, the following procedures will be used to document sample collection and maintain sample integrity and custody during the process of submitting the samples to the analytical laboratories for analysis.

7.1 Field Notes

Field notes will be kept either in a bound notebook or on project-specific data forms to document all aspects of sample collection. Any additions, modifications, variances, or deviations from the sampling procedures described in Section 5 will be documented in the field logbook or on project-specific field data forms. Field notes should be sufficiently complete to re-create a sampling event. At a minimum, field notes should include the following basic information:

- Identification of RSAP version.
- Location of sampling and field personnel present.
- Date and time of activity.
- Description of activity (e.g., produced water, natural gas sampling).
- Physical and meteorological conditions at time of sample collection.
- Standard used to conduct activity (e.g., reference to standard operating procedures [SOPs] followed).
- Any additions, modifications, or deviations from the standard method for implementation of the activity.
- Results of any field radiation measurements, including surveys of sample containers, as applicable.
- Sample preparation used (e.g., filtered [list filter size], not filtered).
- Description of sample appearance (e.g., odor, smell, color, clarity, texture, etc.).
- Sample preservation used.
- Special handling or safety precautions.
- Collection of field and quality control samples.

- Type of sample collected (e.g., composite vs. grab, type of composite, homogenization activities, etc.).
- Sample volumes collected, container types, and sample analyses (e.g., gamma-emitting radionuclides by spectroscopy, radiochemical analysis, etc.).
- Decontamination procedures, as applicable.
- Any pertinent information to assist in reconstructing the sampling event (e.g., drilling terminated due to refusal, insufficient sample volume due to low yield; therefore, no QC samples collected, analyses prioritized because of low sample volume, etc.).
- Names of field personnel. When using initials, ensure that they can be uniquely identified with an individual.

All entries will be recorded with indelible ink. Should corrections be necessary, field personnel should place a single strike-out line through the erroneous information, add the correct information, and initial and date the correction.

After field activities, all field notes will be reviewed for completeness and correctness, after which the field notes will be copied. The original logbooks and field forms will be sent to the project files. Data users will use working copies of logbooks and field notes rather than the originals.

7.2 Sample Containers, Preservation, and Holding Time Requirements

To maintain sample integrity, requirements for sample containers, preservation, and holding times have been established. (Table 6) presents the sample container, preservation, and holding time requirements for radiological. (Table 7) provided similar information for non-radiological analytes, which are no longer required. (Table 7) remains in this version to maintain the structure of the document.

7.3 Field Quality Control Samples

Field quality control samples consist of field duplicates and additional sample volume for the laboratory to prepare matrix spike and duplicate or matrix spike duplicate samples as appropriate for the analytical methods. Tables 6 presents the field QC requirements for radiological samples.

7.4 Sample Labeling

A sample label will be placed on each sample container. The sample label will include a unique sample identification number, the date and time of sample collection, the sampler's initials, the analyses requested, filtration status, and any preservatives present.

The sample identification number will consist of the site identifier, the sample matrix, sample type (grab [G], composite [C]), field type (primary [P] or duplicate [D], and fraction (total [TF] or dissolved [DF]). Components of the sample identification number will be separated by dashes. An example sample identification is BM35-21D-PW-GPTF which indicates a primary produced water (PW) grab sample collected from gas well BM35-21D for total fraction analysis. Other sample matrix identifiers include natural gas (NG), drill cuttings (DC), surface soils (SS), makeup water (MW), fracing fluids (FW), flowback fluids (FB), trip blank (TB), storm water (ST), drilling fluid (DF), and extracted drilling mud fluid (MF) or mud solids (MS).

Table 6. Sample Handling and Field QC Requirements for Radiological Analytes.

Analysis Parameter	Analytical Laboratory	Analytical Method	Sample Container	Minimum Sample Volume	Preservation Requirements	Holding Time	Frequency of Field QC		
							Field Duplicate	MS	MSD or DUP
Natural Gas									
Carbon-14 (^{14}C)	Isotech	Internal Lab SOP	LP Tank	5 L Methane [1]	None	None	1 per 20 field samples	NA	NA
Tritium (^{3}H)	Isotech	Internal Lab SOP	LP Tank	5 L Methane [1]	None	None	1 per 20 field samples	NA	NA
Water									
Tritium (^{3}H)	Isotech	EPA 906.0 mod.	125 mL Liter Plastic or glass	125 mL	≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
Drill Cuttings or Soil									
Tritium in soil moisture	GEL	EPA 906.0 mod.	16 oz. Plastic or glass wide mouth jar	1000 g	None	6 months	1 per 20 field samples	NA	1 per 20

Note 1. Generally, a 19 L sample is collected.

Table 7 Reserved. Non-Radiological Analytes DELETED.

Sample labels may be pre-printed prior to a sample event or hand-written at the time of sample collection. If pre-printed samples labels are used, the sampler will complete the portions for the date and time collected and the sampler's initials at the time of sample collection.

Sample labels will be completed with indelible ink. After the label is placed on the sample container, it will be affixed to the sample container by means of covering the label with clear packing tape (i.e., wrap clear tape around the container) or fastening the label to the container handle (i.e., liquid propane [LP] tanks) to maintain the integrity of the label through sample shipment.

7.5 Sample Chain-of-Custody

Written documentation of sample custody from the time of sample collection through the generation of data by analysis of that sample and until disposal is recognized as a vital aspect of any QA effort. The chain of custody (COC) of the physical sample and its corresponding documentation will be maintained throughout the handling of the sample. All samples will be identified, labeled, and logged onto a COC form as a part of the procedure designed to assure the integrity of the resulting data. When transferring the possession of samples, the individuals relinquishing and the individuals receiving the samples should sign, date, and note the time on the form. The original COC form will be included in the analytical data package.

The record of the physical sample (location and time of sampling) will be joined with the analytical results through accounting of the sample custody. Sample custody applies to both field and laboratory operations. All laboratories completing chemical analyses will be required to maintain samples in a secure location with limited access from the time of sample receipt through sample disposal.

7.6 Sample Packing and Shipping

Samples collected under this program will be shipped to the laboratory via an overnight carrier. If the samples are shipped via an overnight carrier, the following procedure will be used for packaging non-gas samples (e.g., produced water, fracing fluid, flowback fluid, drill cuttings, groundwater, or surface water):

- Inert cushioning material will be placed in the bottom of the cooler;
- The cooler will be lined with a large plastic bag;
- Each sample container will be sealed in a re-sealable plastic bag and placed upright in the cooler;
- Pertinent paperwork such as the COC form will be placed in a re-sealable plastic bag and taped to the inside lid of the cooler;
- A signed custody seal will be attached to the cooler in two places and covered with clear tape in such a way that the custody seal must be broken to open the cooler;
- The cooler will be sealed with packaging tape; and
- A shipping label will be affixed to the outside of the cooler.

For shipments by overnight carriers, the overnight carrier will not sign the sample COC records because the shipping containers will remain sealed until receipt at the laboratory. The laboratory will document the condition of the custody seals upon receipt of the coolers, noting the condition of the custody seals upon receipt. If the custody seals remained intact, it will be assumed that integrity of the samples was maintained throughout the shipping process.

Natural gas samples collected will be transported from the field to an overnight carrier (e.g., Federal Express or United Parcel Service). Transport of the natural gas sample containers (e.g., 20-lb liquid propane (LP) cylinders) from the field to an overnight carrier is regulated under the U. S. Department of Transportation (DOT) Materials of Trade (MOT) regulations (49 Code of Federal Regulations Part 173.6) where natural gas is considered a flammable gas (Division 2.1). Placards are not required on the transport vehicle if the combined gross weight of the MOT transported is less than 440 pounds and, in the case of flammable gases, each cylinder or tank may not weigh more than 220 lbs. The gas cylinders or tanks shall be properly labeled to indicate their contents prior to transport.

Natural gas samples collected in LP tanks will prepared for overnight carrier shipment by a qualified person who has the appropriate DOT or International Air Transportation Association (IATA) training for shipping dangerous materials. After ensuring that the tank valve is tightly closed and the sample container is properly labeled, the LP tanks will be placed in their individual shipping cartons supplied by the laboratory. The outer package shall be properly marked and labeled in accordance with the dangerous goods shipping regulations. (Figure 9) shows marking and labeling that has been compliant for prior shipments. The dangerous goods shipping paperwork (**Figure 10**) will be completed by a person with the appropriate DOT/IATA training. The marking, labeling and paperwork should be confirmed by the qualified shipper. The following hazardous material information will be included on the shipping paperwork and/or package as appropriate:

Ship to: Isotech Laboratories, Inc.
1308 Parkland Court
Champaign, Illinois 61821
Telephone: (217) 398-3490
Fax: (217) 398-3494

Transportation Details: Cargo Aircraft Only
Airport of Destination: CMI (Willard Airport, Champaign, Illinois)
Shipment Type: Non-radioactive

UN or ID No: UN1971
Proper Shipping Name: Methane, Compressed Gas
Class or Division: 2.1, Flammable Gas
Quantity and Type of Packaging: fiberboard box x 1 kg
Packing Instructions: 200

Type of Packaging: U. S. DOT approved LP gas cylinders
Maximum Allowed Quantity per Package: 150 kg
Description of Contents: Gas cylinders containing methane gas samples

The laboratory will be notified of all shipments.

Left and Right Sides of Shipping Carton

Top of Shipping Carton

Figure 9. Example Labeling for Natural Gas Shipping Carton.

SHIPPER'S DECLARATION FOR DANGEROUS GOODS **(Provide at least three copies to the airline.)**

Shipper
URS Corporation
713 Cooper Avenue, Suite 100
Glenwood Springs, CO 81601
(970) 384-4731

Air Waybill No. 8646 7433 4659

Page 1 **of** 1 **Pages**

Shipper's Reference Number *(optional)* 22239457.54210.00002

Consignee
Isotech Laboratories
1308 Parkland Court
Champaign, IL 61821
(217) 398-3490

FedEx Express

Two completed and signed copies of this Declaration must be handed to the operator

WARNING

Failure to comply with all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties.

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: *(delete non applicable)*

~~PASSENGER AND CARGO AIRCRAFT~~ XXX	CARGO AIRCRAFT ONLY

Airport of Departure

Airport of Destination: CMI

Shipment type: *(delete non-applicable)* NON-RADIOACTIVE | ~~RADIOACTIVE~~ XXXXXXXX

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification						
UN or ID No.	Proper Shipping Name	Class or Division (Subsidiary Risk)	Pack-ing Group	Quantity and type of packaging	Packing Inst.	Authorization
UN 1971	Methane, Compressed Gas	2.1		1 fiberboard box x 1 kg	200	

Additional Handling Information

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable International and National Governmental Regulations. I declare that all of the applicable air transport requirements have been met.

Name/Title of Signatory
Tim Joseph, H&S Manager

Place and Date
Glenwood Springs, CO

Signature *(see warning above)* [A typed signature may be used if the origin and destination are in the United States or its territories.]

(303) 740-2721/(800) 424-9300 **Emergency Telephone Number**

FOR RADIOACTIVE MATERIAL SHIPMENT ACCEPTABLE FOR PASSENGER AIRCRAFT, THE SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN OR INCIDENT TO RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT. ADR EUROPEAN TRANSPORT STATEMENT: CARRIAGE IN ACCORDANCE WITH 1.1.4.2.1

Figure 10. Example FedEx Shippers Declaration for Dangerous Goods.

8 SAMPLE ANALYSIS AND QUALITY CONTROL

To obtain data of known quality for meeting project DQOs, samples will be analyzed using approved, prescribed methods. Section 8.1 specifies the analytical methods that will be used and the RL objectives. Section 8.2 describes the laboratory QC sample requirements for each method. Section 8.3 discusses the data reduction methods. Section 8.4 specifies the laboratory data reporting requirements.

Isotech Laboratories is not a traditional environmental analytical laboratory. They analysis they provide is not available from more conventional laboratories. Isotech does not provide a complete data package typically supplied by environmental laboratories. This issue has been evaluated and accepted in the context of the unique analysis capability they provide. Quality review of the Isotech data is required. Exceptions to the quality control requirements of the RSAP should be noted, but in general the data should be accepted as usable.

8.1 Analytical Methods and Reporting Limits

(Table 8) presents the analytical parameters and methods for each sample matrix, including the laboratory that will perform the analysis, the method that will be used, and the associated detection level for radiological analytes. A similar table was included in prior versions of the RSAP for non-radiological analytes. This requirement is no longer included in this revision. (Table 9) remains in this version to maintain the structure of the document.

The 900 series methods are found in *Prescribed Procedures for Measurement of Radioactivity in Drinking Water*, EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980. The HASL 300 methods are found in the DOE *Environmental Measurements Laboratory Procedures Manual, 28th Edition*, revised February 1997. In addition, Isotech Laboratories will conduct the ^{3}H and ^{14}C analyses in accordance with laboratory SOPs that are consistent with the methodologies presented in these two sources. The laboratory QA manuals will be obtained, where available, for review upon request. The SW846 series of methods are specified in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,* 3rd Edition, including all updates, prepared by EPA's Office of

Solid Waste. The 100 and 300 series methods are specified in *Methods for the Chemical Analysis of Water and Wastewater (*EPA 1983).

8.2 Laboratory Quality Control Samples

QC practices used for radiochemical analyses are intended to assure that the radionuclide determinations are under control. QC involves continuous testing of those processes that influence the extent to which the results of the analyses remain within the required limits of precision and accuracy. QC samples that are analyzed for radiological methodologies consist of five types: instrument calibration standards, blank samples, control samples, "spiked" samples, and replicate samples. Each type of QC sample and the overall QC frequency is described below.

Table 8. Analytical Methods and Reporting Limits for Radiological Analytes.

Parameter	Analytical Laboratory	Analytical Method	Analytical Technique	Definitive or Screening Analysis	Lower Limit of Detection	Analytical TAT[11]
NATURAL GAS						
Carbon-14 (^{14}C)	Isotech	Laboratory SOP[12]	liquid scintillation counting	definitive	0.5 pMC	45 days
Tritium (^{3}H)	Isotech	Laboratory SOP	liquid scintillation counting	definitive	10-15 TU[13]	28 days
WATER						
Tritium (^{3}H)	Isotech	EPA 906.0 modified	liquid scintillation counting	definitive	10-15 TU	28 days
Tritium (^{3}H)	GEL	EPA 906.0 modified	liquid scintillation counting	definitive	400 pCi/g	28 days
SOIL						
Tritium in soil moisture	GEL	EPA 906.0 modified	liquid scintillation	definitive	400 pCi/L	28 days

pMC = percent Modern Carbon
TU = Tritium Units
pCi/L = picoCuries per liter
pCi/g = picocuries per gram

Method Sources: EPA 900 series methods found in "*Prescribed Procedures for Measurement of Radioactivity in Drinking Water*," EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980. HASL 300 methods found in USDOE Environmental Measurements Laboratory Procedures Manual, 28th Edition, Revised February 1997.

[11] TAT = turn-around time
[12] Gas sample preparation for ^{14}C and ^{3}H Analysis by internal standard operating procedure; analysis of ^{14}C is subcontracted to the Illinois State Geological Survey Radiocarbon Laboratory.
[13] 1 tritium unit (TU) = approximately 3.2 pCi/L.

Table 9. Reserved. Non-Radiological Analytes DELETED.

8.2.1 Instrument Calibration

Instrumentation calibration assures that accurate and reliable measurements are obtained. Instrument calibration standards are certified reference materials used primarily to calibrate the measurement apparatus. A key requirement of such materials is that they be traceable to the National Institute of Standards and Technology or to other recognized organizations.

All instruments will be calibrated in accordance with the analytical method requirements. All analytes reported will be present in the initial and continuing calibrations, and these calibrations will meet the acceptance criteria specified in the method, at a minimum. All results reported will be within the calibrated range. Multipoint calibrations will contain the minimum number of calibration points specified in the method. The standards used in the calibration will include all contiguous standards analyzed within the calibration range. It is permissible to drop the highest and lowest concentration standards from the calibration if the calibration range is adjusted appropriately. Records of standards preparation and instrument calibration will be maintained and submitted with the final data package.

8.2.2 Blank Samples

Blank samples, commonly called "method blanks," are prepared using deionized water that is analyzed like the samples. A blank is prepared to represent the sample matrix as closely as possible and analyzed exactly like the calibration standards, samples, and QC samples. All appropriate reagents are added to the sample, in the proper sequence, and the normal steps involved in the analysis are followed. Ideally, the blank samples would be the same matrix as the routine sample but without the analyte of interest. Results of method blanks provide an estimate of the within-batch variability of the blank response and an indication of bias introduced by the analytical procedure.

For radiological analyses, the activity of each routine sample is typically corrected by subtracting the instrument background count rate from it to obtain net activity. All the uncertainties of the measurements obtained throughout the analytical procedure should be propagated when calculating the uncertainty of the result. However, very often, only the Poisson errors of the counts of the background count and of the sample are propagated when they are the most significant contributors to the total uncertainty. Control, Spiked, and Replicate Samples

Control samples contain known concentrations of the analyte. If possible, they should be the same matrix as the routine samples, and they should have concentrations in the same range as the routine samples. Control samples are usually included by the analyst in the sample batches to be analyzed, and their values should be known with an uncertainty better than that which will be required of measurements of the routine samples.

“Spiked” samples are prepared by adding a known amount of the radionuclide of interest to blank samples (i.e., LCS) or to samples that have already been analyzed (i.e., matrix spike samples) to provide a matrix with a known activity.

Replicate samples usually consist of two or more aliquots of homogenized solid, liquid, or gas samples. Individual samples that are measured by nondestructive techniques, such as gamma-ray spectroscopy, may be measured more than once to obtain replication of the data. If a single replicate measurement is made, it is called a matrix duplicate.

8.2.3 QC Sample Frequency

For most radiochemical procedures, QC samples are added to make up between 10 and 20 percent of the sample stream. (Table 10) presents the laboratory QC sample frequency for the various radiological analytes. (**Table 11**) provided similar information for non-radiological analytes, which are no longer required. (Table 11) remains in this version to maintain the structure of the document.

It is good analytical practice to process high-level and low-level samples in independent batches whenever possible to minimize the possibility of cross-contamination. When radiological samples of very low activity are to be analyzed, blank sample analyses and instrument background measurements should be increased.

The best estimates of a reagent blank or blank sample activity, instrument background count rate, and detection efficiency are obtained from the mean value of replicate determinations. Whenever possible, the mean and standard error of the replicate determinations should be used in calculating a final value for radiological analyses.

8.3 Data Reduction

The quality of the data reported by the laboratory depends not only upon the care with which sampling and analysis are performed, but also upon the care with which calculations of the resulting data are performed, and upon the way the data are presented in reports. A key aspect of a QA program is maintaining records that document each step of the process that leads to the data that ultimately are reported. This section outlines the methodology for assuring the correctness of the data reduction process.

The specific data reduction, verification, and reporting procedures and assigned personnel vary between laboratories; however, equivalent procedures shall be performed by each laboratory to assure that accurate and consistent data handling, review, and reporting are achieved.

The laboratory analyst performing analyses is responsible for the reduction of raw data generated at the laboratory bench to calculate sample concentrations. The data reduction procedures are described in the laboratory’s method SOPs. For many methods, data reduction software is included with the instrument of the Laboratory Information Management System (LIMS). In those cases, the analyst shall verify that the data reduction was correct. The system may require manual manipulation to correctly calculate sample concentrations.

The analytical process includes verification of a QA review of the data. Specific requirements, acceptance criteria, and corrective actions for each analysis are included in the analytical methods. The QC checks are reviewed at several levels by laboratory analysts, supervisors, designated QC specialists, document control staff, or by a combination of these staff. After the data have been reviewed and verified, the laboratory reports are signed and released for distribution.

Table 10. Laboratory Quality Control Criteria for Radiological Analytes.

Parameter	Analytical Method	Laboratory Control Sample (LCS) Frequency	Matrix Spike Frequency	Matrix Duplicate Frequency
Natural gas				
Carbon-14 (^{14}C)	Laboratory SOP	1 per batch	NA	NA
Tritium (^{3}H)	Laboratory SOP	1 per batch	NA	1 per 10
Water, Drill Cutting, or Soil				
Tritium (^{3}H)	EPA 906.0 mod	1 per batch	1 per 20	1 per 20

Notes:

1. An analytical batch consists of a set of up to 20 samples of the same matrix prepared and analyzed in the same time frame.
2. Instrument calibration frequency for all radiological analytes is to be done in accordance with analytical method requirements.
3. Method blank frequency for all radiological analytes is 1 per batch.

Table 11. Non-Radiological Analytes DELETED

Most laboratories use a LIMS to electronically track and report sample and QC data. The data are reported electronically from the LIMS to the project staff using pre-established formats. The LIMS files shall undergo a QC check to verify that the results are complete and correct, and that the files are properly formatted.

8.4 Laboratory Data Reporting

The laboratory will report the results in both hardcopy data packages and EDDs.

Hardcopy reports will include the following:

- Cover sheet listing the field samples and corresponding laboratory identification number (ID) for the samples reported in the data package
- Detailed case narrative describing any problems encountered with analysis and any deviations from laboratory SOPs or prescribed methods
- Tabulated sample results for all field samples, including associated uncertainties

- Tabulated results for all blank samples
- Tabulated results for all QC samples
- Initial calibration and continuing calibration summary data
- Raw data to support all information reported on summary forms
- Standards traceability data
- Sample tracking and receiving information, including the original COC form

The specifications for EDDs will be agreed upon prior to sample collection.

9 DATA VERIFICATION AND VALIDATION FOR RADIOCHEMISTRY PARAMETERS

To evaluate if the analytical data are sufficient for their intended use, all data will be validated. Validation will consist of two levels. The first level of data validation occurs at the analytical laboratory and is discussed in Section 9.1. The second level of validation is independent of the laboratory and is discussed in Section 9.2. The results of the independent data validation process will be documented in a data validation report (Section 9.3) that includes an overall assessment addressing the DQIs of sensitivity, accuracy, precision, completeness, comparability, and representativeness.

9.1 Laboratory Validation

Data reduction is the process of converting measurement system outputs to an expression of the parameter that is consistent with the comparable objective identified in this plan. As discussed in Section 8.3, reduction of analytical data will be completed in accordance with the laboratory's QA Plan and SOPs.

The first level of data review, which may contain multiple sublevels, will be conducted by the analytical laboratory. The laboratory has the initial responsibility for the correctness and completeness of the analytical data. The laboratory data reviewer will evaluate the quality of the analytical data based on an established set of laboratory guidelines (laboratory QA Plan and SOPs) and the RSAP. The laboratory reviewer will review the data packages to confirm the following:

- Sample preparation information is correct and complete.
- Analysis information is correct and complete.
- The appropriate laboratory SOPs have been followed.
- Analytical results are correct and complete.
- QC sample results are within established control limits.
- Blank results are within appropriate QC limits.
- Analytical results for QC sample spikes, sample duplicates, initial and continuous calibration verifications of standards and blanks, standard procedural blanks,

laboratory control samples, and other method-specific QC analyses are correct and complete.

- Tabulation of reporting limits related to the sample is correct and complete.
- Documentation is complete (all anomalies in the preparation and analysis have been documented; holding times are documented).

The laboratory will perform the in-house analytical data reduction and QA review under the direction of the laboratory manager or designee. The laboratory is responsible for assessing data quality and advising of any data that were rated "preliminary" or "unacceptable," or other notations that would caution the data user of possible unreliability. Data reduction, QA review, and reporting by the laboratory will include the following:

- Raw data produced by the analyst are processed and reviewed for attainment of quality control criteria as outlined in the RSAP, the laboratory QA Plan and SOPs, and/or established EPA methods and for overall reasonableness.
- The laboratory data reviewer will check all manually entered sample data for entry errors, will check for transfer errors for all data electronically uploaded from the instrument output into the software packages used for calculations and generation of report forms, and will decide whether any sample re-analysis is required.
- The laboratory data reviewer will review initial and continuing calibration data and calculation of response factors, surrogate recoveries, matrix spike/matrix spike duplicate recoveries, post-digestion (analytical) spike recoveries, internal standard recoveries, LCS recoveries, sample results, and other relevant QC measures.
- Upon acceptance of the preliminary reports by the laboratory data reviewer, the Laboratory QA Officer or designee will review and approve the data packages, prior to the final reports being generated.

The data reduction and the QC review steps will be documented, signed, and dated by the analyst and the laboratory project manager or designee.

9.2 Independent Data Validation

Section 9.1 describes the level of review of the analytical data by the laboratory. The second level of review and validation of the analytical data will be performed by data validation personnel independent of the laboratory generating the data. The purpose of this second level of review is to provide an independent review of the data package; it will include a review of laboratory performance criteria and sample-specific criteria. The following subsections discuss the process for independent review of laboratory performance criteria and sample-specific criteria. The amount and level of data validation will be based on the end use of the data and nature of the decisions that will be based on the data.

The first level of independent data review by the analytical laboratory includes a thorough review of laboratory performance parameters (which are independent of the field samples being analyzed). The independent validation will include a verification of the laboratory review of the performance criteria for the following:

- A minimum of one data package per method per matrix per site per year
- Ten percent of the data for each matrix (i.e., soil or water), whichever is greater

Regardless of the number of samples, a minimum of one data package will be reviewed for all combinations of samples, analyses, and laboratory operations to verify that the laboratory analysis is in compliance with method specifications. The review of laboratory performance criteria is discussed in Section 9.2.1.

The second level of independent data review will also include a review of sample-specific parameters for 100 percent of the data packages from each laboratory, for each analysis type for those parameters that are sample-related such as: holding times, blank results, sample-specific chemical recovery, matrix spike recoveries, duplicate analysis precision, and field duplicate agreement. Because transcription and calculation are reviewed and verified by the laboratory and are in the laboratory’s control, these parameters will be evaluated from the results reported by the laboratory. Any significant problems identified during the review of the laboratory performance criteria that indicate a systematic problem will also be included during the review of the sample-specific criteria. The review of sample-specific criteria is described in Section 9.2.2.

Validation acceptance criteria will be method-specified acceptance criteria. The sample-specific and laboratory performance evaluation procedures discussed for radiological parameters are based on guidance in SAIC (1993).

During the process of data validation, the reviewer will assign data qualifiers to results to indicate limitation on data usability. A list of data qualifiers and their definitions is provided as Table12.

Table 12. Independent Reviewer Data Qualifier Definitions.

The following definitions provide brief explanations of the data qualifiers assigned to results during the independent data review process. If the data reviewer chooses to use additional qualifiers, a complete explanation of those qualifiers will accompany the data review.	
U	The analyte was analyzed, but was not detected at a level greater than or equal to the level of the adjusted reporting limit for sample and method.
J	The analyte was positively identified and the result is an approximate concentration of the analyte in the sample (due either to the quality of the data because certain QC criteria were not met, or the concentration of the analyte was below the reporting limit).
NJ	The analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration.
N (Rads)	Analyte was identified as present, but a quantitative value was not reported.
UJ	The analyte was not detected at a level greater than or equal to the adjusted reporting limit. However, the reported adjusted reporting limit is approximate and may be inaccurate or imprecise.
R	The sample results are unusable because certain data quality criteria were not met. The analyte may or may not be present in the sample.

9.2.1 Laboratory Performance Parameters

The subsections below provide a general overview of the data validation procedure for each of the following laboratory performance review parameters.

- Calibration (radionuclides and non-radionuclides)
- Laboratory Control Sample (radionuclides and non-radionuclides)
- Radionuclide Quantitation and Implied Detection Limits (radionuclides)
- Chemical Separation Specificity (radionuclides)
- Target Radionuclide List Identification (radionuclides [gamma spectroscopy])
- Tentatively Identified Radionuclides (radionuclides [gamma spectroscopy])
- Compound Identification (non-radionuclides)

- Target Analyte Quantification (non-radionuclides)
- Method Specific QC Checks (non-radionuclides)
- Verification (radionuclides and non-radionuclides)
- System Performance (radionuclides and non-radionuclides)

For packages designated for review of laboratory performance parameters, the following evaluation parameters will be reviewed as applicable to the individual analytical methods.

Calibration

Compliance requirements for satisfactory instrument calibration are established to ensure that the instrument is capable of producing acceptable quantitative data. Initial and continuing calibration demonstrates that the instrument is capable of acceptable performance at the beginning of the calibration period, and routine calibration verification and system verification checks document that the initial calibration is still valid.

The reviewer will verify that the instrument was calibrated each time the instrument was set up and at the required frequency in the analytical method. The reviewer will evaluate the quality of the raw calibration data (e.g., shape and smoothness of high voltage plateaus, efficiency versus energy curves, and quench curves). The data reviewer will observe the QC charts and verify that the proper limits have been established and that recalibration was performed whenever the limits were exceeded. Additionally, the reviewer will verify calibration calculations.

For radiological parameters, if the specified calibration and/or verification frequency is not followed, the efficiency or quench curves are not smooth (radiological analyses), or the QC results fall outside appropriate tolerance limits, the results for affected analytes will be qualified as estimated (J or UJ). If errors are found to occur at a significant rate, if less than 100 percent of the results are recalculated, and the estimated magnitude of potential bias associated with such errors would be between 10 and 20 percent in typical sample results, all associated results will be qualified as estimated (J or UJ). Analogously, results will be qualified as unusable (R) if the estimated potential bias in unchecked sample results is greater than 20 percent.

If the initial or continuing calibration evaluation criteria for any analyte are not satisfied, then all results for that analyte associated with the initial calibration will be qualified as estimated (J or UJ). If the data reviewer can discern a probable magnitude and/or direction of bias to the associated sample results based on the information provided, it will be documented in the data validation report.

Laboratory Control Sample (as applicable to the method)

The LCS serves as a monitor of the overall accuracy and performance of all steps in the analysis, including the sample preparation. LCS should be analyzed for every matrix, every batch, or for every 20 samples (5 percent of samples), whichever is more frequent.

For radiological analyses, the following evaluation criteria apply when the activity in the LCS is greater than 10 times the detection limit (also referred to as the "minimum detectable activity" [MDA]). The reviewer will compare recoveries for aqueous LCSs to the acceptance range of 80 to 120 percent and recoveries for solid media to the acceptance range of 70 to 130 percent. The reviewer will verify that the LCS recoveries for at least one of the analytes was calculated properly.

- For aqueous samples, if the LCS recovery is within 50 to 80 percent or 120 to 150 percent, results for the associated analytes will be qualified as estimated (J). If the LCS recovery is less than 50 percent or greater than150 percent, the associated results will be qualified as unusable (R).
- For solid samples, if the LCS recovery is within 40 to 70 percent or 130 to 160 percent, results for the associated analytes will be qualified as estimated (J). If the LCS recovery is less than 40 percent or greater than 160 percent, the associated results will be qualified as unusable (R).

In the case of unacceptably low LCS recoveries, the reviewer will verify that the laboratory re-prepared and re-analyzed all associated samples, including the LCS and that acceptable results were obtained for the new LCS.

Radionuclide Quantitation and Implied Detection Limits

The raw data will be reviewed to ensure that the reported quantitation results are accurate and that the required detection limits were met.

Radionuclide activities shall be calculated according to the appropriate procedures specified in the analytical methods. Detection limits specified in (Table 6) shall be met unless other detection limits are approved or the nature of the sample matrix precludes attaining the detection limit in (Table 6). For example, the high solids content of the formation waters that will be analyzed may not allow the detection level for gross alpha to be achieved. Analytical uncertainties shall be reported with all results, regardless of the sign or size of the result. The reported uncertainty shall include all uncertainties associated with the analysis. If the reported uncertainty only includes counting uncertainty, this fact shall be documented in the case narrative.

For solid samples, a minimum of 100 grams shall be homogenized prior to subsampling an aliquot for analysis. Homogenization of the entire sample is recommended for all samples and is required for liquid samples with more than one phase. The minimum homogenized sample aliquot size used for analysis shall be 1 gram for dry solids or 1 milliliter for liquid samples, although further dilution may be performed after chemical dissolution or extraction.

The reviewer will review the raw data to verify the correct calculation of sample results reported by the laboratory. The reviewer will recalculate a minimum of one sample result for each matrix. The reviewer will verify that there are no transcription or reduction errors (e.g., dilutions, percent solids, sample weights) on one or more samples. The reviewer will verify that all analytical uncertainties have been propagated and reported or otherwise documented. The reviewer will verify that appropriate aliquot sizes have been used for sample preparation and mounting.

The reviewer will check the detection limits by verifying that, for blanks and other samples with uncertainties greater than the result, the 2 standard deviation uncertainty multiplied by 1.65 is less than or equal to the specified detection limit.

If errors are found in the calculations, the laboratory will be contacted to resolve the problem. Professional judgment will be used to assign data qualification.

If inappropriate sample sizes are used, all associated results will be qualified as estimated values (J).

Net negative results at a frequency more than that expected from a 2 standard deviation uncertainty that have combined uncertainties smaller than the absolute values of the negative results may be an indication of improper blank subtraction or measurement error. In such cases, the data reviewer will contact the laboratory to determine the root cause of the error and whether the raw data can be re-processed to correct the problem. If contact with the laboratory is unable to resolve the problem, data associated with this condition may be qualified as unusable (R) or estimated (J) depending on the magnitude of the potential error taking into consideration project objectives.

If detection limit requirements were not met, the cause will be investigated. The effect on data usability will be evaluated and documented in the data validation report.

If analytical uncertainties are not reported for radionuclides and they cannot be obtained from the laboratory, the associated results will be qualified as unusable (R).

If any discrepancies are found, the reviewer may contact the laboratory to obtain additional information. If a discrepancy cannot be resolved, the data reviewer will use professional judgment to determine if data qualification is warranted. All uses of professional judgment will be documented in the data validation report.

Chemical Separation Specificity (radiological analyses)

For analytes that are chemically separated prior to analysis (e.g., alpha speciation by spectroscopy), the chemical separation specificity will be evaluated. Chemical separation specificity evaluates the laboratory’s ability to chemically separate various isotopes with similar chemical properties. There should be no radionuclides that interfere with the quantitation of the radionuclide of interest once the chemical separation process has been completed.

For example, the chemical separation specificity can be verified for alpha spectroscopy measurements by observation of the alpha energy spectrum. Thus, for alpha spectroscopy, the reviewer will check that the energy of the observed peak of interest is within 40 kilo electron volts (keV) of the energy for the radionuclide of interest. The reviewer will also check the energy spectra for any peaks that overlap or that have associated peaks that may interfere with the peak radionuclide of interest. Lastly, if interfering radionuclides are present and can be corrected from associated peaks in the spectrum, the reviewer will check to see if the peak area for the radionuclide of interest has been properly corrected.

Data will be qualified as nondetect (U) if the energy of the peak of interest is more than 40 keV from the energy of the radionuclide of interest and no other peaks are found within 40 keV. Results will be qualified as unusable (R) or estimated (J) if the energy spectrum contains any peaks that overlap with or have associated peaks that may interfere with the peak of the radionuclide of interest and it is impossible to correct for the interference, or if the results have not been properly corrected for the interfering radionuclide. The reviewer will use professional judgment in choosing the proper qualifier dependent on the magnitude of the potential interference relative to project objectives.

Verification

The reviewer will verify that information reported on the summary forms was calculated properly and that the results are traceable back to the raw data for 10% of the reported sample results in the data packages undergoing an evaluation of laboratory performance parameters. In addition, the reviewer may also verify that all spike solutions and standards were used within their recommended shelf lives.

If errors are found in the reported sample results, the laboratory will be contacted and corrected results will be requested. The data review narrative will detail any such instances and the resultant resolution. The reviewer will collate the revised data into the data package and mark all revised and all superseded data accordingly.

System Performance

A thorough review of ongoing data acquisition may yield indicators of instrument performance and changes in the system that may degrade the quality of the data being generated. Some examples of changes in instrument performance include abrupt, discreet shifts in background; change in detector response as noted by contamination and/or gain or threshold changes; and poor spectroscopy, denoted by high background or shifts in energy calibration, extraneous peaks, loss of resolution, peak tailing, or peak splitting. The reviewer will evaluate the raw data for each sample to evaluate if unexpected activity, extraneous peaks, loss of resolution, or loss of expected background peaks has occurred.

If the raw data indicate that the system performance had degraded, the reviewer will use professional judgment to decide if the system has degraded to the point of affecting data quality or validity and assign appropriate qualification.

9.2.2 Sample-Specific Criteria

The subsections below provide a general overview of the data validation procedure for each of the following sample-specific review parameters:

- Case narrative comments
- COC and Sample Receipt
- Holding times
- Blanks
- Matrix-specific QC samples
    - Sample-specific chemical recovery (radionuclides)
    - Matrix spike recovery
    - Duplicate analysis
- Standard uncertainty (radionuclides)
- Field QC samples
    - Field duplicate agreement
    - Rinsate blanks
    - Field blanks
    - Trip blanks
- Balance of total to partial analyses
- Data package completeness

For all data packages, the following evaluation parameters will be reviewed as applicable to the individual analytical methods.

<u>Case Narrative Comments</u>

The case narrative will be reviewed. The case narrative should include comments related to any problems encountered during the preparation and analysis of the samples. Any problems noted in the case narrative will be investigated by the data reviewer and evaluated against method requirements. If the analytical method does not specify requirements related to the criterion under evaluation, the data reviewer should utilize professional judgment to evaluate the effect of the reported item or condition on the associated analytical data. The effect on data quality and usability of any such problems will be noted in the data validation report. All uses of professional judgment will be described in the report of the data validation process.

Chain of Custody and Sample Receipt

The COC document will be reviewed to verify that all requested analyses were performed on the sample submitted. Additionally, the sample receiving information will be reviewed to evaluate the integrity of the samples upon receipt at the laboratory.

If criteria for sample preservation are not met, associated sample results may be qualified as estimated (J). If sample integrity was compromised during shipment (e.g., breakage) the effect on data quality and usability will be noted in the data validation report. All uses of professional judgment must be described in the report of the data validation process.

Holding Times

Holding times will be evaluated by comparing the sample collection date on the COC form to the analysis date found on the laboratory analysis reports (i.e., data sheets). Holding time will be compared to the holding time requirements listed in (Tables 6 and 7).

If criteria for holding times are not met, associated sample results will be qualified as estimated (J). However, the reviewer will also use professional judgment to determine the reliability of the data and the effects of additional storage on the sample results based on the half-lives of the compound of interest and its parent isotopes. Consideration will be given to whether the result can be corrected back to the time of sample collection to provide more accurate and reliable data. The expected bias may be high or low, depending on the rates of decay and in-growth, and the reviewer may determine that results less than the critical level (CL) are unusable (R).

Blanks

Blank analysis results are used to assess the existence and magnitude of contamination problems. If a problem exists with any blank, the reviewer will evaluate whether there is an inherent variability in the data for the entire data set or if the problem is an isolated occurrence not affecting other data.

Blanks should be analyzed for every matrix and every batch, or at a frequency of 5 percent, whichever is more frequent. The results for all blanks should be plotted to determine that each blank result falls within the recommended tolerance limits of ± 3 standard deviations.

For radiological parameters, the net blank result (e.g., the blank result after subtraction of background) shall be less than the associated uncertainty if the average blank or instrument background counts are subtracted to determine net counts. If the net blank result is larger than the associated uncertainty, contamination will be suspected. If the blank QC results fall outside the appropriate tolerance limits or if the net blank result is greater than the associated uncertainty, and the sample concentration is less than five times the blank concentration or within the combined uncertainty, the sample results will be qualified as nondetect (U) for the associated analyte. Results for associated samples that are greater than five times and less than ten times the blank amount will be qualified as estimated (J).

If reported, negative blank concentrations will be evaluated for potential effects (low bias) on sample data when the absolute value of the negative concentration is >RL. If the negative concentration in a blank may potentially have produced more than a 25% effect on a reported sample result or sample reporting limit, the associated sample result will be qualified as estimated (J/UJ). For example, if the associated blank result is –2 mg/l, the RL is 1 mg/l, and the associated sample result is 5 mg/l, the sample result will be qualified as estimated because a potential low bias of 2 mg/l represents 40% of the reported concentration and the absolute value of the blank concentration is >RL.

Sample Specific Chemical Recovery (radiological methods)

Laboratory performance on individual sample analyses subject to chemical process and separation is established by means of spiking with tracer quantities of other radioisotopes of the same element or carrier quantities of the inactive isotope of the same or a chemically similar element. All samples are spiked prior to preparation. The evaluation of these spikes is not necessarily straightforward, because the sample matrix may produce interferences which are outside the control of the laboratory.

While professional judgment will be used to evaluate the results obtained for sample-specific chemical recovery, the following qualification strategy may be used for results whose quantitation does not include correction for the low recoveries:

- For recoveries between 50 and 120 percent, the data are acceptable for use without qualification.
- For recoveries between 20 and 50 percent and 120 and 150 percent, associated results may be qualified as estimated (J).
- For recoveries greater than 150 percent or less than 20 percent, associated results may be qualified based on professional judgment as estimated (J) or unusable (R).
- If the calculation includes correction for low recoveries, the following strategy may be used:

For recoveries between 10 and 120 percent, the data are acceptable for use without qualification.

For recoveries between 5 and10 percent and 120 and 150 percent, associated results may be qualified as estimated (J).

For recoveries greater than 200 percent or less than 5 percent, associated results may be qualified as unusable (R).

Any use of professional judgment will be explained in the data validation report.

Matrix Spike (as applicable to the method)

The matrix spike sample analysis provides information about the effect of each sample matrix on the digestion and measurement methodology. A matrix spike sample should be analyzed for every matrix and every batch, or for every 20 samples (5 percent of samples), whichever is more frequent, when sample-specific chemical recovery mechanisms are not available and the sample undergoes a chemical process. Samples identified as field blanks must not be used for spiked sample analysis.

For radiological parameters, the reviewer will compare recoveries for aqueous matrix spike samples to the acceptance range of 80 to 120 percent and recoveries for solid media to the acceptance range of 70 to 130 percent. However, the spike recovery limits do not apply when the sample concentration exceeds the spike concentration by a factor of 4 or more. The reviewer will verify that the matrix spike recoveries were calculated properly for at least one of the analytes.

- For aqueous samples, if the MS recovery is within 50 to 80 percent or 120 to 150 percent, results for the associated analytes will be qualified as estimate (J). If the LCS recovery is less than 50 percent or greater than 150 percent, the associated results will be qualified as unusable (R).

- For aqueous samples, if the MS recovery is within 40 to 70 percent or 130 to 160 percent, results for the associated analytes will be qualified as estimate (J). If the LCS recovery is less than 40 percent or greater than 160 percent, the associated results will be qualified as unusable (R).

Duplicate Analysis (matrix duplicate or spiked duplicate)

Duplicate analyses are indicators of laboratory precision based on each sample matrix. Samples identified as field blanks should not be used for duplicate analyses. At least one duplicate should be analyzed for every matrix, every batch, or for every 20 samples (5 percent of samples), whichever is more frequent.

For radiological parameters, the duplicate analyses results must be in agreement when the 2 standard deviation (95 percent confidence limit) uncertainties are considered. For this to be true, the duplicate error ratio (DER) should be less than 1. The DER is calculated as follows:

$$DER = \frac{|S - D|}{\sqrt{(2\sigma_S)^2 + (2\sigma_D)^2}}$$

where,

S = First Sample Value (original)
D = Second Sample Value (duplicate)
$2\sigma_S$ = First Sample Uncertainty at the 2σ level
$2\sigma_D$ = Second Sample Uncertainty at the 2σ level

The reviewer will compare reported DERs to the evaluation criterion of less than one. The reviewer will recalculate at least one DER value. If the DER value is greater than 1, the results for affected analyte will be qualified as estimated (J) in all associated samples of the same matrix. Other equations used by laboratories to express duplicate agreement will be considered using professional judgment with the concept that the criterion should be consistent with agreement within the 95-percent confidence limits.

Standard Uncertainty (radionuclides)

In addition to criteria for individual measures of accuracy and precision, the data will be evaluated against a criterion for “total” or standard uncertainty. To evaluate the standard uncertainty, one must first choose the measure of accuracy and precision for a given set of samples that will be used in the calculation. If an MS measurement has been made on a site sample of similar matrix, then the MS result will be used as the contributing accuracy QC measure. If such a matrix-specific number is not available, then the Laboratory Control Sample (LCS) results will be used. If no LCS is available, then the calibration verification or calibration check analyses will be used. For precision, the duplicate measurements on the sample performed by the laboratory will be used.

A standard uncertainty (SU) value will be calculated for each batch of samples analyzed. The standard uncertainty will be calculated using the equation shown below. This equation is modified after Equation 19.4 of the MARLAP manual (USEPA et al. 2004).

$$SU(\%) = \sqrt{\left(\frac{1}{(n(n-1)}\right)\left[(A - Ec_{ms})^2 + (P - Ec_p)^2\right]} * 100$$

where:

Ec_{ms} = counting error (square root of the number of counts or half the 2-sigma error)

Ec_p = square root of the sum of squares of the duplicate counting errors

A = measured accuracy

P = measured precision

n = 2

For example, if the MS recovery is 80 percent (A=0.2), the duplicate RPD is 22 percent (P=0.22), and the 1 sigma counting error for the MS sample is 0.8 mg/kg for a reported concentration of 4 mg/kg (Ec_{ms} = 0.2). Additionally, the counting error for the first sample used for the duplicates analysis is 1.1 for a reported concentration of 5 mg/kg and the counting error for the second sample used for the MS was 1.3 mg/kg for a reported concentration of 4 mg/kg, then

$$Ec_p = \frac{\sqrt{(1.1)^2 + (1.3)^2}}{\frac{(5+4)}{2}} = 0.38$$

Thus, calculated standard uncertainty is:

$$SU(\%) = \sqrt{\left(\frac{1}{(2(2-1)}\right)\left[(0.2 - 0.2)^2 + (0.22 - 0.38)^2\right]} * 100 = 11\%$$

Thus, for standard uncertainty, if A and P are small compared to Ec, then the standard uncertainty value calculated will be close to Ec. Conversely, if A and P are large compared to Ec, then a typical error value is calculated.

For sample batches whose calculated standard uncertainty is greater than 50 percent, each sample within the batch will be qualified as estimated (J).

Field Quality Control Samples

The types of field quality control samples that will be collected under this RSAP include field duplicates, rinsate blanks, field blanks, and trip blanks. The evaluation for each type of field quality control sample is described below.

Field Duplicate Agreement

Field duplicate sample results will be used as an indication of overall precision (i.e., field and laboratory precision) and/or the representativeness of the samples to the medium sampled.

Results for radiochemical activity in field duplicate samples will be reviewed by evaluating differences in results relative to the two-sigma counting error (uncertainty) for each result, as reported by the laboratory. The difference between the field duplicate result and the field original result is compared against a laboratory reported uncertainty (2 sigma counting error) for each sample result. If one of the field duplicate pair is nondetect (with no uncertainty reported), the uncertainty is calculated as if equal to that of the positive result. Field duplicates sample results differing from the field original results by a magnitude more than the combined uncertainty for both the field original and field duplicate results (i.e., DER greater than 1) will be discussed in the data validation report.

Field Blank Results

The results for field blanks reported in the data package will be reviewed. Sample results for analytes detected in an associated field blank at concentrations <5x the equivalent blank concentration (<10x for common laboratory contaminants) will be qualified as nondetect (U). The result will be qualified as nondetect at the reported concentration if the reported concentration is >RL or as nondetect (U) at the RL if the reported concentration is <RL.

For aqueous blanks applied to soil/sediment samples, qualification is assigned based on comparison of the sample result to the equivalent concentration in the blank. The equivalent concentration is determined by assuming that all of the analyte present in the blank aliquot analyzed is present in the soil sample aliquot analyzed. The reviewer should note that the blank analyses may not involve the same weights, volumes, or dilution factors as the associated samples. These factors shall be taken into consideration when applying the 5x or 10x criterion, such that a comparison of the total contamination is actually made.

Trip Blank Results

The results for trip blanks reported in the data package will be reviewed. Sample results for analytes detected in an associated trip blank at concentrations <5x the equivalent blank concentration (<10x for common laboratory contaminants) will be qualified as nondetect (U). The result will be qualified as nondetect at the reported concentration if the reported concentration is >RL or as nondetect at the RL if the reported concentration is <RL.

For aqueous blanks applied to soil/sediment samples, qualification is assigned based on comparison of the sample result to the equivalent concentration in the blank. The equivalent concentration is determined by assuming that all of the analyte present in the blank aliquot analyzed is present in the soil sample aliquot analyzed. The reviewer should note that the blank analyses may not involve the same weights, volumes, or dilution factors as the associated samples. These factors shall be taken into consideration when applying the 5x or 10x criterion, such that a comparison of the total contamination is actually made.

Method-Specific Quality Control

For inorganic methods, method specific QC measures may include post-digestion spikes, serial dilution tests, internal standard performance, and cation/anion balance calculation.

Post Digestion Spike Recovery

The analyte recoveries obtained for post-digestion spike analyses will be compared to the appropriate acceptance ranges in the method. Under some circumstances, laboratories will quantify results by the method of standard additions to compensate for low post-digestion spike recovery. In such a case, the low post-digestion spike recovery would not indicate poor accuracy. However, if the result for the sample on which the post-digestion spike analysis was performed was not obtained by the method of standard additions and the post-digestion spike recovery is outside of the acceptance limits, qualify the result for the sample on which the post-digestion spike was run based on the following guidance:

- If the recovery is > the upper acceptance limit, detectable results are qualified as estimated (J). No action needs to be taken for non-detects.
- If the recovery is < the lower acceptance limit, but ≥ 30%, detectable and non-detectable results are qualified as estimated (J/UJ).
- If the recovery is <30%, detectable results are qualified as estimated (J) and non-detectable results are qualified as unusable (R).

The data reviewer should use professional judgment in conjunction with other QC sample results, such as matrix spike recoveries, to determine the need for qualification of results for other samples (if any) associated with the post-digestion spike analysis.

Serial Dilution Test

ICP serial dilutions are run to help evaluate whether or not significant physical or chemical interferences exist due to sample matrix. Serial dilution analyses are typically conducted at a frequency of 1/20 samples (one analysis per metals data package). When analyte concentrations are sufficiently high (the concentration in the original sample is minimally a factor of 50 above the instrument detection limit [IDL] or method detection limit [MDL]), the results obtained for a fivefold-dilution of the original sample are compared to the original results by means of a percent difference (%D). The %D is compared to a precision acceptance limit of ±10%. If the absolute value of the %D between the diluted and original result is >10%, all results for that analyte in that sample batch are qualified as estimated (J/UJ).

Generally, the diluted result can be considered to be the more accurate result, as long as the diluted concentration is well above the detection limit. Therefore, the data reviewer can generally discern a potential bias direction from a comparison of the diluted and undiluted results. For example, if the diluted result is higher than the original result, the bias direction (associated with the original result) is considered to be potentially low.

Internal Standards (inorganic methods)

Internal standards are used routinely in the analysis for metals by ICP-MS; however, internal standards may be used in the analysis of metals by ICP-ES. Internal standard recoveries for every sample and standard (as the requested level of reporting permits evaluation) will be compared to an acceptance range of 30-120%. Results associated with internal standard recoveries outside the acceptance range where the sample was not diluted and reanalyzed will be qualified as estimated (J/UJ). If upon reanalysis the internal standard recoveries are still outside the acceptance range, the results will be qualified as estimated (J/UJ).

Surrogate Spike Compound Recovery

The surrogate recoveries obtained for each sample analysis for which surrogates were analyzed will be compared to the acceptance range specified in the method or that provided by the laboratory (statistically derived acceptance ranges). Results for analytes in the sample associated with surrogate recoveries outside the acceptance range will be qualified as follows:

- If the surrogate recovery is greater than the upper acceptance limit for any surrogate suggesting a potential high bias in reported results, all positive results for associated analytes in that sample are qualified as estimated (J) whereas non-detect results are considered to be acceptable for use without qualification.
- If the surrogate recovery is < the lower acceptance limit but ≥10% suggesting a potential low bias in reported results, positive and nondetect results for associated analytes in that sample are qualified as estimated (J or UJ).
- If any surrogate recovery is <10%, positive results for associated analytes in that sample are qualified as estimated (J) whereas associated non-detect results are qualified as unusable (R).

It is important to note that professional judgment may be utilized in assigning data qualification especially for methods in which more than one surrogate compound is used or in which there may have been multiple reasons for qualification on an individual result, or there may have been multiple analyses of the same sample. The data review narrative will detail any instance in which professional judgment was used.

Balance of Total to Partial Analyses

Results for the total analysis of a particular analyte should be greater than the results for a partial analysis of that analyte. For example, the results for gross alpha particle activity should be greater than or equal to the results for any individual analyte contributing to the gross alpha result, and Total Uranium should be greater than the results for individual uranium isotopes. Because all results are limited by the accuracy of the analysis, the criteria for accuracy of the analysis will be used as the basis for criteria to evaluate the agreement between the results for the partial analysis and the total portion.

Where both results are greater than five times the higher RL, the criterion used will be that the two values should agree within ±30 percent for aqueous samples and ±50 percent for solid samples. For example, the aqueous partial analysis result should not be more than 30 percent higher than the total analysis result. Where either of the results is less than five times the RL, an evaluation criterion of plus or minus two times the higher RL (minus 3.5 times the higher RL for solids) is compared against the difference between the partial and total results. If the results for the partial versus total analyses did not satisfy the appropriate evaluation criterion, results for the partial and total analyses will be qualified as estimated (J/UJ).

Data package completeness

All analytical data received from the laboratory shall meet the data package requirements specified in Section 8.4. Fully validatable data packages will be submitted as appropriate. The laboratory will be contacted regarding any missing or incorrect deliverables in the data packages, as noted during the validation process. The data reviewer will document all subsequent submittals and re-submittals from the laboratory, recalculations, and data reviewer corrections. The full deliverable data package will be reviewed for evaluation and compliance with method specifications.

A summary of the laboratory performance and sample-specific validation criteria is provided in (Table 13) for radiological analytes. (Table 14) provided similar information for non-radiological analytes, which are no longer required. Table 14 remains in this version to maintain the structure of the document.

9.3 Data Validation Reports

The results of the independent data validation process will be documented in a data validation report, which will include an overall assessment addressing the DQIs of sensitivity, accuracy, precision, completeness, comparability, and representativeness. The data validation report will include definitions of all data qualifiers assigned, discuss all instances in which evaluation criteria were not satisfied and data qualification assigned, and state whether the data are considered usable for the intended purpose. Additionally, any method non-compliances identified during the review, professional judgments used, and conclusions reached concerning usability of non-compliant data will be described in data validation reports.

Table 13. Laboratory Performance and Sample-Specific Validation Criteria for Radiological Analytes.

Laboratory Performance Criteria	Criterion	Qualification
LCS	80-120% (aqueous)	50-80% or 120-150% - Qualify results as estimated (J/UJ) <50 or >150 – Qualify associated results as unusable (R)
	70-130% (solid)	40-70% or 130-160% - Qualify results as estimated (J/UJ) <40 or >160 – Qualify associated results as unusable (R)
DL	If the uncertainty is greater than the result, than 2δ x 1.65 ≤DL	Qualify the result as estimated (J)
Net Negative Results	Criteria specified in Section 9.2.1	Data associated with this condition may be qualified as unusable (R) or estimated (J) depending on the magnitude of the potential error taking into consideration project objectives.
Chemical Separation Specificity (alpha spectrometry only)	Criteria specified in Section 9.2.1	Data will be qualified as nondetect (U) if the energy of the peak of interest is more than 40 keV from the energy of the radionuclide of interest and no other peaks are found within 40 keV. Results will be qualified as unusable (R) or estimated (J) if the alpha energy spectrum contains any peaks that overlap with or have associated peaks that may interfere with the peak of the radionuclide of interest and it is impossible to correct for the interference, or if the results have not been properly corrected for the interfering radionuclide.
Target Radionuclide List Identification (gamma spectrometry)	Criteria specified in Section 9.2.1	Professional judgment, however, Section 9.2.1 of the RSAP provides guidance.
Tentatively Identified Radionuclide (gamma spectroscopy)	Criteria specified in Section 9.2.1	Professional judgment, however, Section 9.2.1 of the RSAP provides guidance.
Sample Specific Criteria	**Criterion**	**Qualification**
Holding Time	Holding times are presented in Table 6	Sample results will be qualified as estimated (J/UJ).
Method Blank	MB < the appropriate tolerance limits or The net blank result < the associated uncertainty	If the sample concentration is < 5x the blank concentration or within the combined uncertainty, the sample result is qualified as nondetect (U). If the sample concentration is greater than five times and less than ten times the blank amount, the sample result is qualified as estimated (J).
Sample Specific Chemical Recovery (as applicable)	50-120%	20-50% and 120-150% - Qualify results as estimated (J). <20% or >150% - Qualify results as unusable (R)
Matrix Spike Samples (as applicable to the method)	80-120% (aqueous)	50-80% or 120-150% - Qualify results as estimated (J/UJ) <50 or >150 – Qualify associated results as unusable (R)
	70-130% (solid)	40-70% or 130-160% - Qualify results as estimated (J/UJ) <40 or >160 - Qualify associated results as unusable (R)
Duplicate Analysis (method duplicate or spike duplicate)	DER ≤1	Qualify the results in all associated samples as estimated (J/UJ)
Field Duplicate	DER ≤1	Comment in the data validation report.
Balance of Total to Partial Analyses	±30% (Aqueous) ±50% (Solid)	Qualify total and partial results as estimated (J/UJ).
Standard Error	<50%	Qualify all associated results as estimated (J/UJ).
Standard Uncertainty		For sample batches whose standard uncertainty is > 50%, each sample in the batch will be qualified as estimated (J)

Table 14. Non-Radiological Analytes. DELETED

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Appendix A
Tier I Radiological Incident Management Plan
For Natural Gas Exploration and Production Activities
Near the Project Rulison Test Site

Revision 4

July 2017

▪ Appendix A. Radiological Incident Management Plan

This Tier I Radiological Incident Management Plan was developed to support natural gas drilling operations near Project Rulison, the site of a previous underground nuclear detonation in 1969. The plan provides guidance concerning the mitigation, response, and recovery in the unlikely event of a radiological release while drilling within the Tier I monitoring zone near Project Rulison. The Tier I monitoring zone encompasses the area within a one-mile radius of the Project Rulison device emplacement well R-E. This plan is not required for well sites within the Tier II monitoring zone, i.e., the area within a one- to three-mile radius of the Project Rulison device emplacement well R-E.

The purpose of this plan is to supplement the existing Company incident management plans to mitigate, recognize, and respond to potential radiological incidents that might conceivably occur during gas well drilling within the Tier I monitoring zone. This plan is designed to facilitate a swift and appropriate response in the unlikely event of an unexpected radiological release incident during Tier I gas well drilling activities within a one-mile radius of the Project Rulison device emplacement well R-E.

○ *Tier I Radiological Incident Management Plan Organization*

This Tier I Radiological Incident Management Plan is comprised of five sections, including this introduction (Section 1). Section 2 discusses radiological incident mitigation measures. Section 3 discusses radiological incident preparedness and response. Section 4 briefly describes incident recovery measures. Section 5 lists the references cited in this plan. Attachment A-1 includes personnel decontamination procedures.

▪ Radiological Incident Mitigation

○ *Risk Assessment*

Natural disasters and events (e.g., flash floods, high winds, electrical storms, fires, blizzards, freezing) or man-made events (e.g., structural collapse, vehicle accidents, equipment fires,) that might occur in the Project Rulison area are not likely to affect the natural gas drilling operations so that a radiological release could occur. The potential source of radiation is located at a depth of approximately 8,426 feet below ground surface, thus natural disasters occurring at ground surface are not likely to result in a radiation release from that depth. Furthermore, drilling will not occur in areas that are expected to contain elevated radiation levels.

Additionally, standard drilling operations maintain sufficient head in a borehole, using drilling muds and fluids, so that an uncontrolled release of radiologically-contaminated subsurface material at the surface is not likely, unless well control is lost (i.e., a blowout occurs).

○ *Mitigation of Releases from Man-Made Events*

Although unlikely to result in a release of radiological material, man-made events or incidents will be mitigated by the implementation of health and safety programs and management systems that specify engineering controls, administrative controls, and personal protective equipment (PPE). Controls include (but are not limited to) barricades, lockout procedures, fire protection systems, equipment inspections, worker training, and appropriate PPE. These procedures are part of the day-to-day operations at all drilling sites and are detailed in Company-specific safety plans and programs. This Tier I radiological incident management plan is designed to supplement existing Company incident response plans in the unlikely event of a radiological release.

○ *Mitigation of Releases During Natural Events*

Although natural events are unlikely to result in a release of radiological material at the surface, the potential of a release during a natural event (e.g., flash floods, high winds, electrical storms, fires, blizzards, freezing) will be mitigated in several ways. Site design standards and other regulatory requirements incorporate prevention or mitigation of potential contaminant releases; this may include berms around reserve pits during drilling, secondary containment berms or steel rings around tanks during production as required by Spill Prevention Control and Countermeasures (SPCC) requirements, and stormwater controls to divert runoff away from the well pad. Structures will be constructed to withstand expected wind events. Well pad locations will be located outside of flash flood zones. In the event of a significant natural event, work will be stopped until equipment damage and the potential for an unexpected release of radiological materials can be assessed.

▪ Radiological Incident Preparedness and Response

○ *Radiation Safety Briefing*

A one-time radiation safety briefing will be conducted for the drilling crews and Company personnel before initiating drilling at a Tier I well pad. All drill site and production personnel will be required to attend the briefing and their attendance documented. The briefing may include the following:

- Review of the history of Project Rulison

- Radiation awareness training and an overview of this Tier I Radiological Incident Management Plan

- Recognition of a radiological incident, discussion of procedures that are in place to minimize the potential for exposure if an unexpected radiological incident occurs, radiological screening methods, decontamination methods, action levels, and incident communication procedures

- What personnel should do if a radiological incident occurs to determine if they have been exposed to radiologically-contaminated materials

- Basic radiation safety, emergency procedures, alarms, rallying points, and other relevant site information.

The radiation safety briefing will also be offered to, but not required for, community responders including fire departments, law enforcement, emergency medical services (EMS), and hospitals identified to respond to site incidents regarding the contents of this plan. A radiological briefing packet will be prepared that can be shared with community responders. The briefing packet will include community notification information for a radiological incident. The location of well pads within the Tier I monitoring zone will be available as a map to the community responders to facilitate rapid emergency response in the event of an incident.

○ ***Potential Radionuclides of Concern***

The most likely radionuclide that might be encountered during a radiological release incident is ^{3}H, because it is potentially mobile in both the produced water and natural gas. ^{3}H is a weak beta emitter and poses little or no health threat at low doses. Other radionuclides, such as ^{99}Tc, ^{137}Cs, and ^{90}Sr or their decay products, that are more abundant but considerably less mobile that could conceivably be encountered may emit alpha, beta, and/or gamma radiation of various energies. Beta and gamma radiation are primarily external exposure hazards. Alpha radiation is an internal exposure concern because it does not normally penetrate the outer layer of skin. Both alpha and low-energy beta particles are shielded by thin rubber gloves or other protective equipment.

○ ***Site Safety and Radiation Safety Officer***

During drilling operations a Site Safety Officer (SSO), or a designated representative, will be on site at all times for the **closest designated well** drilled within a Tier I monitoring sector and locally available for all other wells drilled within Tier I. The SSO, or designated representative, will be properly trained to understand the requirements of the Rulison Sampling and Analysis Plan (RSAP) and this Tier I Radiological Incident Management Plan and will have the authority to implement all actions to comply with this plan. The SSO, or designated representative, will be supported as needed by the Radiation Safety Officer (RSO), or an alternate RSO, who will be available by phone on a 24-hour basis. The RSO will be trained and experienced health physics professional. The RSO and alternate RSO are subject to approval by the Colorado Oil and Gas Conservation Commission (COGCC). The RSO's and alternate RSO's resumes will be submitted to the COGCC for review and approval prior to initiating drilling within the Tier I monitoring zone.

○ ***Background Radiation Survey***

A one-time background radiation survey will be performed by the Companies, or their designated representative, prior to drilling at the well pad with the **closest designated well** within each Tier I monitoring sector. If the pad with the closest designated Tier I well in a sector has been previously constructed and drilled prior to the implementation of this SAP, a background radiation survey will also be conducted at the pad to document the existing background radiation conditions prior to drilling additional Tier I wells.

The background radiation survey will be performed by screening each well pad area using hand-held radiation survey equipment to measure the background activities of alpha, beta, and gamma radiation. Alpha, beta, and gamma radiation screening will be performed using a hand-held Fluke ASM-990 survey meter equipped with a Model 489-110D Pancake GM detector and an alpha-beta filter, or equivalent. Gamma radiation exposure measurements will be performed using a hand-held Fluke 451P ion chamber survey meter, or equivalent. Photographs of these hand-held instruments are shown in (Figure A-1).

Background radiation screening will be performed on a 9-point grid over the area of the well pad. The 9 points will include measurements at each corner of the pad (4), at the midpoint of the sides of the pad (4), and at the center of the pad (1). (Figure A-2) is a sketch showing the typical background radiation survey measurement locations.

The alpha, beta, and gamma radiation screening will be performed by placing the pancake detector probe within about 1 inch of the ground surface and recording the radiation response. A radiation measurement will also be collected by holding the pancake detector probe about 3 feet ("waist high") above the ground surface and recording the reading. The measurements will be repeated to determine gamma radiation by placing the alpha-beta filter on the pancake detector and repeating the above measurements. Radiation readings within 1 inch of the ground surface and at waist level will also be performed using the Fluke 451P ion chamber survey meter. The radiation measurements will be recorded in a field logbook or on sample forms (Appendix C) as microRoentgen per hour (microR/hr) or counts per minute (cpm). Radiation survey equipment will be operated, tested, and calibrated in accordance with the manufacturer's instructions. The equipment will be tested each day it is used to document its performance before and after each survey using a radiation check source disk (e.g., ^{137}Cs; Figure A-1) and the instrument response recorded in a field logbook (Appendix A Section 3.10.2). Radiation survey instruments shall be calibrated by the manufacturer or a certified service center in accordance with state regulations at intervals not to exceed 12 months.

○ ***Recognizing a Potential Radiological Incident***

Companies have their own individual incident management plans to address a wide range of possible incidents. Common steps that apply to any incident response include the following:

- Sounding of a general alarm to alert all on-site personnel. All site activities will be stopped when the alarm is sounded and work will not resume until it is confirmed safe

- Activating emergency shutdown procedures to stop the incident or associated releases

- Accounting for all personnel and providing medical and other emergency support as needed. Community first responders and hospitals will be notified if medical care or other emergency support is occurring or needed, and

- Assessing the type and extent of a given incident and implementing appropriate follow-up actions, including containment or remedial actions as well as notifications to regulatory agencies, local governments, and the public.

While the above four steps are common operational responses to any incident, the specific operational responses will be governed by each Company's incident management plan. This Tier I Radiological Incident Management Plan will supplement existing Company incident management plans and focuses on the radiological aspects of potential incidents. Three types of potential radiation incidents are addressed in this plan and include loss of well control, release of drilling fluids (i.e., drilling muds, natural gas, or produced water) or drill cuttings to the environment, or elevated radiation measurements in subsurface fluid or solid media brought to the surface. The Companies recognize that the Colorado Department of Public Health and Environment (CDPHE) will be involved if a verified Project Rulison-related radiological incident occurs and that a radioactive materials license may be required if contaminated materials are detected above regulated activities.

- **Loss of Well Control**

Company emergency response procedures will be implemented in the event of loss of well control (i.e., an uncontrolled flow of natural gas or well fluids, typically referred to as a “blowout”). As a supplement to the well loss emergency response procedures, the radiological response procedures outlined in Section 3.9 (Appendix A) of this plan will be implemented to determine whether a radiological release has occurred at the site so that appropriate radiological response procedures can be implemented if necessary.

In the unlikely event that a loss of well control occurs, the area will be secured by the Companies. Once well control has been re-established and the area is safe, the SSO, or designated representative, will contact the RSO, or alternate RSO, for guidance and direction. If warranted, the RSO, or alternate RSO, will mobilize to the site to direct the radiological response measures. The RSO, or alternate RSO, will consult with Company management to determine the appropriate actions. The Companies will immediately inform the COGCC, CDPHE, DOE Office of Legacy Management (OLM), and other government agencies (e.g., Garfield County Sheriff and Emergency Management Office), as appropriate, of a verified Project Rulison-related radiation incident.

Once the well is controlled and prior to resuming drilling, completion, or production operations, the RSO, or alternate RSO, will perform a radiation survey of the area affected by the blowout to verify that residual radiation above action levels (Table A-1) is not present in the area. If radioactively contaminated areas are found, those areas will be delineated by flagging the area with radiation tape, rope, and/or signs to warn against the radiological hazard and discourage entry. The RSO, or alternate RSO, will also inspect the continuous radiological monitoring equipment to determine that it was not damaged during the blowout and is operating as designed.

- **Release of Drilling Fluids or Cuttings**

Company spill response procedures will be implemented in the event of a release of drilling fluids or cuttings to the environment. Typically, the initial operation response focuses on containment of the release as well as protecting the safety of on-site personnel. To supplement the operational spill response procedures, the radiological response procedures outlined in

Section 3.9 (Appendix A) will be implemented to determine whether a suspected radiological release has occurred at the site so that the appropriate radiological response procedures can be implemented, if necessary. If a verified radiological release occurs above the action levels (Table A-1), the SSO, or designated representative, will contact the RSO, or alternate RSO, for guidance and direction. If warranted, the RSO, or alternate RSO, will mobilize to the site to direct the radiological response measures. The RSO will consult with Company management to determine the appropriate actions. The Companies will immediately inform the COGCC, CDPHE, DOE OLM, DOE RAP, and other government agencies (e.g., Garfield County Sheriff and Emergency Management Office), as appropriate, of a verified Project Rulison-related radiation incident.

The amount of radioactively contaminated material released to the environment will be minimized, as warranted, using drilling and engineering controls, with particular focus on limiting the volume of the release and minimizing the potential for released materials to be dispersed via uncontrolled runoff into local surface water drainages. Uncontrolled runoff may be contained using existing stormwater controls. However, depending on the size of the release, additional engineering measures (e.g., diversion ditches, hay bales, straw wattles, silt fences, etc.) may be needed to prevent widespread dispersal of radiologically contaminated drilling fluids or cuttings.

Once a release of drilling fluids and cuttings is controlled and prior to resuming drilling or production operations, the released radiologically contaminated materials will either be removed or cordoned off, depending on their location, areal extent, and potential threat to water sources. The RSO, or alternate RSO, will perform a radiation survey of the area affected by the release to verify that residual radiation in the materials does not pose a threat to workers, the public, or the environment. Radioactively contaminated areas will be delineated using radiation tape, rope, and/or signs, or equivalent, to warn against radiological hazard and discourage entry.

- ***Emergency Response Drills***

Emergency response drills will be conducted on a monthly basis at Tier I drill sites with active drilling operations to familiarize the drilling crews and on-site personnel with the radiation incident emergency procedures outlined in this plan. At a minimum, the emergency response drill should include sounding of the radiation alarm, identification, location, and purpose of the wind sock, and assembly of the drilling crews and on-site personnel in the specified upwind assembly areas. The emergency response drill will also include a brief discussion of the radiation emergency response procedures for personnel that may have been exposed to radiation or injured during an actual incident. The emergency response drills will be conducted by the Site

Safety Officer (SSO), or designated representative, and recorded as indicated in Section 3.10 (Appendix A).

- ***Radiological Incident Response Communication***

The radiological action levels provided in (Table A-1) have been set at radiation activities well below recommended exposure limits; however, any confirmed elevated radiation measurements above these action levels will be immediately reported to Company management by the RSO, or alternate RSO. This approach will maintain exposure to radiation as low as reasonably achievable (ALARA) and allow for early agency notification if unexpected verified Project Rulison-related radiological conditions are confirmed to have occurred at the site.

In the event of a verified Project Rulison-related radiological incident, the SSO, or designated representative, is responsible for immediately calling the following:

- 911 and/or the local hospital immediately if site personnel are injured and need medical attention, and
- Contacting the RSO, or alternate RSO, and Company management in the event of a radiological incident, as directed in (Table A-1). (Table A-2) provides a list of Company emergency contact telephone numbers for the appropriate Company managers, the RSO, and alternate RSO.

Company management will contact the COGCC, CDPHE, DOE OLM, DOE RAP, and other government agencies (e.g., Garfield County Sheriff and Emergency Management Office), as appropriate, if any verified Project Rulison-related radiological condition is encountered that exceeds the action levels in (Table A-1), regardless of whether the exposure is estimated to be in excess of the 100-millirem-per-year standard for any member of the public. The agency emergency contact telephone numbers are provided in (Table A-3).

Satellite phones are generally the primary means of outside communication available at a drill site. Should these communication channels fail, a designated site representative will drive to the nearest phone to call the emergency responders (if needed), the RSO, and Company management.

- ***Radiological Incident Site Access Control***

The Project Rulison site is located in a relatively remote area that is sparsely populated and not readily accessible by public roads. Access to each drill pad within Tier I is controlled by the Company representative at each location who maintains a log of personnel arrival and departure at the site. The site access logs are stored in the Company files. However, inadvertent access to a drill site during a radiological incident could occur. In the unlikely event of a verified radiological incident, the Garfield County Sheriff and Emergency Management Office will be notified so that public access to the affected site can be controlled. The controlled area dimensions will be specified and a map provided of the exclusion zone so that radiation exposures to the sparse local community are kept as low as reasonably achievable (ALARA).

- ***Radiological Incident Response Procedures***

If a verified Project Rulison-related radiological incident occurs that has or may potentially expose personnel or the public to radiation or has or may release radioactively contaminated media to the environment, the following procedures will be followed as applicable to the specific incident:

- If a radiation release above the action levels specified in (Table A-1) is verified, work will be immediately suspended and the actions listed below and in (Table A-1) implemented. The RSO, or alternate RSO, and Company management will provide guidance and direction. The Companies will immediately inform the COGCC, CDPHE, DOE OLM, DOE RAP, and other government agencies (e.g., Garfield County Sheriff and Emergency Management Office), as appropriate, of a verified Project Rulison-related radiation incident.

- Suspend operation of all equipment and moving vehicles in the vicinity of the site as quickly as possible. Do not allow any vehicles involved in the incident to leave the site.

- Rescue and provide first aid to injured personnel, and secure emergency services if necessary. If injured personnel are potentially contaminated, keep them on site until emergency assistance arrives. The SSO, or designated representative, or RSO, or alternate RSO, will brief emergency response personnel on the situation and personnel radiation exposure levels.

- The SSO, or designated representative, or RSO, or alternate RSO, will screen (i.e., frisk) any potentially contaminated site personnel with a hand-held Geiger-Mueller detector with pancake probe to determine if they are radiologically contaminated. Each individual at the site during the incident will be screened for radioactivity by passing the pancake probe over the person’s clothing at a distance of about ½ inch or less and the radiation readings observed. The pancake probe should not touch the potentially contaminated person to avoid contamination of the probe. The frisking results will facilitate notification of emergency response teams if personnel are radiologically contaminated.

- If personnel are contaminated above the action levels in Table A-1, non-injured personnel will be decontaminated by having the affected individuals remove their outer clothing and shower with soap and water (see Attachment A-1). All potentially contaminated personnel, whether injured or not, will be kept on site until emergency assistance arrives. Personnel who have been exposed to significantly elevated levels of radiation will be referred to a medical provider for evaluation.
- The SSO, or designated representative, or RSO, or alternate RSO, will cordon off the area having the elevated radiation measurements with flagging, rope, and/or signage to discourage access. The perimeter of the cordoned area should be established at a minimum distance of 100 feet from areas with elevated radiation readings.
- Keep personnel away from and upwind of the potential radiological release until the situation is assessed by the RSO, or alternate RSO, and the radiation levels are known.
- If equipment or vehicles are involved in an incident, keep all equipment or vehicles in the area until they can be thoroughly screened for radioactivity and released by the RSO, or designated representative.
- For most incidents, the RSO, or designated representative, will mobilize to the site; conduct a radiation survey; and recommend, develop, and implement appropriate response actions.

○ *Radiological Equipment Calibration and Testing*

▪ Radiological Equipment

The following radiation survey instruments will be kept on site and used during drilling operations of the **closest designated** Tier I well within each monitoring sector to screen for radiation (see RSAP Section 4):

- Hand-held Fluke ASM-990 survey meter equipped with a Model 489-110D Pancake GM detector, or equivalent, capable of detecting alpha, beta, and gamma radiation for frisking personnel or surveying potentially contaminated areas, and

- Hand-held Fluke 451P ion chamber survey meter, or equivalent for surveying potentially contaminated areas at environmental dose rate levels.
- Check source(s) for performance testing the alpha, beta, and gamma radiation monitoring instruments.
- Water and soil sampling supplies described in the RSAP.

These instruments are not required at Tier II drilling sites.

- **Equipment Calibration and Testing**

Instruments used for radiation monitoring must be properly maintained, calibrated, tested, and documented. Instruments shall be calibrated by the manufacturer or a certified service center at intervals not to exceed 12 months. Calibration will be performed in accordance with industry standard procedures.

Per industry standards, at least two of each hand-held radiation survey instruments specified for the project will be maintained on site or locally available. Each hand-held instrument's performance will be verified each day the instrument is used. Instrument performance will be tested using a radiation check source (e.g., ^{137}Cs) prior to and following the use of the instrument. A record of the performance tests will be maintained in an instrument logbook indicating the date and time of the performance test, the radioisotope and activity of the check source used for the test, and the measured instrument result.

○ ***Radiobioassay Procedures and Equipment***

In the unlikely event of a radiological incident that exposes workers, bioassays may be performed, as necessary, by the Company's medical provider to determine radiation exposures. Bioassays involve the direct counting of exposed individuals to determine their exposure to radiation and/or the collection of urine samples for radiochemical analysis. Radiobioassay results will be evaluated using the dosimetry models in NUREG-4884 (Lessard et al. 1987).

- **Radiobioassay Sampling Procedures**

For a radiologically contaminated individual, radiobioassay sampling will be conducted through each Company's medical provider using established methods. However, if contaminated personnel are not able to see a medical provider quickly, then urine samples may be collected in bottles maintained on site for radiobioassay analyses. The timing and volume required for urine collection depends on the type of radionuclide to which an individual is exposed. The procedures for urine sample collection are discussed in detail in USACHPPM (1998) and summarized below.

In the event of an exposure to ^{3}H, the most likely radionuclide that one might be exposed to during an incident, it is critical that the urine specimen collected for analysis be representative of the ^{3}H concentration in the body water. A specimen collected too soon after exposure will not be representative, because the ^{3}H will not have equilibrated throughout the body. Therefore, urine samples obtained for ^{3}H analysis should follow the procedure outlined below:

- Discard the initial void of the bladder following exposure. This should occur within 2 hours following the exposure
- Discard any additional voids that occur prior to 4 hours post exposure
- Allow a minimum of 4 hours to elapse following the exposure, wash hands, then collect a urine specimen following this post-exposure (4 hour) waiting period. The sample should be collected in a pre-cleaned, leak-proof, 125 milliliter (mL), high-density polyethylene (HDPE) environmental sample bottle. At least 100 mL of urine should be collected for analysis
- **Do not** add any chemicals or preservatives to the sample.

In the event of an exposure to radionuclides other than ^{3}H, a 24-hour urine specimen is typically required and can be analyzed for ^{3}H, uranium, gross alpha, gross beta, and gamma-emitting radionuclides. The instructions for collecting a 24-hour urine specimen are provided below:

- For radionuclides other than ^{3}H, collect a 24-hour urine specimen **as soon as practical after exposure**
- Discard the initial void of the bladder following exposure and note the time. This time is the start of the 24-hour collection period
- Completely void all urine during the 24-hour time period into a pre-cleaned, 1,000 mL, HDPE environmental sample bottle. Two 1,000 mL sample bottles may be necessary, because a 24-hour void for the average adult is 1,500 mL. The final specimen should be voided just prior to the end of the 24-hour period
- **Do not** add chemicals or preservatives to the sample.

All radiobioassay samples will be labeled with the employee's name, date and time of collection, type of specimen, and type of analysis required. The bottles will be double-bagged in a Ziploc® or similar bag and subsequently handled, packaged, and shipped in accordance with the instructions in RSAP Section 7.

- **Radiobioassay Sample Analyses**

Urine samples collected for radiobioassay analyses will be analyzed by GEL Laboratories, LLC in Charleston, South Carolina. The samples collected will be shipped under standard chain-of-custody procedures by overnight carrier (e.g., FedEx) to GEL for analysis. GEL's sample shipping address and telephone number is:

GEL Laboratories, LLC
2040 Savage Road
Charleston, SC 29407
(843) 556-8171

○ ***Plan Modifications***

Depending upon the severity of any radiological incident encountered, the Companies and the COGCC, CDPHE, and DOE staff will meet to discuss modifications to this Tier I Radiological Incident Management Plan that may be necessary.

▪ Radiological Incident Recovery

Company procedures and federal, state, and local guidance will be followed in the event of a radiological release incident. DOE, trained company personnel, contractors, and the RSO, or alternate RSO, may be involved in cleanup after a radiological incident. These entities will delineate the boundary of any elevated levels of radioactivity, develop appropriate cleanup procedures, and conduct the cleanup activity. Any cleanup activity and waste disposal will be conducted in accordance with all applicable regulations. DOE will be responsible for managing and disposing of any verified Project Rulison-related radioactive material encountered during an incident.

Routine briefings will be conducted with the COGCC, CDPHE, DOE, other government agencies (e.g., Garfield County Sheriff and Emergency Management Office), and local hospitals and responders, as appropriate, by designated Company representatives during incident recovery until it is confirmed that no radiation exposure hazards remain.

Typical cleanup activities would likely consist of screening, identification, containment, excavation, and disposal of contaminated soils, drilling fluids, or drill cuttings. Confirmation samples will be collected for laboratory analysis to verify that all contaminated materials are removed below action levels that are protective of workers, the public, and the environment. Cleanup procedures for equipment will include hand washing or pressure washing of equipment (with wash water collected) and field screening to ensure that the radiological contamination is removed.

Following a radiological incident, an incident review and root cause analysis will be conducted by the Companies, the RSO, COGCC, CDPHE, DOE, and others, as appropriate, to identify additional incident mitigation opportunities and to improve incident response planning.

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Figure A-1
Hand-Held Radiological Instrument Photographs

Fluke 451P Ion Chamber Survey Meter (μR/Hr)

Example Check Source

Fluke ASM-990 with 489-110D Geiger-Mueller Pancake Probe

Figure A-2
Well Pad Background Radiation Survey Pattern

Numbers represent background survey measurement locations at well pad

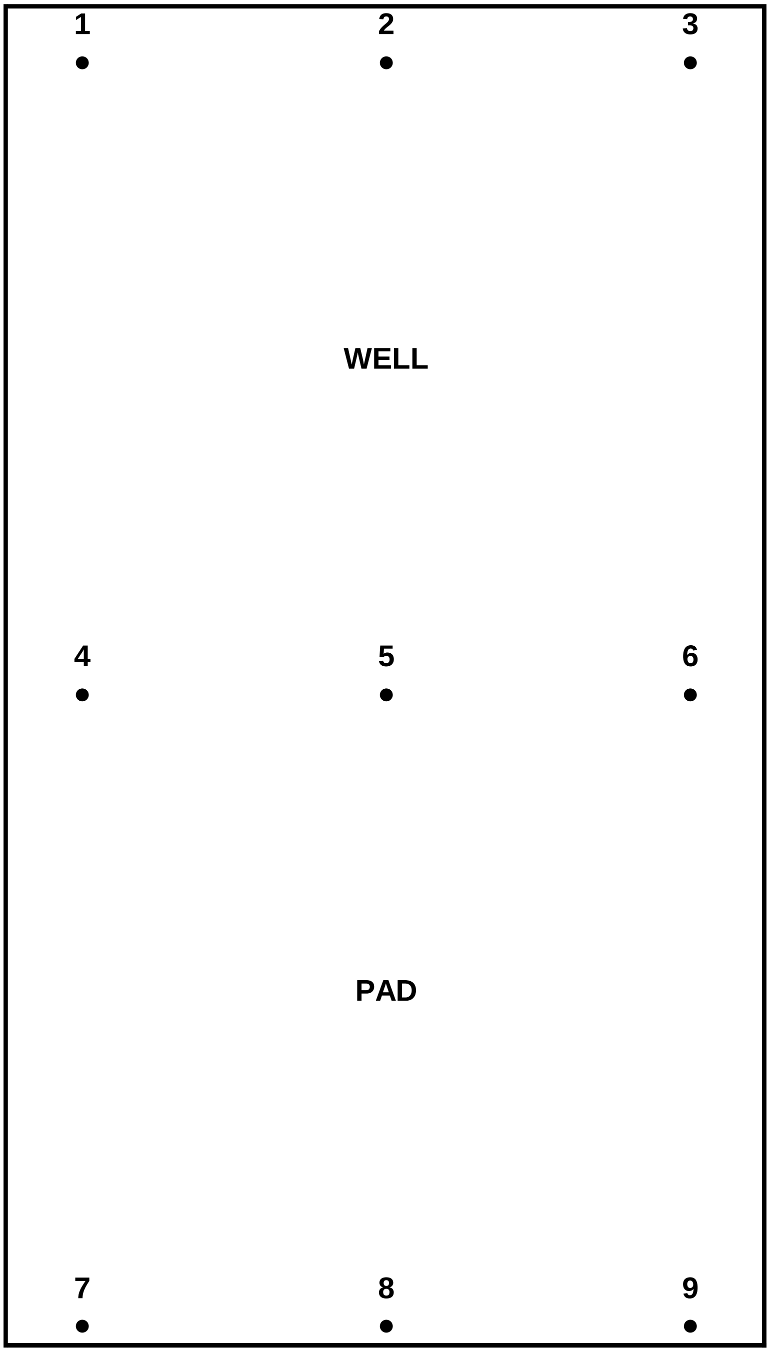

Table A-1
Action Levels for Tier I Radiation Monitoring

Instrument Reading/Location	Action
Well Pad Area Screening	
Microrem survey meter (Fluke 451P ion chamber survey meter or equivalent) – survey readings greater than twice background[14] at 1 foot distance but less than 100 microrem/hour at 1 foot distance.	Contact RSO, or alternate RSO, for guidance and direction and to identify appropriate radiological controls; continue work. Contact Company management.
Microrem survey meter (Fluke 451P ion chamber survey meter or equivalent) – survey readings greater than 100 microrem/hour at 1 foot distance	Suspend work, cordon off the area and do not allow access. Contact RSO, or alternate RSO, for guidance and direction. Contact Company management.
Pancake meter (Fluke ASM-990 with 489-110D probe, or equivalent) - count rate readings greater than twice background at 1 inch but less than 1,000 cpm at 1 inch distance	Contact RSO, or alternate RSO, for guidance and direction and to identify appropriate radiological controls; continue work; frisk personnel that may have contacted radiologically contaminated materials (e.g., drilling mud or fluids). Contact Company management.
Pancake meter (Fluke ASM-990 with 489-110D probe, or equivalent) - Count rate readings greater than 1,000 cpm at 1 inch distance	Suspend work, cordon off the area and do not allow access. Contact RSO, or alternate RSO, for guidance and direction. Contact Company management.
Frisking For Potentially Contaminated Personnel	
Pancake meter (Fluke ASM-990 with 489-110D probe, or equivalent) - Count rate readings greater than twice background at ½ inch distance	Wash the affected area of the person's body soap and plenty of water. Contain the rinse water. Contact RSO, or alternate RSO, for guidance and direction. Contact Company management.
Screening Areas with Public Access	
Pancake meter (Fluke ASM-990 with 489-110D probe, or equivalent) - Count rate readings greater than twice background at 1 inch distance	Cordon off the area and do not allow public or media access. Contact RSO, or alternate RSO, for guidance and direction. Contact Company management.

[14] Twice background allows for natural variability in ambient radiation while providing a low action level to identify potential releases.

Table A-2
Company Emergency Phone Numbers

To be developed on a site-specific basis

Contact	Phone Number

Table A-3
Local, State, and Federal Agency Emergency Contacts

Agency Contacts	Phone Number
Local Emergency Response	911
Grand River Medical Center 501 Airport Road, Rifle, CO	(970) 625-1100
Battlement Mesa Medical Center 73 Sipprelle Drive, Parachute, CO	(970) 285-7046
Colorado Department of Public Health and Environment Radiation Management	(303) 692-3403 (303) 877-9757 (24-Hour Radiation Incident)
Colorado Oil and Gas Conservation Commission	(303) 894-2100 (888) 235-1101
Environmental specialist Colorado Oil and Gas Conservation Commission	(970) 625-2497
Engineer Colorado Oil and Gas Conservation Commission	(970) 625-2497
Grand Valley Fire Protection District	(970) 285-9119 (970) 285-1466
Emergency Operations Commander Garfield County Sheriff and Emergency Management	(970) 625-8095
U.S. Department of Energy Office of Legacy Management Grand Junction, Colorado	(970) 248-6070

Attachment A-1

Personnel Radiological Decontamination Procedures

All personnel potentially exposed to suspected radiological contamination must be decontaminated prior to leaving the contaminated area unless they are injured and require immediate medical attention or an emergency rig condition (e.g., fire, explosion, etc.) occurs.

Potentially contaminated personnel will be decontaminated using the following steps:

Step 1. Personnel leaving the contaminated area must remove the gross soil from their outer clothing and boots.

Step 2. Personnel will remove their coveralls and gloves, their hard hats, and their boots and/or boot covers before leaving the contaminated area.

Step 3. All individuals will be frisked by the SSO, or designated representative, or the RSO, or alternate RSO, for radioactive contamination using a pancake meter (Figure A-1) as they leave the contaminated area (see Appendix A Section 3.9).

A. All positive findings (instrument readings greater than twice background) will be further evaluated by the SSO, or designated representative, or the RSO or alternate RSO. The presence of contamination confirmed to be above the guidance for skin surfaces (Table A-1) will be reported to the RSO, or alternate RSO, who will advise/assist with decontamination.

B. Areas found to be contaminated above the levels in Table A-1 will be decontaminated using the methods described below. In brief, the skin will be gently scrubbed with soap and water and subsequently frisked for any remaining radiation. The following procedure is recommended:

1. Survey the worker to determine the contaminated areas of the skin.
2. Wipe, using a gloved hand, loose contamination with a gauze sponge or cotton applicators dipped in mild antiseptic detergent. Do not spread contamination to uncontaminated areas.
3. Rub the skin lightly with the applicators to produce good suds.

4. Use soft bristle scrub brushes for fingernails and other difficult-to-clean areas as long as the skin barrier is maintained intact. It may be difficult to decontaminate the cuticles and under the nails.
5. Dry the skin area with cleansing tissue.
6. After the skin is thoroughly dry, survey it for any remaining contamination.
7. If no contamination is detected, apply a good-quality hand cream to prevent chapping.

Successful decontamination will be confirmed by the SSO, RSO, or alternate RSO. Those individuals not successfully decontaminated to levels below the skin contamination guide will be referred to the nearest hospital for further decontamination efforts. Prior to the beginning of fieldwork, the RSO or alternate RSO will confirm the nearest local hospital that is equipped and trained to treat patients who may be radiologically contaminated.

The following personnel decontamination equipment will be maintained on site:

- Hand-held radiation survey instruments to frisk potentially contaminated personnel
- Disposable protective clothing (e.g., disposable coveralls, overshoes, gloves)
- Standard first aid kit, including cotton swabs, nail clippers, etc.
- Shower facility in on-site trailer
- Portable eye wash station
- Soft bristle scrub brushes (e.g., fingernail brush, etc.)
- Soap and shampoo (e.g., baby shampoo, antibacterial soap)
- Hand cream
- Trash bags
- Radioactive waste labels

▪ Appendix B. Example Field Forms

Field Data Sheet
Revision 3

Project Name:	Rulison Sampling and Analysis	**Site Operator:**	
Project Number:		**Well Pad:**	
Project Location:	Battlement Mesa	**Well Number:**	
RSAP Version Used:	RSAP Version 3	**SOPs Used:**	Procedures in RSAP Version 3
Field Personnel:		**SOPs Modified:**	☐ Yes ☐ No If Yes, Describe
Field Personnel:		**Weather Conditions:**	
Field Personnel:		**Outdoor Temperature:**	

Sampling Activity Description:			
Sample ID:		**Sample Date:**	**Sample Time:**
Sample ID:		**Sample Date:**	**Sample Time:**
Sample Medium:	☐ Produced Water ☐ Natural Gas ☐ Drilling Mud ☐ Fracing Water ☐ Flowback Water ☐ Surface Water ☐ Groundwater ☐ Spring Water ☐ Surface Soils ☐ Drill Cuttings		
Sample Type:	☐ Primary ☐ Duplicate ☐ Grab ☐ Composite If Composite, No. of Sample Aliquots per Composite: ______________		

Water Quality or Natural Gas Field Parameter Measurements

Temperature (°C):	**pH (std units):**
Conductivity: mS/cm µS/cm	**Salinity (ppt):**
Turbidity (NTU):	**Dissolved Oxygen:** % Sat mg/L
ORP (mv):	**Gas Pressure (psi):** Vessel Hose
Measurement Time (Start/Finish):	**Other:**

Sample Collection Information

Description of Sample Appearance:
(e.g., odor, color, clarity, condensate layer)

Total Number of Containers	Field Filtered	Analyses Required
	☐ Yes ☐ No	☐ Radionuclide Analytes ☐ Non-Radionuclide Analytes

QA/QC Sample(s):	☐ Yes ☐ No	**Sample Number(s):**	
QA/QC Sample Type:	☐ MS/MSD ☐ Trip Blank		
Background Radiation Screening:	☐ Yes ☐ No	Gamma Scintillator Result (µR/Hr):	Pancake GM Result (µR/Hr):
Sample Radiation Screening:	☐ Yes ☐ No	Gamma Scintillator Result (µR/Hr):	Pancake GM Result (µR/Hr):
Decontamination Procedure(s):	☐ Yes ☐ No	☐ Used Dedicated, Pre-Cleaned Equipment ☐ Followed Decontamination Procedure in RSAP Revision 2	

Comments (e.g., basis for decisions, sampling comments, issues, observations, etc.):

Photo Log

Background Radiation Survey

Project Name:	Rulison Sampling and Analysis	Operator:	
Project Number:		Well Pad:	
Project Location:	Battlement Mesa, Garfield Co., CO	Well Number:	
RSAP Version Used:	RSAP Revision 3	SOPs Used:	
Field Personnel:		Weather Conditions:	
Field Personnel:		Outdoor Temperature:	

Rad Survey Instrument	Serial Number	Calibrated	Source Check	Date	Time
ASM-990 - Pancake GM	662 - 126749	☐ Yes ☐ No			
ASM-990 - NaI(Tl) Gamma	662 - 2025	☐ Yes ☐ No			
451P Ion Chamber Meter	2854	☐ Yes ☐ No			

Site No. 1	**UTM Coordinates (ft)**	N	E	**UTM Coordinates (ft)**	N	E	Site No. 6
	Elevation (ft msl):		Zone	Elevation (ft msl):		Zone	
	Radiation Measurement	**Waist Level**	**Ground Level**	**Radiation Measurement**	**Waist Level**	**Ground Level**	
	Pancake GM (µR/Hr):			Pancake GM (µR/Hr):			
	Pancake GM (kcps):			Pancake GM (kcps):			
	NaI(Tl) Gamma (µR/Hr):			NaI(Tl) Gamma (µR/Hr):			
	NaI(Tl) Gamma (kcps):			NaI(Tl) Gamma (kcps):			
	Ion Chamber (µR/Hr):			Ion Chamber (µR/Hr):			
Site No. 2	**UTM Coordinates (ft)**	N	E	**UTM Coordinates (ft)**	N	E	Site No. 7
	Elevation (ft msl):		Zone	Elevation (ft msl):		Zone	
	Radiation Measurement	**Waist Level**	**Ground Level**	**Radiation Measurement**	**Waist Level**	**Ground Level**	
	Pancake GM (µR/Hr):			Pancake GM (µR/Hr):			
	Pancake GM (kcps):			Pancake GM (kcps):			
	NaI(Tl) Gamma (µR/Hr):			NaI(Tl) Gamma (µR/Hr):			
	NaI(Tl) Gamma (kcps):			NaI(Tl) Gamma (kcps):			
	Ion Chamber (µR/Hr):			Ion Chamber (µR/Hr):			
Site No. 3	**UTM Coordinates (ft)**	N	E	**UTM Coordinates (ft)**	N	E	Site No. 8
	Elevation (ft msl):		Zone	Elevation (ft msl):		Zone	
	Radiation Measurement	**Waist Level**	**Ground Level**	**Radiation Measurement**	**Waist Level**	**Ground Level**	
	Pancake GM (µR/Hr):			Pancake GM (µR/Hr):			
	Pancake GM (kcps):			Pancake GM (kcps):			
	NaI(Tl) Gamma (µR/Hr):			NaI(Tl) Gamma (µR/Hr):			
	NaI(Tl) Gamma (kcps):			NaI(Tl) Gamma (kcps):			
	Ion Chamber (µR/Hr):			Ion Chamber (µR/Hr):			
Site No. 4	**UTM Coordinates (ft)**	N	E	**UTM Coordinates (ft)**	N	E	Site No. 9
	Elevation (ft msl):		Zone	Elevation (ft msl):		Zone	
	Radiation Measurement	**Waist Level**	**Ground Level**	**Radiation Measurement**	**Waist Level**	**Ground Level**	
	Pancake GM (µR/Hr):			Pancake GM (µR/Hr):			
	Pancake GM (kcps):			Pancake GM (kcps):			
	NaI(Tl) Gamma (µR/Hr):			NaI(Tl) Gamma (µR/Hr):			
	NaI(Tl) Gamma (kcps):			NaI(Tl) Gamma (kcps):			
	Ion Chamber (µR/Hr):			Ion Chamber (µR/Hr):			
Site No. 5	**UTM Coordinates (ft)**	N	E	**Comments:**			
	Elevation (ft msl):		Zone				
	Radiation Measurement	**Waist Level**	**Ground Level**				
	Pancake GM (µR/Hr):						
	Pancake GM (kcps):			**Photo Log:**			
	NaI(Tl) Gamma (µR/Hr):						
	NaI(Tl) Gamma (kcps):						
	Ion Chamber (µR/Hr):						