PRESCO, Inc.
Baseline and 2005 Annual Water Sampling Report
Battlement Mesa Area, Garfield County, Colorado

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LIST OF ACRONYMS AND TERMS

AEC	Acronym for the Atomic Energy Commission
ALI	Annual Limit on Intake for occupational exposures to radionuclides established by the United States Nuclear Regulatory Commission. The ALI is the derived limit for the amount radioactive material taken into the body of an adult worker by inhalation or ingestion over a period of a year
Alpha Particles (α)	Radioactive particles consisting of two protons and two neutrons, the same as a helium nucleus. These particles can be shielded by a piece of paper and cannot penetrate the outer layer of dead skin cells, but pose a hazard if inhaled
Analyte	A substance or chemical constituent undergoing analysis or the substance being measured by an analytical procedure. Any chemical, parameter, or radionuclide in a water sample with a concentration or activity capable of be measured by a laboratory
Anion	A negatively charged ion
Aquifer	A body of rock that is sufficiently permeable to conduct groundwater and yield significant quantities of potable water to wells and springs
Aquitard	A confining bed of rock that retards but does not prevent the flow of water to or from an adjacent aquifer. An aquitard does not readily yield water to wells or springs, but may serve as a storage unit for groundwater
Background	Naturally occurring ionizing radiation from sources including cosmic radiation, terrestrial radiation, internal radiation from potassium in our bodies, and indoor radon concentrations
BART™	A patented biological activity reaction test biodetection system which can be customized to determine the aggressivity and composition of selected contsortia of microorganisms (bacteria)
Beta Particles (β)	Radioactive particles consisting of electrons. Beta particles can travel no more than 10 meters in air or about 1 centimeter in tissue, and can be shielded by a pad of paper. Beta particles can cause damage to skin cells in high doses outside the body and can cause damage to cells and critical organs when emitted inside the body through ingestion or inhalation

BTEX	Acronym for the volatile organic compounds benzene, toluene, ethylbenzene, and xylenes
Cation	A positively charged ion
CDPHE	Acronym for the Colorado Department of Public Health and Environment
CFU	Colony Forming Units (units for microbiological samples)
COGCC	Acronym for the Colorado Oil and Gas Conservation Commission
CO_2	Chemical formula for carbonate
Connate Water	Water that is trapped inside a bedrock formation and was present at the time that the sediments were deposited, as opposed to meteoric water that has fallen as precipitation and percolated into the ground
CPM	Counts per minute. A measure of radioactive disintegration
Curie (Ci)	A unit of radioactivity measurement. One curie equals 3.7×10^{10} disintegrations per second. One Becquerel (Bq) is the International System of Units (SI) unit and equals 1 disintegration per second
DAC	Derived Air Concentrations. The DAC represents occupational exposure limits to radionuclides established by the United States Nuclear Regulatory Commission. The DAC is defined as the concentration of a radionuclide in air and the time of exposure to that radionuclide in hours
Darcy (d)	A standard unit of permeability, equivalent to the passage of one cubic centimeter of fluid of one centipoise viscosity flowing in one second under a pressure differential of one atmosphere through a porous medium having an area of cross section of one square centimeter and a length of one centimeter.
DO	Abbreviation for dissolved oxygen, or the concentration of dissolved oxygen in a water sample
DOE	United States Department of Energy (formerly known as the AEC)
EPA	United States Environmental Protection Agency
EPA Method	A specific method required by the EPA for laboratory analysis of specific parameter or analyte and is followed by the method number

Fission Products	Radionuclides created during the detonation of a nuclear device or products resulting from the nuclear fission of uranium
Gamma (γ)	gamma radiation is electromagnetic with high energy, similar to x-rays. Gamma radiation is given off by the nucleus of radionuclides, while x-rays come from outside the nucleus, and can travel long distances and penetrate through the human body. Gamma radiation is a hazard to all organs from both inside and outside the body. Gamma radiation can be shielded by heavy materials such as lead and barium
gpm	gallons per minute
Half-life	The time it takes for half of the radioactive atoms present to decay. The half-life is dependent on the radionuclide, some having half lives measured in seconds, days, years, or in millions of years
HCO_3	Chemical formula for bicarbonate
LANL	Los Alamos National Laboratory located in Los Alamos, New Mexico
MCi	A mega curie equals one million (10^6) curies
MCL	Maximum Contaminant Limit(s) set by the EPA as the maximum concentration or activity allowed in a municipal drinking water supply
MDA	Minimum Detectable Activity is the minimum activity emitted by a given radionuclide that the laboratory can detect
MDL	Method Detection Limit is the same as the laboratory reporting limit or the minimum concentration of an analyte that the laboratory can accurately quantify using a particular laboratory method
meq/L	milliequivalents per liter is a measure of ionic charge in an aqueous solution. Used for both cations, positively charged ions, and anions, or negatively charged ions
Methane	A volatile organic compound, with chemical formula CH_4. Methane can form as a naturally occurring byproduct of bacterial decay of organic matter, forming "biogenic" methane caused by reduction of CO_2. Methane can also form as a result of thermal breakdown of heavier hydrocarbons, and is a large constituent of natural gas as formed by geologic processes, known as "thermogenic" methane.
mg/L	milligrams per liter One milligram equals one thousandth (10^{-3}) of a gram per liter of water, and is approximately equivalent to parts per million

millidarcies	The customary unit of measurement of fluid permeability, equivalent to 0.001 darcy, abbreviated md.
mrem	millirem (See "rem")
MTBE	methyl tertiary butyl ether is a volatile organic compound
NO_2	Chemical formula for nitrites
NO_3	Chemical formula for nitrates
pH	is a measure of acidic or basic conditions of water. A pH of 7.0 is "neutral" where low pH readings (4.0) are acidic, and higher pH readings (10.0) are basic. Natural pH conditions range from 6.0 standard units (su) to 9.0 su
ppb	parts per billion, approximately equivalent to micrograms per liter
ppm	parts per million, approximately equivalent to milligrams per liter
pCi/L	picoCuries per liter is a measurement of radioactivity in water. One picoCurie is one trillionth of a curie
PO_4	Chemical formula for phosphate
Project Rulison	An experiment conducted by the AEC and a private oil company on September 10, 1969 involving the detonation of a nuclear device to stimulate natural gas production from low permeability sandstone at a depth of 8,426 feet
QA/QC	Quality Assurance/Quality Control is an evaluation of the accuracy and precision of laboratory analytical results
Radionuclide	a radioactive isotope of a chemical element
Radionuclides of Interest	Those radionuclides which could be entrained in the natural gas or encountered during drilling activities. Concentrations of radionuclides related to Project Rulison are not expected to be encountered
rem	A measurement of radioactivity dose. A radiation dose is a measure of the amount of energy absorbed by body tissues. One mrem is one thousandth (10^{-3}) of a rem

roentgen (R)	Measure of radiation exposure, or the amount of ionizing radiation produced by gamma radiation or x-rays in the air. An exposure of one milliroentgen (mR) would result in a dose of approximately one millirem (mrem)
SAR	Sodium Adsorption Ratio. SAR is an agricultural measurement of soils with an accumulation of exchangeable sodium, or salt impact, characterized by poor tilth and low permeability. The equation to calculate SAR is expressed as the milliequivalent concentration of sodium divided by the square root of one-half the milliequivalent concentrations of calcium and magnesium added together.
Shielding	The use of a physical barrier, such as a lead apron, as protection from radiation
SO_4	Chemical formula for sulfate
Solifluction	Unconsolidated, water logged deposits resulting from erosion and mass wasting of sediments derived from alluvial and colluvial debris flows
TDS	Total Dissolved Solids. TDS is a measure of the amount of dissolved minerals, principally salts, in water.
Tritium	A radioactive form of hydrogen, H-3, forms naturally by reactions in the upper atmosphere with cosmic rays, and also by the detonation of nuclear devices
TU	Tritium Units, an older unit of measurement equal to 3.21 pCi/L tritium
µd	microdarcies, a unit of fluid permeability equal to 0.000001 darcies, representative of low permeability sediments or media
µg/L	micrograms per liter, or one millionth (10^{-6}) of a gram per liter of water, approximately equivalent to parts per billion
µCi/L	microCuries per liter, or one millionth (10^{-6}) of a curie, a measurement of radionuclide activity concentration per liter of water
Unconsolidated	A sediment that is loosely arranged, unstratified, or whose particles are not cemented together, or “lithified”as a sedimentary rock, occurring either at the surface or at depth. Soil material that is in a loosely aggregated form.
USGS	Acronym for the United States Geological Survey

1.0 Introduction

PRESCO Inc. (PRESCO) retained Cordilleran Compliance Services, Inc. (Cordilleran) to conduct baseline and annual water sampling activities associated with PRESCO's development of natural gas resources in the vicinity of Battlement Mesa, Garfield County, Colorado. This report presents the data collected during the 2004 baseline water sampling event and the 2005 annual water sampling event.

1.1 Purpose of Monitoring

The purpose of the water quality monitoring was to document baseline water quality conditions prior to PRESCO's development of natural gas resources in the area and to assess potential water quality impacts during natural gas exploration and production (E&P) activities. PRESCO and Cordilleran developed a Baseline Water Sampling Work Plan in September 2004. Since the Work Plan also contained monitoring activities for PRESCO's gas well drilling, it was finalized in January 2005 and revised in May 2005. The Work Plan outlined the following objectives of the water sampling activities:

1.) Review available geologic and groundwater information to develop an understanding of the local hydrogeology;
2.) Identify potential receptors including water supply wells and surface waters;
3.) Identify baseline sample locations including water supply wells, monitoring wells, springs, and surface waters;
4.) Establish protocols for collecting groundwater and surface water samples; and
5.) Evaluate the data for an ongoing sampling program.

Cordilleran conducted baseline water sampling at fourteen locations in November 2004. PRESCO began natural gas well drilling activities in the fall of 2005. PRESCO has prepared their drilling program and natural gas well completion plans in order to protect area water resources, the public, and the environment. Special consideration has been given to development of natural gas resources within proximity of Project Rulison test site. Figure 1 presents the sample locations described in this report. Table 1 presents the sample locations and well completion information. Table 2 presents the Analyte Reference Table, or the analytes for which analysis was performed.

1.2 Project Rulison Test

According to Colorado Oil and Gas Conservation Commission's Project Rulison Study, (Macke, 1998) the Atomic Energy Commission (AEC), a predecessor to the United States Department of Energy (DOE), and Austral Oil Company, an independent oil company, co-sponsored the Rulison nuclear test under the Plowshare Program. The Plowshare

Program consisted of a series of nuclear and conventional explosive tests conducted to explore peacetime uses of nuclear devices. The Project Rulison nuclear test took place on September 10, 1969 with the detonation of a 40-kiloton device at a depth of 2,568 meters (8,426 feet) and was designed to stimulate natural gas production from low-permeability sandstone of the Mesa Verde Formation. The Project Rulison experiment utilized a uranium nuclear device built by Los Alamos National Laboratory (LANL) in New Mexico and was installed within the Hayward #25-95 (R-E) emplacement well located in the Northeast Quarter of the Southeast Quarter of Section 25, Township 7 South, Range 95 West of the Sixth Principal Meridian.

According to the Project Rulison Manager's Report (AEC 1973), the detonation created a roughly spherical to egg-shaped cavity where the surrounding sandstone and shale were vaporized and the melted rock cooled to form a glass, lining the cavity. The Project Rulison experiment also resulted in a zone of fractured rock surrounding the cavity, and a "chimney" of rock rubble above and surrounding the shot point. The DOE calculated the chimney cavity radius at 75 feet, and the outer radius of the fracture zone calculated at 220 feet. Most of the radionuclides, or residual radioactive elements from the detonation of the Rulison device, are trapped within the glass slag, and are immobile. Radionuclides possibly entrained in natural gas present within the cavity or in the surrounding fracture zone include tritium, carbon-14, and krypton-85. Table 3 presents radionuclides of interest, or those fission products that remotely could be encountered in the development of natural gas resources. Radioactivity is expected to represent background.

Approximately one year after the September 10, 1969 detonation a separate re-entry well (R-EX) was directionally drilled into the chimney cavity and fracture zone created by the nuclear detonation. Natural gas production testing from the cavity began in 1970 and was completed in April 1971. The Project Rulison test produced a total of 450,000,000 cubic feet of gas, which was flared to the atmosphere at the site from 1970 to1971. Cleanup was initiated in 1972, and the wells were plugged and abandoned in 1976.

According to the COGCC Project Rulison Study (Macke, 1998) and the plaque onsite drilling of natural gas wells is not permitted below 6,000 feet inside of "Lot 11", also described as the Northeast Quarter of the Southwest Quarter of Section 25, Township 7 South, Range 95 West, of the 6th P.M., on land containing the Hayward 25-95 (R-E) well. The DOE established this 40-acre area and prohibits drilling below a depth of 6,000 feet. The DOE also entered into an agreement with the COGCC to notify the DOE of any application to drill within a three mile radius of the Project Rulison test site. This three mile radius does not prohibit drilling and development of natural gas resources, but allows the DOE the opportunity to conduct testing. The COGCC met with the DOE prior to 1998 to address concerns that drilling activities were encroaching on the Project Rulison site. The COGCC Order #139-43 on February 10, 2004 approved PRESCO'

request for an order to amend the 640 acre drilling for wells in the Williams Fork but required a hearing before the Commission prior to approving any permits to drill for wells located within ½ mile of the Project Rulison site.

1.3 Battlement Mesa Setting, Geology, and Hydrogeology

Battlement Mesa is located in central Garfield County, Colorado on the Colorado Plateau along the southern edge of the Piceance Basin, a geologic structural depression in the earth's crust created as a result of tectonic forces associated with the uplift of the Colorado Rocky Mountains and the Colorado Plateau. During the Cretaceous geologic period, much of the western United States was occupied by a shallow inland sea. Marine and near shore sediments containing organic materials became deeply buried and the resulting heat and pressure from the earth acting on these organic materials produced the natural gas resources contained within the Mesa Verde Formation.

The Mesa Verde Formation is overlain by impermeable sedimentary rock including the Tertiary Wasatch Formation and Green River Formation. These thick sedimentary rock strata limit the downward migration of surface water and are covered by unconsolidated sediments and boulders of basalt eroded from the top of Battlement Mesa.

A review of the information contained in the database maintained by the State Engineer's Office – Division of Water Resources confirms that water wells in the area are typically less than 250 feet deep, with water being produced from "All Unnamed Aquifers" indicating that this water is not being produced from a named bedrock aquifer. The underlying bedrock units of the Green River Formation, Wasatch Formation, and Mesaverde Formation are thousands of feet thick and are not designated as aquifers. These formations are generally considered confining units or aquitards (Robson and Banta, 1995). The Ohio Creek member of the Mesa Verde Formation is an aquifer in some places in the region; however, the Ohio Creek member is not an aquifer on Battlement Mesa as described below.

Prior to conducting the Project Rulison test, the DOE worked with the United States Geologic Survey (USGS) to log the emplacement well where the Rulison device was to be detonated. The USGS logged the emplacement well and tested bedrock zones for the presence of groundwater. These results were summarized in USGS Open-File Report 474-68, Geohydrology – Project Rulison, Garfield County, Colorado with a section on Aquifer Response, March 1970 (Appendix A). The USGS concluded that:

1.) *"all zones below a depth of 6,129 feet in the Rulison exploratory hole that yielded any water during drilling, or zones interpreted from geophysical logs as being likely to contain water, were hydraulically tested. The pressures recorded during the drill-stem tests of the different zones indicated negligible or no fluid entry to*

the hole while the test tool was open. No fluid was recovered on any of the swab tests performed during the drill stem tests."

2.) *"Hydrologic tests on the Rulison exploratory hole indicate little or no water occurs in the Ohio Creek conglomerate and the Mesa Verde Group which are the stratigraphic units most likely to yield water to that hole."*

3.) *"Studies of preshot and postshot hydrologic conditions indicate that the detonation did not significantly or permanently affect wells, springs, steams, shallow aquifers, or reservoirs in or near the Rulison site." and*

4.) *"The ground-water resources in the Rulison area are confined primarily to unconsolidated surficial deposits (e.g. flood-plain deposits and terrace and fan gravel shed from the flanks of the mesa). Essentially all the wells and most of the springs in the area derive their water from these deposits. The underlying bedrock formations generally have low permeability and yield little or no water."*

The unconsolidated, eroded, surficial deposits consist of mudflows, talus accumulations, fan and pediment gravel, slump blocks, and alluvium of Battlement Creek and the Colorado River. These deposits generally range in thickness from 20 feet to 40 feet, but locally may be more than 100 feet thick. Ground water occurs in many of these deposits yielding water to area water wells and springs. According to the Geologic Map of the Rulison Quadrangle, 1988, the surficial sediments in the Battlement Creek drainage consist of mudflow and fan-gravel deposits that are derived largely from, the slow downward migration of waterlogged soil, known as solifluction deposits, located higher up in the drainage. These deposits are poorly sorted, with clasts ranging in size from pebbles, to cobbles, and boulder sized clasts, consisting primarily of unweathered basalt, in a matrix of coarse sand and gravel, but also containing some sandstone, marl, siltstone, and claystone.

Figure 2 prepared by Mr. Brian Richter, U.S. Capitol Energy and PRESCO's Managing Geologist for the Battlement Mesa Project, shows the relationships between the bedrock units and overlying unconsolidated deposits.

1.4 Previous Water Quality Studies

Several water quality studies have been conducted in the vicinity of Battlement Mesa in conjunction with Project Rulison, and for other purposes. A description of some of these studies follows.

United States Geological Survey

The DOE worked with the USGS to collect water samples from area water wells, springs, and surface water resources in the vicinity of the proposed Rulison test site prior to conducting the Project Rulison test, as well as during, and after the Rulison test. The water samples were analyzed for a variety of water quality parameters, elements, and compounds, as well as for radionuclides including tritium, a radioactive form of

hydrogen, and gamma emitting radionuclides. The USGS water sampling activities were conducted from 1967 until 1972. The results of these analyses indicated that concentrations of tritium were detected that represented naturally occurring concentrations or atmospheric tritium that results from world wide nuclear testing in the 1950s and 1960s. The USGS report presents the tritium data in tritium units (TU), an older unit used in geology and hydrology references. The TU is an estimated ratio of tritium atoms to stable hydrogen atoms prior to nuclear weapons testing, and is set at 1 x 10^{18} atoms. One TU is equal to 3.231 picoCurie per liter (pCi/L) of water. A copy of the USGS report is included as Appendix A.

United States Environmental Protection Agency

In 1972 the United States Environmental Protection Agency (EPA) took over the water sampling activities from the USGS. The EPA has conducted annual water sampling, as well as sampling other environmental media in the area, for tritium and gamma emitting radionuclide analysis since 1972. A copy of the EPA Annual Water Quality Report for 2004 is included as Appendix B. Copies of reports from previous years are available from the DOE website www.doe.gov. The EPA has sampled the Grand Valley municipal supplementary drinking water springs, water supply wells for five local ranches, a surface water sample from Battlement Creek, and two surface discharge spring sites in the vicinity of the Project Rulison test site. According to the EPA Annual Report for Calendar Year 2004:

- *"Tritium has never been observed in measurable concentrations in the Grand Valley Springs. All of the remaining sampling sites show detectable concentrations of tritium, which have generally exhibited a stable or decreasing trend over the last two decades."*
- *"The detectable concentrations of tritium activities are consistent with values found in current precipitation and, perhaps, a small residual component remaining from clean-up activities at the site."*
- *"Desert Research Institute analysis, indicates that most of the sampling locations at the Rulison site are shallow, drawing water from the surficial aquifer, and therefore, unlikely to become contaminated by radionuclide migration from the Project Rulison cavity."*

All gamma-ray spectral analysis results indicated that no man-made gamma ray emitting radionuclides were present above the minimum detectable activity (MDA). The EPA did not analyzed water samples for other parameters.

Colorado Oil and Gas Conservation Commission

The Colorado Oil and Gas Conservation Commission (COGCC) collected water samples for water quality parameters from area water 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 samples for radionuclides. Copies of analytical tables from the COGCC are presented as Appendix C.

1.5 Ionizing Radiation

Radiation is a form of kinetic energy, or energy in motion. Ionizing radiation has enough kinetic energy to strip electrons from atoms. Radioactive decay is the process by which a radioactive atom releases energy in the form of radiation to become more stable. A half-life is the time that it takes for half of the radioactive atoms present to decay. The half-life is dependent on the radionuclide and may occur in a matter of seconds, days, years, or even millions of years.

Not all ionizing radiation released during the decay process has the same amount of energy, and the energy released is dependent on the radionuclide. The three types of radiation include:

- alpha particles (α) which consists of 2 protons and 2 neutrons, the same as a helium nucleus;
- beta particles (β) which consist of an electron; and
- gamma (γ) radiation and x-rays which consist of electromagnetic radiation, are similar to light, ultraviolet light, and microwaves, but have more kinetic energy.

The type of radiation and energy released are dependent on the radionuclide. Ways to control radiation dose to the human body are dependent on the following factors:

1. Minimize the time of exposure to the source of radiation;
2. Maximize the distance to the source of radiation; and
3. Use shielding, or a physical barrier, to reduce the exposure to the human body.

Alpha radiation has the least amount of energy, traveling only about five centimeters in air, or 0.01 centimeters in tissue. Alpha particles can be shielded by a piece of paper and are not a hazard outside the body since they cannot penetrate the outer layer of skin cells. If inhaled, alpha particles can be a high hazard inside the body because they can cause a lot of damage to cells in a small volume of tissue.

Beta Particles, as electrons, are smaller in particle size, and will travel no more than 10 meters in air or about 1 centimeter in tissue. Beta particles can be shielded by a pad of paper, and can cause skin damage at high dose levels from outside the body. They can cause damage to cells and critical organs when the beta particles are emitted inside the body when ingested or inhaled.

Gamma rays and x-rays are electromagnetic radiation with high energy. Gamma radiation is given off by the nucleus; whereas x-rays come from outside the nucleus.

Gamma radiation can travel long distances and can penetrate through the body. Gamma radiation is a hazard to all organs from both inside and outside the body. Gamma rays can be shielded by heavy materials such as the cab of a vehicle, lead apron, barium compounds, or thick sedimentary rock sequences.

1.6 Background Radiation

Background radiation is ionizing radiation from natural sources including cosmic radiation and sources within the earth, and those that are incorporated in food and water, and in tissues of the human body. Natural background radiation originates from three primary sources: cosmic radiation, terrestrial sources, and radon.

Cosmic Radiation

All living things on the earth are constantly bombarded by radiation from outside our solar system. This radiation interacts in the atmosphere to create secondary radiation that rains down. The dose rate from cosmic radiation varies in different parts of the world based largely on the geomagnetic field and land elevation. The background radiation levels on the Colorado western slope range from 50 millirem (mrem) to 100 mrem per year.

Terrestrial Radiation

Naturally occurring radioactive material is found throughout nature in the soil, rocks, water, air, and vegetation. The primary radionuclides responsible for terrestrial radiation are potassium, uranium, and thorium. These radionuclides undergo a well documented radioactive decay process which yield daughter products that are distinct from the fission products released during the detonation of a nuclear device, such as the one used for the Project Rulison experiment.

1.7 Radionuclides of Interest

Radionuclides of interest are those identified by previous water quality studies conducted by the USGS and EPA, who have conducted sampling prior to Project Rulison, and annually in the thirty-six years since the experiment was conducted. The historic data from these studies indicates that concentrations of tritium are consistent with background levels, and that gamma emitting radionuclides have not been detected.

Tritium

The primary radionuclide analyzed by the EPA at underground nuclear test sites is tritium. As a product of underground nuclear testing, high levels of tritium are found in the test cavities. Some of the tritium is expected to be in the form of free water in the cavity, and also as water vapor. Since tritium may be incorporated into water molecules, it is expected to be the first radionuclide to migrate from a test cavity. Therefore, tritium serves as an indicator of radionuclide migration. Tritium has a half-life of 12.3 years.

Most hydrogen is made up of one proton, and an orbital electron, but tritium has two extra neutrons in the nucleus. In nature, tritium is produced when cosmic rays interact with nitrogen (^{14}N) or oxygen (^{16}O), causing spallation from the nuclei, and forming tritium (^{3}H) and carbon (^{12}C), or when cosmic rays interact with deuterium (^{2}H). These interactions primarily occur in the upper atmosphere and the resulting tritium falls to earth as precipitation, as rain or snow. The USGS and EPA data indicate the presence of naturally occurring, atmospheric tritium in surface water samples and samples from shallow aquifers, and springs closely connected to shallow aquifers.

Prior to atmospheric nuclear weapons testing, the global equilibrium tritium inventory was estimated at 80 megaCuries (MCi). Surface waters such as lakes and streams are estimated to have had a concentration of 5 to 10 pCi/L. Post World War II atmospheric testing caused an increase in atmospheric input rate of about 6 to 7 MCi per megaton yield. The United States and former Soviet Union stopped their above-ground tests in the early 1960s; however, China did not stop until much later. With rapid hydrosphere mixing, a half-life of 12 years, greater than natural level concentrations of man-made tritium can now be found in surface and shallow groundwaters. These tritium levels have been declining back to the natural background levels with the reduction in aboveground nuclear weapons testing.

The drinking water supply wells in the area produce water from shallow, unconsolidated aquifers, and consequently, do not represent groundwater from the bedrock formations, known as connate water. Connate water is trapped in the pore spaces and fractures within the sedimentary rock, which lacks sufficient permeability to allow this water to be produced. Connate water typically has much higher total dissolved solids (TDS).

Project Rulison was conducted at a depth of 8,425 feet, more than a mile and half below ground surface, and is below sea level. The Project Rulison test cavity is well below the depth of shallow water resources used for drinking water in the area. Connate water trapped in the Mesa Verde Formation is largely immobile, and dates to the late Cretaceous when these sediments were deposited, millions of years before the present. Since tritium has a 12.3 year half-life, naturally occurring tritium is not present in the Mesa Verde Formation, and tritium found within the Mesa Verde could only be from the Rulison cavity.

The concentrations of tritium are measured in picoCuries, or one trillionth of a Curie, in a liter of water. Therefore, the laboratory is capable of measuring extremely low levels of tritium radioactivity. The EPA has established a drinking water standard for tritium of 20,000 pCi/l, expected to result in a total body dose of 4 millirems (mrem) per year. Due to the time lapsed since the test in September 1969, any tritium remaining is approximately one-eighth of the original amount generated during the Project Rulison test, and the extremely low permeability of the formation inhibits migration of the tritium

away from the cavity. The maximum permissible exposure whole body burden to tritium is 1 milliCurie (mCi) or 1,000,000,000 pCi. Table 3 presents the occupational exposure limits for tritium and other radionuclides of interest.

Tritium is one of the weakest beta particle emitter known. The range of the most energetic tritium beta particles is only about 5 millimeters in air or 0.005 millimeters in water or soft tissue, making it nonhazardous outside the body, but its lack of energy presents a detection problem. Where other radionuclides can be detected by their penetrating radiation, tritium has to be introduced directly inside the detector or counter in order to be measured. Therefore, water samples must be sent to a laboratory to be able to detect the presence of tritium.

Tritium is almost always found as water, or "tritiated" water. Once tritium enters the body it disperses quickly and is uniformly distributed throughout the body. Since tritium is in the form of water and disperses through the body, there are no target organs as is the case with other radionuclides. Tritium is excreted through urine within a month or so after ingestion. Organically bound tritium can remain in the body for a longer period. While not impossible, ingesting a large enough dose of tritium to cause any significant harm to a person is unlikely.

Gamma Emitting Radionuclides

Since gamma radiation has the highest energy, and is produced in association with the release of alpha particles and beta particles during decay of certain radionuclides, gamma emitting radionuclides are also of interest. According to the EPA reports, the first time samples are collected from a well, concentrations of strontium isotopes, plutonium isotopes, and uranium isotopes are determined, in addition to the tritium analysis. At least one, one gallon capacity sample, from each site is analyzed by gamma spectrometry.

In the absence of nuclear testing, ambient gamma radiation rates naturally differ among locations since rates vary with altitude (cosmic radiation) and with radioactivity in the soil (terrestrial radiation). Ambient gamma radiation will also vary slightly at a location due to changes in weather patterns and other environmental factors.

2.0 Baseline and Annual Sampling

The following sections describe the water sample locations, field sampling techniques, field screening data and observations, and other information about the sample locations.

2.1 Water Sample Locations

The scope of work consisted of sampling a representative number of water wells, springs, and surface water locations in the vicinity of the Project Rulison test site to establish baseline conditions prior to PRESCO's natural gas well drilling activities. The water sample locations requested by PRESCO include many of the same water locations sampled by the USGS, EPA, and COGCC during previous studies. Access letters were sent out to well and spring owners requesting permission to sample prior to the 2004 baseline and 2005 sampling events. After obtaining permission and making arrangements with the water well or spring owners, the baseline water samples were collected in November 2004, and the 2005 samples were collected in October 2005.

Participation in the baseline and annual sampling events is voluntary on the part of the well or spring owner. PRESCO provided a brief letter report, table comparing the results to the EPA drinking water standards, and a copy of the water results to each of the well or spring owners in exchange for allowing Cordilleran to collect a sample for laboratory analysis.

A total of 14 water sample locations and two duplicate samples were collected during the 2004 baseline sampling event, and again during the 2005 annual sampling event. The water sample locations included seven water supply wells, four springs including the Grand Valley municipal springs, and three surface water sampling locations including Battlement Creek near the USGS gauging station, Hayward Creek near the Project Rulison site, and Monument Creek near the Parachute water treatment facility. Figure 1 shows the 14 sample locations.

2.2 Field Parameter Screening Data

Field parameters were measured using a *Quanta Hydrolab* water quality meter including pH, dissolved oxygen, specific conductivity, temperature, total dissolved solids, and turbidity. Field measurements are presented in Table 4. The field parameters were measured by placing the *Quanta* probe into a five gallon bucket with water purged from the well or spring hydrant and garden hose, or directly within the stream flow at the surface water sampling location where the flow was sufficient to be measured. Where possible, approximately ten gallons of water were purged, estimated by bucket fill from the well and spring hydrants prior to sampling. The water sampling locations were screened for the presence of radioactivity using a Ludlum Model 3 survey meter and

pancake probe. Levels of radioactivity were consistent with background levels. All field parameters including visual and olfactory observations were recorded in the field logbook. Samples were submitted for laboratory analysis of analytes listed in Table 2.

2.3 Water Sample Collection

Water samples were collected from the well or spring hydrant and garden hose at each of the private well or spring locations. Surface water samples were collected in an unpreserved bottle from the stream flow which was then used to fill the other bottles in the sample suite. The samples were collected in a suite of laboratory provided sample containers some of which contained preservatives for individual analytes. The samples were stored in plastic coolers on ice pending shipment to the laboratory. The following locations were sampled during the 2004 baseline and 2005 annual water sampling events. The sample identification for each of the locations is shown in parentheses.

- Juanita Satterfield, Guy Botkin's water well, (JLS-W1) from Morrisania Mesa;
- Battlement Creek surface water near the USGS gauging station (USGS-BC1);
- Cary Weldon's water well (CW-W2) from near the Project Rulison site;
- Hayward Creek surface water (HC-S2) near the Project Rulison site;
- Lynn Shore's water well (LJS-W3) from Morrisania Mesa;
- the Grand Valley Springs (GVS-SP1) from Morrisania Mesa;
- Ethel Gardner's spring (EG-SP2) from near the Project Rulison site;
- Wesley Kent's spring (WK-SP3) from near the Project Rulison site;
- Judi Hayward's 96 Ranch spring (LH96-SP4) near the Project Rulison site;
- Joan Savage and Roy Savage's (RS-W4) water well east of Doghead Mountain;
- Christy Koenke's (CK-W5) water well from Morrisania Mesa;
- Tim and Karla Jacobs'(TJ-W6) water well from Morrisania Meas;
- Pat and Randy Warren's Take a Break Ranch well (PW-W7); and
- Monument Creek surface water outside of the Parachute water treatment facility (MC-S3).

2004 Baseline Sampling Event

The baseline water sampling event included samples collected from 14 locations on November 9 and 10, 2004, and also on December 2, 2004, and December 15, 2004. A duplicate sample (RW-W8) was collected from the Take a Break Ranch water well, and a partial duplicate, for BTEX only, was taken from the (JH-SP5) was collected from the 96 Ranch spring during the 2004 baseline sampling. The sample results correlated well with the PW-W7 and LH96-SP4 samples, indicating that the laboratory results are reproducible.

The baseline water sample from the Grand Valley springs was collected from the pipe into the settling basin. The chlorinator had been reportedly been turned off for

maintenance of the Grand Valley springs. Therefore the sample was collected from the inlet pipe to the settling basins without affecting water quality parameters. This is the location where the EPA reportedly collects their annual samples; however, radionuclides are not affected by chlorinization. The absence of bacteria reported for the 2004 BART™ analysis suggests that residual chlorine may have been present.

2005 Annual Water Sampling Event

In addition to the 14 locations sampled during the 2004 baseline event, a sample was collected from a spring fed drainage to a culvert near PRESCO's BM 36-23 well pad. The 2005 Annual Sampling Event was conducted on October 17 and 18, 2005, and the BM 36-23 Culv sample was collected on October 21, 2005. Additional samples were collected for volatile organics analysis on December 20 and December 28, 2005 due to laboratory irregularities discussed in the next section.

Duplicate samples were collected from Wesley Kent's spring (WK-SP3D) and from the well at a house owned by Christy Koeneke (CK-W5D) during the 2005 annual water sampling event. These samples did not show any significant differences from the WK-SP3 and CK-W5 samples, indicating that the laboratory results were reproducible.

At the time of the 2005 water sampling event was collected from the spring box shed since the chlorination unit had not been deactivated, so the decision was made to collect the water sample from the top of the spring box "upstream" of the chlorination unit. Cordilleran was later informed that this flow was from only one of the springs, and that the flow fed from the other springs is piped into the bottom of the spring box. In the future, Cordilleran will request that the chlorinator be deactivated a couple of hours prior to sampling so as to not affect the water chemistry.

2.4 Analyte List and Laboratory Parameters

The water samples collected from the Battlement Mesa area included analysis for the analytes listed in Table 2. During the 2004 baseline analysis the water samples were submitted to ACZ Laboratories in Steamboat Springs, Colorado, and for the 2005 annual water sampling event the samples were submitted to Paragon Analytics (Paragon) in Fort Collins, Colorado. The BART samples were analyzed by Grand Junction Laboratories, in Grand Junction, Colorado for both the baseline and 2005 water sampling events. ACZ Laboratories subcontracted Hazen Research of Golden, Colorado to analyze the 2004 baseline samples for tritium by the conventional method.

During the 2005 sampling event holding times were exceeded on a four of the BTEX samples collected, including the samples from the 96 Ranch (LH96-SP5) and from the Take a Break Creek Ranch (PW-W7) samples and two trip blanks. Paragon also reported benzene concentrations in one of their method blanks, and benzene was also reported in samples from the Grand Valley Springs and Ethel Gardner's spring. Additional samples were collected from these locations on December 20, 2005 and submitted to Evergreen

Analytical in Wheat Ridge, Colorado for analysis of BTEX, which indicated that benzene was not detected.

2.5 Well Completions

A review of information obtained from the Colorado Department of Natural Resources, State Engineer's Office, Division of Water Resources, indicates that the water wells in the Battlement Creek area are producing water from the unconsolidated materials including colluvium and alluvium. The water well depths range from 98 feet to 250 feet below ground surface. The well logs indicate that the wells are completed within the clays, silts, and basaltic or "volcanic rock" cobbles that comprise the mudflow and fan-gravel deposits described on the Geologic Map of the Rulison Quadrangle (Yeend, Donnell, Smith, 1988).

Two of the seven wells Cordilleran sampled were completed into bedrock. Mr. and Mrs. Weldon's well is completed to a depth of 98 feet, with a screened interval from 60 feet to 90 feet, producing water from a gravel interval at the interface with the Wasatch bedrock. The well was drilled eight feet into the Wasatch Formation to provide a sump. The well owned by Mr. and Mrs. Warren, is completed to a depth of 250 feet below ground, with a screened interval from 215 feet to 240 feet, producing water from gravels at the bedrock interface, and ten feet into the Wasatch Formation, from 240 feet to 250 feet. The remaining five wells Cordilleran sampled are completed entirely within the mudflow and gravel-fan alluvium and colluvium, as are the springs present in the vicinity of the Project Rulison site. These water sources contain meteoric water and may be directly or indirectly in communication with surface water from Battlement Creek and its tributary streams.

3.0 Laboratory Analytical Results

The following sections present the laboratory analytical data collected during PRESCO's 2004 baseline and 2005 annual water sampling events. The analyses for the 2004 baseline samples were performed by ACZ in Steamboat Springs, Colorado, and the analyses for the 2005 results were performed by Paragon, in Fort Collins, Colorado. The BART™ analyses were performed by Grand Junction Laboratories, in Grand Junction, Colorado. The two sets of analytical results for individual parameters correlate very well between the two laboratory data sets. Copies of the 2004 baseline analytical results are presented in Appendix D, and copies of the 2005 annual water quality results are presented as Appendix E. Stiff diagrams presenting a graphic representation of the major cations and anions are presented in Appendix F, and are plotted on Figure 3.

3.1 2004 Baseline Results

The 2004 baseline analytical results were performed prior to PRESCO's drilling activities in the Battlement Mesa area. The samples were submitted to ACZ Laboratories; however, ACZ subcontracted Hazen Research in Golden, Colorado to perform the tritium analysis. The tritium results indicate that tritium concentrations were consistent with background activities.

The gamma spectrometry performed by ACZ did not indicate the presence of fission products associated with the Project Rulison test. Man-made radionuclides, Cobalt-60 (half-life 5.27 years) in sample LH96-SP4, and Sodium-22 (half-life 2.6 years) in sample JLS-W1, were reported slightly above the laboratory minimum detectable activity (MDA) in a couple of the baseline samples. Cobalt-60 is an activation product; however, it has a half-life of 5.3 years and any residual Cobalt-60 from Project Rulison would have decayed out so it is most likely an artifact in the analysis. Sodium-22 is an accelerator produced nuclide with a half-life of 2.6 years. It would not be related to Project Rulison (Johnson, personal communication). These radionuclides were not detected in the 2005 annual samples from these sample locations.

The results indicated low concentrations of naturally occurring radionuclides, such as those involved in the uranium and thorium decay series. Lead-210 activities elevated above published background were present in water samples from some of the well and spring locations sampled. Lead-210 is a naturally occurring radionuclide in the uranium decay series and is not likely associated in any way with Project Rulison or the gas drilling operations in the Battlement Mesa area. This is a mineralized area so it is not surprising that elevated levels of naturally occurring radionuclides would be present in ground water. The EPA has not set a specific standard for Pb-210 it is included in the

dose limit of 4 mrem per year for beta-gamma emitters. (Johnson, personal communication). All of the Lead-210 were reported by ACZ, and were not subsequently detected in the 2005 samples analyzed by Paragon Analytics. Therefore, the Lead-210 results may be a laboratory bias.

The radionuclide concentrations were well below the Nuclear Regulatory Commission (NRC) occupational standards for these radionuclides and are shown on Table 3. Field screening measurements with the Ludlum meter in counts per minute (CPM) are presented in Table 4. Cumulative results for tritium, volatile organic compounds, metals, inorganic compounds, and bacteria are presented in Table 5.

The ACZ analytical results for BTEX, MTBE, and Methane, indicate that these volatile organic compounds were not detected in the baseline water samples, with the exception of estimated concentrations of BTEX detected in the water sample JLS-W1 and estimated concentration of toluene in the GVS-SP4 sample. These concentrations were reported at concentrations between the method detection limit (MDL) and the practical quantitation limit (PQL), and were qualified with a "J."

Analytical results for the inorganic parameter analysis indicate concentrations of anions, metals, and water quality parameters were within expected ranges. The first batch of water samples collected on November 9 and November 10, 2004 were submitted for analysis of nitrate/nitrite as nitrogen (N), by Method 353.2 automated cadmium reduction, for ortho Phosphorus (P) by Method 365.1 Automated Ascorbic Acid dissolved, and for reactive sulfide (S) by SW-846 and Method 9030. These parameters were run outside of holding times, since pH has an immediate holding time. Subsequent samples run on December 2, 2004 and December 15, 2004 were analyzed by different methods to address holding time issues. The results indicate that sulfides were not detected in any of the samples.

Total hardness as carbonate ($CaCO_3$) ranged from 92 mg/L to 390 mg/L, and were similar to Total Alkalinity, and the values for Bicarbonate as $CaCO_3$. This indicates that the water is of bicarbonate type. Concentrations of nitrogen as ammonia, selenium, and sulfides were not detected in any of the water samples.

The laboratory analytical results for the Warren's well indicate the highest total dissolved solids concentration (TDS) at 1,480 mg/L and 1,300 mg/L. This exceeds the secondary water quality standard of 500 mg/L established by the EPA as a guideline for municipal drinking water sources. Secondary standards are not an MCL, or enforceable standard for municipal drinking water sources. Also the concentration of sulfates at 770 mg/L and 630 mg/L were elevated as compared to the other water samples collected. These concentrations exceed the secondary water quality standard of 250 mg/L for sulfate. The elevated concentrations of these parameters is most likely due to the fact that Warren's

water well is located further away from the Battlement Creek drainage, the total depth and screened interval depth of the well are much deeper than other wells in the area, and the Warren's well is completed into the Wasatch Formation.

The TDS concentration in the LH96-SP4, 96 Ranch spring sample, also had a TDS of 520 mg/L which exceeds the EPA secondary standard of 500 mg/L. A couple of the other water samples had TDS concentrations that were in the 390 mg/L to 460 mg/L range.

Concentrations of iron were elevated in samples collected from Battlement Creek (USGS-BC1), Wesley Kent's spring (WK-SP3), and also in the sample from Warren's well (PW-W7) as compared to the other sample location results. The concentrations in the WK-SP3 sample, at 0.65 mg/L, and PW-W7 sample, at 39 mg/L, exceed the EPA secondary drinking water standard of 0.3 mg/L.

Concentrations of manganese were detected in samples from the Warren's (PW-W7) water well and also in the sample from Battlement Creek, USGS-BC1. The manganese concentration detected in the water sample PW-W7 at 0.058 mg/L exceeds the EPA secondary drinking water standard of 0.05 mg/L. Concentrations of manganese were not detected in the majority of the other water samples.

The BART™ analysis performed by Grand Junction laboratories indicated that concentrations of iron related bacteria, ranging from 25 colony forming units (CFU) to 9,000 CFU, and slime forming bacteria, ranging from 500 to 350,000 CFU, were present in all of the water samples except for the sample from the Grand Valley Springs. The sample collected from the Grand Valley Springs did not exhibit any bacteria which is likely due to the sample being collected at a point after the chlorinator. Sample results from a number of the wells and springs indicated that concentrations of sulfate reducing bacteria were absent. Samples from the surface water sources had the highest concentrations of sulfate reducing bacteria, with up to 700,000 CFU.

3.2 2005 Annual Results

The 2005 annual water sampling results indicated that tritium was not detected above the minimum detectable concentration (MDA) in any of the water samples. Concentrations of gamma emitting radionuclides were not detected above the MDA, with the exception of tentatively identified levels of Strontium-124 and Cobalt-56 in the water sample (JLS-W1) collected from the Guy Botkin well reported to Juanita Satterfield. The source of these radionuclides is unknown; however, based on the half lives of these radionuclides 60 days and 77 days, respectively, they cannot be related to Project Rulison. Based on the low concentrations near the laboratory MDA, it is likely that they are laboratory artifacts. Paragon reported a low bias in the reported concentrations of Bismuth-214 and Lead-214, and provided estimated concentrations of these radionuclides for all samples.

Naturally occurring radionuclides, e.g., Bismuth-214 and Lead-214, also showed up in the analyses as exceeding the detection limit. Bismuth-214 and Lead-214 are short-lived decay products of Radon-222, and are not related to human activities in the area (Johnson, personal communication).

Concentrations of BTEX and MTBE were not detected in twelve of the fifteen samples. However, the BTEX and MTBE results for the initial samples from the 96 Ranch spring, LH96-SP4, collected October 17, 2005, and for the BTEX and MTBE sample from Pat and Randy Warren's water well, and two trip blanks, were run outside of holding time. Even though the organic analysis was completed within three hours on the fifteenth day, and the results indicated that BTEX concentrations were not detected, additional samples were collected in December 2005 since the analysis exceeded the fourteen day holding time. The other water samples were analyzed within the fourteen day holding time.

Paragon reported concentrations of benzene were detected in the laboratory method blank and also for samples from Ethel Gardner's spring (EG-SP2) and from the Grand Valley Springs (GVS-SP1). The laboratory results indicated that the concentration of benzene in the sample EG-SP2 was 2.7 µg/L and the benzene concentration in GVS-SP1 was 4.4 µg/L, neither of which exceeds the MCL for benzene of 5 µg/L; however, benzene was also detected in the laboratory method blank at a concentration of 1.4 µg/L. Due to these irregularities, these locations were sampled again in December 2005, and the water samples were submitted to Evergreen Analytical (Evergreen) in Wheat Ridge, Colorado. The results from Evergreen indicate that concentrations of BTEX and MTBE were not detected in these samples.

Concentrations of methane were not detected in any of the water samples. Methane analysis was performed by Data Chem in Salt Lake City, Utah. Data Chem is the parent company for Paragon Analytics. However, the methane samples were sent directly to Data Chem for methane analysis since Paragon does not perform this analysis.

The analytical results for Total Alkalinity as $CaCO_3$ indicate that the water is of bicarbonate type. Stiff diagrams in Appendix F show the cation and anion distribution for each water sample.

Cordilleran requested that Paragon analyze the water samples for additional anions including bromide, chloride, and fluoride. These anions were analyzed in addition to nitrates/nitrites, bicarbonate, phosphate, sulfide, and sulfate to evaluate ion balance. The concentrations of these anions were found to be within the expected ranges. Sulfates were elevated in the water sample collected from the Warren's well, at 790 mg/L, but was consistent with the range of values observed during the 2004 baseline. The TDS concentrations were also again higher, at 1600 mg/L, in the sample from the Warren's water well than the other water sources sampled. The TDS concentrations in the other

samples ranged from 140 mg/L in the sample from Battlement Creek to 550 mg/L in the LH96-SP4 sample. The EPA secondary standard for TDS is 500 mg/L, and the secondary standard for sulfates is 250 mg/L.

During the 2005 sampling event Cordilleran requested that the water samples be analyzed for boron. Concentrations of boron are typically higher in produced water than from drinking water sources. Boron concentrations were either not detected, or were present at concentrations slightly above the detection limit. In some cases connate water in sedimentary rock that was deposited in a near shore or marine setting has higher boron concentration since boron in seawater ranges from 4 mg/L to 5 mg/L.

Concentrations of manganese were detected in samples from the Warren's (PW-W7) water well and also in the sample from Battlement Creek, USGS-BC1. The concentrations of manganese in the sample from the Warren's water well did not exceed the EPA secondary drinking water standard of 0.05 mg/L. Concentrations of manganese were not detected in the other water samples.

Concentrations of selenium were detected in water samples collected from Christy Koeneke's water well (CK-W5), from the Warren's water well (PW-W7), and from Monument Creek. The concentrations of selenium did not exceed the EPA drinking water standard for selenium of 0.05 mg/L. Natural background selenium concentrations are known to be high in some parts of Garfield County. Selenium is toxic and can have an adverse affect on livestock if present in elevated concentrations.

The BART™ analysis performed by Grand Junction laboratories indicated that concentrations of iron related bacteria, ranging from 500 CFU to 9,000 CFU, sulfate reducing bacteria results ranged from "absent" to 700,000 CFU, and slime forming bacteria, ranging from 12,500 CFU to 350,000 CFU. The highest concentrations were from the three surface water sources; Battlement Creek, Hayward Creek, and Monument Creek. High concentrations of bacteria may cause nuisance conditions by corrosion of piping and equipment, clogging well pumps, causing red staining, or black sulfide deposits by reacting with metals, or foul odors.

4.0 Data Comparison and Evaluation

The following sections provide a narrative comparison and evaluation of the data collected during the 2004 baseline and the 2005 annual sampling event. This section also compares PRESCO's data (Table 5 and Table 6) with data collected during the earlier studies including data gathered by the USGS prior to and after Project Rulison, EPA data for water monitoring conducted for tritium and gamma emitting radionuclides, and data collected by the COGCC in 1998 for baseline water quality. Where possible a statistical analysis of these data sets is used for ease of comparison.

4.1 Tritium Results

The USGS completed an inventory and conducted hydrologic monitoring of all water wells, springs, and surface water resources within a ten mile radius of Project Rulison. The USGS used an elaborate sample identification system based on the legal description of Quarter-Quarter Section, Section, Township, Range, Principal Meridian, and Quadrant in the State where the sample was collected. The water analysis included inorganic water quality parameters and tritium.

The tritium results were reported in tritium units, with only three detections out of 28 select wells, springs, and cistern sample results, and the remaining 25 samples less than 220 TU, or approximately 710 pCi/L. The maximum tritium detection was 323 TU (1037 pCi/L). Out of 31 surface water samples, ten samples had detectable activities of tritium with a maximum tritium concentration of 430 TU (1390 pCi/L), and the rest were less than 220 TU.

Hazen Research analyzed the 2004 baseline samples for tritium and reported that tritium concentrations were not detected above the detection limit. Results plus or minus the detection limit were provided as an estimate of tritium activity. Paragon indicated that tritium was not detected above the MDA in any of the water samples collected during the 2005 annual sampling event. Both laboratories analyzed the water samples by the conventional method, which has a MDA of approximately 400 pCi/L. Although estimated results are not accurate below the MDA, a comparison is presented below

Data Set	Maximum H3 (pCi/L)	Average H3 (pCi/L)	Median H3 (pCi/L)	Total Number of Samples
PRESCO (2yr)	580 ± 460 (1,040)	438	310	30
USGS (2 yrs)	1,390	983 1017	954 890	Groundwater: 28 Surface water: 31
EPA/DOE (32 yrs)	1,310	161	97.5	432

The maximum reading was 580 pCi/L, which would be in the range of the highest results obtained by the USGS and EPA. These values are well below the EPA drinking water standard of 20,000 pCi/L. The tritium results for samples collected during PRESCO's 2004 baseline and 2005 annual water sampling events are presented in Table 5 and Table 6.

The USGS sample results for tritium are present at higher concentrations because of the time frame in which they were collected. Global atmospheric tritium concentrations were higher because of aboveground nuclear testing and have been decreasing since test ban treaties went into effect.

4.2 Alpha Radiation and Beta Radiation Screening Results

The USGS screened six of the groundwater samples for gross beta and gross alpha radiation, which indicated that the highest gross beta radiation count was 8 pCi/L, and the highest alpha radiation count was 10 pCi/L.

The DOE and EPA screened water samples for gross alpha and gross beta radiation as part of the annual sampling events from 1972 until 1978. The maximum alpha radiation recorded was 14 pCi/L and. The average reading for alpha radiation was 3.77 pCi/L and the median alpha radiation was 2.8 pCi/L. The maximum beta radiation was 7 pCi/L, with an average beta radiation reading of 2.75 pCi/L, and a median beta radiation reading of 3.5 pCi/L. These activity levels are consistent with terrestrial background radiation.

PRESCO did not request laboratory analysis of gross alpha radiation or gross beta radiation; however, the samples were screened by Paragon upon arrival as a routine protocol for receiving samples for radionuclide analysis and the screening did not indicate the presence of radioactivity above background levels. The screening levels recorded on the laboratory sheets ranged from 15 pCi/L to 16 pCi/L. PRESCO did not request analysis for alpha radiation or beta radiation since it has not been performed by the EPA as part of the annual water sampling since the mid-1970s.

4.3 Gamma Spectrometry Results

The DOE and EPA have conducted gamma spectrometry analysis and have not detected levels of gamma radioactivity in any of the water samples collected annually since 1972. The 2005 analytical results from Paragon indicate that gamma emitting radionuclides were not detected in any of the water samples submitted. The analytical results for samples collected during the 2004 baseline sampling indicate that low, background levels of naturally occurring radionuclides, such as the daughter products of uranium or thorium decay series, were present in a few of the samples. The results for the gamma spectrometry analysis are presented in Table 6.

4.4 Volatile Organic Compound Results

The COGCC analyzed water samples for BTEX, butane, ethane, hexane, methane, pentane, and propane as part of its 1997 to 1999 sampling program. A total of 21 samples were analyzed for BTEX. With the exception of some low concentrations of toluene at or below the MCL in six of the samples, the results indicated that BTEX compounds were not detected. The COGCC analyzed a total of 20 samples for methane, and the results indicate that methane was not detected. The results also indicated that butane, ethane, hexane, pentane, and propane were not detected in any of the samples. A statistical comparison for the volatile organic compounds was not practical since most of the results were "non-detect" and because the USGS and DOE/EPA did not analyze for these compounds.

The PRESCO baseline and 2005 samples were analyzed for BTEX, MTBE, and methane. Concentrations of BTEX, and MTBE were not detected, with the exception of concentrations of benzene and toluene that were "estimated" or reported as "J" values in the samples JLS-W1, GVS-SP1, and RW-W8 (duplicate) in 2004, GVS-SP1 and EG-SP2 in 2005. Paragon reported that benzene was also detected in the method blank during the 2005 laboratory analysis. None of these concentrations exceeded the maximum contaminant limit (MCL). The GVS-SP1 and EG-SP2 locations were re-sampled and the samples were submitted to Evergreen Analytical Laboratory in December 2005. The Evergreen analytical results indicated that concentrations of benzene were not detected. Subsequent sampling and analysis indicates these compounds were not detected which suggests that these estimated concentrations are due to laboratory interference rather than these compounds actually being present in the samples.

4.5 Inorganic Compound Results

The values obtained as laboratory results for PRESCO's 2004 baseline sampling event and 2005 annual sampling event for these parameters are included in Table 5.

The following section presents a comparison of the inorganic results from PRESCO's 2004 baseline and 2005 annual sampling water results with results from the USGS, EPA, and COGCC studies. The data sets show good correlation with one another with the exception of some of the data obtained from the DOE/EPA for iron and calcium which appear anomalous.

The statistical average and median values have been calculated for each parameter including metals/cations, anions, and water quality parameters for ease of comparison between the data sets. Typically the average and median values fall within the same range of numbers for each of the data sets, however, Cordilleran does not warrant and

cannot verify the accuracy of other agency results. In most cases the data was presented in reports or as tables, and the laboratory data was not included.

Cations

The following inset table presents the mean value, median value, and standard deviation for metals analysis performed on the water samples for the water quality studies.

Data Set	Boron (mg/L)	Calcium (mg/L)	Iron (mg/L)	Magnesium (mg/L)	Manganese (mg/L)	Potassium (mg/L)	Selenium (mg/L)	Sodium (mg/L)
USGS 1969	13 samples	25 sample	30 sample	24 samples	13 samples	13 samples	13 samples	13 samples
Mean	0.16	59.4	0.16	26.7	0.025	2.96	< 0.1	83.8
Median	0.07	66	0.04	29	0.02	3.4	< 0.01	25
Standard Deviation	0.2	26.7	0.52	12.0	NC	0.9	NC	200.9
DOE/EPA 1974-77	0 samples	25 samples	25 sample	25 samples	25 samples	25 samples	0 samples	25 samples
Mean	NA	28.4	103.1	26.4	75.3	2.19	NA	42.06
Median	NA	22	100	30	100	2.25	NA	47
Standard Deviation	NA	17.8	11.7	13.3	NC	0.97	NA	29.4
COGCC 1997-99	0 samples	57 samples	57 sample	57 samples	57 samples	57 samples	57 samples	57 samples
Mean	NA	51.7 (d)	0.09 (d)	36.8 (d)	0.0078 (d)	2.58 (d)	NA	65.02 (d)
Median	NA	51.4 (d)	0.02 (d)	36.4 (d)	0.007 (d)	2.35 (d)	NA	50.8 (d)
Standard Deviation	NA	23.94 (d)	0.12 (d)	16.67 (d)	NC	1.08 (d)	NA	60.8 (d)
PRESCO 2004-05	15 samples	29 samples	29 sample	29 samples	29 samples	29 samples	29 samples	29 samples
Mean	0.15	53.3	3.25	36.9	0.024	2.85	0.0095	51.7
Median	0.13	47.6	0.19	30	0.015	2.15	0.0094	45.05
Standard Deviation	0.076	25.9	7.59	30.08	NC	2.10	NC	41.1

Notes: mg/L – milligrams per liter

NA – Not Analyzed

NC – Not Calculated (Majority of results were below detection)

(d) – dissolved metals (rather than total metals)

Anions

The following inset table presents the mean value, median value, and standard deviation for inorganic parameter analysis performed on the water samples for the water quality studies.

Data Set	Bicarbonate (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrate/Nitrite (mg/L)	Phosphate (mg/L)	Sulfate (mg/L)
USGS 1969	37 samples	37 samples	13 samples	13 samples	13 samples (NO3)	13 samples	13 samples
Mean	380.05	0.68	11.15	0.22	10.5	< 0.01	137
Median	411	0	8.5	0.2	9	< 0.01	39
Standard Deviation	134.2	NC	9.63	0.14	8	NC	309.5
DOE/EPA 1974-77	0 samples	0 Samples	25 samples	25 samples	25 samples	25 samples	25 samples
Mean	NA	NA	6.8	0.53	1.08	0.006	36.16
Median	NA	NA	5.35	0.4	0.28	0.002	29
Standard Deviation	NA	NA	5.9	0.57	1.17	0.007	32.09
COGCC 1997-99	57 samples	57 samples	57 samples	57 samples	57 samples	0 samples	57 samples
Mean	322	18.63	8.58	0.38	1.4 (d)	NA	76.09
Median	322	< 2	5	0.4	1.2 (d)	NA	30
Standard Deviation	55.98	NC	9.28	0.14	1.18	NA	173.8
PRESCO 2004-05	29 samples	15 samples	15 samples	15 samples	29 samples	29 samples	29 samples
Mean	268.8	0	8.53	0.25	0.67	0.09	119.7
Median	303	0	2.95	0.26	0.32	0.07	56
Standard Deviation	94	NC	9.8	0.1	0.71	NC	214

Notes

NA – Not Analyzed

NC – Not Calculated (Majority of Results were Non Detect)

NO3 – Only nitrates were measured

(d) – dissolved concentrations measured rather than total

The results for cations and anions show similar results for each of the data sets, with the exception of iron in the DOE/EPA data set which appears to be anomalous as most of the readings were 100 mg/l. The calcium values reported by the DOE/EPA are also lower than those reported in the other three data sets, but overall most of the parameters fall within similar ranges. The COGCC analyzed for dissolved phase metals rather than total metals; however, this does not appear to have had a significant difference in the reported concentrations for most parameters.

Other water quality parameters, such as hardness, total dissolved solids, and pH, are also consistent between the individual data sets. The average and median values for these parameters are presented on the inset table on the following page. The data from the USGS, DOE/EPA, and the COGCC are presented in Appendix A, Appendix B, and Appendix C, respectively.

Water Quality Parameters

Data Set	Hardness as CaCO3 (mg/L)	Total Alkalinity (mg/L)	Nitrogen as Ammonia (mg/L)	pH (Standard Units)	Total Dissolved Solids (mg/L)	Residue, Filterable (TDS) @180 (mg/L)
USGS 1969	22 samples	0 samples	0 samples	34 samples	0 samples	26 samples
Average	274.5	NA	NA	7.86	NA	485
Median	322	NA	NA	7.75	NA	424
Standard Deviation	92.6	NA	NA	0.78	NA	440
DOE/EPA 1974-77	0 samples	25 samples	25 samples	0 samples	25 samples	0 samples
Average	NA	258.8	0.022	NA	312.3	NA
Median	NA	240	0.019	NA	330	NA
Standard Deviation	NA	137.5	NC	NA	124.4	NA
COGCC 1997-99	57 samples	57 samples	0 samples	57 samples	57 samples	57 samples
Average	18.63	323.4	NA	7.9 (l)	394.7	449.6
Median	17.5	331	NA	7.9 (l)	379.5	395
Standard Deviation	NC	58	NA	0.28	80.9	311.4
PRESCO 2004-05	15 samples	29 samples	29 samples	29 samples	0 samples	29 samples
Average	305.13	272.7	< 0.1	7.86 (f)	NA	467.3
Median	269	306	< 0.1	7.83 (f)	NA	395
Standard Deviation	165.4	94.07	NC	0.42	NA	370.8

Notes: mg/L – milligrams per liter

TDS – total dissolved solids

NA – Not Analyzed

NC – Not Calculated

(l) – laboratory measured pH

(f) – field measured pH using a HACH Quanta Water Quality Meter

4.6 Bacteria Results

The BART™ results indicate that elevated numbers of iron related and slime forming bacteria are present in the water at the sample locations. The surface water locations show the highest numbers of bacteria colonies, and the springs typically had higher numbers of bacteria colonies than the wells. Sulfate reducing bacteria were generally low or absent from the wells sampled.

Owners of wells and springs were informed that the presence of bacteria in the water samples indicate that these bacteria could cause problems with water quality and water quantities produced from the wells or springs if corrosion or clogging of equipment should occur. The owners were advised to contact a licensed water well contractor to treat the well or spring if there is a change in water quality or diminished water capacity.

Bacteria analyses data were not presented in the USGS, DOE/EPA, or COGCC water quality studies. The presence of high concentrations of certain bacteria may generate methane, as biogenic methane, or in rare instances may thrive in the presence of methane. Due to the change in bacteria populations the chemistry of the water in the well will also change resulting in production of hydrogen sulfide gas (H_2S) or result chemical precipitates such as iron sulfide or manganese sulfide. Sulfides were not detected, manganese was either not detected or was reported at concentrations slightly above the laboratory detection limit. Similarly, the laboratory reported low concentrations of iron.

5.0 SUMMARY

Concentrations of tritium were not detected in water samples collected during PRESCO's 2004 baseline or 2005 annual water sampling events. Concentrations of tritium at background levels are well below the laboratory MDL, or what the laboratory can accurately quantify using the conventional method of analysis. The conventional method MDL of approximately 400 pCi/L is well below the EPA drinking water standard for tritium of 20,000 pCi/L. According to the EPA 2004 Annual Report, tritium concentrations have been remaining stable or are decreasing over time. Plots of tritium concentrations with respect to time are presented in Appendix G.

Concentrations of gamma emitting radionuclides were not detected in water samples collected during the 2004 baseline or 2005 annual water sampling events, other than low activities of gamma emitting daughter products resulting from the decay series of naturally occurring uranium or thorium. These radionuclides are very different from fission products that result from the detonation of a man-made nuclear device.

According to (Johns, Sharfman, ad Shaw, et al, 1989, page 71) to study the migration of radionuclides from underground tests, the DOE drilled a test well at the Nevada Test Site, where groundwater is present and with a gradient toward the south-southwest. The test well was drilled near the underground nuclear test known as "Cambric" which was detonated in a vertical hole in 1965. It was found that most of the radioactivity produced by the test was retained within the fused rock formed by the explosion, although low concentrations of radioactive material were found in the water at the bottom of the cavity. The DOE pumped more than 3 billion gallons from a satellite well drilled 300 feet from the cavity in an effort to draw water from the region of the Cambric test, and only extremely small quantities of radionuclides, were detected at activities below the permitted level for drinking water.

According to the COGCC Project Rulsion Study (Macke, 1998), the radionuclides produced by the type of nuclear device used at Project Rulison that potentially could appear as contaminants in natural gas are tritium, krypton-85, and carbon 14, which are primarily beta radiation emitters. Only about five percent of the total tritium produced from the detonation is contained in the gaseous phase, and it is estimated that about 40 percent would be trapped in the melted rock and about 55 percent in water. Most of the fission products present are immobile and contained within the glassy slag or in water at the bottom of the Project Rulison cavity at a depth of 8,426 feet below sea level.

The Preliminary Site Characterization Report, Rulison Site, Colorado (IT Corporation, 1996) states that preshot permeability for the Mesaverde Formation was first estimated at 0.5 microdarcies (µd) and then a 0.01 µd, while postshot production data and reservoir

simulation studies indicated that actual matrix permeability was approximately 0.001 to 0.04 µd. This indicates very low permeability, and therefore limited groundwater mobility in the Mesaverde in contrast to the DOE Cambric groundwater experiment where there was measurable groundwater flow. According to the IT Corporation, Preliminary Site Characterization Report for the Rulison Site, Colorado,

1. "*Studies of pre-shot* (sic) *and postshot hydrologic conditions indicate that the detonation had no effect on the physical, chemical, or radiochemical characteristics of wells, springs, streams, shallow aquifers, or reservoirs in or near the Rulison Site (Vogegeli et al, 1970, p.48; AEC, 1973, p. 18). The USGS also sampled springs, rivers, and wells before and after reentry drilling and after each of the three gas production tests with the same negative results."*
2. *"The Rulison device was emplaced near the base of the Mesaverde Formation at a depth of 2,568 m (8,426 ft). Essentially all of the explosion-produced radionuclides were contained within the Mesaverde Formation. Any mobile water in the Mesaverde Formation which becomes contaminated with (fission products), and is located below 2,133.6 m (7,000 ft), is expected to move downward or laterally, but not upward. Above 2,133.6 m (7,000 ft), any contaminated mobile waters are expected to move laterally. Groundwater movement in this formation is estimated to be a maximum of 0.3048 m (1 ft) per day. The most probable rate is essentially negligible."* (IT Corp, 1996 page 5-33)

Although the BART™ analyses indicate the presence bacteria, PRESCO's baseline and 2005 analytical results indicate that sulfide concentrations were not detected; manganese were not detected, or were seldom detected at low concentrations slightly above the detection limit; and iron was detected at low concentrations. Methane was not detected in any of the water samples.

Concentrations of BTEX often accompany thermogenic methane dissolved in groundwater when there is an impact to water resources resulting from natural gas drilling activities. Considering the number of natural gas wells drilled in Garfield County since the 1950s, the number of cases where natural gas well drilling and well completion activities have impacted groundwater resources is extremely rare. The USGS did an extensive survey of the area prior to Project Rulison and did not indicate the presence of any natural gas seeps. The only historic gas wells in the immediate area are those associated with the Project Rulison experiment which were properly plugged and abandoned (AEC, 1973).

Estimated concentrations of benzene and toluene were reported as "J" values in a few samples below the laboratory method detection limit in both the 2004 baseline samples and the 2005 annual water samples. The concentrations detected in sample JLS-W1 and GVS-SP1 during the 2004 baseline preceded PRESCO's drilling activities. These locations are several miles from PRESCO's area of exploration and Project Rulison.

Paragon reported concentrations of benzene in the GVS-SP1 and EG-SP2 samples during the 2005 sampling event; however, the laboratory qualified the results since benzene was also detected in the laboratory blank. Subsequent samples were collected and analyzed by Evergreen Analytical Laboratory for BTEX analysis indicated that neither benzene nor toluene were detected in water samples submitted from these locations. None of the estimated concentrations for benzene or toluene exceeded drinking water standards for these compounds. With the exception of the spring sample BM 36-23 Culv, none of PRESCO's natural gas wells drilled during 2005 were in close proximity to the water sample locations reportedly used as drinking water sources since they are located within close proximity to the Project Rulison site, and PRESCO's activities are outside the ½ mile radius established by the COGCC. The COGCC Order #139-43 requires a hearing for any wells PRESCO intends to drill within ½ mile of the Project Rulison site.

There are no bedrock aquifers in the area, and groundwater resources supplying wells and springs are contained within the unconsolidated alluvial and colluvial sediments on Battlement Mesa. Only a couple of the wells sampled as part of PRESCO's sampling program are completed into the upper part of the Wasatch Formation, which is the uppermost bedrock unit exposed in the Battlement Creek drainage valley. These water wells only extend 10 feet or less into the upper part of the Wasatch Formation, and serve as sumps for the screened interval completed in the overlying alluvium and colluvium. The groundwater resources supplying water to wells and springs in the area are vertically separated from the Project Rulsion test site by thousands of feet of impermeable sedimentary rock.

Inorganic parameters, such as cations and anions and other water quality parameters reported for samples during the 2005 annual sampling event are consistent with the results obtained during the 2004 baseline water sampling event. The samples were analyzed by different laboratories and the agreement in the sample results from the two events indicates good reproducibility despite a few laboratory irregularities.

Additionally the results are consistent with or within the range of results obtained during previous water quality studies conducted by the USGS, the DOE/EPA, and the COGCC. Several of the water sample locations accessed by PRESCO are included in these previous studies, while others were selected because of their proximity to Project Rulison.

PRESCO and Cordilleran wish to thank all of the private water well owners, and the private and municipal spring owners who participated in PRESCO's 2004 and 2005 water sampling events. PRESCO will continue these annual sampling efforts with continued access to these water resources. PRESCO intends to continue to provide well and spring owners with a copy of their analytical results for those who participate in the sampling events.

Additionally PRESCO will perform the following actions to further reduce the potential for impact to water resources:

- PRESCO, Inc. will set additional conductor casing to a minimum depth of 100 feet on wells drilled from the 36-23 pad (this includes current permits 36-24, 36-14, 36-22) and wells drilled from the 36-31 pad (this includes current permit 36-31.) These pads have been identified as being located on the basaltic boulder deposit;

- A high quality cement job will be achieved on the conductor casing on all wells near the Project Rulison site or Battlement Creek drainage;

- When drilling the surface holes on these wells, fluid loss will be closely monitored and loss circulation sweeps will be used to control any seepage;

- PRESCO's annual water quality monitoring will continue; and

- Monitoring will be performed during the drilling of gas wells.

PRESCO has and will continue to conduct other monitoring activities which will be described in a separate report. This report is expected to be complete by the end of April 2006.

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FIGURES AND TABLES