RULISON SAMPLING AND ANALYSIS PLAN

Operational and Environmental Monitoring Within a Three-Mile Radius of Project Rulison

JULY 2010

REVISION 3

Prepared by:

URS

noble energy

Williams

EnCana

EnCana Oil & Gas (USA) Inc.

FINAL
RULISON SAMPLING AND ANALYSIS PLAN
FOR
OPERATIONAL AND ENVIRONMENTAL RADIOLOGICAL MONITORING WITHIN A THREE-MILE RADIUS OF PROJECT RULISON

REVISION 3

Prepared for:

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July 31, 2010

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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
EDD	electronic data deliverable
EPA	U.S. Environmental Protection Agency
FB	flowback fluids
ft msl	feet above mean sea level
FW	fracing fluids
G	Grab sample
gpm	gallons per minute
GPS	global positioning system
GW	groundwater
IAEA/WMO	International Atomic Energy Agency/World Meteorological Organization

LIST OF ACRONYMS

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
mV	millivolt
N	tentatively identified data qualifier
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
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

Noble Energy, Inc. (Noble), Williams Production RMT (Williams), and EnCana Oil & Gas (USA), Inc. (EnCana), hereafter collectively referred to as the "Companies," have agreed to voluntarily prepare and submit this consolidated Rulison Sampling and Analysis Plan (RSAP) to monitor gas wells whose bottom-hole locations are within a 3-mile radius of the site known as Project Rulison (Figure 1) in Garfield County, Colorado. Project Rulison is the site of a subsurface 43 plus or minus (±) 8-kiloton nuclear detonation conducted at a depth of 8,426 feet below ground on September 10, 1969 by the Atomic Energy Commission (AEC), a predecessor agency to the United States Department of Energy (DOE), and Austral Oil Company in an effort to increase natural gas production from low-permeability sandstones in the Williams Fork Formation.

The Companies (i.e., Operators) have initiated development of this revised RSAP and understand that implementing this RSAP will become a Condition of Approval (COA) for future Applications for Permit to Drill (APDs) issued within a three-mile radius of Project Rulison. This RSAP also incorporates certain COAs previously identified on individual APDs as agreed to in a meeting with the Colorado Oil & Gas Conservation Commission (COGCC) on December 4, 2008 and recommendations resulting from an audit conducted by the COGCC during the summer of 2008 (Chew and Associates 2008).

There are currently no gas wells within a half-mile radius of Project Rulison, and the Companies have voluntarily agreed to a drilling moratorium within a half-mile radius of Project Rulison during 2010. The Companies recognize that 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 Companies also recognize that the COGCC has limited the total number of drill rigs within the Project Rulison monitoring zone (i.e., three-mile radius) for all Companies to five rigs at any time. Furthermore, the COGCC has specified that no individual Company shall use more than one drill rig within the Tier I monitoring zone (i.e., one mile radius) or two rigs within the Project Rulison monitoring zone (i.e., three-mile radius) at any given time without written consent from the COGCC. A hearing before the COGCC is required to increase the number of rigs operating within the Project Rulison monitoring zone. However, to allow the Companies to streamline drilling operations, such as batch drilling and cementing surface casings prior to drilling a production hole, rig count limitations will only apply to production hole drilling beneath the surface hole casing depth.

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 within a three-mile radius of Project Rulison are conducted and monitored in a safe and responsible manner, reflective of the environmental health and safety needs of the Companies employees, contractors, and the public. The monitoring activities described in this RSAP will be implemented immediately upon approval of this RSAP revision by the COGCC. The monitoring approach will be reviewed by the COGCC and the Companies no later than December, 2010 (and possibly before that time, if needed) to review its implementation, effectiveness, and success. Modifications will be made, as needed, to improve the monitoring approach.

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 equal sectors within a three-mile radius surrounding Project Rulison.

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. Produced water will also be screened for non-radiological constituents that may either be associated with Project Rulison or gas exploration and production. Tier I monitoring will be conducted at selected gas wells located beyond Lot 11 and within a 1-mile radius of the Project Rulison device emplacement well R-E. Tier II monitoring will be conducted at gas wells located between a 1- and 3-mile radius of the Project Rulison device emplacement well R-E.

The **areal environmental monitoring program** is designed to monitor groundwater and surface water quality in the Project Rulison area and involves the collection and analysis of water samples for both radiological and non-radiological constituents from 15 well, spring, or stream locations established by the Companies (Figure 2). Sample sites located on private property will only be sampled with the landowner's permission. Identification and selection of additional environmental monitoring locations (i.e., permitted water wells, adjudicated springs, and local streams) within a half-mile radius of new gas wells will be determined on a case-by-case basis based on input from the COGCC as well as the Companies standard operating practices.

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 both the operational and the areal environmental monitoring programs 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 a brief 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 brief summary of the historical and current environmental monitoring results. Section 4 summarizes the operational and areal environmental 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 a URS Safe Work Plan, Example Field Forms, and Radiological Equipment Information, respectively.

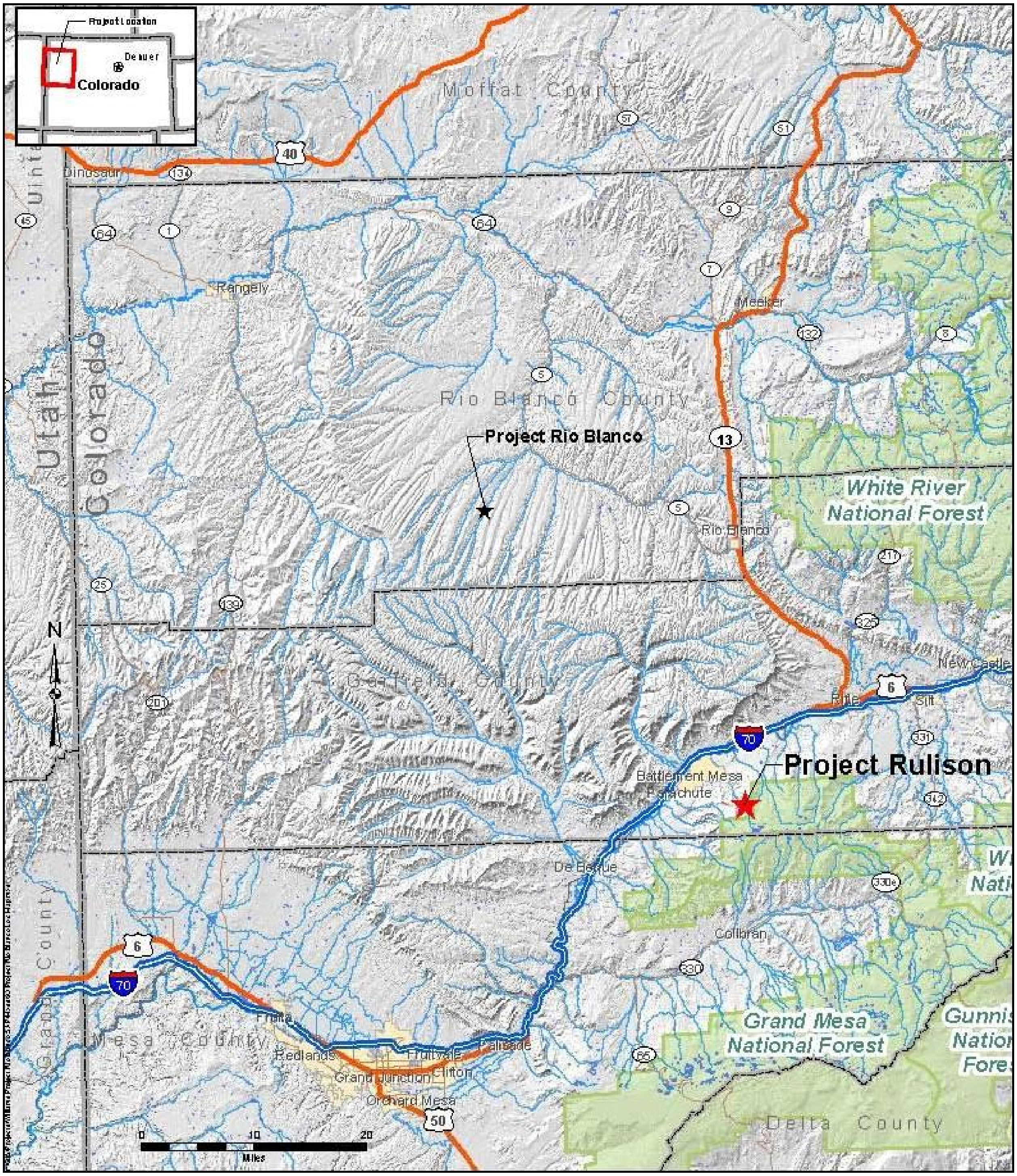
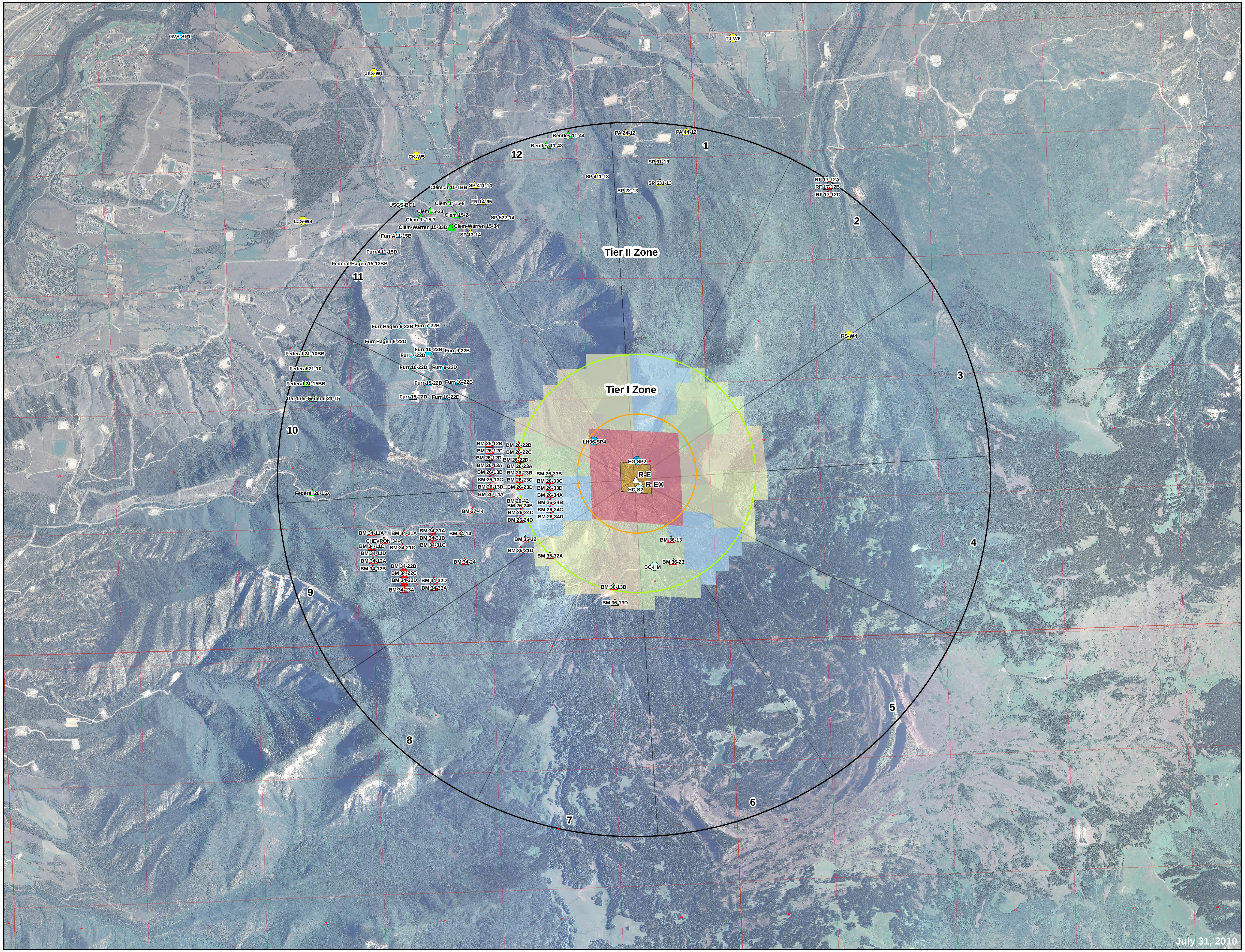


Figure 1. Project Rulison Location Map



File Path = Y:\GIS\Projects\Presco\mxds\Figure 2 Tier I and II Monitoring Zones Revision 3..mxd

Legend

▲ Existing Noble Gas Well
▲ Existing EnCana Gas Well
▲ Existing Williams Gas Well
▲ Existing Laramie Gas Well
△ Project Rulison Well

Environmental Sample Location

● Domestic Spring
● Domestic Well
○ Surface Water
☐ COGCC Half- Mile Radius
☐ 1 Mile Radius Tier I Zone
☐ 3 Mile Radius Tier II Zone
■ Project Rulison Lot 11
■ Noble-Williams 2010 Voluntary Drilling Moratorium
■ Tier I Sector 1
■ Tier I Sector 2
■ Tier I Sector 3
■ Tier I Sector 4
■ Tier I Sector 5
■ Tier I Sector 6
■ Tier I Sector 7
■ Tier I Sector 8
■ Tier I Sector 9
■ Tier I Sector 10
■ Tier I Sector 11
■ Tier I Sector 12
☐ Township-Range-Section
— Monitoring Sectors

N

0 0.5 1
Miles

Figure 2
Tier I and II Monitoring Zones
Project Rulison Area
Garfield County, Colorado

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.

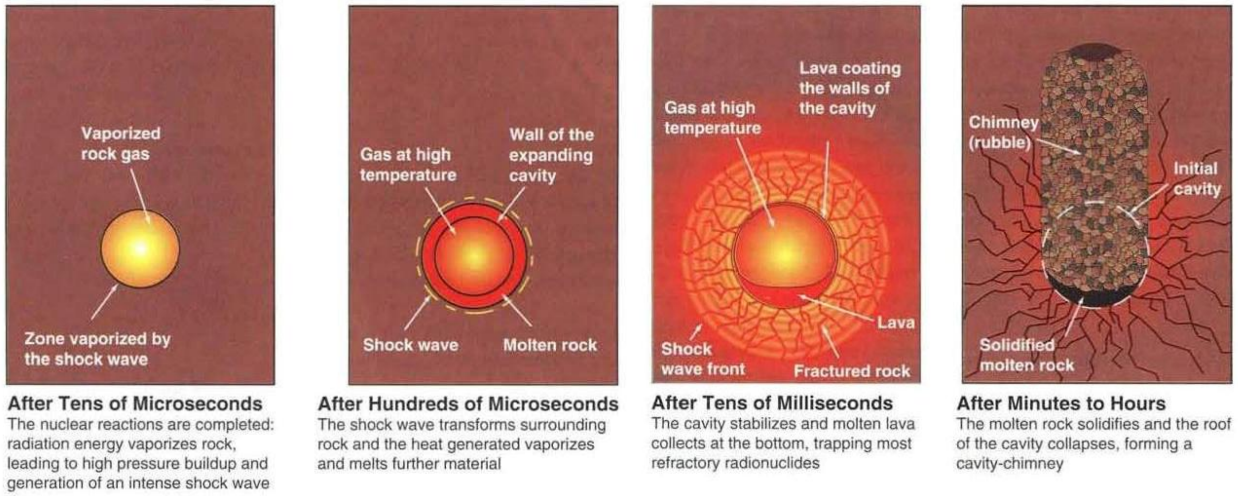
Project Rulison was a joint industry-government partnership (AEC 1973a). The industry sponsor was Austral Oil Company, which acquired gas leases in the project area and conducted a feasibility study in cooperation with CER Geonuclear Corporation. Project Rulison was conducted in three phases:

- 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. 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. The nuclear device was detonated on September 10, 1969

- 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.



After Tens of Microseconds
The nuclear reactions are completed: radiation energy vaporizes rock, leading to high pressure buildup and generation of an intense shock wave

After Hundreds of Microseconds
The shock wave transforms surrounding rock and the heat generated vaporizes and melts further material

After Tens of Milliseconds
The cavity stabilizes and molten lava collects at the bottom, trapping most refractory radionuclides

After Minutes to Hours
The molten rock solidifies and the roof of the cavity collapses, forming a cavity-chimney

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).

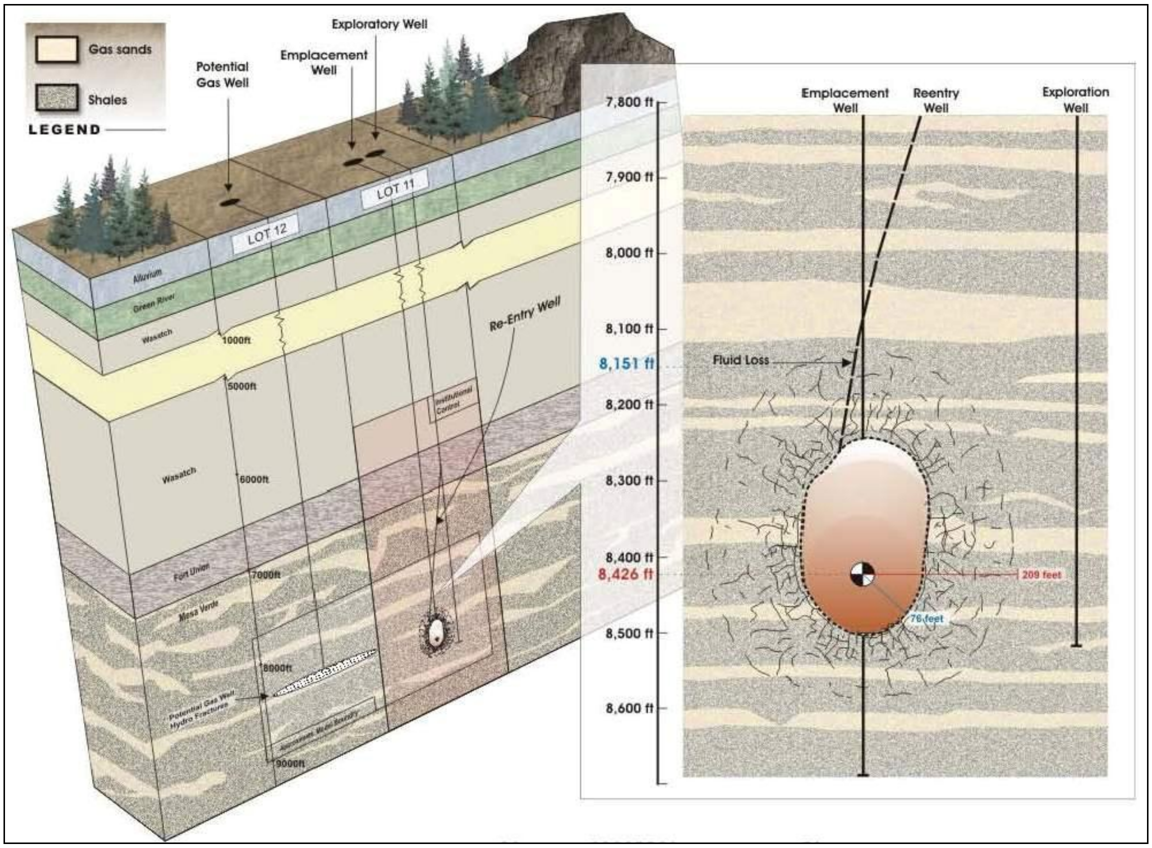


Figure 4. Schematic Cross-Section of the Project Rulison Detonation Zone (DOE 2009b).

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.

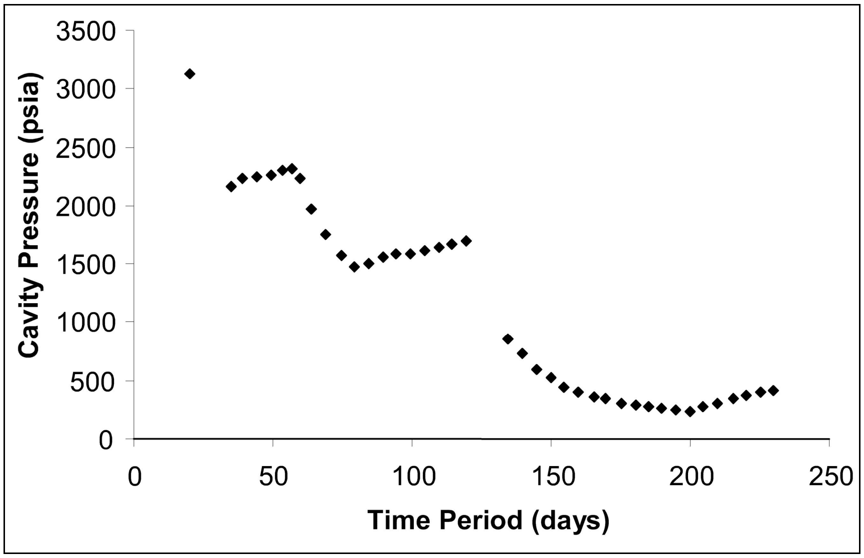


Figure 5. Nuclear Chimney Pressure Measurements during Re-Entry Testing (AEC 1973).

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 31, 2010, and the potential exposure medium. To be conservative, the initial activities shown in Table 1 have not been reduced to account for the removal of gaseous radionuclides during gas production testing. 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

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

Radionuclide	**Half-Life[2] (years)**	**Initial Activity (Curies)**	**Activity in 2010[3] (Curies)**	**Percent Initial Activity Remaining[4]**	**Potential Exposure Medium**	**Potential Source[5]**
Tritium (^{3}H)	12.33	10,000[6]	1,003	10.03	Gas, Produced Water	Cosmogenic Nuclear Testing
Cesium-137 (^{137}Cs)	30.07	7,500[7]	2,921	38.95	Cuttings, Produced Water	Nuclear Testing
Strontium-90 (^{90}Sr)	28.79	5,900[7]	2,204	37.35	Cuttings, Produced Water	Nuclear Testing
Krypton-85 (^{85}Kr)	10.76	1,100[6]	79	7.17	Gas	Cosmogenic Nuclear Testing
Argon-39 (^{39}Ar)	269	24.3[8]	22	90.00	Gas	Cosmogenic, Nucleogenic Nuclear Testing
Technetium-99 (^{99}Tc)	211,100	4.04[8]	4.04	99.99	Cuttings, Produced Water	Nuclear Testing
Chlorine-36 (^{36}Cl)	301,000	2.82[8]	2.82	99.99	Cuttings, Produced Water	Cosmogenic, Nucleogenic Nuclear Testing
Carbon-14 (^{14}C)	5730	2.20[9]	2.19	99.51	Gas, Produced Water	Cosmogenic Nuclear Testing

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[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 2010 is referenced to July 31, 2010, and assumes a closed system (i.e., no loss of parent or daughter radionuclides).

[4] Percent initial activity remaining does not account for radionuclide mass removed during gas production testing. Actual activities for ^{3}H, ^{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] Cosmogenic – produced in upper atmosphere; nucleogenic – produced in subsurface by natural nuclear reactions.

[6] Initial activity in Rulison cavity from Reynolds (1971).

[7] Initial activity in Rulison cavity from Nork and Fenske (1970).

[8] Initial activity in Rulison cavity from DOE (2005).

[9] 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 health 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 (1,003 Curies [Ci]; Table 1) with the decay-corrected inventories of ^{85}Kr (79 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.

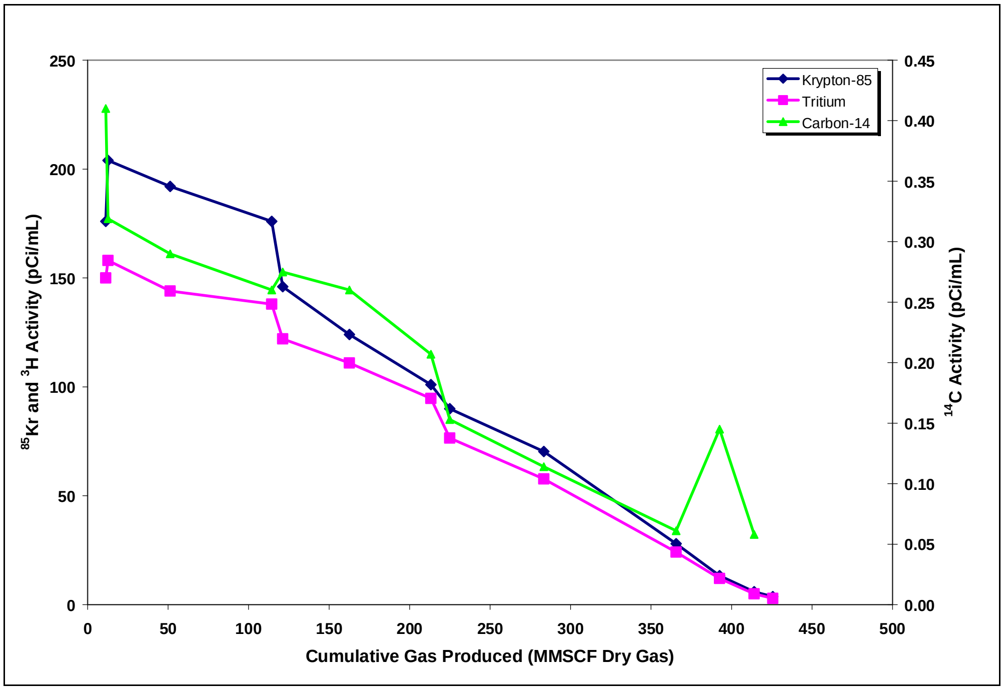


Figure 6. ^{3}H, ^{85}Kr, and ^{14}C Activities in Gas Produced from the Project Rulison Test Cavity (data from Smith 1971B).

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 previous (PRESCO) and current (Noble, EnCana, Williams, and Laramie Energy II) operators 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 brief 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 2009a and 2009b), 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 brief 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 (^{90}Sr)-yttrium-90 (^{90}Y) equivalent)
- ^{3}H - 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 ^{90}Sr-^{90}Y equivalent)
- ^{3}H - 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).

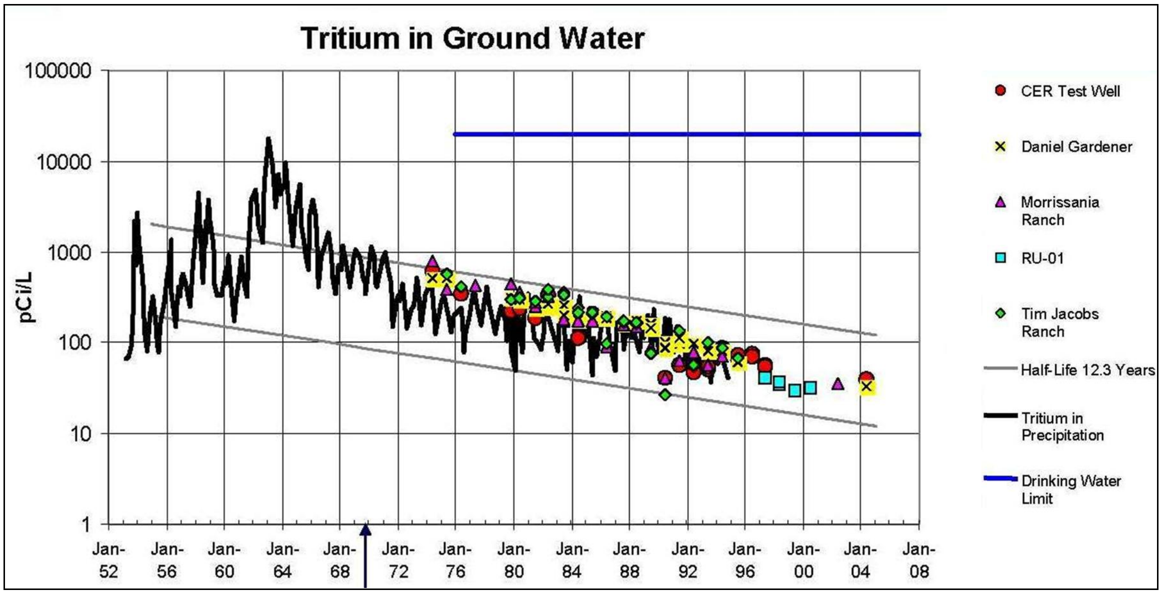


Figure 7. ^{3}H Activity in Precipitation at Ottawa, Ontario and in Water at Project Rulison (Ottawa ^{3}H data from IAEA/WMO 2004; graphic from DOE 2007b).

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 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).

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

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 ^{3}H from the nuclear cavity (Earman et al 1996; Cooper 2004; DOE 2007b; and Cooper et al. 2009). The modeling studies predicted that ^{3}H 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 draft Rulison path forward document (DOE 2009) that discusses recommendation's 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.

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, the COGCC formally established a half-mile radius, with 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

The 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).

3.1.8 PRESCO Studies

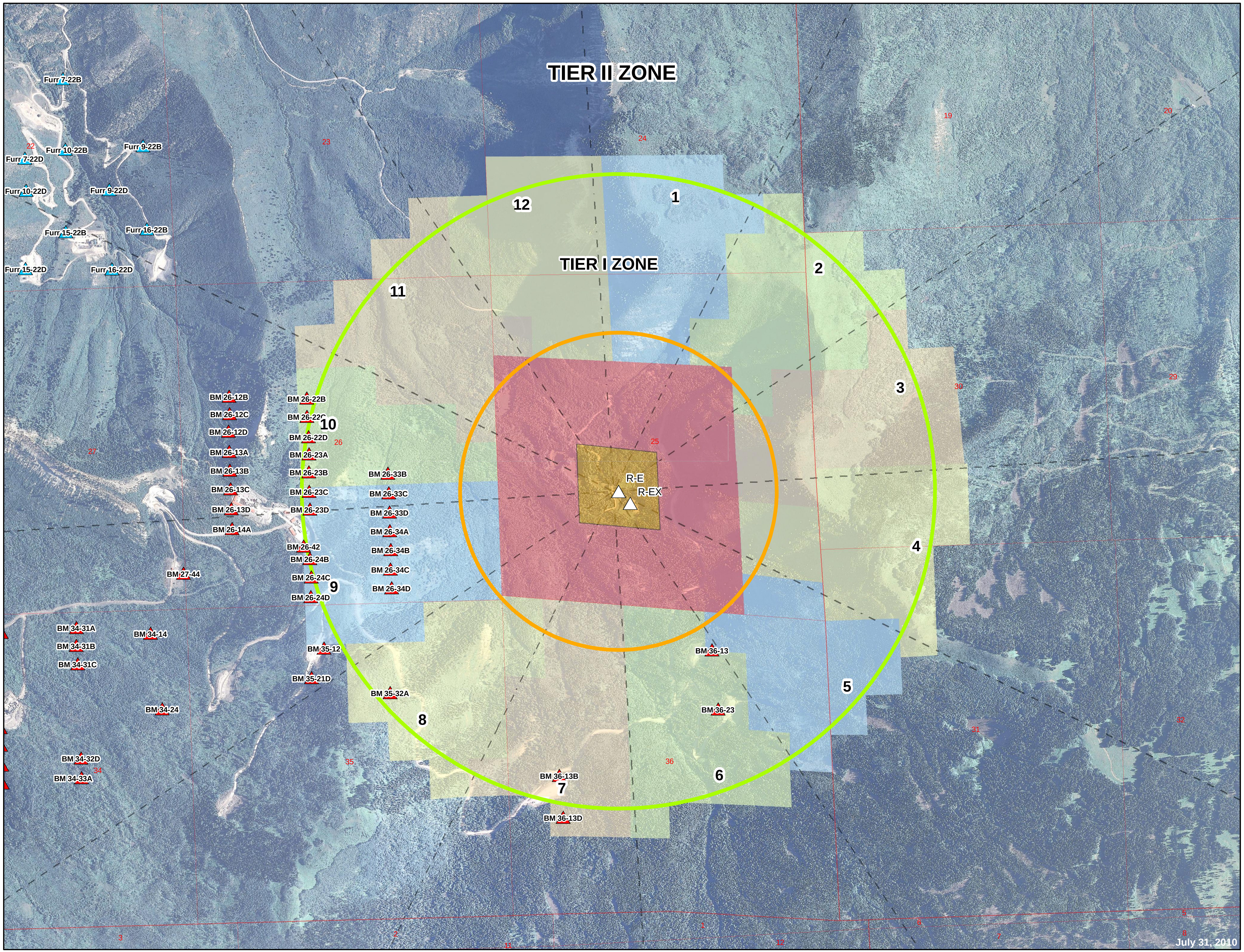
PRESCO Inc. (PRESCO), a former natural gas leaseholder in the area, performed baseline monitoring of water resources (e.g., springs, streams, and wells) in 2004, prior to the initiation of natural gas drilling near Project Rulison. Sampling was conducted by Cordilleran Compliance, and the samples were 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; Figure 8) 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 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). 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



File Path = Y:\GIS\Projects\Presco\mxds\Figure 8 Tier I Monitoring Zones Revision 3.mxd

Figure 8
Tier I Monitoring Zones
Project Rulison Area
Garfield County, Colorado

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 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.

Subsequent sampling and analysis performed by the Companies after the Rulison Sampling and Analysis Plan, Revision 2 (URS 2008) was approved by the COGCC has generated large quantities of additional radiological and nonradiological data for produced water, natural gas, and drill cuttings within the Tier I and II monitoring zones established around Project Rulison. The sampling and analysis results are reported in quarterly monitoring reports submitted to the COGCC, CDPHE, and DOE (URS 2008a; URS 2008b; URS 2009a; URS 2009b; URS 2009c; URS 2009d; URS 2010a; and URS 2010b). To date, approximately 15 Tier

I and 90 Tier II gas wells have been drilled within the Project Rulison monitoring zone (i.e., the 3-mile radius). The results of analyses from these wells 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 within environmental media sampled over the 40-year period since the test are generally within background ranges or are naturally-occurring radionuclides that are found in the geologic formations. These monitoring studies have also 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 in the area of the test site.

4 MONITORING APPROACH

The Companies have developed 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. The objectives of the 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 and are divided into 12 equal sectors. Areal environmental monitoring includes permitted wells, adjudicated springs, and streams both within and outside of the operational monitoring tiers. This RSAP defines the monitoring requirements for both the operational and areal environmental monitoring programs 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 and non-radionuclide constituents that may or may not be associated with Project Rulison. The specifics of each monitoring component are discussed below and summarized in Table 2.

The **operational monitoring program** is designed to document that no verified Project Rulison-related radionuclides are present in any of the existing gas wells at the time this RSAP was initially implemented in 2008. It is also designed to screen future 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.

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

(To Be Reviewed Annually As Needed)

Monitoring Activity	Tier I Zone (Up to 1 Mile Radius from Project Rulison)	Tier II Zone (Between 1 and 3 Mile Radius of Project Rulison)
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. • Ambient radiation dosimetry shall be performed during drilling of the closest designated gas well within each Tier I monitoring sector. • Continuous, real-time gamma screening of drill cuttings and fluids shall be conducted at the closest designated gas well within each Tier I monitoring sector. • Sampling and analysis 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 can not 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 can not 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.

(To Be Reviewed Annually As Needed)

Monitoring Activity	Tier I Zone (Up to 1 Mile Radius from Project Rulison)	Tier II Zone (Between 1 and 3 Mile Radius of Project Rulison)
Drilling (New Wells)	• 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 (New Wells)	• Perform ambient environmental dosimetry during fracing at the closest new gas well within each Tier I monitoring sector. • 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. • 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. • 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.

(To Be Reviewed Annually As Needed)

Monitoring Activity	**Tier I Zone (Up to 1 Mile Radius from Project Rulison)**	**Tier II Zone (Between 1 and 3 Mile Radius of Project Rulison)**
Production (Existing and New Wells)	• Perform one-time sampling and analysis of produced water for radiological and non-radiological analytes in Tables 3 and 4 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 and the nonradiological analytes in Table 4 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 and non-radiological analytes in Tables 3 and 4 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 and produced water for the nonradionuclides listed in Table 4 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 (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.
Environmental Groundwater and Surface Water	• Annual sampling and analysis of groundwater and surface water areal environmental monitoring locations will be performed for the radiological and non-radiological analytes listed in Tables 3 and 4. • Further testing contingent on the occurrence of verified Project Rulison-related radionuclides in Tier I gas wells.	• Annual sampling and analysis of groundwater and surface water areal environmental monitoring locations will be performed for the radiological and non-radiological analytes listed in Tables 3 and 4. • Further testing contingent on the occurrence of verified Project Rulison-related radionuclide detection in Tier I gas wells.

Table 3. Radiological Analyte List.

Sample Medium	**Gross Alpha**	**Gross Beta**	**Gamma-Emitting Radionuclides (includes ^{137}Cs)**	**Tritium (^{3}H)**	**Carbon-14 (^{14}C)**	**Strontium-90 (^{90}Sr)**	**Technetium-99 (^{99}Tc)**
Natural Gas	-----	-----	-----	x	x[10]	-----	-----
Produced Water	x	x	x	x	-----	x	x
Groundwater	x	x	x	x	-----	x	x
Surface Water	x	x	x	x	-----	x	x
Drilling Mud	x	x	x	x	-----	x	x
Drill Cuttings	x	x	x	-----	-----	x	x
Fracing Fluid	-----	-----	-----	x	-----	-----	-----
Flowback Fluid	-----	-----	-----	x	-----	-----	-----

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[10] The methane analyzed is separated using molecular sieves from other hydrocarbon and gas (e.g., CO_2) constituents that naturally occur in the natural gas. The separated methane is combusted to form carbon dioxide (CO_2) that is captured for ^{14}C analysis.

Table 4. Non-Radiological Analyte List

Parameter	Drilling Monitoring	Completion Monitoring	Production Monitoring	Areal Environmental Monitoring
Trace Metals				
Arsenic	-----	-----	x	x
Barium	-----	-----	x	x
Boron	-----	-----	x	x
Cadmium	-----	-----	x	x
Chromium (total)	-----	-----	x	x
Iron	-----	-----	x	x
Lead	-----	-----	x	x
Lithium	-----	-----	x	x
Manganese	-----	-----	x	x
Mercury	-----	-----	x	x
Selenium	-----	-----	x	x
Strontium	-----	-----	x	x
Major Ions				
Calcium	-----	-----	x	x
Magnesium	-----	-----	x	x
Potassium	-----	-----	x	x
Sodium	-----	-----	x	x
Chloride	-----	-----	x	x
Sulfate	-----	-----	x	x
Fluoride	-----	-----	x	x
Bromide	-----	-----	x	x
Nitrate/Nitrite	-----	-----	x	x
Ammonia	-----	-----	x	x
Orthophosphate	-----	-----	x	x
Water Quality Parameters				
pH	-----	-----	x	x
Total Dissolved Solids	-----	-----	x	x
Total Alkalinity	-----	-----	x	x
Organic Parameters				
Benzene	-----	-----	x	x
Ethylbenzene	-----	-----	x	x
Toluene	-----	-----	x	x
Xylenes (total)	-----	-----	x	x
GRO (Method 8015 modified)	-----	-----	x	x
DRO/RRO (Method 8015 modified)	-----	-----	x	x
Dissolved Methane (RSK 175)[11]	-----	-----	x	x

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[11] If free gas or a methane concentration greater than 2 mg/L is detected in a water quality testing well or spring, compositional analysis and carbon isotopic analysis of methane will be performed to determine gas type (e.g., thermogenic, biogenic, or mixture). If testing indicates biogenic gas, no further isotopic testing is required. If testing indicates a thermogenic or gas mixture, annual testing will be performed and an action plan developed by the operator to determine the source of the methane.

Tier I monitoring will be conducted at gas well locations situated within a 1-mile radius of the Project Rulison device emplacement well R-E. Tier II monitoring will be conducted at gas well locations situated between a 1- and 3-mile radius of the Project Rulison device emplacement well R-E. At present, there are approximately 11 gas wells within the Tier I zone and approximately 67 gas wells within the Tier II zone.

The **areal environmental monitoring program** is designed to monitor water quality in the shallow alluvial aquifer and streams for verified Project Rulison-related radionuclides as well as non-radionuclides, that may or may not be related to Project Rulison, to protect local water users and the environment. The program involves the collection and analysis of surface water and groundwater samples from 15 locations established by the Companies (Figure 2). The environmental monitoring locations occur both within and outside of the Tier I and II operational monitoring zones. Sample sites located on private property will only be sampled with the landowner’s permission. If permission is refused, sampling will not be performed.

Identification and selection of additional environmental monitoring locations (i.e., permitted water wells, adjudicated springs, and local streams) within a half-mile radius of new gas wells will be determined on a case-by-case basis, based on the Companies normal operating practices and considering input from the COGCC, CDPHE, and DOE.

4.1 Tier I Monitoring

Tier I operational monitoring will be conducted at gas wells situated within a 1-mile radius of the Project Rulison device emplacement well R-E. 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 (Figure 8). The selected radionuclide analytes for various media are listed in Table 3. The radiological analytes were selected because they provide a comprehensive set of screening analytes for some of the potentially mobile or abundant Project Rulison-related radionuclides that might be transported in the subsurface fluids. Produced water will also be screened for non-radiological constituents

(Table 4) that might be associated with Project Rulison, well drilling, or with subsurface formation waters within the production zones.

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.

- Ambient radiation monitoring shall be performed using dosimetry in personnel work areas to measure ambient radiation (other than ^3H) that could conceivably be released during drilling of a Tier I gas well. Passive or electronic radiation dosimeters will be placed at the well pad prior to drilling the production hole and remain until the hole reaches total depth. The dosimeters will be placed in work areas or near drilling fluid and cuttings discharge locations on each well pad to measure cumulative radiation intensities to which personnel are exposed. One dosimeter will be placed in a location away from the drilling activities on the wellpad to measure background radiation dose. A minimum of four Quantum Products Instadose™ dosimeters or Mirion Technologies DMC 2000XB electronic dosimeters (Appendix D), or equivalent, will be deployed at each well pad. The Instadose™ dosimeters are based on a Mirion Technologies ionization chamber and a direct ion storage technology (Appendix D). The dosimeters will be weatherproofed, as necessary, for outdoor use. The dosimeters will be periodically retrieved and processed to determine the accumulated dose. At a minimum, the accumulated dose on each dosimeter will be recorded immediately prior to deployment and after they are retrieved. The dosimeters will be handled and placed in accordance with the procedures in Section 5.4. Personnel occupancy times at the well pad will be logged so that, in the event of a radiation incident, personnel doses can be estimated.

- Continuous, real-time ^3H monitoring of drilling fluid and cutting returns at their outfall shall be performed to screen for the presence of ^3H in water vapor above these materials. Monitoring will be performed using a Canberra TAM 100D portable tritium monitor (Appendix D), or equivalent. The Canberra TAM 100D tritium monitor has a minimum detection limit of 500,000 pCi/cubic meter (m^3) or 500 pCi/L. To the extent possible, the equipment will be linked directly to computers in the drilling control station so that the ^3H activities can be recorded and reviewed in real time. The ^3H monitor will be equipped with an alarm to notify personnel of ^3H activities above the screening or action levels. The screening and action levels for real-time ^3H monitoring will be set at background (or the instrument detection limit) + 2 standard deviations or background (or the instrument detection limit) + 3 standard deviations, respectively, whichever is higher. These screening or action levels may be adjusted once the equipment is in the field and background tritium activities and the instrument response have been determined.

  If the ^3H screening or action level alarm is triggered, the Site Safety Officer (SSO) or his designated representative will temporarily stop drilling and call the Radiation Safety Officer (RSO) or alternate RSO identified in the Tier I Radiological Incident Management Plan (Appendix A) for review and guidance. The alarm will be verified by the RSO or alternate RSO by reviewing the ^3H data prior to the alarm to determine whether the ^{3}H monitoring instrument malfunctioned and caused a false alarm. If the ^{3}H monitoring instrument is performing properly, a sample of the drilling mud will be collected for field screening. Water present in the mud will be extracted and analyzed for ^{3}H using a Bioscan Triathler portable liquid scintillation counter (LSC; Appendix D) to determine whether ^{3}H is present at an activity above a LSC ^{3}H screening level of 2,000 pCi/L. If the ^{3}H alarm is verified by the RSO, alternate RSO, or designated representative, the SSO, or his designated representative, will suspend all work immediately and wait for further direction from Company management and the RSO. The Companies will immediately inform the COGCC, CDPHE, and DOE of any verified Project Rulison-related radiation incident.

- Continuous, real-time gamma screening of drill cutting and fluid returns at their outfall shall be implemented to address concerns about radionuclides other than ^{3}H that could conceivably be encountered during drilling. The continuous, real-time gamma screening will be performed using a Ludlum Measurements, Inc. Model 375 area monitor equipped with a Model 44-10 2 inch x 2 inch sodium iodide (NaI(Tl)) gamma scintillator (Appendix D), or equivalent, to determine whether elevated gamma radiation is encountered during drilling that could be related to Project Rulison. The gamma screening system will be calibrated to a National Institute of Standards and Technology (NIST) traceable ^{137}Cs standard. A Berkley Nucleonics Corporation (BNC) 1035 AreaSAM real-time gamma spectrometer system (Appendix D), or equivalent system, will also be used to verify the specific radionuclides if a screening or action level is exceeded. To the extent possible, the real-time gamma screening equipment will be linked directly to computers in the drilling control station so that the gamma radiation activities can be recorded and reviewed in real time. The gamma radiation screening equipment will be equipped with an alarm to notify personnel of gamma radiation measurements above screening or action levels. The screening and action levels for real-time gamma monitoring will be set at background + 2 standard deviations or background + 3 standard deviations, respectively. These screening or action levels may be adjusted once the equipment is in the field and background gamma levels and instrument response have been determined.

If the gamma radiation screening or action level alarm is triggered, the SSO or his designated representative will temporarily stop drilling and call the RSO or alternate RSO identified in the Tier I Radiological Incident Management Plan (Appendix A) for review and guidance. If the gamma alarm is verified by the RSO or alternate RSO, the SSO, or his designated representative, will suspend all work immediately and wait for further direction from Company management and the RSO. The Companies will immediately inform the COGCC, CDPHE, and DOE of any verified Project Rulison-related radiation incident.

- 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 can not 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, that 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 ^3H 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 ^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 written approval from the COGCC if ^3H is less than the ^3H 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 ^3H is equal to or greater than the ^3H 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 ^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.

4.1.3 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 and non-radiological analytes listed in Tables 3 and 4. 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 and produced water for the nonradiological analytes listed in Table 4. 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

Tier II monitoring shall only be conducted at gas wells located between a 1- to 3-mile radius from the Project Rulison device emplacement well R-E (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 and non-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 third-party consultant independent of the Companies. 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 can not 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 ^{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 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 in writing by the COGCC before the flowback fluids can be transported, re-used, or disposed. 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.

4.2.3 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 and non-radiological analytes listed in Tables 3 and 4. 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 and produced water for the nonradiological analytes listed in Table 4. 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

Areal environmental groundwater and surface water monitoring shall be performed annually to continue to document the groundwater and surface water quality within the Project Rulison area. The areal environmental monitoring will include sampling of 15 shallow alluvial groundwater and surface water monitoring locations established by the Companies (Figure 2). Sample sites located on private property will only be sampled with the landowner’s permission. If permission is refused, sampling will not be performed. Although environmental monitoring of the shallow alluvial aquifer and streams by both the DOE and the Companies have not detected any verified Project Rulison-related radionuclides and no pathway for radionuclides to migrate from the Project Rulison cavity to the shallow subsurface has been recognized, the Companies have elected to perform this monitoring because of COGCC, CDPHE, and public concerns about a verified Project Rulison-related radionuclide release to the local water supply.

The groundwater and surface water samples shall be analyzed for the radiological and non-radiological analytes listed in Tables 3 and 4. These analytes are selected because they provide a comprehensive screening suite of some of the potentially mobile or abundant verified Project Rulison-related radionuclides. The samples collected shall be submitted to an accredited laboratory for analysis. The samples shall be collected in accordance with the procedures described in Sections 5.5 and 5.6.

Identification and selection of additional environmental monitoring locations (i.e., permitted water wells, adjudicated springs, and local streams) within a half-mile radius of new well pads within Tier II shall be determined on a case-by-case basis. During normal operations outside of the three-mile radius, the Companies, depending on landowner requests, may at their discretion conduct one-time surface water or groundwater sampling for non-radiological analytes within a half mile radius of the well pad. The Companies will continue to make these decisions within the three-mile radius; however, if sampling is conducted within the three-mile radius, radionuclides will be added to the analyte list.

Additional environmental groundwater and surface water monitoring within Tier II will be contingent upon the detection of verified Project Rulison-related radionuclides within produced water or gas at other Tier I or Tier II gas wells. Additional monitoring needs will be based on discussions with the COGCC and CDPHE. The decisions about what additional monitoring to perform will also be based on factors such as the activity of verified Project Rulison-related radionuclides found, the proximity of groundwater and surface water locations, and the potential for migration to local water supplies.

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 can not 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, can not 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 that are being monitored under this RSAP 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.

4.6.1 Development of Radionuclide Screening and Action Levels

The screening and action levels were developed based on the most likely exposure scenarios to workers, individual members of the public, or the environment. The approach used to determine the screening and action levels for each sample medium is discussed below. The Companies recognize that the COGCC and CDPHE may request that the screening or action levels be modified once a sufficient quantity of background data are collected for each medium.

Natural Gas

The natural gas screening and action levels shown in Table 5 are based on the effluent inhalation activity values provided in the Colorado Standards for Protection Against Radiation 6 CCR 1007-1 Part 4, Appendix 4B, Table 4B2. The air effluent value is the activity (in pCi/L) of a specific radionuclide in methane gas, which if inhaled continuously over the course of a year, would produce a total effective dose equivalent (TEDE) to an individual member of the public or the environment of 50 millirem. The TEDE is exclusive of the dose contributions from natural background radiation, medical tests, or sanitary sewerage. The Colorado TEDE for individual members of the public is 100 millirem (mrem) per year. The natural gas action level is set at 75% of the air effluent activity for ^{3}H and ^{14}C (6 CCR 1007-1 Part 4, Appendix 4B, Table 4B2). The natural gas screening level is set at 10 percent of the action level.

^{3}H in the methane (C1) fraction of natural gas is analyzed and reported by Isotech Laboratories as a ^{3}H concentration (in TU) in water. 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). For ^{3}H analysis of natural gas, water in the gas is removed using a molecular sieve and the dry methane is subsequently combusted to produce carbon dioxide and water. At 20^{o}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 methane gas (pCi/$L_{methane}$), a conversion factor of 1.61E-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/$L_{methane}$.

Produced Water

The produced water screening and action levels shown in Table 5, except for gross alpha and gross beta, are based on the water effluent activity values provided in 6 CCR 1007-1 Part 4, Appendix 4B, Table 4B2 or Colorado Basic Standards for Groundwater Standards (5 CCR 1002-41), where available. Although produced water is contained on site and is not likely to be ingested by either a worker or the public, the action level is established at 75 percent of either the basic groundwater standard (i.e., ^{3}H and ^{90}Sr) or the water effluent activity for specific radionuclides (Table 4B2), which if ingested at the activities (in pCi/L) specified in the regulations continuously over the course of a year would produce a TEDE to an individual member of the public of 50 mrem. The TEDE is exclusive of the dose contributions from natural background radiation, medical tests, or sanitary sewerage. The Colorado TEDE for individual members of the public is 100 millirem (mrem) per year. The produced water screening level is set at 10 percent of the action level, except for ^{3}H where the screening level is set at 10 times the minimum detectable activity (MDA) and ^{90}Sr where the screening level is set at 50 percent of the action level. The gross alpha and beta screening and action levels are determined as background + 2 standard deviations and background + 3 standard deviations, respectively.

Drill Cuttings and Soils

The drill cutting and soil screening action levels shown in Table 5 are conservatively calculated for a residential soil scenario for an exposure frequency of 350 days and an exposure duration of 1 year. The residential soil scenario accounts for the combined effects of inhalation, ingestion, and external exposure to soils containing a specific radionuclide. The action level is calculated for a conservative carcinogenic risk value of 1 in 1,000,000 (1E-6). The action levels were calculated using the preliminary remediation goal (PRG) equation for the residential soil exposure scenario presented on the Risk Assessment Information System web page at http://www.rais.ornl.gov/cgi-bin/prg/PRG_search. Default values provided on the web page were used in the action level calculations. The action level for drill cuttings and soils is set at 75 percent of the risk-based concentrations. The drill cutting and soil screening levels are set at 10 percent of the action level.

Groundwater and Surface Water

The groundwater and surface water screening and action levels shown in Table 5 are established for an individual member of the public that might consume (i.e., drink) either of these media. The action levels are set at 75 percent of the Colorado Basic Standards for Groundwater (5 CCR 1002-41) for specific radionuclides, except for gross alpha and beta which are set at the standard or screening level. The 50 pCi/L gross beta screening level is specified in 40 CFR 141.26(b)(1)(i). 40 CFR 141.26(b)(5) indicates that for gross beta activities greater than 50 pCi/L, a subsequent water sample will be analyzed to determine potential beta-emitting species that are contributing to the gross beta activity.

The derived concentrations for the 4 millirem/year standard for beta and photon emitters were obtained from EPA (2002). With the exception of alpha particle activity, beta and photon emitters, ^{3}H and ^{90}Sr, groundwater and surface water screening levels are set at 10 percent of the action level. The screening levels for alpha particle activity, beta and photon emitters, and ^{90}Sr are set at 50 percent of the action level. The screening level for ^{3}H is established at 10 times the MDA.

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.

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 wells. The well in question shall be temporarily shut-in pending further evaluation

Analyte Result	Required Action
	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. Personnel, field, and laboratory records will be retained a minimum of three years from their date of generation. 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 be offered to the COGCC, CDPHE, or DOE for archiving.

4.8 Data Management

Operational and environmental monitoring field and analytical data will be stored and managed using a Microsoft Access®-based relational data management system (DMS). The DMS will be customized to the specific data management needs of this project. Through the DMS, users can access project data stored for quarterly or more frequent reporting as necessary. The DMS will be used to load and verify laboratory electronic data deliverables (EDDs), input and check field data, perform pre-defined and *ad hoc* data queries, calculate basic environmental statistics, and generate presentation-quality data reports. Data integrity in the database will be enforced using the variety of tools available within Microsoft Access®. If requested, electronic data deliverables will be provided to the COGCC, CDPHE, or DOE.

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.

Table 5
Radionuclide Screening and Action Levels

Radionuclide	**Natural Gas[1]**		**Produced Water[2]**		**Drill Cuttings or Soil[3]**		**Groundwater[4]**		**Surface Water[4]**	
	Screening Level (pCi/L)	**Action Level (pCi/L)**	**Screening Level (pCi/L)**	**Action Level (pCi/L)**	**Screening Level (pCi/g)**	**Action Level (pCi/g)**	**Screening Level (pCi/L)**	**Action Level (pCi/L)**	**Screening Level (pCi/L)**	**Action Level (pCi/L)**
Gross Alpha	-----	-----	*See Note 5*	*See Note 5*	*See Note 5*	*See Note 5*	7.5	15	7.5	15
Gross Beta	-----	-----	*See Note 5*	*See Note 5*	*See Note 5*	*See Note 5*	25	50	25	50
Gamma-Emitting Radionuclides	-----	-----	*See Note 6*	*See Note 6*	*See Note 6*	*See Note 6*	*See Note 6*	*See Note 6*	*See Note 6*	*See Note 6*
Tritium (^{3}H)	7.5	75	400	15,000	3,435	34,350	400	15,000	400	15,000
Cesium-137 (^{137}Cs)	-----	-----	15	150	16	158	15	150	15	150
Strontium-90 (^{90}Sr)	-----	-----	3	6	8	77	3	6	3	6
Technetium-99 (^{99}Tc)	-----	-----	63	630	88	878	63	630	63	630
Carbon-14 (^{14}C)	*See Note 7*	*See Note 7*	150	1,500	252	2,520	150	1,500	150	1,500

NOTES:

[1] Natural Gas - Gas screening and action levels are for ^{3}H and ^{14}C in the methane gas phase only at standard temperature and pressure (STP; 20°C and 1 atmosphere pressure). Reporting units are pCi/L of methane gas. Screening values are from 6 CCR 1007-1 Part 4 Appendix 4B, Table 4B2 (air effluent concentrations). The action level value for ^{3}H in natural gas is 75 percent of the air effluent concentration (1E-7 µCi/mL); the screening level is 10 percent of the action level. Screening and action levels apply to laboratory analyses of ^{3}H and ^{14}C in natural gas.

[2] Produced Water - Action levels for ^{3}H and ^{90}Sr are 75 percent of the drinking water maximum contaminant levels (MCLs); for specific beta and photon emitters, the action level is 75 percent of the derived radionuclide activiy in drinking water that yields a dose of
4 mrem/yr to the total body or to any critical organ (EPA 2002); screening level is 10 percent of the action level, except for ^{3}H where the screening level is set at 10 times the minimum detectable activity (MDA) and ^{90}Sr which is set at 50 percent of t

[3] Drill Cuttings/Soils - Drill cutting and soil action levels were calculated using preliminary remediation goal (PRG) guidance for radionuclides on the Risk Assessment Information System (RAIS) at http://rais.ornl.gov/cgi-bin/prg/PRG_search. Action le calculated for a residential soil scenario for the combined effects of ingestion, inhalation, and external exposure to contaminated cuttings or soil for an exposure frequency of 350 days and an exposure duration of 1 year. The action levels are set at of a carcinogenic risk of 1 in 1,000,000 (1E-6). The screening level is 10 percent of the action level.

[4] Groundwater/Surface Water - Action level for gross alpha is the drinking water MCL; action level for gross beta is based on EPA guidance; for specific beta and photon emitters, the action level is 75 percent of the derived radionuclide activiy in drin that yields a dose of 4 mrem/yr to the total body or to any critical organ (EPA 2002); screening level is 10 percent of the action level, except for ^{3}H where the screening level is set at 10 times the MDA (~40 pCi/L) and gross alpha, gross beta, and ^{90} screening level is set at 50% of the action level.

[5] Gross alpha and beta activity screening levels are determined as background + 2 standard deviations; gross alpha and beta action levels are determined as background + 3 standard deviations. Note that gross alpha activity excludes the alpha activities contributed by radon and uranium and the gross beta activity excludes the beta activity contributed by ^{40}K.

[6] Gamma-emitting radionuclide screening and action levels are not specified; the screening and action level is based on the specific gamma-emitting radionuclide detected (e.g., ^{137}Cs).

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 their wells or springs and schedule sampling activities with Company personnel, landowners, or municipal water facility operators. Water supply wells or springs on private property will not be sampled without the landowners' permission. Sampling will not be performed if permission is refused. The Companies will provide escorted access and support, as necessary, for crews that will sample produced water and natural gas at the well sites. For privately or municipally owned wells or springs, the Companies or their designated representative will schedule in advance a convenient time for the landowners or municipalities where sampling is proposed. If warranted, the Companies will obtain verbal or written access agreements with the landowners or municipalities for annual access to their wells or springs.

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. A URS 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, can be used if a company other than URS is implementing the RSAP.

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 (EnCana locations only)

5.2.2 Sample Location Documentation

Sample location documentation equipment and supplies include:

- Field logbook
- Indelible pens
- Maps or aerial photographs showing the sample locations
- Global-positioning system (GPS) coordinates of previously sampled locations
- Differential hand-held GPS unit with sub-meter accuracy
- Flagging and/or wooden survey stakes to mark sample locations
- Digital camera to photograph sampling site

5.2.3 Radiation Screening and Monitoring

Radiation screening equipment and supplies 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
- Ludlum Measurements, Inc. Model 375 area monitor equipped with a Model 44-10 2 inch x 2 inch sodium iodide (NaI(Tl)) gamma scintillator, or equivalent,
- Berkley Nucleonics Corporation (BNC) 1035 AreaSAM real-time gamma spectrometer system, or equivalent
- Quantum Products Instadose™ dosimeters or Mirion Technologies DMC 2000XB electronic dosimeters, or equivalent, holders, and nylon zip ties
- Canberra TAM 100D portable tritium monitor, or equivalent
- Bioscan Triathler liquid scintillation counter (LSC) and supplies, or equivalent
- Check source (e.g., ^{137}Cs) for performance testing of alpha, beta, and gamma radiation monitoring equipment

This equipment is only required for Tier I drilling sites.

5.2.4 Water Sampling

Surface water, groundwater, and produced water sampling equipment and supplies include:

- Field sampling data sheets (example field forms are provided in Appendix C).
- Multiparameter water quality probe and meter (e.g., YSI, Hach, In-Situ) and calibration and standard solutions (e.g., pH buffers, conductivity standards, etc.).

- 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
- Ice or ice substitute
- 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 using a differential hand-held GPS unit with sub-meter accuracy that meets COGCC requirements so that sampling crews can locate the same site during future sampling events. The sample site coordinates will be recorded in the field logbook or on the field sample sheet to the nearest meter using the Universal Transverse Mercator (UTM) coordinate system. For reference, it is noted that the transition line (108 degrees[°] longitude) between UTM zones 12 and 13 is approximately 2.8 miles west of the Project Rulison site. Thus, care should be taken when surveying sampling locations near the western three-mile radius so that the appropriate UTM zone is referenced. Photographs will be taken at each sample site to document its location and site conditions during sampling. An overall view of the sampling area or property should be taken so that future samplers can locate the sampling site. 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 <u>Sample Site</u>

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). Background radiation will also be measured at environmental monitoring sites (e.g., ranch or livestock wells, springs, or streams) at an exposed ground location adjacent to the sampling site.

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

Field parameter measurements (i.e., pH, conductivity, temperature, dissolved oxygen, redox potential, and turbidity) will be collected at each water (i.e., groundwater, surface water, produced water, fracing fluid, and flowback fluid) sampling site using a multiparameter probe and meter. The instrument will be operated and calibrated in accordance with the manufacturer's instructions. The instrument should be calibrated each morning prior to sampling using certified buffers or standards. Solutions used for calibration will be checked prior to field mobilization to determine if the expiration dates have been exceeded. Any expired solution will be discarded appropriately and replaced with new solution.

For water supply wells, field parameter measurements will be made and recorded in the field logbook or sample form periodically during purging until the water quality field parameters have stabilized. Once stabilized, the final field parameter measurements will be made and recorded in the field logbook. Stability is demonstrated when there is no significant change in pH, temperature, and conductivity over a 10-minute period.

Field parameter measurements at surface water or spring sites can either be made in-situ or on a separate aliquot of water specifically collected for field parameter measurements. Field parameter measurements may be taken before or after collection of the surface water or spring sample. After the measurements have been recorded, the water will be discarded; this sample aliquot will not be used for laboratory analysis. Field parameter measurements are considered satisfactory if the stability criteria in the table below are met.

Field Parameter	**Acceptable Range**
pH	± 0.1 pH unit
Temperature	± 10%
Oxidation-Reduction Potential	± 5 mV
Conductivity	± 10%
Dissolved Oxygen	± 0.1 mg/L
Turbidity	± 10% NTU

Notes: % - percent; mg/L = milligrams per liter; mV = millivolt;
NTU = nephelometric turbidity unit

One duplicate field parameter measurement will be collected for every ten sampling locations (10 percent frequency). Duplicate field parameter measurements are considered satisfactory if the duplicate measurements fall within the acceptable range indicated in the above table. If duplicate acceptance criteria are not met, the instrument shall be re-calibrated and new parameter measurements obtained at the sample location where the original duplicate sample did not meet the acceptance criterion.

5.4 Dosimeters

Ambient external radiation will be monitored during drilling of the closest designated Tier I well using a minimum of four dosimeters as described in Section 4.1.1. The dosimeters will be deployed at each well pad prior to drilling and on the drill rig during drilling and well completion. The dosimeters will be placed in personnel work areas and near drilling fluid and cuttings discharge locations on each well pad to measure cumulative radiation intensities. One dosimeter will be placed in a background area of the well pad. The dosimeters will be placed in locations where they are not likely to be disturbed or damaged, at a height of approximately 3 to 10 feet above the ground or working surface. The dosimeters will be deployed in the holders provided by the manufacturer or enclosed in a weatherproof container. A duplicate dosimeter will deployed for every 10 dosimeters used.

A control dosimeter, supplied with the dosimeter shipment, will be transported with and handled the same as those deployed in the field. The control dosimeter will be used to monitor radiation exposure levels during shipment and handling. The control dosimeter will be kept away from all sources of radiation and retained for shipment back to the manufacturer when the field dosimeters are retrieved and returned for processing and reporting. Control dosimeters are not required if the Instadose™ or electronic dosimeters are used as they are not shipped to the manufacturer for processing. Additional dosimeters may also be placed at locations other than the well pads to measure the areal background radiation over the Tier I and II regions at the Companies discretion.

5.5 Surface Water Sampling

5.5.1 Stream Sampling

Stream water samples will be collected at several of the locations shown on Figure 2. The stream should be sampled at a location where the surface water is freely flowing. Sampling of stagnant water should be avoided. For health and safety reasons, sampling personnel should avoid wading into the stream to obtain a sample. The sample should be obtained with a pre-cleaned, long-handled, polyethylene dipper or decontaminated sampling container. Field personnel performing the sampling will wear disposable, powderless, nitrile gloves to prevent contamination of the samples during collection and subsequent handling. Field parameters, including pH, temperature, conductivity, dissolved oxygen (as mg/L O_2), redox potential, and turbidity will be measured and recorded in accordance with the procedures outlined in Section 5.3.3 prior to or after the collection of each stream water sample. Any equipment introduced into the stream should either be pre-cleaned, dedicated equipment or decontaminated (Section 5.11) prior to use to avoid introducing contaminants into the stream during sampling.

For shallow streams, sampling will be performed by immersing the dipper directly in the stream. The dipper should be rinsed in the stream water prior to taking a sample. To collect a sample, the sampler should face upstream and immerse the dipper beneath the water surface without disturbing the bottom sediment. The sample collected in the dipper is then poured gently into the laboratory-supplied sample bottle to minimize contact with the atmosphere and avoid agitation and aeration of volatile constituents. Stream samples collected for volatile analyses (e.g., BTEX, dissolved methane) should be placed in laboratory-supplied preserved sample containers (volatile organic analysis (VOA) vials) with zero headspace. Dissolved gas sample containers will be filled and sealed with no headspace to prevent loss of volatile gases. 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 ^3H analysis if the sample contains suspended particulates to facilitate laboratory.

Once filled, the sample bottle should be wiped dry and labeled, documented, stored in an iced cooler, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Surface water analytes are listed in Tables 3 and 4.

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, precipitates, a sheen on the surface of the water, condensate layer, petroleum hydrocarbon or other odor, or sample effervescence.

5.5.2 Spring and Seep Sampling

Spring and seep samples will be collected at several of the environmental sampling locations shown on Figure 2. The spring or seep should be sampled at a location where it is freely flowing. Sampling of stagnant water should be avoided. In some cases, it may be necessary to collect samples at a point downgradient of a spring or seep to have the required flow needed to fill sample containers. Field parameters including pH, temperature, conductivity, dissolved oxygen (as mg/L O_2), redox potential, and turbidity will be measured and recorded in accordance with the procedures outlined in Section 5.3.3 prior to or after collection of each spring or seep sample. Any equipment introduced into the stream should either be pre-cleaned, dedicated equipment or decontaminated (Section 5.11) prior to use to avoid introducing contaminants into the spring during sampling.

Where possible, a spring or seep flow rate measurement will be made at the time of sampling. The flow will be measured by clocking (using a stopwatch) the amount of time needed to fill a decontaminated, graduated container. Several fill-ups should be timed and the results averaged to improve the quality of this measurement. This flow measurement approach is generally valid for flows between about one gallon per minute (gpm) and 10 gpm.

The spring or seep will be sampled using a pre-cleaned, disposable, polyethylene dipper or decontaminated sampling container to avoid introducing contaminants to the spring or seep. Field personnel performing the sampling will wear disposable, powderless, nitrile gloves to prevent contamination of the samples during collection and subsequent handling. New gloves will be worn at each sampling site. To collect a sample, the sampler should gently immerse the dipper beneath the water surface without disturbing the bottom sediment. The sample collected in the dipper is then poured gently into the laboratory-supplied sample bottle to avoid agitation and aeration.

Spring or seep samples collected for volatile analyses should be placed in clean, preserved sample containers with zero headspace. Samples collected for other analyses (e.g., total metals, water quality parameters, radionuclides) should be placed into the appropriate preserved or non-preserved sample containers designated by the laboratory. 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 to facilitate laboratory.

Once filled, the sample bottle should be wiped dry and labeled, documented, stored in an iced cooler, and shipped to the laboratory in accordance with the procedures outlined in Section 6. Spring or seep analytes are listed in Tables 3 and 4.

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, precipitates (e.g., iron oxyhydroxides), sheen on the surface of the water, condensate layer, petroleum hydrocarbon or other odor, or sample effervescence.

5.6 Groundwater Sampling

Groundwater samples will be collected from residential or livestock wells at the locations shown on Figure 2. It is anticipated that these wells are equipped with a pump and piping that is suitable for sampling. The wells may also be equipped with water treatment systems or storage tanks. Prior to sampling, the sampling crew should discuss with the well owner the well construction, pump type, typical well yield, and whether the water is treated or stored to use. If possible, the sample crew should determine with the well owner where a water sample can be collected before it enters the treatment system or storage tank. In instances where access to the water before treatment or storage is not available, the water sample will be collected, but the type of treatment should be determined and documented in the field logbook or on the field sample form. A photograph should be taken at each well to document the actual groundwater sampling location. The name, mailing address, and the resident's home and work telephone numbers should be entered into the field logbook. This information will be used to transmit the well sampling results to the landowners, if requested.

For wells equipped with pumps, the well will be purged using the existing pumping system to remove stagnant water standing in the well casing prior to collecting a groundwater sample. For wells without pumps, the well will either be purged manually using a bailer and rope or a portable pumping system. Any equipment introduced into the well will either be pre-cleaned, dedicated equipment or decontaminated (Section 5.11) prior to use to avoid introducing contaminants into the well during sampling. Purge rates should be slow enough to limit turbulence in the well bore and piping that may stir up sediments in the well casing. The well should be purged slowly at first, while pH, temperature, and conductivity parameters are measured with a multiparameter probe and meter. Flow rates should then be gradually increased to a maximum flow rate of 3 to 5 gpm as long as no increase in entrained sediment is observed.

The well discharge should be directed into a clean, white 5-gallon bucket to measure flow and to allow the sampler to monitor water color, odor, effervescence, and entrained sediment as the well is purged. Unless the well owner objects, the well should be purged for at least 15 minutes or until the pH, temperature, and conductivity values have stabilized. To minimize the volume of water pumped, the well should be purged at a flow rate of 5 gpm or less.

The water quality parameters should be recorded in the field logbook or on the field sample forms (Appendix C) for every five minutes of purging. After the field parameters stabilize, pH, temperature, conductivity, dissolved oxygen (as mg/L O_2), redox potential, and turbidity will be measured and recorded in accordance with the procedures outlined in Section 5.3.3 on a separate groundwater sample aliquot. In some cases, well yields may be too low to allow field measurements to stabilize without drawing down a well to the level of the pump intake. In such situations, the well should be sampled using low flow rates at the outset.

For sampling, the well discharge rate should be reduced to 0.1 to 1 gpm to facilitate sample collection at low flow rates. Low-flow sampling reduces the agitation and aeration of dissolved gases and other volatile constituents, if present. Field personnel performing the sampling will wear disposable, powderless, nitrile gloves to prevent contamination of the samples during collection and subsequent handling. New gloves will be worn at each sampling site to avoid cross contamination.

Groundwater will be dispensed directly from the well discharge line or bailer into the laboratory-supplied sample containers so that agitation and aeration of volatile constituents are minimized. Samples collected for volatile analyses (e.g., dissolved methane) should be placed in clean, preserved sample containers with zero headspace to minimize volatile losses. Samples collected for other analyses (e.g., total metals, water quality parameters, radionuclides) should be placed into the appropriate preserved or non-preserved sample containers designated by the laboratory. 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 to facilitate laboratory.

Once filled, the sample bottle should be wiped dry and labeled, documented, stored in an iced cooler, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Groundwater analytes are listed in Tables 3 and 4.

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, precipitates (e.g., iron oxyhydroxides), surface sheen, condensate layer, petroleum hydrocarbon or other odor, or sample effervescence.

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 an iced 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 to facilitate laboratory.

Once filled, the sample bottle should be wiped dry, labeled, documented, stored in an iced 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.

Field parameters, temperature, pH, specific conductance, dissolved oxygen, oxidation-reduction potential, and turbidity, will be measured on a separate sample aliquot at the well site. The field parameters will be measured in accordance with the procedures outlined in Section 5.3.3.

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 can not be collected a 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 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 to facilitate laboratory.

Once filled, the sample bottle should be wiped dry, labeled, documented, stored in an iced cooler, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Produced water analytes are listed in Tables 3 and 4.

Field parameters, including pH, temperature, conductivity, dissolved oxygen (as mg/L O_2), redox potential, and turbidity will be measured on an aliquot of produced water prior to or after the sample is collected. The field parameters will be measured in accordance with the procedures outlined in Section 5.3.3.

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 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 introduced into any well, spring, or stream 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 it use at the next site. One rinsate sample from the decontaminated sampling equipment will be collected and analyzed for every ten samples collected. The rinsate samples will be analyzed for the same analytes as the groundwater samples (Tables 3 and 4). Rinsate samples are not required for pre-cleaned, disposable or dedicated sampling equipment.

6 DATA QUALITY ASSURANCE OBJECTIVES

6.1 Data Quality Objectives

The operation and environmental monitoring program proposed in this RSAP is designed to detect an unanticipated migration of verified Rulison-related radionuclides from the subsurface nuclear cavity to producing gas wells or the environment within a three-mile radius of Project Rulison. This RSAP specifies a subset of radionuclides to monitor that would be derived from a nuclear fission device like that used at Project Rulison and that are likely to be transported in either the natural gas or formation water. Likely mobile gas phase radionuclides (e.g., ^{3}H, ^{14}C, and ^{85}Kr) and less mobile liquid phase radionuclides (e.g., ^{36}Cl, ^{90}Sr, ^{99}Tc, and ^{137}Cs) are considered in response to COGCC and public concerns regarding the migration and release of radionuclides to the environment. 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 proposed 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 or within local water supplies within the region. These monitoring data will provide an early warning of the potential migration of verified Project Rulison-related radionuclides to producing gas wells or the environment. 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 a 3-mile radius 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 a three-mile radius of the Project Rulison emplacement well R-E 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 cause the Colorado 100 millirem TEDE per year public dose limit (6 CCR 1007-1 Part 4.14.1.1) to be exceeded or would cause a radiation release to the environment that would exceed air, groundwater, or surface water quality standards;

- 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 field 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 mutual 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 fewer 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 fewer 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 are usable as long as 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. In essence, 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., groundwater, 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.
- Field parameter measurements, 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., gross alpha/beta, 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 a particular 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.

At the conclusion of 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. Tables 6 and 7 present the sample container, preservation, and holding time requirements for radiological and non-radiological analytes, respectively.

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 and 7 present the field QC requirements for readiological and non-radiological analytes, respectively.

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), groundwater (GW), spring (SP), surface water (SW), drill cuttings (DC), surface soils (SS), makeup water (MW), fracing fluids (FW), flowback fluids (FB), trip blank (TB), stormwater (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									
Gross Alpha Particle Activity	GEL	EPA 900.0 mod.	1 Liter P or G	500 mL	pH<2 HNO_3, ≤ 6°C	6 months	1 per 20 field samples	NA	1 per 20
Gross Beta Particle Activity	GEL	EPA 900.0 mod.				6 months	1 per 20 field samples	NA	1 per 20
Gamma Spectroscopy	GEL	EPA 901.1 mod.	1 Liter P or G	500 mL	pH<2 HNO_3, ≤ 6°C	6 months	1 per 20 field samples	NA	1 per 20
Cesium-137 (^{137}Cs)	GEL	EPA 901.1 mod.	2 x 1 Liter P	2000 mL	≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
Strontium-90 (^{90}Sr)	GEL	GL-RAD-A004 GFPC	1 Liter P or G	500 mL	pH<2 HNO_3, ≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
Technetium-99 (^{99}Tc)	GEL	HASL 300 Tc-01-RC mod.	1 Liter P or G	500 mL	pH<2 HNO_3, ≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
Tritium (^{3}H)	Isotech	EPA 906.0 mod.	125 mL P or G	125 mL	≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
Total Uranium	GEL	GL-RAD-A023	250 mL P	100 mL	pH<2 HNO_3, ≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
Drill Cuttings or Soil									
Gross Alpha Particle Activity	GEL	EPA 900.0 mod.	16 oz P or G wide mouth jar	20 g	None	6 months	1 per 20 field samples	NA	1 per 20
Gross Beta Particle Activity	GEL	EPA 900.0 mod.		20 g	None	6 months	1 per 20 field samples	NA	1 per 20
Gamma Spectroscopy	GEL	EPA 901.1 mod.		200 g	None	6 months	1 per 20 field samples	NA	1 per 20
Total Uranium	GEL	ASTM D5174		20 g	None	6 months	1 per 20 field samples	NA	1 per 20

Notes:

[1] Sample volume depends on methane concentration. 5 liters of pure methane needed for analysis. Generally 19L samples are collected.

LP = Liquid propane
L = Liter
MS = Matrix spike
NA = Not applicable
DUP = Duplicate
ml = Milliliter
P = Plastic
MSD = Matrix spike duplicate
G = Glass

Table 7. Sample Handling and Field QC Requirements for Non-Radiological Analytes.

Analysis Parameter	Analytical Laboratory	Analytical Method	Sample Container	Minimum Sample Volume	Preservation Requirements	Holding Time	Frequency of Field QC			
							Trip Blank	Field Duplicate	MS	MSD or DUP
Trace Metals										
Arsenic	ALS	SW6020	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Cadmium	ALS	SW6020	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Lead	ALS	SW6020	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Manganese	ALS	SW6020	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Mercury	ALS	SW7470A	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Selenium	ALS	SW6020	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Other Metals and Major Cations										
Barium	ALS	SW6010	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Boron	ALS	SW6010	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Calcium	ALS	SW6010	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Chromium (total)	ALS	SW6010	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Iron	ALS	SW6010	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Lithium	ALS	SW6010	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Magnesium	ALS	SW6010	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Potassium	ALS	SW6010	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Sodium	ALS	SW6010	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20
Strontium	ALS	SW6010	1 L poly	1 L	pH<2 HNO_3, ≤ 6°C	6 months	NA	1 per 20 field samples	1 per 20	1 per 20

Table 7. Sample Handling and Field QC Requirements for Non-Radiological Analytes (continued).

Analysis Parameter	Analytical Laboratory	Analytical Method	Sample Container	Minimum Sample Volume	Preservation Requirements	Holding Time	Frequency of Field QC			
							Trip Blank	Field Duplicate	MS	MSD or DUP
Major Ions										
Chloride	ALS	EPA300.0	1 L poly	500 mL	≤ 6°C	28 days	NA	1 per 20 field samples	1 per 20	1 per 20
Fluoride	ALS	EPA300.0	1 L poly		≤ 6°C	28 days	NA	1 per 20 field samples	1 per 20	1 per 20
Nitrate/Nitrite (as N)	ALS	EPA300.0	1 L poly	500 mL	≤ 6°C	28 days	NA	1 per 20 field samples	1 per 20	1 per 20
Orthophosphate (as P)	ALS	EPA300.0	1 L poly		≤ 6°C	48 hours	NA	1 per 20 field samples	1 per 20	1 per 20
Sulfate	ALS	EPA300.0	1 L poly		≤ 6°C	28 days	NA	1 per 20 field samples	1 per 20	1 per 20
Ammonia (as N)	ALS	EPA350.1	125 ml poly	125 mL	pH<2 HNO_3, ≤ 6°C	28 days	NA	1 per 20 field samples	1 per 20	1 per 20
Bromide	ALS	EPA300.0	1 L poly	500 mL	≤ 6°C	28 days	NA	1 per 20 field samples	1 per 20	1 per 20
Water Quality Parameters										
Bicarbonate Alkalinity (as $CaCO_3$)	ALS	EPA310.1	1 L poly	125 mL	≤ 6°C	14 days	NA	1 per 20 field samples	NA	1 per 20
Carbonate Alkalinity (as $CaCO_3$)	ALS	EPA310.1	1 L poly		≤ 6°C	14 days	NA	1 per 20 field samples	NA	1 per 20
Hydroxide Alkalinity (as $CaCO_3$)	ALS	EPA310.1	1 L poly		≤ 6°C	14 days	NA	1 per 20 field samples	NA	1 per 20
Alkalinity, Total	ALS	EPA310.1	1 L poly		≤ 6°C	14 days	NA	1 per 20 field samples	NA	1 per 20
pH	ALS	EPA150.1	1 L poly	125 mL	≤ 6°C	ASAP	NA	1 per 20 field samples	NA	1 per 20
Total Dissolved Solids (TDS)	ALS	EPA160.1	1 L poly	200 mL	≤ 6°C	7 days	NA	1 per 20 field samples	NA	1 per 20
Organic Compound Parameters										
Dissolved Methane	ALS	RSK175 (SW8015M)	3 x 40 ml glass vial	120 mL	≤ 6°C	14 days	1 per cooler	1 per 20 field samples	1 per 20	1 per 20
Gasoline Range Organics (GRO)	ALS	SW8015	3 x 40 ml glass vial	120 mL	pH<2 HNO_3, ≤ 6°C	14 days	1 per cooler	1 per 20 field samples	1 per 20	1 per 20
Diesel Range Organics (DRO) plus motor oil (RRO)	ALS	SW8015MCALUFT	1 L amber glass	1 L	≤ 6°C	7 days to extraction; 40 days to analysis	NA	1 per 20 field samples	1 per 20	1 per 20

Table 7. Sample Handling and Field QC Requirements for Non-Radiological Analytes (continued).

Analysis Parameter	Analytical Laboratory	Analytical Method	Sample Container	Minimum Sample Volume	Preservation Requirements	Holding Time	Frequency of Field QC			
							Trip Blank	Field Duplicate	MS	MSD or DUP
Bezene	ALS	SW8260	3 x 40 ml glass vial	120 mL	pH<2 HNO_3, ≤ 6°C	14 days	1 per cooler	1 per 20 field samples	1 per 20	1 per 20
Ethylbenzene	ALS	SW8260	3 x 40 ml glass vial		pH<2 HNO_3, ≤ 6°C	14 days	1 per cooler	1 per 20 field samples	1 per 20	1 per 20
m,p-Xylene	ALS	SW8260	3 x 40 ml glass vial		pH<2 HNO_3, ≤ 6°C	14 days	1 per cooler	1 per 20 field samples	1 per 20	1 per 20
o-Xylene	ALS	SW8260	3 x 40 ml glass vial	120 mL	pH<2 HNO_3, ≤ 6°C	14 days	1 per cooler	1 per 20 field samples	1 per 20	1 per 20
Toluene	ALS	SW8260	3 x 40 ml glass vial		pH<2 HNO_3, ≤ 6°C	14 days	1 per cooler	1 per 20 field samples	1 per 20	1 per 20

Notess:
SW indicates method is in SW-846, Test Methods for Evaluating Solid Waste, EPA, including all updates
EPA indicates method is in "Methods for the Analysis of Water and Wastewater," EPA 1983.
$CaCO_3$ = calcium carbonate
N = Nitrogen
NA = Not Applicable
ICP = Inductively coupled plasma
ICP/MS = Inductively-coupled plasma/mass spectrometry
IC = Ion chromatography
P&T = Purge and trap
GC = Gas chromatography
GC/MS = Gas chromatography/mass spectrometry
FID = Flame Ionization Detector
RRO = Residual Range Organics
µg/L = micrograms per liter
ppb = parts per billion
P = Phosphorus
RSK175 = Standard Operating Procedure 175, Robert S. Kerr Environmental Research Center, Ada, OK.
MDL = Method Detection Limit
RL = Reporting Limit
TAT = Turn Around Time
TBD = To be determined (in the process of conducting method validation studies)
L = Liter
mL = mililiter
HNO_3 = Nitric acid
H_2SO_4 = sulfuric acid
HCl = Hydrochloric acid
4°C = degress celcius
poly = polyethylene (plastic)
MS = Matrix spike; MSD = Matrix spike duplicate
DUP = Duplicate

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;
- For all coolers containing samples that require ≤ 6°C preservation, blue ice or cubed ice and additional packaging materials will be placed around the containers. Cubed ice must be double-bagged to minimize leakage of melt water;
- A temperature blank will be included in each cooler containing samples that require ≤ 6°C preservation;
- 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 as long as 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 (Figure 9) in accordance with the dangerous goods shipping regulations. The dangerous goods shipping paperwork (Figure 10) will be completed by a person with the appropriate DOT/IATA training. 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

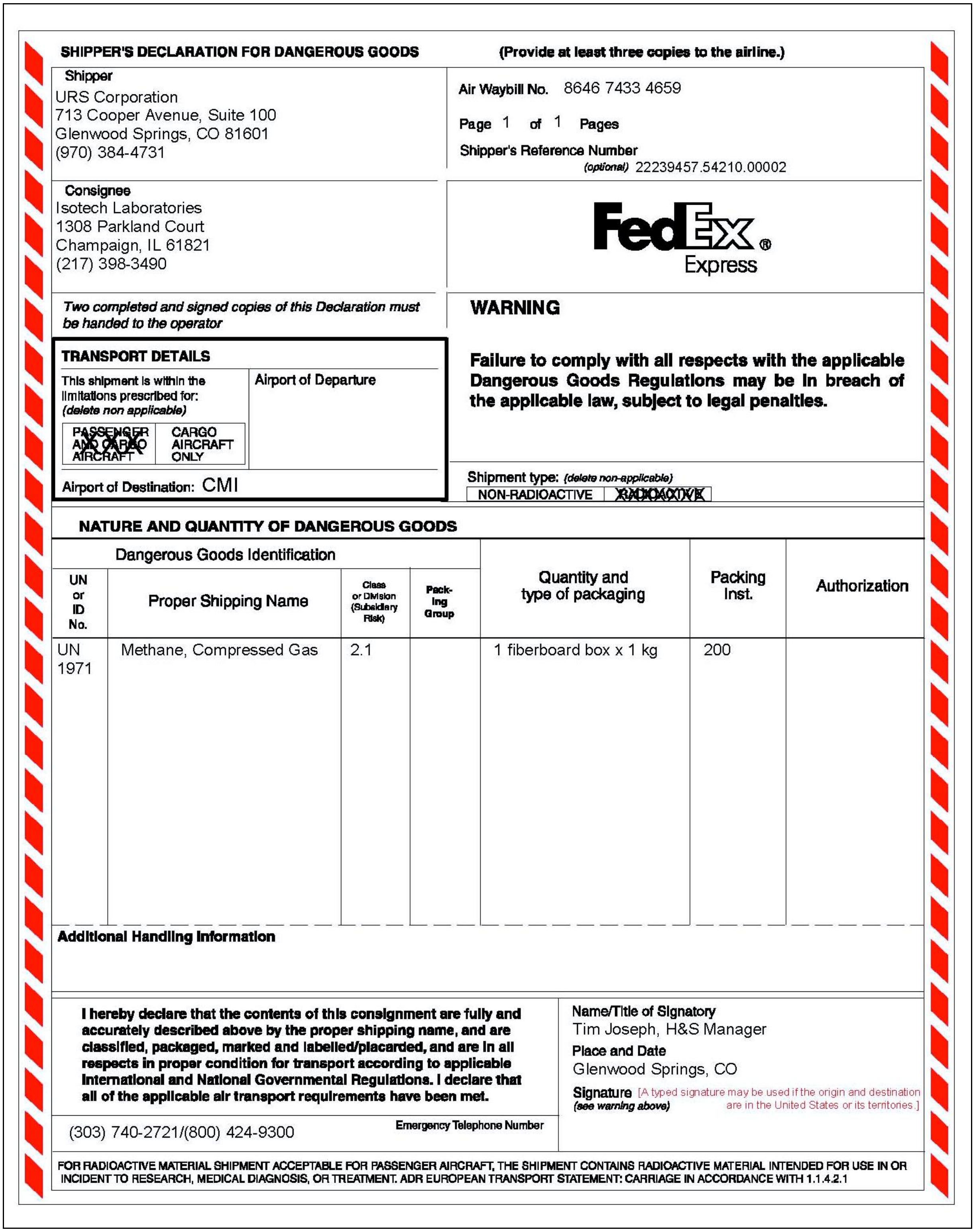
Type of Packaging: U. S. DOT approved LP gas cylinders
Maximum Allowed Quantity per Package: 150 kg
Description of Contents: Gas cylinders containing methane gas samples

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~~ XXXXXXX

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification				Quantity and type of packaging	Packing Inst.	Authorization
UN or ID No.	Proper Shipping Name	Class or Division (Subsidiary Risk)	Pack-ing Group			
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.

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

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.]

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.

8.1 Analytical Methods and Reporting Limits

Tables 8 and 9 present 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 and non-radiological analytes, respectively. 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[12]
NATURAL GAS						
Carbon-14 (^{14}C)	Isotech	Laboratory SOP[13]	liquid scintillation counting	definitive	0.5 pMC	45 days
Tritium (^{3}H)	Isotech	Laboratory SOP	liquid scintillation counting	definitive	10-15 TU[14]	28 days
WATER						
Gross Alpha Activity	GEL	EPA 900.0 modified	gas flow proportional counting	definitive	5 pCi/L	28 days
Gross Beta Activity	GEL	EPA 900.0 modified	gas flow proportional counting	definitive	5 pCi/L	28 days
Gamma Spectroscopy	GEL	EPA 901.1 modified	gamma spectroscopy	definitive	5 pCi/L	28 days
Cesium-137 (^{137}Cs)	GEL	EPA 901.1 modified	gamma spectroscopy	definitive	5 pCi/L	28 days
Strontium-90 (^{90}Sr)	GEL	GL-RAD-A004 GFPC	gas flow proportional counting	definitive	5 pCi/L	28 days
Technetium-99 (^{99}Tc)	GEL	HASL 300 Tc-01-RC modified	liquid scintillation counting	screening	50 pCi/L	28 days
Tritium (^{3}H)	Isotech	EPA 906.0 modified	liquid scintillation counting	definitive	10-15 TU	28 days
Total Uranium	GEL	GEL-RAD-A023	laser kinetic phosphorimetry	definitive	1 µg/L	28 days

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[12] TAT = turn-around time

[13] 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.

[14] 1 tritium unit (TU) = approximately 3.2 pCi/L.

Table 8. Analytical Methods and Reporting Limits for Radiological Analytes (continued).

Parameter	Analytical Laboratory	Analytical Method	Analytical Technique	Definitive or Screening Analysis	Lower Limit of Detection	Analytical TAT
SOIL						
Gross Alpha Activity	GEL	EPA 900.0 modified	gas flow proportional counting	definitive	4 pCi/g	28 days
Gross Beta Activity	GEL	EPA 900.0 modified	gas flow proportional counting	definitive	10 pCi/L	28 days
Gamma Spectroscopy	GEL	EPA 901.1 modified	gamma spectroscopy	definitive	0.1 pCi/L	28 days
Total Uranium	GEL	ASTM D5174	laser kinetic phosphorimetry	definitive	1 µg/g	28 days

pMC = percent Modern Carbon
TU = Tritium units
pCi/L = picoCuries per liter
pCi/g = picocuries per gram
µg/L = micrograms per liter
µg/g = micrograms 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.

Table 9. Analytical Methods and Reporting Limits for Non-Radiological Analyses.

Analyte	Analytical Laboratory	Extraction Method	Analytical Method	Analytical Technique	RL (µg/L)	MDL (µg/L)	Analytical TAT
Trace Metals							
Arsenic	Paragon	SW3005	SW6020	ICP-MS	0.2	0.0109	14 days
Cadmium	Paragon	SW3005	SW6020	ICP-MS	0.03	0.0042	14 days
Lead	Paragon	SW3005	SW6020	ICP-MS	0.05	0.00451	14 days
Manganese	Paragon	SW3005	SW6020	ICP-MS	0.2	0.0206	14 days
Mercury	Paragon	SW7470	SW7470A	CV-AA	0.2	0.00748	14 days
Selenium	Paragon	SW3005	SW6020	ICP-MS	0.1	0.0107	14 days
Other Metals and Major Cations							
Barium	Paragon	SW3005	SW6010	ICP-AES	100.0	0.0999	14 days
Boron	Paragon	SW3005	SW6010	ICP-AES	100.0	3.62	14 days
Calcium	Paragon	SW3005	SW6010	ICP-AES	1000.0	13.9	14 days
Chromium (total)	Paragon	SW3005	SW6010	ICP-AES	10.0	0.508	14 days
Iron	Paragon	SW3005	SW6010	ICP-AES	100.0	8.31	14 days
Lithium	Paragon	SW3005	SW6010	ICP-AES	10.0	0.438	14 days
Magnesium	Paragon	SW3005	SW6010	ICP-AES	1000.0	7.47	14 days
Potassium	Paragon	SW3005	SW6010	ICP-AES	1000.0	28.7	14 days
Sodium	Paragon	SW3005	SW6010	ICP-AES	1000.0	6.01	14 days
Strontium	Paragon	SW3005	SW6010	ICP-AES	10.0	0.0899	14 days

Table 9. Analytical Methods and Reporting Limits for Non-Radiological Analyses (continued).

Analyte	Analytical Laboratory	Extraction Method	Analytical Method	Analytical Technique	RL µg/L	MDL µg/L	Analytical TAT
Major Ions							
Chloride	Paragon	NA	EPA300.0	IC	200	67	14 days
Fluoride	Paragon	NA	EPA300.0	IC	100	33	14 days
Nitrate/Nitrite (as N)	Paragon	NA	EPA300.0	IC	200	67	14 days
Orthophosphate (as P)	Paragon	NA	EPA300.0	IC	500	356	14 days
Sulfate	Paragon	NA	EPA300.0	IC	1000	333	14 days
Ammonia (as N)	Paragon	NA	EPA350.1	Colorimetric	100	11	14 days
Bromide	Paragon	NA	EPA 300.0	IC	200	67	14 days
Water Quality Parameters							
Bicarbonate Alkalinity (as $CaCO_3$)	Paragon	NA	EPA310.1	Titration	5000	546	14 days
Carbonate Alkalinity (as $CaCO_3$)	Paragon	NA	EPA310.1	Titration	5000	546	14 days
Hydroxide Alkalinity (as $CaCO_3$)	Paragon	NA	EPA310.1	Titration	5000	546	14 days
Alkalinity, Total	Paragon	NA	EPA310.1	Titration	5000	NA	14 days

Table 9. Analytical Methods and Reporting Limits for Non-Radiological Analyses (continued).

Analyte	Analytical Laboratory	Extraction Method	Analytical Method	Analytical Technique	RL µg/L (ppb)	MDL µg/l (ppb)	Analytical TAT
Organic Compound Parameters							
Dissolved Methane	Paragon	NA	RSK175 (SW8015M)	GC	1000	TBD	14 days
Gasoline Range Organics (GRO)	Paragon	SW5030	SW8015	P&T/GC-FID	100	16.6	14 days
Diesel Range Organics (DRO) plus motor oil (RRO)	Paragon	SW3510	SW8015MCALUFT	GC-FID	200	33.3	14 days
Benzene	Paragon	SW5030	SW8260	P&T/GC/MS	5.0	1.66	14 days
Ethylbenzene	Paragon	SW5030	SW8260	P&T/GC/MS	5.0	1.66	14 days
m,p-Xylene	Paragon	SW5030	SW8260	P&T/GC/MS	5.0	1.66	14 days
o-Xylene	Paragon	SW5030	SW8260	P&T/GC/MS	5.0	1.66	14 days
Toluene	Paragon	SW5030	SW8260	P&T/GC/MS	5.0	1.66	14 days

Notes:
SW indicates method is in SW-846, Test Methods for Evaluating Solid Waste, EPA, including all updates
EPA indicates method is in "Methods for the Analysis of Water and Wastewater," EPA 1983.
NA = Not Applicable
ICP-AES = Inductively coupled plasma-atomic emission spectroscopy; ICP-MS = Inductively-coupled plasma/mass spectrometry
IC = Ion chromatography
P&T = Purge and trap
GC = Gas chromatography; GC/MS = Gas chromatography/mass spectrometry
FID = Flame Ionization Detector
RRO = Residual Range Organics
µg/L = micrograms per liter
ppb = parts per billion
RSK175 = Standard Operating Procedure 175, Robert S. Kerr Environmental Research Center, Ada, OK.
MDL = Method Detection Limit
RL = Reporting Limit
TAT = Turn Around Time; TBD = To be determined (in the process of conducting method validation studies)

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 as long as 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 final 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. For non-radiological analyses, sample results will not be blank corrected.

8.2.3 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.

8.2.4 QC Sample Frequency

For most radiochemical procedures, QC samples are added to make up between 10 and 20 percent of the sample stream. Tables 10 and 11 present the laboratory QC sample frequency for the various radiological and non-radiological analytes, respectively. 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 manner in which 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	Frequency of Lab QC Samples				
		Instrument Calibration	Method Blank	Laboratory Control Sample (LCS)	Matrix Spike	Matrix Duplicate
Natural Gas						
Carbon-14 (^{14}C)	Laboratory SOP	per method requirements	1 per batch	1 per batch	NA	NA
Tritium (^{3}H)	Laboratory SOP	per method requirements	1 per batch	1 per batch	NA	1 per 10
Water						
Gross Alpha Particle Activity	EPA 900.0 modified	per method requirements	1 per batch	NA	NA	1 per 20
Gross Beta Particle Activity	EPA 900.0 modified	per method requirements	1 per batch	NA	NA	1 per 20
Gamma Spectroscopy	EPA 901.1 modified	per method requirements	1 per batch	NA	NA	1 per 20
Cesium-137 (^{137}Cs)	EPA 901.1 modified	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20
Strontium-90 (^{90}Sr)	GL-RAD-A004 GFPC	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20
Technetium-99 (^{99}Tc)	HASL 300 Tc-01-RC modified	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20
Tritium (^{3}H)	EPA 906.0 modified	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20
Total Uranium	GEL-RAD-A023	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20

Tablee 10. Laboratory Quality Control Criteria for Radiological Analytes (continued)

Parameter	Analytical Method	Frequency of Lab QC Samples				
		Instrument Calibration	Method Blank	Laboratory Control Sample (LCS)	Matrix Spike	Matrix Duplicate
Drill Cuttings or Soil						
Gross Alpha Particle Activity	EPA 900.0 modified	per method requirements	1 per batch	NA	NA	1 per 20
Gross Beta Particle Activity	EPA 900.0 modified	per method requirements	1 per batch	NA	NA	1 per 20
Gamma Spectroscopy	EPA 901.1 modified	per method requirements	1 per batch	NA	NA	1 per 20
Total Uranium	ASTM D5174	per method requirements	1 per batch	NA	NA	1 per 20

Notes:
An analytical batch consist of a set of up to 20 samples of the same matrix prepared and analyzed in the same time frame.

Table 11. Laboratory Quality Control Criteria for Non-Radiological Analytes

Parameter	Analytical Method	Frequency of Laboratory QC Analyses				
		Instrument Calibration	Method Blank	Lab Control Sample (LCS) [1]	Matrix Spike [1]	Matrix Duplicate [1]
Trace Metals						
Arsenic	SW6020	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Cadmium	SW6020	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Lead	SW6020	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Manganese	SW6020	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Mercury	SW7470A	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Selenium	SW6020	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Other Metals and Major Cations						
Barium	SW6010	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Boron	SW6010	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Calcium	SW6010	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Chromium (total)	SW6010	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Iron	SW6010	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Lithium	SW6010	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Magnesium	SW6010	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Potassium	SW6010	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Sodium	SW6010	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Strontium	SW6010	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch

Table 11. Laboratory Quality Control Criteria for Non-Radiological Analytes (continued)

Parameter	Analytical Method	Frequency of Laboratory QC Analyses				
		Instrument Calibration	Method Blank	Lab Control Sample (LCS) [1]	Matrix Spike [1]	Matrix Duplicate [1]
Major Ions						
Chloride	EPA300.0	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Fluoride	EPA300.0	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Nitrate/Nitrite (as N)	EPA300.0	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Orthophosphate (as P)	EPA300.0	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Sulfate	EPA300.0	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Ammonia (as N)	EPA350.1	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Bromide	EPA350.1	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Water Quality Parameters						
Bicarbonate Alkalinity (as $CaCO_3$)	EPA310.1	per method requirements	1 per batch	1 per batch	NA	1 per batch
Carbonate Alkalinity (as $CaCO_3$)	EPA310.1	per method requirements	1 per batch	1 per batch	NA	1 per batch
Hydroxide Alkalinity (as $CaCO_3$)	EPA310.1	per method requirements	1 per batch	1 per batch	NA	1 per batch
Alkalinity, Total	EPA310.1	per method requirements	1 per batch	1 per batch	NA	1 per batch
pH	EPA150.1	per method requirements	1 per batch	1 per batch	NA	1 per batch
Total Dissolved Solids (TDS)	EPA160.1	per method requirements	1 per batch	1 per batch	NA	1 per batch

Table 11. Laboratory Quality Control Criteria for Non-Radiological Analytes (continued)

Parameter	Analytical Method	Frequency of Laboratory QC Analyses				
		Instrument Calibration	Method Blank	Lab Control Sample (LCS) [1]	Matrix Spike [1]	Matrix Duplicate [1]
Organic Parameters						
Dissolved Methane	RSK175 (SW8015M)	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Gasoline Range Organics (GRO)	SW8015	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Diesel Range Organics (DRO) plus Motor Oil (RRO)	SW8015MCALUFT	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Benzene	SW8260	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Ethylbenzene	SW8260	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
m,p-Xylene	SW8260	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
o-Xylene	SW8260	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch
Toluene	SW8260	per method requirements	1 per batch	1 per batch	1 per batch	1 per batch

Notes:

An analytical batch consist of a set of up to 20 samples of the same matrix prepared and analyzed in the same time frame.

[1] Results will be evaluated using current laboratory statistically derived acceptance ranges.

SW indicates method is in SW-846, Test Methods for Evaluating Solid Waste, EPA, including all updates

EPA indicates method is in "Methods for the Analysis of Water and Wastewater," EPA 1983.

$CaCO_3$ = calcium carbonate

N = Nitrogen

NA = Not Applicable

RRO = Residual Range Organics

P = Phosphorus

RSK175 = Standard Operating Procedure 175, Robert S. Kerr Environmental Research Center, Ada, OK.

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). The sample-specific and laboratory performance evaluation procedures discussed for non-radiological parameters were developed using guidance in EPA (2004b) and EPA (1999b).

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

Table 12. Independent Reviewer Data Qualifier Definitions.

<table>
<tr><td colspan="2">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.</td></tr>
<tr><td>U</td><td>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.</td></tr>
<tr><td>J</td><td>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).</td></tr>
<tr><td>NJ</td><td>The analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration.</td></tr>
<tr><td>N (Rads)</td><td>Analyte was identified as present, but a quantitative value was not reported.</td></tr>
<tr><td>UJ</td><td>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.</td></tr>
<tr><td>R</td><td>The sample results are unusable because certain data quality criteria were not met. The analyte may or may not be present in the sample.</td></tr>
</table>

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. For non-radiological analyses, the requirements set forth in the analytical methods will be used to determine whether:

- The initial calibration was performed at the required frequency using the proper number of standards at the proper concentrations,
- The RL is supported by the low point standard,
- Adequate response was obtained for each analyte for each standard,
- The applicable linearity criteria were met, and
- The initial calibration was verified properly.
- The continuing calibration verification was performed at the required frequency using the proper standard at the proper concentration,
- Adequate response was obtained for each analyte in the calibration verification analysis, and
- The responses obtained for the calibration verification indicate that the instrumentation is still operating within an acceptable range (drift).

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).

For non-radiological parameters, the reviewer will verify that all target analytes were spiked into the LCS sample. The LCS percent recoveries will then be compared to the method-specified acceptance range or laboratory statistically derived acceptance limits (if the laboratory acceptance limits are considered to be comparable to those specified in the methods), as applicable.

- If the LCS recovery for an analyte is greater than the upper acceptance limit, suggesting a potential high bias in reported results, all positive results for that analyte in all associated samples will be qualified as estimated (J) whereas nondetect results will be considered acceptable for use without qualification because the high bias does not affect nondetect results.

- If the LCS recovery for an inorganic analyte is less than the lower acceptance limit but ≥30%, suggesting a potential low bias in reported results, positive and nondetect results for that analyte in all associated samples will be qualified as estimated (J or UJ).
- If the LCS recovery for an inorganic analyte is <30%, positive sample results will be qualified as estimated (J), whereas nondetect results will be qualified as unusable (R) for all associated sample results.
- If the LCS recovery for an organic analyte is less than the lower acceptance limit but ≥10%, positive and nondetect results for that analyte in all associated samples will be qualified as estimated (J or UJ).
- If the LCS recovery for an organic analyte is <10%, positive sample results will be qualified as estimated (J) whereas nondetect results will be qualified as unusable (R) for all associated sample results.

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.

Target Radionuclide List Identification (gamma spectroscopy)

The target radionuclide list (TRL) contains those radionuclides for which a quantitative analysis may be required by some programs. If data are provided for TRL analytes, net quantitation with uncertainties will be provided for all TRL analytes, regardless of whether the radionuclide is present or absent.

The reviewer will check that the energy of the identified peaks is within 2 keV of the standard library energy for the identified radionuclide. The reviewer will verify that the net peak areas and associated uncertainties have been obtained for all TRL radionuclides not meeting the above criterion. The reviewer will check the energy spectra for any peaks that overlap or that have associated peaks that may interfere with the peak of the radionuclide of interest. When interfering radionuclides are present and can be corrected from associated peaks in the spectrum, the reviewer will check to see if the peak for the radionuclide of interest has been properly corrected.

For TRL radionuclides that are not detected in the computerized peak search, the net peak area results will be qualified as estimated (J) or unusable (R), depending on the conditions encountered.

Results for TRL radionuclide peaks will be qualified as unusable (R), nondetect (U), or estimated (J) if they are detected but fail to meet the positive identification criteria; the gamma energy spectrum contains interfering peaks that cannot be corrected; or the result includes interferences that could have been corrected but were not. The reviewer will use professional judgment in choosing the proper qualifier dependent on the magnitude of the potential interference relative to project objectives and, in the case of an improper choice of peaks, whether a peak meeting positive identification criteria is present.

Results for TRL radionuclide peaks will be qualified as estimated (J) or unusable (R) if improper quantitation methods were used and the results were not recalculated.

If any discrepancies are found, the reviewer will contact the laboratory to obtain additional information. If a discrepancy remains unresolved, the reviewer will use professional judgment to decide which value is the best value and whether data qualification is warranted.

Tentatively Identified Radionuclides (gamma spectroscopy)

Gamma spectra peaks in radionuclide analyses that are not TRL isotopes are potentially attributable to tentatively identified radionuclides (TIRs). If required by the end use of the data, TIRs shall be qualitatively identified by a radionuclide spectrum library computer search and the identification assessed by the data reviewer. If TIR data are present, the results will be evaluated.

For all samples and blanks, the reviewer will verify that the laboratory has generated a computer library search for all significant peaks (greater than 3 standard deviations of the background activity) in the spectrum not attributable to TRLs.

To be identified as a TIR, the following criteria shall be met:

- Fifty percent of total abundance of all gamma peaks listed in the library spectrum must be present in the sample spectrum.
- The sampling to counting (analysis) time must not be greater than ten half-lives of the identified radionuclide.

The reviewer will examine all gamma peaks in every sample and blank spectra and verify that the TIR peaks present in samples are not found in the blank. The reviewer will check that expected radionuclides are present. Professional judgment will be used in evaluating TIR results and evaluating the need for qualification, however, some qualification guidelines follow:

- All TIR results without supporting data will be qualified as tentatively identified with an estimated concentration (NJ).
- All TIR result without quantitation will be qualified as tentatively identified (N).

- A TIR result will be qualified as unusable (R) if the identification is determined to be unacceptable, a common laboratory artifact, or attributable to the laboratory blank (comparable concentration to blank).

Compound Identification (non-radiological parameters)

For 10% of the results reported in the data packages under going an evaluation of laboratory performance parameters, the reviewer will verify that results positively identified meet all identification acceptance criteria as specified in the analytical method. In addition, the reviewer will examine the data for false negative results.

For organics, this may encompass comparing retention times against retention time windows, evaluating the agreement between dual column confirmation results, comparing relative retention times (RRTs) for samples to RRTs for standards, and comparison of mass spectral data to reference spectra, depending on the analytical technique employed (note: this listing is not all inclusive).

For inorganic methods, compound identification is generally not reviewable from the data packages. However, for some methods, there are items the reviewer can check such as comparing the %RSDs for replicate measurements to a method specific criterion and that target analytes elute in the proper order and expected retention time.

Any problems with compound identification will be noted in the associated data validation report. The reviewer may qualify associated results as tentatively identified (N), estimated (J), or unusable (R) using guidance from the Functional Guidelines and professional judgment in assigning any data qualification.

Target Analyte Quantitation (non-radiological parameters)

The reviewer will verify that reported sample concentrations can be recalculated from the raw data for 10% of the reported sample results in the data packages under going an evaluation of laboratory performance parameters. The reviewer will verify that reported results were calculated using the proper signal response for the sample, calibration factor or relative response factor, internal standard response, dilution factor, internal standard concentration or mass, percent solids, sample weights or volumes, final extract volume, etc. as applicable to the analytical method.

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 the all revised and all superseded data accordingly.

In some cases, multiple analyses for the same sample may be reported. The multiple analyses may be due to high target analyte concentrations that necessitate dilutions, interferences, or QC failures (e.g. low surrogate recoveries). When there is more than one set of data reported for a sample, the reviewer will need to select the best set of data to report based on all of the supporting QC information. This may involve selecting results from each of the multiple analyses. The data review narrative will detail the results selected for reporting and the supporting rationale. The data sheets will be marked to indicate which results were selected for reporting and which were not.

Method-Specific QC Checks (non-radiological parameters)

The supporting QC data will be reviewed to evaluate if the method-specific QC checks were conducted and whether the method-specified acceptance criteria were met. The table below summarizes the method specific QC checks typical of each analytical technique. The reviewer will consult the analytical method for evaluation criteria used to evaluate method-specific QC checks. The reviewer will consult the Functional Guidelines for guidance on issuing data qualification.

QC Check	ICP-ES	ICP-MS	Wet Chemistry	GC	GC/MS	HPLC
Tuning		✓			✓	
Interference Check Sample	✓	✓				
Thermal Stability		✓				
Spectral Resolution		✓			✓	
Mass Calibration		✓			✓	
Chromatography			✓	✓	✓	✓

ICP-ES = Inductively coupled plasma atomic emission spectroscopy.
ICP-MS = Inductively coupled plasma mass spectroscopy.
GC = Gas chromatography.
GC/MS = Gas chromatography mass spectroscopy.
HPLC = High pressure liquid chromatography.

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
- Method-specific QC samples (inorganic analytes)
  - Post-digestion spike recovery
  - Serial dilution test
  - Internal standards
  - Anion/cation balance
- Method-specific QC samples (organic analytes)
  - Surrogate compound recovery
  - Internal standards

- 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.

Case Narrative Comments

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 affect 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, which ever 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).

For non-radiological parameters, the results for method blanks and calibration blanks will be reviewed. Sample results for analytes detected in an associated blank at concentrations <5x the equivalent blank concentration will be qualified as nondetect (U). For the common organic laboratory contaminants (i.e., acetone, methylene chloride, 2-butanone, cyclohexane, and phthalates), sample results <10x the concentration in the associated blank will be qualified as nondetect (U). The result will be qualified as nondetect at the reported concentration if the reported concentration is greater than the reporting limit (>RL) or as nondetect (U) at the reporting limit if the reported concentration is <RL. Method blanks are associated with the samples in the sample preparation/extraction batch. Continuing calibration blank samples are considered to be associated with all samples analyzed in the analytical run and the highest concentration will be used for qualification.

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).

For non-radiological parameters, the matrix spike recoveries are compared to the laboratory's statistically-derived acceptance ranges for instances in which the native sample concentration is less than four times the spike level. When sample concentrations of an analyte are ≥ four times the spiking concentration, the results are considered to be inappropriate for assessing accuracy. The reviewer should also be aware that a matrix spike recovery may be outside acceptance limits when the parent sample was quantified by method of standard additions but the matrix spike was not. In such a case, the matrix spike recovery is not an appropriate measure of accuracy. Data associated with matrix spike recoveries that are outside the acceptance range will be qualified as follows using guidance from Functional Guidelines.

- If the recovery of an inorganic matrix spike analyte exceeds the upper limit of the acceptance range, suggesting a potential high bias in sample results, positive results for that target analyte in all associated samples are qualified as estimated (J); whereas, nondetect results for that analyte are considered to be acceptable for use without qualification.

- If the recovery of an inorganic matrix spike analyte is below the lower limit of the acceptance range, but ≥30% (≥10% for organics), suggesting a potential low bias in sample results, both positive and nondetect results for that analyte in all associated samples for inorganic methods or only the parent sample for organics methods are qualified as estimated (J/UJ).

- If the matrix spike recovery for an inorganic analyte was <30% (<10% for organics), nondetect results are qualified as unusable (R) and positive results are qualified as estimated (J) per Functional Guidelines guidance.

If a matrix spike duplicate is also prepared, the reviewer shall use professional judgment and consider the recoveries for both the matrix spike sample and the matrix spike duplicate sample prior to assigning data qualifiers for inorganic data. All instances in which professional judgment is used to assign data qualifiers will be detailed in the individual data review narratives.

The reviewer should note that for organic data, no qualification of associated samples in the batch or data package will be performed on the basis of matrix spike recoveries alone. The data reviewer should use professional judgment and consider the results of other QC measures such as surrogate recoveries in conjunction with MS/MSD results to determine the need for extending qualification for the affected analytes to the other associated samples.

If the field blank was used for the matrix spike analysis, all other QC data will be carefully checked and professional judgment exercised to evaluate the data.

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.

For non-radiological parameters, the duplicate and spike duplicate sample analysis results are used to evaluate the precision of the laboratory analyses. Laboratory duplicate or spike duplicate results are evaluated using concentration dependent evaluation criteria.

- When both results are > 5x RL, compare the relative percent difference (RPD) between the sample results to a criterion of ≤20% for aqueous samples and ≤35% for soil and sediment samples.
- If either sample concentration is ≤ 5x RL, compare the absolute difference between the results to a criterion of ≤1x the greater RL for aqueous samples and ≤2x the greater RL for soil and sediment samples.

All evaluations are done using the higher RL and the RL is used in calculating the absolute difference for a nondetect result. If the applicable duplicate evaluation criterion is not met for an analyte, all associated sample data for that analyte will be qualified as estimated (J/UJ).

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.

For non-radiological parameters, analytical results obtained for field duplicate sample pairs are compared to each other using the concentration dependent criteria described below.

- When both the sample and duplicate values are >5xRL, acceptable sampling and analytical precision is indicated by an RPD between the results of ≤30% (≤50% for soil samples).
- Where the result for one or both analytes of the field duplicate pair is <5xRL, satisfactory precision is indicated if the absolute difference between the field duplicate results is <2xRL (<3.5xRL for soil samples).

- All evaluations are done using the higher RL and the RL is used for calculating the absolute difference for nondetect results. If the above criteria are not met for an analyte, all associated sample data for that analyte should be qualified as estimated (J/UJ).

Rinsate Blank Results

The results for rinsate blanks reported in the data package will be reviewed. Sample results for analytes detected in an associated rinsate 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.

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. For organic methods, method specific QC measures may include surrogate compound recovery and internal standard performance. Evaluation procedures for each of these method-specific QC measures are described below.

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 five fold-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).

Cation/Anion Balance

Because water is generally electrically neutral, the sum of the dissolved cation concentrations (expressed in milliequivalents per liter) should equal the sum of the dissolved anion concentrations. For projects in which the major cations and anions are being analyzed, the data reviewer may evaluate whether there is an acceptable balance between anion concentrations and cation concentrations. It should be noted that both major cations and anions must be analyzed to complete the anion/cation balance. In accordance with Standard Methods 1030F, the equation used to calculate anion-cation balances is:

$$\boxed{PercentDifference = 100 * \frac{\sum Cations - \sum Anions}{\sum Cations + \sum Anions}}$$

Laboratory accuracy control limits for these types of analytes are typically ±30%. This level of accuracy is considered to be fully acceptable in meeting the end use objectives of groundwater monitoring. A 30% bias in the metals analysis corresponds to an anion-cation balance percent difference of approximately 13%. Therefore, since a 30% bias is not considered to adversely affect the usability of the data, an evaluation criterion of a percent difference less than ± 13% will be used for anion-cation balance evaluation. If the anion/cation balance is greater than ±13% the data reviewer should use professional judgment to discern likely causes of the imbalance and need for qualification of data.

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 (for semivolatile organics by GC/MS, two or more surrogates in either fraction must be high), 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% (for semivolatile organics by GC/MS, two or more surrogates in either fraction are out with at least one of them being less than the lower 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 that 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.

Internal Standards (organic methods)

The analytical method will be used to determine the QC acceptance criteria for internal standard area counts for GC/MS organic analysis. Internal standard area counts are not a direct measure of the accuracy of the analysis. Low internal standard area counts for sample analysis relative to those observed in the associated continuing calibration analysis may be indicative of low extraction or purging efficiency which decreases the analysis sensitivity (raises the detection limit).

High internal standard area counts may be indicative of co-eluting interferences at the retention time of the internal standard in the sample, may be caused by a drift in detector sensitivity, or may be caused by injection of a different amount of sample extract. Co-eluting interferences to the internal standard may result in a low bias in reported results quantified by the given internal standard. Injection of a larger volume of extract would result in increased sensitivity of the analysis (lowered detection limit).

- If data validation indicates that internal standard area counts are below the lower acceptance limit, then results reported as not-detected shall be qualified as estimated (UJ) and results reported as detected will not require qualification since the calculation corrects for reduced extraction efficiency.

- If data validation indicates that internal standard area counts are above the upper acceptance limit, then results reported as detected or as not-detected shall be qualified as estimated (J/UJ).

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 of the 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 with regard to 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 Tables 13 and 14 for radiological and non-radiological analytes, respectively.

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

Laboratory Performance Criteria	Criterion	Qualification
Calibration	Per method requirements	Results for affected analytes will be qualified as estimated (J or UJ) or unusable (R) depending on the severity of the problem.
LCS	Per laboratory's current statistically determined acceptance ranges	Results for affected analytes may be qualified as estimated (J or UJ) or unusable (R) depending on the severity of the problem. See Section 9.2.1 for specific qualification guidance.
Compound Identification	Criteria specified in Section 9.2.1	Professional judgment; Section 9.2.1 provides guidance.
Compound Quantification	Criteria specified in Section 9.2.1	Professional judgment; Section 9.2.1 provides guidance.
Method-specific QC checks	per method requirements	Professional judgment and functional guidelines.
Sample Specific Criteria	**Criterion**	**Qualification**
Holding Time	Holding times are presented in Table 7	Associated samples results will be qualified as estimated (J/UJ); if gross exceedances, reviewer may use professional judgment and qualify results as unusable (R).
Method Blanks	Blank < RL	Section 9.2.1 provides guidance for qualification on the basis of various types of blanks. In general, sample results <5x (<10x for common lab contaminants) the concentration in an associated blank will qualified as nondetect (U).
Matrix Spike Samples (as applicable to the method)	Per Laboratory's current statistically determined acceptance ranges	Associated results may be qualified as estimated (J or UJ) or unsuable depending on the recoveries obtained and other factors. Section 9.2.1 provides guidance.
Duplicate Analysis (method duplicate or spike duplicate)	Both results >RL; RPD≤ 20% for aqueous samples and ≤35% for solid samples. Either result <RL; absolute difference ≤1xRL for aqueous samples and ≤2xRL for solid samples.	Section 9.2.1 provides guidance regarding use of these concentration-dependent evaluation criteria. Results for affected analytes will be qualified as estimated (J or UJ)
Field Duplicate	Both results >RL; RPD≤ 30% for aqueous samples and ≤50% for solid samples. Either result <RL; Abs. Diff ≤2xRL for aqueous samples and ≤3.5xRL for solid samples.	Section 9.2.1 provides guidance regarding use of these concentration-dependent evaluation criteria. Results for affected analytes will be qualified as estimated (J and/or UJ).
Rinsate Blanks, Field Blanks, and Trip Blanks	Blank < RL	Section 9.2.1 provides guidance for qualification based on various blanks. In general, sample results <5x (<10x for common lab contaminants) the concentration in an associated blank will qualified as nondetect (U).
Method Specific QC-Inorganics (PDS, serial dilution, internal standards, charge balance)	Per method requirements and criteria specified in Section 9.2.1	Section 9.2.1 provides guidance for qualification on the basis of various method-specific QC analyses. Results for affected analytes may be qualified as estimated (J or UJ) or unusable (R) depending on the severity of the problem.
Method Specific QC-Organics (surrogate compound recovery, internal standards)	Per method requirements and criteria specified in Section 9.2.1	Section 9.2.1 provides guidance for qualification on the basis of various types of method-specific QC analyses. Results for affected analytes may be qualified as estimated (J or UJ) or unusable (R) depending o9n the severity of the problem.
Balance of Total to Partial Analyses	±30% (Aqueous) ±50% (Solid)	Qualify the total and partial analytical results as estimated (J/UJ).

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APPENDIX A

TIER I RADIOLOGICAL INCIDENT MANAGEMENT PLAN

Appendix A

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

Revision 3

Prepared for:

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July 31, 2010

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1 Introduction

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.

1.1 Rulison Site Background

The Rulison test site is located on the north flank of Battlement Mesa, about 12 miles southwest of the town of Rifle and 8 miles southeast of the town of Parachute. Project Rulison is a site where, in 1969, the Atomic Energy Commission (AEC) under the Plowshare Program detonated a 43 (± 8)-kiloton nuclear fission device 8,426 feet below ground surface in device emplacement well R-E in an attempt to release commercially marketable quantities of natural gas (U.S. Department of Energy [DOE] 2005). The Plowshare Program was a joint industry-government partnership designed to demonstrate the peaceful use of nuclear devices.

The principal radionuclides in the approximately 78-foot by 275-foot radius chimney created by the nuclear blast are thought to be mixed radioactive fission products, plutonium, uranium, and gaseous radionuclides (^{3}H, ^{14}C, and ^{85}Kr [Smith, Esser, and Thompson 1995]). Gaseous radionuclides ^{14}C, ^{85}Kr, and ^{3}H are likely to be the most mobile in the environment, as the radioactive fission products (^{90}Sr and ^{137}Cs) and fissile materials (plutonium and uranium) are mostly bound to the slag formed in the cavity as the melted rock materials cooled. However, the more mobile gaseous radionuclides are likely no longer present in appreciable quantities in the cavity because a significant fraction of the radioactive gases present in the chimney were vented during re-entry drilling and gas flow production tests in 1970 and 1971 (DOE 2007). Of these gases, ^{3}H is the most likely gaseous radionuclide that may remain in the cavity that could potentially migrate with the natural gas (DOE 2007).

Since the Project Rulison test, the DOE has prohibited subsurface drilling for any purpose within a 40-acre area, known as Lot 11, surrounding the former test site. Radiation activities above background have not been detected outside of Lot 11 on the surface or in the subsurface. The surface facilities and contaminated surface soils at Project Rulison were subsequently removed or remediated by the AEC and DOE (AEC 1973; DOE 2005). Numerous

DOE studies of the test site, including numerical modeling of tritium transport (DOE 2007; Cooper et al. 2009), have predicted that significant migration of ^{3}H or any other Project Rulison-related radionuclide is not expected to occur in the subsurface beyond the Lot 11 boundary.

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.

1.2 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. Attachment A-2 provides a description of the U. S. Department of Energy’s Radiological Assistance Program (DOE RAP).

2 Radiological Incident Mitigation

2.1 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). Real-time radiation monitoring will be conducted at the closest designated Tier I well to measure radiation in drilling fluid returns so that any elevated radiation levels of concern will be immediately detected and appropriate responses taken. Otherwise, radiologically-contaminated materials will not be stored at the surface, so they are very unlikely to be affected by natural or man-made events.

2.2 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.

2.3 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.

3 Radiological Incident Preparedness and Response

3.1 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.

3.2 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.

3.3 Site Safety and Radiation Safety Officer

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.

3.4 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 (6 CCR 1007-1 Part 4.17.2).

3.5 Recognizing a Potential Radiological Incident

There are over 30,000 active oil and gas wells in Colorado. Generally, gas and oil drilling and production operations are conducted without incident. However, incidents do occasionally occur, and the 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.

3.5.1 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), DOE Radiological Assistance Program (RAP) office in Idaho Falls, Idaho (Table A-3 and Attachment A-2), 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.

3.5.2 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.

3.5.3 Elevated Readings on the Continuous Gamma Radiation Monitor

Continuous gamma radiation measurements will be conducted at the drill cutting and fluid returns outfall (e.g., shale shaker) during drilling of the **closest designated** Tier I well within each monitoring sector to screen for Project Rulison-related radionuclides (e.g., gamma emitting ^{137}Cs). These measurements will be routed electronically to the drilling control station, where possible, so that an alarm system will notify the driller of radiation levels above the screening or action levels (i.e., background +2 or +3 standard deviations, respectively; see RSAP Section 4.1.1). If an alarm is triggered on the continuous gamma radiation-monitoring system, drilling will be suspended and all work will temporarily stop until the source of the radiation is verified or the site is confirmed to be safe. Note it is possible that a false gamma radiation alarm may occur during well logging. Well logging involves the use of a radioactive source in the logging tool which can be detected by the gamma radiation monitoring equipment used during drilling of Tier I gas wells causing a momentary increase in radiation and an alarm. The alarm can be triggered when the tool is either lowered into or removed from the gas well during the logging operation.

To confirm a positive radiation measurement above the screening or action levels, the SSO, or designated representative, will contact the RSO, or alternate RSO, for further 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.

3.6 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).

3.7 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.

3.8 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).

3.9 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.

3.10 Radiological Equipment Calibration and Testing

3.10.1 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 4.1.1):

- Canberra TAM 100D portable tritium monitor, or equivalent, for real-time tritium monitoring
- Ludlum Model 375 area monitor equipped with a Model 44-10 2 x 2 inch NaI(Tl) gamma scintillator, or equivalent, for real-time gamma radiation monitoring
- Berkley Nucleonics 1035 AreaSAM gamma spectrometer system, or equivalent for real-time gamma radiation monitoring and isotope identification
- 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

- Quantum Products Instadose™ dosimeters or Mirion Technologies DMC 2000XB electronic dosimeters, or equivalent
- Check source(s) for performance testing the alpha, beta, and gamma radiation monitoring instruments
- Bioscan Triathler liquid scintillation counter (LSC) and supplies.

These instruments are not required at Tier II drilling sites.

3.10.2 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 (6 CCR 1007-1 Part 4.17.2). Calibration will be performed in accordance with industry standard procedures. The Bioscan Triathler LSC is not routinely returned to the manufacturer for calibration. Its calibration is accomplished during operation of the LSC using a working standard source packaged as a liquid scintillation sample. Similarly, the Berkley Nucleonics 1035 AreaSAM gamma spectrometer system is not routinely returned to the manufacturer for calibration as it contains an internal ^{40}K standard for calibration at startup.

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.

Radiological emergency response instruments (e.g., hand-held radiation screening instruments and the Bioscan Triathler LSC) will be practiced once each quarter when the instruments are deployed to ensure that the operator is familiar with the operation and use of the instruments in the event of an emergency. During these practice sessions, the operator will also verify that the instruments have been annually calibrated (if required) and that the analytical media (e.g., LSC cocktail, working standards) have not expired. Documentation of the instrument practice sessions will be maintained in the project files.

3.11 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).

3.11.1 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.

3.11.2 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

3.12 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.

4 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.

5 References

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Lessard, E. T., X. Yihau, K. W. Skrable; G. E. Chabot, C. S. French, J. R. Johnson, D. R. Fisher, R. Belanger, J Landmann Lipsztein. 1987. Interpretation of Bioassay Measurements, U. S. Nuclear Regulatory Commission, NUREG/CR-4884, July, 928 pp.

Smith, D. K., B. K. Esser, and J. L. Thompson. 1995. Uncertainties associated with the definition of a Hydrologic Source Term for the Nevada Test Site, UCRL-ID-120322, May 21 pp.

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U.S. Atomic Energy Commission (AEC). 1973. Project Rulison Manager's Report, Nevada Operations Office, Las Vegas, Nevada, NVO-71, April, 247 pp.

U.S. Department of Energy. 2005. Final Rulison Site Environmental Management End State Vision, DOE/NV-950, January, 31 pp.

U.S. Department of Energy. 2007. Tritium Transport at the Rulison Site, a Nuclear-Stimulated Low-Permeability Natural Gas Reservoir, Publication No.45224, DOE/NV/13609-54, DOE-LM/1522-2007, September, 102 pp.

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

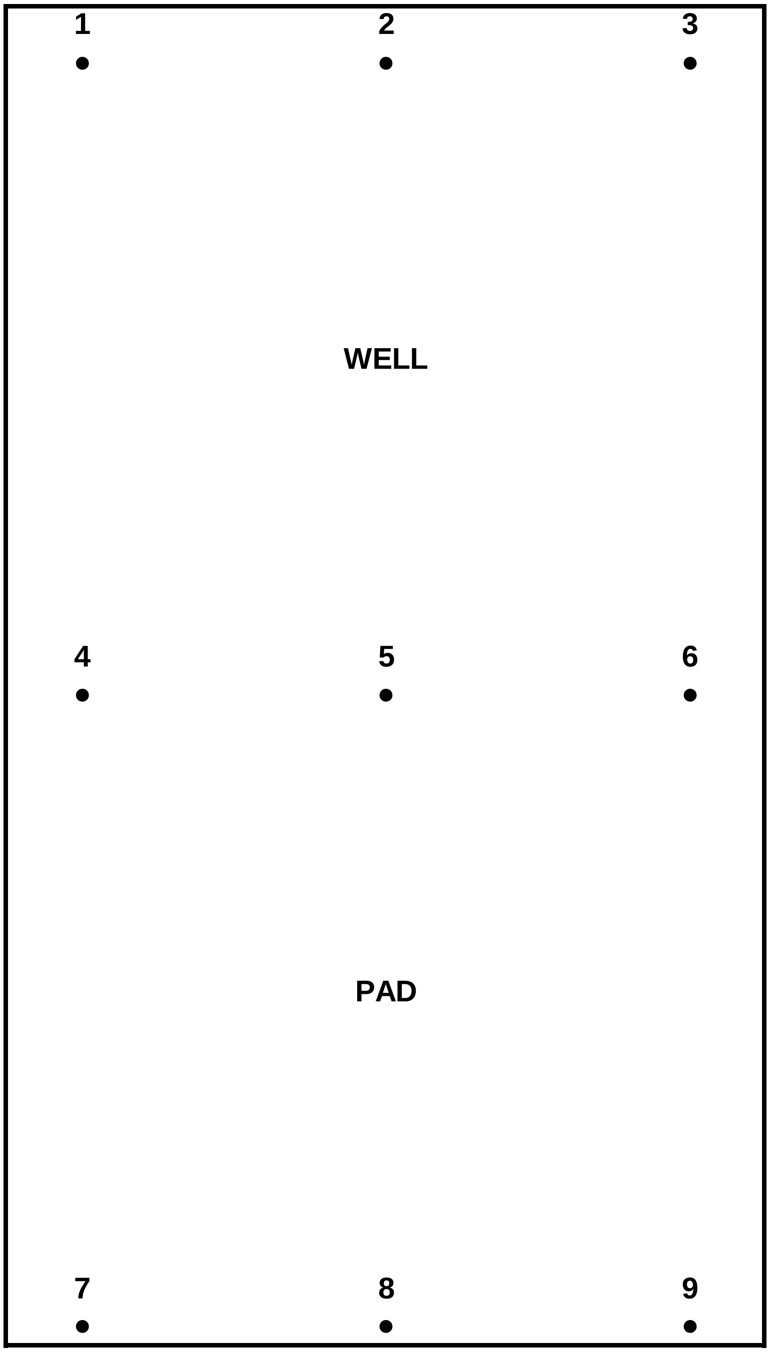

Table A-1
Action Levels for Tier I Radiation Monitoring

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[1] 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.

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[1] 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

Contact	Phone Number
URS Radiation Safety Officer (RSO) Larry Luckett, CHP	(210) 481-5338 (o) (210) 872-3812 (c)
URS Project Manager/Alternate RSO Richard Henry, PG	(303) 740-3978 (o) (303) 994-1747 (c)
Noble Energy, Inc. - Environmental Coordinator - Rockies Chris Del Hierro	(303) 228-4160 (o) (303) 990-0757 (c)
Noble Energy, Inc. - Piceance Asset Manager Jon Bowman	(303) 228-4112 (o) (303) 550-8426 (c)
Noble Energy, Inc. - Piceance District Manager Mike Bonkiewicz	(970) 625-1494 (o) (970) 381-5250 (c)
Noble Energy, Inc. - Northern Region Drilling Manager David Hobbs	(303) 228-4057 (o) (303) 328-8673 (c)
Noble Energy, Inc. - Drilling Superintendent Randy Cates	(970) 778-4966 (o) (573) 429-3094 (c)
Noble Energy, Inc. - Drilling Engineer Tom Rodriquez	(303) 228-4270 (o) (303) 378-5197 (c)
Noble Energy, Inc. - Environmental Specialist - Piceance Brandon Danforth	(970) 625-1494 (o) (970) 420-5184 (c)
Noble Energy, Inc. - Safety Coordinator – Onsite Safety Inc. Royce Bradford	(970) 876-1908 (o) (970) 309-9725 (c)
EnCana Oil & Gas (USA) Inc. – Group Lead South Rockies EH&S Brant Gimmeson	(720) 876-5030 (o) (303) 819-7323 (c)
EnCana Oil & Gas (USA) Inc. – EHS Field Coordinator Brett Middleton	(970) 285-2739 (o) (970) 987-4650 (c)
EnCana Oil & Gas (USA) Inc. – Drilling John Grubich	970) 285-2631 (o) (970) 379-6735 (c)
EnCana Oil & Gas (USA) Inc. – Completion Mark Balderston	(970) 285-2692 (o) (970) 629-5846 (c)
EnCana Oil & Gas (USA) Inc. – Production David Grisso	970) 285-2601 (o) 970) 250-9660 (c)
Williams Production RMT - Manager, EH&S Mike Paules	(303) 606-4396 (o) (303) 638-7385 (c)
Williams Production RMT - Rulison Environmental Lead Gretchen Kohler, PG	(303) 260-4531 (o) (303) 217-0534 (c)
Williams Production RMT - Safety Team Lead Kevin McDermott	(970) 285-2294 (o) (970) 309-1195 (c)
Williams Production RMT - Drilling and Completions Scott Brady	(970) 683-2284 (o) (970) 270-9187 (c)

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) 625-1510
Battlement Mesa Medical Center 73 Sipprelle Drive, Parachute, CO	(970) 285-7046
Colorado Department of Public Health and Environment Radiation Control Division	(303) 692-3300 (o) (877) 518-5608 (after hours)
Colorado Department of Public Health and Environment Radiation Control Division	(303) 877-9757 (24-Hour Radiation Incident)
Colorado Oil and Gas Conservation Commission	(303) 894-2100 (o) (888) 235-1101 (o)
Alex Fischer, PG Colorado Oil and Gas Conservation Commission	(303) 894-2100 x5138 (o)
Chris Canfield, PG Colorado Oil and Gas Conservation Commission	(970) 625-2497 x3 (o) (970) 216-6832 (c)
David Andrews, PE, PG Colorado Oil and Gas Conservation Commission	(970) 625-2497 x1 (o) (970) 456-5262 (c)
David A. Blair, Fire Chief Grand Valley Fire Protection District	(970) 285-9119 (o) (970) 250-9851 (c)
Chris Bornholt, Emergency Operations Commander Garfield County Sheriff and Emergency Management	(970) 945-0453 (o)
U.S. Department of Energy Office of Legacy Management Grand Junction, Colorado	(970) 248-6070 (o)
U. S. Department of Energy Radiological Assistance Program Idaho Falls, Idaho	(208) 526-1515 (o)

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 sudsing.

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

Attachment A-2

U. S. Department of Energy Radiological Assistance Program

U.S. DEPARTMENT OF ENERGY

NATIONAL NUCLEAR SECURITY ADMINISTRATION

RADIOLOGICAL ASSISTANCE PROGRAM (RAP)

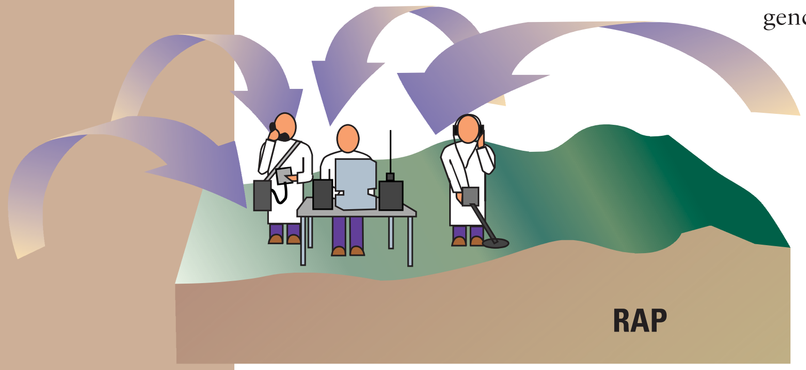
RESPOND ASSESS ADVISE

The Department of Energy's (DOE) National Nuclear Security Administration (NNSA) has the world's leading scientists, engineers and technicians from over 50 years of managing the nation's nuclear weapons program. When the need arises, DOE is prepared to respond immediately to any type of radiological accident or incident anywhere in the world with the following seven radiological emergency response assets.

AMS (Aerial Measuring System) detects, measures and tracks radioactive material at an emergency to determine contamination levels. **ARAC** (Atmospheric Release Advisory Capability) develops predictive plots generated by sophisticated computer models. **ARG** (Accident Response Group) is deployed to manage or support the successful resolution of a U.S. nuclear weapons accident anywhere in the world. **FRMAC** (Federal Radiological Monitoring and Assessment Center) coordinates Federal radiological monitoring and assessment activities with those of state and local agencies. **NEST** (Nuclear Emergency Support Team) provides the nation's specialized technical expertise to the Federal response in resolving nuclear/radiological terrorist incidents. **RAP (Radiological Assistance Program)** is usually the first NNSA responder for assessing the emergency situation and deciding what further steps should be taken to minimize the hazards of a radiological emergency. **REAC/TS** (Radiation Emergency Assistance Center/Training Site) provides treatment and medical consultation for injuries resulting from radiation exposure and contamination, as well as serving as a training facility.

INTRODUCTION

The Radiological Assistance Program (RAP), established in the late 1950's, is one of the emergency response resources, or assets, administered by NNSA. RAP is NNSA's first-responding resource in assessing the emergency situation and advising decision-makers on what further steps could be taken to evaluate and minimize the hazards of a radiological emergency. Specific areas of expertise include assessment, area monitoring, and air sampling, exposure and contamination control.



MISSION

The RAP mission is to provide a flexible, around the clock response capability to Federal agencies, state, Tribal, and local governments, and to private businesses or individuals for incidents involving radiological materials. RAP provides around the clock response capability to radiological emergencies.

CAPABILITIES

RAP is capable of providing assistance in all types of radiological incidents. Requests for assistance may relate to facility or transportation accidents involving radiation or radioactive material. The accident may involve fire, personal injury, contamination, and real or potential hazards to the public. RAP's support ranges from giving technical information or advice over the telephone to sending highly trained people and state-of-the-art equipment to the accident site to help identify and minimize any radiological hazards.

RAP is implemented on a regional basis and has eight Regional Coordinating Offices (RCOs) in the U.S. The eight RAP regional offices (Regions 1 through 8, respectively) are: Brookhaven, NY; Oak Ridge, TN; Savannah River, SC; Albuquerque, NM; Chicago, IL; Idaho Falls, ID; Oakland, CA; and Richland, WA. RAP teams from one region can integrate into and assist RAP teams from other regions. Each RCO has a minimum of three RAP teams. A full RAP team consists of seven members: a team leader, a team captain, four health physics support personnel, and a public information officer. RAP teams may deploy with two or more members; one member is the DOE team leader.

Survey equipment is used to detect and measure radiation.

STEPS IN THE RAP EMERGENCY RESPONSE

If an emergency occurs, RAP team members normally arrive at the scene within four to six hours after notification and conduct the initial radiological assessment of the area. A RAP response is tailored based on the scale of the event and additional RAP teams and resources can be deployed as necessary. RAP team members are trained in the hazards of radiation and radioactive materials to provide initial assistance to minimize immediate radiation risks to people, property, and the environment. RAP may utilize other NNSA assets, such as AMS, ARAC, or REAC/TS in their response. RAP is able to quickly assess the affected area and advise decision-makers on what actions to take and determine if additional resources are necessary to manage the emergency.

respond
assess
advise

ABOUT THE EQUIPMENT

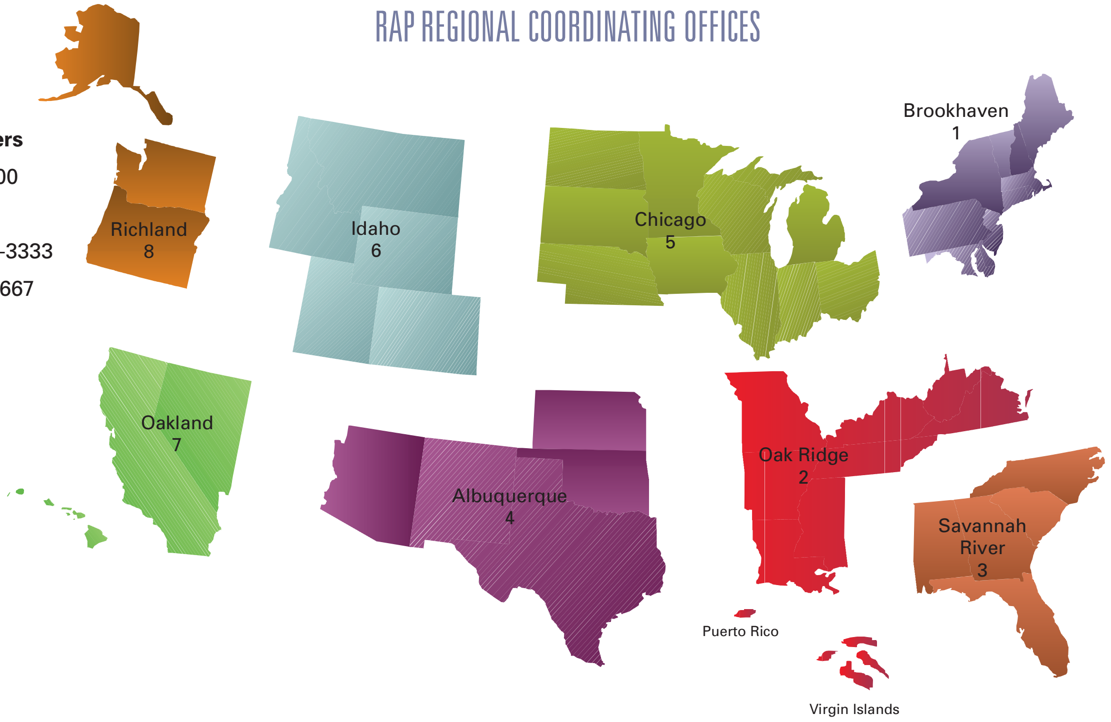
RAP's highly trained teams have access to the most advanced radiation detection and protection equipment available. The RAP teams' capabilities and resources include portable field radiation monitoring instrumentation (alpha, beta, gamma, and neutron), generators, mobile laboratories, air sampling and decontamination equipment. Communications and personnel protective equipment and supplies are also available to support the response.

U.S. DEPARTMENT OF ENERGY

NATIONAL NUCLEAR SECURITY ADMINISTRATION

RAP

RAP REGIONAL COORDINATING OFFICES



Regional Offices — 24 hour numbers

1. Brookhaven, NY — (631) 344-2200
2. Oak Ridge, TN — (865) 576-1005
3. Savannah River, SC — (803) 725-3333
4. Albuquerque, NM — (505) 845-4667
5. Chicago, IL — (630) 252-4800
6. Idaho Falls, ID — (208) 526-1515
7. Oakland, CA — (925) 422-8951
8. Richland, WA — (509) 373-3800

Headquarters — (202) 586-8100

WHEN THE JOB IS DONE

RAP's mission is complete when the need for assistance ends or when there are other resources (state, local, Tribal, or commercial services) able to handle the situation. The primary responsibility for an emergency involving radioactive materials remains with the party responsible for the material. Assistance provided by RAP teams does not preempt state, Tribal, or local authority.

OTHER RAP ACTIVITIES

In addition to providing radiological emergency assistance, RAP can provide emergency response training to state and local first responders, upon request. Since 1996, RAP has been involved in the Weapons of Mass Destruction First Responder Training Program with the objective of preparing the United States for responding to a terrorist attack involving nuclear, biological or chemical weapons of mass destruction. RAP's unique qualifications make it an integral partner in the success of the Domestic Preparedness Program.

For more information, contact:
Office of Emergency Response
U.S. Department of Energy
19901 Germantown Road
Germantown, MD 20874
301-903-3558

PARTNERS IN Emergency RESPONSE

APPENDIX B

URS SAFE WORK PLAN

Appendix B
URS Safe Work Plan
Rulison Sampling and Analysis Plan

Project:	Project Rulison Test Site Area	Project Number:	Various
Work Location:	Battlement Mesa, Colorado	Date:	July 31, 2010

Scope of Work Task Description: URS personnel will perform sampling and monitoring for radiation during drilling, completion, and production activities. Sampling of natural gas and produced water at producing gas wells will only be accomplished with the assistance of an Energy Company representative. Refer to the Rulison Sampling and Analysis Plan for details regarding the scope of work. This project is being conducted in the vicinity of a former nuclear test site called Project Rulison; however, based on monitoring performed to date, URS does not anticipate elevated radiation levels.

Emergency Response Information

Contact	Phone Numbers
Project Manager - Richard Henry	(303) 740-3978 or (303) 994-1747
Health and Safety Manager – Sally Miller Regional H&S Manager – Tim Joseph Radiation Safety Officer – Larry Luckett	(303) 740-2721 or (720) 320-1814 (303) 740-2767 or (303) 884-2548 (210) 481-5338 or (210) 872-3812
URS Nurse – Jeanette Schrimsher (Incident Reporting)	(866) 326-7321 (24-hour)
Emergency	911
Nearest Hospital (map with directions attached)	Grand River Medical Clinic at Battlement Mesa Parachute, Colorado 970-285-7046
Other Hospital (map with directions attached)	Grand Valley Hospital and Medical Center Rifle, Colorado 970-625-1510
Additional Information	See Appendix A in RSAP

☐ URS Safety Management Standards are attached. Note: Safety Management Standards are available from The SoURSe and at www.urshse.com (username = urshse, password = hardhat).

X Job-specific activity hazard analyses are attached.

X Employees have completed required field safety training.

Completed By:	Tim Joseph, CIH	Date:	July 31, 2010
PM Review:	Richard Henry, PG	Date:	July 31, 2010
H&S concurrence:	Tim Joseph, CIH	Date:	July 31, 2010
RSO Concurrence:	Larry Luckett, CHP	Date:	July 31, 2010

Site-Specific Hazards and Controls	
Potential Hazards	**Controls**
Working near drilling operations	• Oil field rigs are very dangerous work environments with multiple hazards • Specific significant hazards include pressurized lines, cranes and pulleys, falls, cable spools, drill rod piles, engulfment by sand/soil and large moving mechanical parts • Hard hat, safety glasses and steel toe boots are always required • **Fire retardant clothing (FRC) is required at well site** • Stay clear of all work activities whenever possible • Notify the drill crews when you will be entering their work areas
Driving to the drill site	• The road to this location is hazardous use caution when traveling to and from the site • Wet conditions will make the road extremely slippery • Dust on windshields will make visibility difficult when the sun is at low angles • At some locations there are drop offs near the shoulder of the road • If the road becomes impassable, turn around and contact the Project Manager from a safe location • Check in and out with the Company man when arriving or leaving the site. Instruct the Company man to contact the Project Manager if URS personnel need assistance
Radiation	• Activities will be conducted within a few miles of a former nuclear test site called Project Rulison. Previous activities in this area have not identified significantly elevated radiation levels • As a precaution, URS will monitor for radiation using dosimeters, hand-held radiation survey meters, and real-time radiation monitoring equipment. Dosimeters will be analyzed after field work is completed • Radiation screening levels and required actions are provided in Appendix A Tier I Radiation Incident Management Plan, Table A-1 • If significantly elevated radiation levels are encountered, work will be stopped and a radiation control program will be implemented • Refer to SMS 52 *Radiation Protection Program*
Natural gas under pressure	• Natural gas samples will only be collected with the assistance of a Energy Company representative • Natural gas samples will be collected in cylinders supplied by the laboratory • Gas pressure may be up to 300 psig or higher • An Energy Company representative will manipulate all valves and equipment to release the gas sample • Use non-sparking (non-ferrous) tools when connecting the sampling equipment to the sampling line or port • Verify that all sample container fittings are tight and pressure ratings on the container are adequate prior to releasing gas • Wear safety glasses • Keep door(s) of separator building open for ventilation • Keep ignition sources out of the area • Refer to the MSDS for Natural Gas

Site-Specific Hazards and Controls	
Potential Hazards	**Controls**
Well field activities	• Watch out for large – fast moving vehicles • Large rocks can be tossed into the air by the tires of these large vehicles • When possible, keep a safe distance from drilling platforms and other activities • Make eye contact with equipment operators before approaching • Stay away from stacked drill rod, cable spools and pinch points • Hard hats, steel toe shoes, safety glasses, and fire retardant clothing (FRC) are required near any well field activities
Dangerous goods shipping	• The gas samples are considered flammable compressed gas cylinders for the purpose of shipping • The cylinders will require special packaging, marking, and shipping • Shipments must be prepared by an individual who has received DOT/IATA training in the past three years • Refer to shipping information provided by the laboratory • Do not transport the cylinders in the same compartment as people in a vehicle. Secure them in the back of a pick up truck • Refer to SMS 48 *Dangerous Goods Shipping*
General Physical Hazards and Controls	
Potential Hazards	**Controls**
All hazards	• Manage projects so that adequate time is allowed to complete tasks • Manage projects so that proper adequate equipment and supplies are available • Promote a positive safety attitude/culture • Employees must read this Safe Work Plan prior to work, and a copy must be available at the work site • Re-evaluate the Task Hazard Analysis **daily;** consider changes in weather conditions, work activities, and other site conditions • Conduct a **daily** safety briefing or tailgate meeting • Document that each employee has completed the appropriate safety training and medical surveillance prior to working in the field; at a minimum, 4-hour Field Safety training is required • Attend any safety briefings required by site operators • Look out for each other and provide safety feedback to co-workers to increase safe behavior
Aggressive individuals or potentially dangerous locations (e.g., high crime areas, deserted buildings, rough terrain)	• Get approval from property owners prior to access and see if the owner will accompany you • Work in teams of two or more • If you are alone maintain contact with someone at the office • Leave and/or contact help if you are threatened

Site-Specific Hazards and Controls	
Potential Hazards	**Controls**
Driving/vehicle safety	• Inspect vehicles prior to use, especially rental vehicles; know how to operate wipers, lights, etc. • Verify that equipment and supplies are secured (inside the cab as well as the truck bed) prior to vehicle movement • Understand and obey all local traffic rules • Wear seat belts and require passengers to wear seat belts • Don't speed, keep work site speeds below 15 mph unless posted otherwise • Don't drive for more than 8 hours in one day and do not work and drive for more than a total of 12 hours • Leave enough time to get to your destination without hurrying • When possible, avoid backing up, especially in parking lots • Park clear of traffic on right-of-ways; park vehicle between you and on-coming traffic • Wear high-visibility vests with reflective strips when working near vehicles • Refer to SMS 57 *Vehicle Safety Program* and SMS 32 *Work Zone Traffic Control*
Heat Stress	• Know the signs and symptoms of thermal stress • Use the buddy system during hot conditions • Have plenty of water available and stay hydrated • Take breaks in a cool/shaded area as appropriate • Wear sun screen • Refer to *SMS 18 Heat Stress*
Cold Stress	• Dress appropriately in layers • Stay dry • Take breaks in a warm area as necessary • Refer to SMS 59 *Cold Stress*
Remote locations	• Identify the best means of communication prior to leaving for the site • Ensure that your cell phone or radio is charged and working and that you understand how to use it • Take plenty of water and some energy food • Take a map, know how to describe your location • Work in teams of at least two when working away from vehicles or when communication with the office is not available • Refer to SMS 36 *Remote Travel Health and Safety* and SMS 84 *Lone Worker*
Lifting	• Minimize the movement of heavy objects, and use dollys or carts whenever possible • Stretch before lifting • Store heavy objects just below waist height • Get help to lift heavy objects and plan the lift • Bend at the knees; do not use your back • Do not twist during lifts • Refer to SMS 69 *Manual Material Handling*

Site-Specific Hazards and Controls	
Potential Hazards	**Controls**
Severe weather	• Identify shelters prior to start of work • Listen to radio for warnings • Discontinue work and seek shelter if severe weather is approaching • Secure equipment and watch for flying debris, doors slamming shut, etc. • Passenger vehicles with the windows rolled up provide good shelter during lightning • Stay out of low lying areas during heavy precipitation due to the potential for flash floods • Beware of the potential for high winds to move car doors, gates, and debris
Sharp objects	• Wear appropriate work boots and work gloves • Avoid handling site debris or placing hands where you can not see • Use caution when working with any tool • Watch out for barbed wire and electrical fences; cover with a car mat to cross, or walk around • Refer to SMS 64 *Hand Safety* and SMS 16 *Hand Tools and Portable Equipment*
Slips, trips, and falls	• Maintain good housekeeping; keep the work area free from debris • Survey the work area and mark dips, holes and other hazards • Avoid steep and uneven terrain; watch where you step • Wear sturdy boots with good tread • Be especially cautious if wet or icy conditions are present; remember that snow can hide icy surfaces • Take the time to find a safe route to the desired location • Do not perform any activity with a fall exposure of 6 feet or more without using fall protection. Consult the Health and Safety Manager. • Refer to SMS 21 *Housekeeping* and SMS 40 *Fall Protection*
Excavations	• Excavation work is not expected during this project. Consult the Health and Safety Manager
Confined space entry	• Confined space entry is **not** authorized for this project. Consult the Health and Safety Manager

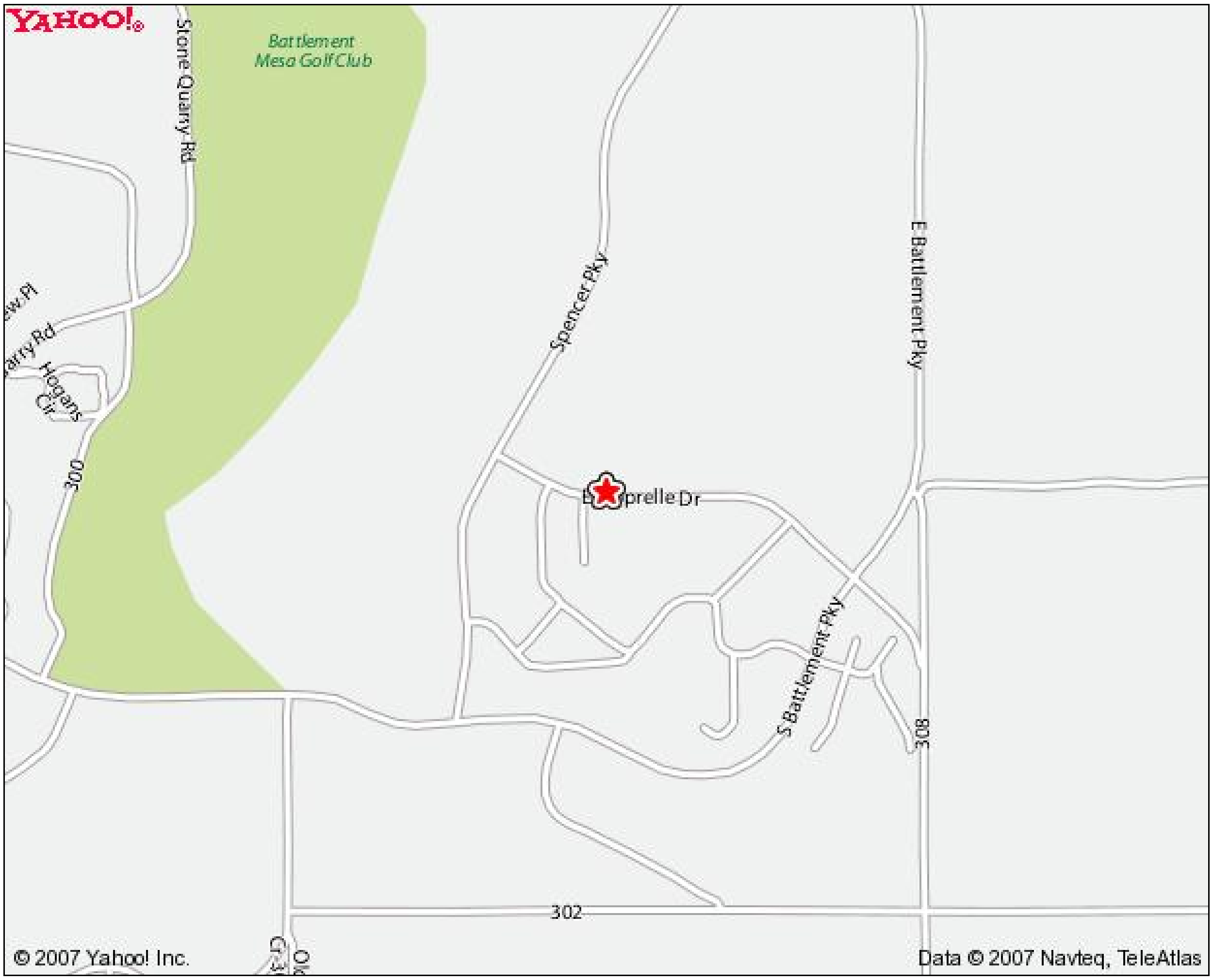
Site-Specific Hazards and Controls	
Potential Hazards	**Controls**
Emergencies and Incident Reporting	• Maintain a first aid kit, fire extinguisher and a roll of "Caution" tape in each vehicle and/or at the site • Consider keeping a disposable camera available at the job site to document near-misses or incidents • Report all incidents and near misses to the PM and the HSM or RHSM • Know the location of the nearest working phones and know how to direct emergency responders to your location prior to starting work • Know appropriate emergency contact numbers (911 or others as appropriate) • Know the location and route to the nearest hospital or clinic; check with locals to confirm • Report work-related injuries immediately to Jeanette Schrimsher, URS Occupational Health Manager (866) 326-7321 (24-hour number) • Refer to SMS 65 *Injury Management* • Refer to SMS 49 *Incident Reporting*

Biological Hazards and Controls	
Potential Hazards	**Controls**
Bloodborne Pathogens (hepatitis, HIV, etc.)	• Use "universal precautions" and assume any blood or body fluids are contaminated • Wear latex gloves to prevent exposure • Refer to SMS 51 *Blood-Borne Pathogens*
Ticks, spiders, mosquitoes, and other insects	• Cover skin with light colored clothing • Wear insect repellant; follow directions for use • Tape the interface between boots and pants if ticks are plentiful • Check for ticks or insect bites after walking in habitat areas • Avoid heavily vegetated areas and wet areas, especially during dusk/night • Be familiar with symptoms of exposure to vectorborne disease (e.g., West Nile virus) and seek treatment immediately if symptoms develop; refer to SMS 47 *Biological Hazards*
Poisonous Plants (poison ivy, poison oak, etc.)	• Poison ivy is present in some moist areas in the Rocky Mountains – remember – "leaves of three, let it be" • Tape long sleeves to work gloves, and tape both legs to boots to avoid contact with poisonous plants • If contact occurs, wash immediately with soap and water and wash clothing after contact • Refer to SMS 47 *Biological Hazards*
Snakes	• Wear high boots or snake chaps if there is a significant snake hazard • Make noise when approaching snake habitat and, to the extent possible, avoid such areas • Leave the immediate area if a snake is sighted; do not disturb or attempt to move snake

Biological Hazards and Controls	
Potential Hazards	**Controls**
Small biting animals, including domestic animals	• Do not reach into potential habitats, e.g., logs, crevices, tall grass • Keep a distance from small animals to avoid potential disease (e.g., plague) • Check with owner prior to entering private property • Stay away from all animals including domestic dogs and cats • Never tease dogs • If approached by a dog and the owner is not there, do not reach your hand out. Stand still and let the dog sniff your shoe or leg • Do not stare at the dog's eyes • Raised hackles, growling, tail held stiffly, and staring are all signs that the dog may bite
Animal droppings (hantavirus, histoplasmosis, etc.)	• Avoid animal droppings, nesting materials, and dead birds or animals • If you must work in areas near droppings/nesting materials, do not disturb and do not create dust. If dust is anticipated, respiratory protection may be needed. Consult the Health and Safety Manager.
Large mammals	• Contact local Ranger Stations to identify hazards • Make noise when walking in remote areas • If you encounter a bear, do not run; walk away slowly • Moose and bison can also attack if threatened • If signs of large mammals are indicated in the work area, contact a safety representative for additional control measures. • Also keep a safe distance from livestock

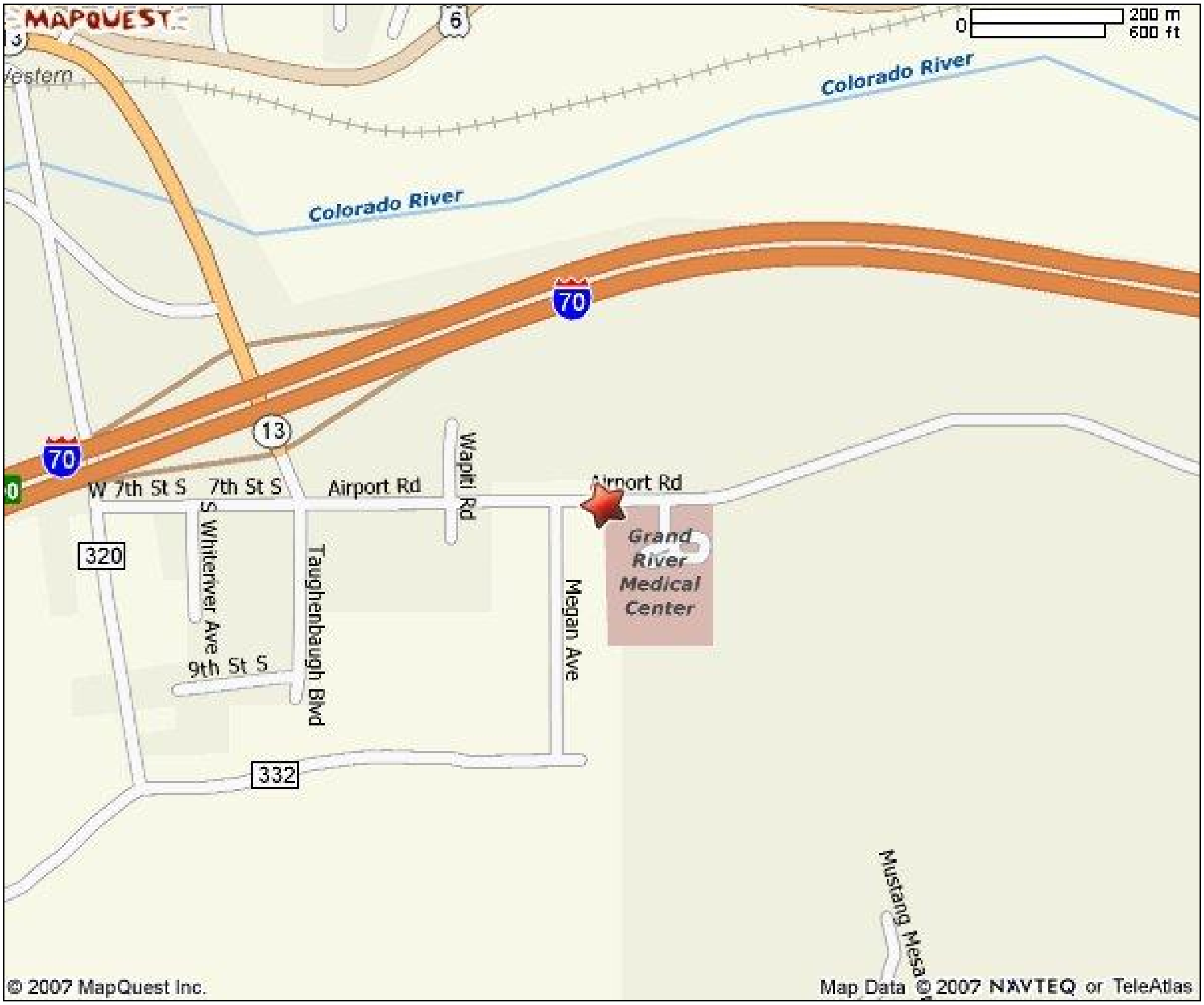
Grand River Medical Clinic at Battlement Mesa
(Monday – Friday 8:30-5:00)
73 Sipprelle Drive, Suite K
Parachute, Colorado 81635

Telephone
970-285-7046



Grand River Hospital and Medical Center
501 Airport Road
Rifle, Colorado 81650

Telephone
970-625-1510



APPENDIX C

EXAMPLE FIELD FORMS

URS

713 Cooper Avenue
Glenwood Springs, CO 80601

Pnone: (970) 384-4730
Fax: (970) 945-9182

Field Data Sheet

Revision 3

Rulison Sampling and Analysis

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 ☐ Driiling 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 (^{o}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

URS

713 Cooper Avenue
Glenwood Springs, CO 80601
(970) 384-4730

Rulison Sampling and Analysis

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
Elevation (ft msl):		Zone
Radiation Measurement	**Waist Level**	**Ground Level**
Pancake GM (µR/Hr):		
Pancake GM (kcps):		
NaI(Tl) Gamma (µR/Hr):		
NaI(Tl) Gamma (kcps):		
Ion Chamber (µR/Hr):		

Site No. 2

UTM Coordinates (ft)	N	E
Elevation (ft msl):		Zone
Radiation Measurement	**Waist Level**	**Ground Level**
Pancake GM (µR/Hr):		
Pancake GM (kcps):		
NaI(Tl) Gamma (µR/Hr):		
NaI(Tl) Gamma (kcps):		
Ion Chamber (µR/Hr):		

Site No. 3

UTM Coordinates (ft)	N	E
Elevation (ft msl):		Zone
Radiation Measurement	**Waist Level**	**Ground Level**
Pancake GM (µR/Hr):		
Pancake GM (kcps):		
NaI(Tl) Gamma (µR/Hr):		
NaI(Tl) Gamma (kcps):		
Ion Chamber (µR/Hr):		

Site No. 4

UTM Coordinates (ft)	N	E
Elevation (ft msl):		Zone
Radiation Measurement	**Waist Level**	**Ground Level**
Pancake GM (µR/Hr):		
Pancake GM (kcps):		
NaI(Tl) Gamma (µR/Hr):		
NaI(Tl) Gamma (kcps):		
Ion Chamber (µR/Hr):		

Site No. 5

UTM Coordinates (ft)	N	E
Elevation (ft msl):		Zone
Radiation Measurement	**Waist Level**	**Ground Level**
Pancake GM (µR/Hr):		
Pancake GM (kcps):		
NaI(Tl) Gamma (µR/Hr):		
NaI(Tl) Gamma (kcps):		
Ion Chamber (µR/Hr):		

Site No. 6

UTM Coordinates (ft)	N	E
Elevation (ft msl):		Zone
Radiation Measurement	**Waist Level**	**Ground Level**
Pancake GM (µR/Hr):		
Pancake GM (kcps):		
NaI(Tl) Gamma (µR/Hr):		
NaI(Tl) Gamma (kcps):		
Ion Chamber (µR/Hr):		

Site No. 7

UTM Coordinates (ft)	N	E
Elevation (ft msl):		Zone
Radiation Measurement	**Waist Level**	**Ground Level**
Pancake GM (µR/Hr):		
Pancake GM (kcps):		
NaI(Tl) Gamma (µR/Hr):		
NaI(Tl) Gamma (kcps):		
Ion Chamber (µR/Hr):		

Site No. 8

UTM Coordinates (ft)	N	E
Elevation (ft msl):		Zone
Radiation Measurement	**Waist Level**	**Ground Level**
Pancake GM (µR/Hr):		
Pancake GM (kcps):		
NaI(Tl) Gamma (µR/Hr):		
NaI(Tl) Gamma (kcps):		
Ion Chamber (µR/Hr):		

Site No. 9

UTM Coordinates (ft)	N	E
Elevation (ft msl):		Zone
Radiation Measurement	**Waist Level**	**Ground Level**
Pancake GM (µR/Hr):		
Pancake GM (kcps):		
NaI(Tl) Gamma (µR/Hr):		
NaI(Tl) Gamma (kcps):		
Ion Chamber (µR/Hr):		

Comments:

Photo Log:

APPENDIX D

TIER I RADIOLOGICAL EQUIPMENT INFORMATION

instadose™

BY QUANTUM PRODUCTS

Instant. Precise. Portable.

Instadose™ from Quantum Products brings radiation monitoring into the digital age. Smaller than a flash drive, this rugged, fully accredited dosimeter provides an instant read-out when connected to any computer with internet access and a USB connection. Based on a patented direct ion storage technology, instadose devices provide radiation workers with a precise measurement of radiation dose.

Instadose comes in four fashionable colors:

- Blue
- Green
- Black
- Silver

Advantages for the Practice

A monitoring program with instadose is a cost-effective way to safeguard your practice from potential legal claims. Employees will be more likely to wear this stylish device, and you can reassure them of their safety and stay in compliance with Federal and State regulations at the same time.

Simplify the administration of your monitoring program. With instadose devices there is no need to send badges to a processing center, as these devices stay with your employees. You will spend less time managing your account with our robust online account management program and dose reading capabilities.

Advantages for the Radiation Worker

This revolutionary device provides radiation workers with complete control over when and how frequently they review their dose, with unlimited readings included for one low price. Concerns about a possible exposure can be addressed immediately, as opposed to other services which provide readings on a quarterly or monthly basis. Instadose devices can be re-read without loss of exposure data, with cumulative exposure maintained.

Instant Dose Readings

With AMP (Account Management Program), you will have easy access to up-to-the-minute exposure reports. If there is ever a concern of radiation exposure, you can log in to your secure account page and check your dose level. Devices can be read on any computer with a USB connection and internet access.

Account administrators can also manage all the elements of a radiation monitoring program with AMP. From account administration to managing individual wearers, devices, and locations, AMP provides real-time access to account details, device assignments, reports, and pertinent account information.

AMP has multiple security levels, restricting users within an account from viewing other wearers' data or changing account information. Users can only perform readings for devices assigned to them.

With AMP, administrators can:

- View current and historical exposure readings
- Perform readings for devices within the account
- View graphical representation and comparative review of user exposure readings
- Manage how frequently devices are read
- Update account information

AMP is also your source for information. Keep up-to-date on radiation monitoring articles for your industry by logging into your AMP account. Whether your industry is veterinary, dentistry, or radiology, you will be able to view and search the news that is relevant to your industry.

PRODUCT COMPARISON

	instadose	Luxel dosimeters	TLD dosimeters
Instant reading of dose	X		
Measures exposure to gamma and x-ray	X	X	X
Multiple reads	X	X	
No need to send badges in for processing	X		
No reader required	X		

APPLICATIONS

Federal and State regulations limit the amount of radiation that workers are allowed to receive. Radiation monitoring should be considered for those who work in occupations where risks may be prevalent due to exposures from X-ray equipment. Instadose is the perfect device to measure photon dose.

FEATURES

- USB compatible detector
- Measures doses as low as 1 millirem
- Instant read results
- User identity is stored on a built-in memory chip

TECHNICAL SPECIFICATIONS*

Badge name	instadose
Badge Type	1=instadose 1.0
Description	Direct Ion Storage device with USB connector
Holder Type	Whole body
Wear Location	Collar or upper torso
Minimum Reportable Dose	1 mrem (0.01 mSv)
Lower Limit of Detection	1 mrem (0.01 mSv)
Useful Dose Range	1 mrem - 500 rem (0.01 mSv - 5 Sv)
Energy Response	Photon 15 keV - 6 MeV
Accreditations/Approvals/ Licenses	NVLAP

*Technical specifications subject to change.

instadose™
BY QUANTUM PRODUCTS

Phone: 800.359.9686
P.O. Box 16451
Irvine, CA 92623
www.instadose.com

DMC 2000XB

Personal Electronic Dosimeter

The use of β particle emitters for radiation therapies (treatments of eye tumors, coronary arteries, or inflammatory joint diseases) has significantly increased during recent years, and this has made the use of dedicated β dosimeters essential.

The DMC 2000XB was designed, to allow simultaneously deep dose equivalent Hp(10) and shallow dose equivalent Hp(0.07) measurements for X-ray, gamma and beta emissions. Furthermore it can be used as an operational dosimetry system for all medical risk assessment including radiological exposures, and in addition has applications in radioactive source production facilities, nuclear power plants and other nuclear facilities.

FEATURES

The DMC 2000XB is an X-ray/gamma and beta detection dosimeter, featuring dose rate and programmable alarms. The DMC 2000XB is user friendly, lightweight and water resistant.

- X-ray/gamma energies: 20 keV to 6 MeV
- Beta energies 60 keV to 3.5 MeV
- Dedicated to simultaneous measurements of X-ray, gamma and beta radiations
- Small, light, ergonomic, compact and rugged
- Compliant with international standards and local rules
- Hand free communication reading system with data centralization

RELATED PRODUCTS

MGP Instruments offers a range of products which can be used with the DMC 2000XB to create integrated dosimetry systems including:

- LDM 220, LDM 230 proximity readers
- LDM 2000 pass-by data exchange
- DOSISERV dosimetry centralization and access control software
- DOSIMASS dosimeter configuration software
- DOSICARE and DOSIFAST operational dosimetry software
- IRD 2000 irradiator for dosimeters

health physics
A Mirion Technologies Division

Featuring:

PHYSICAL CHARACTERISTICS

- Complies with IEC 61526 Ed 1
- **Measurement and display:**
- display units: mSv, µSv or mrem
  - dose display: 1 µSv to 10 Sv (0.1 mrem to 1000 rem)
  - dose rate display: 0.01 mSv/h to 10 Sv/h (1 mrem/h to 1000 rem/h)
  - measurement range: 0.1 µSv/h to 10 Sv/h
- Linearity:
  - < ± 20 % up to 1 Sv/h (100 rem/h)
  - < ± 30 % up to 10 Sv/h (1000 rem/h) for X, γ > 60 keV and β
  - < ± 25 % up to 3 Sv/h (300 rem/h) for X < 60 keV
- Energy response:
  - X, γ rays: 20 keV to 6 MeV
  - β E_{mean} > 60 keV (E_{max} : 0.22 MeV to 2.3 MeV)
- Accuracy: < ± 10 % (^{137}Cs, ~ 30 mSv/h, including ± 5% of extended uncertainty K=2)

ELECTRICAL CHARACTERISTICS

- Li MnO_2 standard CR2450 battery: battery life > 9 months (8h per day in run mode)

MECHANICAL CHARACTERISTICS

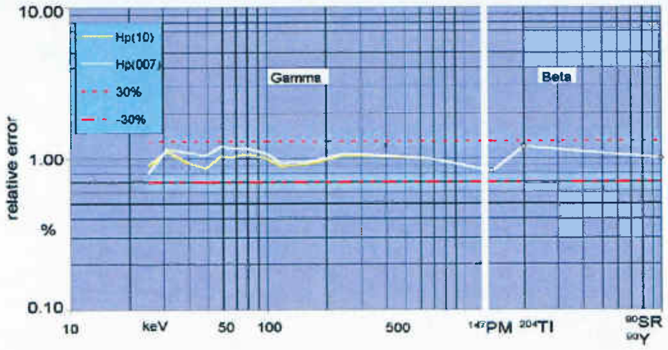
- Dimensions: 87 x 48 x 28 mm (3.4 x 1.9 x 1.1 in) with clip
- Weight with battery: < 59 g (2 oz)
- Worn by a replacable clip

ENVIRONMENTAL CHARACTERISTICS

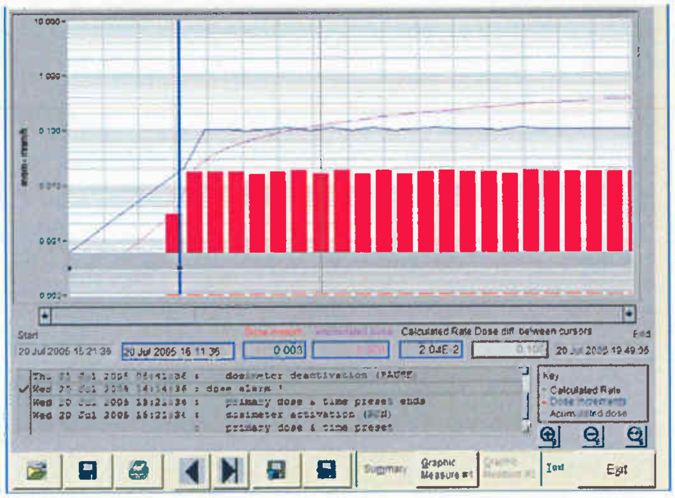
- Temperature range: -10°C to 50°C (14°F to 122°F)
- Humidity: < 90 % at 42°C (108°F)
- Storage: -30°C to 71°C (-22°F to 160°F)
- Shock, vibration and drop resistant, water resistant IP42
- EMC: complies and exceeds CE standards

CUSTOMIZATION

- setup can be acchieved by user with DOSIMASS software



DMC 2000XB energy response



20 Jul 2005 15:21:35
20 Jul 2005 16 11 35
0.003
2.04E-2
20 Jul 2005 19 49 05

[illegible] : dosimeter deactivation (PAUSE)
✓ [illegible] : dose alarm !
[illegible] : primary dose & time preset ends
Wed 20 Jul 2005 [illegible] : dosimeter activation [illegible]
: primary dose & time preset

The history enables detailed event reconstruction for efficient analysis of incident situation circumstances.

Hp(10) - deep dose

Hp (0.07) - shallow dose

With the display directly visible to the wearer, many functions are available using alphanumeric characters.

Technician using the hands-free capability of the DMC 2000S with LDM 2000 reader.

MIRION TECHNOLOGIES Health Physics Division

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451B/451P

Ion Chamber Survey Meter with Beta Slide/ Pressurized µR Ion Chamber Survey Meter

Technical Data

Fluke Biomedical offers two primary ion-chamber survey meters. The 451P is a pressurized ion chamber for µR resolution and the 451B includes a sliding beta shield to serve as an equilibrium thickness for photon measurements and enables beta discrimination. Both models are auto-ranging and measure radiation rate and accumulated dose from various radiation sources (451P: x-ray and gamma; 451B: beta, x-ray, gamma). The ion chamber detector allows for a fast response time to radiation from leakage, scatter beams, and pin-holes. Additionally, the low-noise chamber bias supply provides for fast background-settling time.

The digital display features an analog bar graph, 2.5 digital readout, low battery, and freeze (peak hold) mode indicators, and an automatic backlight function. User controls consist of an ON/OFF button and a MODE button. The case is constructed of lightweight, high strength materials and is sealed against moisture.

The RS-232 interface can be connected directly to a computer for use with the Excel add-in for Windows (451EXL), enhancing the functionality of the instrument. This software allows for data retrieval, user parameter selection and provides a virtual instrument display with audible (requires sound card) and visual alarm indication.

Key features

- µR resolution – 451P only
- Measures skin dose (slide open) and deep dose (slide closed) – 451B only
- High sensitivity measurement of rate and dose simultaneously, with the capability to record peak rate
- Auto-ranging and auto-zeroing
- RS-232 communications interface with optional Windows-based Excel add-in for data logging
- Ergonomic, anti-fatigue handle with replaceable grip, wrist strap and tripod mount
- Programmable flashing LCD display and audible alarm
- Easily-accessible battery door (operated by two 9-volt alkaline batteries) on the outside of the bottom case
- Available with dose equivalent energy response (SI units)

	451P	451B
Detector	Pressurized ion chamber (125 psi)**	Ion chamber
End users	• x-ray manufacturers • state inspectors • government agencies • biomedical technicians • maintenance technicians for airport baggage scanners	• x-ray manufacturers • state inspectors • government agencies • police and fire departments • emergency response and HAZMAT teams • nuclear medicine labs • hospital radiation safety officers • nuclear power workers
Radiation detected	gamma, x-ray	beta, x-ray, gamma

**Due to the pressurized ion chamber, the 451P is considered U.S. Department of Transportation (DOT) Dangerous Goods and must be shipped via IAW DOT special permit DOT-SP 13187.

Technical specifications

Radiation detected
Alpha: > 7.5 MeV
Beta: > 1 MeV (451P);
> 100 keV (451B)
Gamma: > 25 keV (451P);
> 7 keV (451B)

Operating ranges, response time (451P)
0 µR/h to 500 µR/h (5 sec)
0 mR/h to 5 mR/h (2 sec)
0 mR/h to 50 mR/h (1.8 sec)
0 mR/h to 500 mR/h (1.8 sec)
0 R/h to 5 R/h (1.8 sec)

Operating ranges, response time (451B)
0 mR/h to 5 mR/h (8 sec)
0 mR/h to 50 mR/h (2.5 sec)
0 mR/h to 500 mR/h (2 sec)
0 R/h to 5 R/h (2 sec)
0 R/h to 50 R/h (2 sec)

Accuracy
Within 10 % of readings between 10 % and 100 % of full scale indication on any range, exclusive of energy response

Detector
Chamber (cc volume air ionization):
230 cc (451P); 349 cc (451B)
Chamber wall (phenolic):
246 mg/cm^2 (451B)
Chamber window (mylar):
6.6 mg/cm^2 (451B)
Beta slide:
440 mg/cm^2 (451B)
Controls: ON/OFF and MODE (451P)

Automatic features
Auto-zeroing, auto-ranging, and auto-backlight

Power requirements
Two 9 V alkaline, 200 hours operation

Warm-up time
Less than two minutes for initial operation when the instrument is in equilibrium with ambient temperature (451P)
One minute (451B)

Display LCD analog/digital with backlight
Analog: 100 element bar graph 6.4 cm long. Bar graph is divided into 5 major segments, each labeled with the appropriate value for the range of the instrument.
Digital: 2.5 digit display is followed by a significant zero digit depending on the operating range of the instrument. The units of measurement are indicated on the display at all times. Digits are 6.4 mm (0.25 in) high. Low battery and freeze indicators are also provided on the display.

Modes
Integrate mode: Operates continuously 30 seconds after the instrument has been turned on. Integration is performed even if the instrument is displaying in mR/h or R/h.
Freeze mode: Will place a tick mark on the bar graph display to hold on the peak displayed value. The unit will continue to read and display current radiation values.

Environmental
Temperature range:
-4 °F to 122 °F (451P);
-4 °F to 158 °F (451B)
Relative humidity:
0 % to 100 % (451P);
0 % to 100 % (at 140 °F) (451B)
Geotropism:
Negligible (451P);
< 1 % (451B)

Typical energy dependence
^{16}Nitrogen gamma rays are 110 % to 120 % of indicated readings as determined at the University of Lowell

Dimensions (WxDxH)
10 cm x 20 cm x 15 cm
(4 in x 8 in x 6 in)

Weight
451P: 1.07 kg (2.4 lb)
451B: 1.11 kg (2.5 lb)

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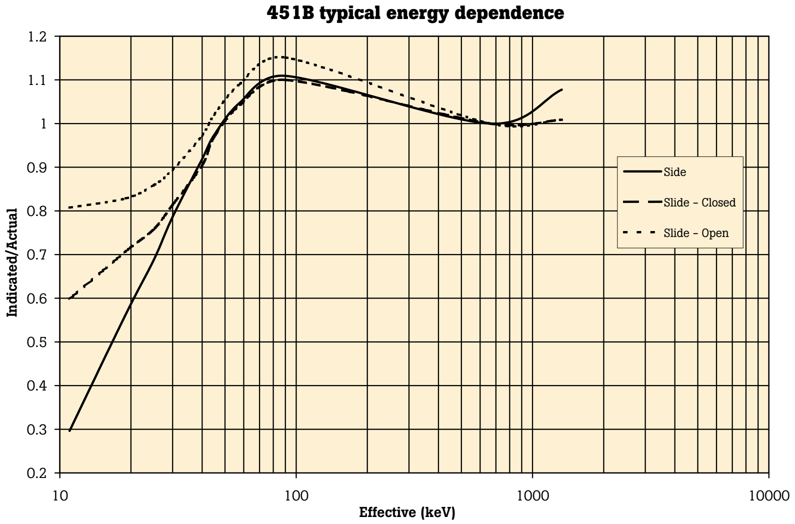
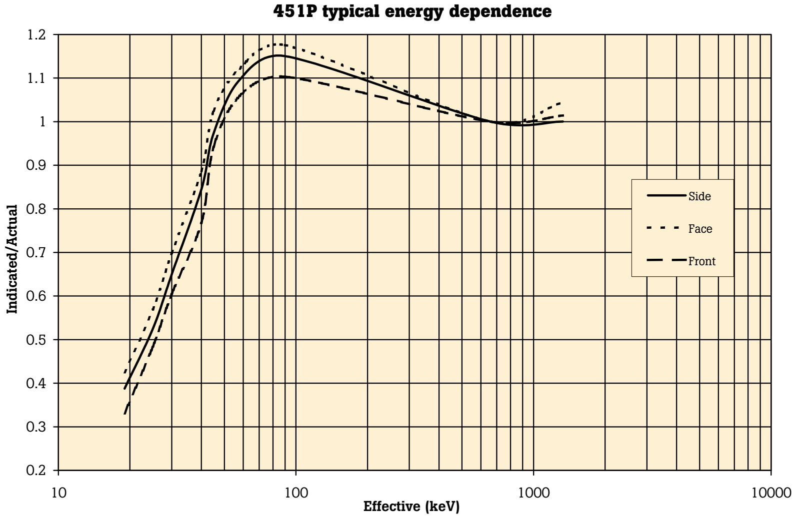

451B typical energy dependence


451P typical energy dependence

Ordering Information

Models

451P-RYR Pressurized μR Ion Chamber Survey Meter with standard chamber

451B-RYR Ion Chamber Survey Meter with Beta Slide and standard chamber

451P-DE-SI-RYR Pressurized μR Ion Chamber Survey Meter with dose equivalent chamber

451B-DE-SI-RYR Ion Chamber Survey Meter with Beta Slide and dose equivalent chamber

Optional accessories

451EXL 451 Assistant for Excel, includes RS-232 interface cable

190HPS Single Unit Carrying Case

62-103 Check Source, ^{137}Cs, 10 μCi. Flat disc, 1-inch diameter

450UCS Check Source, ^{238}Uranium, 0.064 μCi, impregnated, 2 in x 2 in yellow card

About Fluke Biomedical

Fluke Biomedical is the world's leading manufacturer of quality biomedical test and simulation products. In addition, Fluke Biomedical provides the latest medical imaging and oncology quality-assurance solutions for regulatory compliance.

Today, biomedical personnel must meet the increasing regulatory pressures, higher quality standards, and rapid technological growth, while performing their work faster and more efficiently than ever. Fluke Biomedical provides a diverse range of software and hardware tools to meet today's challenges.

Fluke Biomedical Regulatory Commitment

As a medical device manufacturer, we recognize and follow certain quality standards and certifications when developing our products. We are ISO 9001 certified and our products are:

- FDA Compliant
- CE Certified, where required
- NIST Traceable and Calibrated
- UL, CSA, ETL Certified, where required
- NRC Compliant, where required

Fluke Biomedical.

The accuracy you need
from a company you can trust.

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ASM-990 Series
Advanced Survey Meter

Technical Data

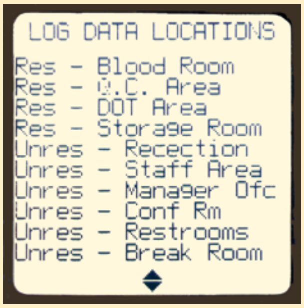
The ASM-990 Series Advanced Survey Meter can detect alpha, beta, gamma, or x-ray radiation within an operating range of 1 µR/hr to 1 R/hr (1 to 5,000,000 CPM), depending on the selected probe (Geiger-Mueller, neutron, proportional counter, scintillation). With the proper probe combination, this meter can be used as a general survey meter, an area monitor, a wipe-test counter, and a contamination monitor.

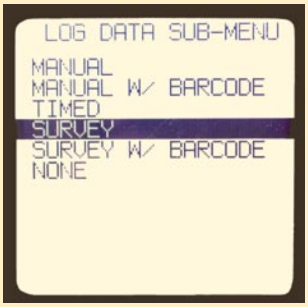
Designed to meet the high-technology requirements of health physics, medical physics, and nondestructive testing applications, the ASM-990 Series is well-suited for a wide range of end users, including: Radiation safety officers, nuclear medicine laboratories, diagnostic x-ray and hospital emergency-room technicians, environmental-health physicists, and emergency responders.

The unit, with purchased probe, is shipped calibrated and ready-to-use and includes an MHV connector to ensure compatibility with all Fluke Biomedical probes. The 992 includes a fully calibrated internal energy-compensated 1 R/hr GM detector. The 993 features a fully calibrated internal pancake detector, as well as an internal energy-compensated 1 R/hr GM detector.

Key features

- Simultaneous auto-scaling measurement of rate and dose, with the capability to record peak rate
- Up to five different probes can be calibrated with one unit
- Data-logging survey mode feature allows user to store up to five separate survey sequences
- Saved data can be uploaded to a PC via included Infrared Data (IrDA) transmitter
- Easy-to-use multifunction keypad for intuitive menu navigation
- Backlit analog/digital LCD display with full-range audio output capability
- Barcode scanner (optional)
- Auto power-down feature extends battery life





Data logging modes

The ASM-990 Series' Log Data feature can easily be accessed via the setup sub-menu. The unit can log/save a maximum of 500 data points in any of three separate modes (manual and survey modes can utilize the optional barcode scanner).

Manual: Individual rate data points can be saved by pressing the Start/Stop/Rst/Save button.

Timed: A data point will automatically be saved at user-selectable time intervals in the range of 1 second to 255 seconds.

Survey: Programmed sequences can be accessed via the menu system. Pressing the Start/Stop/Rst/Save button saves the current reading and displays the next survey location.

Programming of survey sequences, as well as retrieval of logged data, is accomplished via the built-in IrDA port.

Label names up to 20 characters can be programmed into the unit to identify the individual survey locations.

Probe connector: The unit is available with an MHV connector. The unit can be used with multiple probes (5 total) by selecting the appropriate probe from the main menu. All calibration data for each probe is stored in the unit's EEPROM.

Specifications

ASM-990 and ASM-992

Operating modes: Rate, timed-peak hold, integrate, data logging, and scaler (dual option: "based on measurement" or "based on time")

Operating rate ranges (dependent on selected probe): Complementary units in the integrate mode with the integrated time value in seconds

μR/hr	mR/hr	R/hr
μrem/hr	mrem/hr	rem/hr
μSv/hr	mSv/hr	Sv/hr
CPM	CPS	
DPM 99mTc	DPS 131I	
Bq ^{125}I	kBq^{123}I	MBq ^{201}Tl
μCi ^{67}Ga	mCi ^{18}F	Ci ^{57}Co
μR	**mR**	**R**
μrem	mrem	rem
μSv	mSv	Sv
C (counts)	kC	MC
D (distintigrations)	kD 99mTc	MC 131I

Accuracy (dependent on selected probe): Within 10 % of reading between 10 % to 100 % of full scale indication on any range, exclusive of typical energy dependence

Detector: Accepts GM detectors and scintillation probes operating at high voltages between 500 volts and 1300 volts

Temperature range:
-10 °C to 50 °C (14 °F to 122 °F)

Relative humidity:
0 % to 95 %, non-condensing

Warm up time: 5 second diagnostic check

Check source: Natural uranium, mounted on the case

Power requirements: Two "D" cells, 150 hours operation, automatically indicates when battery is low

Housing material: Proprietary polycarbonate, splash-proof case

Display: Liquid crystal display, 5.6 cm x 5.6 cm (2.2 in x 2.2 in)

Dimensions (LxWxH):
10.5 cm x 27.7 cm x 6.4 cm
(4.1 in x 10.9 in x 2.5 in)

Weight (without probe):
0.95 kg (2.1 lb)

ASM-992 and ASM-993

Range: 0.1 mR/hr to 1 R/hr

Radiation detected: Gamma above 60 keV

Accuracy: ± 10 % of reading between 10 % and 100 % of full scale on any range, exclusive of energy dependence

ASM-993

Range: Background to 80 mR/hr

Radiation detected: Alpha above 3.5 MeV, beta above 35 keV and gamma above 6 keV

Window: 15 cm^2 (1.75 in Ø) mica, 1.4 mg/cm^2 to 2.0 mg/cm^2

Typical background: 30 CPM

Protective screen: Stainless steel, hexagonal pattern providing 86 % open area

Accuracy: ± 10 % of reading between 10 % and 100 % of full scale on any range, exclusive of energy dependence (protective cover open)

Effeciency: The internal pancake detector efficiency is shown below. In a recent performance check, the numbers shown represent typical results obtained:

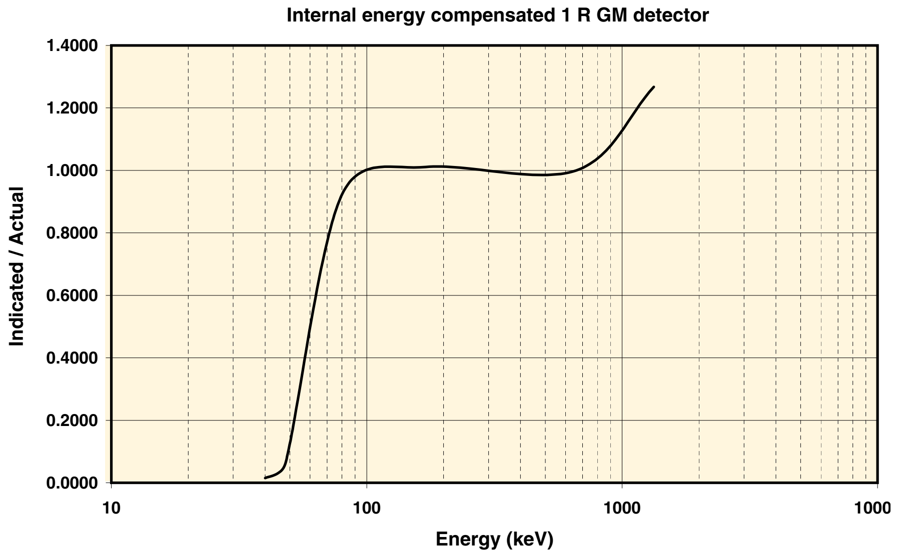
Isotope		% Efficiency	
^{14}C	^{241}Am	5 %	8 %
^{99}Tc	^{129}I	12 %	2 %
^{137}Cs	^{230}Th	24 %	15 %
^{90}Sr	^{239}Pu	59 %	12 %
^{36}Cl		26 %	

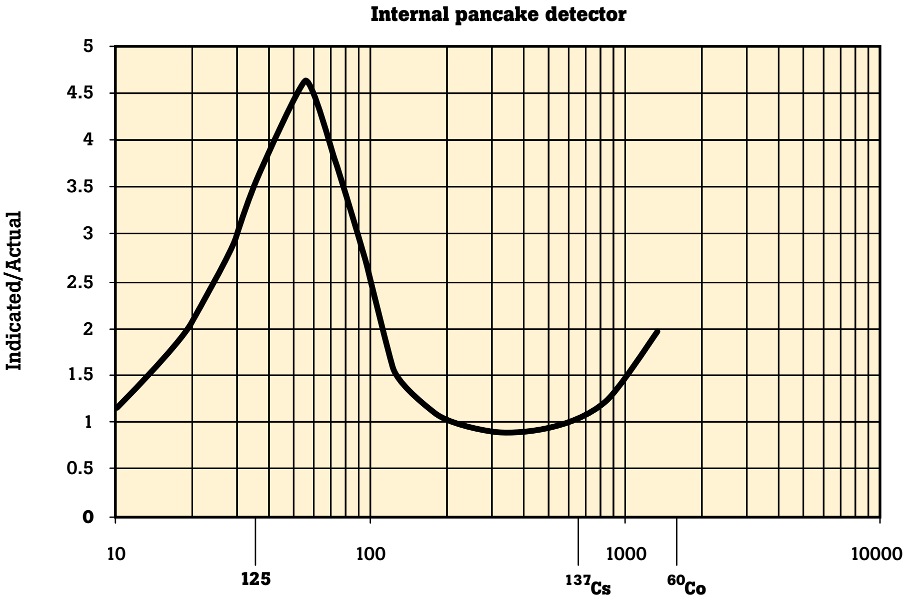
Note: The efficiency formula used to calculate the % Efficiency is: Eff. % = (CPM x 100)/DPM

Dimensions (LxWxH):
10.5 cm x 27.7 cm x 6.4 cm
(4.1 in x 10.9 in x 2.5 in)

Weight (without probe):
1.09 kg (2.4 lb)

Typical energy dependence


Internal energy compensated 1 R GM detector


Internal pancake detector

Model Comparison

Model	Advanced survey meter	Barcode reader	Internal energy compensated 1 R/hr GM detector	Internal pancake detector
990	●			
990BC	●	●		
992	●		●	
992BC	●	●	●	
993	●		●	●
993BC	●	●	●	●

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Geiger-Mueller and Scintillation Probe Selection Guide

Pancake GM Probe

Model 489-110D

- Alpha above 3.5 MeV
- Beta above 35 keV
- Gamma and x-ray > 6 keV
- To 80 mR/hr (800 µSv/hr)

Thin End Window GM Probe

Model 489-35

- Alpha above 4 MeV
- Beta above 70 keV
- Gamma and x-ray > 6 keV
- Up to 80 mR/hr (800 µSv/hr)

Alpha Scintillation Probe

Model 489-60

- Alpha above 4 MeV
- 1.5 in Ø ZnS (Ag)

Alpha/Beta Scintillation Probe Model 425-200

- Alpha above 350 keV
- Beta above 14 keV
- Plastic scintillator

Low Energy Gamma Scintillation Probe

Model 425-110

- Gamma and x-ray > 10 keV
- NaI (Tl) 1 mm thick

Energy Compensated GM Probe Model 90-12

- Beta above 200 keV
- Gamma and x-ray > 12 keV
- Up to 1 R/hr (10 mSv/hr)

Gamma Scintillation Probe

Model 489-50

- Gamma and x-ray > 60 keV
- 1 x 1 in, 1.5 x 1.5 in and 2 x 2 in NaI (Tl) detectors available

Utility 1 R/hr GM Probe

Model 491-40

- Beta above 200 keV
- Gamma and x-ray > 12 keV
- Up to 1 R/hr (10 mSv/hr)

Scintillation Pancake Probe

Model 489-200

- Beta above 100 keV
- Gamma and x-ray > 25 keV
- NaI (Tl) rectangular

100 cm² Beta/Gamma Scintillation Probe

Model 190-100BGS

- Beta ^{90}Sr efficiency 65 %
- 126 cm² active area
- Plastic scintillator

Ordering Information

990 Advanced Survey Meter

990BC Advanced Survey Meter with barcode reader

992 Advanced Survey Meter with an internal 1 R GM detector

992BC Advanced Survey Meter with an internal 1 R GM detector and barcode reader

993 Advanced Survey Meter with an internal 1 R GM detector and internal pancake detector

993BC Advanced Survey Meter with an internal 1 R GM detector, internal pancake

Optional accessories

990-IR-USB USB Port IrDA Adapter

990CC Carrying Case

990WM Wall Mounting Bracket

990PH Probe Holder for 489-110D

990UPH Universal Probe Holder

990SH Soft-Sided Holster

990SA Shoulder Strap Assembly

Note: The shoulder strap assembly is only available for the ASM-993 and must be ordered with the instrument and factory installed.

Note: The ASM-990 series, with the customer selected probe is calibrated to NIST standards. The ASM-990 series with GM probe standard calibration is in R, Sv, and rems. Scintillation detectors are calibrated in counts. Radionuclide specific efficiency calibrations are available upon request. For probe selection and calibration services, see next page.

About Fluke Biomedical

Fluke Biomedical is the world's leading manufacturer of quality biomedical test and simulation products. In addition, Fluke Biomedical provides the latest medical imaging and oncology quality-assurance solutions for regulatory compliance.

Today, biomedical personnel must meet the increasing regulatory pressures, higher quality standards, and rapid technological growth, while performing their work faster and more efficiently than ever. Fluke Biomedical provides a diverse range of software and hardware tools to meet today's challenges.

Fluke Biomedical Regulatory Commitment

As a medical device manufacturer, we recognize and follow certain quality standards and certifications when developing our products. We are ISO 9001 certified and our products are:

- FDA Compliant
- CE Certified, where required
- NIST Traceable and Calibrated
- UL, CSA, ETL Certified, where required
- NRC Compliant, where required

Fluke Biomedical.
The accuracy you need from a company you can trust.

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BNC

Precision Instrumentation since 1963....

areaSAM

Customizable

Networkable

Standalone

Protecting America

areaSAM 1035 Instrument Specifications

Overview

Report Formats
Gamma and Neutron gross CPS, isotope identification, spectrum analysis, dose rate (rem/Sv), total dose.

Integrated Electronics
Digital Multi-Channel Analyzer, spectroscopy amplifier, power supply

Gamma Detectors
2" x 2" NaI detector with integral HV supply
3" x 3" NaI detector with integral HV supply
4" x 4" x 16" NaI detector with integral HV supply
4" x 8" x 16" NaI detector with integral HV supply
Detector cables available: 3 ft. - 150 ft.

Internal Neutron Detector (optional)
He-3 proportional detector with polyethylene (UHMW) moderator
Gas Volume: 10.4 cc
Gas Pressure: 20 atm
Integral HV supply and shaping amplifier
Integral upper and lower level discriminators and logic output for Neutron recognition

Physical Dimensions

Weight: 5 lbs.
Dimensions: 9" W x 8 5/8" H x 2" D

Enclosure: NEMA 4X,
Watertight and dust proof

System Specifications

Energy Range: 18 keV - 3 MeV

Amplifier
Type: Pseudo-Gaussian
Shaping: Bipolar
Coarse Gain: 1x, 2x, 4x, 8x
Fine Gain: 1.000 to 2.550 in steps of approxim

Temp Operating Range: -20 C to +50 C .

ADC
Type: Base Converter 14-bit Successive Approximation
Conversion Modes: Linear - 256, 512, 1024 Channels
QCC - 256, 512 Channels (U.S. Patent 5,608,222)
LLD: 0 to 105% of full scale digitally adjustable in .1% intervals
ULD: 0 to 105% of full scale digitally adjustable in .1% intervals
Zero: -5 % to + 5% of full scale, digitally adjustable

Special Features

Patented Technology
Quadratic Compression Conversion (QCC) allows for identification of mixed isotopes in one second.
Hysteresis: Provides 97% I.D. confidence level in 2 seconds.

Customizability
Modifications of isotopes and their associated energy lines can be added, deleted, or changed in the field.

Trigger Lists
Multiple trigger lists for different field applications (Counter-Terrorism, Industrial, Environmental, Medical)

Ease of Use
Password Lockout Mode for non-technical personnel
Hands-free operation

Calibration
Automatic Coarse Calibration with Cs137
Dose Rate Calibration

Special Features

I/O: USB, Ethernet or DB9M RS-232 port for data transfer

Alarm: Audio/Visual: Gamma - Red LED
Neutron - Yellow LED

Clock: Battery-backed-up clock calendar

Controls: 10-key custom keypad utilizing software programmable function keys

Power: NiMH; Internal battery pack; external factory-supplied dual mode supply/charger, 12w; Continuous 110V Operation Available, 8 hr. battery life

Berkeley Nucleonics
www.berkeleynucleonics.com

CANBERRA

TAM100D/DSI High Sensitivity Wide Range Digital Tritium in Air Monitor

Features

- High sensitivity 0.5 µCi/m^3
- Six decade range
- Flow-through ion chamber
- Solid state electrometer for low-drift operation
- Automatic gamma background and radon subtraction
- Positive displacement high volume air pump and mass flow sensor
- Diagnostics for flow rate, high voltage, memory fail, over range
- Front panel zero-offset pot, electrometer output
- TAM100D operates on 120 V ac power 50/60 Hz
- TAM100DSI operates on 240 V ac power 50/60 Hz

Description

The TAM100 ion chamber-based Tritium monitor can either be stand-alone or have a separate (optional) ADM600 series digital display and control unit for remote operation.

The TAM100D version is calibrated and displays in µCi/m^3 and is configured for 120 V operation (the TAM100DSI is calibrated and displays in SI units and is configured for 240 V operation).

It employs a positive displacement pump to circulate the air sample through a flow-through ion chamber. The ion chamber has both air inlet and exhaust connections. Tritium or noble gas activity is determined by measuring ionization within the chamber. A separate sealed gamma compensation ion chamber of identical volume is provided to subtract the contribution of any gamma background. After the electrical subtraction of signal minus background, the net current is converted by a solid state electrometer to a voltage corresponding to the concentration level.

The TAM100 is sensitive to radioactive particles in the air which contribute to the current signal and also contaminate the ion chamber. To eliminate this potential problem, a user-servicable filter system is provided to screen out particles larger than 0.3 microns in size.

Major components include: inlet filter, ion trap, tritium detection ion chamber, gamma compensation ion chamber, solid state electrometer, microprocessor, display over-range alarm, pump and flow sensor.

The TAM100 also includes a built-in heater to assist in rapid decontamination of the chamber.

Phone contact information

Benelux/Denmark (32) 2 481 85 30 • **Canada** 905-660-5373 • **Central Europe** +43 (0)2230 37000 • **France** (33) 1 39 48 52 00 • **Germany** (49) 6142 73820
Japan 81-3-5844-2681 • **Russia** (7-495) 429-6577 • **United Kingdom** (44) 1235 838333 • **United States** (1) 203-238-2351

For other international representative offices, visit our Web Site: **http://www.canberra.com** or contact the Canberra U.S.A. office.

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TAM100D/DSI High Sensitivity Wide Range Digital Tritium in Air Monitor

Specifications

DETECTOR

- RADIATION MEASURED – Beta in gaseous form (Tritium, Noble Gas, etc.).
- DETECTOR – Flow-through ion chamber.
- DETECTOR VOLUME – 2.4 liter.
- PUMP – Positive displacement air pump with flow rate 7-9 LPM, mass flow controller and at least two ion chamber volume changes per minute with 100 ft (30 m) of air hose at both inlet and outlet.
- PARTICULATE FILTER – Greater than 0.3 micron.
- TRITIUM CALIBRATION – Traceable to NIST.

PERFORMANCE

- TRITIUM RANGE – 0.5 to 10^6 µCi/m^3 (18 kBq/m^3 to 3.7 x 10^4 MBq/m^3).
- RADON COMPENSATION – Alpha, equivalent to ±27 µCi/m^3 (±1 MBq/m^3).
- BACKGROUND COMPENSATION – Gamma, equivalent to ±15 µCi/m^3 (±0.5 MBq/m^3).
- ACCURACY – ±10% of known concentration, above 2nd decade.
- RESPONSE TIME – 1st decade <60 seconds, 2nd decade <15 seconds, all other decades <2 seconds.
- STABILITY – ±6% per 24 hours, ±15% over 30 days.
- ALARMS – Audible and visual, can be locally or remotely reset, 0.4 A at 60 V dc solid-state relay outputs.
- ALARM RESPONSE – <30 seconds.

OUTPUT SIGNALS

- DIGITAL OUTPUT – RS-485 serial data.
- ANALOG OUTPUT – Continuous (log-lin 4-20 mA), accuracy ±5% of display.

CONTROLS/DISPLAYS

- KEYPAD SWITCH – Six-button membrane keypad switch to control mode, display, alarm set points and test.
- ZERO OFFSET – Potentiometer on front panel.
- LCD DISPLAY – 1 x 4 in. LCD for display of digital data and rate bargraph.

PHYSICAL

- OPERATING TEMPERATURE – -10 °C to 40 °C (14 °F to 104 °F).
- OPERATING HUMIDITY – 0% to 95% non-condensing.
- POWER – 120/240 V ac (factory set), 50/60 Hz, 50 VA.
- SIZE – NEMA-12 rated enclosure, 35 x 24 x 33 cm (13.7 x 9.2 x 12.8 in.) (W x H x D).
- WEIGHT – 11.4 kg (25 lb).

OPTION

- ADM606M remote display and controller.

ORDERING INFORMATION

Model TAM100D

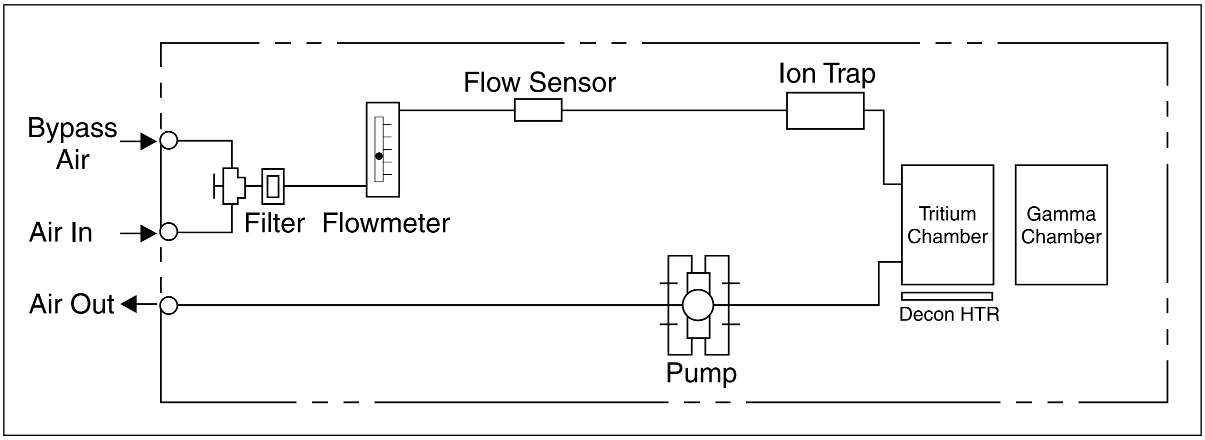
- Displays ambient tritium level in units of µCi/cc.
- Powered by 120 V ac, 50/60 Hz, 45 VA.

Model T100DSI

- Displays ambient tritium level in units of MBq/m^3.
- Powered by 240 V ac, 50/60 Hz, 45 VA.

CE

ISO 9001
SYSTEM
CERTIFIED



TAM100D Tritium In-Air Monitor Flow Diagram

BIOSCAN

Liquid Scintillation Counter

Gamma Counter

Luminometer

Triathler

Triathler

Typical Applications

- ✔ DNA & Protein Labeling
- ✔ Radioimmunoassays
- ✔ $^{14}CO_2$ H. Pylori Test
- ✔ Wipe Tests
- ✔ Radon in Water
- ✔ Filtration Assays
- ✔ Reporter Gene Assays
- ✔ Luciferase Assays

Luminometer

- Photon counting for high accuracy and extended dynamic range
- High sensitivity for both "glow" and "flash" reagents

Liquid Scintillation Counter

- Instant DPM quench correction
- Alpha / Beta separation
- Optional internal shielding for low background

Easy-to-Use

Start counting with one touch of a key. Methods for most isotopes and luminescence are already programmed.

Portable

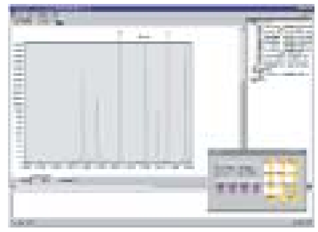
Triathler is compact and light; take it from lab to lab or into the field for on-site measurements.

Flexible

Triathler accepts most types and sizes of vials and microcentrifuge tubes.

Sophisticated

Optional software for advanced spectrum analysis, data export to Excel™, and full instrument control.



Excel™ is a registered trademark of Microsoft.

Gamma Counter

- Preset modes for ^{57}Co, ^{51}Cr, ^{131}I, ^{99m}Tc
- Programmable modes for gamma isotopes up to 1000keV

Tritium Wipe Test

	Wad	Glass Fiber	Paper
^{3}H efficiency	7%	20%	5%
Bkgnd CPM	50	50	50

Alpha Wipe Test

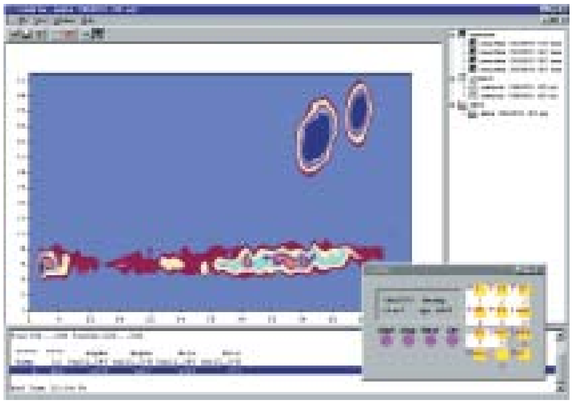
	Paper	Mixed ester	Glass fiber
Alpha efficiency	75%	85%	85%
Bkgnd	0.2	<0.1*	0.9

* no Rn-daughters present

^{32}P Counting Techniques

	Efficiency	Bkgnd	Comment
Cerenkov	40%	<100 CPM	non-destructive
PSA*	75%	<100 CPM	non-destructive
LS “cocktail”	>90%	<150 CPM	destructive

*PSA Plastic Scintillator Adapter



Water Measurements

Triathler has alpha-beta separation electronics, which makes it ideal to detect alpha-isotopes like radon (^{222}Rn) in water. The illustration above shows a 2D spectrum for alpha and beta nuclides of ^{222}Rn and daughters from a well water sample.

Detector:	Photon counting photomuliplier tube
Energy range:	2 keV - 2000keV
Dynamic range:	200CPS - 50,000,000 CPS
Counting time:	0.1 seconds to 99999 minutes
Output:	RS-232C to PC or thermal printer
Power:	110-240V, 12VDC
Dimensions:	**L**13” (33cm), **W**10” (25 cm), **H**7.5” (19cm)
Weight:	20 lbs., 9 kg.

Liquid Scintillation Counting

Samples:	Microtubes, LSC vials or test tubes
Efficiency:	Up to 48% for ^{3}H
Max count rate:	2,000,000 CPM

Gamma Counting

Detector type:	32 mm x 32 mm (1.25 in.) NaI (TI) crystal detector, through hole (15 mm dia.)
Sample size:	Up to 13 mm diameter tubes or vials
Shielding:	10 mm of lead

Luminescence Counting

Samples:	Microtubes LSC-vials or test tubes
Max. count rate:	3 x10^{7}

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www.bioscan.com

BIOSCAN On the right track.

Digital Area Monitors

Features

- Affordable area monitor controller
- Adapts to a wide variety of detectors
- Programmable alarms and units of measure
- Networkable
- Battery backup

Model 375

Part No. 48-2230

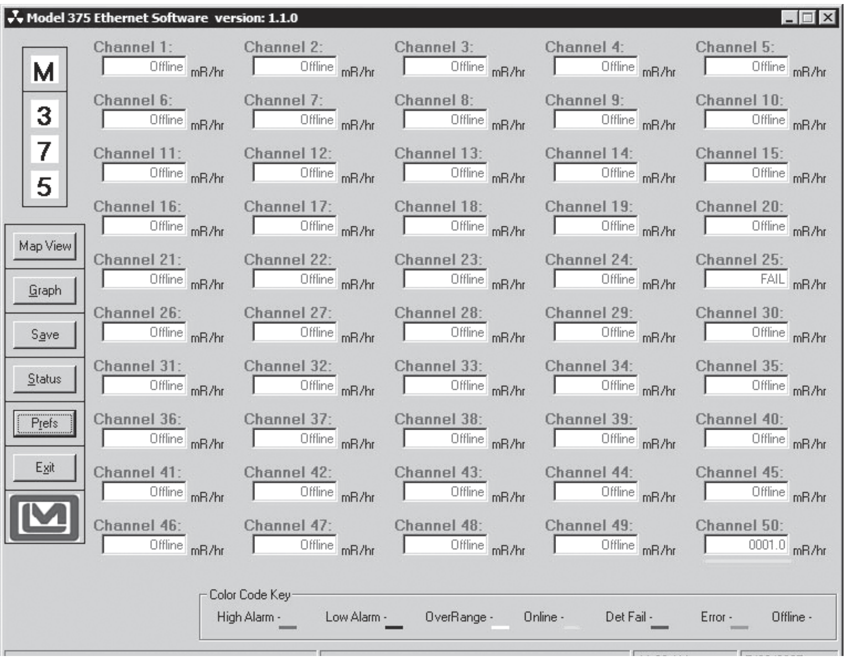
Introduction

The Model 375 is a versatile, compact and very affordable digital electronic controller designed for monitoring radiation in areas. Its simple design accommodates many different detectors suiting a wide variety of applications and is equipped with a local readout and alarms. These versatile units may also be connected to optional auxiliary indicator/annunciators for alerting personnel at remote locations. The user-friendly, digital design enhances setup and operation. These units may also be networked to a central PC-based station where data are logged and alarms posted.

Specifications

INDICATED USE: Area monitoring
SUGGESTED DETECTORS: GM, proportional, scintillation, neutron
DISPLAY: 4 digit LED display with 0.8" (2 cm) digits
DISPLAY RANGE: 000.0 - 9999
DISPLAY UNITS: Can be made to display in µR/hr, mR/hr, R/hr, µSv/hr, mSv/hr, Sv/hr, µrem/hr, mrem/hr, rem/hr, cpm, cps, and others
LINEARITY: Reading within 10% of true value
RESPONSE: Typically 3 seconds from 10% - 90% of final reading
STATUS: Green light, instrument functioning properly
ALARMS: A. Low Alarm: Yellow light, 1 beep/second audible, selectable range: 0-9999
B. High Alarm: Red light, 4 beeps/second audible, selectable range: 0-9999
C. Detector Fail: Red light, constant audible tome > 68 dB at 2 feet
D. Low Bat: Yellow light, indicates less than 2 hours of battery life remaining
HIGH VOLTAGE: Adjustable from 200 - 2500 volts
THRESHOLD: Adjustable from 2 - 100 mV
DEAD TIME: Adjustable to compensate for dead time of detector and electronics *(can be read on display)*
OVERLOAD: Senses detector saturation *(indicated by display reading "-OL-")*
OVERRANGE: Indicates radiation field being measured has exceeded counting range of instrument *(indicated by display reading "– – – –")*
DATA OUTPUT: 9 pin connector providing 5 decade logarithmic output, RS-232 output, signal ground connection, FAIL and ALARM signals *(current sink)*, and direct connection to battery and ground
CALIBRATION CONTROLS: Accessible from front of instrument *(protective cover provided)*
POWER: 95 - 135 Vac *(178 - 240 Vac available)*, 50-60 Hz single phase. 6 volt sealed lead-acid rechargeable battery *(built in)*
BATTERY LIFE: Typically 48 hours in non-alarm condition; 12 hours in alarm condition
BATTERY CHARGER: Battery is continuously trickle charged when instrument is connected to line power and turned on
CONSTRUCTION: Wall mount aluminum housing with ivory powder coat paint
SIZE: 7.4" H x 9.7" W x 2.5" D (18.7 x 24.6 x 6.4 cm)
WEIGHT: 6.5 lbs. (2.3 kg)

Model 375 Ethernet Software



Channel 1: Offline mR/hr	Channel 2: Offline mR/hr	Channel 3: Offline mR/hr	Channel 4: Offline mR/hr	Channel 5: Offline mR/hr
Channel 6: Offline mR/hr	Channel 7: Offline mR/hr	Channel 8: Offline mR/hr	Channel 9: Offline mR/hr	Channel 10: Offline mR/hr
Channel 11: Offline mR/hr	Channel 12: Offline mR/hr	Channel 13: Offline mR/hr	Channel 14: Offline mR/hr	Channel 15: Offline mR/hr
Channel 16: Offline mR/hr	Channel 17: Offline mR/hr	Channel 18: Offline mR/hr	Channel 19: Offline mR/hr	Channel 20: Offline mR/hr
Channel 21: Offline mR/hr	Channel 22: Offline mR/hr	Channel 23: Offline mR/hr	Channel 24: Offline mR/hr	Channel 25: FAIL mR/hr
Channel 26: Offline mR/hr	Channel 27: Offline mR/hr	Channel 28: Offline mR/hr	Channel 29: Offline mR/hr	Channel 30: Offline mR/hr
Channel 31: Offline mR/hr	Channel 32: Offline mR/hr	Channel 33: Offline mR/hr	Channel 34: Offline mR/hr	Channel 35: Offline mR/hr
Channel 36: Offline mR/hr	Channel 37: Offline mR/hr	Channel 38: Offline mR/hr	Channel 39: Offline mR/hr	Channel 40: Offline mR/hr
Channel 41: Offline mR/hr	Channel 42: Offline mR/hr	Channel 43: Offline mR/hr	Channel 44: Offline mR/hr	Channel 45: Offline mR/hr
Channel 46: Offline mR/hr	Channel 47: Offline mR/hr	Channel 48: Offline mR/hr	Channel 49: Offline mR/hr	Channel 50: 0001.0 mR/hr

Color Code Key
High Alarm - Low Alarm - OverRange - Online - Det Fail - Error - Offline -

GENERAL: The Model 375 Ethernet sofware monitors and stores data from up to 50 Ethernet-enabled Model 375s. Instrument readings and status are displayed on the main screen. Ethernet cameras (optional) can capture a picture of what triggers the alarm. This program is relatively easy to setup and ideal for straightforward networks not involving any routers.

COMMUNICATION: Uses User Datagram Protocol (UDP) for basic communications on Local Area Network (LAN). The UDP port is user configurable from 50000 to 59999.

DISPLAY: The main window displays reading boxes for all 50 Model 375s along with their status, units and caption. Clicking on the channel name will display the last image and alarm information that has occurred since the program was running. Holding the mouse over the channel name will display a tool tip with the user-defined comment.

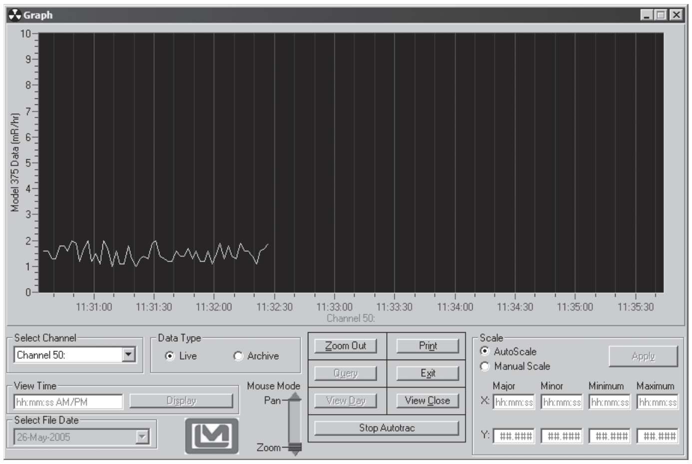
DATA LOGGING: Data is logged to a Microsoft Access® database and also a comma-delimited file. The rate at which the data is logged is user-defined and data can be logged at a different rate when an alarm occurs, which allows more data to be collected during the alarm. Readings are sent from the Model 375 every two seconds. An indicator bar under each reading changes color to indicate the current status of the monitor.

ALARM IMAGE WINDOW: When a high alarm occurs the image will be retrieved from the camera and displayed in a resizable window along with the date, channel caption and reading. The images are saved in the images folder under the installation path.

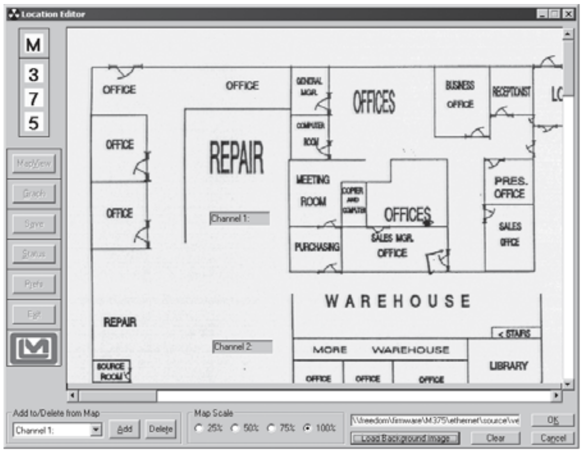
QUICK ALERT WINDOW: When a failure or alarm occurs, a window is displayed showing the channel, date, reading and type of event. This data is available until the window is closed.

E-MAIL SETTINGS TAB: The E-mail Setting tab allows the configuration of the e-mail capability of the software. Four sets of nine e-mail addresses are available separated by day/night and alarms/other events.

GRAPH VIEW WINDOW: The Graph view displays the readings from the Model 375 as a graph with options to view live or previously saved data (archive mode).



Select Channel: Channel 50:
Data Type: ● Live ○ Archive
View Time: hh:mm:ss AM/PM
Select File Date: 26-May-2005
Scale: ● AutoScale ○ Manual Scale
Major Minor Minimum Maximum
X: hh:mm:ss hh:mm:ss hh:mm:ss hh:mm:ss
Y: ##.### ##.### ##.### ##.###



Channel 1:
Channel 2:
Add to/Delete from Map: Channel 1:
Map Scale: ○ 25% ○ 50% ○ 75% ● 100%
\\freedom\firmware\M375\ethernet\source\ve

Gamma Scintillation

Model 44-2

Part No. 47-1532

Model 44-10

Part No. 47-1540

Common Specifications

INDICATED USE: Low-level, wide-energy gamma detection
ENERGY RESPONSE: Energy dependent
SUGGESTED INSTRUMENTS: General purpose survey meters, ratemeters, and scalers
OPERATING VOLTAGE: 500 - 1200 volts

Model 44-62

Part No. 47-1238

	44-2	44-10	44-62
SCINTILLATOR	1″ diameter x 1″ thick NaI (2.5 x 2.5 cm)	2″ diameter x 2″ thick NaI (5.1 x 5.1 cm)	0.5″ diameter x 1″ thick NaI (1.3 x 2.5 cm)
SENSITIVITY	Typically 175 cpm/µR/hr (^{137}Cs gamma)	Typically 900 cpm/µR/hr (^{137}Cs gamma)	Typically 49 cpm/µR/hr (^{137}Cs gamma)
RECOMMENDED ENERGY RANGE	50 KeV-1.5 MeV	50 KeV-3.0 MeV	50 KeV-1.5 MeV
PHOTOMULTIPLIER TUBE	1.125″ diameter (2.86 cm)	2″ diameter (5.1 cm)	0.5″ diameter (1.3 cm)
SIZE	2″ diameter x 7.3″ L (5.1 x 18.5 cm)	2.6″ diameter x 11″ L (6.6 x 27.9 cm)	0.9″ diameter x 7.8″ L (2.3 x 19.7 cm)
WEIGHT	1 lb. (0.5 kg)	2.3 lbs. (1.1 kg)	0.3 lbs. (0.1 kg)
BACKGROUND	1900 cpm	9750 cpm	600 cpm