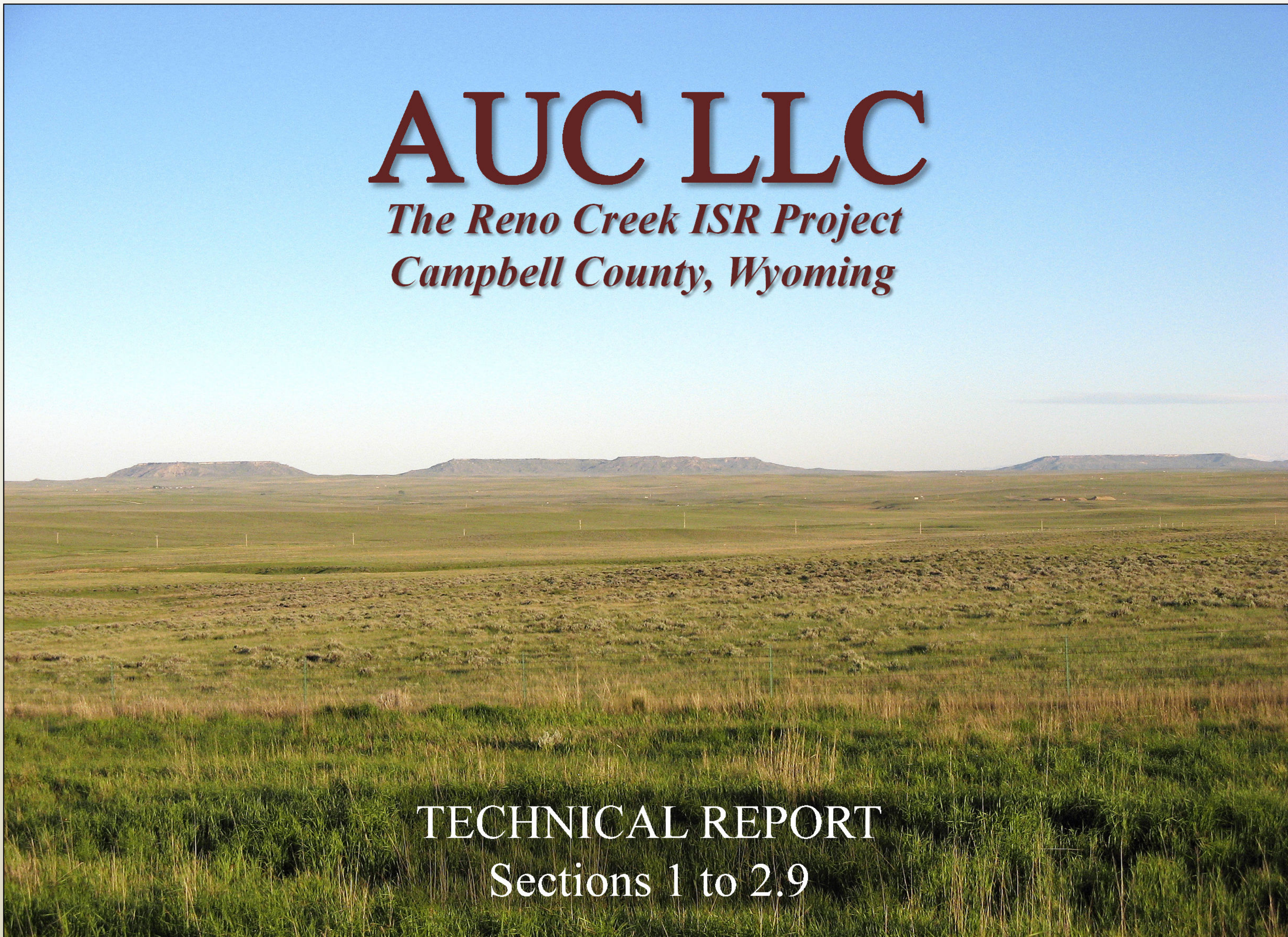
USNRC APPLICATION

Combined Source and 11e.(2) Byproduct Material License



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LIST OF ADDENDA

ABBREVIATIONS AND ACRONYMS

-A-

AADT	Annual Average Daily Traffic
ALARA	As Low As Reasonably Achievable
ALI	Annual Limit Intake
amsl	above mean sea level
ANSI	American National Standards Institute
AP	Airport
APD	Application for Permit to Drill
APE	Area of potential effect
API	American Petroleum Institute
AQD	Air Quality Division
ASME	American Society of Mechanical Engineers
ASOS	Automated Surface Observing System
AUC	AUC, LLC

-B-

BACT	Best Available Control Technology
BCA	Benefit-Cost Analysis
BEA	United States Bureau of Economic Analysis
bgs	below ground service
BKS	BKS Environmental Associates, Inc.
BLM	United States Department of the Interior, Bureau of Land Management
BMP	Best Management Practices
BOE	Bureau of Explosives
BPT	Best Practicable Technology

-C-

CA/T	Central Artery/Tunnel
CAD	Computer-Aided Design
CBM	Coal Bed Methane
CBNG	Coal Bed Natural Gas
CEDE	Committed Effective Dose Equivalent
CERCLA	Comprehensive Environmental, Response, Compensation and Liability Act
CESQG	Conditionally Exempt Small Quantity Generator
CGA	Compressed Gas Association

ABBREVIATIONS AND ACRONYMS (CONTINUED)

CGP	Construction General Permit
CMF	Central Measuring Facility
CO_2	Carbon Dioxide
COOP	Cooperative Observer Program
CPP	Central Processing Plant
CPVC	Chlorinated Polyvinyl Chloride

-D-

DAC	Derived Air Concentration
DDE	Deep Dose Equivalent
DDW	Deep Disposal Well
DEQ	Department of Environmental Quality
DHS	Department of Homeland Security
DVD	Digital Video Disk

-E-

E	East
EA	Environmental Assessment
EDR	Electro Dialysis Reversal
EFI	Energy Fuels Inc.
Eh	oxidation-reduction potential
EIS	Environmental Impact Statement
EJ	Environmental Justice
EJ Study Area	Environmental Justice Study Area
ER	United States Nuclear Regulatory Commission Environmental Report
ESA	Endangered Species Act
ESO	Ecological Services Office
ESRI	Environmental Systems Research Institute

-F-

FEIS	Final Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FIDLER	Field Instrument for the Detection of Low Energy Radiation
FSER	Final Safety Evaluation Report

-G-

ABBREVIATIONS AND ACRONYMS (CONTINUED)

GIS	Geographical Information System
GPS	Global Positioning System
GWR	Ground Water Restoration

-H-

H_2O_2	Hydrogen Peroxide
HDPE	High Density Polyethylene
HMR	Hazardous Materials Regulations
HPIC	High Pressure Ionization Chamber
HTF	Heat Transfer Fluid
HUC	Hydrologic Unit Code
HVAC	"Heating, Ventilation, and Air Conditioning"

-I-

IBC	International Building Code
ICF	ICF International
ICRP	International Commission on Radiological Protection
IDLH	Immediately Dangerous To Life And Health
IML	Inter-Mountain Labs
IMPLAN	Impact Analysis for Planning
ISC3	Industrial Source Complex
ISR	In Situ Recovery
IUC	International Uranium Corporation
IX	Pressurized Downflow Ion Exchange

-J-
-K-

-L-

LLD	Lower Limits Of Detection
LQD	Land Quality Division
LSA	Low Specific Activity

-M-

MCL	Maximum Containment/Concentration Level
MDL	Method Detection Limit
MET	Meteorological

ABBREVIATIONS AND ACRONYMS (CONTINUED)

MIT	Mechanical Integrity Test
MP wells	Baseline production monitor wells
MSL	Mean Sea Level Elevation

-N-

N	North
NAAQS	National Ambient Air Quality Standards
Na_2CO_3	Sodium Carbonate or Soda Ash
NAD	North American Datum
$NaHCO_3$	Sodium Bicarbonate (commonly known as baking soda)
NAICS	North American Industrial Classification System
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPV	Net Present Value
NRC	United States Nuclear Regulatory Commission
NRCS	Natural Resource Conservation Service
NRHP	National Register of Historic Places
NVLAP	National Voluntary Laboratory Accreditation Program
NWI	National Wetlands Inventory
NWP	Nationwide Permit
NWS	National Weather Service

-O-

OHV	Off-Highway Vehicle
OA	Overlying aquifer
OM	Overlying aquifer well
OSHA	Occupational Safety and Health Administration
OSL	Optically-Stimulated Luminescent Dosimeter
OWUS	Other Waters of the United States

-P-

PBL	Performance Based License
PBLC	Performance Based License Condition
PCN	Pre-construction Notification
PFYC	Potential Fossil Classification System

ABBREVIATIONS AND ACRONYMS (CONTINUED)

PM_{10}	Particulate Matter 10 Microns or Larger
PRB	Powder River Basin
PRI	Power Resources, Inc.
PSM	Process Safety Management
PV	Pore volumes
PVC	Polyvinyl Chloride
PZA	Production zone aquifer
PZM	Production zone monitor well

-Q-

QA	Quality Assurance
QAM	Quality Assurance Manual
QC	Quality Control

-R-

R	Range
RAP	Restoration Action Plan
RCRA	Resource Conservation and Recovery Act
REIS	Regional Economic Information System
Reno Creek Project	Reno Creek ISR Uranium Project (Proposed Project)
RM	Monitor well ring wells during production
RME	Rocky Mountain Energy
RMP	Risk Management Plan
RO	Reverse Osmosis
ROD	Record of Division
RPC	Regional Purchase Coefficient
RPP	Radiation Protection Program
RQ	Reporting Quantities
RSO	Radiation Safety Officer
RST	Radiation Safety Technician
RTV	Restoration Target Values
RWP	Radiation Work Permit

-S-

S	South
SA	Shallow water aquitard
SCS	Soil Conservation Service
SDR-17	Standard Dimension Ratio 17

ABBREVIATIONS AND ACRONYMS (CONTINUED)

SDWA	Safe Drinking Water Act
SEO	State of Wyoming Engineering Office
SER	Safety Evaluation Report
SERP	Safety and Environmental Review Panel
SGCN	Species Of Greatest Conservation Need
SHPO	Wyoming State Historic Preservation Office
SIL	Significant Impact Level
SM	Shallow water monitor well
SM unit	Shallow water table unit present in some locations
SODAR	Sonic Detection and Ranging
SOP	Standard Operating Procedures
SP	Spontaneous Potential
SRWP	Standard Radiation Work Permit
SSC	"Structure, System, or Component"

-T-

T	Township
T&E	Threatened and Endangered
TCP	Traditional Cultural Places
TDS	Total Dissolved Solids
TEDE	Total Effective Dose Equivalent
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
TER	Technical Evaluation Report
TLD	Thermo Luminescent Dosimeters
TPQ	Threshold Planning Quantities
TR	United States Nuclear Regulatory Commission Technical Report
TQ	Threshold Quantities

-U-

UA	Underlying aquitard
UM	Underlying aquitard well
U.S.	United States
U_3O_8	"Triuranium Octoxide, or Yellowcake"
UBC	Uniform Building Code
UCL	Upper Control Limit
UIC	Underground Injection Control
USACE	United States Army Corps of Engineers

ABBREVIATIONS AND ACRONYMS (CONTINUED)

USDA	United States Department of Agriculture
USDW	Underground Source Of Drinking Water
USEPA	United States Environmental Protection Agency
USFWS	"United States Department of the Interior, Fish and Wildlife Service"
USGS	United States Geological Survey
UTM	Universal Transverse Mercator

-V-

VRM	Visual Resource Management

-W-

W	West
WAAS	Wide Area Augmentation System
WDEQ	Wyoming Department of Environmental Quality
WDEQ-LQD	Wyoming Department of Environmental Quality – Land Quality Division
WDEQ-SHWD	Wyoming Department of Environmental Quality – Solid and Hazardous Waste Division
WDEQ-WQD	Wyoming Department of Environmental Quality – Water Quality Division
WGFD	Wyoming Game and Fish Department
WL	Working Level
WLM	Working Level Month
WOGCC	Wyoming Oil and Gas Conservation Commission
WoUS	Waters of the United States
WQD	Water Quality Division
WRCC	Western Regional Climate Center
WY	Wyoming
WYDOT	Wyoming Department of Transportation
WYGISC	Wyoming Geographic Information Science Center
WYPDES	Wyoming Pollutant Discharge Elimination System

-X-
-Y-
-Z-

UNITS OF MEASURE

%	percent
% g	percent of gravitational acceleration
μg/Kg	micrograms per kilogram or parts per billion
μg/L	micrograms per liter or parts per billion
μCi/g	microcuries per gram
μCi/Kg	microcuries per kilogram
μCi/L	microcuries per liter
$\mu Ci/m^3$	microcurie(s) per cubic meter
μrem	microrem
μR/h	microrem per hour
μSv	microsievert
^{o}	degrees
^oC	degrees Celsius
^oF	degrees Fahrenheit
ac	acre
ac-ft	acre-feet
cfm	cubic feet per minute
cfs	cubic feet per second
Ci/yr	Curies per year
cm	centimeters
cm^3	cubic centimeter(s)
cpm	counts per minute
dB	decibel
dBA	decibel A-weighting
DPM	disintegrations per minute
ft	foot
ft^3	cubic foot (feet)
g/l	grams per liter
gpm	gallon per minute
in	inch
Km	kilometer
lpm	liter per minute
m	meter
m^2	square meter
mg/L	milligrams per liter or part per million
mi	mile
mph	miles per hour
mR	milli Roentgens
mrem	millirem

UNITS OF MEASURE (CONTINUED)

mrem/hr	millirem per hour
mSv	millisievert
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/Kg	picocuries per kilogram
pCi/m^3	picocurie(s) per cubic meter
ppm	parts per million
psi	pound per square inch
psig	pound per square inch
R	rem
Sv	sievert
yd^3	cubic yard(s)

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1 PROPOSED ACTIVITIES

AUC, LLC (AUC) is providing this Technical Report (TR) in support of an application to the United States Nuclear Regulatory Commission (NRC) for a combined Source and 11e.(2) Byproduct Material License to construct and operate an in-situ recovery (ISR) facility at the proposed Reno Creek Project (Proposed Project) in Campbell County in the State of Wyoming. This TR has been prepared using suggested guidelines and standards found in NRC's NUREG-1569, to ensure that all information provided for NRC Staff is adequate to complete the technical review portion of this license application. AUC also incorporated into this TR the results of NRC's Request for Additional Information (RAI) process from recent applications for ISR facilities and comments received from the NRC Pre-submission Audit.

This section presents a summary of the proposed activities including the nature of the facilities, equipment, and procedures that AUC anticipates employing in the Proposed Project. Each subsection references the locations elsewhere in this application where more detailed discussions of the subject matter will be found.

The Proposed Project will consist of:

- A series of sequentially developed Production Units (12 total) consisting of injection and recovery wells to inject lixiviant and to recover pregnant lixiviant;
- Horizontal and vertical excursion monitoring well networks for detection of recovery solutions outside of the ore body/recovery zones;
- Central Processing Plant (CPP) consisting of pressurized, down-flow ion exchange (IX) columns, resin stripping or elution circuit, precipitation circuit, and yellowcake drying and packaging facilities. The CPP also will be used to facilitate the necessary solutions and processes for groundwater restoration after recovery has ceased;
- The CPP will be equipped to receive and process equivalent feed, pursuant to NRC RIS 2012-06;
- On-site laboratory, office and maintenance building, reagent storage facilities, and other facilities or areas used to house work areas or equipment storage; and
- Up to four Class I UIC deep disposal wells (DDW) to dispose of liquid 11e.(2) byproduct material generated during ISR operations with backup storage pond capacity.

The Proposed Project area contains approximately 6,057 acres. The total controlled area within the Proposed Project area will total approximately 481 acres over the 16-year Proposed Project lifespan. The facilities described above are the significant surface features associated with the uranium in situ recovery operations.

1.1 Licensing Action Requested

AUC is submitting this Technical Report (TR) and accompanying Environmental Report (ER) in support of a license application to the NRC for a combined Source and 11e.(2) Byproduct Material License to develop and operate the Proposed Project.

This license application and TR have been prepared using suggested guidelines and standard formats from both federal and State agencies. The TR is presented primarily in the NRC recommended format in Regulatory Guide 3.46, *"Standard Format and Content of License Applications, Including Environmental Reports, For In Situ Uranium Solution Mining"* (June 1982) and in NUREG-1569, *Standard Review Plan for In Situ Leach Uranium Extraction License Applications* (June 2003). The State of Wyoming has authority to regulate mines in Wyoming; therefore, a Wyoming Department of Environmental Quality (WDEQ) Permit to Mine/Class III Injection Permit will also be required. The TR incorporates information required by the WDEQ/LQD rules and regulations.

1.2 Project History

Substantial historical exploration, development, and mine permitting were performed on the Reno Creek Property. Beginning in the late 1960s and continuing into the mid 1980s, Rocky Mountain Energy (RME), a wholly owned mining subsidiary of the Union Pacific Railroad, drilled thousands of exploration borings on the Reno Creek Property. Summary reports indicate over 5,800 exploratory holes were drilled by RME in the greater Pumpkin Buttes area, with at least 1,083 borings completed on that portion of lands that make up the project boundary of the Proposed Project area. Significant mine permitting studies, including the construction, successful operation, groundwater restoration, and subsequent reclamation of an in-situ recovery pilot plant, were also performed over the years and these activities are detailed below.

The Proposed Project area was acquired by RME and was initially explored in the late 1960s and early 1970s. Exploration drilling at the time delineated several miles of roll front uranium deposits. By the mid 1970's, a partnership was formed between RME, Mono Power Company, and Halliburton Services. The partnership, informally called "ISLCO", was formed to develop the Reno Creek Project.

By the mid 1970's, RME delineated a significant mineral resource at Reno Creek and a decision was made to bring the property to full-scale production using the ISR method. In January 1979, an ISR testing program commenced with the completion of a 100 gallon per minute (gpm) pilot plant (shown in TR Figure 1-2). Two test patterns were installed and operated. The first pattern (Pattern 1) utilized sulfuric acid lixiviant because of the higher recoveries indicated in the amenability tests. Pattern 1 was operated with H_2SO_4 at a pH of 1.7.

The Pattern 1 testing began in February 1979 and was terminated in November 1979 because results from this pattern were unsatisfactory. Severe permeability loss resulted from high levels of calcium mobilized by the acid precipitating as gypsum within the ore sand, sealing off the formation to the point operations had to be curtailed. In addition to significant calcium levels in the pregnant solution, a fungus strain propagated, causing fouling of the ion exchange columns. Analysis indicated that over 20 pounds of calcium were being mobilized from dissolution of calcareous material in the formation for each pound of uranium recovered. Despite attempts to improve recovery and injectivity, the acid pattern ultimately proved that this formation cannot be leached effectively using acid lixiviants. Restoration and stabilization of the groundwater of Pattern 1 was acknowledged and signed off by the NRC in March of 1986 (Accession #8604040293/Docket #04008697).

Unfavorable results with Pattern 1 testing led to the installation and operation of a second pattern (Pattern 2) in October 1980 using a sodium carbonate (Na_2CO_3)/sodium bicarbonate ($NaHCO_3$) lixiviant and hydrogen peroxide (H_2O_2) oxidant. Pattern 2 was constructed as a modified 5-spot, consisting of two recovery wells, four injection wells, and six monitor wells. Pattern 2 was operated from October 1980 to December 1980. The results, coupled with the column leach test results, led RME to the decision to switch to carbonate lixiviant for further testing and commercial development. Uranium recovery and average head grade were especially encouraging.

Restoration of Pattern 2 began in December 1980. Analysis of water quality data following completion of the restoration program indicate that restoration of groundwater affected during ISR was successful. All parameters returned to baseline ranges with the exception of pH, uranium and vanadium. Of these parameters, all were either below WDEQ Class I Groundwater Standards (domestic use) or do not have Class I maximum concentration limits (WDEQ, 1980). Pattern 2 pilot testing culminated in regulatory signoff in June 1983 with the approval of carbonate leaching for commercial operations at Reno Creek under Materials License Number SUA-1338 as part of NRC Docket #04008697/Accession #8306200160. A more detailed discussion on specific historical ISR operations of Rocky Mountain Energy's (RME) Research and Development (R&D) efforts can be found in Addendum 1-A.

In 1992, the Reno Creek property and other nearby properties were acquired by Energy Fuels Inc. (EFI) from RME. Over the next decade, EFI and its merger successor International Uranium Corporation (IUC) (now "Denison") continued to advance the main Reno Creek property toward full permitting and uranium recovery. In 2001, the Reno Creek property was sold by IUC to Rio Algom Mining Corp. Thereafter, the property was acquired by Power Resources Inc. (US subsidiary of Cameco) which dropped its claims in 2003. In 2004 Strathmore staked and filed new mining claims in the area acquiring over 16,000 acres of prospective lands including the proposed Reno Creek Project.

In May 2007, Strathmore entered into a joint venture partnership with American Uranium Corporation Inc. of Nevada, to bring the Reno Creek property to a full-scale ISR operation. Strathmore and American Uranium subsequently sold the Reno Creek Project (the subject of this license application) and the nearby Pine Tree Trend Properties located approximately seven to eight miles to the west and northwest respectively of the Proposed Project, including its corporate owner AUC LLC, to AUC Holdings.

Table 1-1 outlines all information known regarding the proposed property ownership and joint ventures.

1.3 Corporate Entities Involved

AUC's license application, including its ER and TR, are submitted by AUC LLC, a Delaware corporation registered to do business in the State of Wyoming. AUC LLC is a United States-based corporation and is the wholly owned subsidiary of AUC Holdings, also a U.S. based corporation, whose shares are held by Pacific Road Resource Funds, an Australian registered company located at 1 Alfred Street, Level 23, Sydney, NSW, Australia and Bayswater Uranium Corporation, a Canadian corporation located at 1111 Melville Street, Suite 100, Vancouver, British Columbia, V6C 3V6, Canada. The corporate headquarters of AUC LLC and AUC Holdings is 1536 Cole Blvd, Suite 330 Lakewood, Colorado. Pacific Road is a privately held corporation, and Bayswater Uranium is a publicly traded corporation with shares traded (BYU) on the TSX Venture Exchange.

For purposes of conducting NRC-licensed ISR operations, AUC LLC will be the holder of the NRC combined Source and 11e.(2) Byproduct Material license, and its managers and employees will be solely responsible for complying with the NRC's financial and technical qualification regulations under 10 CFR Part 40, Appendix A Criteria, specific license conditions, and relevant guidance and policy. More detailed discussions regarding corporate organization can be found in Section 5 of this TR.

1.4 Project Location and Description

The Proposed Project is located in the southern portion of the Powder River Basin (PRB) in the Pumpkin Buttes Uranium District in Campbell County, Wyoming. The Proposed Project area is 7.5 miles southwest of Wright, 31 miles northeast of Edgerton, and 41 miles south of Gillette. Figure 1-1 depicts the general Proposed Project location in relationship to surrounding population centers, interstates and highways, and county boundaries.

The Proposed Project area encompasses approximately 6,057 acres and is located in an area utilized for livestock grazing, oil and gas wells, and coal bed methane (CBM) production. Access to the Proposed Project area includes Wyoming State Highway 387 which bisects the Proposed Project area, and County Roads 22 (Clarkelen Road) and 25 (Cosner Road) which both run through the Proposed Project area as depicted in Figure 1-2. Several improved and unimproved two-track access roads used for agricultural, oil and gas activities and CBM development provide further access throughout the Proposed Project area.

1.5 Surface and Mineral Ownership

Surface ownership within the Proposed Project area includes private and state owned lands with no federal surface ownership or management. Mineral holdings consist of federal unpatented mining claims, private (fee) mineral leases, and state mineral leases. AUC has executed surface use agreements with all land owners who hold surface ownership in the Proposed Project area, including the State of Wyoming. A more detailed description of surface and mineral ownership in the Proposed Project area is presented in TR Section 2.1.

1.6 Orebody Description

In the Pumpkin Buttes Uranium District, almost all important economic uranium deposits occur in medium to coarse-grained sand facies of the Eocene Wasatch Formation. The Eocene Wasatch Formation is approximately 500 to 700 feet thick in the Proposed Project area though uranium mineralization is confined to the sandy facies and clay/sand boundaries in the lower part of the formation. Uranium deposits accumulated along roll-fronts at the down-gradient terminations of oxidation tongues within the host sandstones. The deposits occur within sandstones which are intermittently interbedded with lenses of siltstone and claystone, commonly referred to as mudstones due to the mixture of particle sizes.

The host sandstones of the Production Zone Aquifer (PZA) were deposited as the result of northward flowing fluvial systems. The thickness of the ore is controlled by the thickness of the sandstone host containing the solution-front. Uranium deposits are generally found within sand units ranging from 50 to 200 feet in thickness, and at depths ranging from 170 to 450 feet below ground surface. Uranium intercepts are variable in thickness ranging from one to 30 feet thick. Thin low-grade residual upper and lower limbs of the roll fronts are found in the less permeable zones at the top and bottom of oxidized sand units bounded by unoxidized mudstones.

As noted in NUREG-1910 (GEIS Section 2.1), the main ore minerals in the unoxidized zone are coffinite and pitchblende (a variety of uraninite). Based on metallurgical testing conducted by AUC, low concentrations of vanadium (~100 ppm) are sometimes associated with the uranium deposits at the Proposed Project. More details regarding the geology of the site and results of metallurgical testing can be found in TR Section 2.6 and accompanying addenda.

Although total recoverable resources for the Proposed Project are not fully developed at this time, AUC estimates, for the purposes of this License Application, mineral resources of approximately 15.7 million pounds of uranium at an average grade of approximately 0.065 percent U_3O_8. Based on AUC analysis and a review of the NUREG-1910 (GEIS p.3-49), the Proposed Project's ore body closely resembles the roll-front deposits assessed previously by NRC in the Nebraska-South Dakota-Wyoming Region, which includes the Proposed Project area, as well as those in all of the other ISR GEIS regional analyses.

1.7 ISR Method and Recovery Process

The ISR process contemplated by AUC is a phased, iterative approach, in which AUC will sequentially construct and operate a series of up to 12 Production Units. Each Production Unit will have from three to seven wellfields, each of which will be equipped with its own header house. AUC expects each header house will serve between 15 to 30 recovery wells and 25 to 50 injection wells (recovery and injection wells are also referred to as production wells) depending upon the design of each wellfield. An estimated 67 header houses are planned to be constructed for the Proposed Project. More detailed discussions relevant to the Proposed Project's ISR process methods and operations can be found in Sections 3 and 5 of this TR.

The proposed Reno Creek ISR chemical process for uranium recovery incorporates both the oxidation and complexation of uranium. Gaseous oxygen, hydrogen peroxide, or other oxidant oxidizes the uranium, which is then complexed with bicarbonate in solution. The carbonate/bicarbonate production solution and oxidant are combined into a leaching solution or lixiviant, which is injected into the ore-bearing sandstone formation through a series of injection wells that have been drilled, cased, cemented, and tested for mechanical integrity. Recovery wells then pump the uranium-bearing solution from the ore-bearing sandstone formation to the surface and into the pressurized downflow ion exchange columns circuit in the processing plant.

AUC anticipates that injection/recovery well patterns will follow the conventional 5-spot pattern, consisting of a recovery well surrounded by four injection wells. However, depending upon the ore configuration, more or fewer injection wells may be associated with each recovery well. In order to recover uranium effectively, and to complete groundwater restoration, all production wells will be completed so that they can be used as either injection or recovery wells. The dimensions of the patterns vary depending on the configuration of the mineralized zone, ore grade and accessibility, but the injection wells typically will be between 75 to 120 feet apart.

Monitor wells will be placed in each of the Production Units, and will include both interior and exterior wells. Interior monitor wells will be located within the wellfield boundaries and will be screened in the Overlying Aquifer above the confining PZA aquitard to monitor potential vertical movement of in situ recovery fluids. After extensive geologic and hydrologic analysis, it is clear that neither the Underlying water bearing unit nor the Surficial water bearing unit can be considered aquifers, and as a result, AUC proposes not to install monitor wells in either zone. Each Production Unit will also be surrounded by an exterior Monitor Well Ring to monitor for the potential lateral or horizontal movement of the in situ recovery fluids beyond the wellfields. The screened interval of these exterior monitor wells will be in the PZA. The monitor well spacing of 500 feet shown in TR Figure 3-3 is typical spacing for the fully saturated portion of the PZA. For the partially saturated portion of the PZA, AUC expects to use 400 foot spacing from the outer edge of the Production Unit and 400 foot spacing between monitor wells. A numerical groundwater flow model included as TR Addendum 2.7-C indicates that these monitor well spacing distances are sufficient to detect potential lateral excursions and discusses monitor well spacing in more detail.

As the lixiviant moves through the formation from injection wells to recovery wells contacting the ore the uranium is oxidized and complexed by the bicarbonate in the lixiviant to form a soluble uranium salt which remains in solution until recovered in the pressurized downflow IX column circuit. The uranium-bearing or pregnant lixiviant is drawn to a recovery well where it is pumped to the surface and transferred to the processing plant. Within the CPP, the process uses the following steps to process uranium from the recovered solutions:

- Loading of uranium complexes onto ion exchange resin;
- Elution (removal) of the uranium complexes from the ion exchange resin;
- Precipitation of uranium from the eluate;
- Drying and packaging of the uranium; and
- Reconstitution of the barren lixiviant by the addition of carbon dioxide and/or carbonate/bicarbonate and oxidant, which is recycled back to the Production Units for continuing operations.

During ISR operations, a slightly greater volume of water will be recovered from the PZA than is injected, to create an inward flow gradient into the Production Units. The difference between the amount of water recovered and injected is the wellfield “bleed”. The minimum bleed rate is anticipated to be approximately 0.5 percent of the total Production Unit recovery rate and the maximum bleed rate typically will be approximately 1.5 percent. The bleed rate will be adjusted as necessary to ensure that the inward flow gradient is maintained. AUC judges that the average bleed will be approximately 1 percent.

The ISR process selectively removes uranium from the ore body. No tailings are generated by the process, thus eliminating a major concern associated with conventional uranium mining and milling. When installing an ISR Production Unit, only limited surface disturbance occurs. During the operating life of the Production Unit, vegetation is re-established over the Production Units and pipeline corridors to prevent erosion and buildup of undesirable weeds.

1.7.1 Advantages of the ISR Process

ISR of uranium is a proven technology which has been successfully demonstrated commercially in Wyoming, Texas, and Nebraska. Uranium ISR is environmentally superior to conventional open pit or underground uranium mining and milling as evidenced by the following:

- ISR results in significantly less surface disturbance because mine pits, byproduct material dumps, haul roads, and tailings ponds are not needed;
- ISR requires much less net water demand than conventional mining and milling by avoiding the water consumption associated with mine dewatering, conventional milling, and tailings transport;
- The lack of heavy equipment, haul roads, 11e.(2) byproduct material impoundments, etc. results in very little air quality degradation at ISR sites;
- Fewer employees are needed at ISR operations, thereby reducing transportation and socioeconomic concerns;
- Aquifers are not excavated, but remain intact during and after ISR;
- Tailings impoundments are not used, thereby eliminating a major potential ground water pollution concern. State of the art lined backup storage pond may be used to manage liquid byproduct streams; and
- Uranium ISR results in the majority of other contaminants (e.g., heavy metals) remaining where they naturally occur instead of moving to byproduct material and tailings impoundments where they present potential environmental concerns.

1.7.2 Ore Amenability to the ISR Method

AUC is certain ISR methods can be successfully employed at the Proposed Project due to the close proximity of the Proposed Project to other established ISR projects, current industry information, and experience gained during the operation of those projects, the Proposed Project's typical roll front geology, typical confined aquifer systems, and AUC's planned similar use of best practicable technology. The proposed concurrent operational controls and environmental monitoring programs will ensure that any potential adverse impact to the environment or public health is minimal.

Furthermore, the amenability to ISR of the uranium deposits in the Proposed Project has been demonstrated through a successful site-specific pilot test conducted by RME at Reno Creek as discussed in Section 1.2 and Addendum 1-A of this TR. The pilot test program convincingly demonstrated both the technical feasibility of mobilizing and recovering uranium with a carbonate lixiviant, and the successful restoration of groundwater. Additionally, existing nearby ISR projects in the Powder River Basin (PRB) in Wyoming (Christensen Ranch, Irigaray, Smith Ranch-Highland and several pilot-scale projects) demonstrate that in situ recovery methods can efficiently extract uranium from roll front deposits in a cost effective manner with minimal environmental impacts. ISR processes can be conducted with no significant risk to the public health or safety, and the affected aquifer can be successfully restored to meet both State and Federal regulatory requirements.

1.8 Operating Plans, Design Throughput, and Production

AUC is requesting that the proposed Reno Creek CPP be licensed to operate a pressurized downflow ion exchange system with a maximum capacity of 11,000 gpm and produce up to two million pounds of yellowcake per year. AUC's license application also incorporates facilities to receive and process uranium-loaded IX resins from other facilities. These include satellite facilities owned and/or operated by AUC, by other ISR licensees, and water treatment entities generating uranium-loaded ion exchange resins that are the same as or substantially similar to those generated at ISR facilities, pursuant to RIS 2012-06. AUC's Safety and Environmental Review Panel (SERP) will be required to review and evaluate the receipt of any such uranium loaded ion exchange resins and certify that these two conditions have been satisfied prior to receiving and off-loading any such resins at the proposed CPP. Based on this request, AUC's license application includes a detailed assessment of potential transportation, resin off-loading and handling, and byproduct material management impacts associated with the production of up to two million pounds of yellowcake per year including the receipt and processing of the aforementioned uranium-loaded ion exchange resins. Sections 4 and 5 of this TR contain more detailed discussions regarding operations, throughput and production.

The pressurized down-flow ion exchange circuit will be designed to handle a flow rate up to 11,000 gpm and produce two million lbs of uranium annually over an 11 year period. The CPP will have the capacity to process up to two million lbs of U_3O_8 per year from the proposed Reno Creek operations as well as future ISR facilities operated by AUC and other uranium-loaded resin generators as discussed above. The acceptance of loaded resin from outside sources along with future amendment areas in the Pumpkin Buttes Uranium District could potentially extend the life of the CPP facilities at the Proposed Project.

1.9 Proposed Operating Schedule

Baseline data acquisition efforts in support of the Proposed Project were initiated in Fall 2010. AUC submitted a letter of intent to the NRC staff on November 3, 2010, which supplemented its original letter of April 9, 2010. This letter notified NRC staff that AUC intended to submit an application to operate an ISR facility at the Reno Creek site. By letter dated July 12, 2011, AUC requested a pre-submission audit of its Reno Creek application. This meeting occurred on November 15-17, 2011, in Wright, Wyoming. The pre-submission audit consisted of an a site tour and an audit of the preliminary draft application. Addendum 1-B presents the NRC staff comments compiled during the preliminary draft application audit, AUC's comments, and where they are addressed within this application. These comments represent the more important issues discussed with the NRC during the debrief meeting.

AUC anticipates that, after the issuance of its requested combined source and 11e.(2) byproduct material license, its WDEQ/LQD Permit to Mine, and other required licenses/permits, facility construction will commence. Initial activities include site grading and excavation; construction of the CPP and associated facilities including a lined backup storage pond, administrative building, and workshop; development of initial Production Unit and associated wellfields; and construction of supporting operations infrastructure such as access roads, transmission lines, control measures (fences, gates, cattle guards, etc.), and domestic sewage facilities.

Construction of each Production Unit is anticipated to take one year to two years, including installation and development of injection, recovery, and monitor wells; and installation of header houses, piping, and utilities. Production Unit construction will be phased, with three to seven wellfields in various stages of construction at one time. Additional Production Unit plans are developed approximately one year prior to the planned commencement of the new wellfield operations. The overall duration of construction is anticipated to be approximately 9 years.

Uranium recovery operations are anticipated to begin approximately 9 to 12 months after initiating construction of the CPP and first Production Unit. The duration of operation of each Production Unit is estimated to be two to three years, but this interval may be longer or shorter depending on uranium recovery levels and available CPP capacity. The overall duration of operations is approximately 11 years for the Proposed Project.

Wellfields will be moved from a production status to a restoration status once the recovery of uranium has decreased to the point where the cost of producing that uranium is more than the value of the uranium produced. Other considerations that could impact the decision to move a wellfield from production to restoration would include, the dilution of the lixiviant stream to the point of non-economic operation, the current operational status of adjacent wellfields, the restoration capacity of the CPP, and the capacity of liquid 11e.(2) disposal.

Similar to Production Unit construction, groundwater restoration will be a phased approach and is anticipated that two to three Production Units will be in various stages of active restoration or stability monitoring at one time. The proposed plan incorporates water balance calculations so that the deep disposal well(s) and back up storage capacity can accommodate the proposed recovery and restoration efforts at any given time. The total duration of groundwater restoration is expected to be approximately 8 years for the Proposed Project.

Decommissioning and Demolition (D&D) of the CPP, access roads, backup pond, and associated infrastructure is expected to last 12 to 18 months. D&D and reclamation activities described above for Production Units will likely commence after receiving NRC and WDEQ/LQD approval of successful groundwater restoration in each Production Unit. The total project lifespan is expected to be approximately 16 years; however, the duration of operations may be extended by processing uranium-loaded IX resin from AUC owned and/or operated satellite facilities or other company(ies). Once groundwater restoration, D&D, and reclamation activities conclude and AUC has met the requirements of 10 CFR 20, Subpart E, the site will be released for unrestricted use.

The anticipated project schedule is shown in Figure 1-3 and outlines the activities described above. The schedule is subject to change due to production schedules, variations with production area recoveries, CPP issues, economic conditions, etc. The exact annual production schedules will be updated in annual reports to NRC and WDEQ/LQD.

1.10 Byproduct Material Management

This section describes the proposed byproduct material management system. Liquid and solid byproduct materials are divided into two general categories: 11e.(2) byproduct materials and non-11e.(2) byproduct material. Additional details regarding byproduct material management are found in Section 4 of this TR.

The major sources of liquid 11e.(2) byproduct material generated from the Proposed Project will include brine and permeate generated from the treatment of the barren lixiviant slip stream and groundwater restoration water. Other liquid 11e.(2) byproduct will include process byproduct water from plant operations, byproduct water from activities in the Production Units, and byproduct water from equipment and personnel decontamination. Liquid Non-11e.(2) byproduct will include storm water runoff, used petroleum products and chemicals, and domestic byproduct water.

Solid 11e.(2) byproduct material will include filtrate and spent filter media, scale and sludge from equipment maintenance, contaminated soil, damaged IX resin, contaminated solids from ISR wells, contaminated personal protective equipment (PPE), and contaminated materials and equipment from decommissioning that cannot be decontaminated to approved levels. Solid non-11e.(2) byproduct will include domestic solid byproduct, construction debris, solid hazardous waste, and decontaminated material and equipment.

Disposal options for liquid 11e.(2) byproduct material include up to four deep well injection in Class I wells or used as plant make-up water.

Solid 11e.(2) byproduct material will be stored on-site until it can be shipped to an NRC-approved 11e.(2) disposal facility. AUC will secure an 11e.(2) byproduct disposal agreement prior to operations as discussed in Section 4.13 of the ER..

Solid waste such as office trash and spent equipment parts not associated with uranium recovery will be collected and stored on-site and periodically removed to an off-site sanitary landfill permitted by the WDEQ Solid and Hazardous Waste Division (WDEQ/SHWD). Hazardous waste such as solvents, and degreasers will be recycled or disposed of offsite at a permitted hazardous waste facility or by other EPA approved disposal methods. It is currently planned that domestic sewage will be disposed utilizing conventional septic/leach field systems. However, alternative systems may be evaluated as facility construction draws near. Domestic sewage disposal systems will be permitted through the WDEQ Water Quality Division (WDEQ/WQD).

1.11 Groundwater Restoration

Groundwater restoration activities will be carried out at the Proposed Project upon completion of ISR in a given Production Unit and as appropriate concurrent with ISR activities in other Production Units. The active groundwater restoration phase, discussed in detail in Section 6 of this TR will include the following methods:

- Groundwater Transfer;
- Groundwater Sweep (targeted or selective); and

- Reverse Osmosis Treatment with Permeate Injection and Reductant Addition.

The application of each method and sequencing will be determined by AUC based on operating experience, restoration treatment system capacity, and liquid 11e.(2) byproduct disposal capacity. As described in Section 6 of this TR, not all stages of groundwater restoration will be used if deemed unnecessary by AUC. AUC will combine these methods selectively to improve groundwater restoration efficiency, reduce consumptive use of groundwater, and decrease the time to restore a given Production Unit.

AUC will install the infrastructure necessary to accomplish groundwater restoration concurrently with uranium recovery operations. This means restoration RO units will be installed and operational prior to the cessation of ISR operations from the first Production Unit in operation. To ensure that a Production Unit will be able to begin groundwater restoration, additional restoration pipelines will be installed along with production pipelines as necessary. The pumps used for production will remain in the wells for use in restoration.

Following restoration, a groundwater stabilization monitoring program will be initiated, and will be conducted in accordance with NRC requirements. Once the restoration target values are reached and maintained, restoration will be deemed complete. Results will be documented in a restoration report and submitted to the WDEQ and NRC for approval. Groundwater restoration is described in more detail in Section 6 of this TR.

1.12 Decommissioning and Reclamation

Surface and subsurface facilities in individual Production Units will be decommissioned following the completion and agency acceptance of groundwater restoration. Individual Production Unit decommissioning will include the plugging and abandonment of all injection and recovery wells in accordance with WDEQ and WSEO requirements (see Addendum 2.6-B of the TR) plus the removal of those Production Unit piping and structures which are no longer required for operation of the Production Unit.

At the completion of project life and after groundwater restoration has been completed and approved; the entire site will be decommissioned fully. Decommissioning will include the removal of remaining Production Unit piping and equipment, demolition and disposal of contaminated buildings and structures, and reclamation of all disturbed areas, except those the landowners have requested to remain. Any structures transferred to landowners will satisfy NRC requirements for unrestricted use. Appropriate NRC and WDEQ guidance will be followed during decommissioning as required. Decommissioning and reclamation are discussed in more detail in Sections 6 of this TR.

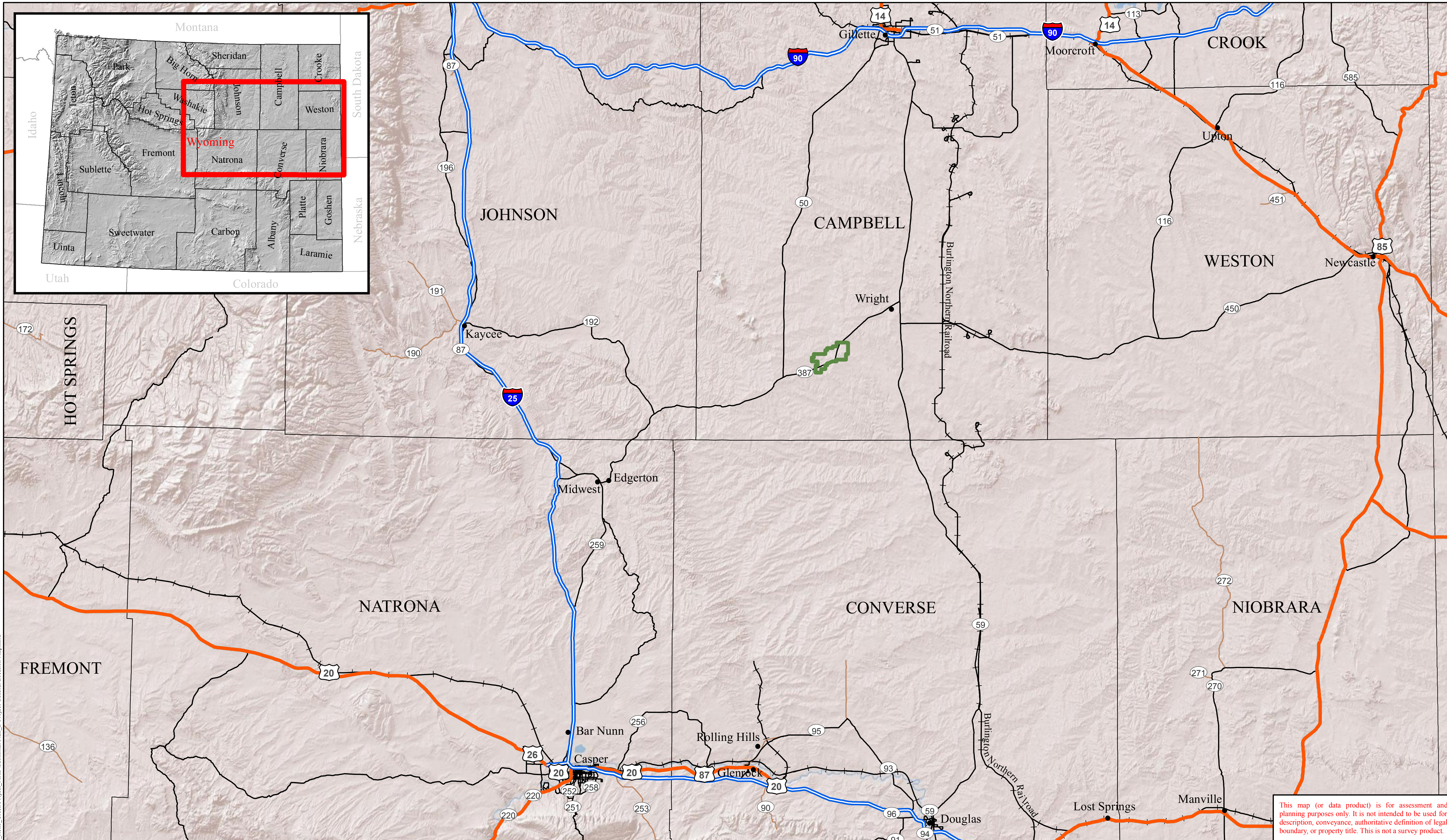
1.13 Financial Assurance Arrangements

AUC will have in place a financial assurance arrangement for the Proposed Project consistent with 10 CFR 40, Appendix A, Criterion 9. NRC currently requires that ISR license applicants provide a Restoration Action Plan (RAP) or the equivalent in a license application to provide NRC Staff with financial assurance calculation methodologies and preliminary cost estimates for all aspects of the Proposed Project, including groundwater restoration, surface reclamation, and D&D of Proposed Project facilities. The financial assurance amount will be revised prior to the commencement of licensed activities and annually thereafter to reflect the estimated costs of final reclamation activities for the proposed Reno Creek Project. The methodology for estimating reclamation cost and potential financial assurance arrangements is discussed in more detail in Section 6 of the TR and in the RAP found in Addendum 6-A of the TR.

Pursuant to these requirements, AUC will comply with Criterion 9 requirements for these annual financial assurance updates and will have, in place, an NRC-approved financial assurance mechanism after receiving its NRC license but before beginning active ISR operations.

Table 1-1: Proposed Project Area Historical Ownership

Company(s)	Partner(s)	Date	Transaction Type	Partnership Name
Rocky Mountain Energy	Union Pacific Railroad	1967 (Est.)	Purchase	None
Rocky Mountain Energy	Mono Power Company and Halliburton Services	1975 (Est.)	Joint Venture	ISLCO
Energy Fuels, Inc.	None	1992	Purchase	None
International Uranium Corporation	Energy Fuels, Inc.	2000 (Est.)	Merger Acquisition	None
Rio Algom Mining Corporation	None	2001	Purchase	None
Power Resources, Inc.	CAMECO	2002 (Est.)	Purchase	None
Strathmore Mining Corporation	David Miller and Associates	2004	Claim Acquisition	None
Strathmore Mining Corporation	American Uranium Corporation, Inc.	2007	Joint Venture	None
AUC, LLC.	Bayswater Uranium Corporation; Pacific Road Resource Funds	2010	Purchase	AUC Holdings



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PROPOSED RENO CREEK PROJECT
CAMPBELL COUNTY, WY

PREPARED FOR **AUC LLC**
LAKEWOOD, CO

Legend
- Proposed Project Boundary
- Cities and Towns
- Railroad
- County Line
- Interstate
- Highway
- Major Road
- Local Road

0 5 10 20 Miles

1:750,000

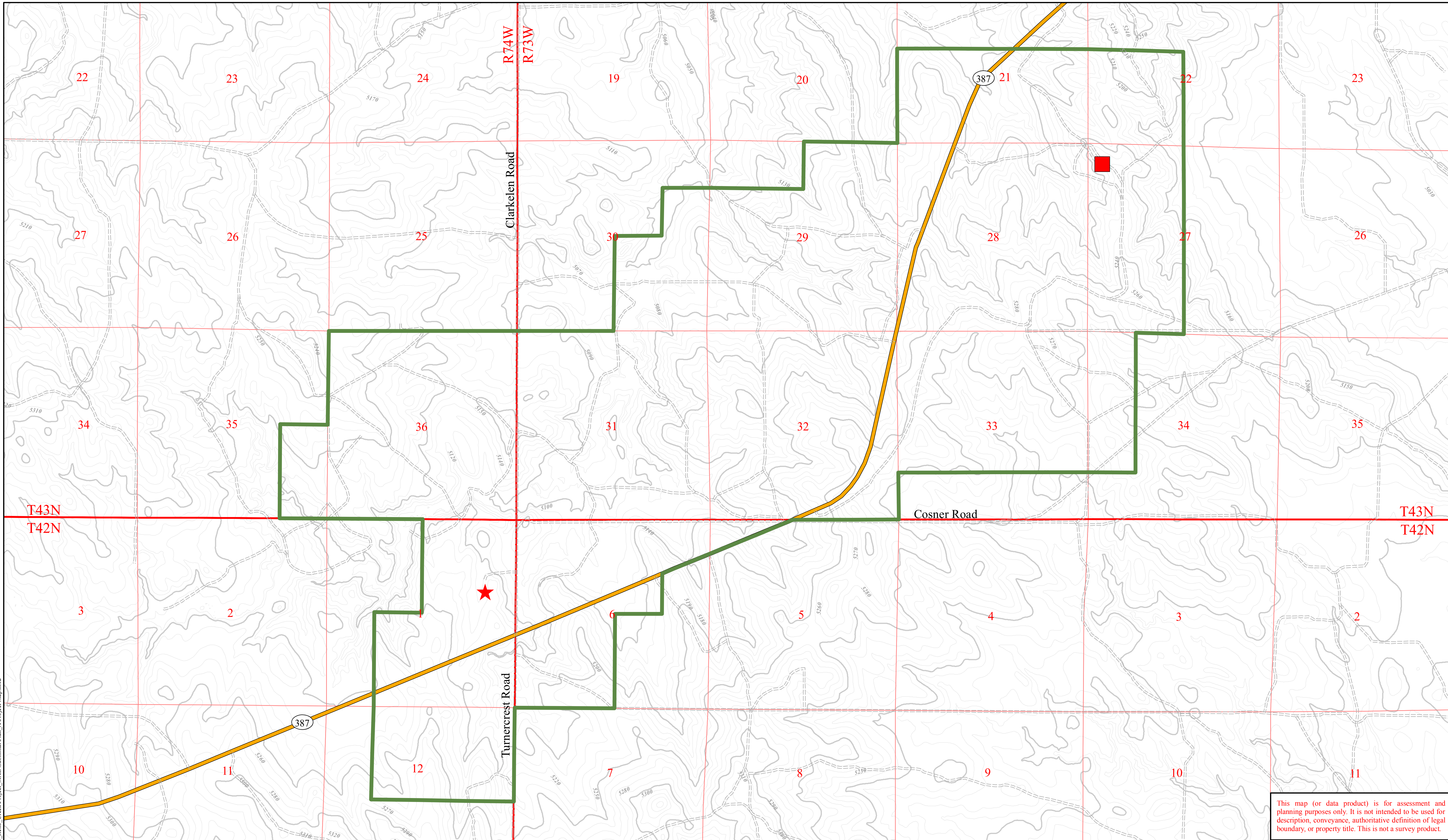
N W E S

DRAWN BY:	RHK
CHECKED BY:	RMD
APPROVED BY:	JEY

Proposed Project General Location

REV #	DESCRIPTION	BY	DATE	FIGURE
0	Draft	RHK	08/18/11	1-1
1	Revised Draft for Review	RHK	10/14/11	
2	Revised Project Boundary	RHK	06/14/12	

Path: O:\WY_Projects\2010-100_AUC_Reno_Creek\Project_MXD\Submittal\Plan_B\Project General Location Map.mxd



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PROPOSED RENO CREEK PROJECT

CAMPBELL COUNTY, WY

PREPARED FOR AUC LLC
LAKEWOOD, CO

Legend

- Proposed Project Boundary
- Central Processing Plant
- Historical RME R&D Site
- Major (Paved)
- Minor (Unpaved)

0 0.25 0.5 1 Miles

Contour Interval = 10 feet   1:30,000

N S W E

DRAWN BY: RHK
CHECKED BY: RMD
APPROVED BY: JEY

Proposed Project Map

REV #	DESCRIPTION	BY	DATE	FIGURE
0	Draft	RHK	08/29/11	1-2
1	Revised Draft for Review	RHK	10/14/11	
2	Final	RHK	10/20/11	

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Installation and Construction
Operate Plant
Operate Production Unit
Groundwater Restoration/Stability
Reclamation
Plant/ DDW Decom. and Reclamation
Regulatory Review Period

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CAMPBELL COUNTY, WY

PREPARED FOR AUC LLC
LAKEWOOD, CO

DRAWN BY: RHK
CHECKED BY: RMD
APPROVED BY: JEY

Proposed Project Schedule

REV #	DESCRIPTION	BY	DATE	FIGURE
0	Draft	RHK	09/08/11	1-3
1	Revised Draft for Review	RHK	12/22/11	
2	Revised Schedule per Client Request	RHK	07/20/12	

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2 SITE CHARACTERIZATION

This section (Sections 2.1 through 2.9) describes the existing conditions of the physical, biological, cultural, and socioeconomic resources in the Proposed Project area as per NUREG-1569. Further detailed discussion of several of these environmental features is included in the accompanying Environmental Report

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2.1 Site Location and Layout

The proposed Reno Creek Project (Proposed Project) is located in the southern portion of the Powder River Basin (PRB), in the Pumpkin Buttes Uranium District in Campbell County, Wyoming within the Wyoming East Milling Region as defined by NUREG-1910 (GEIS Sec. 3.3). Figure 1-1 of this TR shows the general site location of the Proposed Project site and surrounding area within the PRB in relation to surrounding population centers, interstates and highways, and county boundaries.

The Proposed Project is located in Campbell County, Wyoming, between the communities of Wright, Edgerton, and Gillette. Natural features near the Proposed Project area include the Pumpkin Buttes located approximately 7.5 miles northwest of the project boundary and the Thunder Basin National Grassland which bisects the eastern half of the Proposed Project boundary.

The area within the project boundary is classified as semi-arid, with a range of elevations varying from 5,041 feet to 5,296 feet above mean sea level (MSL) with 255 feet of vertical relief across the project area. The project area is at the headwaters of the Belle Fourche and Cheyenne Rivers; both waterways are classified as ephemeral within the Proposed Project boundary. The Proposed Project area comprises of approximately 6,057 acres of all or portions of 15 sections described below:

- T42N R73W:
  Diagonal portion of the north half of the northwest quarter of the northwest quarter of Section 5; West half of Section 6, west half of the northeast quarter of Section 6, and the northeast quarter of the northeast quarter of Section 6;
- T42N R74W:
  East half of Section 1, east half of the southwest quarter of Section 1, northeast quarter of Section 12 and east half of the northwest quarter of Section 12;
- T43N R73W:
  South half of Section 21, southwest quarter of Section 22, west half of Section 27, all of Section 28, south half of Section 29, northeast quarter of Section 29, south half of the northwest quarter of Section 29, southeast quarter of Section 30, southeast quarter of the northeast quarter of Section 30, all of Section 31, all of Section 32, north half of Section 33, north half of the south half of Section 33, west half of the northwest quarter of Section 34 and the northwest quarter of the southwest quarter in Section 34; and
- T43N R74W:
  All of Section 36 and the east half of the southeast quarter Section 35.

Access to the Proposed Project area from the east is via State Highway 59 to State Highway 387; from the north is via State Highway 50 to State Highway 387; and from the west is from I-25 to State Highway 259 to State Highway 387. Primary Access for the Proposed Project area is along Highway 387, which traverses the Proposed Project area. Access throughout the site is available via Campbell County-maintained gravel roads (Clarkelen and Cosner Roads) and private two-track roads established from coal bed methane (CBM) development and agricultural activity. AUC will utilize existing access roads to navigate the Proposed Project area although the primary, secondary, and tertiary roads may be improved or constructed as the Proposed Project develops.

The Proposed Project consists of 157 unpatented lode mining claims (SC 1-47, WR 3-80, BFR 1-18, 21-83), one State of Wyoming mineral lease, and one private mineral lease. The minerals leased in the Proposed Project area are on private lands, with the exception of Section 36, T43N R74W, which is a State owned section. Figure 2.1-1 and Figure 2.1-2 depict the land and mineral ownership respectively in the Proposed Project area, and further characterized in Table 2.1-1. With the exception of 2,873 acres of mineral ownership, none of the land in the Proposed Action area is owned or managed by any Federal agency. AUC has executed surface use agreements with all land owners who hold surface ownership in the Proposed Project area.

The proposed CPP will be located in the southeast quarter of the northeast quarter of Section 1, Township 42 North , Range 74 West. The coordinates for the Proposed Project CPP are North American Datum (NAD) 83 Universal Transverse Mercator (UTM) Zone 13N 448,593 meters and 4,834,906 meters. Figure 2.1-3 shows the proposed site plan and infrastructure for the Proposed Project including the CPP, Production Units, trunk lines, utility corridors, access roads, and DDW.

Although the Proposed Project covers a total of 6,057 acres, not all lands will be affected by the proposed operations. Potentially affected lands during the Proposed Action's 16 year life span include:

- Disturbed lands are estimated to encompass 154 acres or approximately 2.5 percent of the Proposed Project area. Of the 154 acres, there will be two types of disturbance:
    1) Short term- disturbance will be small in time duration (< three months) including trunklines, drill pits and drill pads, top soil storage; and
    2) Long term- disturbance will be extended in time duration (> three months) including the fenced area around the CPP, backup pond, Deep Disposal Well (DDW) pad, and top soil storage.
- Controlled areas will be fenced to limit access to project associated operations and is estimated to encompass 481 acres or approximately 8 percent of the Proposed Project Area. Anticipated controlled areas include all fenced areas around the

CPP, wellfields, backup pond, and DDWs. Restricted areas can be located within controlled areas;

- Restricted areas will control access to protect individuals from exposure toradiation and 11e.(2) byproduct materials including selected areas within the CPP building, 11e.(2) byproduct storage areas, backup pond, DDW buildings, and/or areas exceeding 2 mrem per hour; and
- Unrestricted areas are within the Proposed Project area to which access is neither limited nor controlled by the Proposed Action. These areas encompass approximately 5,576 acres or around 92 percent of the Proposed Project area.

The maps used in this application were derived from United States Geological Survey (USGS) 7.5-minute topographic quadrangle maps, geo-spatial data from the Wyoming Geographic Information Science Center (WYGISC), and the Environmental Systems Research Institute's (ESRI) web based imagery. These are CAD/GIS drawings where each point, line, or polygon is an individual entity with core attributes that allow users to create interactive queries, analyze spatial information, and present the results of all these operations.

Table 2.1-1: Surface and Mineral Ownership Distribution

Ownership Type	**Surface Ownership**		**Mineral Ownership**	
	Acres	Percent of Total Proposed Project Property	Acres	Percent of Total Proposed Project Property
Federal	0	0%	2,873	47.4%
Municipal	0	0%	0	0%
Private	5,417	89.4%	2,544	42.0%
State	640	10.6%	651	10.6%
Total Proposed Project Acreage	6,057	100%	4,793	100%

Table 2.1-2: Estimated Disturbance Calculations

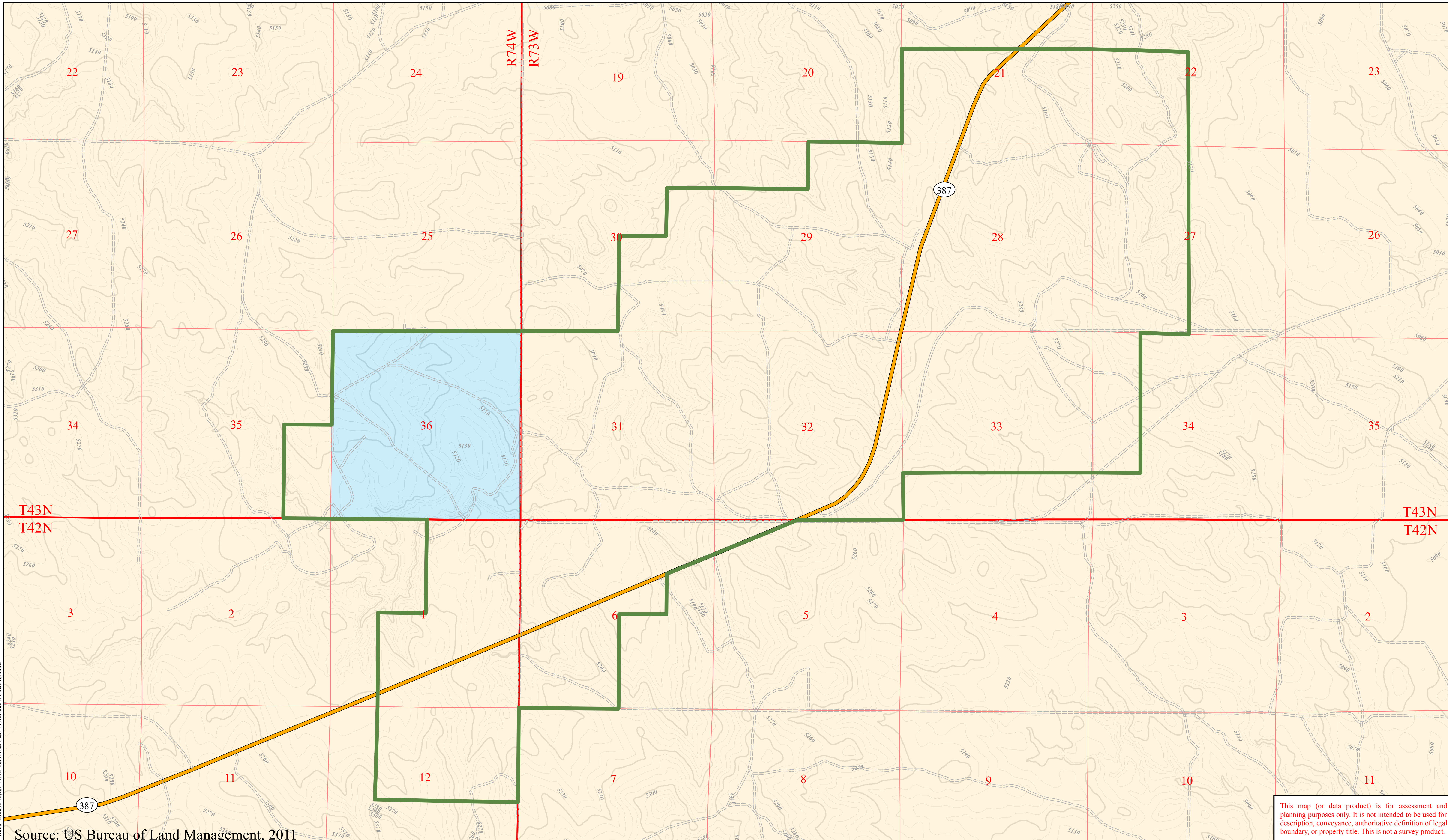
Estimated Production Unit Area Disturbance	Patterns	Area/Pattern (ft^2)	Total Area (ft^2)	Acres
Total Pattern Area per Header House (HH); 67 total	30	10,000	300,000	6.9
Long Term Top Soil Storage (> 6 months)	**Width (ft)**	**Length (ft)**	**Total Area (ft^2)**	**Acres**
Area per Header House	12	30	360	0.01
Proposed Secondary Access Roads to HHs	12	225	2,700	0.06
Long Term Top Soil Storage per HH			3,060	0.07
HH Long Term Top Soil Storage				4.7
Proposed Additional Secondary Roads within Project Boundary	12	18,614	223,369	5.1
Proposed Tertiary Roads (monitor well ring)	8	99,366	794,928	18.2
Total Acres Long Term Disturbance 67 HHs plus Additional New Roads				***28.1***
Short Term Top Soil Disturbance (< 6 Months)	**Width (ft)**	**Length (ft)**	**Total Area (ft^2)**	**Acres**
Well Installation Drill Pit (per pit)(72 total)	7	20	10,080	0.2
Lateral Trenches for pipe from HH to wells	6	5,247	31,482	0.7
Total Area of Short Term Disturbance per HH			***41,562***	***0.95***
Total HH Short Term Top Soil Storage				63.9
Lateral Trunklines to HHs (for 67 HHs)	15	54,269	814,041	18.7
Overlying Monitor Well Installation Drill Pits (134 total)	7	20	18,760	0.4
Ring Monitor Well Installation Drill Pits (469 total)	7	20	65,660	1.5
Total Acres Short Term Disturbance				***84.6***
Estimated Long Term Surface Disturbance (CPP Site Infrastructure)	**Width (ft)**	**Length (ft)**	**Total Area (ft^2)**	**Acres**
Central Processing Plant (CPP)	200	350	70,000	1.6
Backup Pond	100	210	21,000	0.5
Office Building	60	100	6,000	0.1
Maintenance Building	60	100	6,000	0.1
Parking Lot, Chemical Storage Tanks, Laydown area (grading)			570,636	13.1
Total Site Layout			***673,636***	***15.5***
Deep Disposal Well Pad (x4)			174,240	4.0
Total Area of CPP Site Infrastructure Long Term Disturbance			***847,876***	***19.5***
Estimated Short Term Trunkline Top Soil Disturbance (< 6 Months)	**Width (ft)**	**Length (ft)**	**Total Area (ft^2)**	**Acres**
Main Trunklines	25	28,347	708,675	16.3
DDW pipeline	8	32,138	257,104	5.9
Total Area of Short Term Trunkline Disturbance			***965,779***	***22.2***
				Acres
Total Long Term Surface Disturbance				**47.5**
Total Short Term Surface Disturbance				**106.7**
Total Disturbance Area for Removal of Vegetation and Topsoil				**154.3**
				Acres
Total Controlled Area (fenced with or without the removal of topsoil and/or vegetation)				**480.9**
Total Unrestricted Area (all areas outside of controlled area and 2mrem per hour)				**5,576.1**

2.1.1 References

Figure References

Figure 2.1-1 and 1-3 of ER; Site Surface Ownership; Website: http://www.blm.-gov/wy/st/en/resources/public_room/gis/datagis/state/state-own.html

Figure 2.1-2 and 1-4 of ER; Site Mineral Ownership; Website: http://www.blm.-gov/wy/st/en/resources/public_room/gis/datagis/state/state-own.html



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PROPOSED RENO CREEK PROJECT
CAMPBELL COUNTY, WY

PREPARED FOR **AUC LLC**
LAKEWOOD, CO

Legend
- Proposed Project Boundary
- State
- Private
- Major (Paved)
- Minor (Unpaved)

Contour Interval = 10 Feet

1:30,000

0 0.25 0.5 1 Miles

N S E W

DRAWN BY: RHK
CHECKED BY: RMD
APPROVED BY: JEY

Site Surface Ownership

REV #	DESCRIPTION	BY	DATE	FIGURE
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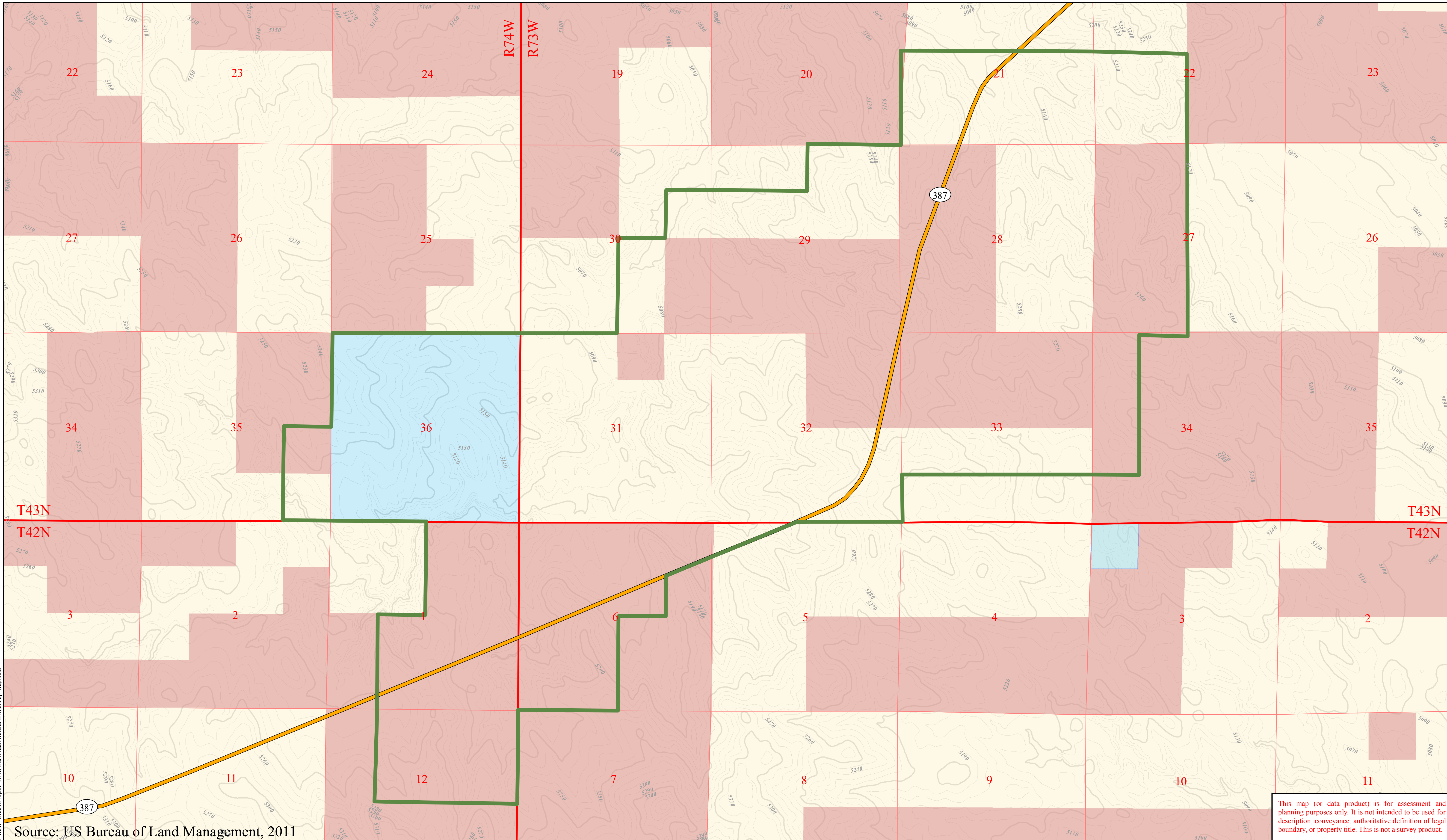
1	Revised Draft	RHK	08/19/11	
2	Final	RHK	10/21/11	



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PROPOSED RENO CREEK PROJECT

CAMPBELL COUNTY, WY

PREPARED FOR AUC LLC

LAKEWOOD, CO

Legend

- State Mineral
- Federal Mineral
- Private Mineral
- Proposed Reno Creek Project Boundary
- Major Road (Paved)

Contour Interval = 10 feet

1:30,000

0 0.25 0.5 1 Miles

N E S W

DRAWN BY: RHK

CHECKED BY: RMD

APPROVED BY: JEY

Site Mineral Ownership

REV #	DESCRIPTION	BY	DATE	FIGURE
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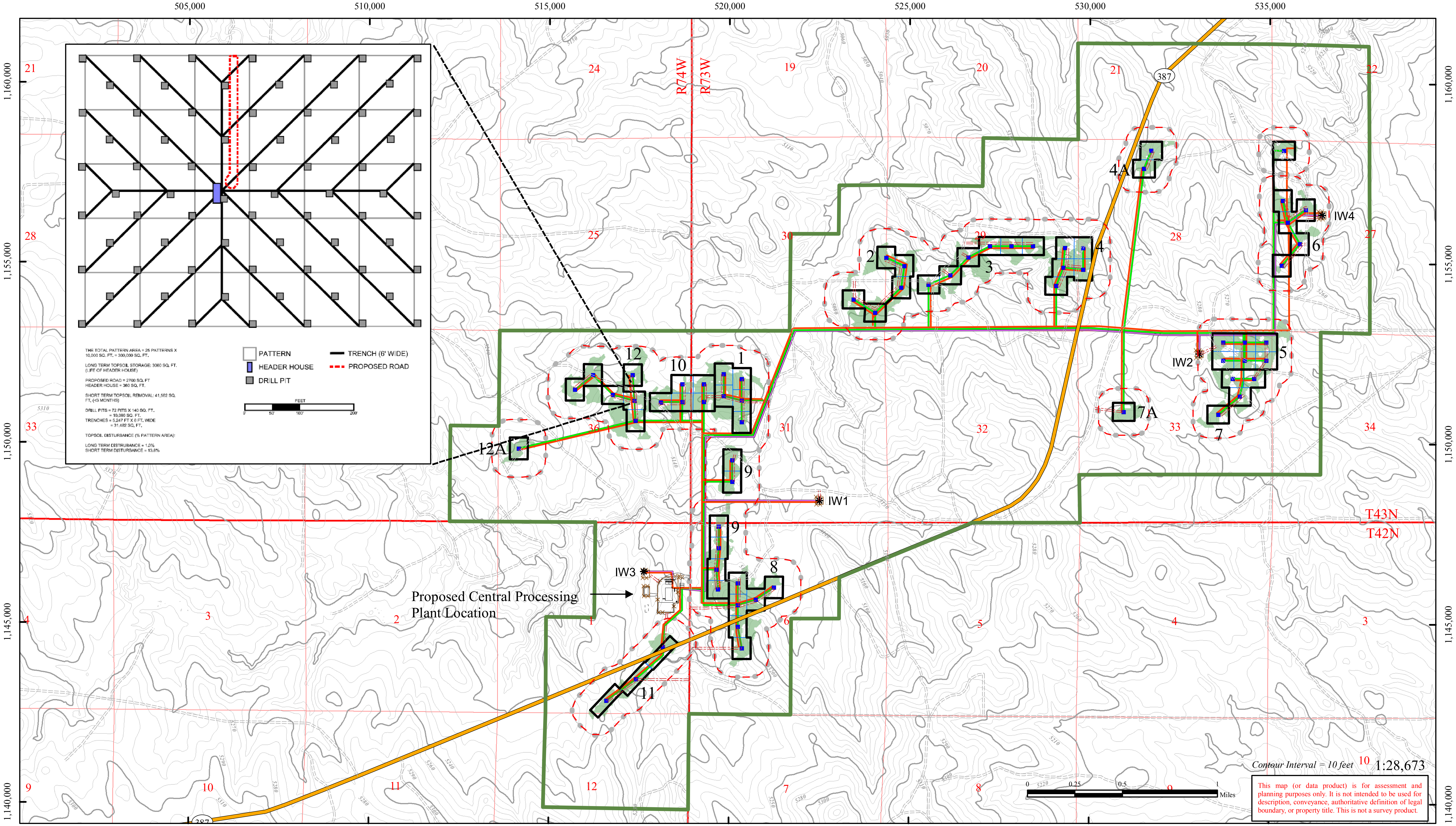
1	Revised Draft for Review	RHK	08/19/11	
2	Final	RHK	10/24/11	



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PROPOSED RENO CREEK PROJECT

CAMPBELL COUNTY, WY

PREPARED FOR AUC LLC
LAKEWOOD, CO

Legend

- Proposed Project Boundary
- Ore Body
- Production Unit
- Proposed Header House Location
- Proposed Header House Pattern
- Proposed Header House Location
- Proposed Monitor Wel Rring
- Deep Disposal Well
- Proposed Trunkline
- Proposed Powerline
- Proposed Deep Disposal Well Pipeline
- Existing Primary and Secondary Access Road
- Proposed Secondary Road
- Proposed Tertiary Road
- Major Road (Paved)
- Minor Road (Unpaved Existing Access Road)

NAD 1983 StatePlane Wyoming Wast FIPF 4901 Feet

N W E S

DRAWN BY: RHK
CHECKED BY: WFC
APPROVED BY: RMD

Conceptual Site Plan

REV #	DESCRIPTION	BY	DATE
0	Draft for Review	RHK	08/29/11
1	Final	RHK	02/27/12
2	Revisions made per Client Request	RHK	07/24/12

FIGURE 2.1-3

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2.2 Uses of Adjacent Lands and Waters

This section includes discussions and summaries of the land use within the proposed Reno Creek Project (Proposed Project) area. Further discussions regarding land use can be found in:

- Section 2.7 of this TR (Water Resources);
- Sections 7.1.1 and 7.2.1 of this TR (Environmental Effects);
- Section 3.1 of the ER (Land Use);
- Section 3.4 of the ER (Water Resources);
- Section 4.1 of the ER (Environmental Impacts);
- Section 5.1 and 5.2 of the ER (Cumulative Impacts)
- Section 6.1 of the ER (Mitigation); and
- Section 8.4.2.2 of the ER (Potential External Costs).

2.2.1 Current Land Use

The Proposed Project landscapes are characterized by a flat to gently rolling topography with small ephemeral drainages and large, open upland grassland mixed with sagebrush shrubland that are typical landscapes within the PRB. The Pumpkin Buttes are visible from the Proposed Project area, but range from 7.5 to 14 miles away. As a result, they do not constitute a potentially significant on-site scenic feature, nor will any of the activities proposed by AUC pose a significant visual impact from anywhere on the Buttes. The Proposed Project area's landscape is rural in character with a number of ranch access roads and industrial development from oil gas and CBM activities

Human influence is evident in existing livestock grazing activities and facilities (stock tanks, fences), oil and gas production facilities, CBM production facilities, and infrastructures that support these activities.

Current areas of disturbance within the Proposed Project area include roads, utilities, oil and gas wells, and activities associated with livestock grazing. Several county roads and unnamed local access roads border or traverse the Proposed Project area. Highway 387, Clarkelen Road, and Cosner Road will be the primary access routes to the Proposed Project area.

Within the Proposed Project area, existing land uses include: oil and gas production, CBM production, transportation, livestock grazing, and wildlife habitat. There is limited opportunity for most recreational activities due to private surface ownership. The mapped land use review area categories within five miles of the Proposed Project area include non-crop and non-agricultural. In the surrounding five mile land use review area, surface use is nearly entirely livestock grazing rangeland, with some areas classified as non-irrigated cropland (ER Figure 3.1-1).

In 2007, cash receipts for livestock sales totaled $37.7 million in Campbell County (USDA-NASS 2010). In 2009, 70.7 percent of the total livestock inventory for Campbell County was cattle and the remaining 29.3 percent was breeding sheep and lambs.

There currently is one residence (the Taffner homestead) located within the Proposed Project boundary (ER Figure 3.1-1), and five residential sites located within the five-mile land use review area outside of the Proposed Project boundary. Based on landowner correspondence, there are currently two occupants at the Taffner homestead and approximately eight occupants currently living in the five residences located outside the project boundary. The Taffner homestead is currently located where the proposed CPP will be located. AUC will acquire the Taffner property prior to construction and it will not thereafter be used as a residence. The domestic water well located at the Taffner residence will be plugged in accordance with all WDEQ Rules and Regulations and will not be used for consumption once construction begins.

Recreational lands for public use within 50 miles of the Proposed Project are limited due to the lack of or infrequent availability of many types of recreational structures such as navigable waterways or developed recreational facilities (ER Figure 3.1-4). Although, the regional setting of the Proposed Project provides broad, panoramic prairie landscapes, the area does provide a setting for a variety of outdoor recreational activities such as hunting, camping, hiking, biking, and horseback riding. Within the project area and five mile review area there is limited opportunity for most recreational activities due to private surface ownership and ephemeral nature of surface waters.

Wyoming is a state with active mineral development. In addition to uranium, the PRB contains major deposits of coal, CBM and other petroleum resources. The closest coal mines are the North Antelope, Rochelle, and Thunder Basin Coal Mines, approximately 16 miles east of the Proposed Project. There is also extensive CBM production within and around the Proposed Project area. There are 324 CBM-classed wells within the Proposed Project and two-mile buffer area. Currently one oil producing well exists within the Proposed Project area; although, there is oil drilling activity adjacent to the Proposed Project area but drilling targets were not available at the time of prepaeration of this report.

Several properties in the Pumpkin Buttes Uranium District owned by Cameco Corporation (North Butte), Uranium One (Moore Ranch), and Uranerz (Hank and Nichols Ranch) have been deemed practicable for ISR uranium production and have been licensed by NRC for ISR development and are currently operating or may be in operation in the future.

Currently there are two operational uranium recovery facilities located within 50 miles of the Proposed Project. These facilities consist of Smith Ranch and Willow Creek operated by Power Resources and Uranium One respectively. There are no nuclear fuel cycle facilities and located within 50 miles (80 km) of the Proposed Project area (NRC 2010a). The nearest uranium hexafluoride conversion facility is in Metropolis, Illinois.

2.2.2 Projected Land Use

Under the Proposed Action and No Action Alternatives, current land uses within the Proposed Project area are expected to continue in the foreseeable future. These include but are not limited to oil and gas production, CBM production, transportation, livestock grazing, wildlife habitat, and recreation. These land uses are consistent with existing land uses and have generally remained unchanged for many years. Future residential development in the proposed project area will likely remain limited due to private surface ownership and lack of public service infrastructure. Potential for other industrial development such as oil and gas production is moderate due to existing active mineral development and abundance of mineral resources near the Proposed Project area and PRB.

2.2.3 References

USDA-NASS (U.S. Department of Agriculture, National Agricultural Statistics Service), 2007 Census of Agriculture – County Profile for Campbell County, Wyoming. Website; http://www.agcensus.usda.gov/Publications/2007/Online_-Highlights/County_Profiles/Wyoming/index.asp. Accessed Dec. 2010

NRC, (U.S. Nuclear Regulatory Commission 2010a). "Locations of Major U.S. Fuel Cycle Facilities" Websites: http://www.nrc.gov/info-finder/materials/fuel-cycle/ and http://www.nrc.gov/infofinder/materials/-uranium/ur-projects-list-public.pdf . Accessed December 2010.

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2.3 Population Ditribution

Information presented in this section summarizes those demographic and social characteristics of the counties and communities that may be affected by the proposed development of a ISR facility at the proposed Reno Creek Project (Proposed Project) in Campbell County, Wyoming. Most data are from the 1980, 1990, 2000, and 2010 U.S. Census of Population, and various State of Wyoming government agencies. All tables and figures referenced in this section are located in Section 3.10 of the ER. Further discussions relating to this section can be found in:

- Sections 7.1.2 and 7.2.2 of this TR (Environmental Effects);
- Section 7.6 of this TR and Section 4.11 of the ER (Environmental Justice);
- Section 3.10 of the ER (Socioeconomics);
- Section 4.10 of the ER (Environmental Impacts);
- Section 5.11 of the ER (Cumulative Impacts); and
- Section 6.10 of the ER (Mitigation).

2.3.1 Regional Population

NUREG-1569 recommends consideration of population data within a 50 mile (80 km) radius from the Proposed Project area's approximate center. The area within the 50 mile radius of the Proposed Project includes portions of seven counties in northeastern Wyoming (Campbell, Converse, Crook, Johnson, Natrona, Niobrara, and Weston Counties) as shown on Figure 3.10-1 of the ER. The Proposed Project area is located in the Wyoming East Milling Region as defined by NUREG-1910 (GEIS, p. 1-2).

The Proposed Project is located in southwest Campbell County. There are several communties within approximately 50 miles that may be directly affected by the Proposed Project. Significant population centers and their 2010 population estimates include Wright (1,807), Edgerton (195), Midwest (404), and Gillette (29,087). The town of Casper (55,316) is located outside the 50 mile review area but may be a potential source of labor, services, and materials to support ISR operations.

Total population within the 50 mile area in 2010 was 45,807. ER Table 3.10-1 reflects the populations within varying radii utilizing the 16 compass sectors extending outward to 50 miles of the Proposed Project. These sectors are shown in Figure 3.10-1 of the ER.

Generally, population declined throughout Wyoming between 1980 and 1990, with the exception of Campbell County which grew by nearly 20 percent, primarily because of ongoing mineral resource development in the Powder River Basin (PRB). The population began to rebound in the 1990s. Between 2000 and 2010, population growth was strong throughout the 50-mile area. All counties within the 50 mile review area except Natrona, Niobrara and Weston exceeded the state growth of 14 percent between 2000 and 2010. Among the municipalities, the largest growth between 2000 and 2010 occurred in Gillette (48 percent) and Wright (34 percent). Population trends between 1980-2010 in counties and communities within an 50 mile distance of the Proposed Project are shown in ER Table 3.10-2.

2.3.1.1 Population Characteristics

In all the counties, the 40 to 64 year age group (which includes the 'baby boom' cohort) comprises roughly a third or more of the population in each of the counties. According to the Wyoming Economic and Demographic Forecast: 2007 to 2016 (WDAI, 2007), the early baby boom population in Wyoming is one of the highest in the nation as a result of the in-migration of workers during the oil boom years in the late 1970s and early 1980s. In contrast, the population in the 27 to 42 year age group in most counties is relatively low. Noticeably different are Campbell and Natrona counties where the the 20-39 year age group is comparable to that of the 40 to 64 year age group. Population numbers in 2010 by age and sex for counties within 50 miles of the Proposed Project are shown in Table 3.10-3 of the ER.

In 2010, 93.7 percent of the total seven-county population of 160,760 was classified as white and non-Hispanic. Hispanics (of any race) were estimated at 6.5 percent of the population. Persons of two or more races comprised 2.1 percent of the total population, Native American comprised 1.0 percent, and Blacks and Asians each comprised 0.6 percent. Persons of all other races comprised a total of 2.0 percent. The racial characteristics of the seven-county area were slightly less diverse than the State of Wyoming, which was estimated to have approximately 14.1 percent minority population, compared to the seven county minority population of 9.9 percent. The two largest population counties (Campbell and Natrona) had the highest proportion of minorities in the seven-county region (USCB, 2010).

2.3.2 Population Projections

The population forecasts are developed by the Wyoming Department of Administration and Information (WDAI), Economic Analysis Division, based on historic trends of demographic and economic variables. All the counties in the region are expected to increase in population, many with increases exceeding 20 percent between 2010 and 2030. The projected growth rate for Campbell County is expected to outpace all of the regional counties and the state's growth as well. Population of Campbell County is expected to increase by approximately 43 percent. The projected populations through

2030 for counties within the 50 mile radius of the Proposed Project are shown in Table 3.10-4 of the ER.

2.3.2.1 Seasonal Population and Visitors

The Proposed Project consists of private and public lands in south-central Campbell County. The surrounding area within an 50 mile radius also contains a mix of private, federal, and state lands, which provide open space for a variety of dispersed outdoor recreation opportunities. With the exception of the towns and areas surrounding those towns, there are no developed recreation sites, such as campgrounds, fishing access sites, interpretive trails, museums, etc. on public lands within the 50 mile radius.

The closest site which could be a destination for tourists to the Proposed Project area is the Bozeman Trail, which lies approximately 12 to15 miles west of the Proposed Project boundary. The Proposed Project includes portions of Thunder Basin National Grassland, managed by the U.S. Forest Service. Recreational use of the Grassland in this area is very minimal and consists primarily of dispersed uses such as hunting. Due to the patchwork nature of land ownership in Thunder Basin National Grassland, hunting can be limited because recreationists may need private landowner permission to access public lands via private lands.

Across Wyoming, the influx of workers has created local population increases that are difficult to quantify utilizing traditional methods. Many workers are not local residents; they live somewhere else and commute to Wyoming in shifts (e.g., ten days on, ten days off). While working in Wyoming, they may live in rental units, housing units owned by their employers, RV parks, on-site facilities (e.g., "workers camps" at the work site) and in hotels.

Census population numbers for a particular place include only people who identify that place as their primary residence and do not include others who list their primary residence elsewhere (such as the "shift-labor" workers described above). As a result, the total of all permanent and part-time residents living in a place at any time could be significantly higher than the census count. Unfortunately, there is no standardized mechanism for counting part-time residents.

To address this issue, the Wyoming Department of Employment Research and Planning has begun to track workers without a Wyoming or Colorado driver's license. The most recent published information available by county are tables with quarterly information between 2005 and 2009. These data show that among all Wyoming counties, Campbell County had the second highest number of worker inflow in the fourth quarter of 2009 with 4,632. Teton County in far western Wyoming led the state with 7,220 such workers. Natrona County had 3,241 such workers in the fourth quarter of 2009. All other counties in the seven-county 50 mile Study Area had less than 500 workers without a Wyoming or Colorado driver's license. Between 2005 and 2009, the peak number in the Study Area was generally in the third or fourth quarter of 2008. In Campbell County the peak was the fourth quarter of 2008 with 5,531 workers without a Wyoming or Colorado driver's license. In Natrona County the peak was 4,912 workers in the third quarter of 2008 (WDOE 2010).

In the 10-year economic forecast released in July 2007, the Wyoming Economic Analysis Division indicated that continuing strong employment had persuaded many out of state mining workers to settle in Wyoming, and projected the trend to continue. The multiplier effect of mining industry activity results in upward movement in job growth in other industries such as construction, wholesale trade, transportation, etc. and some non-resident workers in those sectors may also be moving to live in Wyoming.

Statewide, however, net migration to Wyoming lags behind job growth in the state and many non-resident workers continue to commute in shifts to Wyoming (WDAI, 2007). Since the 10 year economic forecast was released in 2007, the economic recession which affected the nation in 2008 arrived approximately 12 months later in Wyoming toward the end of 2008. The economic summary for the first quarter of 2010 prepared by the Wyoming Economic Analysis Division indicated that the worst of the state's recession was likely over and overall labor market was stabilizing, which was attributed to stabilization of the mining industry (WDAI, 2010). With the stronger job market, it is possible that more shift workers will move permanently to Wyoming.

2.3.3 References

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WDAI (Wyoming Department of Administration & Information-Economic Analysis Division). 2007. 10 Year Outlook: Wyoming Economic and Demographic Forecast 2007 to 2016. Website: http://eadiv.state.wy.us/index.asp

WDOE (Wyoming Department of Employment. 2010. Research and Planning; Commuting In Wyoming. Website: http://doe.state.wy.us/lmi/commute/commute2010/-index.htm

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2.4 Historic, Cultural, and Scenic Resources

This section provides a summary of the historic, cultural and scenic resources located within the Proposed Reno Creek Project (Proposed Project) area. Cultural resources, which are protected under the National Historic Preservation Act (NHPA) of 1966, are nonrenewable remains of past human activity. As noted in NUREG-1910 (GEIS, Section 3.3.8.4), there are no culturally significant places listed in either the National Register of Historic Places (NRHP) or state registers in the Wyoming East Uranium Region. This region includes the entire area of the Proposed Project. More comprehensive discussions regarding historic, cultural and scenic resources can be found in:

- Section 7.1.1.6 and 7.2.3 of this TR (Environmental Effects);
- ER Section 3.8 (Historic & Cultural Resources);
- Addendum 3.8-A of the ER (Historic and Cultural Resources Report);
- ER Section 3.9 (Scenic Resources);
- Sections 4.8 and 4.9 of the ER (Potential Impacts); and
- ER Sections 6.1.1.6, 6.2.1.7, 6.2.1.8, 6.8 and 6.9 (Mitigation).

2.4.1 Regional/Site History

Paleo-Indian culture is believed to have existed in the PRB as far back as 10,000 years ago. However, evidence to this effect is relatively sparse. The PRB is deeply filled with sediments and older artifacts are assumed to be well covered. Since settlement by pioneers, archaeological finds have proceeded from the periphery of the Basin toward the center; however, most known archaeological sites are around the edges of the PRB.

The PRB was disputed hunting grounds between the Sioux, Blackfoot and Crow nations during the late 19th century. When gold was discovered in Montana during the 1860's, pioneers attempted to cross the PRB from the Platte River by means of the Bozeman Trail which sparked many Indian wars along the trail until 1880. The last of the major Indian wars of the northern plains were fought in the Powder River area including famous battles such as Fetterman, Wagonbox, and Crazy Woman Fights (Larson, 1990).

Campbell County was created by law in 1911 out of the western halves of Crook and Weston Counties. Campbell County was named after both John A. Campbell, the first governor of the territory of Wyoming, and Robert Campbell who was with an early expedition to this part of Wyoming from 1825 to 1835. Campbell County officially organized in 1913.

Following World War I, Campbell County had an intense period of homesteading due to the growth of the "dry farming" movement and cattle and sheep ranching. Small coal mines were built around the area as early as 1909 and major oil discoveries in eastern Campbell County in 1956 set off an oil boom in the area which changed land use acreage minimally but added substantially to the economy of the area.

During the 1970's, the modern coal industry in Campbell County began to thrive. Major coal companies flocked to the County to harvest the PRB's low sulfur coal. Railroad companies began adding more lines to ship the coal which paved the way for a new age of railroad history in Gillette. Today coal remains a vital industry in Campbell County (CCGov, 2011).

The initial discovery of uranium near the Proposed Project area was by Dr. John David Love. He asserted that uranium was likely to be found in and associated with the tuffaceous sediments of the Oligocene White River Formation (38-24 million years old) in the PRB and hypothesized that the deposit should occur in the Pumpkin Buttes area of southwest Campbell County. Aerial surveys and field verification in the early 1950's verified the occurrence. During the 1970's and 1980's, the uranium industry acquired large tracts of subsurface uranium mineral rights and leases (WSGC, 2011).

2.4.2 Cultural Resources Survey

A State Historic Preservation Office (SHPO) Records Division file search was conducted on June 6, 2010 for information on previous surveys. The search revealed recorded cultural resources by Drs. John and Mavis Greer from Greer Services. Greer Services also conducted a Class III Cultural Resource Evaluation for the Proposed Project between August 5, 2010 and December 11, 2010 with some additional field checking after that date through August 17, 2011. The purpose of the Class I and Class III survey is to formulate a preliminary determination of the significance of resources and their eligibility for listing in the National Register of Historic Places (NRHP) within the Proposed Project area.

Each site's integrity of location, design, materials, workmanship, feeling and association are considered in the evaluation as well as the National Register's four main criteria. Those criteria include:

- **Criterion A** – the site must make a contribution to the major pattern of American history;
- **Criterion B** – the site is associated with significant people of the American past;
- **Criterion C** – the site embodies distinctive characteristics; and
- **Criterion D** – the site has yielded or may be likely to yield information important to prehistory or history (NRHP 2011).

Seventy-nine cultural localities are known within the Proposed Project area. All 41 previously recorded cultural resources had been evaluated as not eligible for the NRHP, and files indicate SHPO concurrence for all previously recorded sites. All 38 newly recorded localities are also evaluated as not eligible for the National Register. All cultural resources are described in detail in the Class III inventory report included as Addendum 3.8-A of the ER.

The Class III cultural resource inventory report submitted to WDEQ LQD and NRC constitutes documentation for formal consultation with the SHPO and contains information that falls under the confidentiality requirement for archeological resources under the National Historic Preservation Act, Section 304 (16 U.S.C. 470w-3(a)). All Wyoming Cultural Resource Forms are similarly classified as *Confidential*. Non-agency disclosure is exempted by statute as specified in 10 CFR §2.390(a)(3). Therefore, all applicable portions of the final report should remain "*Confidential*" for purposes of Public Disclosure of this application.

2.4.3 Paleontological Resources

The BLM utilizes the Potential Fossil Classification System (PFYC) for land use planning efforts and for the preliminary assessment of potential impacts and proper mitigation needs for specific projects. It is intended to provide a tool to assess potential occurrences of significant paleontological resources. It is meant to be applied in broad approach for planning efforts, and as an intermediate step in evaluating specific projects. Using the PFYC system, geologic units are classified based on the relative abundance of vertebrate fossils or scientifically significant invertebrate or plant fossils and their sensitivity to adverse impacts, with a higher class number indicating a higher potential (BLM 2011). The five primary classes of geologic units are:

- **Class 1**- Very Low;
- **Class 2**- Low;
- **Class 3**- Moderate or Unknown;
- **Class 4**- High; and
- **Class 5**- Very High.

The entirety of the proposed Reno Creek Project area is considered the Wasatch Formation which the BLM designates a PFYC Class 5. Paleontological survey results are provided in Addendum 3.8-A of the ER.

2.4.4 Tribal Consultations

Cultural resources that are considered sensitive and potentially sacred to modern Native American tribes include burials, rock art, rock features and alignments (such as cairns, medicine wheels, and stone circles), Indian trails, and certain religiously significant natural landscapes and features. Some of these resources may be formally designated as traditional cultural places (TCPs) or Indian Sacred Sites. A TCP is a site considered eligible for inclusion on the NRHP because of its association with cultural practices or beliefs of a living community which are (a) rooted in that community's history and (b) important in maintaining the continuing cultural identity of the community (NRHP 2011).

To date there are no Native American Heritage sites which have been formally identified and recorded which are associated with the Proposed Project area. However, the Proposed Project area is geographically located 7.5-miles from the Pumpkin Buttes which have been identified as a TCP and has potential cultural affiliation with nine tribes. The buttes are used in traditional Native American ceremonial activities including rituals and sacred narratives. Uranerz Energy Corporation's (URZ) NRC-approved Nichols Ranch ISR Project is located at the base of the Pumpkin Buttes. A Memorandum of Agreement (MOA) among URZ, NRC, BLM, ACHP, WY SHPO, and seven tribes regarding mitigation of adverse effects to historic properties was reconciled on June 27, 2011. It stipulates general mitigation measures and the procedures in the event of a discovery of a new cultural resource.

According to the Supplemental Environmental Impact Statement and the MOA described above for the Uranerz (URZ) Nichols Ranch ISR Project (NUREG-1910, Supplement 2, Section 3.9.2.3), the TCP boundary for the North Middle Butte of the Pumpkin Buttes is 5,500 feet from the center of the top of the butte. The Proposed Reno Creek Project area, unlike the URZ Nichols Ranch ISR Project, is located well beyond the TCP boundary. This distance between the Proposed Project and the Pumpkin Buttes negates the necessity to obtain a mandatory MOA for the operation of the Proposed Project facility.

Regardless, AUC commits to ongoing monitoring of historic and cultural resources as project development progresses. Mitigation measures proposed to avoid or reduce cultural resource impacts include:

- Consult with Native American governments early in the planning process to identify traditional cultural properties, sacred landscapes, and other issues and concerns regarding the Proposed Project;
- If resources eligible for listing on the NRHP are present, modify the development plan to avoid significant cultural resources;
- Prepare an internal cultural resources management plan, including an Unanticipated Discovery Plan (UDP), to manage the unexpected discovery of cultural resources during any phase of the project shall result in a work stoppage

in the vicinity of the find until the resources can be evaluated by a professional archaeologist. A brief outline of the UDP can be found in ER Section 7.5; and

- Use existing roads to the maximum extent feasible to avoid additional surface disturbance. As noted in NUREG-1910 (GEIS, Section 3.3.8.4), there are no culturally significant places listed in either the NRHP or state registers in the Wyoming East Uranium Region.

Based on the cultural resources evaluations conducted to date, it is deemed unlikely that any such resources will be discovered during construction or operation. However, the plan described above is consistent with approved ISR operations elsewhere in Wyoming.

2.4.5 Visual and Scenic Resources

The BLM is responsible for ensuring that the scenic values of public lands are considered before allowing uses that may have negative visual impacts. BLM accomplishes this through its Visual Resource Management (VRM) system, a system which involves inventorying scenic values and establishing management objectives for those values through the resource management planning process, and then evaluating proposed activities to determine whether they conform to the management objectives.

The VRM system is the basic tool used by the BLM to inventory and manage visual resources on public lands. The inventory consists of a scenic quality evaluation, sensitivity level analysis, and a delineation of distance zones. Based on these three factors, BLM-administered lands are placed into one of four visual resource inventory classes. These inventory classes represent the relative value of the visual resources. Classes I and II being the most valued, Class III representing a moderate value, and Class IV being of least value (BLM 2010).

The area surveyed for visual resources include both the Proposed Project and the two-mile buffer area. The Proposed Project is located predominantly on privately owned land with one section of the project lying on state-owned land. One area of managed land, Thunder Basin National Grassland, bisects the project area in a north and south direction. Landscapes are characterized by flat to rolling topography with prominent ephemeral drainages and large, open upland grassland mixed with sagebrush shrubland.

The BLM has inventoried the landscape; including non-BLM owned land, within the Proposed Project and the surrounding two-mile buffer and rated the areas as VRM Class III.

A site-specific VRM evaluation for the Proposed Project area was conducted July 2011 based on methods provided in BLM Manual 8410. The key factors of landform, vegetation, water, color, influence of adjacent scenery, scarcity and cultural modifications were evaluated and scored according to the rating criteria. Based on guidance provided in NUREG-1569 (Section 2.4), if the visual resource evaluation rating is 19 or less, no further evaluation is required. Based on the site specific evaluation the total score of the scenic quality inventory for the Proposed Project is eight out of the possible 32. Therefore, no further evaluation is required for existing scenic resources and any changes to scenic resources from Proposed Project facilities.

2.4.6 References

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2.5 Meteorology

2.5.1 Introduction

This section summarizes the general climate of the region and local meteorological characteristics of the area where the proposed Reno Creek Project (Proposed Project) is located. Comparable and/or more detailed discussions can be found in:

- Addendum 2.5-A of this TR contains the Meteorological System Audit Report;
- Sections 7.1.4, 7.2.4 and 7.4.1 of this TR (Environmental Effects);
- Section 3.6 of the ER (Meteorology);
- Section 4.6 of the ER (Environmental Impacts);
- Section 5.4 of the ER (Cumulative Impacts);
- Section 6.6 of the ER (Mitigation); and

The Proposed Project is located in a semi-arid or steppe climate. The region is characterized seasonally by cold harsh winters, hot dry summers, relatively warm moist springs and cool autumns. Though summer nights are normally cool, the daytime temperatures can be quite high. Conversely, there can be rapid changes during the spring, autumn and winter when frequent variations of cold-to-mild or mild-to-cold can occur.

As noted in NUREG-1910 (GEIS Section 3.3.6), the Wyoming East region's relatively cool temperatures are a result of Wyoming's elevation. Temperature extremes range from roughly -25° F in the winter to 100° F in the summer. Typically, the "last freeze" occurs during late May and the "first freeze" mid-to-late September.

Yearly precipitation totals are normally near 13 inches. The region is prone to severe thunderstorm events throughout the spring and early summer months and much of the precipitation is attributed to these events. In a typical year, the area will see four or five severe thunderstorm events (as defined by the National Weather Service criteria) and 40 to 50 thunderstorm days. Autumn stratiform rain events also contribute to precipitation totals, but to a lesser degree than those before mentioned. Snow frequents the region throughout winter months (40-50 in/year), but provides much less moisture than rain events.

Windy conditions are fairly common to the area. Nearly five percent of the time hourly wind speed averages exceed 25 mph. The predominant wind directions are west and west/southwest with the wind blowing out of that those directions over 25 percent of the time. A north/northwest secondary mode is also present. Surface wind speeds are relatively high all year-round, with hourly averages from 11 to 15 mph. Higher average wind speeds are encountered during the winter months while summer months experience lower average wind speeds.

A regional overview is presented first. This section includes a discussion of the maximum and minimum temperature, relative humidity, annual precipitation including snowfall estimates, evaporation rates, and a brief wind speed and direction summary. For purposes of the regional analysis, meteorological data were acquired through the Western Regional Climate Center (WRCC, 2011) for 20 COOP and ASOS stations operated by the National Weather Service (NWS). These include Casper Airport (AP), Douglas, Gillette AP, Glenrock, Kaycee, Lance Creek, Midwest, Reno, and others. In addition, Glenrock Coal Mine and Antelope Coal Mine meteorological data have been obtained through the Air Science division of Inter-Mountain Laboratories (IML Air Science) located in Sheridan Wyoming. The latter two mentioned sites are operated in compliance with regulations set forth by the Wyoming Air Quality Division (AQD) for air quality monitoring. IML Air Science has maintained the sites for several decades. Table 2.5-1 provides the station identification, coordinates, and period of operation for each site used in the regional analysis.

Figure 2.5-1 shows the 22 sites in relation to the project license boundary. As can be seen in the figure, Antelope and Glenrock are the closest available sites with wind data. The closest NWS operated station which continuously records all weather parameters are the Casper AP and Gillette AP sites, roughly equidistant from the Proposed Project. The 22 sites in Table 2.5-1 have been analyzed collectively to provide a regional climatic temperature and precipitation analysis of the Proposed Project area. Only the Casper AP, Gillette AP, Glenrock Mine and Antelope Mine sites were analyzed for the regional wind characteristics. The NWS sites were used for snowfall analysis as neither mine site records snowfall data.

The site specific analysis follows the regional analysis. For the site-specific analysis, baseline meteorological information for the Proposed Project was collected from the Reno Creek meteorological station by IML Air Science and subsequently reported to AUC. The baseline monitoring period was approximately one year. Meteorological parameters monitored at the proposed site include wind speed, wind direction, ambient temperature, relative humidity, precipitation, barometric pressure, solar radiation and pan evaporation. An in-depth wind analysis includes wind speed and wind direction statistics, annual and seasonal wind roses, joint frequency distributions to characterize the wind data for the site by stability class, and wind speed frequency distributions. These data are summarized on a monthly, seasonal and annual basis. The seasons are classified in calendar quarters as follows; January-March for winter, April-June for spring, July-September for summer, and October-December for fall. No site specific general climate data are included as this is addressed in the regional evaluation.

The Antelope Coal Mine was analyzed in the site specific analysis due to its proximity to the proposed site and to its similar topography. Antelope Mine is located approximately 20 miles southeast of the Proposed Project site. The Antelope Mine site, like the Proposed Project area, extends from the eastern slope of a ridge downward into a drainage. Both sites are characterized by mildly rolling hills covered with grass and sparse shrubs.

The Antelope Mine and Glenrock Mine meteorological stations were also proposed to the NRC for use in meteorological studies for the Allemand-Ross Project by High Plains Uranium, Inc. (HPU) in August of 2006. Since that time, HPU was acquired by Energy Metals Corporation and subsequently by Uranium One. In a letter from the NRC to HPU dated September 14, 2006, the NRC states that the meteorological stations at the Antelope and Glenrock mines meet the standards identified in NRC Regulatory Guide 3.63, *Onsite Meteorological Measurement Program for Uranium Recovery Programs-Data Acquisition and Reporting,* and can be recognized as “standard installations” per NUREG-1569. Therefore, data from these stations may be used along with NWS Station Data. As described above, the Antelope Mine meteorological station is closer to the Proposed Project than the nearest NWS station and lies in very similar terrain. As a result, AUC believes that weather conditions at the Antelope station generally resemble conditions at the Proposed Project site. Moreover, data from the baseline monitoring year at Antelope are shown in this report to be typical of the last 25 years at that site. By its similarities to the Proposed Project, Antelope serves the purpose of demonstrating that the baseline monitoring year should be typical of the long term at the proposed Reno Creek Project as well.

The nearest mountain ranges to this area are:

- the Bighorn Mountains, approximately 60-miles west of the Proposed Project site and 80-miles west of Antelope Mine;
- the Black Hills, approximately 75-miles east of the Proposed Project site and 100-miles northeast of Antelope Mine; and
- the northern Laramie Range, approximately 80-miles south of Proposed Project site and 80-miles southwest of Antelope Mine.

Due to these large distances, neither the Antelope site nor the Proposed Project site experiences significant weather effects from the three mountain ranges. Also, there are no major bodies of water affecting the meteorology of these two sites. The Antelope site is several hundred feet lower in elevation than Proposed Project. Both, however, are situated on the southeasterly side of the hydrologic divide with a similar vertical relationship to the divide.

Because of the extensive surface coal mining that has developed over the last 30 years, the PRB airshed is one of the most heavily monitored in the country. Coal production in the PRB grew from a few million tons in 1973 to over 400 million tons in 2010. The Clean Air Act and the Surface Mining Control and Reclamation Act of the 1970's prompted a parallel growth in ambient air quality monitoring throughout the PRB. This has led to over 100 particulate monitoring samplers and more than 20 meteorological monitoring towers, all configured to support air quality permitting, compliance and research objectives.

The monitoring programs at these sites meet the Wyoming Department of Environmental Quality requirements for land and air quality permit compliance. Methods used in collecting and validating these data adhere to EPA's "On-Site Meteorological Program Guidance For Regulatory Modeling Applications." Hourly average values for various parameters are generated by field instruments and recorded by continuous data loggers, all operated and maintained by IML Air Science. Data recovery has typically exceeded 95 percent. Depending on the mine, meteorological parameters logged include wind speed, wind direction, sigma theta, ambient temperature, barometric pressure, solar radiation and precipitation. All hourly data are downloaded to IML Air Science's relational database. The database software provides for quality assurance, invalidation of suspect or erroneous data, and various forms of data presentation.

2.5.2 Regional Overview

2.5.2.1 <u>Temperature</u>

According to NUREG-1910 (GEIS Section 1.4.3), the Proposed Project is located in the Wyoming East Uranium Region. The Proposed Project area features a semi-arid or steppe climate. Temperature extremes range from roughly -25° F in the winter to 100° F in the summer. The "last freeze" occurs during late May and the "first freeze" mid-to-late September. The annual average temperature for the region is 46° F. The graph in Figure 2.5-2 shows monthly average temperatures for the two mine sites, the Gillette AP site and the Casper AP site. The graph exhibits very little difference between the four sites. July shows the highest average monthly temperatures followed by August. January and December record the lowest average temperatures for the year. Table 2.5-2 compares the monthly temperature statistics for three of the four sites. The slight differences in average temperatures could be attributed to the small changes in elevation between the stations. Antelope Mine has the highest average temperature and the lowest elevation of the three while Casper has the lowest average temperature and is the highest in elevation.

Large diurnal temperature variations are found in the region due in large part to its altitude and low humidity. Figure 2.5-3 shows this variation for Antelope Mine. Peak daily temperatures generally occur during late afternoon. Diurnal changes in temperature are typically 25° F during the summer with maximum temperature variations of 30 - 40° F observed during extremely dry periods. Less daily variation is observed during the cooler portions of the year as fall and winter have variations averaging about 15° F. The lesser variation in daily temperature can be attributed to the more stable environment the region is exposed to during the fall and winter months. Stable periods have much lower mixing heights and accompanying lapse rates allowing for less temperature variation.

The region is characterized seasonally by cold harsh winters, hot dry summers, relatively warm moist springs and cool autumns. The Proposed Project region has annual average maximum temperatures of 58.5° F and average minimum temperatures of 33.6° F. July has the highest maximum temperatures with averages near 90° F while the lowest minimum temperatures are observed in January with averages near 10° F. Interpolated annual average minimum and maximum temperatures are shown in Figures 2.5-4 and 2.5-5, respectively.

2.5.2.1.1 Cooling, Heating, and Growing Degree Days

The graphs shown in Figure 2.5-6 show the average monthly cooling, heating, and growing degree days for Casper. The data are assumed to be indicative of the region as the other meteorological parameters for the various sites track very closely. The heating and cooling degree days are included to show deviation of the average daily temperature from a predefined base temperature. For heating and cooling degree days, 55° F has been selected as the base temperature. The number of heating degree days is computed by taking the average of the high and low temperature occurring that day and subtracting it from the base temperature. The calculation for computing growing and cooling degree days is the same, except that the base temperature is subtracted from the average of the high and low temperature for the day. Also, the base temperature used for growing degree days is 50° F. Negative values are disregarded for all calculations.

As expected, the heating degree days and cooling degree days are inversely proportional and the number of growing and cooling degree days are directly correlated. The maximum number of heating degree days occurs in January, 980 degree days, which coincides with January having the lowest minimum average temperature. Conversely, July registers the most cooling degree days with 492, which also corresponds to July having the highest maximum average temperature.

2.5.2.2 Relative Humidity

The Casper and Gillette airports provide relative humidity data for this analysis. The graph shown in Figure 2.5-7 presents data taken from the National Climatological Data

Center (NCDC, 2011). The graph shows monthly average relative humidity (%) for the two sites. It can be seen here that July through September is the “driest” period of the year. Figure 2.5-7 also shows the winter months of December through February are the “wettest” portions of the year. This seasonal contrast is largely an artifact of ambient temperatures. Relative humidity is a temperature based calculation which shows the fraction of moisture present divided by the amount of moisture for saturated air at that temperature. The dew point is the temperature at which the existing moisture in the air would reach saturation, and below which moisture would begin to condense. Warm air will hold more moisture than cool air; thus, for a given mass of moisture in the atmosphere, relative humidity will increase as the air cools.

This phenomenon also explains much of the diurnal fluctuation in relative humidity observed in the region. Relative humidity maximums occur more frequently in early morning when temperatures are lowest, while minimums typically occur during the late afternoon when temperatures are highest. Figure 2.5-8 illustrates this pattern for the Gillette AP Site. Average annual readings are 70 percent and 43 percent for mornings and afternoons, respectively. Diurnal changes in relative humidity are compounded by seasonal variations. Mean monthly afternoon values at Gillette range from 24 percent in August to 62 percent in December while morning mean values range from 66 percent in August to 77 percent in May. Table 2.5-3 shows monthly average, average monthly maximum and average monthly minimum relative humidity values recorded for Casper and Gillette.

2.5.2.3 <u>Precipitation</u>

The region is characterized by generally dry conditions. On average, the region experiences only 40 to 60 days with measurable (>0.01 in) precipitation (WRCC, 2011). The Proposed Project region has an annual average precipitation ranging from 11 to 15 inches. Spring and early summer (May-July) thunderstorms produce roughly 45 percent of the precipitation. May is typically the wettest month of the year; all stations average more than two inches during this month. Winter months average the least, with most of the precipitation occurring as snow. January is the driest month of the year as values are generally one half inch or less. December through February typically account for only 10 percent of the yearly totals. A secondary minimum is also evident during August as warm air during the summer months promotes extremely stable conditions. Little precipitation occurs during this time as convective activity is limited. Severe weather does arise throughout the region, but is limited to four to five severe events per year. These severe events are generally split between hail and damaging wind events. Tornadoes can occur but on rare occasions, with less than one tornado per county per year (Martner, 1986). Figure 2.5-9 shows monthly average precipitation for the Gillette AP and Antelope Mine sites. Figure 2.5-11 interpolates annual averages across the region.

Major snowstorms (more than six in/day) also frequent the region. The region surrounding Casper experiences one to two of these major snowstorms per year. Casper AP has the highest annual snowfall of all the regional sites considered, with an average of nearly 78 inches. This value is in sharp contrast to Lance Creek and Reno, which receive on average less than 30 inches of snow per year. Casper's high snowfall can attributed to its proximity to Casper Mountain. The site is located at the base of the northern slopes of the mountains and is influenced by snow events which occur as a result of orographic lifting. Figure 2.5-10 indicates that substantial monthly averages (more than three in/month) occur for over half the year and "measurable" averages (>1 in/month) for at least 2/3 of the year. Figure 2.5-12 interpolates the regional average snowfall amounts based on those NWS stations with snow data available. The project region as a whole averages about 40 inches. This value agrees well with the Wyoming Climate Atlas (Martner, 1986) which lists averages for southwestern Campbell County at 40-50 inches.

2.5.2.4 Wind Patterns

Wyoming is windy and ranks first in the United States with an annual average speed of 12.9 mph (NUREG-1910, p.3.3-37). The Casper AP site averaged 12.8 mph for the 50+ years included in its climate database. The wind patterns throughout the region show very little variability. Strong southwesterly winds dominate the Casper area. More than 40 percent of the time the wind direction in Casper is from the southwest to west sectors and accompanying wind speeds are generally fairly high with averages greater than 12 mph nearly 65 percent of the time (Figure 2.5-13). Winds at the Antelope Mine follow a similar pattern, although the dominant winds are shifted slightly to the westerly and west-southwesterly directions (Figure 2.5-14). At the Glenrock Mine this pattern is concentrated in the west-southwesterly direction (Figure 2.5-15), with the highest average wind speeds in the region.

Figure 2.5-16 shows mean monthly wind speeds at the four regional sites with available wind data. July has the lowest wind speeds, ranging from 9 to 12 mph. January has the highest wind speeds, ranging from 11 to over 18 mph. Table 2.5-4 shows the monthly average wind speeds and peak gusts for Gillette AP, Antelope and Glenrock (NWS wind speeds at sites such as Gillette AP are recorded to the nearest mph). High wind events are a regular event as gust data from both Antelope and Glenrock show every month recording wind gusts greater than 40 mph.

2.5.3 Site Specific Analysis

On October 6, 2010 a 10 meter meteorological station (Figure 2.5-46) was installed within the Proposed Project area and is currently gathering site specific meteorological data. The objective of operating the site station is to generate representative meteorological data for the MILDOS and other air quality modeling and environmental evaluations, and the establishment of long term monitoring units for operations. The Reno Creek meteorological station is located at N 43^{o} 34' 14.4'', W 105^{o} 49' 42.4'' (Figure 2.5-45). Parameters recorded at this station include wind speed, wind direction, ambient temperature, relative humidity, barometric pressure, solar radiation, precipitation and pan evaporation. Table 2.5-5 lists the instruments deployed at this site and the associated instrument specifications. While the Proposed Project meteorological station continues to collect hourly data, the baseline monitoring period for purposes of this study ran from October 6, 2010 to October 3, 2011. Figure 2.5-17 summarizes the on-site baseline monitoring results. Data recovery for all parameters ranged from 97 percent to 99 percent. Semiannual meteorological station audit records are presented in Appendix A of this document.

The Antelope Coal Mine meteorological station was used as a reference for this site specific analysis due to its proximity to the proposed site and to its similar topography. Antelope Mine is located approximately 20-miles southeast of the Proposed Project. While not intended to be strictly representative of Reno Creek, its proximity and similar topography qualify it as generally representative of the weather patterns in the project area. The Antelope Mine site, like the Proposed Project area, extends from the eastern slope of a ridge downward into a drainage. Both sites are characterized by mildly rolling hills covered with grass, sagebrush and very sparse woody coverage.

2.5.3.1 Temperature

The average site temperature during the baseline monitoring year was 44.2° F with temperatures for each site experiencing a maximum as high as 95.9° F and minimum falling down to -25.1° F (Table 2.5-6). Monthly temperatures averaged 22.5° F in January and 71.5° in August. Temperatures at Antelope Mine during the same baseline period were very similar, as illustrated in Figure 2.5-18.

Figure 2.5-19 shows significant diurnal temperature variations at the Proposed Project location for each of the four seasons. Differences between daytime maximum and nighttime minimum temperatures were highest in the summer, at 27º F. The average diurnal temperature swing during the winter months averaged 11º F.

2.5.3.2 Relative Humidity

As with the regional analysis, relative humidity (RH) at the Proposed Project exhibited a strong inverse correlation with temperature. The highest RH values averaged from 68 percent on early summer mornings to 87 percent during early winter mornings (Figure 2.5-20). The lowest RH values averaged from 24 percent on summer afternoons to 57 percent on winter afternoons. This is typical of the entire region, where relative humidity maximums occur more frequently in early morning when temperatures are lowest, while minimums typically occur during the late afternoon. These diurnal changes are superimposed upon seasonal variations, which also depend on ambient temperatures.

2.5.3.3 Precipitation

Precipitation at the Proposed Project location during the baseline year totaled 13.4 inches. Precipitation records show a pronounced peak in May of 2011, when the area received over 5 inches of rain. With the exception of May and June, all other months recorded less than an inch of precipitation. Figure 2.5-21 shows monthly precipitation totals for both the Proposed Project location and Antelope Mine sites for the baseline monitoring year. As with ambient temperatures, precipitation totals were very similar at the two sites.

2.5.3.4 Evaporation

To prevent instrument freeze-up, the Reno Creek pan evaporation gauge was only operated from April to October of 2011. Total pan evaporation during these seven months was approximately 48 inches. This is consistent with the Wyoming Climate Atlas, which shows 47 inches total for the same months at Gillette (Martner, 1986). Projecting these values over a full 12 months based on cold-weather evaporation rates at Casper, yields an annual evaporation for the project site of roughly 60 inches per year. Figure 2.5-22 shows the measured pan evaporation for the Proposed Project, Casper and Gillette by month. Reno Creek data reflect only the baseline monitoring year. July of 2011 was unusually cool and moist in this region, resulting in uncharacteristically low evaporation. Typically, most evaporation occurs during the months of June through September with an average monthly rate of nearly 10 inches. This is the result of high temperatures, low humidity and relatively consistent winds. During the winter, less evaporation occurs because of low temperatures, periods of stable air, and low solar radiation.

2.5.3.5 Wind Patterns

Figures 2.5-23 shows the monthly average wind speeds at the Proposed Project and Antelope Mine monitoring sites. The patterns are remarkably similar, except that wind speeds at the Proposed Project area average nearly two mph higher than Antelope. This may be attributed to the slightly higher elevation and greater exposure of the Reno Creek meteorological station. Both sites show maximum average wind speeds in February and minimum speeds in September.

Figure 2.5-24 presents the wind rose for the baseline monitoring year at the Proposed Project. Winds are predominantly from the west-southwest and southwest, with secondary modes from the northwest/north-northwest and southeast directions. Figures 2.5-25 through 2.5-28 show the quarterly wind roses for the Proposed Project. High pressure located over the southwestern United States causes the strong west/southwesterly winds which dominate the winter months and are also prominent in the fall. Spring and summer exhibit the greatest variability in wind direction. The secondary modes are a result of the synoptic scale transition period that occurs during this time. Low pressure regions develop on the lee side of the Rockies bringing southeast/easterly winds during development. As the low pressure systems form and move off with the general atmospheric flow, winds switch to a north-northwesterly direction.

Figure 2.5-29 summarizes the wind speed statistics at the Reno Creek meteorological station, as a function of wind direction. The highest average wind speeds of 16 to 17 mph occur from the southwest, west-southwest, and north-northwest directions. Winds from the east, east-northeast and northeast average less than 10 mph. Diurnal variations in wind speed are not pronounced, but in all but the summer season they show a maximum during the early to mid-afternoon hours (Figure 2.5-30). The average wind speed for the on-site meteorological station during the baseline monitoring year was 13.5 mph. The median speed was approximately 11.5 mph as indicated in the wind speed frequency distribution in Figure 2.5-31. This figure also shows two modes, at 6 and 10 mph.

The Joint Frequency Distributions (JFDs) for the Proposed Project, on-site monitoring station are provided in Tables 2.5-7 through 2.5-11. The first two tables present the JFD's for the entire baseline monitoring period. The remaining tables present quarterly JFD's for the same site. Each JFD shows the frequencies of average wind speed for each direction based on stability class. Stability class A represents the least stable, or most turbulent atmospheric conditions and stability class F represents the most stable conditions. Stability classes A, B, and C are shown in the first of each pair of tables, while classes D, E, and F are shown in the second table of each pair.

Atmospheric stability can be classified by one of several available methods. The Proposed Project meteorological station records hourly average standard deviation of horizontal wind speed (sigma theta), which provides the basis for one of these methods. Another method allows the use of solar radiation and vertical temperature gradient (SRDT). However, since this temperature gradient was not measured at the Proposed Project, only a hybrid between the sigma theta method and the SRDT method is possible. The hybrid method would employ solar radiation during the daytime and sigma theta during the nighttime hours. Figure 2.5-32 compares the results obtained from these two methods, which are similar. For simplicity and consistency, the sigma theta method was chosen for characterizing atmospheric stability at the Proposed Project. As demonstrated in Figure 2.5-32, stability class D accounts for roughly 70 percent of all of the hourly averages recorded during the baseline year. This is typical of eastern Wyoming. Stability class D represents near neutral to slightly unstable conditions. The light winds which accompany stable environments can be seen by stability class F, which accounts for less than three percent of the hourly averages.

2.5.3.6 Average Inversion and Mixing Layer Heights

Mixing height is the height of the atmosphere above the ground that is well mixed due either to mechanical turbulence or convective turbulence. The air layer above this height is stable. Higher mixing heights are associated with greater dispersion, all other parameters being the same. Stable periods have much lower mixing heights and accompanying lapse rates allowing for less temperature variation. The MILDOS-AREA model uses mixing height, along with other wind parameters, to predict pollutant dispersion. Unstable air leads to more dispersion, which leads to lower predicted impacts on ambient air quality. The default mixing height used by MILDOS-AREA is 100 meters, a very conservative value given that typical mixing heights exceed 1,000 meters.

The nearest upper-air data available from the National Weather Service are from Rapid City, South Dakota, approximately 150 miles east-northeast of the project area. Average mixing heights were derived from the AERMOD calculations used for dispersion modeling, based on hourly data obtained from the National Weather Service stations in Rapid City (upper air). The AERMOD calculation is based on a combination of mechanically and convectively driven boundary layer processes. The results of these calculations are provided for morning and afternoon in Table 2.5-12. The annual average mixing height is 1,110 meters, with morning mixing heights averaging 333 meters and afternoon mixing heights averaging 1,547 meters.

The Air Quality Division of the Wyoming Department of Environmental Quality (WDEQ-AQD) has provided statewide mixing heights to be used in dispersion modeling with the Industrial Source Complex (ISC3) model. These are based on the methods of Holsworth (1972) as applied to Lander, located in central Wyoming. For modeling purposes, the annual average mixing heights are assigned according to stability class as follows:

- Class A = 3,450 meters
- Class B = 2,300 meters
- Class C = 2,300 meters
- Class D = 2,300 meters
- Class E = 10,000 meters
- Class F = 10,000 meters

Stability classes E and F are given an arbitrarily high number to indicate the absence of a distinct boundary in the upper atmosphere. Based on the predominance of stability class D, data obtained from the NWS in Rapid City produce roughly half the mixing height used by WDEQ-AQD. The default MILDOS model mixing height is set at 100 meters, far more conservative than either of these sources.

2.5.3.7 Bodies of Water and Special Terrain Features

There are no major bodies of water affecting the meteorology of the Proposed Project site. The area is characterized by small, ephemeral streams and sparse stock ponds. The nearest perennial stream is the Powder River, approximately 25-miles west of the Proposed Project site. There are no major lakes within a 50-mile radius of the Proposed Project.

The nearest mountain ranges to this area are:

- Bighorn Mountains, approximately 60-miles from the Proposed Project site and 80-miles from Antelope Mine;
- Black Hills, approximately 75-miles from the Proposed Project site, and 100 miles from Antelope Mine; and
- Northern Laramie Range, approximately 80-miles south of Proposed Project site and 80-miles southwest of Antelope Mine.

Due to these large distances, neither the Antelope site nor the Proposed Project site experiences significant wind channeling or shielding from any of the three mountain ranges.

2.5.3.8 Demonstration That the Baseline Year Represents Long Term

The Proposed Project is situated in northeastern Wyoming. The baseline meteorological monitoring period extended approximately one year, from October 6, 2010 through October 3, 2011. To demonstrate that this baseline year is representative of the longer term wind and temperature conditions, the Antelope Mine meteorological monitoring site was analyzed. This site is approximately 20-miles southeast from the Proposed Project site. The closest NWS operated station which continuously records all weather parameters is the Gillette Airport, some 50-miles to the north. Among the weather stations in this region, the Antelope Mine is the closest to Reno Creek meteorological station. It also has similar topography and elevation. It was therefore selected as most representative of the Proposed Project area meteorology. Available hourly data from Antelope span from 1986 to 2011 and therefore represent the last 25 years. These data were collected in accordance with EPA's On-Site Meteorological Program Guidance for

Regulatory Modeling Applications (EPA, 2000). All meteorological instruments at the Antelope station meet or exceed NRC guidelines. Audit records for this station are presented in Appendix A to this document.

Figure 2.5-33 shows wind roses for Antelope. The wind rose on the right reflects 25 years of monitoring, while the one on the left reflects the baseline monitoring period only. It can be seen that wind speeds and directions are very similar between the 25 year and one year monitoring periods.

In order to quantify this similarity, it is useful to isolate wind speed and wind direction variables and correlate short-term and long-term frequency distributions. IML Air Science has developed a statistical methodology for assessing the degree to which the distributions of wind speed class and wind direction frequencies from baseline monitoring at a particular location represent the long-term distributions at that same location.

For the joint frequency wind distribution used in the MILDOS-AREA model, wind speeds are divided into six classifications ranging from mild (0 – 3 mph) to strong (> 24 mph) as illustrated in Tables 2.5-7 through 2.5-11. Figure 2.5-34 compares the frequency of occurrence of each of the six classifications during the one year and 25 year periods. The percent of the time the wind speed falls within each of the six wind speed classes shown, is also quite similar for the two monitoring periods.

Likewise, wind directions are divided into 16 categories corresponding to the compass directions illustrated in the wind roses and in Figure 2.5-35. The percent of the time that winds occur in each of the six wind speed categories can be calculated to produce a wind speed frequency distribution. The percent of the time that winds blow from each of the sixteen directions can be calculated to produce a wind direction frequency distribution. For each parameter, the one year and 25 year distributions can then be compared. Linear regression analysis provides a useful tool to assess the degree of correlation between short and long-term distributions.

Figure 2.5-36 presents this correlation for the wind speed distributions at Antelope. Each point represents one of the six wind speed classes. The x coordinate corresponds to the percent of the one-year period during which the wind speed fell in a given class, while the y coordinate corresponds to the percent of the 25 year period during which the wind speed fell in that same class. The regression line (red) in Figure 2.5-36 represents the least-squares fit to the six data points. The corresponding R^2 value of 0.99 implies very strong linear correlation between short and long-term wind speed classifications.

A similar analysis can be performed for wind direction frequencies. Figure 2.5-37 presents this correlation, again for the Antelope site. Each point represents one of the sixteen wind direction categories. The x coordinate corresponds to the percent of the one year period during which the wind blew from a given direction, while the y coordinate corresponds to the percent of the 25 year period during which the wind blew from that same direction. The regression line (red) in Figure 2.5-37 represents the least-squares fit to the 16 data points. The corresponding R^2 value of 0.96 implies very strong linear correlation between short and long-term wind direction classifications.

Figures 2.5-36 and 2.5-37 offer conclusive evidence that monitored wind conditions during the 2010-2011 baseline monitoring year adequately represent wind conditions over the last 25 years at the Antelope site. Since the one year wind data serve as reliable predictors of the long-term wind conditions at Antelope, and since the Proposed Project site experiences similar regional weather patterns, it is proposed here that the one year baseline monitoring at the Proposed Project represents long-term wind conditions at that site.

A case has been made that Antelope Mine is representative of regional wind conditions and is exposed to the same general climate patterns as the Proposed Project. The spatial correlation between these two sites, however, is not as strong as the temporal correlation demonstrated at the Antelope site. Figure 2.5-38 shows the wind speed distributions to be fairly similar between these two sites during the baseline year. Figure 2.5-39 shows the wind direction distributions to be somewhat similar between these two sites during the baseline year. Figure 2.5-40, however, shows the wind direction correlation to be much weaker than that shown in Figure 2.5-37. An R^2 value of 0.51 indicates only slight correlation.

This trend of weak spatial correlations and strong temporal correlations can be observed throughout the region. Variations in wind patterns from year to year rely on synoptic weather systems, which tend to deviate only mildly. On the other hand, wind variations from one location to another tend to be more pronounced, driven by localized effects such as elevation, surrounding topography, ground cover, etc.

The method used to correlate short and long-term wind speeds and directions can also be applied to monthly average temperatures. Figure 2.5-41 graphs these averages for the Antelope Mine site, demonstrating rough equivalence between the baseline monitoring year and the 25 year average. Figure 2.5-42 presents a linear regression analysis between short and long-term monthly average temperatures. An R^2 value of over 0.97 indicates strong correlation between the two time frames. Since the one-year temperature data serve as reliable predictors of the long-term temperatures at Antelope, and since the Proposed Project site experiences similar regional weather patterns, it is proposed here that the one-year baseline monitoring represents long-term temperatures at the Proposed Project.

As a point of interest, average ambient temperatures tend to be less dependent on localized effects than wind conditions. Figure 2.5-43 graphs monthly average temperatures for the Proposed Project site and the Antelope Mine site during the baseline monitoring year. Since these sites have comparable elevations and topographic features and are only 20 miles apart, average temperatures between the two sites are quite similar. Figure 2.5-44 presents a linear correlation between monthly average temperatures at the Proposed Project and Antelope during the baseline monitoring year. An R^2 value of 0.99 represents nearly perfect correlation between the two sites. Unlike wind conditions, then, temperatures at Antelope are highly representative of temperatures at the Proposed Project.

A case has already been made that short-term wind speed and direction statistics closely represent long-term wind statistics at Antelope, and that its proximity and geographic similarity to the Proposed Project warrant a similar conclusion for that site. The same case has been made for temperature statistics. It has been further demonstrated that in the project vicinity temperatures correlate spatially as well as temporally. Since the spatial correlation is even stronger, it may be inferred that long-term temperatures at Antelope provide a better predictor of long-term temperatures at the Proposed Project than do baseline-year temperatures at the Proposed Project. This distinction is mostly academic, as temporal and spatial correlations of monthly average temperatures both yield high R^2 values.

As a result of the above analysis, it is appropriate and scientifically sound to use the year of on-site meteorological data for the Proposed Project as a basis for the MILDOS analyses, and to site the long term air quality monitoring units described.

2.5.4 Air Quality

The Proposed Project is located in and adjacent to counties that are designated as attainment with EPA National Ambient Air Quality Standards (NAAQS) for all criteria pollutants. The nearest and only designated nonattainment areas in Wyoming are the city of Sheridan, in Sheridan County and the Upper Green River Basin Area in Lincoln, Sublette, and Sweetwater Counties (EPA, 2012). The city of Sheridan is approximately 102 miles northwest of the Proposed Project, The Upper Green River Basin is over 200 miles southwest. The terrain within the region where the proposed site is located, combined with windy conditions can potentially provide good conditions for dispersion of air pollutants (BLM, 2003). The nearest residence to the Proposed Project in each compass sector are listed in ER Table 3.1-3. Potential air emissions for the Proposed Project are described in Section 4.6.

As discussed in GEIS Section 3.3.6.2, the EPA has established air quality standards to promote and sustain healthy living conditions. These standards, known as NAAQS, address six pollutants EPA refers to as criteria pollutants: carbon monoxide (CO), lead (Pb), nitrogen dioxide (N02), particulate matter (PM_{10} and $PM_{2.5}$), ozone (0_3), and sulfur dioxide ($S0_2$). EPA revised the NAAQS standards after the preparation of the GEIS. This includes a new rolling 3-month average standard for lead at 0.15 $\mu g/m^3$ and a new 1-hour nitrogen dioxide standard at 100 parts per billion. WDEQ adopted the EPA NAAQS, as summarized in the GEIS (NRC, 2009, Table 3.2-8). States may develop standards that are stricter than, or that supplement, the NAAQS. Wyoming has a more restrictive standard for sulfur dioxide (annual at 60 $\mu g/m^3$ and 24-hour at 260 $\mu g/m^3$) and supplemental standards for particulate matter (annual PM_{10} at 50 $\mu g/m^3$ and 24 hour $PM_{2.5}$ at 35 $\mu g/m^3$) (WDEQ, 2012). The principal nonradiological emissions from activities at the Proposed Project include diesel combustion engine emissions and fugitive road dust (particulate matter) described in Section 4.6.

Particulate matter (PM) refers to particles found in the air. Some particles are large enough to be seen as dust, soot, or smoke, while others are too small to be visible. As noted previously, NAAQS for PM_{10} and $PM_{2.5}$ limit the allowable concentration of PM particles to smaller than 10 and 2.5 µm. Emissions from highway and nonroad construction vehicles comprise approximately 28 percent of total PM_{10} and $PM_{2.5}$ emissions. The largest source of PM includes fugitive dust from paved and unpaved roads, agricultural and forestry activities, wind erosion, wildfires, and managed burning.

The WDEQ Air Quality Division analyzes measurements from 26 stations located throughout Wyoming to ensure ambient air quality is maintained, in accordance with NAAQS. The results are synthesized into the Wyoming Ambient Air Monitoring Annual Network Plan (WDEQ, 2009). The baseline air quality conditions of the Proposed Project were determined by evaluating data from several monitoring stations in the region to provide a reasonable representation of the air pollutant levels that could be expected to occur at the site. Additionally, meteorological station information from Reno Creek was obtaining as site specific baseline data. Furthermore, the GEIS reported that all areas within the Wyoming East Uranium Milling Region were classified as being in attainment for NAAQS (NRC, 2009).

As discussed in GEIS Section 3.3.6.2, of the Prevention of Significant Deterioration (PSD) requirements identify maximum allowable increases in concentrations for particulate matter, $S0_2$, and NO_2 for areas designated as attainment. There are several different classes of PSD areas, with Class I areas having the most stringent requirements. GEIS Table 3.4-9 identifies the Class I areas in Wyoming, South Dakota, Montana, and Nebraska. GEIS Figures 3.2-16 and 3.4-20 map the locations of Class I areas. Wind Cave National Park, the closest Class I area to the Proposed Project, is located approximately 113 miles to the east of the Proposed Project. Cloud Peak Wilderness Area, the closest Class II area to the Proposed Project, is located approximately 105 miles to the northwest of the Proposed Project.

Table 2.5-1: Meteorological Stations Included in Climate Analysis

Name	Agency	Lat	Long	Elev (ft)	Years Operation	Wind Spd	Wind Dir	Temp	Precip	Evap	RH	Snow
Casper AP	NWS	42.91	-106.47	5338	1948-2005	X	X	X	X	X	X	X
Douglas	NWS	42.74	-105.39	4820	1909-2005	X	X	X	X	X	X	X
Dull Center	NWS	43.41	-104.96	4420	1926-2005			X	X			
Glenrock 5 ESE	NWS	42.83	-105.79	4950	1941-2005			X	X			X
Kaycee	NWS	43.71	-106.64	4660	1900-2005			X	X			
Lance Creek 3 WNW	NWS	43.05	-104.70	4340	1962-1984			X	X			
Midwest	NWS	43.42	-106.27	4820	1939-2005			X	X			
Newcastle	NWS	43.87	-104.21	4314	1952-2005			X	X			X
Reno	NWS	43.47	-105.54	5080	1963-1983			X	X			
Torrington	NWS	42.49	-104.15	4859	1994-2005			X	X			X
Reno Creek Met	NRC	43.68	-105.52	5080	2010-2011	X	X	X	X	X	X	
Gillette AP	NWS	44.34	-105.54	4354	1902-2009	X	X	X	X	X	X	X
Devils Tower	NWS	44.58	-104.71	3862	1959-2009			X	X			
Weston	NWS	44.64	-105.30	3530	1951-2009			X	X			X
Moorcroft	NWS	44.27	-104.95	4262	1903-2009			X	X			X
Gillette ESE	NWS	44.26	-105.49	4640	1931-2009			X	X			
Echeta	NWS	44.47	-105.91	4000	1949-2009			X	X			X
Leiter	NWS	44.84	-106.29	4160	1945-2009			X	X			
Hulett	NWS	44.70	-104.60	3758	1945-2010			X	X			X
Sundance	NWS	44.41	-104.35	4200	1945-2010			X	X			X
Antelope Coal Mine	EPA	43.50	-105.32	4675	1986-2011	X	X	X	X			
Glenrock Coal Mine	EPA	43.06	-105.84	5674	1996-2010	X	X	X	X			

Sources: National Climatic Data Center, 2011; IML Air Science, 2011 NAD 83

Table 2.5-2: Monthly Temperature Statistics for Region

MONTH	Average Temperature (°F)			Average Daily Minimum Temperature (°F)			Average Daily Maximum Temperature (°F)		
	Antelope Coal	Glenrock Coal	Casper AP	Antelope Coal	Glenrock Coal	Casper AP	Antelope Coal	Glenrock Coal	Casper AP
Jan	25.2	26.9	23.4	15.9	17.8	13.0	35.5	32.2	33.7
Feb	25.9	27.2	27.1	17.1	19.5	16.4	37.1	34.1	37.8
Mar	33.5	34.6	33.7	24.3	24.4	21.6	45.9	42.3	45.8
Apr	43.4	44.1	42.7	32.2	32.7	29.3	54.2	50.1	56.1
May	53.3	53.1	52.5	41.6	42.1	38.3	63.5	61.0	66.7
Jun	63.1	63.2	62.7	50.8	50.5	46.9	74.9	71.4	78.6
Jul	73.8	74.5	70.9	58.0	60.0	54.1	84.5	82.0	87.7
Aug	70.3	70.4	69.2	56.6	57.7	52.5	83.5	78.9	85.8
Sep	59.3	60	58.4	45.5	48.5	42.4	72.4	68.2	74.4
Oct	44.3	45.2	46.5	33.8	36.5	32.5	58.0	54.2	60.5
Nov	35.5	36.9	33.4	24.3	27.0	22.2	44.4	42.4	44.6
Dec	24.3	26.1	25	15.7	17.6	14.9	35.3	30.9	35.2
Year-Round	46.0	46.9	46.5	34.6	36.2	32.0	57.4	54.0	58.9

Table 2.5-3: Monthly and Relative Humidity Statistics for Region

MONTH	Average Relative Humidity (%)		Average Daily Minimum Relative Humidity (%)		Average Daily Maximum Relative Humidity (%)	
	Casper AP	Gillette AP	Casper AP	Gillette AP	Casper AP	Gillette AP
Jan	64.4	61.4	51.3	46.2	78.2	78.7
Feb	62.7	64.5	47.5	44.1	78.0	82.0
Mar	57.1	61.2	34.4	34.4	79.7	81.8
Apr	59.8	60.8	32.7	38.2	86.8	84.1
May	62.0	62.5	36.8	36.0	88.1	87.7
Jun	55.8	59.2	26.6	33.5	87.5	86.7
Jul	46.5	46.7	19.1	22.5	76.8	76.7
Aug	37.0	47.9	16.0	21.8	68.5	78.1
Sep	39.3	49.7	16.3	26.1	69.2	76.5
Oct	60.2	63.2	33.9	35.5	81.8	83.8
Nov	55.3	56.8	33.9	36.4	75.5	80.1
Dec	68.2	64.3	54.4	46.6	81.3	78.8
Year-Round	55.7	58.2	33.6	35.1	79.3	81.3

Table 2.5-4: Monthly Wind Speed Statistics for Region

MONTH	Average Wind Speed (mph)			Maximum Wind Speed (mph)		
	Antelope Mine	Glenrock Mine	Gillette AP	Antelope Mine	Glenrock Mine	Gillette AP
Jan	12.5	17.5	12.4	50.6	59.4	46.0
Feb	11.5	16.3	10.7	44.0	57.6	48.0
Mar	11.8	15.6	11.6	50.7	53.4	43.0
Apr	11.7	14.9	11.5	45.1	51.8	35.0
May	11.2	13.8	10.7	46.3	55.6	39.0
Jun	10.2	13.3	9.0	42.5	45.2	38.0
Jul	9.3	11.7	8.8	41.7	41.4	32.0
Aug	9.1	12.1	9.1	47.3	45.2	33.0
Sep	9.1	12.9	9.8	41.6	50.6	33.0
Oct	10.2	14.6	10.4	42.6	52.7	38.0
Nov	11.9	16.2	11.1	41.9	55.3	41.0
Dec	12.8	18.4	11.1	51.7	55.4	36.0
Year-Round	10.9	14.8	10.5	45.5	52.0	48.0

Table 2.5-5: Proposed Project Meteorological Station Instrument Specifications

Parameter	Instrument	Range	Accuracy	Threshold	Instrument Height
Wind Speed	RM Young 05305 Wind Monitor AQ	0 to 112 mph	±0.4 mph or 1% of reading	0.9 mph	10 meters
Wind Direction	RM Young 05305 Wind Monitor AQ	0 to 360º	±3º	1.0 mph	10 meters
Temperature	Fenwal 107 Temperature Probe	-35º to 50º C	±0.2º C @ 0 - 60º C, ±0.4º C @ -35º C	-- º C	2 meters
Relative Humidity	Vaisalla HMP50-L15 Temp and RH Probe	0 to 98%	±3% at 20 º C	--	2 meters
Barometric Pressure	Campbell Scientific CS-106 BP sensor	500-1100 millibars	±0.3 mb at 20 º C	--	2 meters
Precipitation	Hydrologic Services TB3/0.01P Tipping Bucket Rain Gauge	Temp: -20ºto 50º C	±0.5% @ 0.5 in/hr rate	--	1 meter
Evaporation	Novalynx 255-100 Evaporation Gauge	0 to 944"	0.25%	--	1 meter
Evaporation Pan Temperature Gauge	Fenwal 107 Temperature Probe	-35º to 50º C	±0.2º C @ 0 - 60º C, ±0.4º C @ -35º C	--	1 meter
Solar Radiation	LI-COR LI200X Solar Radiation Sensor	0 to 3000 watts/m^2	± 5%	--	1 meter
Data Logger	Campbell Scientific CR1000 Data Logger	--	--	--	--

Table 2.5-6: Proposed Project Monthly Temperature Statistics

Month	Average Temperature (°F)	Minimum Temperature (°F)	Maximum Temperature (°F)
Jan	22.5	-19.9	43.5
Feb	20.1	-25.1	50.0
Mar	34.3	4.2	59.6
Apr	38.5	17.1	72.6
May	45.2	25.3	71.7
Jun	59.5	39.1	89.7
Jul	72.2	50.6	95.9
Aug	71.5	48.8	95.3
Sep	60.7	35.9	86.7
Oct	49.9	26.1	86.4
Nov	30.3	-12.1	71.3
Dec	25.9	-7.6	48.7
Year-Round	44.2	15.2	72.6

Table 2.5-7: Proposed Project Baseline Year Joint Frequency Distribution

Stability Class	Wind Direction	Wind Speed (mph) - Annual Average						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
A	N	0.000346	0.001384					0.001730
	NNE	0.000461	0.000807					0.001269
	NE	0.000461	0.000692					0.001153
	ENE	0.000461	0.000923					0.001384
	E	0.000231	0.001269					0.001499
	ESE	0.000461	0.001153					0.001615
	SE	0.000807	0.001269					0.002076
	SSE	0.000692	0.002537					0.003230
	S	0.000231	0.002076					0.002307
	SSW	0.000461	0.000923					0.001384
	SW	0.000807	0.002422					0.003230
	WSW	0.000807	0.001730					0.002537
	W	0.000346	0.001499					0.001845
	WNW	0.000577	0.001384					0.001961
	NW	0.000346	0.003114					0.003460
	NNW	0.000231	0.003230					0.003460
B	N	0.000231	0.000923	0.000115				0.001269
	NNE		0.000807	0.000115				0.000923
	NE	0.000115	0.000577	0.000115				0.000807
	ENE	0.000231	0.000461	0.000346				0.001038
	E	0.000231	0.000577					0.000807
	ESE	0.000115	0.000692					0.000807
	SE	0.000346	0.002191					0.002537
	SSE		0.002422	0.000231				0.002653
	S		0.001961	0.000231				0.002191
	SSW		0.001499	0.000115				0.001615
	SW	0.000115	0.001384					0.001499
	WSW	0.000115	0.001845	0.000577				0.002537
	W	0.000115	0.002422	0.000115				0.002653
	WNW	0.000346	0.002422	0.000231				0.002999
	NW	0.000115	0.002884	0.000231				0.003230
	NNW	0.000115	0.001730	0.000577				0.002422
C	N	0.000115	0.000461	0.003460				0.004037
	NNE		0.000577	0.001153				0.001730
	NE		0.000461	0.001615				0.002076
	ENE	0.000115	0.000461	0.000461				0.001038
	E	0.000231	0.000692	0.001153				0.002076
	ESE	0.000346	0.000692	0.001153				0.002191
	SE		0.001730	0.001845				0.003576
	SSE	0.000115	0.001384	0.003345				0.004844
	S		0.000461	0.001961				0.002422
	SSW		0.000692	0.002884				0.003576
	SW		0.000692	0.004037				0.004729
	WSW	0.000231	0.000923	0.004498				0.005652
	W	0.000115	0.000461	0.005306				0.005882
	WNW	0.000461	0.001269	0.004844				0.006574
	NW		0.001153	0.004844				0.005998
	NNW		0.001038	0.005652				0.006690

Table 2.5-7: Proposed Project Baseline Year Joint Frequency Distribution (cont.)

Stability Class	Wind Direction	Wind Speed (mph) - Annual Average						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
D	N	0.000231	0.002191	0.011880	0.009343	0.002884	0.000115	0.026644
	NNE	0.000231	0.001961	0.008304	0.005998	0.000231		0.016724
	NE	0.000115	0.001384	0.005536	0.001499	0.000115		0.008651
	ENE	0.000115	0.002307	0.003230	0.001269	0.000115		0.007036
	E	0.000346	0.003460	0.005767	0.003460	0.000346		0.013379
	ESE	0.000346	0.006805	0.019377	0.012457	0.003691	0.000807	0.043483
	SE	0.000115	0.007151	0.025721	0.020761	0.004037	0.001615	0.059400
	SSE	0.000231	0.005075	0.014533	0.010035	0.000231	0.000115	0.030219
	S		0.003114	0.010381	0.007958	0.000577	0.000115	0.022145
	SSW	0.000115	0.001961	0.008766	0.008881	0.002076	0.000346	0.022145
	SW	0.000923	0.003691	0.022376	0.049481	0.022261	0.011303	0.110035
	WSW	0.001730	0.009573	0.025836	0.044637	0.027105	0.011880	0.120761
	W	0.001845	0.012687	0.016494	0.013495	0.004037	0.001845	0.050404
	WNW	0.001961	0.012457	0.014648	0.012803	0.003576	0.001038	0.046482
	NW	0.000923	0.009112	0.018454	0.024567	0.010727	0.003691	0.067474
	NNW	0.000461	0.005190	0.016378	0.025836	0.016840	0.005536	0.070242
E	N	0.000346	0.001038	0.000461				0.001845
	NNE	0.000231	0.001384	0.002422				0.004037
	NE	0.000577	0.002076	0.002422				0.005075
	ENE	0.000231	0.002191	0.001153				0.003576
	E	0.000115	0.004268	0.001845				0.006228
	ESE		0.005536	0.006920				0.012457
	SE		0.003922	0.006805				0.010727
	SSE	0.000231	0.002422	0.001961				0.004614
	S	0.000577	0.002076	0.002653				0.005306
	SSW		0.001615	0.001961				0.003576
	SW	0.000461	0.003345	0.005536				0.009343
	WSW	0.001153	0.007843	0.006920				0.015917
	W	0.000923	0.010842	0.003230				0.014994
	WNW	0.001615	0.008651	0.005767				0.016032
	NW	0.000807	0.007843	0.004498				0.013149
	NNW	0.000231	0.003691	0.003922				0.007843
F	N	0.000577	0.000692					0.001269
	NNE	0.000692	0.000231					0.000923
	NE	0.000577	0.000577					0.001153
	ENE	0.000577	0.000346					0.000923
	E	0.000807	0.000231					0.001038
	ESE	0.000692	0.000346					0.001038
	SE	0.000577	0.000923					0.001499
	SSE	0.000692	0.000461					0.001153
	S	0.000923	0.001269					0.002191
	SSW	0.000577	0.001153					0.001730
	SW	0.000692	0.000461					0.001153
	WSW	0.000692	0.000923					0.001615
	W	0.001269	0.000807					0.002076
	WNW	0.001499	0.001153					0.002653
	NW	0.000692	0.001038					0.001730
	NNW	0.000461	0.000231					0.000692

Table 2.5-8: Proposed Project 1st Quarter Joint Frequency Distribution

Stability Class	Wind Direction	Wind Speed (mph) - Winter						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
A	N							
	NNE		0.000926					0.000926
	NE							
	ENE	0.000463	0.000926					0.001389
	E	0.000463	0.000926					0.001389
	ESE	0.000926	0.000463					0.001389
	SE	0.000463	0.000463					0.000926
	SSE		0.000926					0.000926
	S		0.000926					0.000926
	SSW							
	SW	0.000463	0.000463					0.000926
	WSW	0.000926						0.000926
	W							
	WNW	0.000463	0.000463					0.000926
	NW		0.001389					0.001389
	NNW		0.001852					0.001852
B	N							
	NNE		0.001389					0.001389
	NE		0.000463					0.000463
	ENE							
	E	0.000463	0.000463					0.000926
	ESE		0.000463					0.000463
	SE	0.000463	0.000463					0.000926
	SSE		0.000926					0.000926
	S			0.000463				0.000463
	SSW							
	SW	0.000463						0.000463
	WSW			0.000463				0.000463
	W		0.001389					0.001389
	WNW		0.000926					0.000926
	NW		0.000926					0.000926
	NNW		0.000926					0.000926
C	N	0.000463	0.000463					0.000926
	NNE			0.000463				0.000463
	NE							
	ENE							
	E	0.000463	0.000463					0.000926
	ESE	0.000463	0.000463					0.000926
	SE		0.003241	0.000926				0.004167
	SSE		0.000463	0.000463				0.000926
	S		0.000463	0.000463				0.000926
	SSW			0.001389				0.001389
	SW		0.000463	0.000926				0.001389
	WSW	0.000463	0.000463	0.000926				0.001852
	W			0.003241				0.003241
	WNW	0.000463	0.001389	0.001852				0.003704
	NW		0.000463	0.001852				0.002315
	NNW		0.000926	0.001852				0.002778

Table 2.5-8: Proposed Project 1st Quarter Joint Frequency Distribution (cont.)

Stability Class	Wind Direction	Wind Speed (mph) - Winter						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
D	N		0.003704	0.014815	0.006944	0.001389	0.000463	0.027315
	NNE	0.000926	0.001852	0.005093	0.003704			0.011574
	NE	0.000463	0.000463	0.003704	0.001852			0.006481
	ENE			0.002315				0.002315
	E	0.000463	0.001852	0.006019	0.001852			0.010185
	ESE		0.004167	0.018056	0.009259	0.001389		0.032870
	SE	0.000463	0.005556	0.020370	0.016667	0.001852		0.044907
	SSE		0.002315	0.011574	0.003704			0.017593
	S		0.003241	0.007870	0.006019			0.017130
	SSW	0.000463	0.002778	0.007407	0.006481	0.000463	0.000463	0.018056
	SW	0.000926	0.002778	0.030556	0.085185	0.040278	0.017593	0.177315
	WSW	0.002315	0.007870	0.037963	0.074537	0.061574	0.023148	0.207407
	W	0.001852	0.007870	0.023148	0.013426	0.004630	0.002778	0.053704
	WNW	0.001852	0.008796	0.017593	0.017593	0.005556	0.000926	0.052315
	NW	0.000926	0.009259	0.018981	0.032870	0.008796	0.000926	0.071759
	NNW		0.006944	0.019907	0.024537	0.012500	0.002315	0.066204
E	N		0.001389	0.000926				0.002315
	NNE		0.000926	0.001389				0.002315
	NE	0.000463	0.001852	0.001389				0.003704
	ENE		0.000926	0.000463				0.001389
	E	0.000463	0.001389	0.000926				0.002778
	ESE		0.003704	0.005093				0.008796
	SE		0.004630	0.002778				0.007407
	SSE		0.001389	0.001389				0.002778
	S	0.000926	0.003241	0.001852				0.006019
	SSW		0.001852	0.002315				0.004167
	SW		0.003241	0.003704				0.006944
	WSW	0.001389	0.004630	0.009259				0.015278
	W	0.000463	0.004630	0.003704				0.008796
	WNW	0.001852	0.008333	0.006019				0.016204
	NW	0.000926	0.006944	0.007407				0.015278
	NNW		0.002315	0.003241				0.005556
F	N	0.000463	0.000463					0.000926
	NNE	0.000926						0.000926
	NE	0.001389						0.001389
	ENE	0.000463						0.000463
	E	0.002315						0.002315
	ESE	0.000463						0.000463
	SE	0.001852	0.001852					0.003704
	SSE	0.000463	0.000463					0.000926
	S							
	SSW	0.001389						0.001389
	SW		0.000463					0.000463
	WSW	0.000926	0.000463					0.001389
	W	0.001852	0.000926					0.002778
	WNW	0.003241	0.000926					0.004167
	NW	0.000926	0.000463					0.001389
	NNW							

Table 2.5-9: Proposed Project 2nd Quarter Joint Frequency Distribution

Stability Class	Wind Direction	Wind Speed (mph) - Spring						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
A	N	0.000917	0.000917					0.001834
	NNE	0.000459	0.000459					0.000917
	NE	0.001376						0.001376
	ENE	0.001376	0.001376					0.002751
	E		0.000459					0.000459
	ESE		0.000917					0.000917
	SE	0.000917	0.000917					0.001834
	SSE		0.001834					0.001834
	S		0.001834					0.001834
	SSW		0.001376					0.001376
	SW	0.000917	0.000917					0.001834
	WSW		0.000459					0.000459
	W		0.001376					0.001376
	WNW	0.000917	0.000917					0.001834
	NW		0.003210					0.003210
	NNW	0.000459	0.001376					0.001834
B	N	0.000459	0.000917					0.001376
	NNE		0.000459	0.000459				0.000917
	NE		0.000917					0.000917
	ENE		0.000459					0.000459
	E		0.000917					0.000917
	ESE							
	SE		0.003668					0.003668
	SSE		0.002751	0.000917				0.003668
	S		0.001834	0.000459				0.002293
	SSW		0.001376					0.001376
	SW		0.001376					0.001376
	WSW	0.000459	0.000917					0.001376
	W		0.003210					0.003210
	WNW		0.001376					0.001376
	NW		0.004585					0.004585
	NNW	0.000459	0.002293	0.000459				0.003210
C	N		0.000459	0.004585				0.005044
	NNE		0.001376	0.001376				0.002751
	NE		0.000917	0.002293				0.003210
	ENE		0.000917	0.000917				0.001834
	E		0.000459	0.001834				0.002293
	ESE		0.000917	0.002293				0.003210
	SE			0.002293				0.002293
	SSE		0.000917	0.004127				0.005044
	S		0.000917	0.004127				0.005044
	SSW		0.001376	0.003210				0.004585
	SW		0.000459	0.005961				0.006419
	WSW		0.000917	0.005502				0.006419
	W		0.000459	0.005044				0.005502
	WNW		0.000917	0.006419				0.007336
	NW		0.000459	0.005961				0.006419
	NNW		0.001376	0.006419				0.007795

Table 2.5-9: Proposed Project 2nd Quarter Joint Frequency Distribution (cont.)

Stability Class	Wind Direction	Wind Speed (mph) - Spring						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
D	N	0.000459	0.001376	0.021550	0.015131	0.001834		0.040348
	NNE		0.001834	0.013755	0.011463			0.027052
	NE		0.002751	0.011463	0.000917			0.015131
	ENE		0.002751	0.003668	0.003210			0.009629
	E		0.005502	0.004585	0.009629	0.000459		0.020174
	ESE		0.004585	0.016048	0.015589	0.007795	0.003210	0.047226
	SE		0.005044	0.025218	0.033012	0.012838	0.006419	0.082531
	SSE		0.004127	0.016048	0.008253			0.028427
	S		0.001834	0.008712	0.005502	0.000459		0.016506
	SSW		0.000917	0.005961	0.004585	0.001834		0.013297
	SW	0.000917	0.001376	0.013297	0.030261	0.019257	0.007336	0.072444
	WSW	0.001376	0.009170	0.019257	0.027052	0.011921	0.012838	0.081614
	W	0.001376	0.012838	0.014672	0.017423	0.007795	0.004585	0.058689
	WNW	0.002293	0.013297	0.012380	0.012838	0.005502	0.003210	0.049519
	NW	0.000917	0.011463	0.018340	0.031637	0.013297	0.009170	0.084823
	NNW	0.000459	0.006419	0.022925	0.040807	0.019716	0.007336	0.097662
E	N	0.000459	0.001376					0.001834
	NNE		0.001376	0.001376				0.002751
	NE		0.000917	0.003668				0.004585
	ENE		0.001834	0.001834				0.003668
	E		0.004585	0.000459				0.005044
	ESE		0.008712	0.005502				0.014214
	SE		0.001376	0.002751				0.004127
	SSE		0.002751	0.002293				0.005044
	S		0.000917	0.001834				0.002751
	SSW		0.000459	0.000459				0.000917
	SW		0.003210	0.004585				0.007795
	WSW	0.001834	0.004585	0.004127				0.010546
	W	0.001376	0.005961	0.001834				0.009170
	WNW	0.001834	0.005502	0.004585				0.011921
	NW		0.005502	0.004127				0.009629
	NNW		0.005961	0.006878				0.012838
F	N	0.000459	0.000459					0.000917
	NNE	0.000459	0.000459					0.000917
	NE	0.000459	0.000459					0.000917
	ENE							
	E							
	ESE	0.000459	0.000917					0.001376
	SE		0.000459					0.000459
	SSE	0.000459	0.000459					0.000917
	S	0.000917	0.000917					0.001834
	SSW		0.000917					0.000917
	SW	0.000917						0.000917
	WSW	0.000917						0.000917
	W	0.001376	0.000917					0.002293
	WNW	0.000917	0.000459					0.001376
	NW	0.000459	0.001376					0.001834
	NNW	0.000459	0.000459					0.000917

Table 2.5-10: Proposed Project 3rd Quarter Joint Frequency Distribution

Stability Class	Wind Direction	Wind Speed (mph) - Summer						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
A	N		0.004076					0.004076
	NNE	0.001359	0.001812					0.003170
	NE		0.002264					0.002264
	ENE		0.001359					0.001359
	E	0.000453	0.002717					0.003170
	ESE	0.000453	0.002264					0.002717
	SE	0.001812	0.003170					0.004982
	SSE	0.001812	0.006341					0.008152
	S		0.004076					0.004076
	SSW	0.001359	0.001812					0.003170
	SW	0.001359	0.004529					0.005888
	WSW	0.001812	0.004076					0.005888
	W	0.000906	0.004529					0.005435
	WNW	0.000906	0.002717					0.003623
	NW	0.000906	0.007246					0.008152
	NNW	0.000453	0.009058					0.009511
B	N		0.002264	0.000453				0.002717
	NNE		0.001359					0.001359
	NE		0.000906	0.000453				0.001359
	ENE		0.001359	0.001359				0.002717
	E		0.000453					0.000453
	ESE	0.000453	0.001812					0.002264
	SE	0.000453	0.004076					0.004529
	SSE		0.004982					0.004982
	S		0.002717					0.002717
	SSW		0.004076	0.000453				0.004529
	SW		0.001812					0.001812
	WSW		0.003623	0.001812				0.005435
	W		0.004076					0.004076
	WNW		0.006341	0.000906				0.007246
	NW	0.000453	0.004982	0.000906				0.006341
	NNW		0.003170	0.001812				0.004982
C	N		0.000453	0.009058				0.009511
	NNE		0.000453	0.002717				0.003170
	NE		0.000906	0.003623				0.004529
	ENE		0.000906	0.000906				0.001812
	E	0.000453	0.000453	0.002717				0.003623
	ESE	0.000453		0.000906				0.001359
	SE		0.001812	0.003170				0.004982
	SSE		0.002717	0.007699				0.010417
	S		0.000453	0.002264				0.002717
	SSW		0.000906	0.004529				0.005435
	SW		0.001812	0.008152				0.009964
	WSW		0.000453	0.010870				0.011322
	W	0.000453	0.000453	0.011775				0.012681
	WNW	0.000453	0.000453	0.009511				0.010417
	NW		0.000906	0.009964				0.010870
	NNW		0.000906	0.011322				0.012228

Table 2.5-10: Proposed Project 3rd Quarter Joint Frequency Distribution (cont.)

Stability Class	Wind Direction	Wind Speed (mph) - Summer						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
D	N		0.002264	0.009058	0.011322	0.003623		0.026268
	NNE		0.001359	0.012681	0.007246	0.000906		0.022192
	NE		0.002264	0.006793	0.003170	0.000453		0.012681
	ENE	0.000453	0.005435	0.006793	0.001812	0.000453		0.014946
	E		0.004076	0.009964	0.001812	0.000906		0.016757
	ESE	0.000906	0.010870	0.030797	0.019475	0.001812		0.063859
	SE		0.009058	0.038496	0.024004			0.071558
	SSE		0.006793	0.018569	0.020380	0.000453		0.046196
	S		0.002717	0.011322	0.011322	0.000453		0.025815
	SSW		0.000906	0.010417	0.009964	0.000906	0.000453	0.022645
	SW	0.001812	0.002264	0.016304	0.021739	0.005888		0.048007
	WSW	0.001359	0.004076	0.017210	0.024909	0.008152		0.055707
	W	0.002264	0.010870	0.014493	0.013134	0.001812		0.042572
	WNW	0.001359	0.010870	0.009511	0.008152	0.000453		0.030344
	NW	0.000906	0.005435	0.011322	0.007246	0.004076		0.028986
	NNW	0.000453	0.002264	0.012681	0.015399	0.005435	0.001812	0.038043
E	N		0.000906	0.000906				0.001812
	NNE	0.000906	0.001359	0.005888				0.008152
	NE	0.000453	0.004529	0.003623				0.008605
	ENE	0.000906	0.004076	0.001812				0.006793
	E		0.009964	0.004982				0.014946
	ESE		0.005888	0.014946				0.020833
	SE		0.004076	0.011322				0.015399
	SSE	0.000453	0.000906	0.001359				0.002717
	S	0.000453	0.002264	0.002717				0.005435
	SSW		0.002264	0.003623				0.005888
	SW	0.000906	0.000906	0.002717				0.004529
	WSW		0.008605	0.004982				0.013587
	W	0.001359	0.014946	0.002264				0.018569
	WNW	0.000453	0.007246	0.003623				0.011322
	NW	0.000906	0.007699	0.002264				0.010870
	NNW	0.000453	0.002717	0.002264				0.005435
F	N	0.000906	0.001812					0.002717
	NNE	0.000453	0.000453					0.000906
	NE		0.001812					0.001812
	ENE	0.001359	0.001359					0.002717
	E	0.000453	0.000906					0.001359
	ESE	0.000906	0.000453					0.001359
	SE	0.000453	0.000906					0.001359
	SSE	0.001359						0.001359
	S	0.000906	0.002717					0.003623
	SSW	0.000453	0.002264					0.002717
	SW	0.000906	0.000906					0.001812
	WSW		0.002264					0.002264
	W	0.000453						0.000453
	WNW	0.001359	0.001359					0.002717
	NW	0.000453	0.001812					0.002264
	NNW	0.000453	0.000453					0.000906

Table 2.5-11: Proposed Project 4th Quarter Joint Frequency Distribution

Stability Class	Wind Direction	Wind Speed (mph) - Fall						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
A	N	0.000486	0.000486					0.000971
	NNE							
	NE	0.000486	0.000486					0.000971
	ENE							
	E		0.000486					0.000486
	ESE	0.000486	0.000486					0.000971
	SE							
	SSE	0.000971	0.000971					0.001943
	S	0.000971	0.001457					0.002428
	SSW		0.000486					0.000486
	SW	0.000486	0.003400					0.003885
	WSW	0.000486	0.002428					0.002914
	W	0.000486						0.000486
	WNW		0.001457					0.001457
	NW	0.000486	0.000486					0.000971
	NNW		0.000486					0.000486
B	N	0.000486	0.000486					0.000971
	NNE							
	NE	0.000486						0.000486
	ENE	0.000971						0.000971
	E	0.000486	0.000486					0.000971
	ESE		0.000486					0.000486
	SE	0.000486	0.000486					0.000971
	SSE		0.000971					0.000971
	S		0.003400					0.003400
	SSW		0.000486					0.000486
	SW		0.002428					0.002428
	WSW		0.002914					0.002914
	W	0.000486	0.000971	0.000486				0.001943
	WNW	0.000971	0.000971					0.001943
	NW		0.000971					0.000971
	NNW		0.000486					0.000486
C	N		0.000486					0.000486
	NNE		0.000486					0.000486
	NE			0.000486				0.000486
	ENE	0.000486						0.000486
	E		0.001457					0.001457
	ESE	0.000486	0.001457	0.001457				0.003400
	SE		0.001943	0.000971				0.002914
	SSE	0.000486	0.001457	0.000971				0.002914
	S							
	SSW		0.000486	0.000971				0.001457
	SW			0.000971				0.000971
	WSW	0.000486	0.001943	0.000486				0.002914
	W		0.000971	0.000971				0.001943
	WNW	0.000971	0.002428	0.001457				0.004857
	NW		0.002914	0.001457				0.004371
	NNW		0.000971	0.002914				0.003885

Table 2.5-11: Proposed Project 4th Quarter Joint Frequency Distribution (cont.)

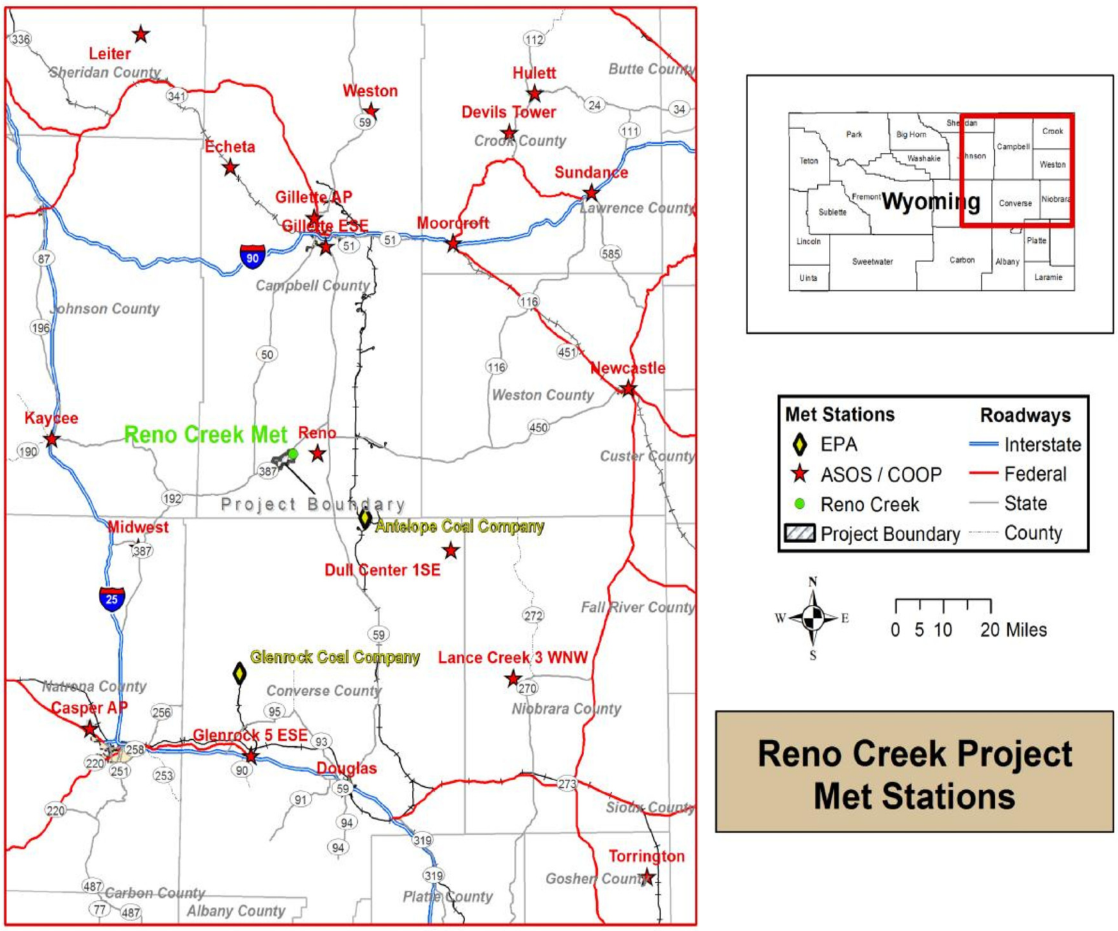
Stability Class	Wind Direction	Wind Speed (mph) - Fall						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
D	N	0.000486	0.001457	0.001943	0.003885	0.004857		0.012627
	NNE		0.002914	0.001457	0.001457			0.005828
	NE							
	ENE		0.000971					0.000971
	E	0.000971	0.002428	0.002428	0.000486			0.006314
	ESE	0.000486	0.007771	0.012627	0.005342	0.003885		0.030112
	SE		0.009228	0.018456	0.008742	0.001457		0.037882
	SSE	0.000971	0.007285	0.010685	0.006799	0.000486	0.000486	0.026712
	S		0.004857	0.012142	0.009228	0.001457	0.000486	0.028169
	SSW		0.003400	0.010685	0.014570	0.005342	0.000486	0.034483
	SW		0.008742	0.028655	0.061195	0.024769	0.021370	0.144730
	WSW	0.001943	0.016999	0.029626	0.050024	0.027683	0.012142	0.138417
	W	0.001943	0.018456	0.014085	0.010199	0.001943		0.046625
	WNW	0.002428	0.016999	0.019427	0.013113	0.002914		0.054881
	NW	0.000971	0.010685	0.025741	0.027683	0.017484	0.004857	0.087421
	NNW	0.000971	0.005342	0.010199	0.023312	0.031083	0.011170	0.082079
E	N	0.000971	0.000486					0.001457
	NNE		0.001943	0.000971				0.002914
	NE	0.001457	0.000971	0.000971				0.003400
	ENE		0.001943	0.000486				0.002428
	E		0.000971	0.000971				0.001943
	ESE		0.003885	0.001943				0.005828
	SE		0.005828	0.010685				0.016513
	SSE	0.000486	0.004857	0.002914				0.008256
	S	0.000971	0.001943	0.003885				0.006799
	SSW		0.001943	0.000971				0.002914
	SW	0.000971	0.006314	0.010685				0.017970
	WSW	0.001457	0.014085	0.009713				0.025255
	W	0.000486	0.017970	0.005342				0.023798
	WNW	0.002428	0.014085	0.009228				0.025741
	NW	0.001457	0.011170	0.003885				0.016513
	NNW	0.000486	0.003885	0.003400				0.007771
F	N	0.000486						0.036053
	NNE	0.000486						0.030110
	NE	0.000486						0.019538
	ENE	0.000486						0.009591
	E	0.000486						0.011140
	ESE	0.000971						0.011165
	SE		0.000486					0.009100
	SSE	0.000486	0.000971					0.017032
	S	0.001943	0.001457					0.014060
	SSW	0.000486	0.001457					0.011682
	SW	0.000971	0.000486					0.012097
	WSW	0.000971	0.000971					0.011656
	W	0.001457	0.001457					0.013519
	WNW	0.000486	0.001943					0.018945
	NW	0.000486	0.000486					0.021865
	NNW	0.000971						0.041199

Table 2.5-12: Upper Atmosphere Characteristics at Rapid City, South Dakota

Time Period (Filtered)	Average Mixing / Inversion Height
Morning (2 am – 6 am)	333 meters (1,093 ft)
Afternoon (12 pm – 4 pm)	1,547 meters (5, 075 ft)

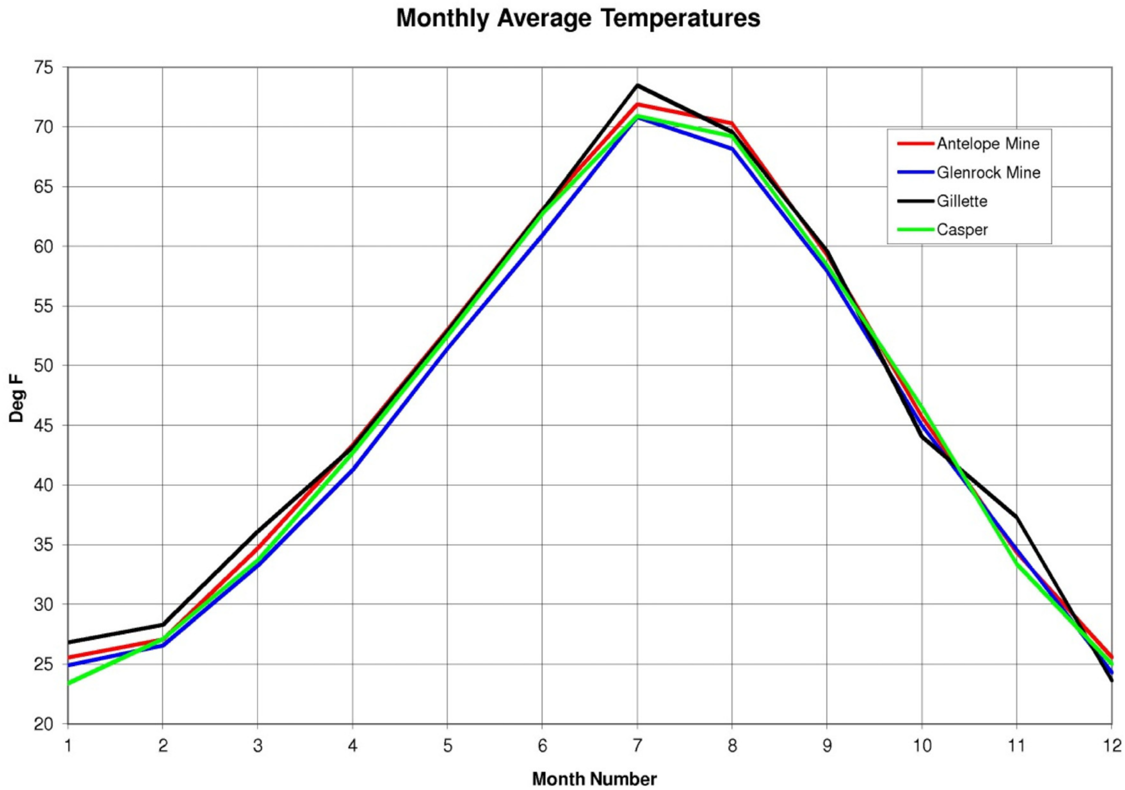
Source: IML computation based on data from National Climate Data Center, 2011

Figure 2.5-1: NWS and Coal Mine Meteorological Stations



Source: National Climatic Data Center, 2011
Period: (varies by monitoring location – see Table 2.5-1)

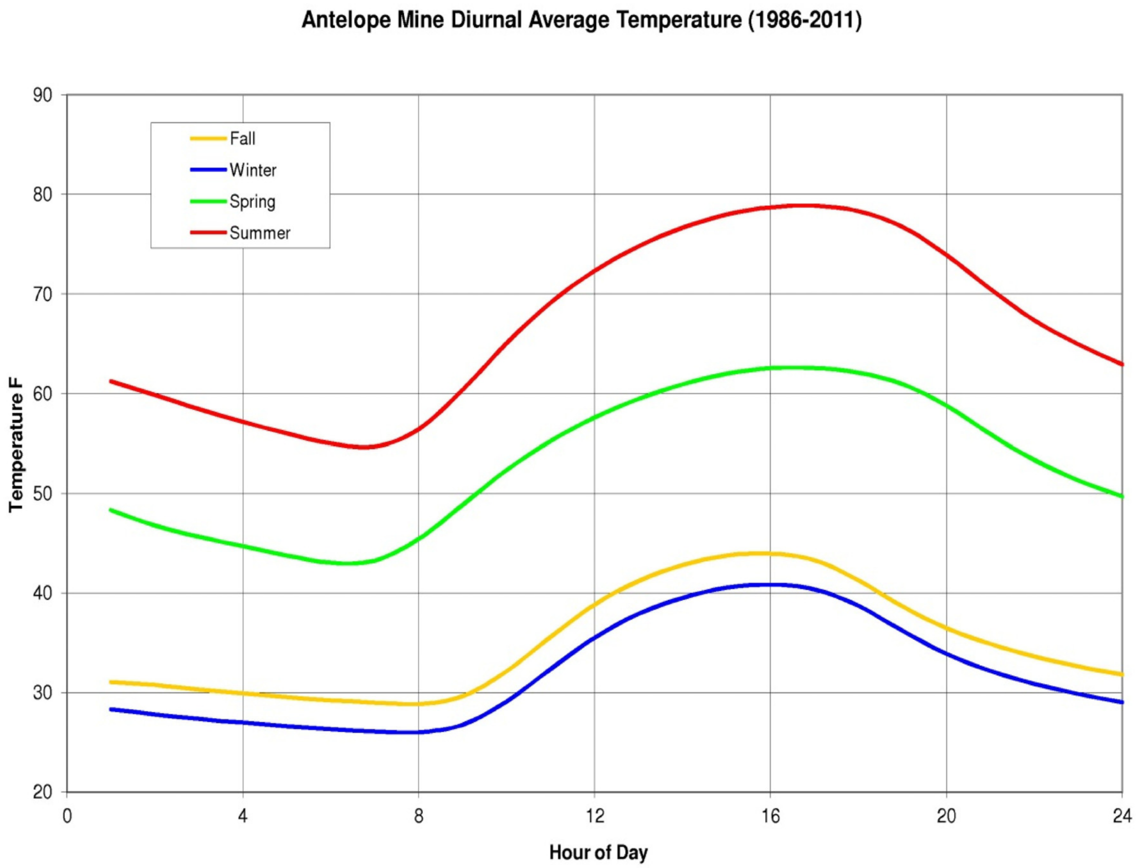
Figure 2.5-2: Regional Average Monthly Temperatures



Sources: National Climatic Data Center, 2011; IML Air Science meteorological database, 2011

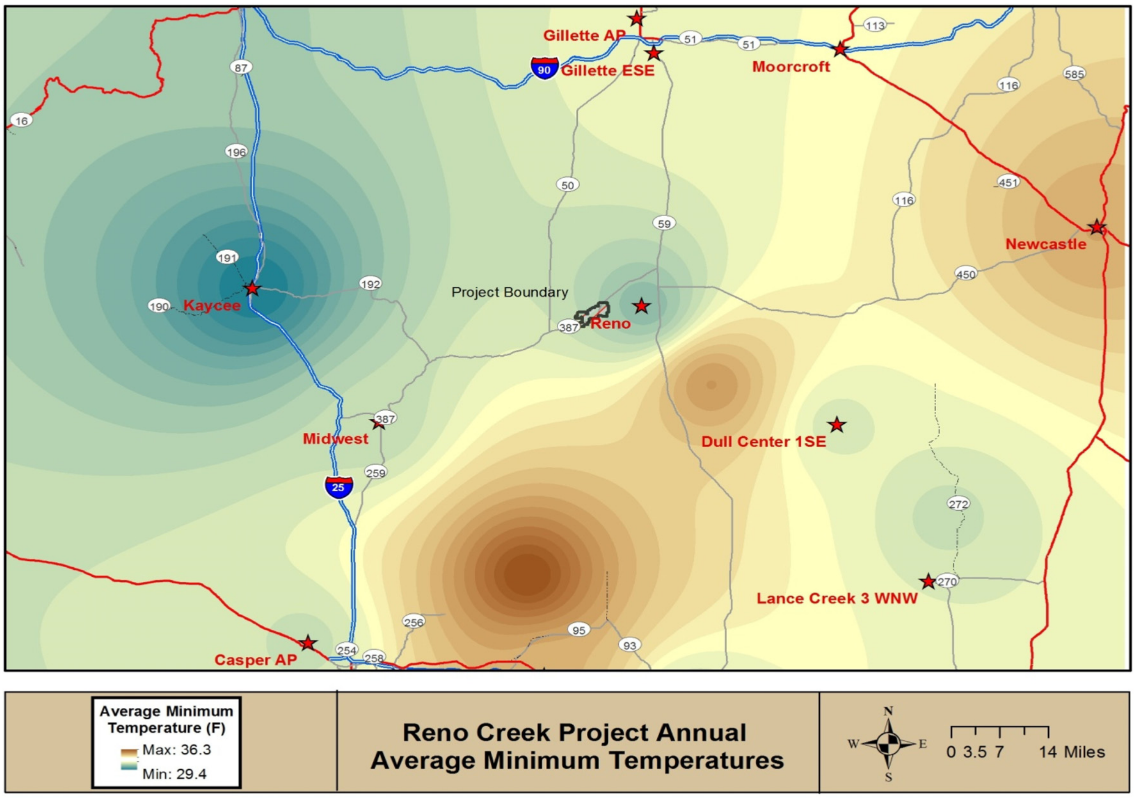
Period: (varies by monitoring location)

Figure 2.5-3: Antelope Mine Monthly Diurnal Temperature Variations



Source: IML Air Science meteorological database, 2011
Period: 1986-2011

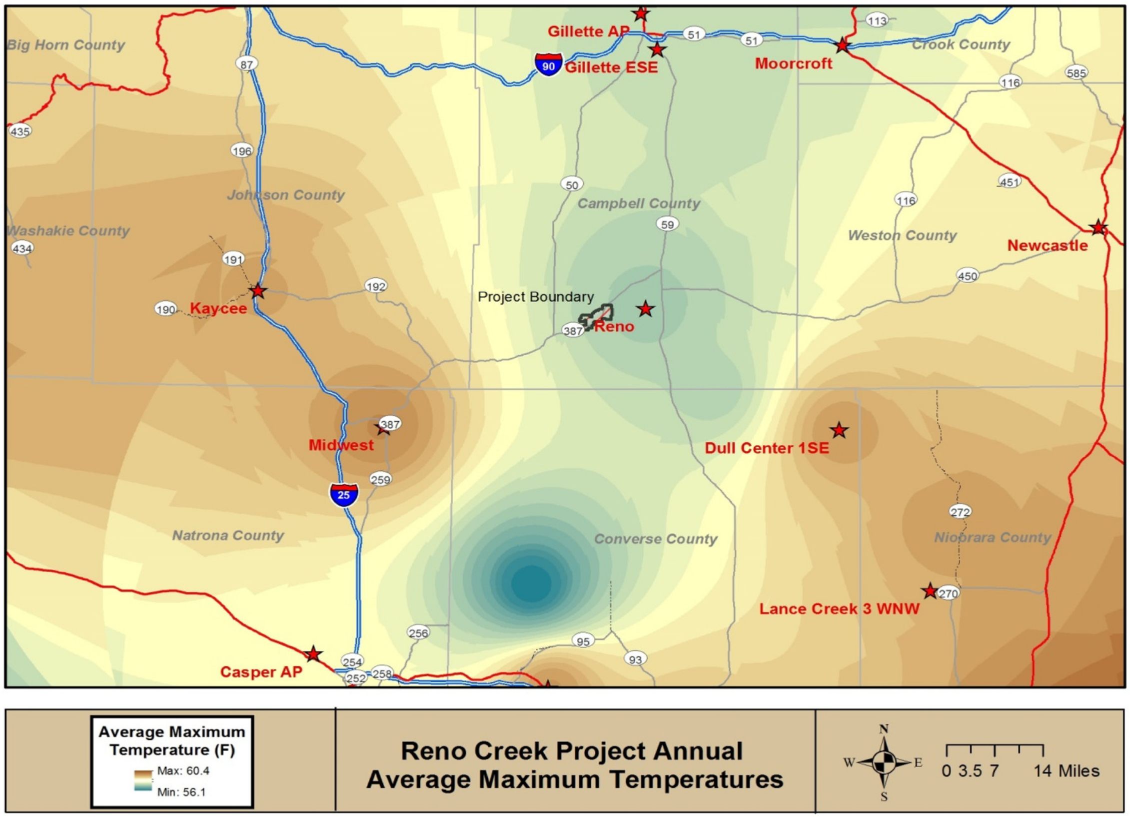
Figure 2.5-4: Regional Annual Average Minimum Temperatures



Source: National Climatic Data Center, 2011

Period: (varies by monitoring location – see Table 2.5-1)

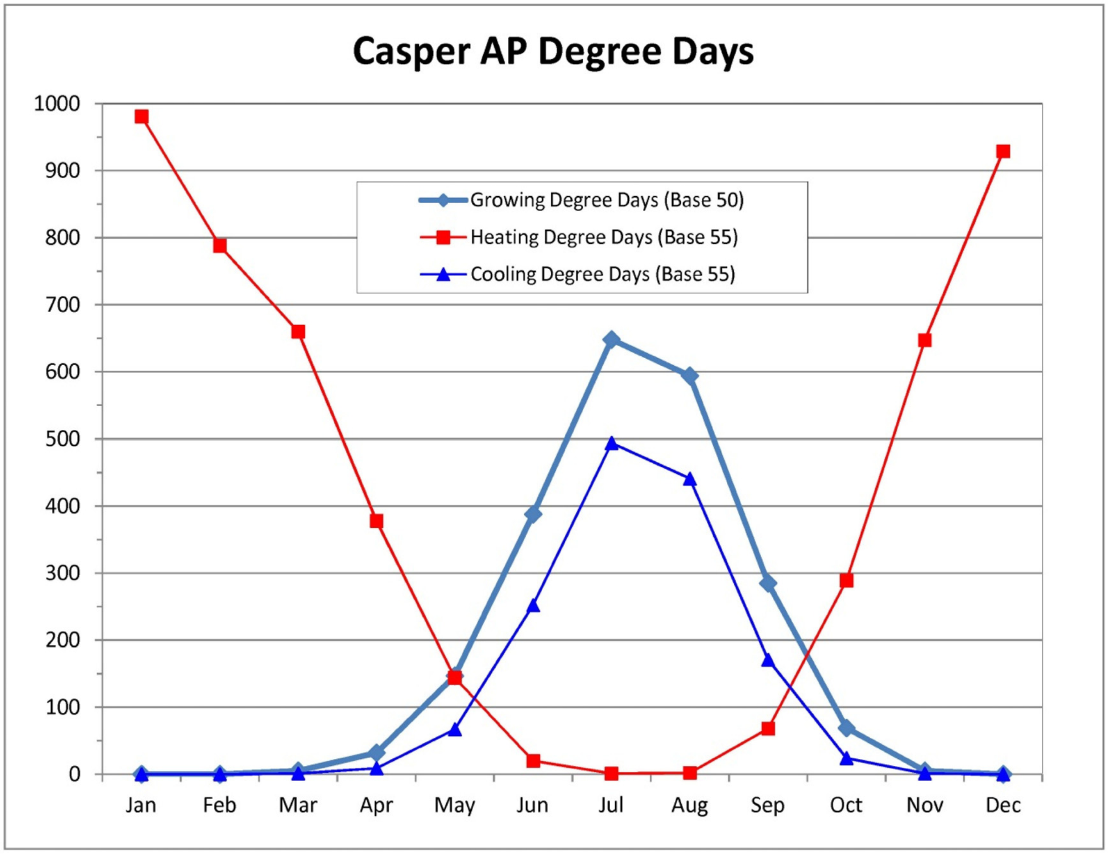
Figure 2.5-5: Regional Annual Average Maximum Temperatures



Source: National Climatic Data Center, 2011

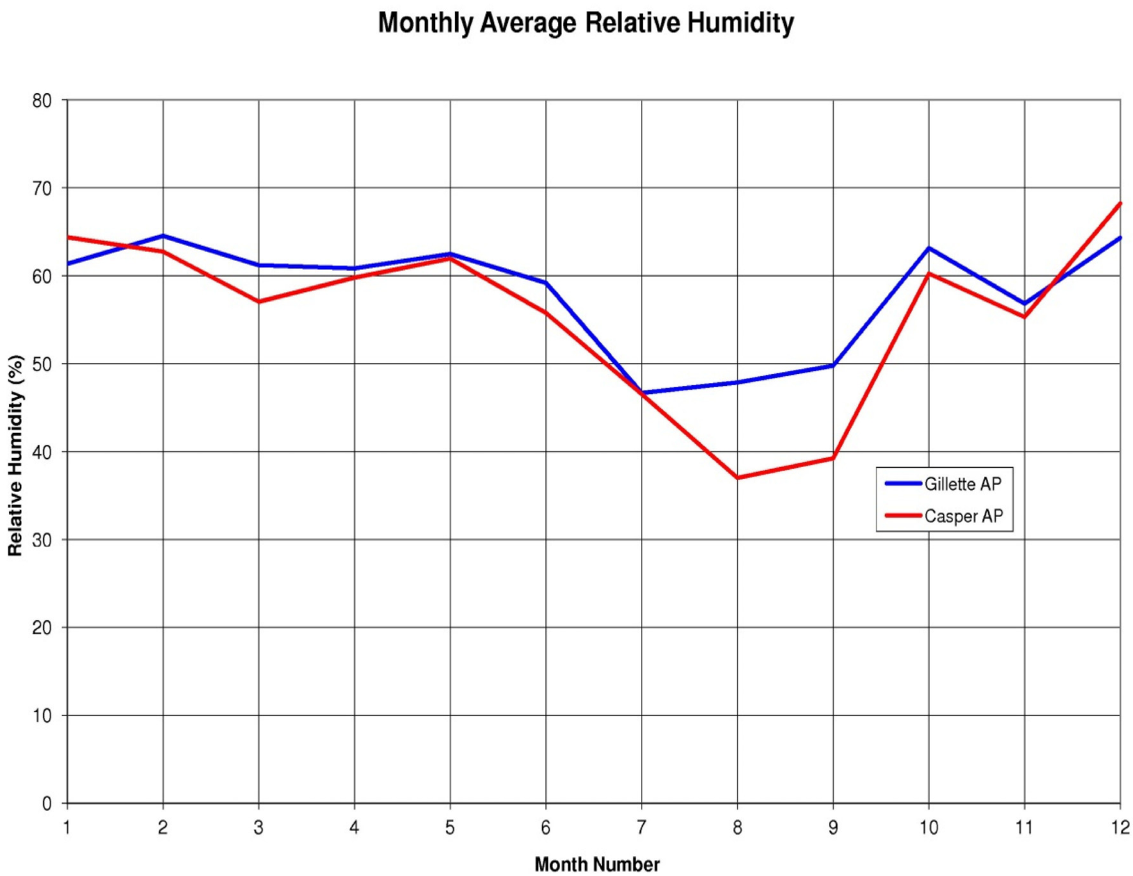
Period: (varies by monitoring location – see Table 2.5-1)

Figure 2.5-6: Casper Airport Degree Days



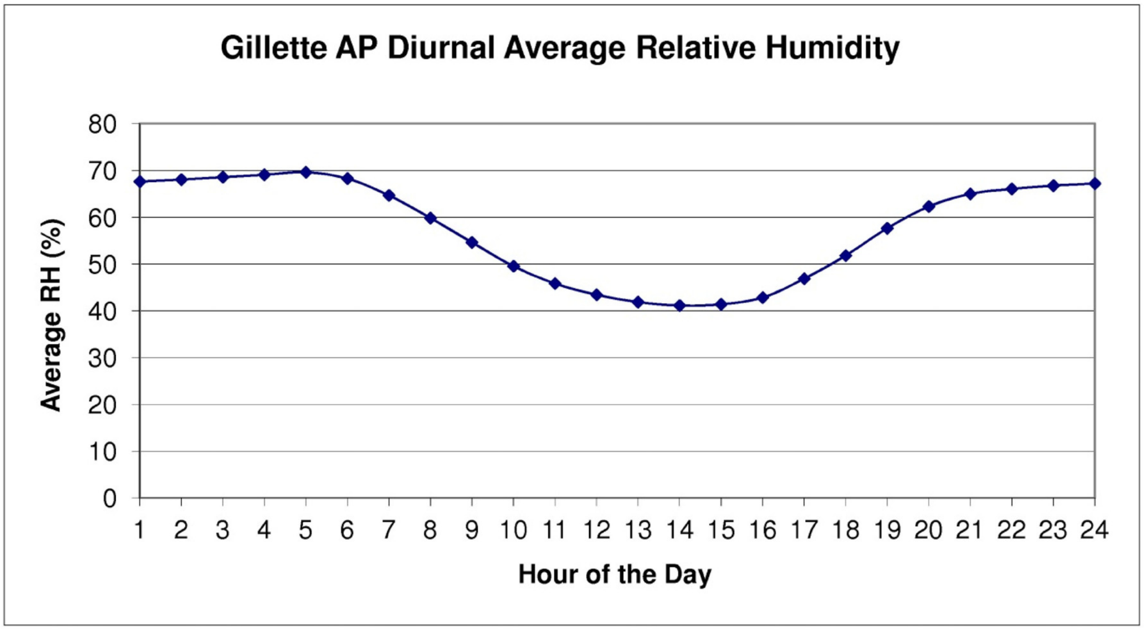
Source: National Climatic Data Center, 2011
Period: 1948-2010

Figure 2.5-7: Mean Monthly Relative Humidity for Gillette and Casper



Source: National Climatic Data Center, 2011
Period: (varies by monitoring location)

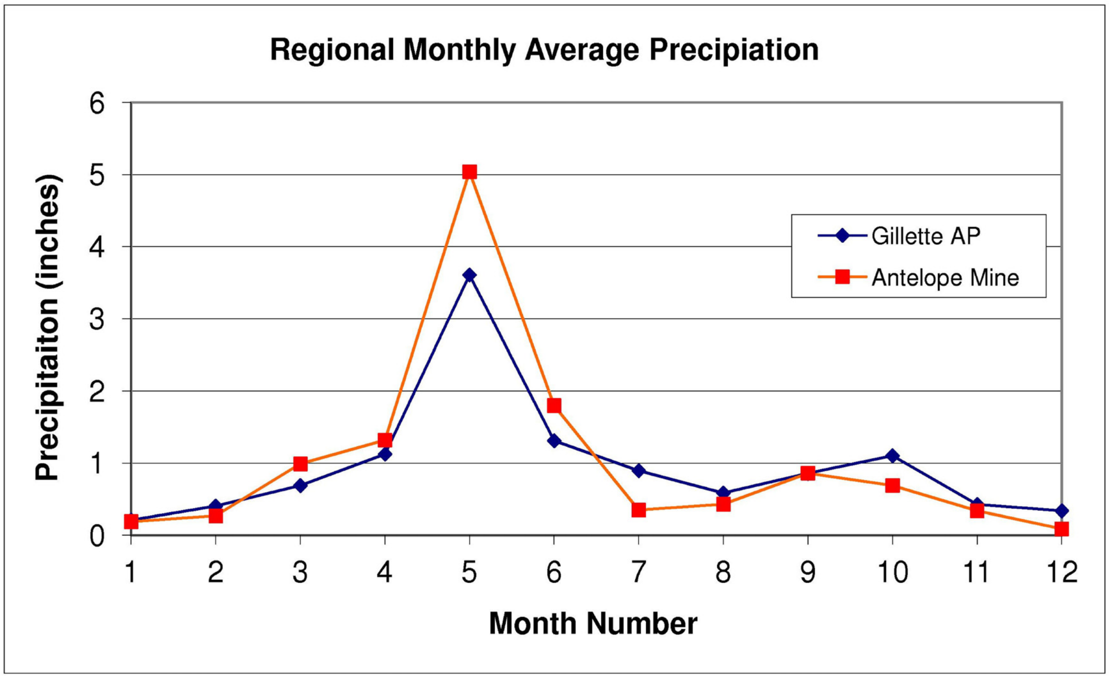
Figure 2.5-8: Diurnal Average Relative Humidity for Gillette AP



Source: National Climatic Data Center, 2011

Period: 2005-2009

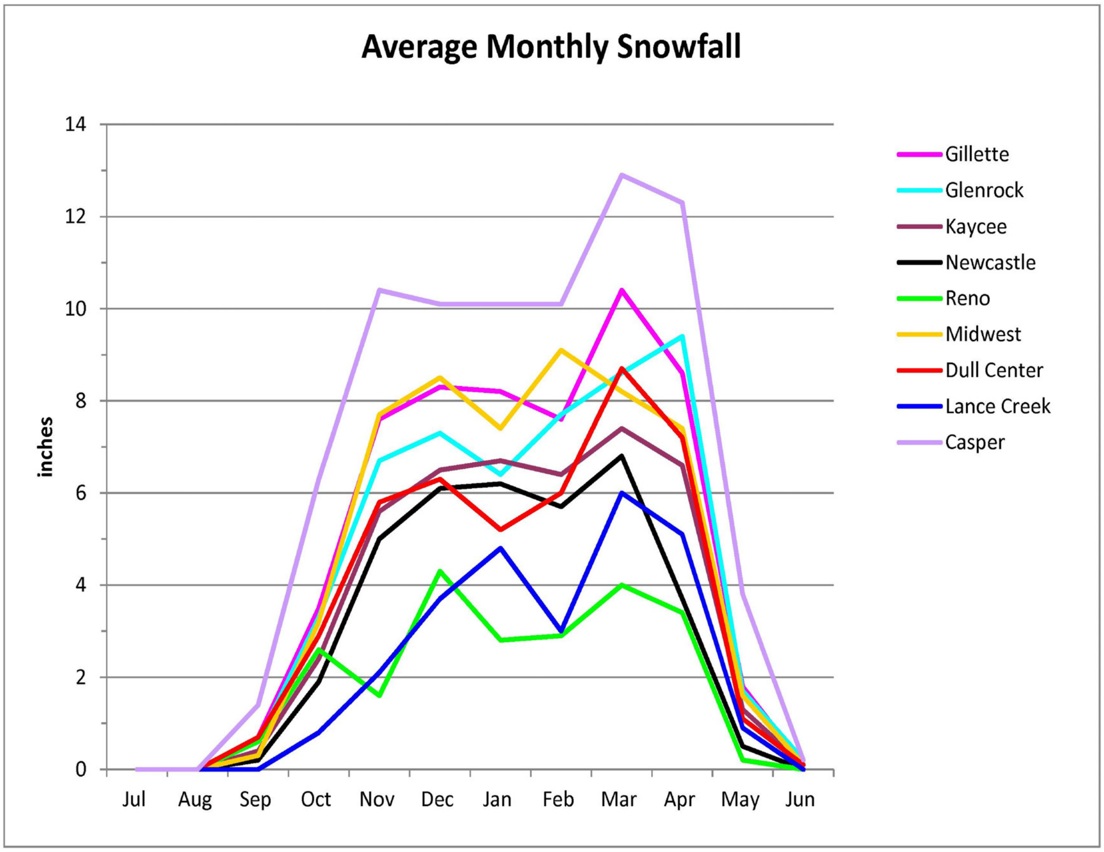
Figure 2.5-9: Regional Monthly Average Precipitation



Sources: National Climatic Data Center, 2011; IML Air Science meteorological database, 2011

Period: (varies by monitoring location)

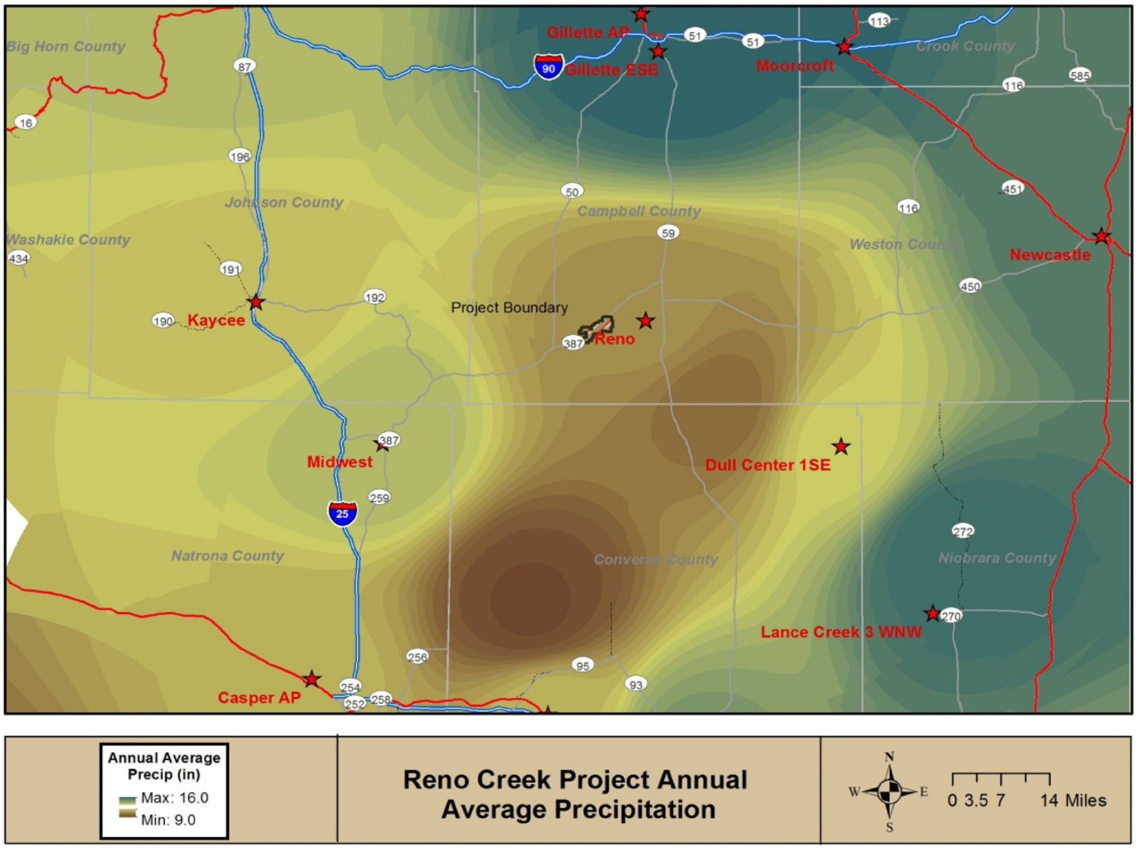
Figure 2.5-10: NWS Station Monthly Snowfall Averages



Source: National Climatic Data Center, 2011

Period: (varies by monitoring location – see Table 2.5-1)

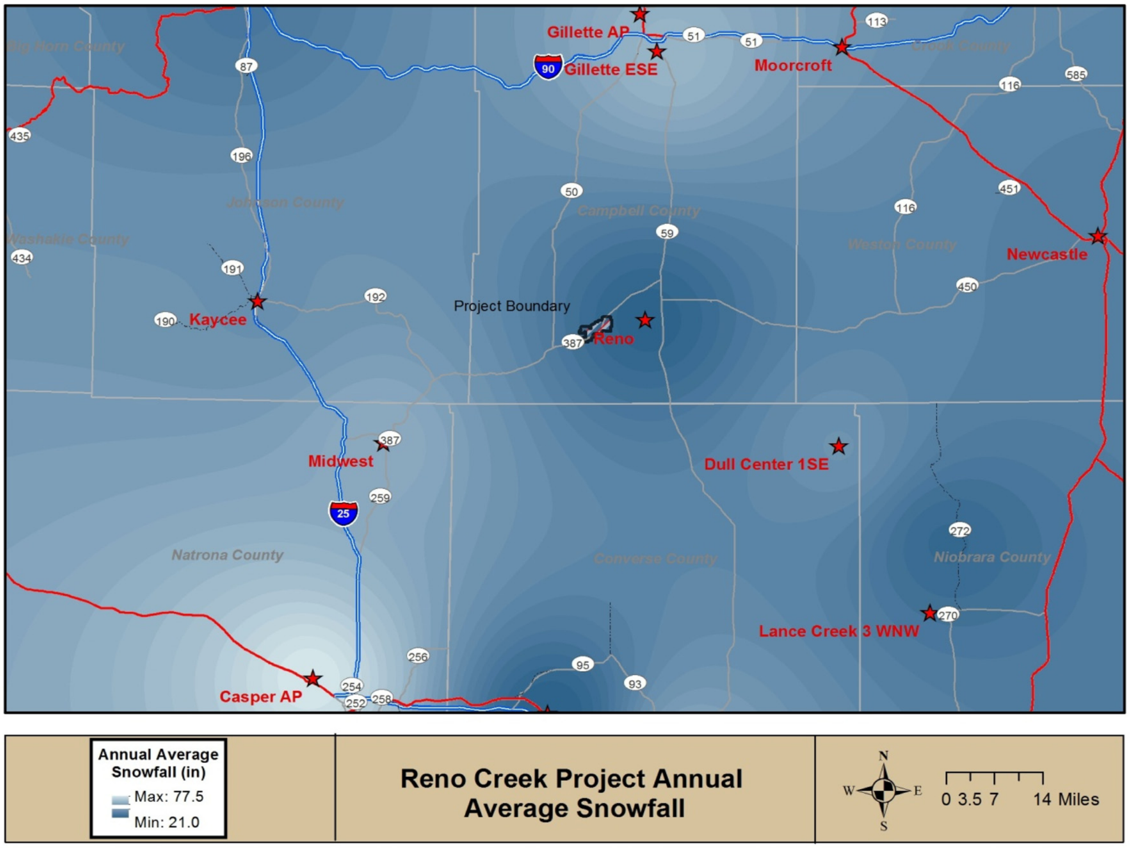
Figure 2.5-11: Regional Annual Average Precipitation



Source: National Climatic Data Center, 2011

Period: (varies by monitoring location – see Table 2.5-1)

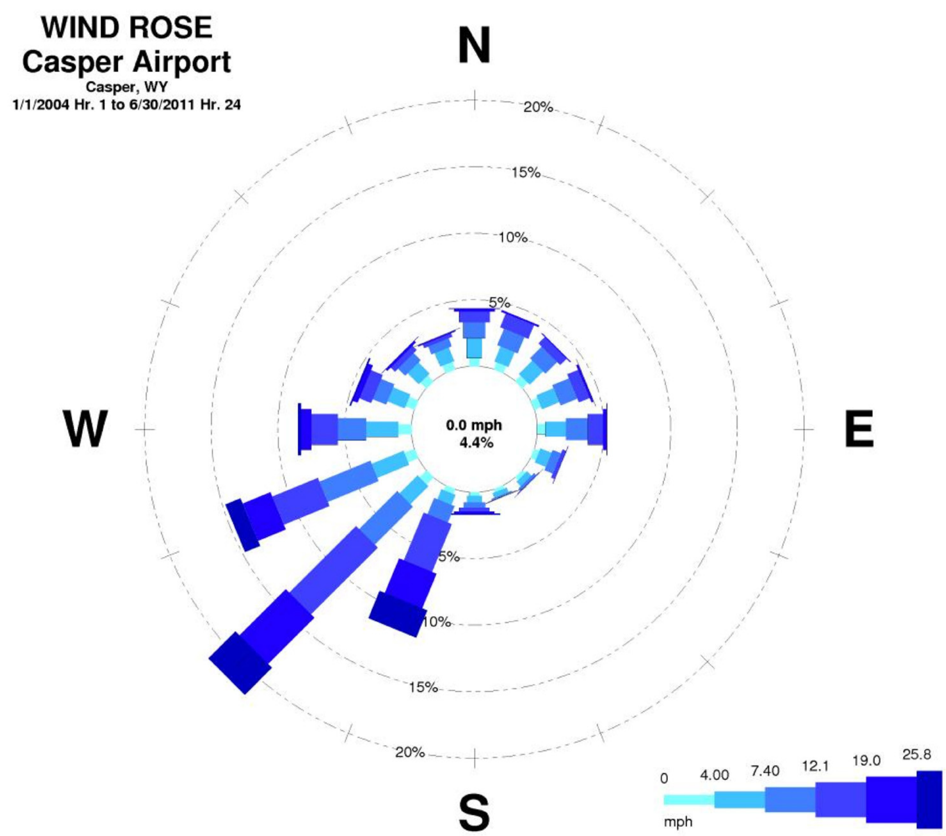
Figure 2.5-12: Regional Annual Average Snowfall



Source: National Climatic Data Center, 2011

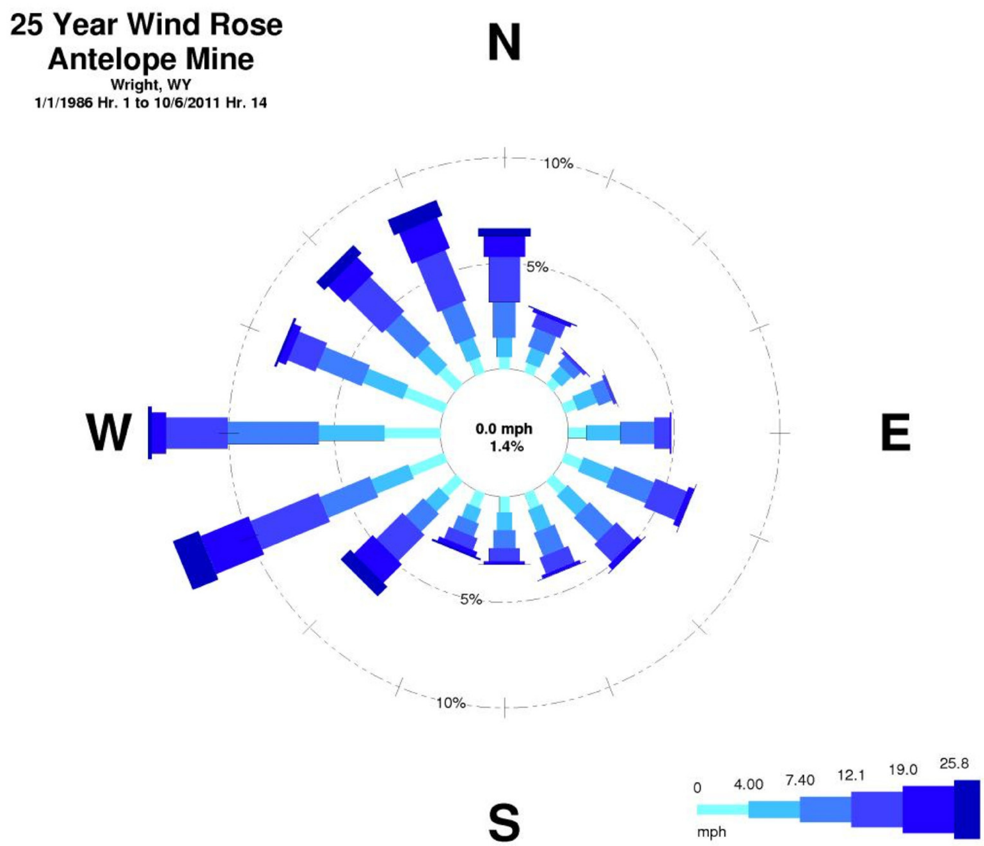
Period: (varies by monitoring location – see Table 2.5-1)

Figure 2.5-13: Casper Airport 8-Year Wind Rose



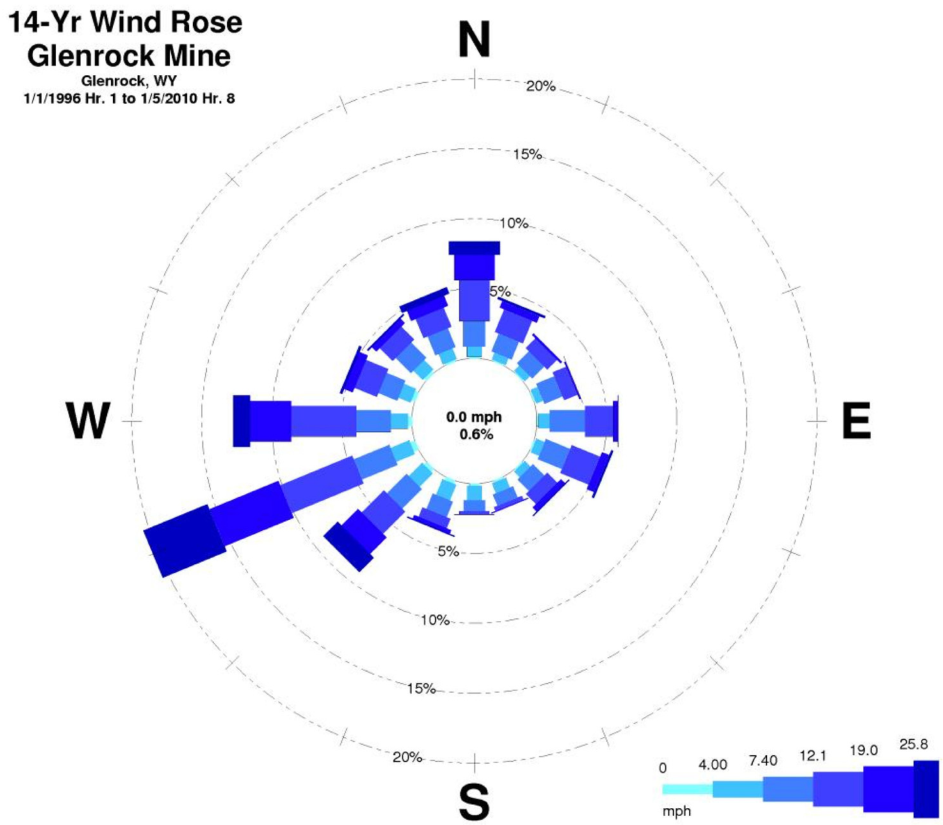
Source: National Climatic Data Center, 2011
Period: 2004-2011

Figure 2.5-14: Antelope Mine 25-Year Wind Rose



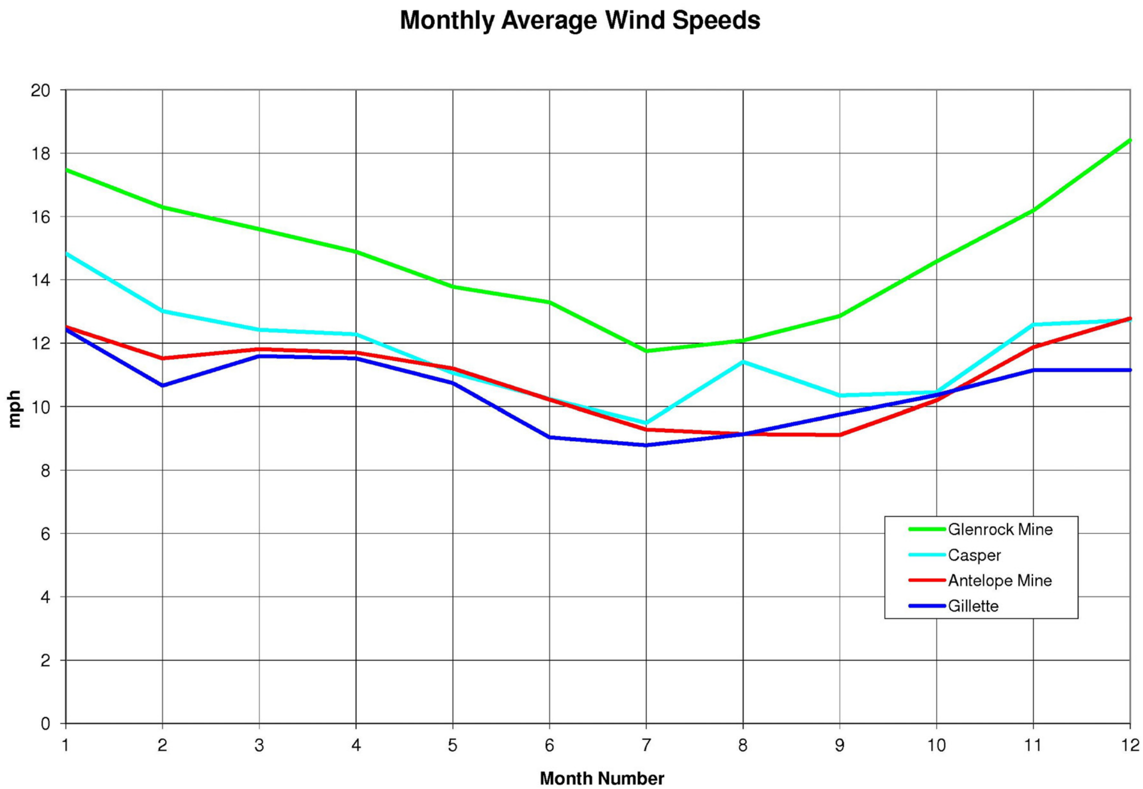
Source: IML Air Science meteorological database
Period: 1986-2011

Figure 2.5-15: Glenrock Mine 14-Year Wind Rose



Source: IML Air Science meteorological database
Period: 1996-2010

Figure 2.5-16: Regional Wind Speeds by Month



Sources: National Climatic Data Center, 2011; IML Air Science meteorological database, 2011
Period: (varies by monitoring location)

Figure 2.5-17: Reno Creek Project 1-Year Meteorological Summary

Reno Creek

Meteorological Data Summary

10/6/2010 - 10/3/2011

Hourly Data

	Average/Total	Max	Min
Wind Speed (mph)	13.5	42.0	1.1
Sigma-Theta (°)	10.5	73.7	0.4
Temperature (F)	44.3	95.9	-25.1
Relative Humidity (%)	63.5	100.0	8.0
Precipitation (in)	13.39	0.30	
Bar. Pressure (in Hg)	24.7	25.3	23.9
Solar Radiation (w/m^2)	176.1	1,008.0	

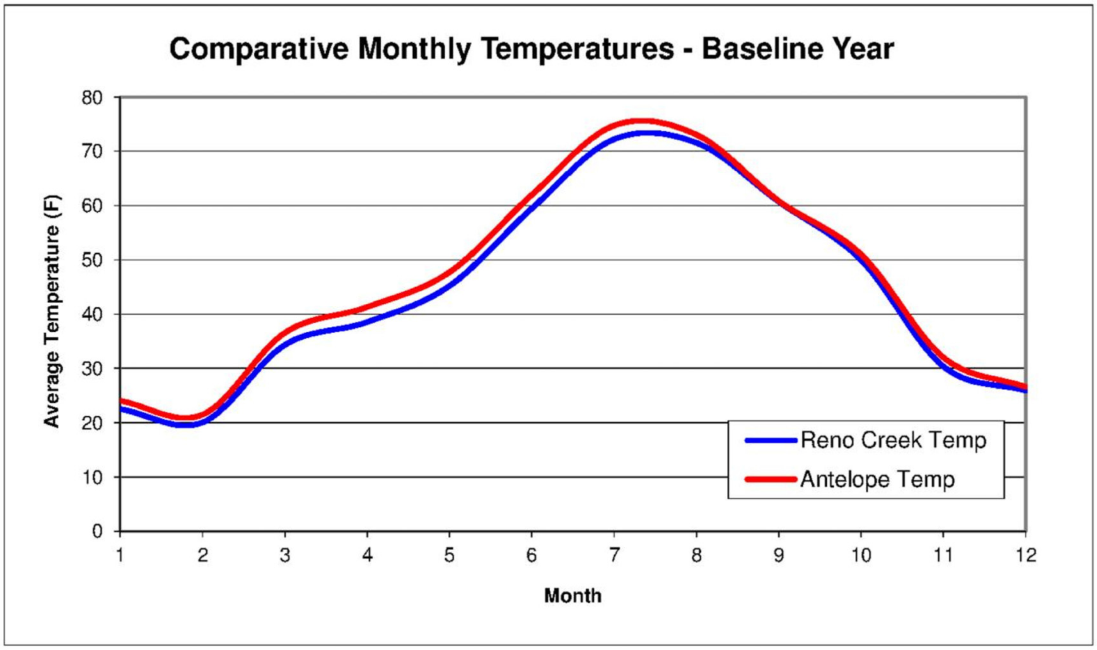
Predominant wind direction was from the WSW sector,
accounting for 14.9% of the possible winds

Data Recovery

Parameter	Possible (hours)	Reported (hours)	Recovery
Wind Speed	8683	8670	99.85%
Wind Direction	8683	8670	99.85%
Sigma-Theta	8683	8670	99.85%
Temperature	8683	8670	99.85%
Relative Humidity	8683	8414	96.90%
Precipitation	8683	8670	99.85%
Bar. Pressure	8683	8412	96.88%
Solar Radiation	8683	8414	96.90%

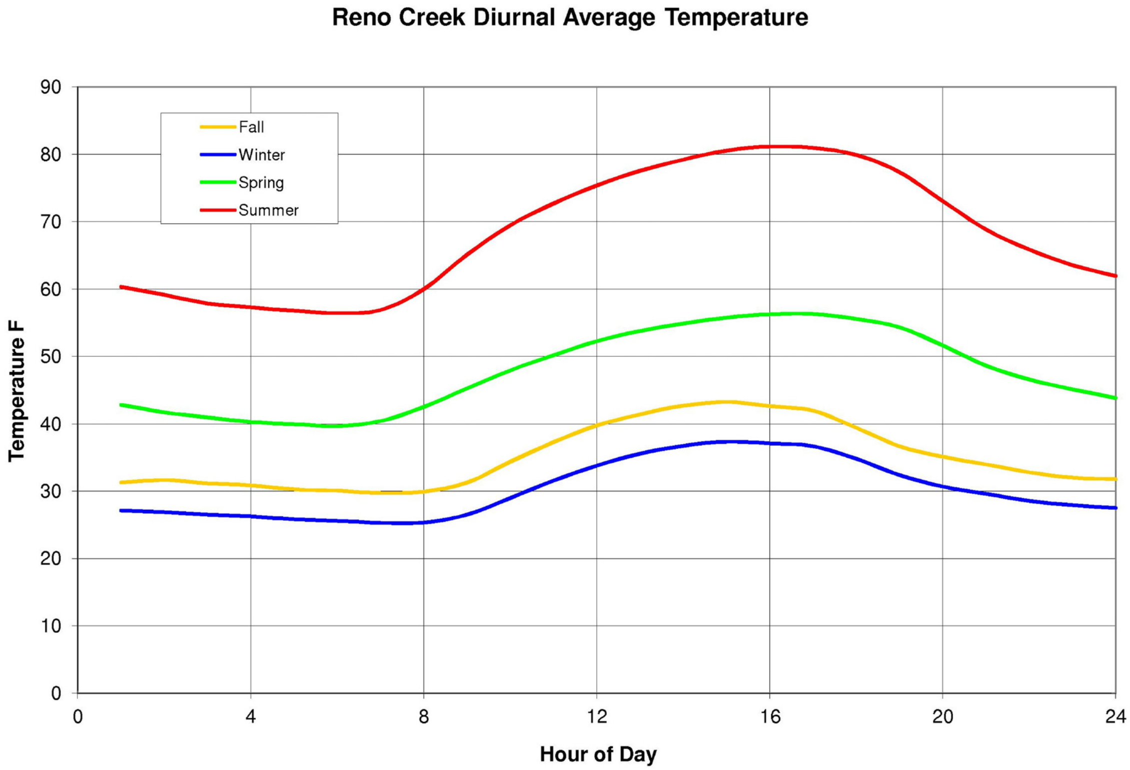
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-18: Reno Creek vs. Antelope Monthly Average Temperatures



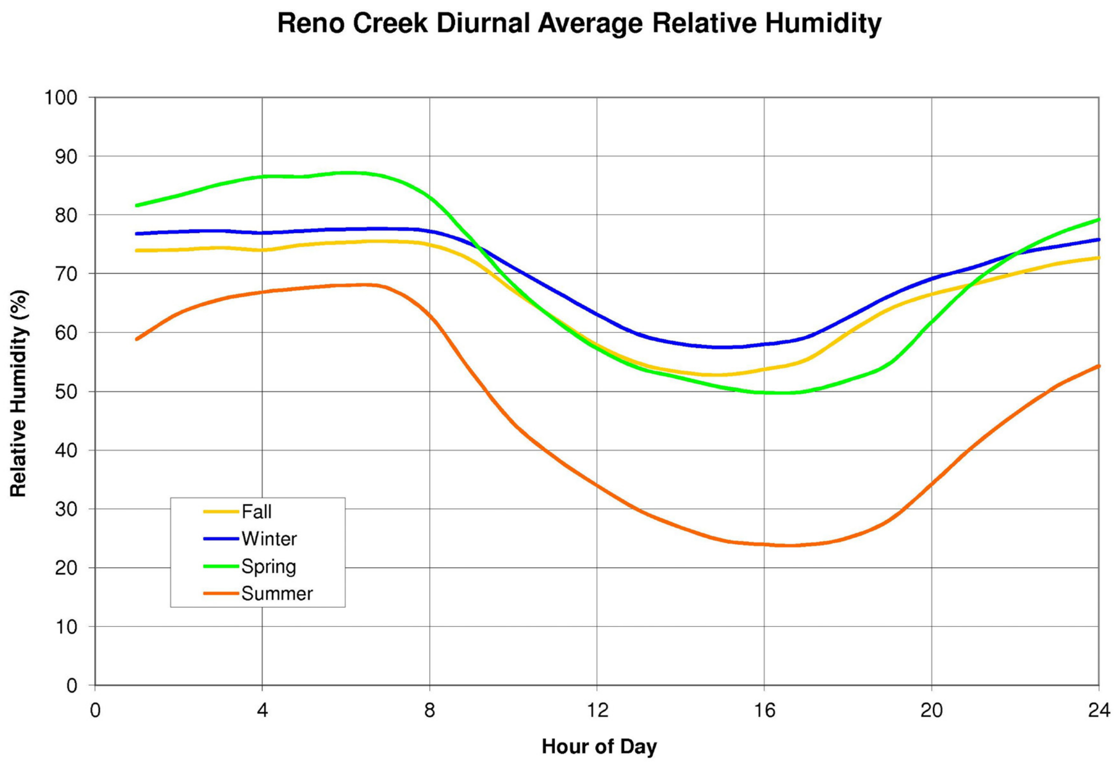
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-19: Proposed Project Diurnal Average Temperatures



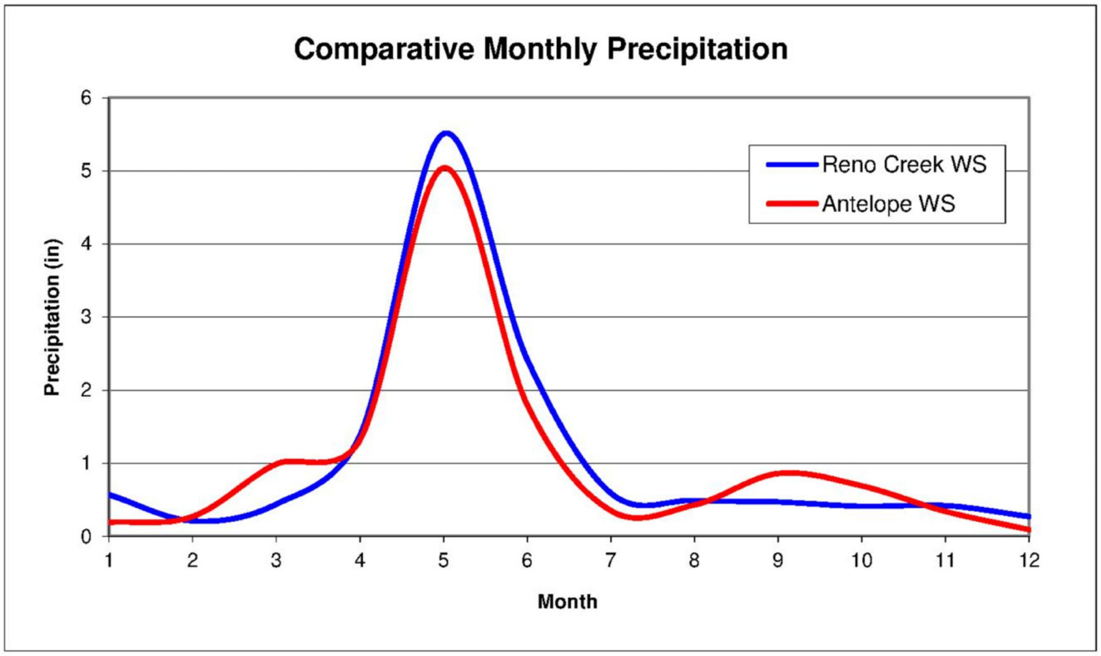
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year, 2010-2011

Figure 2.5-20: Proposed Project Diurnal Average Relative Humidity



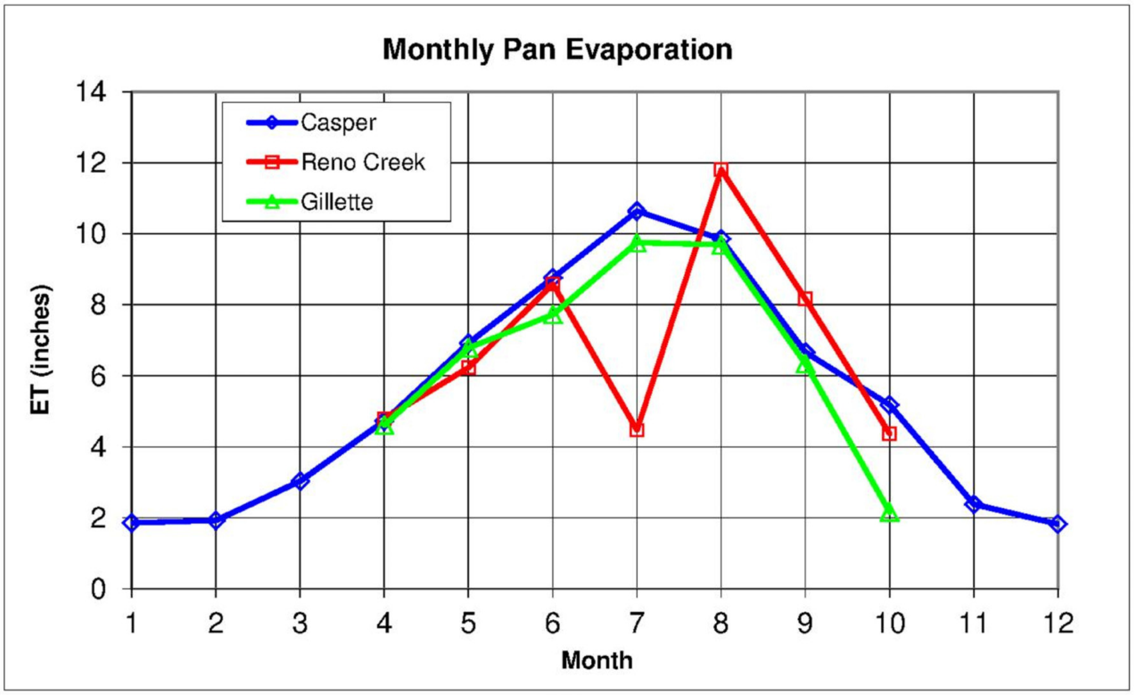
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year, 2010-2011

Figure 2.5-21: Proposed Project vs. Antelope Monthly Precipitation



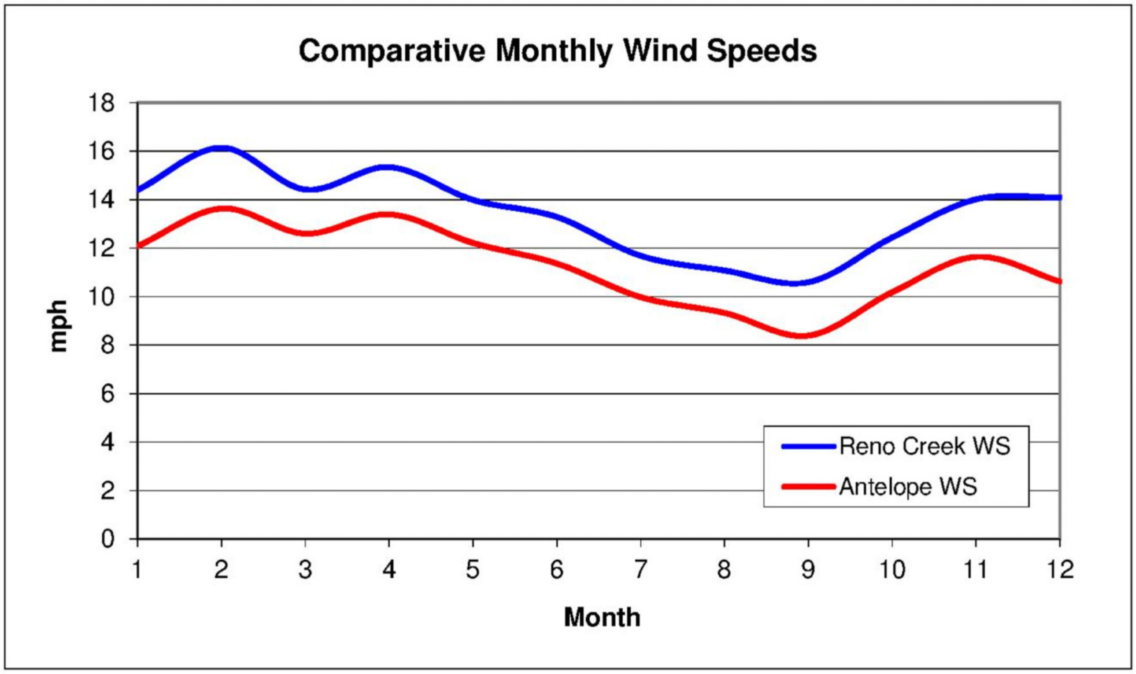
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-22: Proposed Project Monthly Evaporation



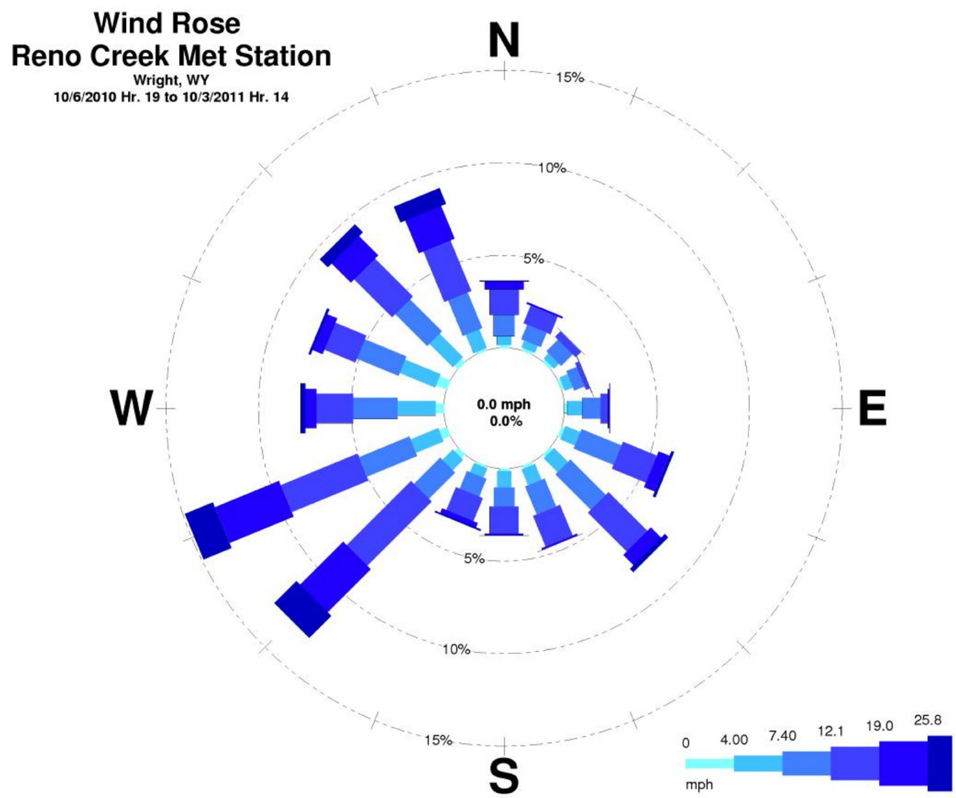
Source: IML Air Science calculations and meteorological database, 2011

Figure 2.5-23: Reno Creek Project vs. Antelope Monthly Average Wind Speeds



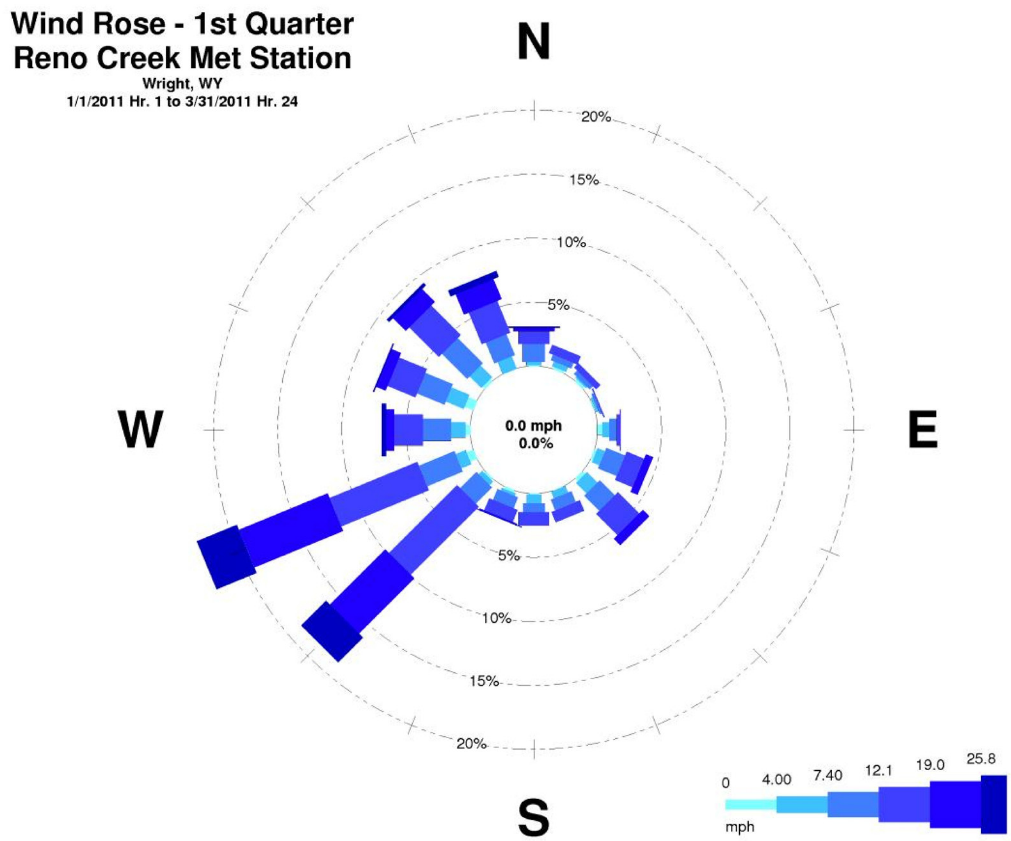
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-24: Reno Creek Project Windrose



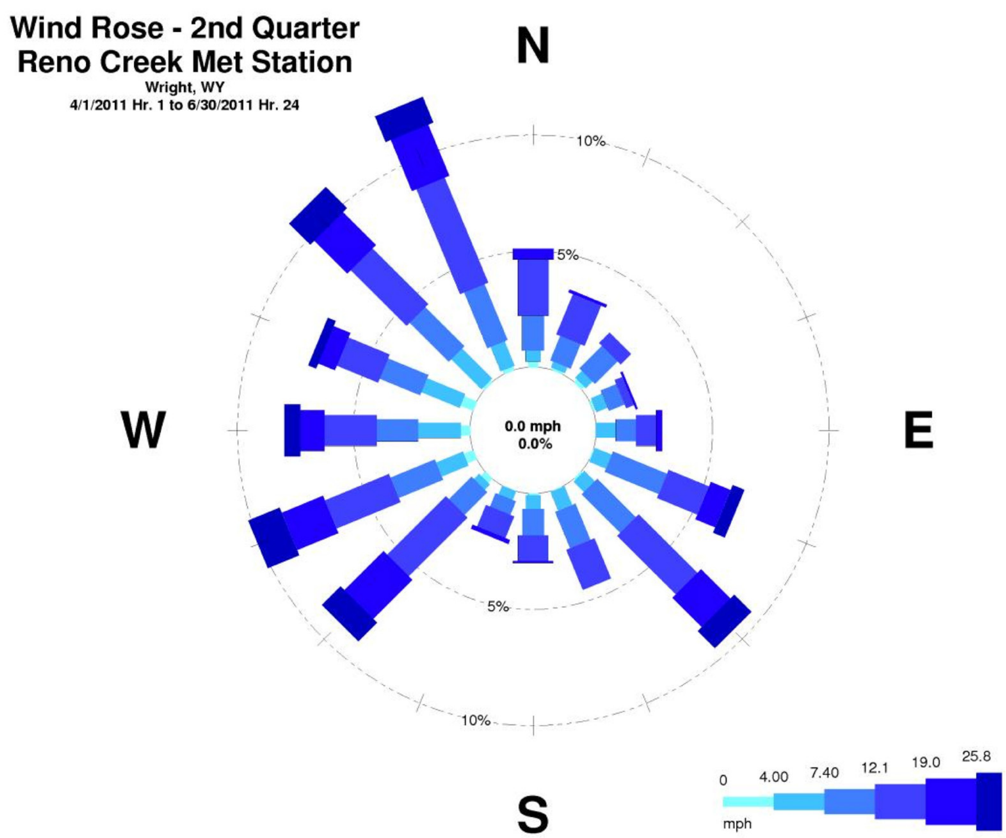
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-25: Proposed Project Wind Rose: 1st Quarter



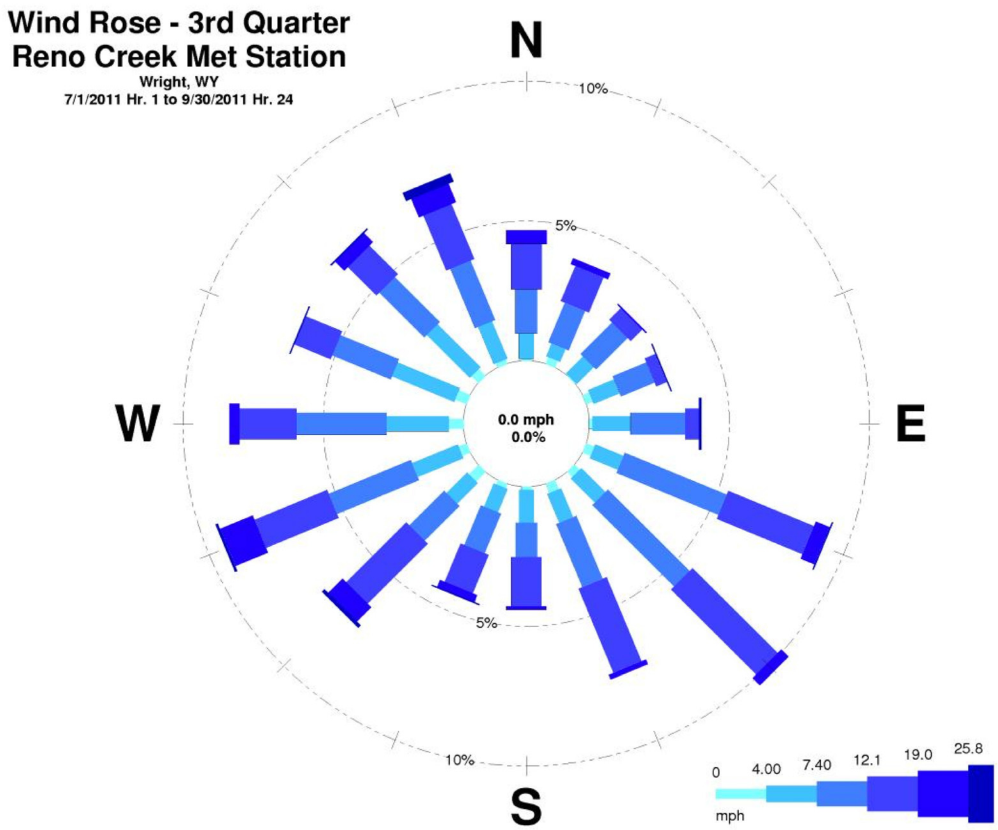
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-26: Proposed Project Wind Rose: 2nd Quarter



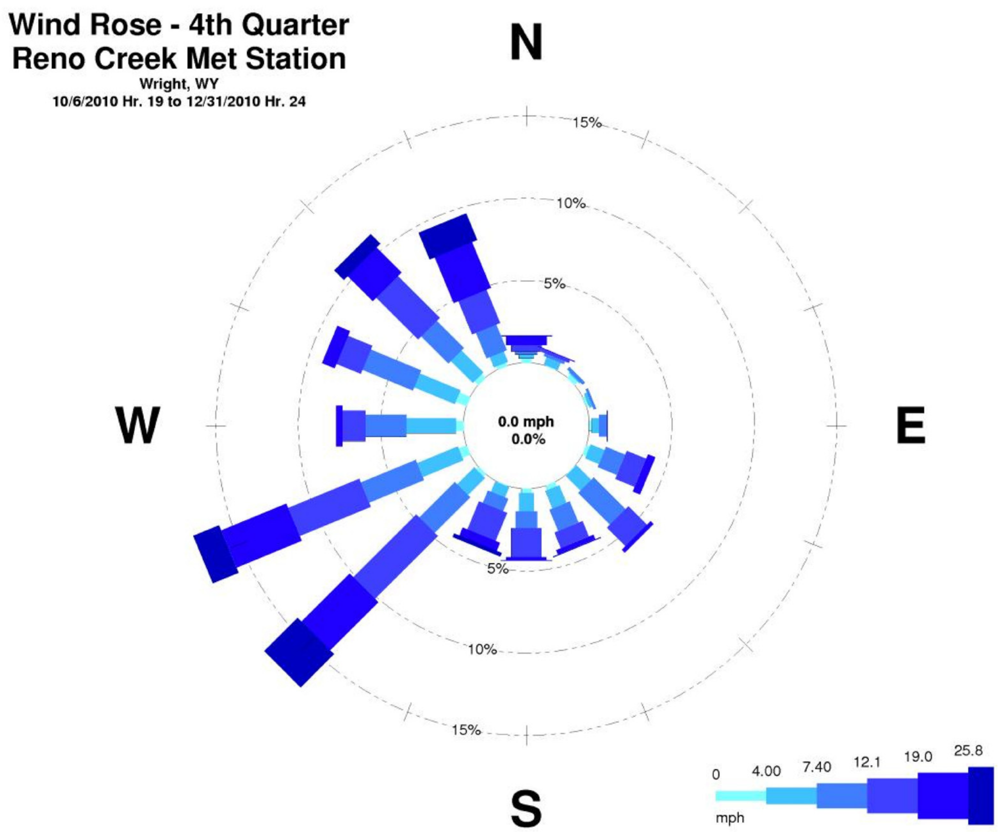
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-27: Proposed Project Wind Rose: 3rd Quarter



Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-28: Proposed Project Wind Rose: 4th Quarter



Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-29: Proposed Project Wind Summary

Reno Creek

Wind Data Summary

10/6/2010 7:00:00 PM - 10/3/2011 2:00:00 PM

Hourly Data

		Average	Max	Min
Wind Speed (mph)		13.49	41.97	1.15
Sigma Theta (º)		10.49	73.66	0.39
Wind Direction				
	N	12.55	29.92	2.22
	NNE	11.26	23.97	2.07
	NE	9.49	22.42	2.12
	ENE	8.67	26.64	2.47
	E	9.46	27.56	2.23
	ESE	12.28	30.83	1.87
	SE	12.84	34.81	1.65
	SSE	10.93	28.52	1.54
	S	10.91	29.51	1.55
	SSW	12.37	30.30	1.83
	SW	17.34	41.97	1.36
	WSW	16.22	41.07	1.15
	W	11.14	34.83	1.18
	WNW	10.61	33.14	1.38
	NW	13.67	38.51	1.25
	NNW	15.68	35.83	2.19

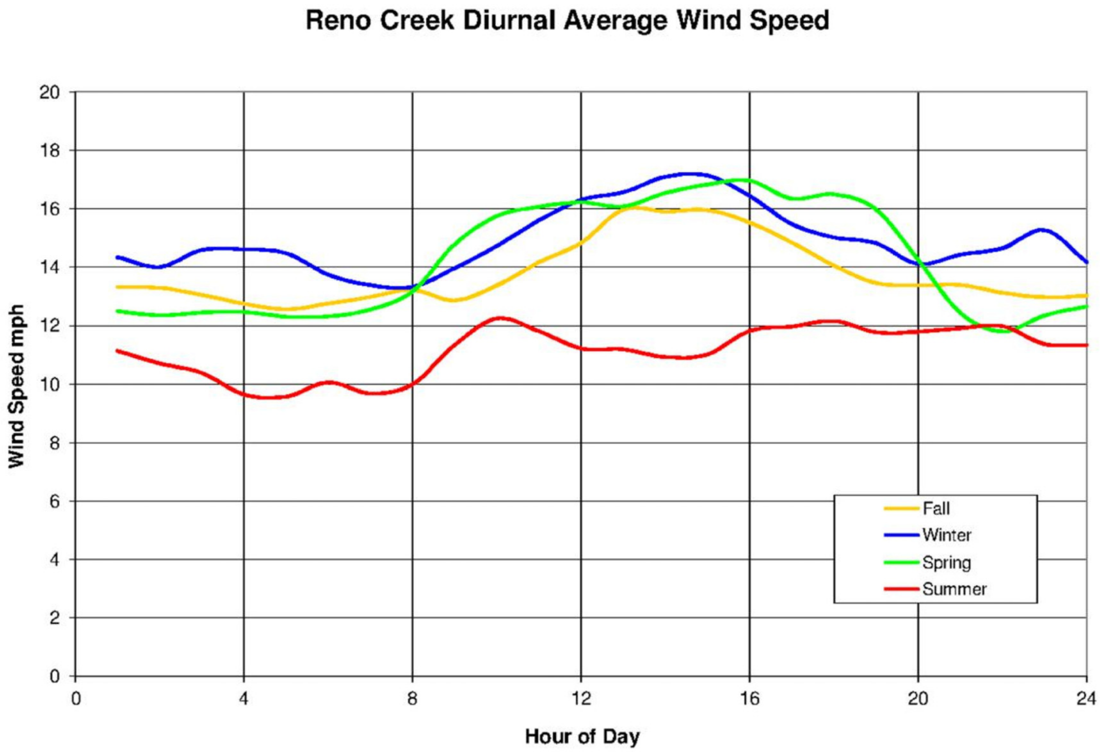
Predominant wind direction was from the WSW sector, accounting for 14.9% of the winds, the average wind direction was 255°.

Data Recovery

	Possible (hours)	Reported (hours)	Recovery
Wind Speed	8707	8670	99.58%
Sigma Theta	8707	8670	99.58%
Wind Direction	8707	8670	99.58%

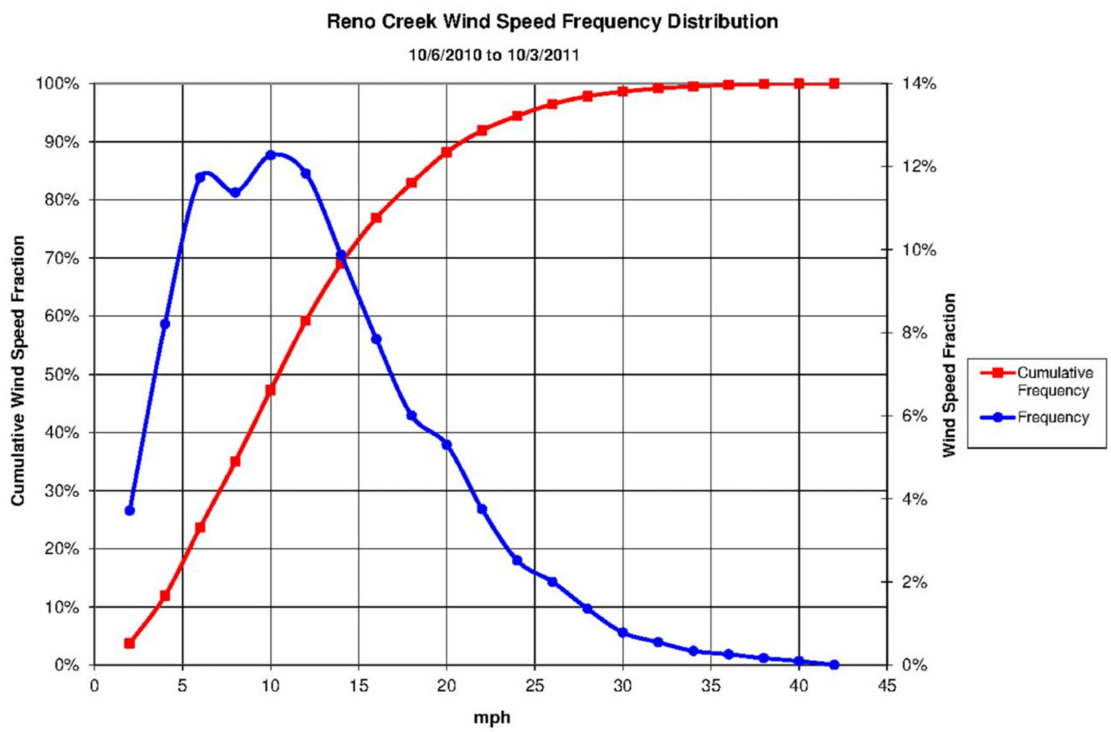
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-30: Proposed Project Diurnal Average Wind Speeds



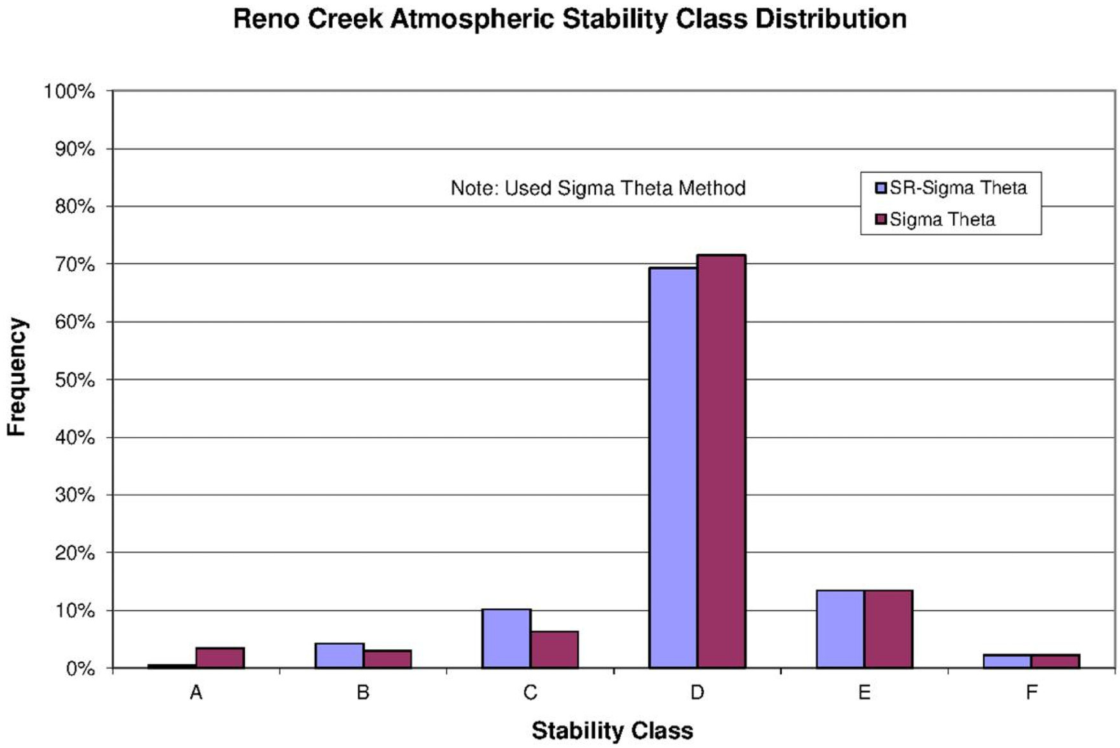
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year, 2010-2011

Figure 2.5-31: Proposed Project Wind Speed Frequency Distribution



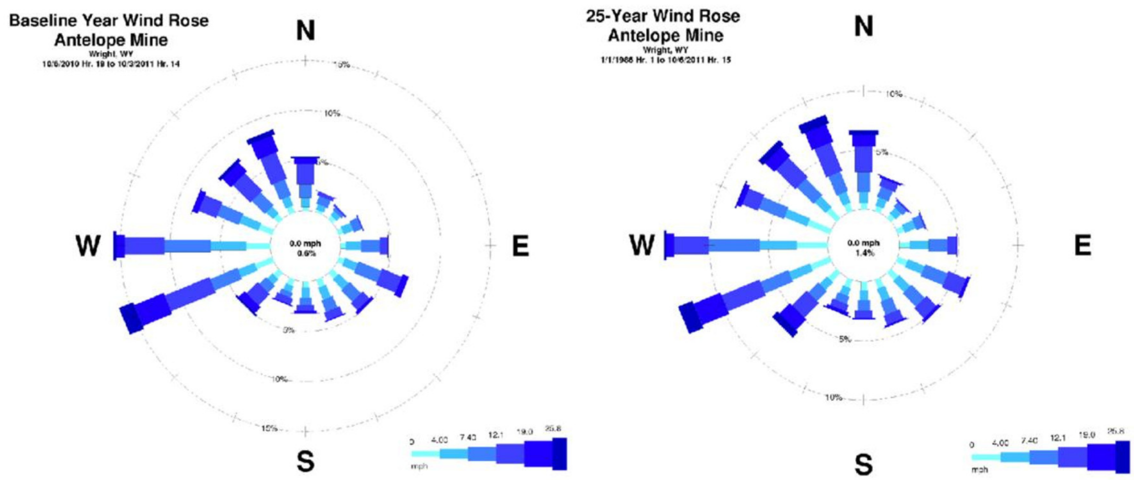
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year

Figure 2.5-32: Reno Creek Stability Class Analysis



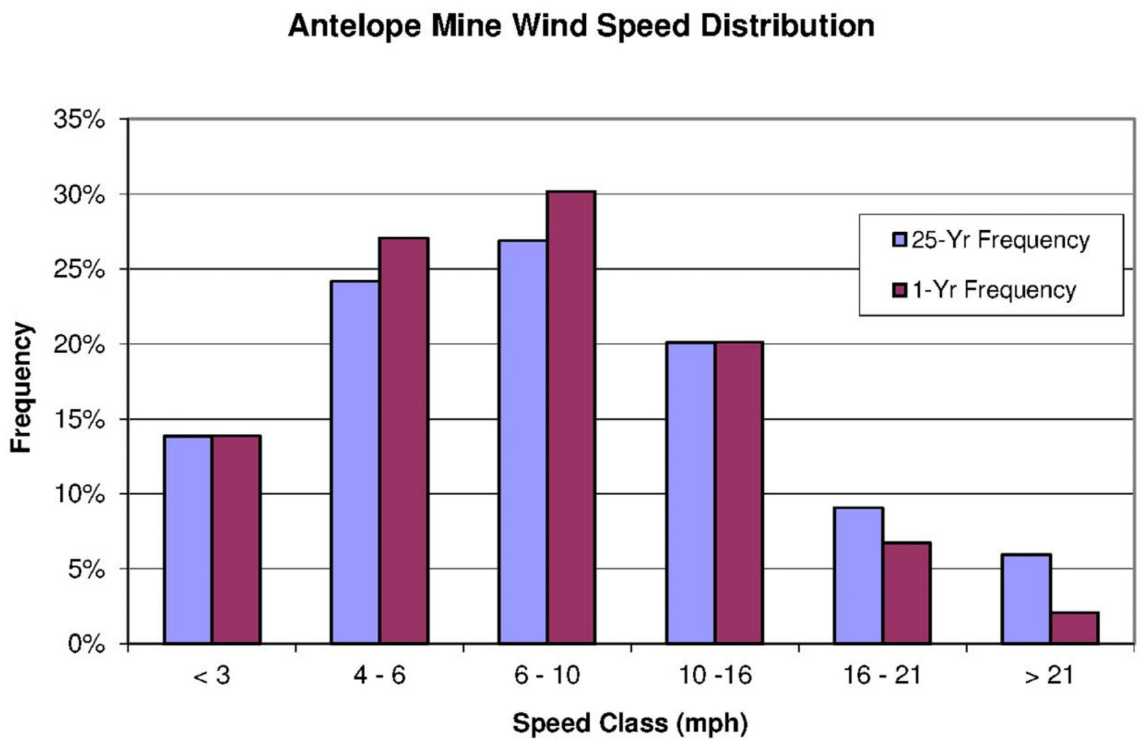
Source: Analysis by IML Air Science using meteorological database, 2011
Period: Baseline monitoring year, 2010-2011

Figure 2.5-33: Antelope Mine Short and Long-Term Wind Roses



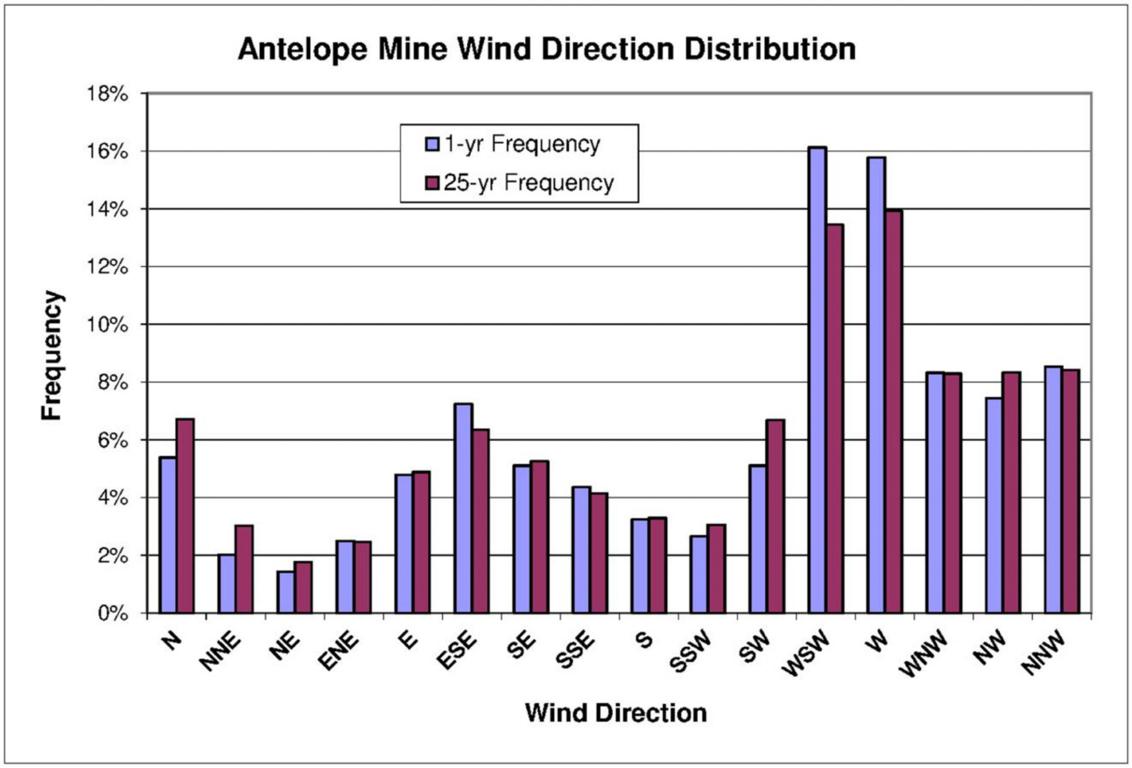
Source: IML Air Science meteorological database, 2011
Period: 1986-2011

Figure 2.5-34: Antelope Short and Long-Term Wind Speed Distributions



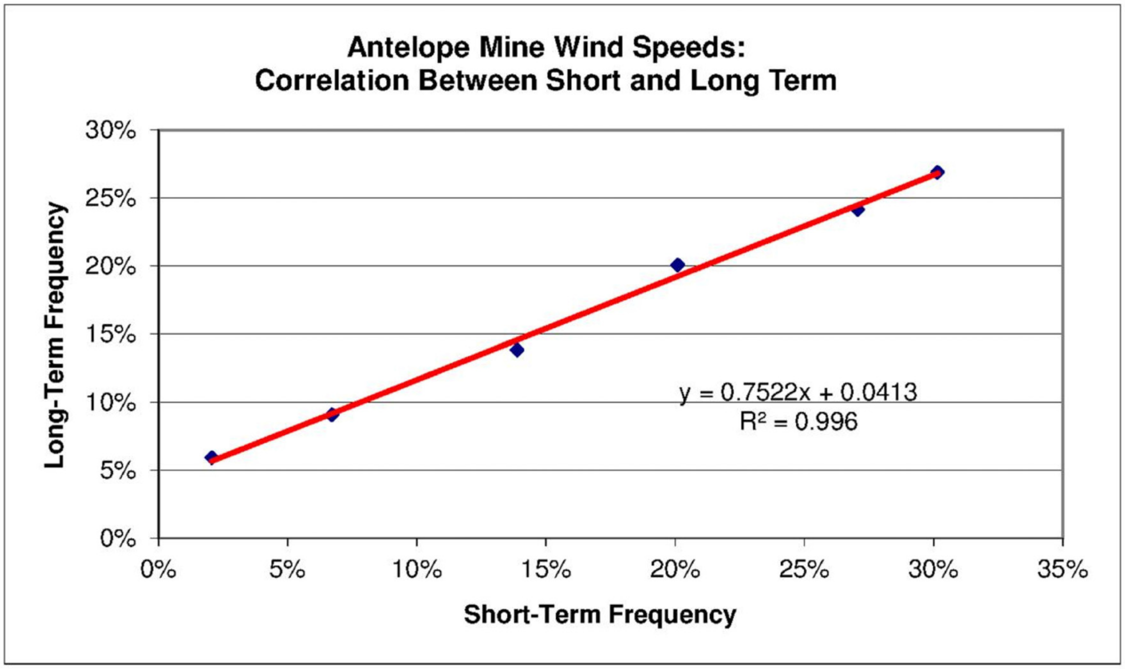
Source: IML Air Science meteorological database, 2011
Period: 1986-2011

Figure 2.5-35: Antelope Short and Long-Term Wind Direction Distributions



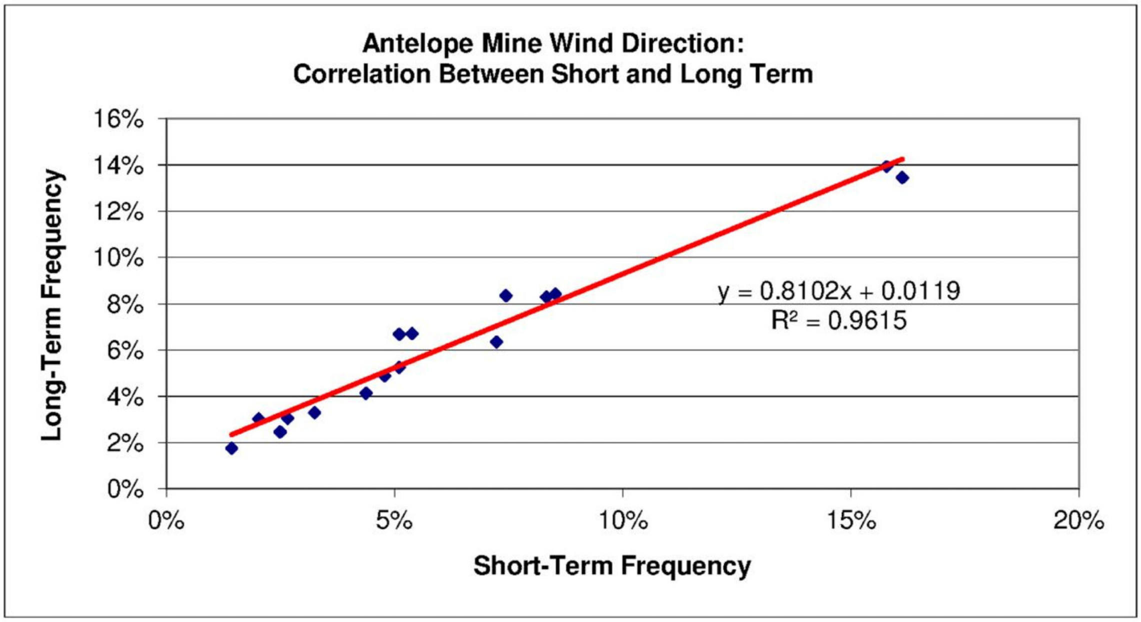
Source: IML Air Science meteorological database, 2011
Period: 1986-2011

Figure 2.5-36: Antelope 25-Year vs Baseline Year Wind Speed Distributions



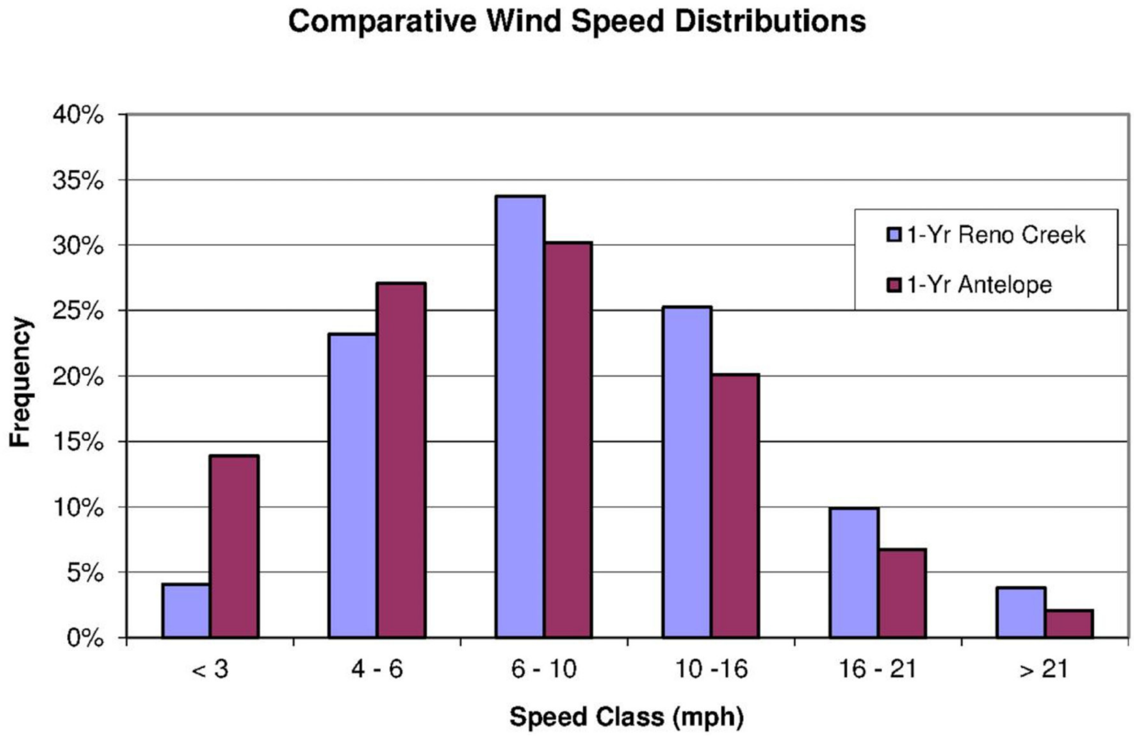
Source: Analysis by IML Air Science using hourly database from 1986 through 2011

Figure 2.5-37: Antelope 25-Yr vs Baseline Year Wind Direction Distributions



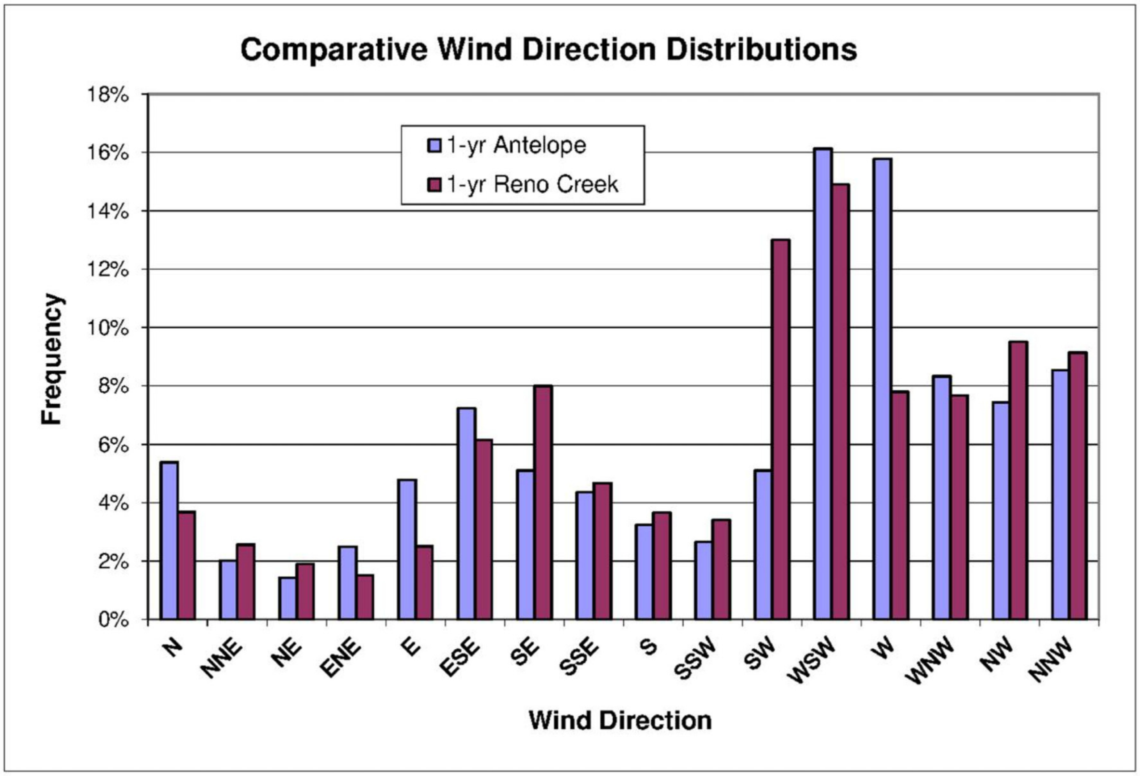
Source: Analysis by IML Air Science using hourly database from 1986 through 2011

Figure 2.5-38: Antelope vs Reno Creek Baseline Yr Wind Speeds



Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year, 2010-2011

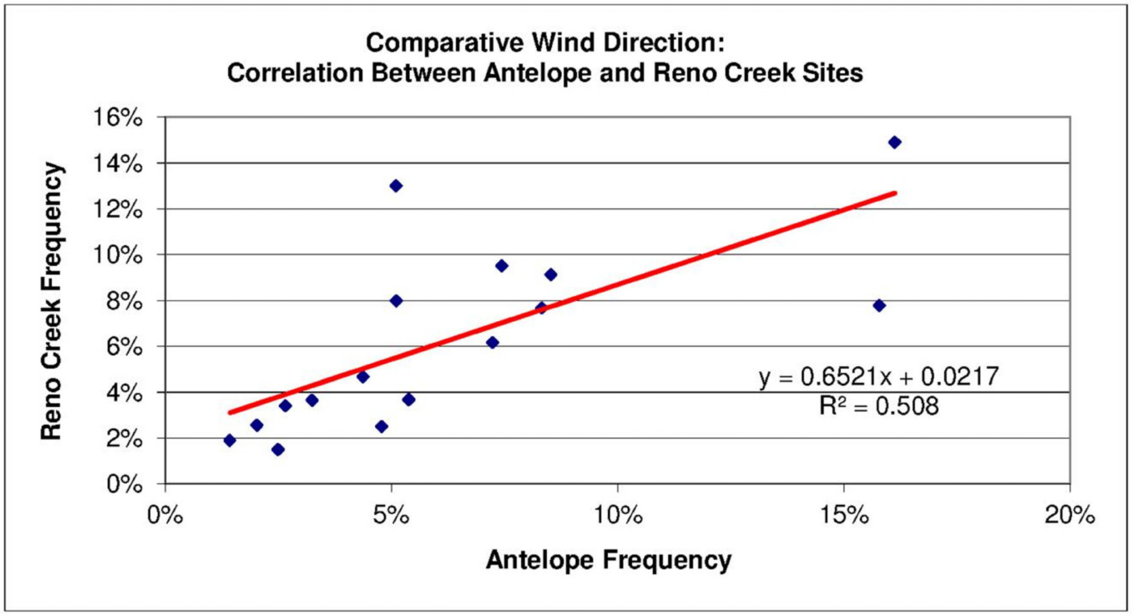
Figure 2.5-39: Antelope vs Reno Creek Baseline Yr Wind Directions



Source: IML Air Science meteorological database, 2011

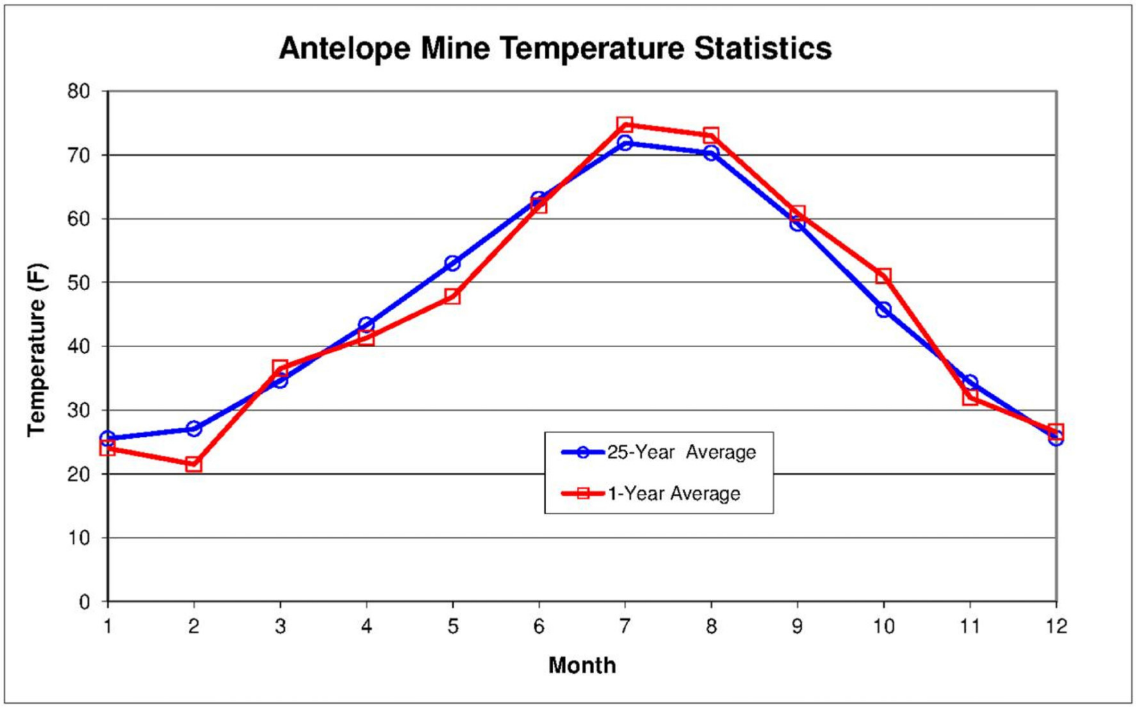
Period: Baseline monitoring year, 2010-2011

Figure 2.5-40: Antelope vs Reno Creek Baseline Yr Wind Direction Distributions



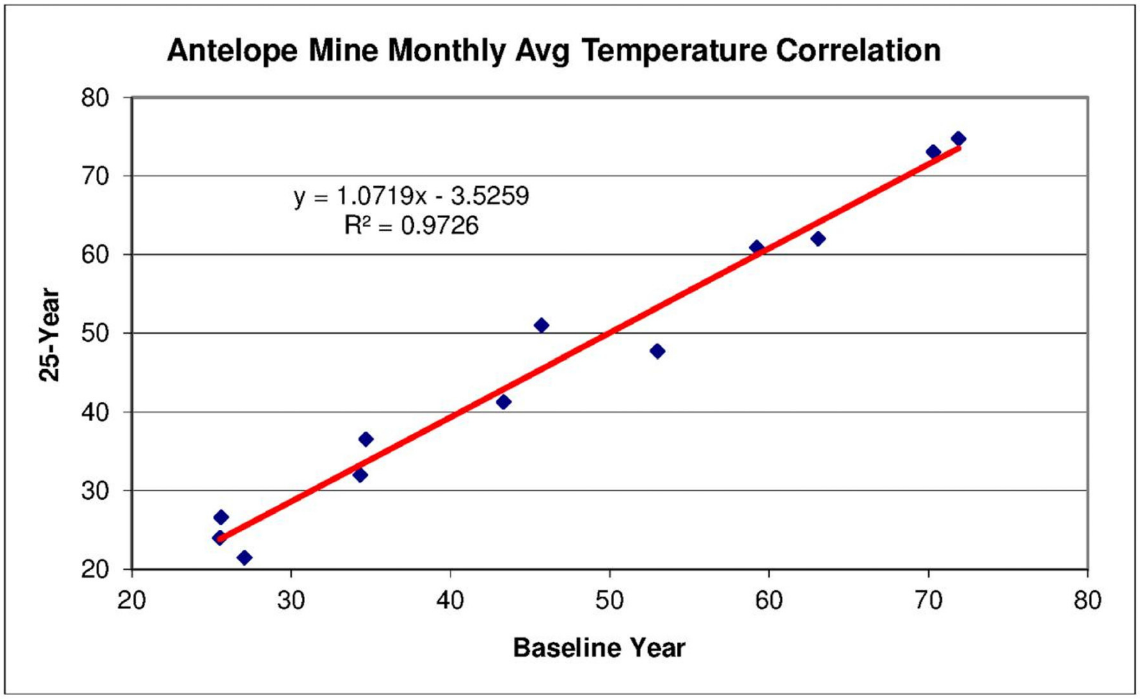
Source: Analysis by IML Air Science using meteorological databases
Period: Baseline monitoring year, 2010-2011

Figure 2.5-41: Antelope Short and Long-Term Monthly Average Temperatures



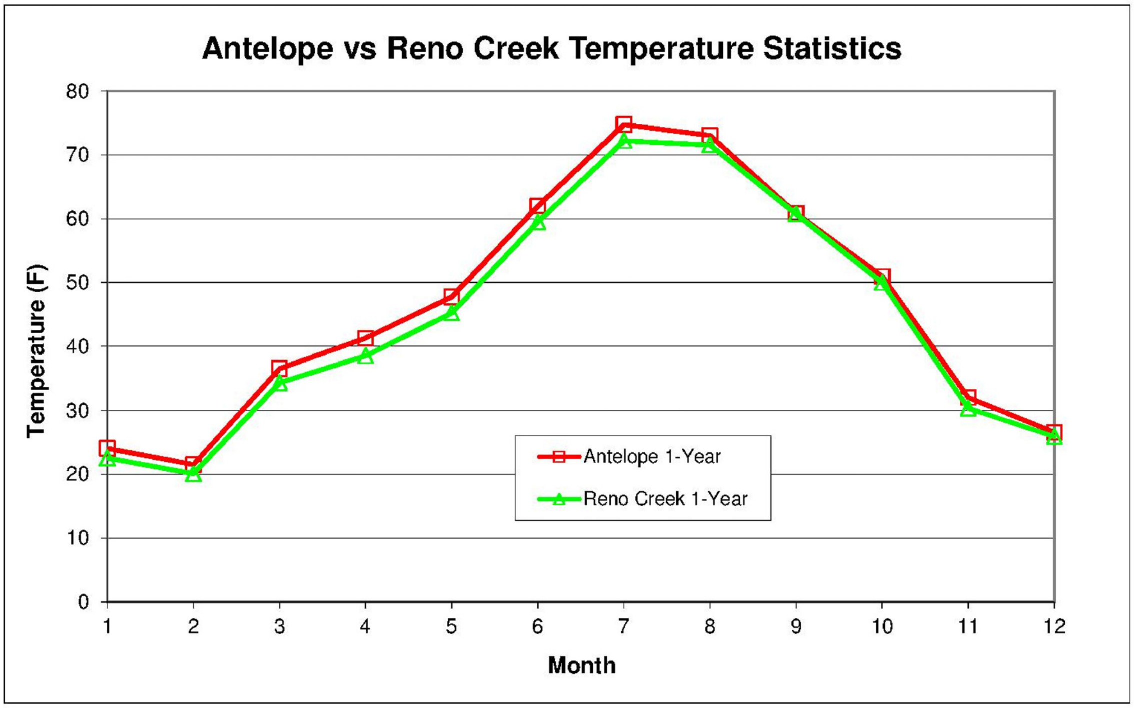
Source: IML Air Science meteorological database, 2011
Period: Baseline monitoring year, 1986-2011

Figure 2.5-42: Antelope Short and Long-Term Monthly Temperature Correlation



Source: Analysis by IML Air Science using meteorological databases
Period: 1986-2011

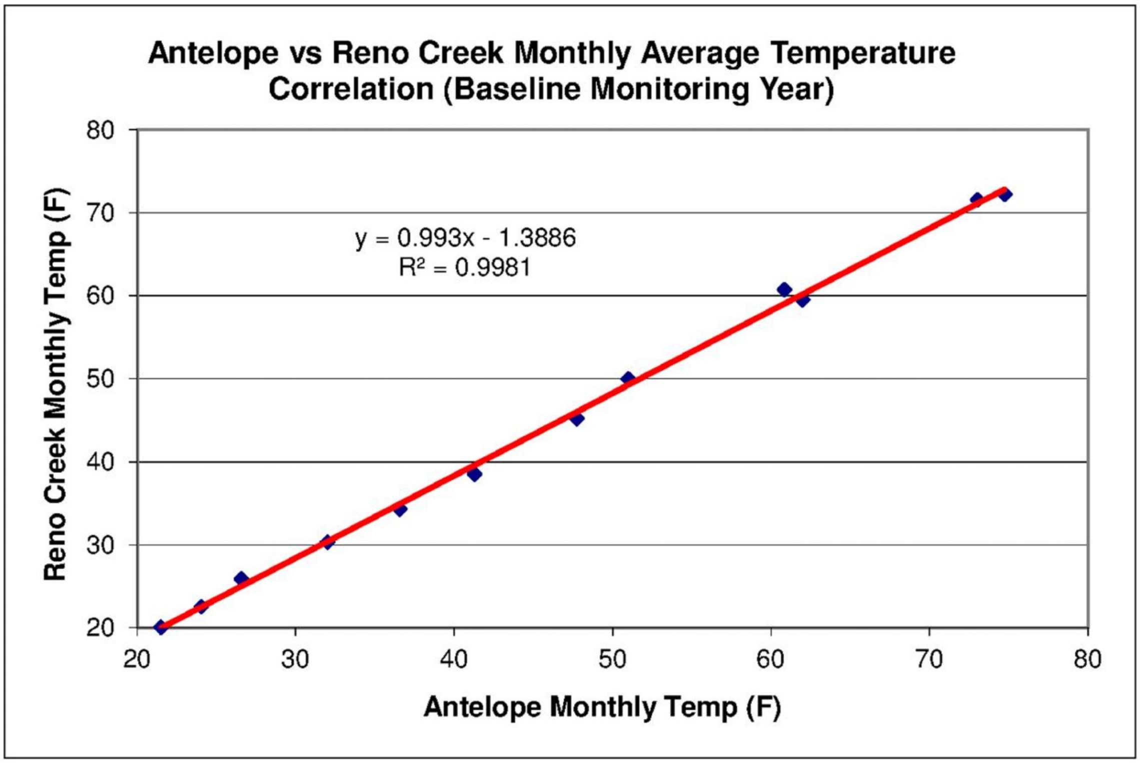
Figure 2.5-43: Antelope and Reno Creek Baseline Yr Monthly Avg. Temperatures



Source: IML Air Science meteorological database, 2011

Period: Baseline monitoring year, 1986-2011

Figure 2.5-44: Spatial Correlation of Monthly Average Temperatures



Source: Analysis by IML Air Science using meteorological databases

Period: Baseline monitoring year, 2010-2011

Figure 2.5-45: Proposed Project Meteorological Monitoring Map

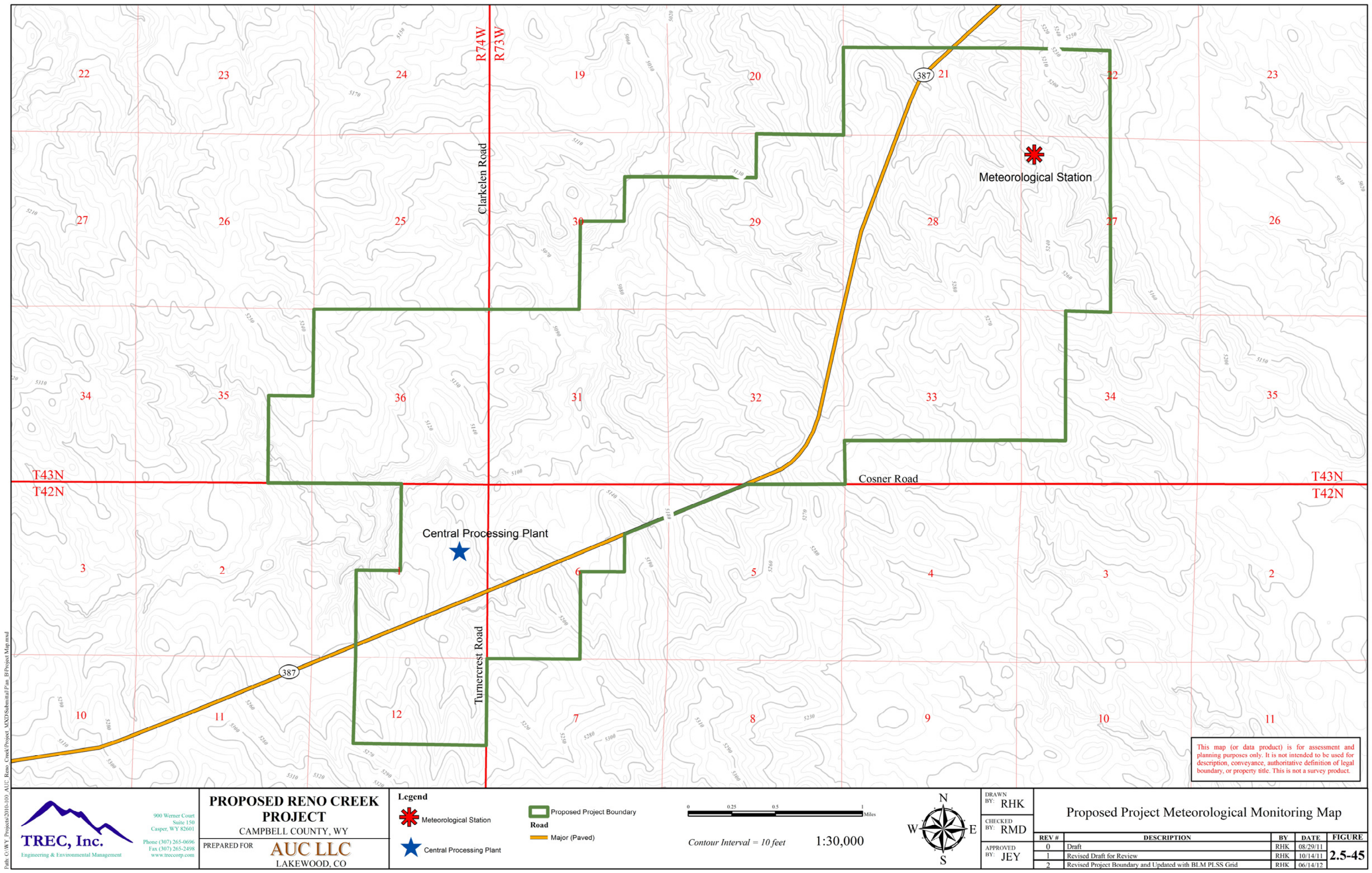


Figure 2.5-46: Reno Creek Meteorological Monitoring Station

2.5.5 REFERENCES

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WDEQ "Chapter 2, Ambient Standards" Cheyenne WY: Wyoming Department of Environmental Quality. 2012.
Website: http://deq.state.wy.us/aqd/standards.asp

<u>Tables References</u>

Table 2.5-1: Meteorological Stations Included in Climate Analysis; Sources: National Climatic Data Center, 2011; Website: http://www.hprcc.unl.edu/data/-historical/index.php?state=wy&action=select_state&submit=Select+State; IML Air Science, 2011.

Table 2.5-2: Monthly Temperature Statistics for Region; Sources: National Climatic Data Center, 2011; Website: http://www.hprcc.unl.edu/data/historical/index.php?-state=wy&action=select_state&submit=Select+State; IML Air Science, 2011.

Table 2.5-3: Monthly and Relative Humidity Statistics for Region; Sources: National Climatic Data Center, 2011; Website: http://www.hprcc.unl.edu/data/historical-/index.php?state=wy&action=select_state&submit=Select+State; IML Air Science, 2011.

Table 2.5-4: Monthly Wind Speed Statistics for Region; Sources: National Climatic Data Center, 2011; Website: http://www.hprcc.unl.edu/data/historical/index.php?state-=wy&action=select_state&submit=Select+State; IML Air Science, 2011.

Table 2.5-12: Upper Atmosphere Characteristics at Rapid City, SD; Source: IML computation based on data from National Climate Data Center, 2011

Figure References

Figure 2.5-1: NWS and Coal Mine Meteorological Stations; Source: National Climatic Data Center, 2011

Figure 2.5-2: Regional Average Monthly Temperatures; Sources: National Climatic Data Center, 2011; IML Air Science meteorological database, 2011

Figure 2.5-3: Antelope Mine Monthly Diurnal Temperature Variations; Source: IML Air Science meteorological database, 2011; Period: 1986-2011

Figure 2.5-4: Regional Annual Average Minimum Temperatures; Source: National Climatic Data Center, 2011

Figure 2.5-5: Regional Annual Average Maximum Temperatures; Source: National Climatic Data Center, 2011

Figure 2.5-6: Casper Airport Degree Days; Source: National Climatic Data Center, 2011; Period: 1948-2010

Figure 2.5-7: Mean Monthly Relative Humidity for Gillette and Casper; Source: National Climatic Data Center, 2011

Figure 2.5-8: Diurnal Average Relative Humidity for Gillette AP; Source: National Climatic Data Center, 2011; Period: 2005-2009

Figure 2.5-9: Regional Monthly Average Precipitation; Source: National Climatic Data Center, 2011

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2.6 Geology

The discussions of geology, soils, and seismicity related to the proposed Reno Creek Project (Proposed Project) are contained in this section. Detailed information about the Proposed Project area and its immediate surroundings is provided to the extent that AUC is permitted to acquire such data under 10 CFR Part 40.32(e) and the regulations of the State of Wyoming. More comparable and/or detailed discussions regarding geology and soils can be found in:

- All Section 2.6 tables and figures are located in Addendum 2.6-A;
- Addenda 2.6-A through 2.6-C of this TR;
- Sections 7.1.5, 7.2.5 and 7.5 of this TR (Environmental Effects);
- Section 3.3 of the ER (Geology and Soils);
- Addenda 3.3-A through 3.3-G of the ER;
- Section 4.3 of the ER (Environmental Impacts);
- Section 5.5 of the ER (Cumulative Impacts);
- Section 6.3 of the ER (Mitigation); and
- Section 7.1.3 of the ER (Environmental Measurements and Monitoring).

A discussion of the Production Zone Aquifer (PZA) and the mudstone units providing geologic confinement above and below the PZA is found in Section 2.6.2 of this chapter. The PZA is an Eocene-age sandstone formation which hosts the uranium mineralization for the Proposed Project. There is continuous geologic confinement of the PZA over the entire Proposed Project area. As a consequence, ISR operations in the PZA can be conducted without significant potential impacts to groundwater resources.

2.6.1 Regional Geology

The Proposed Project is located in the Pumpkin Buttes Uranium District in the central PRB of Northeast Wyoming as shown in Figure 2.6A-1 in Addendum 2.6-A. Outcrop geology of the district is also depicted on Figure 2.6A-1.

Active uranium projects in the Pumpkin Buttes District are depicted on the map including Reno Creek (AUC LLC), Moore Ranch, Willow Creek and Irigaray (Uranium One), and Uranerz' Hank Unit and Nichols Ranch projects. Willow Creek is currently producing uranium using ISR methods.

According to NUREG-1910 (GEIS Section 3.3.3), the PRB encompasses an area of about 31,000 km^2 (12,000 mi^2) in Campbell, Johnson, and Converse counties within the Eastern Wyoming Uranium District. The first uranium discoveries in the PRB near Pumpkin

Buttes were in 1951 (Davis, 1969). Other uranium deposits were found along a 60-miles northwest-southeast trend in the southwest portion of the PRB. Production began in 1953.

2.6.1.1 Structural Geology

The PRB extends over much of northeastern Wyoming and southeastern Montana, and consists of a large north-northwest trending asymmetric syncline depicted in Figure 2.6A-2, Structure Map, showing contours on the top of the Fox Hills Sandstone which lies at approximately 6,500 feet in depth in the Proposed Project area (Figures 2.6A-3 and 2.6A-4). The basement axis lies near the western edge of the basin, and the present surface axis lies to the east of the basement axis near the Pumpkin Buttes approximately 10-miles west of the Proposed Project. The basin is bounded by the Big Horn Mountains to the west, the Black Hills to the east, and the Hartville Uplift and Laramie Mountains to the south.

The PRB is filled with sediments of marine and continental origin ranging in age from early Paleozoic through Cenozoic as shown in Figure 2.6A-3. Sediments reach a maximum thickness of about 20,000 feet in the deepest parts of the basin. The top of the Precambrian is projected to be 17,500 feet deep in the Proposed Project area.

Figure 2.6A-4 is an oil and gas log (Yates Petroleum, API # 49-005-45589) located immediately to the north of the Proposed Project area in Section 19, T43N, R73W. The total depth of the well is 10, 690 feet. The location of the well is shown on Figure 2.6A-5, a location map for oil and gas (non CBM) tests in and adjacent to the Proposed Project.

During Paleozoic time most of northeastern Wyoming lay beneath shallow marine waters on the continental shelf. Throughout this time, gentle subsidence of the shelf and intermittent uplifts were accompanied by the deposition of marine limestone, shale and sandstone.

Periods of oceanic regression and transgression began in the region during the late Paleozoic and increased in the Mesozoic. These cycles resulted in the deposition of layers of marine sand and carbonates interbedded with coarse-grained, non-marine clastic sediments.

Following a long period of stability during the Mesozoic, tectonic forces of late Paleocene to early Eocene ushered in mountain building events related to the Laramide orogeny. Uplift began to affect the western continental margin and modify the landscape of central and eastern Wyoming (Seeland, 1988). As a result of these tectonic forces, the PRB was the site of active subsidence surrounded by orogenic uplifts (Big Horn Mountains, Laramie Mountains, Black Hills, etc). The Tullock Member of the Fort Union marks the first evidence of basin downwarp and synorogenic filling (outcrop geology shown on Figure 2.6A-1).

Throughout the Paleocene, uplift of the Big Horn Mountains, Laramie Mountains and Black Hills continued on the margins of the PRB. Erosion of these highlands produced clastic material which now constitutes the upper members of the Fort Union Formation in the basin's flood plain. Thick sequences of mudstone in the Lebo Shale Member around the margins of the basin indicate a typical Laramide depositional environment. The Laramide orogeny was near its peak activity in Tongue River time as indicated by a marked increase in the deposition of coarse sandstones. A period of deformation and erosion accompanied by westward tilting of the basin preceded a final Laramide surge and deposited the clastic rocks of the Eocene Wasatch Formation, the uranium-bearing host rock in the Proposed Project. The Wasatch dips northwestward at approximately one degree to two and a half degrees in this portion of the PRB (Sharp et al., 1964).

During the Oligocene, regional volcanism to the west of the basin resulted in the deposition of tuffaceous claystone, sandstone and conglomerate of the White River Formation. Downwarping of the basin was completed in early Cenozoic time and subsidence of the enclosing mountain ranges after deposition of the White River Formation caused local tilting of these and older beds toward the mountains. Remnants of the White River Formation overlie the Wasatch Formation in the center of the Pumpkin Buttes District (Figure 2.6A-1).

Throughout the Miocene, most of Wyoming was an upland over which windblown sands were deposited. Erosion prevailed throughout most of the region during the Pliocene but locally tuffaceous clay and fresh water limestone were deposited in low lying, regional lakes.

In the late Pliocene the region again underwent uplift and, since the Pleistocene the area has been undergoing erosion. Most of the White River Formation and much of the Wasatch Formation have been removed. Remnants of the White River conglomerate resisted erosion to form the mesa caps of the Pumpkin Buttes. Concurrently, upper Cenozoic and Quaternary gravels were deposited on terraces, flood plains and valley floors. More recently, Holocene alluvium has filled channels eroded in the older rocks and windblown sand has formed dunes, predominantly in the southwest corner of the basin.

2.6.1.2 Regional Stratigraphy

Outcrops of post-marine formations in the southern part of the basin consist of the Lance, Fort Union, Wasatch and White River Formations (Figures 2.6A-1, 2.6A-3, and 2.6A-4). The Upper Cretaceous Lance Formation is the oldest of these units, and consists of 1,000 to 3,000 feet of thinly-bedded, brown to gray sandstones and shales. The upper part contains minor, dark carbonaceous shales and thin coal seams, indicating a changing depositional environment over time.

The Paleocene Fort Union Formation conformably overlies the Lance and consists of continental and shallow non-marine deposits in two members. The lower member consists of fine-grained, clay-rich, drab to pink sandstone, with minor claystone and coal. The sandstones were deposited as alluvial fans and braided stream channels during erosion of the uplifted Black Hills, Bighorn, and Laramie Mountains. The upper member consists of shale, clayey sandstone, fine-to-coarse-grained sandstone, and some extensive sub bituminous coal beds. The total thickness of the Fort Union Formation varies between 2,000 and 3,500 feet (Sharp et al., 1964).

The Fort Union Formation is the water source for the City of Wright, located approximately 10 miles east of the Proposed Project. Due to its position (up dip) of the Proposed Project, the PZA (the host for uranium mineralization) is eroded away and is not present in the Wright area.

The early Eocene Wasatch Formation unconformably overlies the Fort Union Formation around the margins of the basin. However, the two formations are conformable and gradational towards the basin center and the Proposed Project area. The relative amount of coarse, permeable clastics increases near the top of the Fort Union, and the overlying Wasatch Formation contains numerous beds of sandstone which are sometimes correlatable over wide areas. Except in isolated areas of the PRB, the Wasatch-Fort Union contact is generally set at the top of the thicker coals or of some thick sequence of clays and silts. The Badger Coal is regarded as the approximate formation boundary in the Proposed Project area.

The Wasatch Formation crops out at the surface in the Proposed Project area. The Wasatch is similar to the Fort Union, but also contains thick lenses of coarse, crossbedded, arkosic sands deposited in a high-energy fluvial environment. The Wasatch Formation reaches a maximum thickness of approximately 500 to 700 feet within the Proposed Project area.

Remnants of the Oligocene White River Formation crop out on the Pumpkin Buttes, located approximately 10-miles to the west-northwest of the Proposed Project area. Virtually all of the White River has otherwise been eroded away. The youngest sediments consist of Quaternary alluvial sands and gravels locally present principally in drainages.

The central part of the PRB contains at least 10,000 feet of sediments underlying the Upper Cretaceous Lance Formation. Most of the rocks are marine shales and mudstones. Notable sandstones below the Lance are found in the Cretaceous Fox Hills Formation (transitional marine to non-marine), and the Teckla, Teapot, and Parkman members of the Mesa Verde Formation (Figure 2.6A-3 and 2.6A-4). The Teapot and Parkman sandstones are approximately 7,100 to 8,150 feet below land surface in the Proposed Project area, and are sandstones currently employed in the Basin for disposal of ISR 11e.(2) liquid byproduct through Class I UIC injection wells. AUC considers the Teckla to be a potential disposal zone as well.

The Upper Cretaceous Teapot and Parkman sandstone members of the Mesa Verde Formation lie approximately 7,500 feet below the PZA. AUC has applied for Class I UIC Permits from the WDEQ to inject 11e.(2) liquid byproduct into the Teapot and/or Parkman sandstones as part of the Proposed Project. More detailed information is found in Section 4 of this TR including a copy of the UIC Permit application in Addendum 4-B. The water quality of three well samples from the Teapot/Parkman sandstone from nearby oil wells in Campbell County contained total dissolved solids ranging from 12,130 to 13,800 mg/l.

The Teckla, Teapot, and Parkman Formations are regarded as potential oil and gas targets in this portion of the PRB. Deeper Cretaceous oil and gas targets below the Mesa Verde Formation shown on Figure 2.6A-4 include the Niobrara Shale and the Turner Sandstone. These formations occur over 2,000 feet deeper than the potential deep disposal zones. The great thickness of low-permeability units overlying and underlying the potential disposal zones effectively isolate the units from sandstones higher and lower in the geologic section.

The Madison limestone and Tensleep sandstone are approximately 15,000 feet below the land surface (Figure 2.6A-3).and approximately 7,000 to 8,000 feet below the Teckla, Teapot and Parkman Formations.

2.6.2 Site Geology

Discussions of local geologic conditions present at the site are included in the following sections.

2.6.2.1 Structure

The Proposed Project area lies within a portion of the PRB that generally dips to the northwest at approximately one degree (Figure 2.6A-2). Based on historic and recent geophysical and lithologic logs covering an area of more than 50 square-miles, including the Proposed Project area, mineralized host sandstone exhibits a dip ranging from 35 to 60 feet per mile.

A structure map (Figure 2.6A-6) drawn on the base of the Lower Felix Coal shows the local dip at the Proposed Project. The Upper and Lower Felix Coals occur within a mudstone unit immediately above the PZA and are locally continuous, making them excellent correlation markers in the Proposed Project area. As shown in Figure 2.6A-6, dips are gentle and do not suggest the presence of faults. Faulting has not been detected across the entirety of the Proposed Project area.

2.6.2.2 Stratigraphy

According to NUREG-1910 (GEIS Section 3.3.3), the primary hosts for uranium mineralization at the Proposed Project area are sandstones of the lower Wasatch Formation of Eocene age (49 to 54.8 million years). The formation consists of interbedded, arkosic sandstone, conglomerate, siltstone, mudstone and carbonaceous shale, all compacted but poorly cemented (Harshman, 1968).

The upper Wasatch has been largely eroded away in the Proposed Project area. The Wasatch Formation is a fluvial sedimentary sequence deposited during a period of wet, subtropical climatic conditions (Seeland, 1988). Laramide tectonic forces uplifted highlands to the south and southwest that provided sediments which were transported northward by rivers flowing into the PRB. Sands deposited by meandering streams formed channel and point bar deposits that typically fine upwards through the sequence. In addition to the fluvial sands, claystones, siltstones, carbonaceous shale, and thin coal seams were deposited in overbank environments. Fine grained sediments were deposited as levees, splays, and in backwater swamps adjacent to sands deposited by higher energy fluvial environments.

The Wasatch Formation occurs at the surface in the Proposed Project area, except where it is occasionally covered by recent alluvium in shallow drainages. The generally accepted base of the Wasatch in the Proposed Project area is the top of the Badger Coal, located approximately 250 feet below the sandstone horizon proposed for uranium recovery operations.

Unconformably underlying the Wasatch is the Paleocene age Fort Union Formation. The Paleocene Fort Union Formation is composed of continental and shallow non-marine deposits associated with Laramie uplift and basin filling. Thicknesses noted by Hodson (1973) are approximately 2,300 feet in the eastern basin, 2,900 feet in the southwest, and almost 3,500 feet in the northwest part. The Fort Union is a heterogeneous unit of fine-grained sandstones, interbedded shales, carbonaceous shale and coal. The formation thickens to the southwest and is conformably underlain by the Lance Formation and unconformably overlain by the Eocene-age Wasatch Formation. Outcrops of the Fort Union Formation encircle most of the basin and beds dip basinward.

The Fort Union Formation is the major source of coal in the PRB and also hosts significant volumes of exploitable CBM reserves. The largest coal mines in the United States are located along the north-south trending outcrop of the Fort Union approximately eight-miles east of Wright, Wyoming, and extending north to the Gillette, Wyoming area. The mines produce coal from the Anderson/Big George coal seams that reach thicknesses of over 100 feet.

The CBM production that is present in parts of the Proposed Project area is from the Anderson/Big George Coal, at approximately 1,000 to 1,100 feet below ground surface. The coal seams occur approximately 600 feet below the base of the PZA, the sandstone unit proposed for uranium ISR operations. This depth relationship is illustrated on the Deep Oil and Gas Type Log (Figure 2.6A-4).

Research by the Wyoming State Geological Survey (Clarey, 2009) has shown that the CBM production in the Anderson/Big George has had no measurable effect on water levels in any Wasatch aquifer. More details about the relationship of CBM production and potential uranium production are found in Section 2.7.

The All Night Creek (ANC) well cluster was installed by the US Bureau of Land Management (BLM) to assess the effects of CBM dewatering activity in Section 36, Township 43N, Range 74 West, in the western portion of the Proposed Project area (Figure 2.7B-11, ANCVSS is within the well cluster, west side of map). Water levels in the well cluster were gauged for over 10 years providing an excellent historical record. Water level data from the ANC cluster regarding dewatering of the Big George Coal were used in the Clarey report.

The deepest well in the BLM's ANC cluster was completed in the Big George Coal at approximately 1,070 feet. After approximately six years of CBM dewatering activity in the area the well went dry in 2007, and has stayed dry to the present time. Other wells in the cluster were completed in shallower sandstone units including the Proposed Project's Production Zone Aquifer, and Overlying Aquifer. During the period from 2002 through the present, water levels in the Production Zone Aquifer and the Overlying Aquifer were unaffected by pumping (Figures 2.7B-55 through 2.7B-57) indicating that CBM dewatering will not impact AUC's ISR operations.

AUC contacted the BLM in 2010 and was granted access to the ANC wells for water level monitoring points during pump testing of AUC's PZM5, located approximately 4,000 feet to the east-southeast of the ANC cluster. Water levels in the ANC well cluster were unaffected by the PZM5 hydrologic test (Figure 2.7B-46), further evidence that CBM and ISR operations can coexist without adverse effects.

2.6.2.2.1 Hydrostratigraphic Units

Units immediately underlying the mineralized host sandstone, the host sandstone, and units overlying the host sandstone are discussed in the following section.

Geophysical logs representative of various portions of the Proposed Project area are found as Figures 2.6A-7 through 2.6A-10. A geological cross section index map (Figure 2.6A-11) and five cross sections (Figures 2.6A-12 through 2.6A-16) are also incuded to provide several views over the entire length and breadth of the Proposed Project. A second set of cross sections are provided to show more detail regarding each of the ore body areas (Figures 2.6A-17 through 2.6A-23). The individual geophysical logs and cross sections demonstrate the continuity of the PZA and the over and underlying confining aquitards.

The following summary provides the stratigraphic nomenclature and acronyms with descending depth utilized for the Proposed Project for the units of interest present in the Wasatch Formation.

- SM Unit (SM wells): Shallow water table unit present in some locations. Based on geologic and hydrologic data, this unit does not meet the requirements of an aquifer in the Proposed Project area;
- Overlying Aquifer (OM wells): Overlying aquifer relative to the production zone. This aquifer also represents the uppermost aquifer observed in the Proposed Project area;
- Overlying Aquitard (OA): Confining unit providing isolation between the production zone and overlying aquifer;
- Production Zone Aquifer (PZA);
- Underlying Aquitard (UA): Confining unit providing isolation between the production zone and underlying unit; and
- Underlying Unit (UM wells): Discontinuous underlying sand units relative to the production zone. Based on geologic and hydrologic data, this unit does not meet the requirements of an aquifer in the Proposed Project area.

In the Proposed Project area, the lower-most unit of the Wasatch Formation comprises the UA Aquitard, which lies below the Production Zone Aquifer (PZA) and above the Badger Coal. The aquitard is approximately 150 to 250 feet thick and consists of laterally continuous silt and clay rich mudstones, and locally, discontinuous lenticular sandstones. This confining unit is present under the entire Proposed Project area. An isopach map of the UA Aquitard is included (Figure 2.6A-24).

The first significant sandstone in closest proximity (subjacent) to the Production Zone Aquifer (PZA) is designated as the Underlying Unit. As depicted on the cross sections in Addendum 2.6-A, the Underlying Unit is not an aquifer or a continuous, correlatable zone.

The mineralized host sandstone, or PZA, overlies the UA Aquitard. The PZA is a discrete and laterally continuous sandstone ranging from under 75 feet to approximately 220 feet thick as shown in Figure 2.6A-25. In the central portion of the Proposed Project area, the PZA is divided into an upper sandstone and a lower sandstone by a five to 30 foot thick mudstone. This division occurs locally in other portions of the project as well, and multiple mudstone lenses of limited lateral extent are commonly observed throughout the Proposed Project area. In areas where the PZA is bifurcated mineralization can be found both above and below the mudstone lens.

At various localities within the Proposed Project area all horizons from the base to the top of the host sandstone can be favorable for uranium deposition. However, economically significant uranium mineralization occurs most frequently in the lower half of the PZA.

In the far eastern portion of the Proposed Project area the PZA is partially saturated, and in limited areas uranium mineralization is present above the potentiometric surface of the PZA. Based on recent work by AUC, the mineralization in the uppermost, unsaturated portion of the PZA does not represent a significant percentage of the overall uranium resource. As work on the project progresses this saturated/partially saturated relationship to mineralization will be examined in detail.

Sandstones within the PZA that host the uranium mineralization are commonly crossbedded, graded sequences fining upward from very coarse at the base to fine grained at the top, representing sedimentary cycles from five to twenty feet thick. Stacking of depositional cycles has resulted in sand body accumulations over 200 feet thick.

The unit overlying the PZA in the Proposed Project area is the Overlying (OA) Aquitard. Figure 2.6A-26, an isopach map of the unit, addresses the thickness of the zone from the top of the PZA to the first significant overlying sandstone. The unit consists of a laterally continuous sequence of silt and clay rich mudstones, thin coal seams, and discontinuous sandstones. The thickness of the OA Aquitard can change rapidly due to discontinuities in the overlying sandstone units contained within this portion of the section, but is present as a continuous confining unit across the entire Proposed Project area.

The Felix Coal seams form a laterally continuous marker bed within the lower part of the OA Aquitard. In the eastern portion of the Proposed Project area, there are Upper and Lower Felix Coal seams, separated by approximately five feet of mudstone. The Upper Felix Coal seam pinches out or climbs in the section in the western portion of the

Proposed Project area, causing a correlation break from east to west. The Felix Coal seams range from five to 10 feet in thickness. A structure map drawn on the base of the Lower Felix Coal is shown in Figure 2.6A-6. Minor structural undulations are indicated by the mapping, but generally the dip is consistent and no faulting is evident.

The Felix coals are not CBM production targets in the Proposed Project area. The closest permits for possible usage of the Felix seam for CBM production is approximately 20 to 25 miles north of the Proposed Project area.

The first significant sandstone above the Felix Coal is designated as the Overlying Aquifer. Generally the sandstones comprising Overlying Aquifer are discontinuous, difficult to correlate over distances exceeding a few thousand feet, and are contained within mudstones of the OA Aquitard. This conceptual depositional relationship is depicted on cross sections in Addendum 2.6-A of this TR. In the central portion of the Proposed Project area the sandstone is well developed and attains a thickness of approximately 90 feet near the PZM4 well cluster.

A discontinuous, water table zone, referred to as the SM Unit, has also been identified by drilling at four of the well cluster locations. To determine if a water table zone is present at the well clusters, test borings were air-drilled to a depth of approximately 70 feet. Two-inch I.D. slotted PVC casing was temporarily installed for observation of groundwater infiltration. If a minimum of five feet of water was observed after standing a few days the temporary well was recompleted as a permanent monitoring well. The shallowest water level in the SM Unit was approximately 35 feet below ground surface.

Three of the seven SM tests proved to be dry, and the four that were converted to wells are poor producers. The term SM Unit has been used to describe the shallow water bearing zones as they do not fit the definition of aquifers. A discussion of this definition can be found in Section 2.7.2.3 of this TR.

The above data demonstrate that the PZA is geologically confined across the entire area of the Proposed Project, and that only the Overlying Aquifer exhibits characteristics of an aquifer. All other water bearing units outside of the PZA are not classed as aquifers.

Figures 2.6A-6 through 2.6A-10 are typical geophysical logs RC0005 (West), RC0004 (Central), RC0003 (Southeast), and RC0001 (East) that illustrate characteristics of the various units across the Proposed Project area.

As outlined in the above discussion, stratigraphic continuity of the OA Aquitard (including the Felix Coal seams), the PZA, and the UA Aquitard has been demonstrated by drilling and mapping of the units across the five mile length of the Proposed Project area.

2.6.2.3 Lithologic Characteristics

Lithologic data at the Proposed Project is extensive. Records from historic and recent drilling include descriptions of samples and geophysical logs from thousands of drill holes beginning with exploration drilling in the late 1960s.

Drilling a total of 807 plug holes, well pilot holes, and core holes has been conducted by AUC since August 2010. Cuttings samples were collected at five-foot continuous intervals for lithologic descriptions by AUC geologists from surface to total depth. A collection of cuttings samples have been saved for future reference. The new drilling has been incorporated into AUC's extensive database of historic log data providing thousands of geologic data points in the Proposed Project area. New and historical drill holes are shown on Figure 2.6B-1 through 2.6B-3 in Addendum 2.6-B.

A deep stratigraphic test hole penetrating the total thickness of the Wasatch Formation through the Badger Coal marker at the top of the Fort Union Formation, was drilled in each of AUC's seven well clusters. The stratigraphic hole was the first hole drilled in each cluster in order to provide lithologic and stratigraphic information for use in determining completion depths of each of the various wells in the group. Three additional stratigraphic test holes to the Badger Coal were drilled in the southwestern portion of the Proposed Project area to provide more detailed sub regional control.

AUC recovered core samples from the Overlying and Underlying Aquitards and the Overlying Aquifer in the PZM4 Well Cluster, and from the PZA in the west (Section 36, T43N, R74W) and southwest (Section 6, T42N, R73W) portions of the Proposed Project area. Cores from the multiple zones were recovered to evaluate characteristics of each of the lithologic units, and were obtained from 10 separate core hole locations during the past year. Figures 2.6B-1 through 2.6B-3 illustrate the locations of the core holes.

Cores were collected for multiple purposes and analyses as follows:

1) Visual inspection and lithologic logging of sandstones, mudstones, and the Felix Coal seams;
2) Vertical and horizontal permeability and porosity analyses by various methods in major lithlogic units including aquitards (claystones, mudstones, siltstones), unmineralized sandstones, and mineralized sandstones;
3) Effective Porosity;
4) Bulk density;
5) Grain size analysis;
6) Clay content and mineralogy;
7) PZA sandstone lithology, mineralogy, and petrology;

8) Uranium mineral(s) identification; and
9) Metallurgical testing by bottle roll and column leach using varied oxidants and lixiviant strengths. Testing will provide data regarding amenability of uranium leaching and insights regarding geochemistry at the Proposed Project.

Results are complete for the first six items listed above, and are summarized on Tables 2.6A-1 through 2.6A-3 in TR Addendum 2.6-A. The last three items listed above are yet to be completed.

Although petrograhic analyses on recent core has yet to be completed, general conclusions regarding lithologic characteristics of the major units can be made on the basis of recent core and cuttings examinations and historical data originally generated by Rocky Mountain Energy.

The three lithologies encountered most commonly at the Proposed Project are mudstones, sandstones and coal (lignite). A thin veneer of soil is developed at the ground surface due to weathering of the lithologic units of the Wasatch Formation.

Mudstone is the term used for silt and clay dominated sediments at the Proposed Project. Very fine grained sands are also found within these low-energy depositional sequences. Depending on clay and silt content these units can range from siltstones to claystones. Mudstones closely adjacent to the Felix Coal seams often have the visual appearance of true claystones. Petrographic studies, clay analysis, and grain size distribution analyses are underway and/or planned to more definitively determine the type and percentage of sediments comprising the mudstone sequences.

As observed in core, mudstone units are often dark to medium gray, thinly laminated, and occasionally contain carbonaceous material. Carbonaceous clayey units grading to lignites adjacent to the Felix Coal seams have been observed in core. Increasing clay content often imparts a dense waxy appearance in zones with very low visual permeability.

Sandstones at the Proposed Project are described as arkosic and/or feldspathic in composition. Sands range from very fine to very coarse grained. Occasional pebble size clasts are also present. Colors range from light gray to dark gray in unoxidized areas, and yellowish gray (limonitic) to pink (hematitic) in oxidized areas. Cores often exhibit low angle cross bedding, but can be massive with only minor visible bedding planes. Fining upward sequences are often observed within depositional sequences. Accessory minerals include pyrite (trace to five percent) and calcium carbonate that form isolated hard lenses up to ten feet thick. Carbonaceous material is occasionally present in reduced portions of the sandstone. Grains have undergone considerable transport and range in appearance from sub angular to well rounded. Sorting ranges from good to poor with interstitial clay and/or silt forming a less permeable matrix in isolated areas.

2.6.2.4 Permeability and Porosity Measurements

Core samples from the PZM4 Well Cluster were collected for analysis of permeability and porosity (P&P) from the Overlying Aquifer, Overlying Aquitard, and Underlying Aquitard. Additional core samples from wide spaced core holes in the southwest portion of the Proposed Project area (RC0001C, 2C, 6C, 7C, and 9C) were recovered for analysis of properties of the PZA.

Permeability, porosity, and measurements of other rock properties were conducted by Core Laboratories and Weatherford Laboratories. Results are found in Tables 2.6A-1, 2.6A-2, and 2.6A-3.

Overlying Aquifer

Klinkenberg air permeability results from the Overlying Aquifer (two horizontal, one vertical) ranged from 1376 to 1775 md. Porosity measurements ranged from 35.65 percent to 40.63 percent.

Production Zone Aquifer

Klinkenberg air permeability results from the PZA sandstone (five horizontal, one vertical) ranged from 1073 to 3121 md. Porosity measurements ranged from 32.30 percent to 34.43 percent.

Klinkenberg air permeability results from the PZA cemented by calcium carbonate (one horizontal, one vertical) ranged from .178 to 2022 md (2022 md is a high, questionable result apparently due to a fractured core plug). Porosity measurements ranged from 12.67 percent to 15.07 percent, consistent with the observed tight, highly cemented condition.

One analysis of effective porosity was made on a PZA sandstone sample from core hole RC0007C. In this case the Klinkenberg permeability was 1801 md, the non-effective porosity was 31.8 percent; however the effective porosity measurement of this sample was 23.7 percent. Effective porosity excludes porosity related to bound water in clays resulting in a lower number.

Underlying Aquitard

Klinkenberg air permeability results from the Underlying Aquitard mudstone (two vertical) ranged from 5.2 to 10.1 md. Porosity measurements ranged from 21.95 percent to 29.92 percent.

This same Underlying Aquitard interval was also tested using a liquid permeability test (cap rock analysis) by Core Laboratory. In this case the vertical permeability result was 0.000584 md, a much lower result due to the method used. Liquid permeability measurement methods are regarded as a much more appropriate method for this type of analysis; therefore while the air permeability results of 5.2 to 10.1 md are useful in a qualititative sense, AUC regards the 0.000584 md liquid permeability result to be the accurate measurement. Pump test results also confirm that the aquitard is a very effective non-leaky hydrostratigraphic unit.

Overlying Aquitard

The Overlying Aquitard was also tested using a liquid permeability test (cap rock analysis) by Core Laboratory. The vertical permeability result was 0.0005877 md, very low and similar to the result from the Underlying Aquitard.

Based on these data, permeability and porosity of the PZA appears to be favorable for ISR operations. Liquid vertical permeability tests performed on core from Overlying and Underlying Aquitards indicated they exhibit highly impermeable, favorable conditions for confinement of fluids within the PZA.

2.6.2.5 Mineralogy

Sandstones at the Proposed Project are described as arkosic and/or feldspathic in composition. Quartz grains are a major component with moderate amounts of potassium and calcium feldspars. Accessory minerals include pyrite (less than five percent)) and calcium carbonate cement. Carbonaceous material is occasionally present in reduced portions of the sandstone.

Recent whole rock mineralogy work by AUC and reports from analytical work by Rocky Mountain Energy in the late 1970s indicate that quartz ranges from 50 to 60 percent, feldspars comprise approximately 20 to 25 percent, and clays are present as smectite, kaolinite, and illite may comprise up to 20 percent of the total.

AUC has collected core for submission for analytical work to determine the uranium mineralogy. Analyses of core from mineralized sandstones will be conducted to determine the type of uranium minerals present at the Proposed Project. In addition AUC will test for any associated elements that may be present such as vanadium to provide a basic understanding of the geochemistry of the deposit.

As noted in NUREG-1910 (GEIS Section 2.1), the main ore minerals in the unoxidized zone are coffinite and pitchblende (a variety of uraninite). Low concentrations of vanadium (~100 ppm) are sometimes associated with the uranium deposits at the Proposed Project, based on metallurgical testing conducted by AUC. Of five recently tested core samples, only one exhibited molybdenum (0.6 mg/kg) Also, selenium was only detected in one sample at 6.9 mg/kg. Arsenic was detected in all samples ranging from 1.4 to 14 mg/kg. Scattered lenses of calcium carbonate cement occur throughout the area, but only rarely contain anomalous uranium.

AUC will verify past work and will have petrographic work conducted to more accurately determine the composition of the host sandstones, siltstones, and claystones.

2.6.2.6 Uranium Mineralization

Uranium deposits accumulated along roll-fronts (also referred to as redox fronts) at the down-gradient terminations of oxidation tongues within the PZA sandstone. According to NUREG-1910 (GEIS Section 3.3.3), these roll fronts are stratabound and genetically related to geochemical interfaces. The oxidation tongues are extensive, covering square miles down dip of oxidized outcrops. Ore grade concentrations occur on the reduced side of the geochemical interface.

The Eocene Wasatch Formation is approximately 500 to 700 feet thick in the Proposed Project area. Uranium mineralization is confined to the host sandstone of the Production Zone Aquifer (PZA). The PZA occasionally contains significant mudstone sequences with varying silt and clay content. Uranium deposits are found within a sand unit ranging from 50 to 200 feet in thickness, and at depths ranging from 170 to 450 feet below ground surface.

Uranium intercepts are variable in thickness ranging from one foot to over 40 feet thick. Thin low grade residual upper and lower limbs of the roll fronts often occur in reduced mudstones that form upper and lower boundaries of oxidized sand units.

The uranium mineralization occurs as coatings on sand grains within the host sandstone aquifer. Dissolved uranium carried in groundwater precipitated as groundwater flowed laterally (downgradient) through the redox boundary. The maximum dimensions of the ore bodies are at the leading edge of the solution-front where the alteration tongue protrudes down gradient of the original depositing groundwater flow direction (Anderson, 1969).

While in solution, uranium is readily transported and remains mobile as long as the oxidizing potential of the groundwater is not depleted. When the dissolved uranium encounters a reducing environment it is precipitated and deposited at the interface

between the oxidizing and reducing environments known as the redox front. The redox front will progress down gradient as new influxes of oxidizing groundwater redissolve and transport uranium. Although groundwater flow through porous sands can be in the range of a few feet per day, progression of the redox front is several magnitudes slower.
Alteration or oxidation of the PZA sandstone in the Reno Creek area was produced by the down-gradient movement of oxidizing, uranium bearing groundwater solutions. Uranium mineralization was precipitated by reducing agents and carbonaceous materials in the gray, reduced sands. The host sandstones, where altered, exhibit hematitic (pink, light red, brownish-red, orange-red) and limonitic (yellow, yellowish-orange, yellowish-brown, reddish-orange) alteration colors which are easily distinguished from the unaltered medium-bluish gray sands. Feldspar alteration, which gives a “bleached” appearance to the sands from the chemical alteration of feldspars into clay minerals, is also present. Limonitic alteration dominates near the “nose” of the roll fronts. The remote barren interior portions of the altered sands are usually pinkish-red in color. The uranium mineralization is contained in typical Wyoming roll-front deposits that are highly sinuous in map view. A diagram of a roll front using electric logs from the southwest portion of the Proposed Project area is included as Figure 2.6A-27.

Carbon trash is occasionally present in both the altered and reduced sands. In general, the unaltered sands have a greater percentage of organic carbon (~0.2 percent) than the altered sands (0.13 percent) in selected cores (historical data) analyzed. Carbon in unaltered sands is shiny; while it is dull and flaky in the altered sands.

2.6.2.7 History of Uranium Exploration and Development

Initially, Rocky Mountain Energy (“RME”) and subsequently Energy Fuels Nuclear, Inc. (“EFN”) and its successor International Uranium Corporation (IUC) performed exploratory drilling in the Reno Creek area from 1968 through 1994, including more than 2,000 drill holes. In the mid 1970’s RME formed a joint venture with Mono Power and Halliburton Company to develop the property for mining. The joint venture applied for and received a research and development (R&D) Pilot Plant license in 1978 from the NRC and DEQ. RME tested two injection/recovery patterns under the license.

Pilot Test Pattern 1 incorporated the use of an acid lixiviant. However, it was determined in pilot scale testing that severe permeability reduction caused a loss of injectivity and production, resulting in the test’s early termination. The cause of permeability loss was the result of high levels of calcium mobilized by the acid and precipitating as gypsum within the void spaces of the target sand, thus sealing off the formation Restoration and stabilization of the groundwater of Pattern I was acknowledged and signed off by the NRC in March of 1986 (Accession #8604040293/Docket #04008697).

Subsequently, RME conducted a second test (Pattern 2) using a carbonate lixiviant. This model consisted of six monitor wells, four injection wells, and two production wells. Pattern 2's testing objectives were: to develop a successful and efficient system for commercial development, confirm the effectiveness of the carbonate lixiviant, and to substantiate groundwater restoration according to Wyoming DEQ standards. The Pattern 2 ISR pilot test was successful, showing both good recovery and a lack of permeability lost. Test production was terminated in 1980, and restoration was started Pattern 2 pilot testing culminated in regulatory signoff in June 1983 with the approval of carbonate leaching for commercial operations at Reno Creek under Materials License Number SUA-1338 as part of NRC Docket #04008797/Accession #8309220119.

The Reno Creek Pattern 2 restoration report can be viewed in Addendum 1-A of this TR. Addendum 1-A provides more detail regarding the historical in-situ recovery operations of RME Research and Development (R&D) and restoration efforts in the Proposed Project area.

RME also conducted a large scale Hydrogeologic Integrity Test during 1982. The investigation had two objectives:

- Determine if historical exploration holes drilled prior to the enactment of drill hole abandonment regulations had naturally sealed themselves; and
- Determine if there is hydraulic communication between the PZA sandstones and the Overlying Aquifer using a series of pump tests in the PZA.

The tests of historical drill hole plugging involved re-entering 33 abandoned drill holes to check for closure. This was due to the swelling of naturally occurring mudstone layers. In addition, twenty-four monitoring/test wells were constructed, of which 18 were pump-and/or injection-tested. The Hydrogeologic Integrity Test report can be found in Addendum 2.7-E.

During re-entry of the old holes, obstructions were generally encountered at each of the mudstone horizons present from water table to the base of the PZA. An inflatable packer was set above each of these obstruction horizons as encountered and pressure-tested to see what hydrostatic pressure the obstruction could withstand. The obstructions in the mudstone units referred to herein as the Overlying Aquitard (lying above, between, and below the Felix Coal seams) consistently withheld surface gauge hydrostatic pressures of 120 to 150 psi without bleeding off. Clays in the Overlying Aquitard were recognized at the time to be of a swelling variety, contributing to the natural sealing observed by RME. All subsequent drill hole abandonment, including to the present, incorporated plugging of drill holes with bentonite or other material in accordance with WDEQ regulations. The current plug and abandonment practices can be found in Addendum 2.6-B.

RME's pump testing showed that there was no measurable communication between the PZA and the Overlying Aquifer. Full details concerning the pump testing and the hydrologic characteristics of the PZA are described in Section 2.7.2.6 of this TR.

EFN/IUC acquired the Reno Creek project from RME and submitted its applications to NRC for a commercial source materials license and to WDEQ for a Permit to Mine. Changing economic conditions caused IUC to withdraw its application in 1999, and ultimately the mining claims and fee mineral leases were dropped. Strathmore Minerals Corporation re-staked mining claims starting in 2004 and operated the project via AUC LLC. Bayswater Uranium Corporation and Pacific Road Resources Funds jointly acquired AUC LLC in 2010.

2.6.3 Drill Holes

The Reno Creek Project area was extensively explored from the late 1960s through 1991 by Union Pacific Railroad and its subsidiaries Rocky Mountain Energy (RME) and Union Pacific Resources. Energy Fuels Nuclear (later International Uranium Corporation, IUC) and Power Resources (PRI) acquired the properties and drilled an additional 300 to 400 holes in the 1990's and early 2000's time frame. Drill holes locations are shown on Figures 2.6B-1through 2.6B-3 of Addendum 2.6-B.

Additionally, American Nuclear (ANC) and Tennessee Valley Authority (TVA) explored the southwest portion of the Proposed Project area during approximately the same time period that Rocky Mountain Energy was active in the area. ANC and TVA drilled approximately 695 holes in the general area on properties adjacent to RME's holdings.

AUC's properties span the former holdings several of the former operators, and include approximately 2,665 historical drill holes and plugged wells within the Proposed Project boundary. An additional 215 holes lie within the 0.5 mile drill hole review area (2,880 holes total). Approximately 100 of the holes were cased wells that were plugged and abandoned by previous operators.

AUC LLC drilled 807 holes from 2010 through 2012, 45 of which are cased wells that will remain in place for an unknown period of years for groundwater monitoring purposes.

The 762 holes that are not cased wells were plugged and abandoned in accordance with WDEQ-LQD Chapter 8 and per the WDEQ approved "AUC LLC Reno Creek Project Drilling Notification 401 Permit Amendment 2, TFN 5 6/175" dated February 9, 2011. AUC's Plug and Abandonment Plan can be found in TR Addendum 2.6-B.

All future exploration and delineation plug holes will be capped, sealed or plugged in accordance with WDEQ-LQD Non-Coal Rules and Regulations Chapter 8 “Exploration by Drilling” as amended. The plugging procedure is outlined in Section 2 of Chapter 8 and requires an approved grout be emplaced in the drill hole from the bottom of the hole to within five feet of the ground surface. Grout means sealant material that is stable, has low permeability and possesses minimum shrinking properties such that it is an optimal sealing material for well plugging and drill hole abandonment. Following the installation of the grout, the drill hole shall be backfilled to the surface with dry non-slurry materials or capped with a concrete cap set at least two feet below the ground surface and then backfilled to the surface with native earthen materials to ensure the safety of people, livestock, wildlife, and machinery in the area.

During the past year 12 historic holes were found in the southwest portion of the project area.. The holes were surveyed and found to match coordinate locations of ANC/TVA drill holes. AUC opened the holes to total depth, ran geophysical logs and plugged with high solids bentonite grout per the procedure described above. AUC proposes to use a similar procedure for plugging other historic drill holes at the site as follows:

- A search for old holes will be conducted in the southwest portion of the site where drilling was conducted by ANC and TVA in mineralized areas. AUC currently has no electric logs for the ANC or TVA holes so AUC will gain value by opening the holes to total depth, examining the type of plugging that currently exists (natural or otherwise), and probing the holes with down hole geophysical logging equipment. Once logged, the holes will be plugged using standard procedures described above;
- In other areas of the project where AUC possesses historic electric logs, AUC will be prepared to search for, and plug old drill holes in proximity to future production units if pump testing and hydrologic results indicate that leakage through old drill holes might be a problem. Holes will be plugged as described above;
- Integrity testing by Rocky Mountain Energy (Hydrogeologic Integrity Evaluation, 1982 Addendum 2.7-E) indicated that old drill holes have been sealed by either natural swelling clays or by plug gel which was in use following regulatory requirements after approximately 1980. The integrity testing provides a strong indication that re-plugging of old drill holes may not be necessary; and
- AUC will plug any old open holes that may be encountered while working anywhere within the Proposed Project area.

In addition to uranium exploration logs, CBM drilling logs are publicly available and have been examined and correlated across the Proposed Project area. The US Bureau of Land Management completed a cluster of wells in the southwest portion of the project area, and logs and water level data from the wells has been incorporated into AUC’s database. The wells were completed in the Big George Coal horizon and four sandstone aquifers above the Big George as reported by the Wyoming State Geological Survey (Clarey, 2009).

Common practice in the Pumpkin Buttes Uranium District was to drill bore holes using 4¾ to 5¼ -inch diameter bits by conventional rotary drill rigs circulating drilling mud. The cuttings were typically collected over five-foot intervals and laid out on the ground in rows of 20 samples (100 feet) by the driller. The site geologist examined the cuttings in the field to determine lithology and geochemical alteration.

Upon completion of the drilling, the bore holes were logged, from the bottom of the hole upward, with a gamma-ray, self-potential, and resistivity probe by either a contract logging company or possibly a company-owned logging truck. In some of the drill holes, after running the log, a drift tool (film-shot) was lowered into the hole for survey at 50 or 100 feet intervals to record drilling deviations from vertical. Deviations were typically less than 1-3º, and since the dip of the beds is very gentle (½º), the mineralized intercepts recorded represent essentially true thickness.

All of AUC's bore holes were logged by an independent down-hole geophysical contractor, Century Geophysical Corporation, immediately after the holes were drilled. Lithologic and geophysical logs are stored electronically and on hard copy by AUC for future use.

Table 2.6B-1 in Addendum 2.6-B lists all drill holes known to AUC in the Proposed Project area and ½ mile buffer.

2.6.4 Soils

The Proposed Project area was evaluated by BKS Environmental Associates, Inc., Gillette, Wyoming in 2010 and 2011. A total of 6,057 acres were included in the final soil mapping of the Proposed Project area. Soils mapped by BKS Environmental Associates, Inc. are illustrated on the Soils Map in Addendum 3.3-A of the ER.

Stripping depths for the Proposed Project unit were evaluated during mapping and sampling. Soil depths within a given mapping unit will vary based on any combination of the five primary soil forming factors, i.e., climate including effective precipitation, organisms, relief or topography, parent material, and time. Subtle differences in any one of the previously mentioned factors will impact development between series and within series designation but may not be as noticeable as when topography is a major factor. The topsoil salvage depths for the Proposed Project area are based on laboratory data of the samples found within the perimeter of the area, as well as field observations and knowledge of the soils in Southern Campbell County, Wyoming. The parameters for suitable, marginal, and unsuitable topsoil material are taken from WDEQ Guideline 1, Table I-2 (August 1994 Revision).

Soils in the Proposed Project area are typical for semi-arid grasslands and shrublands in the Western United States. Parent material included colluvium, residuum, and alluvium. Most soils are classified taxonomically as Ustic Paleargids, Ustic Haplargids, Ustic Torriorthents, and Ustic Haplocambids.
Most soils have some suitable topsoil. The primary limiting chemical factor within the Proposed Project unit is Selenium. The primary limiting physical factor is texture.

Large scale soil surveys had been previously conducted, by the U.S. Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS) in 1972 and 1991. The major objective of the 2010-2011 assessment was to define the existing topsoil resource within the Proposed Project area and determine the extent, availability, and suitability of soils material for use in reclamation. Mapping and reporting for the Proposed Project area incorporated map unit information from previous NRCS soil surveys. Three sample pedons were analyzed for soil series covering greater than 160 acres, two sample pedons were analyzed for soil series covering 40 to 160 acres, and one sample pedon was analyzed for each soil series covering less than 40 acres.

Refer to these ER addenda for the following soils information:

- Addendum 3.3-A for the Soils Map;
- Addendum 3.3-B for all tables cited in Section 2.6.4;
- Addendum 3.3-C for Soil Mapping Unit Descriptions;
- Addendum 3.3-D for Sampled Soils Series Descriptions;
- Addendum 3.3-E Laboratory Results of the sampled soils;
- Addendum 3.3-F for the Soil Sample Photos; and
- Addendum 3.3-G for the Prime Farmland Designation.

2.6.4.1 Soil Survey Methodology

Construction of the project area soil map (ER Addendum 3.3-A) was completed according to techniques and procedures of the National Cooperative Soil Survey. Guideline No. 1 (Updated August, 1994) of the Wyoming Department of Environmental Quality, Land Quality Division (WDEQ-LQD) was followed during all phases of the work.

2.6.4.1.1 Field Sampling

Soil series were sampled to reflect recommended sample numbers in WDEQ Guideline 1 (August 1994 Revision) based on preliminary mapping acreage identified at that time. Series were sampled and described by coring with a mechanical auger, i.e., truck-mounted Giddings. The physical and chemical nature of each horizon within the sampled profile was described and recorded in the field. Although numerous holes were augured for soil series and map unit verification, only the field locations of profiles selected for laboratory analysis are plotted on the soils map included within this report. Sampled soil material was placed in clean, labeled, polyethylene plastic bags and kept cool to limit chemical changes. Samples were kept out of direct sunlight prior to analysis. A total of 30 sites in the Proposed Project area were sampled for analysis; all had corresponding soil profile descriptions written. Refer to Table 3.3B-1 Soils Series Sample Summary and Table 3.3B-2 Soil Sample Locations in ER Addendum 3.3-B.

2.6.4.1.2 Laboratory Analysis of Field Sampling

Samples were individually placed into lined aluminum pans to air dry. Coarse fragments were measured with a 10 mesh screen prior to grinding; the entire sample was then hand ground to pass 10 mesh. An approximate 20 ounce subsample was obtained through splitting with a series of riffle splitters and subsequently analyzed. A second subsample was maintained in storage at the laboratory. Approximately 10 percent of the samples are run for duplicate analysis. Actual laboratory analysis follows the methodology outlined in WDEQ-LQD Guideline 1 (August 1994 Revision). In general, samples were analyzed within 45 days of receipt of the samples at the laboratory. All analytical data is presented in Addendum 3.3-D, Original Laboratory Data Sheets.

Refer to Table 3.3B-3 in ER Addendum 3.3-B for soil mapping unit designations and associated acreage within the Proposed Project area.

2.6.4.2 Soil Survey Results

General topography of the area includes rolling hills and ridges, as well as drainages. The soils occurring on the Proposed Project area were generally fine textured throughout with patches of sandy textures on upland areas and fine textured soils occurring near or in drainages. The project area contains deep soils on lower toe slopes and flat areas near drainages with shallow and moderately deep soils located on upland ridges and shoulder slopes.

2.6.4.2.1 Soil Mapping Unit Interpretation

The primary purpose of the 2010-2011 fieldwork was to characterize the soils within the Proposed Project area in terms of topsoil salvage depths and related physical and chemical properties. The total number of samples per series was established in line with WDEQ Guideline 1 (August 1994 Revision) recommendations based on estimated acreage of soil series known within the Proposed Project area. Samples were collected throughout the project area to allow for maximum flexibility in planning soil disturbing activities. Refer to ER Addenda 3.3-C and 3.3-D for soil mapping unit descriptions and soil series descriptions, respectively.

2.6.4.2.2 Analytical Results

Analyzed parameters, as defined in WDEQ Guideline 1 (August 1994 Revision), are in ER Addendum 3.3-E, Soil Laboratory Analysis. Laboratory soil texture analysis did not include percent fine sands. Field observations of fine sands within individual pedestals as well as sample site topographic position were used in conjunction with laboratory analytical results to determine series designation. Soil sample photos can be viewed in Addendum 3.3-F.

2.6.4.2.3 Evaluation of Soil Suitability as a Plant Growth Medium

Approximate salvage depths of each map unit series is presented in Table 3.3B-4 and ranged from 0.2 to 3.6 feet. Within the Proposed Project area, suitability of soil as a plant growth medium is generally affected by the physical factor of high clay. The chemical limiting factors were selenium (Se) and excessive calcium carbonate ($CaCO_3$) as determined in field with 10 percent hydrochloric acid (HCl). Marginal material, according to WDEQ Guideline 1, was found in seven of the 31 profiles. No unsuitable material, according to WDEQ Guideline 1, was found in any of the profiles. Marginal or unsuitable parameter information for sampled profiles is identified in Table 3.3B-5. Soils were also field tested for $CaCO_3$ with 10 percent HCl.

2.6.4.2.4 Topsoil Volume Calculations

Based on the 2010-2011 fieldwork with associated field observations and subsequent chemical analysis, the recommended topsoil average salvage depth over the Proposed Project boundary was determined to be 1.31 feet. Refer to Table 3.3B-4 in ER Addendum 3.3-B, Approximate Soil Salvage Depths.

In accordance with WDEQ Guideline 4, suitable topsoil shall be salvaged from planned disturbances, when possible. All long-term topsoil stockpiles will be constructed and maintained in accordance with WDEQ-LQD Rules and Regulations, Chapter 2.

Within the project area, an estimated 481 acres will be controlled and/or fenced for construction or production purposes. Within the controlled/fenced areas, it is anticipated that approximately 154 acres will be disturbed and require topsoil salvage. Within the 154 acres of disturbance, approximately 202 acre/feet of salvageable topsoil is present.

2.6.4.2.5 Soil Erosion Properties and Impacts

Based on the soil mapping unit descriptions, the hazard for wind and water erosion within the Proposed Project unit varies from slight to severe. The potential for wind and water erosion is mainly a factor of surface characteristics of the soil, including texture and organic matter content. Given the fine-loamy and sandy texture of the surface horizons throughout the majority of the Proposed Project unit, the soils are more susceptible to erosion from wind than water. See Table 3.3B-6 in ER Addendum 3.3-B for a summary of wind and water erosion hazards within the Proposed Project site.

The fenced controlled areas are underlain by soils with a moderate potential for water erosion and a slight to moderate potential for wind erosion. All topsoil will be stripped, stockpiled and maintained in accordance with WDEQ-LQD rules and regulations, the surface will be graded and stormwater will be routed. These measures will help reduce the effect of construction on soil erosion.

The soils underlying the proposed production units are at a moderate to severe risk of erosion from both wind and water. Though only small and non-contiguous areas of topsoil will be stripped from the wellfields, construction may result in an increase in the erosion hazard from both wind and water due to the removal of vegetation and the physical disturbance from heavy equipment. All areas are reseeded as soon as possible to keep the duration of bare soil to a minimum. Reseeding will help mitigate the increased erosion potential from the construction disturbance.

Detailed soil impact mitigation plans can be found in ER Section 6.3 (Mitigation of Potential Geology and Soils Impacts).

2.6.4.2.6 Prime Farmland Assessment

No prime farmland was indicated within the Proposed Project area based on a reconnaissance survey by the NRCS. Refer to ER Addendum 3.3-G, Prime Farmland Designation, for the NRCS letter of negative determination.

2.6.5 Seismology

The discussion of seismology within the Proposed Project and surrounding areas includes: an analysis of historic seismicity, a deterministic analysis of nearby faults, an analysis of the maximum credible "floating earthquake," and a discussion of the existing short- and long-term probabilistic seismic hazard analysis. Intensity values and descriptions can be found in Tables 2.6C-1 and 2.6C-2 in TR Addendum 2.6-C.

2.6.5.1 Seismic Hazard Review

The seismic hazard review was based on analysis of available literature and historical seismicity for the Proposed Project area. Appendix A to 10 CFR Part 40 presents criteria relating to the operation of conventional uranium mills and the disposition of tailings or wastes. Criterion 4 of that Appendix lists site and design criteria that must be adhered to whether tailings or wastes are disposed of above or below grade. Because there will be no mill or tailings impoundment at the Proposed Project, AUC contends that Criterion 4 design criteria are not necessary for either of the previously mentioned structures to support this application. Criterion 4(e) deals with seismic hazards and states that, "The impoundment may not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand. As used in this criterion, the term 'capable fault' has the same meaning as defined in section III (g) of Appendix A of 10 CFR Part 100. The term 'maximum credible earthquake' means that earthquake which would cause the maximum vibratory ground motion based upon an evaluation of earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material." There are no capable faults (i.e., active faults) with surface expression mapped within or near the Proposed Project area, according to the USGS (2009a).

2.6.5.2 Seismicity

The following discussion of seismicity in Wyoming and the Proposed Project area is based primarily on Wyoming State Geological Survey Information Pamphlet 6 (Case and Green 2000), Seismological Characterization.

2.6.5.3 Historic Seismicity Near the Proposed Project Area

Historic seismic events for Campbell County and other counties surrounding the Proposed Project area including Natrona, Converse, and Johnson Counties are summarized below.

2.6.5.3.1 Campbell County

Five magnitude 2.5 and greater earthquakes have been recorded in Campbell County. The first earthquake recorded in the county occurred on May 11, 1967. This magnitude 4.8 earthquake was centered in southwestern Campbell County approximately seven miles west-northwest of Pine Tree Junction. The second event took place on February 18, 1972, when a magnitude 4.3 earthquake occurred approximately 18 miles east of Gillette. No damage was reported for either event.

Two earthquakes were recorded in Campbell County during the 1980s. On May 29, 1984, a magnitude 5.0, intensity V earthquake occurred approximately 24 miles west-southwest of Gillette. The earthquake was felt in Gillette, Sheridan, Buffalo, Casper, Douglas, Thermopolis, and Sundance. On October 29, 1984, a magnitude 2.5 earthquake occurred approximately 25 miles west-northwest of Gillette. No damage was reported. Most recently, on February 24, 1993, a magnitude 3.6 earthquake occurred in southeastern Campbell County approximately 10 miles east-southeast of Reno Junction. No damage was reported.

2.6.5.3.2 Natrona County

Twelve magnitude 2.5 or intensity III and greater earthquakes have been recorded in Natrona County. The first earthquake that occurred in Natrona County took place on December 10, 1873, approximately two miles south of Powder River. People in the area reported feeling the earthquake as an intensity III event. Two of the earliest recorded earthquakes in Wyoming occurred near Casper. On June 25, 1894, an estimated intensity V earthquake was reported approximately three miles southwest of Evansville. Residents on Casper Mountain reported that dishes rattled to the floor and people were thrown from their beds. Water in the Platte River changed from fairly clear to reddish, and became thick with mud due to the riverbanks slumping into the river during the earthquake (Mokler, 1923). An even larger earthquake was felt in the same area on November 14, 1897. This intensity VI-VII earthquake, one of the largest recorded in central and eastern Wyoming caused considerable damage to a few buildings. On October 25, 1922, an intensity IV-V earthquake was detected approximately six miles north northeast of Barr Nunn. The event was felt in Casper; at Salt Creek, 50-miles north of Casper; and at Bucknum, 22 miles west of Casper. No significant damage was reported at Casper.

One of the first earthquakes recorded near Midwest occurred on December 11, 1942. The intensity IV-V event occurred approximately 14 miles south of Midwest. Although no damage was reported, the event was felt in Casper, Salt Creek, and Glenrock. On August 27, 1948, another intensity IV earthquake was detected approximately 6 miles north-northeast of Bar Nunn. No damage was reported.

In the 1950's, two earthquakes caused some concern among Casper residents. On January 23, 1954, an intensity IV earthquake occurred approximately seven miles northeast of Alcova. No damage was reported. On August 19, 1959, an intensity IV earthquake was recorded north of Casper, approximately six miles north-northeast of Bar Nunn. People in Casper reported feeling this event. However, it is uncertain if this earthquake actually occurred in the Casper area, as it coincides with the Hebgen Lake, Montana, earthquakes that initiated on August 17, 1959.

Only one earthquake was reported in Natrona County in the 1960s. On January 8, 1968, a magnitude 3.8 earthquake occurred approximately 10 miles north-northwest of Alcova. No damage was reported.

An earthquake of no specific magnitude or intensity occurred approximately 13-miles southeast of Ervay on June 16, 1973. No one felt this earthquake and no damage was reported.

No other earthquakes occurred in Natrona County until March 9, 1993, when a magnitude 3.2 earthquake was recorded 17-miles west of Midwest. No damage was reported. A magnitude 3.1 earthquake also occurred in the far northwestern corner of the county on November 9, 1999. No one reported feeling this earthquake that was centered approximately 32 miles northwest of Waltman.

Most recently, on February 1, 2003, a magnitude 3.7 earthquake occurred approximately 16-miles north-northeast of Casper. Numerous Casper residents felt this event.

2.6.5.3.3 Converse County

Twelve magnitude 3.0 and greater earthquakes have been recorded in Converse County. These earthquakes are discussed below. The first earthquake recorded in Converse County occurred on April 14, 1947. The earthquake had an intensity of V, and was felt near LaPrele Creek southwest of Douglas.

On August 21, 1952, an intensity IV earthquake occurrred approximately seven miles north-northeast of Esterbrook in Converse County. It was felt by several people in the area, and was reportedly felt 40 miles to the southwest of Esterbrook. Three additional earthquakes have occurred in the same location as the August 21, 1952 event. The first, a small magnitude event with no associated magnitude or intensity, occurred on September 2, 1952. The second, an intensity III event, occurred on January 5, 1957. The most recent, an intensity IV event occurred on March 31, 1964. No damage was reported for any of the events.

On January 15, 1978, a magnitude 3.0, intensity III earthquake occurred approximately three miles northeast of Esterbrook, in Converse County. No damage was reported.

Two earthquakes occurred in Converse County in the 1980's. On November 15, 1983, a magnitude 3.0, intensity III earthquake occurred approximately 15-miles northeast of Casper in western Converse County. No damage was reported. On December 5, 1984, a non-damaging magnitude 2.9 earthquake occurred in the Laramie Range in southern Converse County.

Four earthquakes occurred in Converse County in the 1990's. On June 30, 1993, a magnitude 3.0 earthquake was located approximately 15-miles north of Douglas. No damage was reported. On July 23, 1993, a magnitude 3.7, intensity IV earthquake occurred in southern Converse County, approximately 13-miles north-northwest of Toltec in northern Albany County. This event was felt as far away as Laramie. On December 13, 1993, another earthquake occurred approximately eight-miles east of Toltec. This non-damaging event had a magnitude of 3.5. Most recently, on October 19, 1996, a magnitude 4.2 earthquake was recorded approximately 15-miles northeast of Casper in western Converse County. No damage was reported, although the event was felt by many Casper residents.

2.6.5.3.4 Johnson County

Eight magnitude 2.5 and greater earthquakes have been recorded in Johnson County. The first earthquake recorded in the county occurred on October 24, 1922. The location was originally determined to be near Buffalo, and classified the event as an intensity II earthquake. Based upon a description of the earthquake in the October 27, 1922 edition of the Sheridan Post, however, the location and assigned intensity may be in error. The Sheridan Post reported that at Cat Creek, eight-miles east of Sheridan, houses were shaken and dishes were rattled. In addition, the October 26, 1922 edition of the Sheridan Post reports that only a slight earthquake shock was felt in Sheridan. Based upon this information, it seems reasonable to locate the earthquake eight miles east of Sheridan, and to assign an intensity of IV-V to the event.

On September 6, 1943, an intensity IV earthquake was felt in the Sheridan area, although the epicenter was determined to be approximately three- to four-miles south-southwest of Buffalo. Beds and chairs were reported "to sway" in the Sheridan area.

Two earthquakes were recorded in Johnson County in the 1960s. A magnitude 4.7 earthquake occurred on June 3, 1965. This event was centered approximately 12-miles south of Kaycee. On April 12, 1966, an earthquake of no specified magnitude or intensity was detected approximately 25-miles southwest of Buffalo. No one reported feeling these events.

On September 2, 1976, a magnitude 4.8, intensity IV-V earthquake was felt in Kaycee. The event was located approximately 33-miles northeast of Kaycee. No damage was reported.

A magnitude 5.1, intensity V earthquake occurred on September 7, 1984, approximately 33-miles east-southeast of Buffalo. The earthquake was felt throughout northeastern Wyoming, including Buffalo, Casper, Kaycee, Linch, and Midwest, and in parts of southeastern Montana. No significant damage was reported.

Two earthquakes were detected in Johnson County in 1992. The first occurred on February 22, 1992. This magnitude 2.9 event was recorded approximately 18-miles east of Buffalo. As expected with such a small earthquake, no damage was reported. Most recently, a magnitude 3.6, intensity IV earthquake occurred on August 30, 1992. The earthquake was centered near Mayoworth, approximately 22-miles west-northwest of Kaycee. It was felt in Barnum and Kaycee, but no damage was reported.

2.6.5.4 Probablistic Seismic Hazard Analysis

The USGS publishes probabilistic acceleration maps for 500-, 1,000- and 2,500-year time frames. The maps show what accelerations may be met or exceeded in those time frames by expressing the probability that the accelerations will be met or exceeded in a shorter time frame. For example, a 10 percent probability that acceleration may be met or exceeded in 50 years is roughly equivalent to a 100 percent probability of exceedance in 500 years.

The USGS has recently generated new probabilistic acceleration maps for Wyoming (Case, 2000). Copies of the 500-year (10 percent probability of exceedance in 50 years), 1,000-year (five percent probability of exceedance in 50 years), and 2,500-year (two percent probability of exceedance in 50 years) maps can be found in Addendum 2.6-C. Until recently, the 500-year map was often used for planning purposes for average structures, and was the basis of the most current Uniform Building Code (UBC). Recently, the UBC has been replaced by the International Building Code (IBC), which is based upon probabilistic analyses. Campbell County adopted the IBC in 2005. The new IBC, however, uses a 2,500-year map as the basis for building design. The maps reflect current perceptions on seismicity in Wyoming. In many areas of Wyoming, ground accelerations shown on the USGS maps can be increased due to local soil conditions. For example, if fairly soft, saturated sediments are present at the surface, and seismic waves are passed through them, surface ground accelerations will usually be greater than would be experienced if only bedrock was present. In this case, the ground accelerations shown on the USGS maps would underestimate the local hazard, as they are based upon accelerations that would be expected if firm soil or rock were present at the surface.

Intensity values and descriptions can be found in Table 2.6C-1 and 2.6C-2 in Addendum 2.6-C.

Based upon the 500-year map (10 percent probability of exceedance in 50 years) (Figure 2.6C-1), the estimated peak horizontal acceleration in Campbell County ranges from approximately three percent/g in the northeastern corner of the county to greater than 6 percent/g in the southwestern corner of the county. These accelerations are roughly comparable to intensity IV earthquakes (1.4 percent/g – 3.9 percent/g) to intensity V earthquakes (3.9 percent/g – 9.2 percent/g). These accelerations are comparable to the accelerations to be expected in Seismic Zones 0 and 1 of the Uniform Building Code. Intensity IV earthquakes cause little damage. Intensity V earthquakes can result in cracked plaster and broken dishes. Gillette would be subjected to an acceleration of approximately five percent/g or intensity V.

Based upon the 1,000-year map (five percent probability of exceedance in 50 years) (Figure 2.6C-2), the estimated peak horizontal acceleration in Campbell County ranges from four percent/g in the northeastern corner of the county to greater than 10 percent/g in the southwestern quarter of the county. These accelerations are roughly comparable to intensity V earthquakes (3.9 percent/g – 9.2 percent/g) to intensity VI earthquakes (9.2 percent/g – 18 percent/g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Depending upon local ground conditions, Gillette would be subjected to an acceleration of approximately nine percent/g or greater and intensity V or VI.

Based upon the 2,500-year map (two percent probability of exceedance in 50 years) (Figure 2.6C-3), the estimated peak horizontal acceleration in Campbell County ranges from eight percent/g in the northeastern corner of the county to greater than 20 percent/g in the southwestern corner of the county. These accelerations are roughly comparable to intensity V earthquakes (3.9 percent/g – 9.2 percent/g), intensity VI earthquakes (9.2 percent/g – 18 percent/g), and intensity VII earthquakes (18 percent/g – 34 percent/g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Intensity VII earthquakes can result in slight to moderate damage in well-built ordinary structures, and considerable damage in poorly built or badly designed structures, such as unreinforced masonry. Chimneys may be broken. Gillette would be subjected to an acceleration of approximately 18 percent/g or intensity VI to VII.

As the historic record is limited, it is nearly impossible to determine when a 2,500-year event last occurred in the county. Because of the uncertainty involved, and based upon the fact that the new International Building Code utilizes 2,500-year events for building design, it is suggested that the 2,500-year probabilistic maps be used for Campbell County analyses. This conservative approach is in the interest of public safety.

Current earthquake probability maps that are used in the newest building codes (2,500-year maps) suggest a scenario that would result in moderate damage to buildings and their contents, with damage increasing from the northeast to the southwest. More specifically, the probability-based worst-case scenario could result in damage at points throughout Campbell County and surrounding areas as mentioned in Tables 2.6C-1 and 2.6C-2.

2.6.5.5 Deterministic Analysis of Regional Active Faults with a Surficial Expression

There are no known exposed active faults with a surficial expression in Campbell County. As a result, no fault-specific analysis can be generated for Campbell County. Figure 2.6C-4 shows historic earthquakes and faults in relation to the Proposed Project.

2.6.5.6 Floating or Random Earthquake Sources

Many federal regulations require an analysis of the earthquake potential in areas where active faults are not exposed, and where earthquakes are tied to buried faults with no surface expression. Regions with a uniform potential for the occurrence of such earthquakes are called tectonic provinces. Within a tectonic province, earthquakes associated with buried faults are assumed to occur randomly, and as a result can theoretically occur anywhere within that area of uniform earthquake potential. In reality, that random distribution may not be the case, as all earthquakes are associated with specific faults. If all buried faults have not been identified, however, the distribution has to be considered random. “Floating earthquakes” are earthquakes that are considered to occur randomly in a tectonic province.

It is difficult to accurately define tectonic provinces when there is a limited historic earthquake record. When there are no nearby seismic stations that can detect small-magnitude earthquakes, which occur more frequently than larger events, the problem is compounded. Under these conditions, it is common to delineate larger, rather than smaller, tectonic provinces.

The U.S. Geological Survey identified tectonic provinces in a report titled “Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States” (Algermissen and others, 1982). In that report, Campbell County was classified as being in a tectonic province with a “floating earthquake” maximum magnitude of 6.1. Geomatrix (1988b) suggested using a more extensive regional tectonic province, called the “Wyoming Foreland Structural Province”, which is approximately defined by the Idaho-Wyoming Thrust Belt on the west, 104° West longitude on the east, 40° North latitude on the south, and 45° North latitude on the north. Geomatrix (1988b) estimated that the largest "floating" earthquake in the "Wyoming Foreland Structural Province" would have a magnitude in the 6.0 – 6.5 range, with an average value of magnitude 6.25.

Federal or state regulations usually specify if a "floating earthquake" or tectonic province analysis is required for a facility. Usually, those regulations also specify at what distance a floating earthquake is to be placed from a facility. For example, for uranium mill tailings sites, the Nuclear Regulatory Commission requires that a floating earthquake be placed 15 kilometers from the site. That earthquake is then used to determine what horizontal accelerations may occur at the site. A magnitude 6.25 "floating" earthquake, placed 15 kilometers from any structure in Campbell County, would generate horizontal accelerations of approximately 15 percent/g at the site. Critical facilities, such as dams, usually require a more detailed probabilistic analysis of random earthquakes. Based upon probabilistic analyses of random earthquakes in an area distant from exposed active faults (Geomatrix, 1988b), however, placing a magnitude 6.25 earthquake at 15 kilometers from a site will provide a fairly reasonable estimate of design ground accelerations in the northeastern and eastern parts of Campbell County, but will be inadequate in the southerstern part of the county.

2.6.6 References

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2.7 Water Resources

The information in this section provides relevant data concerning surface and ground water resource characteristics of the proposed Reno Creek Project (Proposed Project) and the surrounding region for NRC licensed ISR operations in accordance with NUREG-1748 and NUREG-1569 (Section 2.7). Comparable and/or more discussion of water resources can also be found in:

- TR Addenda 2.7-A (Surface Water Tables and Figures) and 2.7-B (Groundwater Tables and Figures);
- TR Addenda 2.7-C (Groundwater Modeling Report), 2.7-D (Pump Test Report), and 2.7-E (Hydrogeologic Integrity Test Report);
- Section 5.7.8 of this TR (Groundwater/Surface Water Monitoring Program);
- Section 6 of this TR (Groundwater/Surface Water Restoration);
- Sections 7.1.6, 7.2.6, 7.4.2, and 7.5 of this TR (Environmental Effects);
- Section 3.4 of the ER (Water Resources);
- Section 4.4 of the ER (Environmental Impacts);
- Section 5.6 of the ER (Cumulative Impacts);
- Section 6.4 of the ER (Mitigation Measures); and
- Section 7.1.5 of the ER (Water Resource Monitoring).

As noted in NUREG-1910 (GEIS Sec. 3.3.4.1), the surface water characteristics of the PRB include ephemeral and intermittent water bodies, and stock ponds. None of the surface water bodies in the Proposed Project area are designated ‘fisheries’ due to the ephemeral nature of those surface waters. Section 3.3.4.3 of the GEIS (NUREG-1910) also details the groundwater characteristics of the regional systems. Included in the groundwater discussions which follow is reference to the Eocene-age aquifer sandstone formation. As noted in the GEIS (Section 3.3.4.3.3), this formation is a geologically confined aquifer and is the host production zone for uranium mineralization at the Proposed Project, More specific discussions of these surface water (Section 2.7.1) and groundwater (Section 2.7.2) characteristics follow below.

To evaluate water characteristics for the Proposed Project, two graphical methods were employed to prepare geochemical fingerprints of these different waters. Piper diagrams were prepared to provide an overall view of the surface waters and ground waters geochemistry. Stiff diagrams were also prepared to show individual water samples on a cross section for the ground waters.

The diagrams were prepared using the EnviroInsite program (HydroAnalysis, 2012). The points plotted on the Piper diagram represent average compositions if more than one set of results was available for the calculations.

2.7.1 Surface Water Hydrology

2.7.1.1 Regional Description

The Proposed Project is located within the eastern extent of the structurally bounded PRB on the divide between the Belle Fourche River and Cheyenne River Drainage Basins. The Proposed Project straddles a sub-regional surface water divide for those two drainages. The Belle Fourche and the Cheyenne Rivers are both tributaries to the Missouri River. The most significant drainage in the Proposed Project area is the Belle Fourche River drainage which extends NNE through the western portion of the project area and drains the area by way of ephemeral, tributary channels. The main channel of the Belle Fourche River is ephemeral in the Proposed Project area. In the Proposed Project area, the Belle Fourche River is part of the Belle Fourche-All Night Creek sub basin, Hydrologic Unit Code (HUC) 10120201. The eastern half of the Proposed Project area contains the upper portions of two sub drainage basins: Spring Creek-Antelope Creek and Upper Porcupine Creek-Antelope Creek, HUC 10120101. These drainages are shown in Figure 2.7A-1 in TR Addendum 2.7-A. The Spring Creek and Upper Porcupine Creek are tributaries to the Cheyenne River. The Belle Fourche joins the Cheyenne River in South Dakota which subsequently flows to the Missouri River. All drainages within the Proposed Project area are ephemeral in nature. However, CBM wells contribute co-produced water to these drainages.

According to data from the Western Regional Climate Center (WRCC) for Wright, Wyoming (located approximately 7.5 miles northeast of the Proposed Project), the mean annual precipitation from 1991 through 2010 was 13.52 inches. The average annual precipitation for Glenrock, Wyoming (located approximately 54 miles south of the Proposed Project) from 1948 to 2007 ranged from 11.96 to 15.19 inches (WRCC). Recorded data from the onsite meteorological station and long-term climate data is provided in TR Section 2.5.

Elevations near the Proposed Project area and its surrounding two mile buffer area are approximately 5,200 feet. Climate in the area is semi-arid, typical of a high desert area, with low annual precipitation and high evaporation rates. Hydrographs for streams in the upper portions of the Antelope and Upper Belle Fourche watersheds peak during snowmelt in the late spring/early summer. Summer thunderstorms also influence smaller hydrograph peaks.

2.7.1.2 Surface Water Monitoring Stations

There are no automated data collection sites within the Proposed Project or the two mile buffer area (Figure 2.7A-2 in TR Addendum 2.7-A), as all streams within the Proposed

Project area and two mile buffer are classified as 3B streams (NUREG 1910, GEIS Section 3.3.4). A class 3B stream is defined as an intermittent or ephemeral stream incapable of supporting fish populations or drinking water supplies. The nearest automated real time stream gage is the Belle Fourche River below Rattlesnake Creek (06425720) which is approximately 23.7 miles northeast of the Proposed Project near Gillette, Wyoming. The Cheyenne River near Dull Center (06365900) is a real time station located 32.7 miles southeast of the Proposed Project area. There is historical data from several sites around the Proposed Project area; however there are no gage sites within the project area itself.

There is historical data from five pertinent sites:

1) Caballo Creek Gaging Station (USGS 06425800);
2) Belle Fourche Gaging Station (USGS 06425780);
3) Coal Creek near Piney Gaging Station (USGS 06425750);
4) Porcupine Creek Gaging Station (USGS 06364300); and
5) Antelope Creek Gaging Station (USGS 06364700).

Caballo Creek, Belle Fourche River above Dry Creek, and Coal Creek gages are located within the Upper Belle Fourche River Basin while Porcupine Creek and Antelope Creek gages are located within the Antelope Creek Basin.

<u>Caballo Creek</u>

Caballo Creek near Gillette, Wyoming gaging station is located 32.4 miles northeast of the Proposed Project area and recorded the flow for 260 square miles. Caballo Creek is located northeast of the Proposed Project boundary, and is located 0.9 miles to the northwest of the confluence with the Belle Fourche River as shown on Figure 2.7A-2 in TR Addendum 2.7-A. The data is limited to August 31, 1977 through September 30, 1983. The historical daily mean discharge for this gage is an average flow of 2.45 ft^3/second (cfs) and a median flow of 0.62 cfs. The maximum daily mean flow was 1,500 cfs on May 19, 1978. The historical annual peak flows ranged from 129 cfs to 2,170 cfs; the maximum peak flow was recorded on May 19, 1978 (USGS, 2008).

<u>Belle Fourche River</u>

Belle Fourche River above Dry Creek gaging station is located 27.5 miles northeast of the Proposed Project boundary and potentially could receive runoff from the west portion of the Proposed Project area. Data was collected at this gage from October 1, 1975 to September 30, 1983 and historical daily mean discharge for this gage is an average daily flow of 4.33 cfs and median flow of 1.39 cfs. The maximum average daily flow from this historical period was 2,150 cfs on May 18, 1978. The historical annual peak discharge measurements from February 10, 1976 through February 14, 1983 produced an average peak flow of 259 cfs and the median peak flow was 677 cfs. The historical annual peak flows ranged from 21 cfs to 5,630 cfs; the maximum peak flow was recorded on May 18, 1978 (USGS, 2008).

Coal Creek

Creek near Piney gaging station is located 24.4 miles northeast of the Proposed Project boundary and is and is located 2.1 miles south of the confluence of the Belle Fourche River. Data was collected at this gage from October 1, 1980 to September 30, 1983. The historical daily mean discharge for this gage is an average daily flow of 1.09 cfs and median flow of 0.17 cfs. The maximum average daily flow from this historical period was 251 cfs on May 27, 1981. The historical annual peak discharge measurements for August 22, 1983 produced an average peak flow of 6.6 cfs and the median peak flow was 6.6 cfs.

Porcupine Creek

Porcupine Creek near Teckla gaging station is located 15.0 miles southeast of the Proposed Project boundary and is located 8.5 miles to the northwest of the confluence with Antelope Creek. Data was collected at this gage from October 1, 1975 to September 30, 1983. The historical daily mean discharge for this gage is an average daily flow of 0.29 cfs and median flow of 0.22 cfs. The maximum average daily flow from this historical period was 7.9 cfs on September 11, 2005. The historical annual peak discharge measurements from June 17, 2003 through September 11, 2005 produced an average peak flow of 6.9 cfs and the median peak flow was 4.6 cfs. The historical annual peak flows ranged from 3.1 cfs to 13 cfs; the maximum peak flow was recorded on September 11, 2005 (USGS, 2008).

Antelope Creek

Antelope Creek near Teckla, Wyoming gaging station is located 22.8 miles southeast of the Proposed Project boundary and is located at the confluence of Porcupine Creek and Antelope Creek southeast of the Proposed Project. Data was collected at this gage from September 8, 1977 to September 30, 1981. The historical daily mean discharge for this gage is an average daily flow of 9.37 cfs and median flow of 3.54 cfs. The maximum average daily flow from this historical period was 2,560 cfs on May 18, 1978. The historical annual peak discharge measurements from August 17, 1979 through August 5, 1981 produced an average peak flow of 836 cfs and the median peak flow was 677 cfs. The historical annual peak flows ranged from 70 cfs to 1,760 cfs; the maximum peak flow was recorded on August 5, 1981 (USGS, 2008).

2.7.1.3 Drainage Basin Description

All drainages in the Proposed Project area are ephemeral in nature. The predominant source of surface water is from summer thunderstorms and spring snowmelt. According to NUREG-1910 (GEIS Section 3.3.4.1), flow occurs in channels for a very short duration and is directly related to these surface runoff as a result of the local precipitation events. The watershed hydrology within the Proposed Project area includes man-made reservoirs or stock ponds and WYPDES discharge sites from CBM de-watering activities. There are two watersheds within the Proposed Project boundary; the Upper Belle Fourche Basin and the Antelope Creek Basin.

Upper Belle Fourche Basin

The Upper Belle Fourche watershed has been broken down into three sub-basins, but only the Mud Spring Creek sub-watershed is present within the Proposed Project. Mud Spring Creek is the south-eastern most sub-watershed included in the Upper Belle Fourche watershed. Mud Springs Creek is the southern most drainage present in the Mud Springs Creek sub-watershed, however it is the northern most drainage within the Proposed Project. It drains 72.1 square miles and has a channel length of 13.1 miles. The maximum elevation is 5,400 feet and the minimum elevation is 5,000 feet at the confluence with the Belle Fourche River.

Mud Spring Creek has been divided into seven drainages, and only Mud Spring Creek 7 is present within the Proposed Project; it drains the majority of the Proposed Project to the west. Mud Spring Creek 7 is composed of 18,536 acres, of which 5,037 acres are within the project boundary.

Antelope Creek Basin

The Antelope Creek watershed is in the Proposed Project on the eastern most area and drains approximately 5,042 acres of which 1,019 acres are within the Proposed Project boundary.

Lower Antelope Creek is the northern most sub-watershed within the Antelope Watershed. Lower Antelope Creek has a channel length of approximately 32.6 miles and a total drainage area of 341.9 square miles. The maximum elevation within this drainage is approximately 5,200 feet and the minimum elevation is approximately 4,750 feet. Lower Antelope Creek has been further divided into five drainages, and only Lower Antelope Creek 4 is present within the Proposed Project area; it drains the eastern most portion of the Proposed Project area.

2.7.1.4 Surface Runoff Estimates

The total project is approximately 6,057 acres and is comprised of 29 watershed basins, either in whole or partial. For design purposes however, 37 watersheds were analyzed which includes areas upstream from the Proposed Project boundary. These were included to determine the most realistic runoff from the site. Portions of the design basis were determined by the NRC Regulatory Guide 3.8 and WDEQ Guideline 8- Hydrology Coal and Non-coal.

Peak runoff rates and volumes were calculated for the 2-yr, 10-yr, 25-yr, 50-yr, and 100-yr return intervals as suggested by WDEQ Guideline. Duration time periods include 1-hr, 6-hr, and 24-hr (Table 2.7A-1 in TR Addendum 2.7-A). Precipitation depths for the five return intervals were determined for the 6-hr and 24-hr duration periods using the NOAA Atlas 2 isopluvials maps. The 1-hr duration was only used for the 2-yr and 100-yr intervals because NOAA Atlas 2 only provides precipitation equations for these years. A nomogram was available for other return intervals, but it was decided not to estimate precipitation values for the 10-yr, 25-yr and 50yr periods. This is also consistent with the reporting within the Strata Ross ISR application.

Locations reported for flow and volumes include one location prior to entering the project site (Junction 5), four intermediate locations within the project boundary (Junctions 9, 10, 11, and 14), and six outflow locations from the site (Sinks 1, 2, 3, 5, 6, and 7). Figure 2.7A-3 in TR Addendum 2.7-A provides these locations for reference.

2.7.1.4.1 Methods

The HEC-HMS software program, developed by the U.S. Army Corp of Engineers, was used to perform the watershed and channel routing based on user specified parameters. This program utilizes the Soil Conservation Service (SCS) Unit Hydrograph Runoff Method which is an appropriate method for the large acreage, as well as, overland and river routing. This method is also applicable for areas with heterogeneous sub-basins. The Rational Method was discarded since it is more applicable to small areas and urbanized watersheds. HEC-HMS is also listed as an approved program in both NUREG-1623 and WDEQ guidelines. HEC-HMS simulates precipitation/runoff for dendritic streams and provides a large diversity of routing methods to choose from within the program. The program includes three aspects: the watershed model, meteorological data, and hydrologic simulation. Each is briefly described below. For additional information regarding the HEC-HMS program, please refer to the Hydrologic Modeling System HEC-HMS User’s Manual and Technical Reference Manual. A website link is provided for these documents in the reference section.

The model used for the Proposed Project area consists of four elements: basins, reaches, junctions, and sinks. Basins are defined as an element which usually has no inflow and only one outflow. Runoff calculations for basins use the Soil Conservation Service (SCS) Unit Hydrograph for Type II storms over a 24-hr duration (Table 2.7A-2 in TR Addendum 2.7-A). Calculations and variables required for input include: SCS Curve Number (CN), initial abstraction, overland flow time to concentration, channel flow time to concentration, and lag time. Refer to Tables 2.7A-3 and 2.7A-4 in Addendum 2.7-A.

The CN value was determined based upon vegetative cover and soil data provided by BKS Environmental Associates, Inc. BKS identified the vegetation to be semi-arid grassland and shrublands with some minimal grazing. Vegetation cover was estimated to be approximately 75 to 80 percent. Soils in the area indicate loamy sands to sandy clay loams. The area was determined to be homogenous for soil and vegetative conditions. The hydrologic soil group ranges between B and C. From this information a value of 72 was chosen from Table 2-2d of TR-55, for all watershed basins (NRCS 1986).

Reaches are defined as an element with one or more inflow and only one outflow. The Muskingum-Cunge method was used for translation of the water within the channel. Muskingum-Cunge provides river routing based on a combination of conservation of mass and a diffusion representation of conservation of momentum.

Junctions are defined as an element with one or more inflows and only one outflow. No calculations or variables are required for this element.

Sinks are defined as an element with one or more inflows but no outflow and are used to represent an outlet of the model. No calculations or variables are required for this element.

<u>Precipitation Data</u>

Precipitation depths for the design storms were obtained using both isopluvial maps and regression equations from NOAA Atlas 2, Volume II-Wyoming. Table 2.7A-5 in TR Addendum 2.7-A summarizes precipitation depths used for the design storms.

<u>Design Assumptions</u>

General Watershed Assumptions

Land cover and soil type are considered homogeneous through the watershed, thus only one CN value. Similarly, the sub-basins are considered to be homogeneous in terrain.
No large bodies of water were identified in the license application. Multiple stock reservoirs are present within the design area, but for design purposes the sub-basins were assumed to have no reservoirs which served as storm water detention elements within the

model; all stock reservoirs were assumed to be at full capacity prior to the start of the design storm simulation.

Manning's roughness coefficient is used within the velocity method to determine Tc for channel flow. Surface characteristics affect the runoff by slowing the flow. To determine the coefficient for channels within the model a base value was determined with corrections added to the base value to determine a final coefficient. The base value for the channels was assumed to be a fairly uniform section with a sandy bottom, akin to fine gravel. The correction for channel irregularity, defined as differences in the channel surface, was determined to be minor irregularity. The correction for cross-section variance is estimated to be an occasional variance; since the watershed has small slopes across the areas it is assumed that there are no drastic changes in cross-section shape. The correction for obstructions was assumed to be minor because it is assumed that there are no large boulders or downed trees to obstruct channel flow. The correction for vegetation was assumed to be low vegetation. Although the streams are ephemeral, the dry conditions of the area suggest the channel bottoms may have stands of grasses, but no large trees and few bushy growths. The correction for meandering, or sinuosity, was based off of a visual review of the channel paths and observed oxbows from the DEM file. The summation results in a Manning's roughness coefficent value of 0.045.

Post-Development Runoff Hydrologic Consequences

The majority of the land within the project boundary will remain in its natural state. Small locations throughout the boundary will have well housing, but the footprints of these buildings are anticipated to be insignificant when compared to the size of the sub-basin. One CPP will be constructed with a larger footprint size and this is expected to be built within sub-basin 24 (B24). The area of disturbance was provided by the client and anticipated to be eight acres. The entire area was assumed to be impervious which amounted to 3.6 percent of the sub-basin, which is 221.52 acres. This was entered into the sub-basin characteristics in the HEC-HMS model. The model was then run for the 100-yr, 24-hr storm. Pre- and post-development runoff volumes were compared at three locations downstream from the developed watershed. A summary of pre- and post-discharge and volumes are provided in Table 2.7A-6 in TR Addendum 2.7-A. The greatest disparity between pre- and post- analysis is at Sink 2 where flow discharges from the project site. The conclusion is that post-development in the project boundary has minimal effect on rates or volumes leaving the project boundary.

2.7.1.4.2 <u>Results</u>

The peak discharge (cfs) and volume (acre-foot) for the application are provided in Table 2.7A-7 in Addendum 2.7-A. HEC-HMS output of the drainage basin designation and watershed characteristics can be found in Tables 2.7A-8 and 2.7A-9 in Addendum 2.7-A.

2.7.1.5 Flood Inundation Study

Flood frequency is analyzed to determine the potential impact of flooding from nearby and adjacent rivers and creeks to the Proposed Project. Specifically, this determination looks at the potential for inundation of the well fields, the CPP, and the project's associated infrastructure. Inundation may create the potential of surface water being contaminated from process fluids.

As previously described, the Proposed Project area straddles a ridge that forms the divide between the Upper Belle Fourche and the southern basin is the Antelope Creek drainage basins. The Belle Fourche River originates approximately five miles to the west of the project such that runoff is primarily ephemeral (e.g. due to snow melt or rainfall events) at the project location. Drainage from the small watersheds collected by the Belle Fourche River are considered either shallow concentrated flow or very small ephemeral channels (i.e. gullies).

Project drainage basins and infrastructure are illustrated in Figure 2.7A-4 in TR Addendum 2.7-A. The CPP is proposed to be located on a hill within Basin B24 such that there is limited to no chance of flood inundation. Facility planning will ensure that surface runoff is directed away from the plant and associated infrastructure (e.g. backup storage pond). Approximate well field locations are depicted on the figure as elliptical Production Units. A number of the Production Units are expected to span small ephemeral channels with limited watershed area (< 1 square mile) and no floodplain. Runoff conditions for these small drainage areas do not warrant flood analysis.

The Belle Fourche River is the primary drainage feature, running from SW to NE through the Project area. Flood analysis is provided to quantify flooding depths and delineate the associated flooding limits as they relate to the Proposed Project infrastructure.

2.7.1.5.1 Methods

The Army Corps of Engineers' HEC-RAS software was used to model the hydraulic capacity of the Belle Fourche River. HEC-RAS was selected based on its universal acceptance in flood modeling applications. For additional information regarding the HEC-RAS program, please refer to the HEC-RAS River Analysis System User's Manual (ACOE, 2010) and Hydraulic Reference Manual (ACOE, 2010).

The 100-year design flow rate of 2,742 cfs at Sink 2 is used based on the hydrologic calculations presented in Hydrology Section 2.7.1.3. This assumption is considered conservative as the flow rate is calculated at the location where the Belle Fourche River leaves the project boundary, which is downstream of the reach being analyzed.

Manning's n was selected as 0.035 based on the *Hydraulic Reference Manual Table 3-1* for a "high grass" floodplain. The longitudinal slope and cross-sectional areas were determined from USGS DEM topology which was generated based on 10 meter grids. This grid spacing does not allow for detailed channel characterization (e.g. channel width and depth). However, the DEM data does provide for accurate representation of large scale topographic features, specifically the Belle Fourche River floodplain and its associated longitudinal slope. As such, the DEM data is adequate in determining the capacity of the floodplain and providing 100-year water surface elevation with a level of accuracy sufficient for the intended design purposes (see Results section for detailed discussion).

Forty-nine (49) cross-sections are used to model approximately five miles of river. Additional cross-sections are interpolated between each of the 49 cross-sections to facilitate "model stability" associated with balancing energy and momentum equations in the water surface calculation.

2.7.1.5.2 Results

HEC-RAS results are presented in TR Addendum 2.7-A. Flow depths generally range from three feet deep in the wide floodplain sections and five feet deep in the narrow floodplain sections. Table 2.7A-10 provides detailed tabulation of results for each of the Belle Fourche floodplain cross-sections, including interpolated cross-sections. Figure 2.7A-5 provides cross-section views for each of the 49 cross-sections (non-interpolated) to illustrate section geometry and flow depth.

The calculated flood plain was delineated relative to the DEM surface to determine the limits of 100-year flood inundation area. The 25-year and 50-year flood inundation studies were not performed due to the ephemeral nature of the stream. The delineated floodplain is presented in the Flood Study figure located in Figure 2.7A-4.

The intended design purpose of the flood inundation study is to quantify potential flood inundation areas to identify if mitigation measures need to be incorporated into the design of proposed infrastructure as described in NUREG 1569. The below design items are provided as a direct response to NUREG 1569 criteria:

- ***"Assessment of the potential for erosion or flooding that may require special design features or mitigation measures to be implemented*** **"**- The CPP is proposed to be located on a hill such that there is limited to no chance of flood inundation. Portions of multiple Production Units are located inside the calculated floodplain. The flood analysis presented provides for 100-year floodplain delineation for which to base future planning and mitigation decisions. If necessary, mitigation measures may include fitting well-heads with water tight seals, and any infrastructure that cannot be made flood resistant should be located beyond the flood plain (e.g. header houses); and

- ***"An assessment of typical seasonal ranges and averages and the historical extremes for levels of surface-water bodies"*** - The flood analysis provided herein represents a projected "historical extreme". Refer to Technical Report section 2.7.1.4 for "an assessment of typical seasonal ranges and averages".

Surface water runoff from precipitation (rain and snowmelt) at the Proposed Project facilities will flow from the facilities area to natural drainages. Precipitation runoff is not expected to significantly exceed natural condition, as the increase in runoff from some areas (e.g., building roofs) will be balanced by the decrease in runoff from other areas (flat, gravel parking lots, etc.). Figure 2.7A-4 in TR Addendum 2.7-A shows the location of the CPP and backup storage pond in relation to the location of the nearest natural drainages and shows that none of the runoff will flow directly into either artificial or natural streams or wetlands. The potential for contamination of surface-water runoff is also minimal because the CPP and backup storage pond are self-contained and all exterior chemical and fuel tanks will have a means of secondary containment. These secondary containment methods include cement curbs, berms and CPP walls. The CPP and backup storage pond area will be graded and sloped to direct precipitation runoff away from building foundations in all directions to a storm water conveyance system. Potential run-on will also be intercepted and directed around the CPP and backup storage pond area. The stormwater conveyance system will be designed to pass the 50-year flood. Due to the location of the CPP, backup storage pond, and wellfield areas related to the surrounding topography, impacts from flooding are expected to be minimal.

Downstream gage data, presented below, is not sufficient to provide an adequate Log-Pearson Type III flood frequency analysis. According to USGS guideline 17B for determining flood flow frequency, a minimum of 10 years of gage data is needed to "warrant statistical analysis".

2.7.1.6 Surface Water Use

A query of all surface water uses was submitted using the Wyoming SEO Water Rights Database. The results are provided in Table 2.7A-11 in TR Addendum 2.7-A and shown in Figure 2.7A-6. The use of surface water is devoted to stock wells for the cattle which are rotated among various pastures. See Table 2.7A-12 in Addendum 2.7-A for a list of the Wyoming surface water classes and use designations.

2.7.1.7 Surface Water Features

As discussed earlier in TR Section 2.2, no land is used for crops or other irrigated vegetation within the Proposed Project boundary. The few water bodies that do exist across the Proposed Project area are scattered and small (Figure 2.7A-7). As stated above, all streams within the Proposed Project area are characterized as ephemeral.

Several small dams and ponds exist within and downstream of the project that provide a level of control and storage of surface water. During normal runoff conditions, these ponds will contain all upgradient runoff. Many of these water features may contain higher levels of water after spring runoff or after large precipitation events but are generally reduced to small, isolated pools or are completely dry by the end of the summer. Relatively small amounts of surface discharge from CBM operations may also maintain small pools of water in these ponds during dry summer months.

Properly sized culverts will be used for secondary access roads crossing across small drainages. Efforts will be made to construct secondary access roads to avoid crossing major drainages. However, if crossing a major drainage is required, then adequately sized culverts will be utilized and embankments will be protected from erosion using adequate best management practices (rip rap, rock, etc.) in accordance with WDEQ-LQD Rules and Regulations, Chapter 3. Culverts across significant drainages will be designed to pass the 25-year peak runoff event using head available at the entrance. The minimum culvert size of 18 inches will be utilized to divert drainage from roads or for crossing small drains or swales. Crossings for major drainages will be constructed at or near right angles.

2.7.1.8 Surface Water Quantity

Due to all streams being ephemeral and drainages only supporting water during storm events, snow melt, and CBM contributions, water quantity was not measured as part of baseline studies. Discussion of gaging stations within the vicinity of the Proposed Project is provided below.

2.7.1.9 Proposed Reno Creek Project Surface Water Quality

Surface water monitoring included the collection of water samples from 21 locations within the Proposed Project as part of baseline studies. The data are provided in Table 2.7A-13 in TR Addendum 2.7-A.
Water quality data were available from one USGS stream gage (06364700) located on Antelope Creek near Teckla, Wyoming (22.8 miles from the Proposed Project) from October 3, 1977 through September 7, 2005. This gage is located 22.8 miles southeast of

the Proposed Project boundary. Water quality data analyses revealed a mean temperature of 10.4 degrees Celsius (°C) and a range from 0 to 30°C. Mean dissolved oxygen was 7.8 milligrams/Liter (mg/L) and ranged from 2.8 to 11.7 mg/L. Total nitrogen averaged 0.55 mg/L and ranged from 0.21 to 1.8 mg/L. Mean ammonia as nitrogen concentrations were 0.04 mg/L and ranged from 0 to 0.13 mg/L. Nitrite plus nitrate as nitrogen averaged 0.04 mg/L, with a range from 0 to 0.29 mg/L. Average phosphate was 0.03 mg/L and average dissolved selenium was 0.56 mg/L (USGS 2007).

Within the Proposed Project area, surface water samples were collected from 21 sampling locations at upstream and downstream locations from proposed production areas. Sampling began in early fall of 2010 and continued through January of 2012 (Table 2.7A-14 in TR Addendum 2.7-A). All locations are existing stock ponds or areas in drainages where ponding occurs. Locations of these sample sites are shown on Figure 2.7A-8 in Addendum 2.7-A.

In general, surface water contained in the ponds at the sampling locations will exhibit typical saline characteristics of coal-bed methane surface discharge (higher values for conductivity, TDS, and bicarbonate) during summer and fall months. Sampling data shows that surface water quality changes during spring months when dilution occurs from snow melt or heavy precipitation events. A list of the surface water monitoring constituents can be seen in Table 2.7A-15 in Addendum 2.7-A.

2.7.1.9.1 Water Quality Sampling

The sampling data from the 21 sites is provided in Table 2.7A-13 in TR Addendum 2.7-A. The locations are provided in both Figure 2.7A-8 and Table 2.7A-14 of Addendum 2.7-A.

Sampling began at some sites in the fall of 2010. Of the 21 sampling sites, 16 were dry at least six months during the four quarterly sampling efforts. This is due to the seasonal weather variations and ephemeral nature of these stock ponds, CBM outfalls and areas of drainage where ponding can occur. To date at least four quarterly sampling efforts for baseline studies have been conducted for all 21 sites.

2.7.1.9.2 Surface Water Quality Analysis

Per NUREG 1569 and WDEQ LQD Chapter 11, the objectives of the overall surface water characterization required to permit ISR operations included:

- Evaluating the occurrence of surface water with respect to location and seasonal variability in flow and water quality;
- Determining the dominant water types; and

- Assessing potential impacts from non-ISR operations (e.g., CBM production).

Geochemical assessment of water quality is a key component to the overall characterization. A summary of surface water quality results is presented in Table 2.7A-13 in TR Addendum 2.7-A.

Figure 2.7A-9 is a plan view that shows selected surface water locations throughout the Proposed Project area. As described in Section 2.7.1.1, the Proposed Project lies along the drainage divide between the Belle Fourche and Cheyenne River systems. Because of the project's location and the ephemeral nature of the alluvial channels in the Proposed Project, there is rarely any significant surface water, and the locations sampled are all artificial impoundments. The impoundments accumulate limited rainfall and snowmelt, plus CBM discharge water and water from stock wells.

Geochemical characterization of the site surface waters was conducted to:

- Characterize the surface water compositions throughout the Proposed Project area. This provides necessary background information and will facilitate subsequent comparisons with other waters during operations;
- Characterize the water composition of CBM related discharges to the surface environment in and near the Proposed Project area; and
- Compare the composition of AUC's anticipated lixiviant to CBM discharge water and surface waters from the previously characterized sources.

AUC collected the samples from the surface water sample locations on a quarterly basis. However, because many locations were dry during the sampling events the number of samples from each location has varied. For example, six sampling locations only had a single sample available due to the dry conditions. Eight of the sampling locations had just two samples taken while one other (SW 19) had three samples. Four quarterly samples were taken from four sample locations including SW 11, SW 16, SW 18, and SW 22. Two sampling locations, SW5 and SW 6, remained dry during all four quarterly sampling efforts.

The Piper diagram uses major ions only (Na+K, Ca, Mg, Cl^-, HCO_3^- + CO_3^{-2}, and SO_4^{-2}) and normalizes concentrations. The purpose of normalization is to show the relative concentrations of the analytes. The normalization also allows for the plotting of these compositions on triangular diagrams. Dilute waters and concentrated waters of similar cation/anion relative abundances will plot at the same locations in the diagram. In preparing a Piper diagram, the relative abundances of cations (as equivalent percentages) are plotted as single points in the left triangle; and the anions are similarly plotted in the right triangle. Because the concentrations are ultimately plotted as percentages of cations or anions on the two triangles, the use of equivalents or milliequivalents will produce the same final result.

The Piper diagram (Figure 2.7A-10 in TR Addendum 2.7-A) results for each sample were prepared using EnviroInsite (HydroAnalysis, 2012). The major ion compositions from the individual sample locations were averaged before plotting the results.

There are 63 Wyoming Pollutant Discharge Elimination System (WYPDES) permits within two miles of the Proposed Project area (Figure 2.7A-7). Nine of these permits are located within the Proposed Project area. All nine are operated by Williams Production RMT Company. These nine permits and other nearby WYPDES permits can be found in Table 2.7A-16 in TR Addendum 2.7-A. All permits are associated with either oil and gas production or CBM production. The associated outfall discharge points are also shown in Figure 2.7A-7 in Addendum 2.7-A. WYPDES effluent limitations and discharge concentrations for the facilities are shown in Table 2.7A-17 in Addendum 2.7-A.

Several of the surface water collection locations are close to, and often related to, coal bed methane (CBM) permitted discharge points, which are included on Figure 2.7A-9. The CBM discharge permit water quality data were in a different format than the quarterly samples collected specifically for this project and the last available reported discharge data were used for each parameter. These data were obtained from the publically available Wyoming Department of Environmental Quality CBM permitting program (WYPDES Coalbed Methane Permits). CBM discharge results are based on daily maximum values throughout the six month reporting period. Therefore, there is only a single composition for each location. Because of the nature of the reporting requirements the different parameters may actually represent different water samples or in some cases even different reporting periods. In many of the locations some parameters were not included in the summary data; sulfate is a good example of a parameter that was not consistently reported. Ten CBM discharge samples were originally selected for consideration. However, only three locations had sufficient data to allow for plotting of Piper Diagrams. Because of the nature of discharge permit water quality data, the compositions of the CBM water samples represent a composite of reports from several time periods. The three CBM waters did not report total dissolved solids concentrations (TDS); consequently those values were calculated based upon the major ion concentrations used for the samples. The calculated TDS values were approximately 500 mg/L for WY0048542_003, 650 mg/L for WY0048542_010 and 850 mg/L for WY0042340_010.

Figure 2.7A-10 in Addendum 2.7-A demonstrates that there are significant differences among the different surface water locations. For example, SW15 is extremely dilute and appears to have a composition similar to rainwater. Other dilute waters include SW7, SW9 and SW14.

On the other end of the spectrum, the CBM discharge waters are characterized by relatively high total dissolved solid (TDS) concentrations and are dominantly sodium bicarbonate waters. In spite of the issues related to the CBM discharge database, the three points plot in a small area on the Piper diagram, indicating that the CBM discharge waters are all similar to each other, all being derived from the same, continuous coal formation (Big George Coal of the Fort Union Formation). On Figure 2.7A-10 in Addendum 2.7-A, the three CBM water samples (WY0048542-003 and 010 and WY0042340-010) all plot in the bottom of the quadrilateral.

Several surface water samples compare well with the CBM discharges, indicating that their chemistry is strongly influenced by the CBM discharges. For example, SW11 appears to have the largest TDS concentration among the samples associated with the CBM discharges. When TDS values from SW11 are compared to calculated TDS values for CBM discharges it appears that CBM waters have somewhat lower TDS values. It is possible that TDS concentrations in these surface water locations reflect some evaporative concentration in the discharge pond. CBM waters are also characterized by very low sulfate concentrations. Sulfur in coal beds is present as sulfide, the reduced form, so the oxidized form of sulfate is not expected to be present. SW3 and SW11 show compositions similar to CBM discharge, SW22 also displays the sodium bicarbonate dominated composition but it is more dilute than the SW3 and SW11 samples. The sample from SW9 appears to be CBM type water that has undergone some dilution and possible interaction with minerals in the soil. The other potential end member composition is the SW19 sample which is dominantly calcium magnesium sulfate water. It has a cation composition in units of milliequivalents of 40 percent Ca, 40 percent Mg and 20 percent Na+K. The dominant anion is sulfate at over 90 percent of the anionic milliequivalents. The remaining three SW samples are difficult to classify, and the dilute nature of the SW7 and SW14 samples suggest mainly a precipitation (rain or snow) dominated source. The SW7 data was based upon two samples collected in March and June of 2011; the June sample shows a significant increase in alkalinity. The single sample from SW14 was collected in March; it is considered to be dilute and sulfate dominant. Sample SW18 has a high TDS and high sodium concentrations. It is dominantly a CBM discharge water, but the relative sulfate concentration appears to have increased.

Graphical analysis of surface and CBM discharge waters in the vicinity of the Proposed Project area demonstrates that CBM waters have distinctive geochemical fingerprints related to their high sodium and bicarbonate concentrations. These compositions are apparent in some of the surface water sampling locations, but in other locations different compositions have been identified including dilute waters that appear to be derived from rain or snow melt. The use of these graphical methods provides a simple and effective means to characterize and classify the different surface waters present in the area. Water quality fingerprints also enable the rapid and verifiable determination of any potential contamination due to leaks or spills, and to the remediation of any such contamination.

2.7.2 Groundwater

This section describes regional and local hydrogeology, including hydrostratigraphy, groundwater flow patterns and hydraulic gradients, and aquifer parameters including site-specific pump testing results found in TR Addendum 2.7-D. In particular, information in this section provides hydrologic verification of the geologic confinement discussed in Section 2.6 of this TR. Further, data demonstrates that ISR operations can be conducted in the PZA without significant potential impacts to groundwater resources, both during production and restoration. Information on groundwater quality and local groundwater usage in the vicinity of the Proposed Project area is also presented in this section. Discussion is based on regional published literature, site-specific hydrologic data, as well as the more detailed geologic information presented in Section 2.6 of this TR.

2.7.2.1 __Regional Hydrogeology__

The Proposed Project is located in the south-central portion of the PRB, approximately 43 miles south of Gillette and 7.5 miles southwest of Wright, and approximately 30 miles east of the north-flowing Powder River. The basin is an asymmetrical, doubly plunging, down-warped synclinal structural feature defined by more steeply dipping western limb and shallower dipping eastern limb, with a north to northwesterly trending basin axis. The Proposed Project site is located approximately 15 to 20 miles east of the basin axis, where sediments have accumulated to depths of approximately 20,000 feet. The PRB lies within the Northern Great Plains Aquifer system that contains overlapping aquifers in the Lower Tertiary, Upper and Lower Cretaceous, and Upper and Lower Paleozoic strata (USGS, 1996). Figure 2.7B-1 illustrates the generalized column of hydrostratigraphic units of this aquifer system near the site. Table 2.7B-41 in Addendum 2.7-B summarizes the general transmissivity and general water yields within the Northern Great Plains Aquifer Systems. The following discussion focuses on the relatively shallower hydrostratigraphic units of the Upper Cretaceous aquifer system that include the Fox Hills and Lance Formation, and the Lower Tertiary aquifer system that includes the Fort Union and Wasatch Formations. Hydrostratigraphic units deeper than the Fox Hills that lie below the regional confining unit of the Lewis Shale (also referred to as the Pierre Shale) near the Proposed Project are generally too deep to economically develop for domestic water supplies or uranium recovery. These hydrostratigraphic units typically have elevated dissolved solids concentrations and therefore are not included in this discussion of regional hydrogeology with respect to the Proposed Project.

During Early Cretaceous time, thick sequences of shale were deposited and interfingered with marine sandstones. In the Late Cretaceous time, sea levels fell and shorelines regressed, depositing the Fox Hills Sandstone and continental shales, sandstones, and coals of the Lance Formation in a tropical, near sea-level environment. Basin deposition continued through the Early Tertiary time with Fort Union and Wasatch Formation deposition. During this time, the shape of the basin was established and the bounding margins had uplifted above the basin floor. Later in the Tertiary, there was regional uplift and more arid conditions as basin filling continued with deposition of sandstones, siltstones, and larger clast conglomerates near the mountains. Erosion of Precambrian metamorphic and igneous rocks to the southwest provided a source of sediments. Subsequent erosion has removed most all of these later Tertiary sediments, except in erosional remnants like the Pumpkin Buttes in the central portion of the PRB (Lowry et al., 1986).

The Eocene-age Wasatch Formation, which is the host for uranium mineralization at the Proposed Project, crops out at the surface at the Proposed Project site and in much of the central portion of the basin. The Oligocene-age White River Formation, which is observed cropping out along the basin margins to the south and in erosional remnants in areas such as the Pumpkin Buttes to the northwest, has been eroded from most locations in the central part of the basin. Quaternary-age alluvium deposits also are observed in some stream channel valleys, which provide a small groundwater supply source within the basin; but in general, groundwater in this unit are not extensively developed due to better water quality and higher yields are available in the underlying Wasatch to Fox Hills sequence (Rankl and Lowry, 1990). Lying unconformably below the Wasatch is the Paleocene-age Fort Union, which is included in the Lower Tertiary aquifer system in the PRB. The Lance Formation lies conformably below the Fort Union, and unconformably above the Fox Hills Sandstone, and these two units comprise the Upper Cretaceous aquifer system in the area.

Lower Tertiary aquifers of the Fort Union and Wasatch consist of semi-consolidated to consolidated sandstone beds that are interbedded with shale, mudstone, siltstone, lignite, and coal. The permeability of the lower Tertiary aquifers is variable and directly related to the thickness and continuity of sandstone beds that compose the aquifers. Some of the thick coal beds may yield groundwater, particularly if the coal is fractured or has been burned, forming typically higher permeability clinker zones.

Upper Cretaceous aquifers are widespread in the subsurface but generally contain groundwater of potable quality only where they crop out or short distances from the upland recharge areas at the basin margins. In the southern portion of the basin, these upper Cretaceous aquifers include the Lance Formation and underlying Fox Hills Sandstone. Upper Cretaceous aquifers are composed of consolidated sandstone interbedded with shale, siltstone, and occasional lenticular beds of coal. Much of the available information related to the hydrology of the Lance and Fox Hills considers these two formations as a single hydrostratigraphic unit, as these formations are connected hydraulically on a regional scale. The Lewis Shale underlies the Fox Hills Sandstone and is a thick sequence of shale with minor interbedded sandstones that is a major regional confining unit (USGS, 1996). Available groundwater in the Lewis Shale is generally more highly mineralized and exhibits relatively poorer groundwater quality with depth.

Groundwater in the lower Tertiary aquifer generally moves northward and northeastward in the Wyoming portion of the PRB from the upland areas of recharge along the basin margins, to areas of groundwater flow that changes locally where there is discharge to larger surface streams. Groundwater in the Upper Cretaceous aquifers generally moves in a similar trend, to the north and northeast in Wyoming from areas of recharge (USGS, 1996).

Hydrostratigraphic units of interest in the southern PRB are shown on the stratigraphic column in Figure 2.7B-1. Discussion of regional characteristics of these units is provided below, in order of deepest to shallowest. It is noted that some of the available information on regional hydrologic properties and groundwater quality (presented in Section 2.7.2.10) considers the combined formations of the Upper Cretaceous sequence (Fox Hills and Lance) and of the Lower Tertiary sequence (Fort Union and Wasatch), or applies to the entire relatively shallow sequence of Fox Hills to the Wasatch, and are noted in these discussions:

- Lewis Shale (Late Cretaceous);
- Fox Hills Sandstone (Late Cretaceous);
- Lance Formation (Late Cretaceous);
- Fort Union Formation (Paleocene); and
- Wasatch Formation (Eocene).

Lewis Shale

The Lewis Shale (also regionally known as the Pierre Shale) is a late Cretaceous sequence of marine shales with interfingered sandstones that underlies the Fox Hills Sandstone and is approximately 900 feet thick near the Proposed Project (Fox & Higley, 1987). This unit is noted as a regional confining aquitard between the overlying Wasatch to Fox Hills sequence and underlying lower Cretaceous units. Hodson (1973) describes the unit as primarily shale containing sandy shale zones and lenticular fine-grained sandstones which thicken from approximately 200 feet in the northwest of the basin to almost 500 feet in the southwest. Most of the formation does not yield usable volumes of groundwater, but some sandy zones may yield as much as 10 gpm.

Fox Hills Sandstone

The Fox Hills Sandstone is the basal aquifer unit in the Lower Tertiary/Upper Cretaceous aquifer system. The Fox Hills is noted as fine- to medium-grained sandstone beds deposited during receding marine seas in barrier island, neritic, and marine environments. Sandstone is generally thin to massively bedded, weakly cemented, friable, lenticular, and interbedded with carbonaceous shale and siltstone. In the southwestern basin, the basal Fox Hills is a massive cliff-forming sandstone, while the upper part has increased shale interbeds. In the southern basin, the Fox Hills ranges from 400 to 500 feet in Niobrara County to 700 feet in Natrona County. The Fox Hills thins to the north with increasing shale content, and is noted to be 150 to 200 feet thick in Crook County. The Fox Hills is not mapped as a separate stratigraphic unit in the northwestern basin, but equivalent strata are included in the basal Lance Formation (Feathers, 1981).

Hodson (1973) notes that well yields as high as 200 gpm are found in the sandstone beds of the Fox Hills in the eastern part of the basin, and postulates maximum yields less than 100 gpm in the western basin. Several wells utilized for water flooding in Rozet (east of Gillette) produce approximately 200 gpm. The Fox Hills is also utilized for groundwater supply in the Hilight Field (general location is T45N, R71W) located in southeastern Campbell County (Feathers, 1981). Both of these industrial groundwater supply locations utilize wells completed across the Lance and Fox Hills sequence.

Feathers (1981) discusses properties of the Fox Hills in conjunction with the overlying Lance Formation, as these units are hydrologically connected throughout much of the basin. The Lance and Fox Hills interval is extensively developed in outcrop areas for relatively small yield domestic and stock wells, as well as industrial applications at Hilight and Rozet. Municipal water supply is provided from this sequence for the cities of Gillette, Glenrock, and Moorcroft (Feathers, 1981, and Hutson, et. al., 2004 for Table 2.7B-42). Edgerton and Midwest have historically utilized this interval for municipal water supply, but presently receive piped water from Casper due to higher dissolved solids in the Fox Hills.

Most hydrologic data are from shallow wells located near outcrops, which are primarily lower yield stock wells where single yield and drawdown results are generally reported. There is good potential for relatively low-yielding wells (i.e., 20 gpm) where upper Cretaceous sediments are near the surface. Larger volume industrial wells that perforate the entire Lance/Fox Hills interval can have yields up to 380 gpm (Feathers, 1981). Specific capacity values from these wells reported by Feathers (1981) average about 0.6 gpm per foot of drawdown (gpm/ft) and range from 0.1 to 2 gpm/ft. The high yield wells located in southeastern Campbell County average 323 gpm and have an average specific capacity of 0.3 gpm/ft. The range of reported transmissivities for the Lance/Fox Hills generally ranges from 100 to 2,000 gpd/ft (13 to 270 ft^2/d) (Feathers, 1981), and Lowry (1972) reports a minimum transmissivity of about 250 gpd/ft (33 ft^2/d) for the entire aquifer system in southeastern Campbell County.

Regional potentiometric data from Hotchkiss and Levings (1985) are presented in a potentiometric contour map (Figure 2.7B-2) for the Lance and Fox Hills aquifer system. The potentiometric maps indicates a general northward regional groundwater flow direction, with a groundwater divide in southeastern Campbell County and subsequent groundwater flow towards the southeast, which is also noted by Feathers (1981). These aquifers principally discharge by subsurface, stratigraphically controlled underflow into

Montana, as well as local discharge into topographically lower major drainages. Vertical leakage from the overlying Wasatch and Fort Union sequence is proposed by Lowry (1973), due to the heads observed in overlying strata that are several hundred feet higher in elevation. Core data for other ISR sites in Wyoming from confining mudstones suggest vertical hydraulic conductivities in the range of approximately 10^{-8} cm/s, which suggests vertical leakage potential is minimal. There is also limited localized recharge observed in some of the eastern outcrop areas.

Lance Formation

During the last seaward regression in the Late Cretaceous, continental deposits of the Lance Formation were deposited as interbedded, light yellow-grey, fine- to medium-grained, crossbedded, and lenticular sandstones, with grey carbonaceous shale, and siltstone, as well as thin coals. The contact with the underlying Fox Hills Sandstone is generally placed at the prominent change from massive sandstones of the Fox Hills, to the overlying shale and siltstone of the Lance Formation. Formation thickness varies from approximately 3,000 feet in Natrona County and the south-central basin, to 1,600 to 2,500 feet in Niobrara County, to less than 1,000 feet in Crook County in the northeastern basin (Feathers, 1981). On the west side of the basin, thickness decreases to the north, with an estimated 2,400 feet in southern Johnson County, to approximately 2,000 feet near Buffalo decreasing to about 600 feet into southern Montana (Hodson, 1973). In the Upper Cretaceous aquifer system, the Lance Formation represents the uppermost aquifer in the region that also includes the Fox Hills. The upper hydrologic boundary of the Lance/Fox Hills generally corresponds to the zone of lower permeabilities present in the finer-grained Lebo Shale Member of the Fort Union Formation (Feathers, 1981).

Hodson (1973) notes that well yields from the Lance Formation are generally less than 20 gpm, but yields of several hundred gpm may be possible from the entire section. Most wells drilled to the Lance Formation are located near outcrops and are utilized for domestic and stock usage. In much of the PRB, the Lance Formation is considered hydrologically connected to the Fox Hills Sandstone and characterized together as the Upper Cretaceous aquifer system. Excluding limited data from shallow outcrop wells that target the Lance Formation, much of the available hydrologic data are from the Lance/Fox Hills sequence, previously summarized in the previous section on the Fox Hills Sandstone.

Fort Union Formation

The Paleocene Fort Union Formation is composed of continental deposits associated with Laramie uplift and basin filling. Thicknesses noted by Hodson (1973) are approximately 2,300 feet in the eastern basin, 2,900 feet in the southwest, and almost 3,500 feet in the northwest portion of the basin. The Fort Union is a heterogeneous unit of sandstones, interbedded shale, carbonaceous shale and coal. The formation thickens to the southwest and is conformably underlain by the Lance Formation and unconformably overlain by the Eocene-age Wasatch Formation. Outcrops of the Fort Union Formation encircle most of the basin and beds dip basinward. This formation is the major source of coal in the PRB and also hosts significant volumes of exploitable CBM reserves. Uranium deposits are hosted in coarse grained sandstone facies of the Fort Union Formation in the southern portion of the basin

In much of the basin, the Fort Union is divided into three members: the basal Tullock Member, the Lebo Shale, and the upper Tongue River Member. The Tullock Member lithology is similar to the Lance Formation deposited in a continental fluvial environment of fine-grained sandstone, sandy siltstone, shale, and coal. Tullock sands do not differ greatly from the Lance Formation sandstones except they are yellowish, thinner, and more lenticular, and contain no conglomeratic layers. Mapped thickness of the Tullock Member in the eastern basin is about 1,000 feet, as noted by Robinson et al. (1964), but thins to 500 feet at the Montana border. Brown (1993) indicates a maximum thickness of 370 feet in the northern basin and almost 1,500 feet in the southern basin. The Lebo Shale is approximately 250 feet in thickness and is comprised of finer-grained sequence of dark grey claystone and shale, with brown carbonaceous shale beds, and thin lenticular fine-grained sandstones, and with a noted absence of coal. The increased shale content of the Lebo Shale, which is apparent from geophysical logs, is noted as a partial hydrologic barrier in much of the basin (Feathers, 1981).

The upper Tongue River Member is about 800 feet thick in the northeastern part of the basin and thickens westward. It is composed of lighter-colored interbedded fine-grained sandstone, siltstone, sandy shale, and relatively significant coal deposits. There are seven to nine major minable coals in the Tongue River Member, but the Wyodak seam is the only one actively mined in the state. The Wyodak coal ranges from approximately 25 to 175 feet in thickness, and averages approximately 70 feet thick in the eastern basin. This unit outcrops along the eastern basin margin where extensive surface mining of this seam occurs. It is alternatively referred to as the Wyodak-Anderson and Anderson-Canyon coals. West of Gillette, the Wyodak separates into the Anderson and Canyon coal beds, and north of Gillette the Wyodak separates into the Upper and Lower Wyodak seams (Lowry, 1986). Feathers (1981) notes that the Tongue River and Lebo Members are not differentiated in eastern basin outcrops south of T47N, and in the southern portion of the basin Sharp and Gibbons (1964) note two members of the Fort Union, characterized as lower fine-grained clayey sandstone with minor siltstone and coal and an upper member of clayey siltstone containing ironstone lenses and coals. Localized lenticular conglomeratic beds and coarser-grained sandstones are also noted in the middle Fort Union in the western portion of the basin (Whitcomb et al, 1966).

Most of the wells completed in the Fort Union for stock and domestic groundwater supply are generally completed across short intervals of single formations or completed into sand bodies at depths less than 500 feet, where yields of 20 gpm can be obtained with suitable water quality. The Fort Union also serves as a municipal water supply for the city of Wright, as well as supplementing the municipal supply for the city of Gillette. Hodson (1973) indicates maximum yields of up to 150 gpm in the Fort Union and indicates specific capacity values of 0.3 to 0.9 gpm/ft for several locations in the eastern half of the basin. Dissolved solids range from approximately 200 to more than 3,000 mg/L, but commonly range between 500 and 1,500 mg/L, and water type is primarily sodium bicarbonate and to lesser degree, sodium sulfate.

Feathers (1981) indicates that yields of 250 gpm can be found in wells of the Wasatch and Fort Union that perforate thick saturated sandstones, locally coarse sands, in zones of high secondary fracture permeability near basin margins or near clinker zones, and in areas with surface water hydrologic connections. Specific capacities are highly variable, ranging from 0.1 to 3 gpm/ft, with higher values of over one gpm/ft located in the western basin that are associated with coarser grained and conglomeratic aquifers. Extremely high values of 2,250 gpm/ft have been observed in the clinker aquifers near the basin margins. Permeability is lithology dependent and highly variable, as clinker is generally the most permeable, followed by coals, and then sandstones. Clinker permeabilities are several hundred gpd/ft^2 or higher (approximately 25 to 40 ft/d), coals can range between one to 100 gpd/ft^2 (approximately 0.1 to 13 ft/d); and while Fort Union sandstone data are sparse, it is likely in the range of 0.1 to 10 gpd/ft^2 (0.01 to 1.3 ft/d), similar to that observed in the Wasatch sands. Fort Union sands near Gillette have reported transmissivities of several thousand gpd/ft.

Much of the available data to characterize the Fort Union and Wasatch sequences are from shallow stock and municipal wells, and hydraulic head data from these cannot adequately define the potentiometric surface regionally, as there are often large head differences that are present with varying depths. Hotchkiss and Levings (1985) presents approximate potentiometric surface data for the three members of the Fort Union Formation: the Tullock, Lebo Shale, and Tongue River Members, which are presented in Figures 2.7B-3, 2.7B-4, and 2.7B-5 in Addendum 2.7-B, respectively. As can be seen in these potentiometric contour maps, the head in the Fort Union generally decreases with depth in these three formation members. General groundwater flow direction on a regional scale is to the north in the basal Tullock and overlying Lebo Shale. Potentiometric contours in the Tongue River are more highly variable and reflect localized discharge to the major alluvial valleys, such as the Powder, Little Powder, Tongue, and Belle Fourche Rivers.

Recharge to the Fort Union is primarily through infiltration at outcrops and through the highly permeable clinker zones at the basin margins, as well downward leakage from the overlying Wasatch, where present. Shallow groundwater circulation is generally topographically controlled under water table conditions and deeper strata exhibit stratigraphically controlled horizontal flow. Hydrogeologic conditions in the Fort Union can vary from water table conditions to fully confined between and within individual sandstone units. Regionally, groundwater discharge is to the north into Montana, but topographic valleys may also represent important discharge points.

Wasatch Formation

The Eocene-age Wasatch Formation, which contains the uranium mineralized sandstones at the Proposed Project, is composed of alternating beds of valley and channel-fill fine- to coarse-grained lenticular, sandstones, and interbedded shale and coal, with relatively coarser-grained deposits toward the southern part of the basin that are adjacent to the uplifted basin margins. The Wasatch is approximately 1,600 feet thick in southern Campbell County, although subsequent basin erosion since the middle Tertiary has removed approximately half of the original deposited material (Feathers, 1981). In the northwest basin near the Bighorn Mountains, the Wasatch is divided into two conglomeratic members, the Kingsbury and overlying Montcrief Members, which consist of as much as 2,000 feet of siltstone, sandstone, cobbles, and boulders which grade into finer-grained facies of the Wasatch several miles east of the mountains (Hodson, 1973). The contact with the overlying Fort Union Formation is unconformable and is noted by Anna (1996) at the top of the Roland-Anderson coal bed, which is a coal seam 50 to 100 feet thick that is areally extensive in the southern PRB. The Wasatch generally dips to the northwest at approximately one to two degrees and the sands that contain uranium mineralization are generally coarse, cross-bedded, arkosic sands deposited in a high-energy fluvial environment, with individual channel sand deposits possessing a general orientation to the north.

Hodson (1973) reports groundwater well yields of 10 to 50 gpm in the northern basin, generally increasing to the south with yields of 500 gpm or more possible in the southern portion of the basin. A well near Gillette in T50N R72W has a specific capacity of 4 gpm/ft, and wells in T44N R72W reported specific capacities ranging from 5 to 14 gpm/ft. Dissolved solids concentrations can range from 200 to greater than 8,000 mg/L in the Wasatch, but commonly are in the range of 500 to 1,500 mg/L. In general, the dominant Wasatch water types are sodium sulfate and sodium bicarbonate (Hodson, 1973).

As with the Fort Union Formation, much of the available hydrologic data are from shallow stock and domestic wells, and as hydraulic heads often vary with depth and between sandstones, hydraulic head data from these wells does not adequately define the potentiometric surface in the Wasatch.

Wasatch recharge is primarily through infiltration at outcrops and to a lesser degree surface infiltration, as the Wasatch is the dominant surficial geologic unit in the central portions of the PRB (Feathers, 1981). As with the Fort Union, shallow groundwater circulation is primarily topographically controlled, and at greater depths flow is horizontal and defined by stratigraphy. Groundwater discharge for the Wasatch primarily occurs in topographic alluvial valleys.

The Wasatch also contains many important coal bearing seams, which attain thicknesses of eight feet in the Tongue River Member. These coals are exploited targets for CBM in portions of the basin, but no Wasatch seams are currently being surface mined in the PRB (Lowry 1986). Stone and Snoeberger (1977) conducted hydrogeologic investigations on the Felix Coal seam approximately 15 miles south of Gillette and observed anisotropic permeabilities associated with cleat orientation in the Felix, with reported maximum and minimum permeabilities of 6.6 and 3.7 gpd/ft^2 (0.9 and 0.5 ft/d), respectively, at their study site. Additional site specific information on the hydrogeology of the Felix Coal at the Proposed Project is provided in the following section on site hydrogeology.

According to records from the Wyoming Oil and Gas Conservation Commission, indicates usage of the Felix for CBM (either as an individual seam or multiple permitted seams) occurs in two general areas. The eastern area is in the general vicinity of T47N-T53N and R73W-R75W (generally east of Gillette), and the western area is in the vicinity of T50N-T55N and R80W-R83W (generally near Buffalo and to the north). The closest permitted usage of the Felix seam for CBM to the Proposed Project is approximately 20 to 25 miles to the north. Outcrops of the Felix can be observed in roadcuts along Cosner Road, near the upper northwest corner of Section 35, T43N, R73W (see Figure 2.7B-6).

2.7.2.2 Site Hydrogeology

The Proposed Project area has a long history of hydrogeologic investigations beginning with hydrologic testing conducted by Union Pacific and Rocky Mountain Energy (RME) between 1978 and 1982. These data include geologic characterization and hydrologic pump testing (RME, 1982). Additional investigations by RME included a hydrogeologic integrity study to reveal the natural sealing of mudstones in exploratory boreholes, which is discussed in detail in Section 2.7.2.3. RME conducted extensive exploratory drilling and prepared a Class III UIC Permit to Mine Application and a Source Material License Application for the Reno Creek Project in 1993 and 1994. Energy Fuels Nuclear, Inc. (EFNI) also conducted additional hydrologic investigations in 1993 and 1994 that included multiple pump tests. These test data are of significant value in terms of hydrologic characterization at Reno Creek.

AUC LLC has been collecting lithologic, water level, water quality, and pump test data as part of its ongoing evaluations of hydrologic conditions at the Proposed Project during 2010 and 2011. AUC has conducted the most comprehensive hydrologic testing to date that includes multi-well and single-well pump testing at four well clusters in the Proposed Project area. These well clusters include the PZM1, PZM3, PZM4, and PZM5 well clusters. There are an additional two well clusters that have been installed at the PZM6 and PZM7 locations in the western and southwestern portion of the Proposed Project area for the purposes of baseline groundwater monitoring. Figure 2.7B-6 shows the locations of the current monitoring wells utilized in the site hydrologic evaluation. Table 2.7B-1 provides completion data for the current monitoring wells installed by AUC.

AUC's approach to hydrologic characterization is consistent with the requirements of NUREG 1569 and the objectives of these investigations were as follows:

- Evaluate the aquifer characteristics of transmissivity (T) and storativity (S) within the production zone aquifer (PZA) within the Proposed Project area;
- Demonstrate isolation of the PZA with respect to overlying aquifer and underlying aquifer (if present) within the Proposed Project area;
- Evaluate the presence or absence of hydrologic boundaries within the PZA within the Proposed Project area; and
- Evaluate the transmissivities of overlying aquifer and underlying aquifer (if present) within the Proposed Project area.

Section 2.7.2.3 describes the hydrostratigraphic units of interest at the Proposed Project area, which include a shallow water table unit (where present, includes SM prefix wells), the overlying aquifer (OM wells), the PZA, and the underlying unit (UM wells). The confining zones with respect to the PZA include the overlying aquitard (OA) and the underlying aquitard (UA). It is noted that based on the hydrologic characteristics of the shallow water table unit and underlying unit, these units do not meet the requirements of an aquifer, which is discussed in the following section.

Section 2.7.2.4 summarizes the Hydrogeologic Integrity Study conducted by RME to assess the potential for cross-aquifer flow through exploratory boreholes that were not properly abandoned. The results of this study indicate that the mudstones present above the PZA have naturally sealed and thus do not represent potential conduits to flow. Recent pump tests also support this conclusion.

Section 2.7.2.5 describes the potentiometric surfaces, groundwater flow direction and hydraulic gradients. A summary of aquifer testing activities is presented in Section 2.7.2.6 that includes a review of the historical pump testing and summarizes the pump testing conducted at the four well clusters PZM1, PZM3, PZM4, and PZM5.

The level of characterization of the hydrogeology within the Proposed Project area is substantial. The results of testing conducted by AUC in 2010 and 2011 indicate that the PZA is in hydraulic communication at well cluster testing locations and has been adequately characterized for the purposes of this license application. Additional hydrologic testing was also conducted on the water table (SM unit, where present), the overlying aquifer, and the underlying unit at the four well cluster locations. The results of testing indicate that overlying and underlying confinement with respect to the PZA is sufficient and no hydraulic responses were observed in the overlying aquifer or the underlying unit during any testing activities.

2.7.2.3 Hydrostratigraphic Units

A detailed discussion of stratigraphy within the proposed Reno Creek ISR Project is presented in Section 2.6. The following summary provides the stratigraphic nomenclature and acronyms with descending depth utilized for the Proposed Project for the units of interest present in the Wasatch Formation.

- SM Unit: Shallow water table unit present in some locations. Based on geologic and hydrologic data, this unit does not meet the requirements of an aquifer in the Proposed Project area;
- Overlying Aquifer (OM wells): Overlying aquifer relative to the production zone. This aquifer also represents the uppermost aquifer observed in the Proposed Project area;
- OA Aquitard: Confining unit providing isolation between the production zone and overlying aquifer;
- PZA Aquifer: Production zone aquifer;
- UA Aquitard: Confining unit providing isolation between the production zone and underlying unit; and
- Underlying Unit (UM wells): Discontinuous underlying sand unit relative to the production zone. Based on geologic and hydrologic data, this unit does not meet the requirements of an aquifer in the Proposed Project area.

Typical geophysical logs depicting the units of interest throughout the Proposed Project area are presented in Figures 2.6A-7 through 2.6A-10 in TR Addendum 2.6-A. Water level data collected from the PZA aquifer as part of AUC's hydrologic investigations are presented in Table 2.7B-2 in Addendum 2.7-B. Water level data for the SM Unit, Overlying Aquifer, OA coal seams, and Underlying Unit are summarized in Tables 2.7B-3, through 2.7B-6 respectively. A description of each of the various aquifers/confining units is presented below.

SM Unit

In some locations of the Proposed Project area, a perched shallow water table unit was encountered. These locations include SM3, SM5, SM6, and SM7 and are shown in Figure 2.7B-6. Water level data is included in Table 2.7B-3. The SM unit is not continuous across the site. This sand is generally partially saturated, and approximately 10 to 20 feet thick, occurring between 40 and 80 feet below ground surface (ft bgs). Borings were also installed to this unit at the PZM1, PZM2, and PZM4 cluster areas, but no water was observed at these locations and no permanent well was installed.

Permeability of this perched water table unit is extremely low relative to the production zone. Table 2.7B-7 presents a summary of hydrologic testing conducted in this unit and is detailed further in Section 2.7.2.4. Specific capacity evaluations from the two locations where testing was conducted indicate values of 0.07 to 0.13 gallons per minute per foot (gpm/ft). Transmissivity values are also very low, between 0.3 ft^2/day and 0.014 ft^2/day. Calculated hydraulic conductivities range between 0.001 ft/day to 0.02 ft/day.

Based upon the extremely low well yields and hydraulic conductivities at wells completed in this perched water table unit, the SM unit does not meet the definition of an aquifer according to 10 CFR Part 40, Appendix A, which states:

> "*Aquifer means a geologic formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs.*"

Hydrologic data collected from the SM unit at two locations are presented in Sections 2.7.2.7.2 (at well SM3) and 2.7.2.7.4 (well SM5). The SM unit wells installed at clusters PZM1, PZM3, and PZM4 were observed to be dry. Based on the conclusion that the SM unit is not an aquifer, the overlying aquifer is the first observed and uppermost aquifer in the Proposed Project area.

Overlying Aquifer

The overlying aquifer appears continuous on a local scale within the PZM well clusters, but the specific units present in each of the well clusters do not correlate with each other over the greater distances across Proposed Project. Therefore, while it is true that a water bearing Overlying unit, exhibiting aquifer characteristics, is found in all areas across the site, based on geologic and potentiometric data, the Overlying Aquifer is not a single, discrete unit, but a series of aquifer-like units that do not correlate or connect to one another.
The overlying aquifer is partially saturated near the PZM1 cluster, and fully saturated at clusters PZM3, PZM4, and PZM5. At the PZM1 cluster, the overlying aquifer is approximately 60 feet thick, occurring at depths of approximately 155 to 215 feet bgs. At the PZM3 cluster, the overlying aquifer is approximately 20 feet thick at depths between 150 to 170 feet bgs. In the central portion of the Proposed Project area at the PZM4 cluster, the overlying aquifer is approximately 60 feet thick, occurring between depths of 125 to 185 feet bgs. And in the western PZM5 cluster, the overlying aquifer is substantially thinner (12 feet thick), occurring between depths of 70 to 82 feet bgs.

Table 2.7B-7 presents a summary of hydrologic testing conducted in the overlying aquifer, which is detailed further in Section 2.7.2.7. Based on testing, there is a wide range of permeability associated with this unit. Hydraulic conductivities calculated in the overlying aquifer at the PZM1, PZM4, and PZM5 clusters were 1.0 ft/day, 0.84 ft/day, and 3.3 ft/day, which is similar in scale to the conductivity of the PZA. The conductivity of the overlying aquifer at the PZM3 cluster and the two historical testing locations (see Figure 2.7B-7) were on the order of 0.03 to 0.05 ft/day.

The overlying aquifer is the uppermost aquifer observed within the Proposed Project area. A potentiometric surface map of this aquifer could not be constructed due to the discontinuous nature of this aquifer across the project area. A map of observed water level elevations in the overlying aquifer is presented in Figure 2.7B-8. Water level data is presented in Table 2.7B-4.

Within the Proposed Project area, the overlying aquifer is considered the uppermost aquifer. Based on the depth to the top of the overlying aquifer, which ranges between approximately 70 and 155 ft bgs, and the observed sequence of finer grained silt and shale that overlies this aquifer, the overlying aquifer is considered isolated from the surface water drainages present in the Proposed Project area. As all surface drainages in the Proposed Project area are characterized as ephemeral, the lack of a perennial wetting front and the distance between ground surface and the top of the overlying aquifer (characterized primarily by shale and finer grained sediments) support this conclusion of isolation between surface water infiltration reaching the overlying aquifer.

OA Aquitard

The overlying OA aquitard is a laterally continuous sequence of clays and silts, including the Felix Coal seam. There is a minimum thickness of approximately 25 feet observed in the OA aquitard, lying between the PZA and the local Overlying Aquifer, across the Proposed Project area. The Felix Coal is one or two laterally continuous marker beds lying in the lower portion of the OA aquitard. These coal seams are separated from the underlying PZA and overlying aquifer by continuous mudstone units present in varying thickness across the site. Over the eastern ¾ of the Proposed Project area, there are Upper and Lower Felix Coal seams, separated by at least five feet of mudstone. The Upper Felix Coal seam pinches out or climbs in the section in the western ¼ of the Proposed Project area (see cross sections included in Addendum 2.6-A), where there is only one seam of the Felix present. These coal seams range between five and 10 feet in thickness. Piezometers were installed in the Upper and Lower Felix coal seams at the PZM4 cluster to evaluate the hydrologic properties of these coal seams and determine whether these seams are aquifers. Based on the lack of yield in these wells, it was determined that these coal seams do not qualify as aquifers (additional details are presented in Section 2.7.2.7.3).

Total thickness of the OA aquitard is approximately 45 feet thick, 85 feet thick, 35 feet thick, and 100 feet thick at the PZM1, PZM3, PZM4 and PZM5 clusters, respectively. An isopach map of the OA unit is presented as Figure 2.6A-26 in Addendum 2.6-A and shows the lateral continuity of this unit across the Proposed Project area. Water level data is presented in Table 2.7B-5.

<u>PZA Aquifer</u>

The production zone aquifer (PZA) is a discrete and continuous aquifer across the Proposed Project area. The sand occurs between depths of approximately 260 to 380 ft bgs at the PZM1 cluster, 270 to 420 ft bgs at the PZM3 cluster, 220 to 380 ft bgs at PZM4 cluster, and 180 to 330 ft bgs at the PZM5 cluster. Based on the isopach map of the PZA across the site, thicknesses range between approximately 75 to 200 feet (Figure 2.6A-25 in Addendum 2.6-A).

Groundwater flow in the PZA is to the northeast and structural dip, as seen in the structural map at the bottom of the Felix Coal marker bed (Figure 2.6A-6 in Addendum 2.6-A), is to the northwest at approximately 35 to 50 feet per mile. Geologic confinement of the PZA by the overlying and underlying aquitards exists across the entire project area. Aquifer conditions transition from fully saturated in the western portion of the Proposed Project area to partially saturated conditions in the eastern project area, as shown by the approximate boundary line on Figure 2.7B-6. Based on available information to date, partially saturated conditions exist in approximately 30 percent of the Proposed Project area. At PZM1 and PZM3, the saturated thickness of the PZA is approximately 94 feet and 109 feet, and total sand thickness at these locations is approximately 125 feet and 165 feet. There is an unidentified mudstone unit that is present in some portions of the Proposed Project area that divides the PZA into upper and lower sand units. At the PZM4 cluster, there is a difference of approximately four to five feet in potentiometric elevation between the upper PZA and lower PZA. Further characterization of the impacts of this mudstone unit will be addressed in wellfield-scale hydrologic testing at a later date.

Uranium mineralization occurs most frequently in the lower portion of the PZA, or in the lower PZA where present. Sands in the PZA that host the uranium mineralization are commonly crossbedded, graded sequences fining upward from very coarse at the base to fine grained at the top. Additional lithologic discussion of this unit is presented in Section 2.6. Calculated transmissivities within the PZA range from approximately 20 ft^2/day to 1,428 ft^2/day and calculated hydraulic conductivities range between 0.3 ft/day and 13 ft/day (see Section 2.7.2.7). Water level data is presented in Table 2.7B-2.

<u>UA Aquitard</u>

The UA aquitard is a laterally continuous sequence of undifferentiated mudstones and clays, with discontinuous and often lenticular sandstones that is approximately 300 to 400 feet thick extending to the Badger Coal. Within the Proposed Project area, this aquitard includes the underlying unit, which is described below. The thickness of the UA aquitard above the underlying unit is approximately 60 feet, 35 feet, 35 feet, and 105 feet thick at well clusters PZM1, PZM3, PZM4, and PZM5. An isopach map of the UA aquitard is presented in Figure 2.6A-24 in Addendum 2.6-A a minimum thickness of approximately 10 feet is present across the Proposed Project area.

Underlying Unit

The underlying unit within the Proposed Project area is comprised of relatively ratty sandstones that are discontinuous and often lenticular. This underlying unit is not continuous or hydraulically connected across the project area, based on geologic data and potentiometric data. The underlying unit is generally 10 to 20 feet thick, occurring between depths of 415 to 480 feet bgs, and is fully saturated across the site (see cross-sections included as Figures 2.6A-12 to 2.6A-17. Water level data is presented in Table 2.7B-6.

Table 2.7B-7 summarizes the hydrologic testing conducted in the underlying unit and shows the relatively low permeability that is observed in this unit. Calculated conductivities are on the order of 0.005 to 0.02 ft/day, which is significantly less than in the PZA.

Based upon the extremely low well yields and hydraulic conductivities at wells completed in this underlying unit, this unit does not meet the definition of an aquifer according to 10 CFR Part 40, Appendix A, which states:

> "*Aquifer means a geologic formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs.*"

Single-well pump tests were conducted at the four well cluster locations in the UM-prefix wells completed in this underlying unit and are summarized in Section 2.7.2.7. These data support the conclusion that this underlying unit does not meet the definition of an aquifer within the Proposed Project area.

2.7.2.4 Hydrogeologic Integrity Study

The Reno Creek Project first began as an exploration prospect during 1967. The project moved toward the development phase after an ISR Pilot Plant was built in 1978, and successfully demonstrated that uranium in the PZA was amenable to carbonate solution recovery and subsequent groundwater restoration. Following the pilot plant demonstration, a UIC Class III feasibility report was completed in January 1982. The feasibility report noted that over 3,000 exploratory boreholes had been drilled during the previous 15 year history of the project, and most were drilled prior to abandonment and sealing regulations since this practice was not yet required by law. Before more capital would be committed toward the project, characterization of the natural self-sealing ability of the clays present within the borehole needed to be further evaluated.

2.7.2.4.1 Methodology

Rocky Mountain Energy (RME) conducted a series of hydrogeologic investigations within the Reno Creek Project area in 1982, in order to evaluate exploratory boreholes that were drilled prior to the enactment of well abandonment regulations and determine whether the boreholes have sealed themselves naturally and no longer represent potential locations for cross-aquifer groundwater flow. A portion of the summary and accompanying figures of the Hydrogeologic Integrity Study is included as Addendum 2.7-E. The evaluation focused primarily on the integrity of the overlying aquitard situated between the overlying aquifer and the production zone aquifer. RME performed these hydrogeologic investigations in areas referred to as the northern and southern mine block areas. It is important to note that the southern mine block area is located almost two miles south of the Proposed Project area in Section 33 of T43N R73W. The detailed investigations associated with the northern block were concentrated in areas that comprise the current Proposed Project area. In the northern block, investigations were performed in four different study areas. Figure 2.7B-7 presents the locations of historic boreholes, including the four different study areas that were investigated by RME. The four study areas that were investigated by RME correspond to the ore bodies located near the PZM1, PZM3 and PZM4 well cluster/pump test areas (Figure 2.7B-7).

As part of the hydrogeologic integrity testing, RME reentered 33 old exploration boreholes to evaluate for closure with respect to the swelling of mudstone and clay layers. Additionally, 24 new groundwater monitoring wells were installed, 18 of which were constructed for pumping and injection testing. Figure 2.7B-7 presents the locations of historical boreholes that were investigated by RME.

Existing boreholes were entered via an air rotary drill rig and drilling was advanced until an obstruction was encountered. These obstructions were sampled, when possible, using a coring barrel, in an effort to identify and determine the nature of the borehole obstruction. Previous site studies by Honea (1981) identified the clays associated with the Felix coal and overlying confining unit as the swelling type. Once the obstructions sealing the borehole were identified, an inflatable bottom hole packer was set just above the seal/obstruction, and water pressure was applied via the drill pipe. Pressure was increased to a maximum of 150 psi as measured at the surface, or until a drop in pressure was observed. Pressure was maintained or observed for approximately 30 minutes, and the packer was subsequently removed.

Bottom hole and straddle packer tests were conducted on 16 existing exploration boreholes at 39 intervals in what RME identified as the northern block. As mentioned earlier, the northern block generally corresponds to the current Proposed Project area. Additional packer testing was also conducted in 12 additional boreholes and 17 seal/obstruction intervals located within the southern block, which is located outside of the Proposed Project area. The age of the boreholes ranged from as recent as three to four years old, and as old as 10 years, at the time of the study.

2.7.2.4.2 Results

During borehole reentry investigations, mudstone obstructions were generally encountered at the mudstones above, between, and below the Felix Coal, within the unidentified mudstone present in middle portion of the PZA, and within a basal mudstone near the bottom of the PZA that separates a relatively less permeable sand within the PZA (identified as the #5 sand by RME).

In the northern block area of investigations (see Figure 2.7B-7), the mudstone overlying the Felix coal consistently held up to surface gauge hydrostatic pressures of 120 to 150 psi without bleeding off. Similar results were seen at slightly lower pressure in the mudstone separating the Upper and Lower Felix, and the mudstone below the Felix. The results of the packer testing indicated that the mudstone above the Felix consistently held up to surface gauge pressures of 120 to 150 psi, and the mudstones between and below the Felix withstood somewhat lower pressures. Regardless of location, packer testing of the basal PZA mudstone did not usually withstand much pressure and suggested that this mudstone provided minimal confinement between the upper ore sands and lower ore sand #5 (RME nomenclature). RME concluded that the sands of the PZA should be treated as one hydrologic unit.

Results of the pump and injection tests indicated that the production zone sand has good permeability and should is amenable to ISR recovery. Transmissivity values ranged from 149 to 555 ft^2/day; permeability values ranged from 0.9 to 4.1 ft/day; and storativity values ranged from 4.0×10^{-5} to 1.0×10^{-3}. No responses were observed in the overlying aquifer during any hydraulic testing activities. RME did not identify an underlying aquifer during their investigations.

The significance of the Hydrogeological Integrity Study conducted by RME demonstrates that the numerous exploratory boreholes do not provide a conduit to crossflow of groundwater between aquifer units, due to the natural sealing capacity of the swelling clays present in confining units with respect to the production zone sand. Recent pump testing conducted across the project area has also provided additional confirmation of the absence of open boreholes as hydraulic isolation of the overlying aquifer and underlying unit (which is not considered an aquifer) with respect to the production zone has been demonstrated.

In Section 2.7.2.7.2, an example of an improperly constructed and leaky well is presented that was discovered during pump testing at the PZM3 cluster (see Figure 2.7B-30). The significant drawdown response observed in the underlying unit (approximately three feet) illustrates a typical hydrograph at a well that is not completed properly. The underlying unit in this well essentially responds in the same manner as a well completed in the PZA pumping horizon.

2.7.2.5 Potentiometric Surface, Groundwater Flow Direction and Hydraulic Gradient

The hydrologic investigations at the Proposed Project included measurements of water levels completed in the production zone PZA aquifer, the shallow water table SM unit (where present), the overlying aquifer, and underlying unit to assess the potentiometric levels, and groundwater flow direction and hydraulic gradient in these aquifers. As previously mentioned, the SM unit and underlying unit do not meet the definition of an aquifer. Hydrologic data collected from these units is included in this document to support this conclusion. Additionally, two piezometers were installed at the PZM4 well cluster in the Upper and Lower Felix coal seams within the overlying OA confining zone. A summary of water level measurements in the PZA aquifer is provided in Table 2.7B-2. Summaries of water level data collected in the SM unit, overlying aquifer, OA confining unit, and underlying unit are presented in Tables 2.7B-3 through 2.7B-6, respectively. Vertical gradients between the water table unit (where present), overlying and PZA aquifers, and the underlying unit at the six well clusters are presented in Table 2.7B-8.

Potentiometric surfaces could not be constructed for the perched water table SM unit, overlying aquifer, and underlying unit due to the discontinuous nature of the sandstones that were identified and completed within these intervals. Figure 2.7B-8 presents the observed water level elevations at the seven OM-prefix wells from August 2011. Similarly, a potentiometric surface could not be constructed from water level data in the underlying unit due to discontinuity of sands below the PZA in the Proposed Project area. Figure 2.7B-9 presents water level elevations at the seven UM-prefix wells from August 2011.

Two potentiometric surface maps are presented for the production zone PZA aquifer. Figure 2.7B-10 presents the potentiometric surface as measured in October 1993 as part of historical hydrologic investigations conducted by ENFI. Figure 2.7B-11 presents the current potentiometric surface for the Proposed Project area from August 2011. The direction of groundwater flow in the PZA for both potentiometric surfaces is to the northeast. These two datasets are in good agreement and support the observed groundwater flow direction and gradients observed within the Proposed Project area. The horizontal hydraulic gradient from the 1993 potentiometric surface across the area of investigation is approximately 0.0027 ft/ft (14.4 ft/mile). The hydraulic gradient from 2011 in the southwestern portion of the Proposed Project area near the PZM5, PZM6 and

PZM7 well clusters is approximately 0.0032 ft/ft (16.9 ft/mile) and is similar to the gradient in the northeastern portion of the Proposed Project area (approximately 0.0035 ft/ft [18.5 ft/mile]). The hydraulic gradient in the center of the project area is approximately 0.0017 ft/ft (9.0 ft/mile). This area of lower hydraulic gradient is likely related to the presence of thicker and more transmissive sands, which is supported by pump testing data (see Section 2.7.2.7).

At the PZM4 well cluster, the PZA aquifer is bifurcated by a mudstone present within the PZA that separates the upper and lower PZA at this location (see geophysical log in Figure 2.6-14). At PZM4, the mudstone is approximately 40 feet thick and is also present at wells PZM16 (approximately eight feet thick) and PZM15 (approximately 30 feet thick). The mudstone is not observed to the west at well PZM17 (see the A-A' cross section in Figure 2.6-6). At the PZM4 cluster, there is a head differential of approximately four feet between the higher head observed in the upper sand of the PZA (monitored in well PZM4) and the underlying lower PZA (monitored in well PZM4D). The potentiometric surface from 2011 in Figure 2.7B-9 utilizes the head in the lower PZA at well PZM4D. Based on the results of pump testing at the PZM4 cluster (presented in detail in Section 2.7.2.7), the area to the west near well PZM17 appears to represent an area of higher transmissivity, which may also be related to the relative flattening of the hydraulic gradient in this area.

Vertical gradients were calculated at the six well clusters where there is sufficient hydrologic data (PZM1, PZM3, PZM4, PZM5, PZM6, and PZM7) and are presented in Table 2.7B-8. Hydraulic head decreases with depth from the water table SM unit (where present) down to the underlying unit, and the downward hydraulic gradients are consistent at all locations. At the three locations where the SM unit was encountered (SM3, SM5, and SM6), the SM unit potentiometric elevation is approximately 66 feet, 3 feet, and 45 feet higher than the overlying aquifer potentiometric elevation, respectively. In the eastern portion of the project area at clusters PZM1 and PZM3, head in the overlying aquifer is approximately 110 feet and 165 feet higher than the underlying PZA aquifer, respectively. In the central portion of the project area at the PZM4 cluster, the overlying aquifer is 52 feet higher in head than the upper PZA. In the western half of the project area, the head in the overlying aquifer is approximately 91 feet, 79 feet, and 57 feet higher than the PZA aquifer at clusters PZM5, PZM6, and PZM7, respectively. Head in the underlying unit ranges between approximately 2 feet and 36 feet lower than the PZA at the six well clusters presented in Table 2.7B-8.

Water level hydrographs for the SM unit, overlying aquifer, PZA, and underlying unit are presented at the PZM5 cluster and shown in Figures 2.7B-12 through 2.7B-15, respectively. These hydrographs present approximately eight months of data, from February through September 2011 for the SM unit, overlying aquifer, and underlying unit. The PZA aquifer at well PZM5 has water level data over a 10 month period from December 2010 to September 2011.

2.7.2.6 Historical Pump Testing and Aquifer Properties

Pump testing in the Proposed Project area has been conducted in the past by previous operators between the years 1979 and 1994. These historical testing activities included multiple single-well tests as well as several multi-well observation well tests. The results of testing are presented in this section and summarized in Table 2.7B-9.

ENFI and Hydro-Engineering re-analyzed historical testing conducted by RME in 1979, 1981, and 1982, and conducted additional hydrologic testing in 1993 as part of the Class III UIC Permit to Mine Application and a Source Material License Application for the Reno Creek Project in 1993. The following presents a summary of these hydrologic results, which are also presented in Table 2.7B-9; Figure 2.7B-7 shows the locations of these investigations. These investigations reported in this document include:

- Five multi-well pump tests in the PZA and monitoring at a total of eleven PZA observation wells, one upper PZA well, and one overlying aquifer well;
- 16 single-well pump tests in the PZA at ten locations; and
- Three single-well pump tests in the overlying aquifer.

OB-1 Test

A multi-well pump test was conducted at pumping well OB-1, located approximately 2,000 feet northwest of the PZM1 well cluster (see Figure 2.7B-7). The PZA at this location is partially saturated and the net sand thickness is 115 feet. Well OB-1 was pumped at 16.8 gpm for 165 minutes, with a maximum observed drawdown in the pumping well of 14.8 feet. Observation wells P-1, I-1, and M-4 (not shown on Figure 2.7B-7) were monitoring during testing and evaluated for aquifer properties.

Calculated transmissivity from the pumping well OB-1 was 123 ft^2/day, and ranges between 138 to 225 ft^2/day in the observation wells. Specific yield values for the two observation wells were 2.4×10^{-2} and 4.7×10^{-2}. Based on 115 feet of sand in the PZA near this location, the calculated horizontal hydraulic conductivities range between 1.1 and 2.0 ft/day (Table 2.7B-9).

P-10 Test

A multi-well pump test was conducted in 1980 at pumping well P-10, located approximately 2,300 feet northwest of the PZM1 well cluster (Figure 2.7B-7). The PZA at this location is partially saturated and the net sand thickness is 113 feet. Well P-10 was pumped at an average rate of 18.9 gpm for 240 minutes, with a maximum observed drawdown of 7.6 feet. Observation wells I-12 and M-16 (not shown on figure) were monitoring during testing and evaluated for aquifer properties.

The calculated transmissivity for the pumping well was 254 ft^2/d from early time data as the straight line portion of the drawdown lasted approximately one minute before drawdown became essentially steady. Calculated transmissivities for wells I-12 and M-16 were 242 and 247 ft^2/d, respectively, and specific yield values of 6.9×10^{-2} and 6.0×10^{-2} were calculated from these wells, respectively. Based on 113 feet of sand thickness in the PZA, calculated horizontal conductivities range between 2.1 and 2.2 ft/day (Table 2.7B-9).

RI-5 Tests

Several historical pump tests were conducted at well RI-5 (located approximately 800 feet west of PZM1 cluster, see Figure 2.7B-7). The PZA at this location is partially saturated and net sand thickness is 96 feet. Testing conducted in 1982 included pumping RI-5 at an average rate of 11.9 gpm for 360 minutes, and additional monitoring of the PZA observation well RI-22. Drawdown in the pumping well was approximately 13.6 feet at the end of testing. A second single-well test was conducted in 1982 at an average rate of 18.6 gpm for 120 minutes, resulting in approximately 30 feet of drawdown at pumping well RI-5. A third single-well test was conducted by ENFI in 1993 at RI-5 that consisted of pumping at an average rate of 6.7 gpm for 41 minutes, resulting in 5.3 feet of drawdown.

The calculated T from the pumping well RI-5 during the first test (11.9 gpm) was 75.4 ft^2/d utilizing early time data, and 298 ft^2/d utilizing later time data. The match of late time data appears more appropriate, as early time data includes withdrawal from casing storage. The calculated T from the RI-22 observation well at late time is 205 ft^2/d, with a specific yield value of 2.6×10^{-3}. Calculated T from the second single-well test at RI-5 was 174 ft^2/d from drawdown data and 203 ft^2/d from monitored recovery data. Calculated T from the third test from 1993 was 289 ft^2/day. The results of these tests at RI-5 indicate similar results, and calculated horizontal conductivities range between 1.8 and 3.1 ft/day (Table 2.7B-9).

RI-28 Test

A multi-well pump test was conducted in 1982 at RI-28, which is located approximately 700 feet southeast of the PZM4 well (Figure 2.7B-7). The PZA at this location is fully saturated and has a net sand thickness of 164 feet. Well RI-28 was pumped at an average rate of 30.3 gpm for 2,580 minutes (1.8 days), resulting in a maximum drawdown of 53 feet. Water levels in PZA at well RI-34 (not shown in Figure 2.7B-7), which is located 77 feet from the pumping well, were also monitored.

Calculated T from drawdown data in RI-5 was 207 ft^2/d, and the same value was calculated from the recovery data. Calculated T in the RI-34 observation well was 217 ft^2/d from drawdown data, and 206 ft^2/d from recovery data. Storativity calculated from

RI-34 was 1.3 x 10^{-4}. Calculated horizontal conductivities for all analyses were 1.3 ft/day (Table 2.7B-9).

RI-1 Tests

Two single-well pump tests were conducted in 1982 at RI-1, which is located approximately one mile southwest of PZM4 (Figure 2.7B-7). The PZA at this location is fully saturated and has a net sand thickness of 169 feet. In the first test, RI-1 was pumped at a constant rate of 44.8 gpm for 100 minutes, resulting in 23 feet of drawdown. The second test at RI-1 was pumped at a constant rate of 25 gpm for approximately 2,500 minutes, resulting in approximately 18 feet of maximum drawdown. A third single-well test was conducted in 1993 by ENFI, as well RI-1 was pumped at 3.8 gpm for 51 minutes.

Calculated T values shown in Table 2.7B-9 compare well; calculated T from drawdown data in the first test was 868 ft^2/d and 813 ft^2/d from the recovery data. Calculated T from drawdown data in the second test was 802 ft^2/d and 828 ft^2/d from recovery data. Calculated T from the 1993 test was slightly lower at 639 ft^2/d. Calculated horizontal conductivities for all analyses range from 3.8 to 5.1 ft/day (Table 2.7B-9).

RI-2 Test

A single-well test was conducted in 1982 at RI-2, which is located approximately 1,300 feet southwest of the PZM4 well (Figure 2.7B-7). The PZA at this location is fully saturated and has a net sand thickness is 121 feet. Well RI-2 was pumped at a constant rate of 41.2 gpm for 100 minutes, resulting in 39 feet of drawdown. Recovery monitoring was also conducted. A single-well test was also conducted in 1993 by ENFI at this location, pumping at a rate of 3.5 gpm for 46 minutes.

Calculated T from drawdown data was 189 ft^2/d, and T from the recovery data was calculated to be slightly lower at 156 ft^2/day. Calculated T from the 1993 test from drawdown data was 156 ft^2/d. Calculated horizontal conductivities are 1.3 ft/day to 1.6 ft/day from drawdown data and 1.3 ft/day from recovery data (Table 2.7B-9).

RI-3 Test

Two single-well pump tests were conducted in 1978 and 1982 at well RI-3, which is located approximately 3,600 feet northeast of well PZM4 (Figure 2.7B-7). A third single-well test was also conducted in 1993. The PZA at this location is fully saturated and has a net sand thickness is 154 feet. Well RI-3 was pumped at a constant rate of 34.7 gpm for 100 minutes for the first test conducted in 1978, resulting in 24 feet of drawdown. In 1982, the well was pumped at an average rate of 24.8 gpm for 360 minutes, resulting in

19 feet of drawdown. In the 1993 test, the well was pumped at an average rate of 7.6 gpm for 52 minutes.

Calculated T values for the first test from drawdown and recovery data were 451 ft^2/day and 459 ft^2/day, respectively. Calculated T values from the second test from drawdown and recovery data were 468 ft^2/day and 588 ft^2/day, respectively. Calculated T from drawdown data for the third test was 497 ft^2/d. Calculated hydraulic conductivities range between 2.9 and 3.8 ft/day (Table 2.7B-9).

<u>RI-4 Test</u>

A single-well test was conducted in 1982 at well RI-4, which is located approximately 4,300 feet northwest of PZM1 (see Figure 2.7B-7). The PZA at this location was indicated to be saturated, with a net sand thickness of 124 feet. The well was pumped at an average rate of 22.2 gpm for 100 minutes, resulting in 50 feet of drawdown. A second single-well test was conducted in 1993 and the well was pumped at an average rate of 8.0 gpm for 180 minutes.

Calculated T values from drawdown and recovery data were 72 ft^2/day and 75 ft^2/day, respectively, for the first test. Calculated T of the second test was 156 ft^2/day. Hydraulic conductivities were calculated at approximately 0.6 ft/day for the first test and 1.3 ft/day for the second test (Table 2.7B-9).

<u>RI-6 Test</u>

A single-well test was conducted in 1982 at well RI-6, located approximately 2,000 feet northeast of well PZM3 (Figure 2.7B-7). The PZA at this location is partially saturated, with a sand thickness of 67 feet. The well was pumped at an average rate of 15.9 gpm for 141 minutes. A second single-well test was conducted in 1993 and the well was pumped at a rate of 5.7 gpm for 38 minutes.

Calculated T values from drawdown and recovery data of the first test were 105 ft^2/d and 110 ft^2/d, respectively. Calculated T from drawdown data of the second test was 109 ft^2/d. Hydraulic conductivities were calculated at approximately 1.6 ft/day (Table 2.7B-9).

<u>RI-7 Test</u>

A single-well test was conducted in 1982 at well RI-7, located approximately 2,500 feet southeast of the PZM3 well (Figure 2.7B-7). The PZA at this location is partially saturated, with a sand thickness of 56 feet. The well was pumped at an average rate of 16.6 gpm for 110 minutes.

Calculated T values from drawdown and recovery data were 185 ft^2/d and 124 ft^2/d, respectively. Hydraulic conductivities were calculated at 3.3 ft/day and 2.2 ft/day from the drawdown and recovery analysis, respectively (Table 2.7B-9).

RI-28 Test

A single-well test was conducted in 1982 at well RI-28, located approximately 700 feet southeast of well PZM4 (Figure 2.7B-7). The PZA at this location is fully saturated with a sand thickness of 164 feet. The well was pumped at an average rate of 30.3 gpm for approximately 2,580 minutes.

Calculated T values from drawdown and recovery data were 176 ft^2/d and 175 ft^2/d, respectively. Hydraulic conductivities were calculated at approximately 1.1 ft/day (Table 2.7B-9).

RI-42C

A single-well test was conducted in 1993 by ENFI at well RI-42C, which is located approximately 2,000 feet east of well PZM3 (Figure 2.7B-7). The PZA at this location is partially saturated with a sand thickness of 74 feet. The well was pumped at a rate of 20 gpm for 241 minutes, resulting in a drawdown of approximately 27 feet.

The calculated T value from drawdown was 504 ft^2/d. Hydraulic conductivity at this location is approximately 6.8 ft/day (Table 2.7B-9).

RI-43C

A single-well test was conducted in 1993 by ENFI at well RI-43C, which is located approximately 2,500 feet east-southeast of well PZM4 (Figure 2.7B-7). The PZA at this location was noted as fully saturated at a lower permeability unit at the top of the sand, and static water level was approximately 80 feet above this unit. The well was pumped at a rate of 20 gpm for 411 minutes, resulting in a drawdown of approximately 67 feet.

The calculated T value from the drawdown data from this test was 203 ft^2/day. Hydraulic conductivity at this location is approximately 2.3 ft/day (Table 2.7B-9).

MP-9 Multi-Well Test

ENFI conducted a multi-well pump test within the lower portion of the production zone sand at pumping well MP-9, which is located approximately 1,400 feet east-northeast of well PZM4. (Figure 2.7B-7) The PZA is fully saturated and sand thickness at this location is 103 feet. In addition to the pumping well, four additional wells (MP-2, RI-46, RI-45, RI-47) in the lower sand were monitored during testing which were located approximately 90 feet west, 105 feet north, 175 feet west, and 217 feet north from the pumping well, respectively. Additional monitoring was conducted at a single well (MO-2) in the upper portion of the PZA and at a single well (MU-2) in the overlying aquifer at this location. Well MP-9 was pumped at an average rate of 15.5 gpm for 24 hours, resulting in 40 feet of drawdown. Drawdowns in observation wells MP-2, RI-46, RI-45, and RI-47 were 21 feet, 19 feet, 18 feet, and 12 feet.

The potentiometric level in the upper sand of the PZA at this location was approximately seven feet higher than the level in the lower sand, while the overlying aquifer well indicates the potentiometric level in the overlying aquifer is approximately 70 feet higher than the lower sand of the PZM. Pumping from the lower sand of the PZA from well MP-9 produced no response in the PZA upper sand at well MO-2 (located 50 feet from the pumping well), and no response in the overlying aquifer at well MU-2 (located 100 feet from the pumping well).

Calculated transmissivities are presented in Table 2.7B-9 and the Theis, Cooper-Jacob straight-line, and Theis recovery evaluated data show good agreement, ranging between 45 ft^2/d to 62 ft^2/d, with hydraulic conductivities ranging between 0.4 ft/day and 0.6 ft/day. The average transmissivity at this location is approximately 50 ft^2/d. Storativity values at this location are range between 5.5×10^{-5} to 2.2×10^{-4}.

RI-15U – Overlying Aquifer

Two single-well tests were conducted in 1993 at well RI-15U, which is completed in the overlying aquifer at this location. Well RI-15U is located approximately 1,200 feet east of the PZM3 well (Figure 2.7B-7). The first test results indicate an interruption in pumping and a pumping rate (3.8 gpm) that was too high for the well, as water level data are indicative of wellbore storage. The second test was conducted at one gpm for 26 minutes, resulting in approximately 17.5 feet of drawdown.

Calculated T values from drawdown data were significantly less than values seen in the PZA at this location. The calculated T value from the second test was 1.4 ft^2/d. Based on the log from this well, sand thickness is approximately 30 feet. Hydraulic conductivity at this location was calculated at approximately 0.05 ft/day (Table 2.7B-9).

RI-24U – Overlying Aquifer

A single-well pump test was conducted at well RI-24U, which is completed in the overlying aquifer and located approximately 4,300 feet northwest of PZM1 (Figure 2.7B-7). The well was pumped at an average rate of 1.5 gpm for 77 minutes, resulting in approximately 59 feet of drawdown.

Calculated transmissivity from the drawdown data was extremely low at 0.2 ft^2d. Based on the log at this location, the sand quality is relatively poor and thin, with approximately 8 feet or less of sand. The calculated hydraulic conductivity in this sand is approximately 0.03 ft/day (Table 2.7B-9).

RI-30U – Overlying Aquifer

A single-well pump test was conducted in the overlying aquifer well RI-30U, located approximately 700 feet southeast of well PZM4 (Figure 2.7B-7). The well was pumped at a rate of 4.3 gpm for 20 minutes, resulting in 2.9 feet of drawdown.

Calculated T from drawdown data was 164 ft^2/d. Based on a sand thickness of 61 feet, the calculated hydraulic conductivity at this location is approximately 2.7 ft/day (Table 2.7B-9).

2.7.2.7 Recent Pump Testing and Aquifer Properties

AUC has conducted four multi-well pump tests in 2010 and 2011 at four well cluster locations, PZM1, PZM3, PZM4, and PZM5. Based on the results of testing, both the water table SM unit and underlying unit below the PZA do not meet the definition of an aquifer. Data from these units are included in this section to support this conclusion. The following summarizes the wells tested and monitored during these activities:

- Four multi-well pump tests were conducted in the PZA; a total of 20 wells monitored in the PZA; aquifer properties determined for 14 wells in the PZA;
- A total of two SM unit wells, four overlying aquifer wells, and five underlying unit wells monitored during PZA multi-well tests; and
- Single-well pump tests conducted in the SM unit (two), overlying aquifer (four), and underlying unit (four) to determine aquifer properties.

These pump tests represent the most complete hydrologic characterization completed to date at the Proposed Project and provide more than sufficient characterization for the purposes of this license application. Hydrostratigraphic diagrams at the four well clusters are presented in Figures 2.7B-16 through 2.7B-19. Aquifer characteristics of transmissivity (T) and storativity (S) were evaluated for the PZA at the four cluster locations. Additionally, single-well pump testing was conducted in the overlying SM unit, overlying aquifer, and the underlying unit to determine transmissivity of these units. Hydraulic isolation of the PZA with respect to the overlying aquifer and underlying unit has been demonstrated at all four well cluster locations, as no drawdown responses were observed. Addendum 2.7-D presents the full detailed reports related to the well cluster hydrologic investigations.

It is noted that due to surface discharge concerns of water quality from the ore bodies, the pumping wells at the four well cluster locations were be located outside of the ore bodies.

2.7.2.7.1 PZM1 Well Cluster

The PZM1 well cluster is located in the NW ¼ of Section 27, T43N, R73W (see Figure 2.7B-6). Multi-well pump testing of the PZA aquifer was conducted during December 2010 and single-well tests of the overlying aquifer and underlying unit were conducted during October 2011. Testing was conducted to evaluate hydrologic characteristics of the PZA, overlying aquifer, and the underlying unit, and demonstrate isolation of the PZA with respect to the adjacent overlying aquifer and underlying unit. A detailed report of these testing activities is provided in the PZM1 data package, included as Addendum 2.7-D. The results of testing indicate that the PZA at this location is hydraulically connected at the monitoring locations, and no drawdown responses were observed in the overlying aquifer or underlying unit, demonstrating that there is sufficient confinement at this location for the purposes of ISR operations.

A hydrostratigraphic diagram for the PZM1 well cluster integrating geophysical log data and water level data is presented in Figure 2.7B-16. The PZA at the PZM-1 well is partially saturated but geologically confined by a relatively thick mudstone and occurs between depths of 256 and 385 feet bgs, with mineralization occurring in the lower half of the aquifer (see Figure 2.6A-10 for the type log near the PZM1 cluster). Depth to water at PZM1 is approximately 292 feet below top of casing (feet btoc), resulting in a saturated sand thickness of approximately 94 feet. Total sand thickness at this location is 128 feet.

The overlying aquifer at this location is approximately 50 to 60 feet thick, occurring between 156 to 215 feet bgs at the PZM1 well, and completed between 191 ft and 211 feet at well OM1. The overlying OA confining unit at the well cluster is between 35 and 53 feet thick, and observed at depths of 215 to 256 feet bgs at the PZM1 pumping well. The underlying unit is 17 feet thick at well UM1 and occurs at depths between 432 and 449 ft bgs, and the underlying UA aquitard is a mudstone approximately 49 feet thick, at depths of 383 to 432 feet bgs at UM1.

For the multi-well pump test conducted at PZM1, three PZA observation wells were monitored, PZM9, PZM8, and PZM10. These wells are located 58, 81, and 235 feet from the pumping well, respectively. Water levels in the overlying OM1 well and the underlying UM1 well were also monitored to demonstrate hydraulic isolation between the PZA and the overlying aquifer and underlying unit.

Two relatively short term single-well tests were conducted in wells OM1 and UM1 to evaluate aquifer characteristics in the overlying aquifer and the underlying unit. The following summary details the results of testing at this location.

PZM1 Multi-Well Pump Test

Pumping well PZM1 was pumped at an average rate of 8.9 gpm for 2,595 minutes (1.8 days). Total drawdown observed in the pumping well was 46.8 feet; drawdown observed in wells PZM9, PZM8, and PZM10 were 1.4 feet, 1.6 feet, and 0.5 feet, respectively, and summarized in Table 2.7B-10. Figure 2.7B-20 shows the relative water levels of the three PZA observation wells versus the PZM1 pumping well. All data presented have been corrected for barometric pressure (BP) fluctuations. The PZA aquifer at this location is highly efficient with respect to barometric pressure. Barometric efficiency (BE) is 0.81 at PZM8 and between 0.93 and 0.96 at the remaining PZA wells. Thus at PZM8, the aquifer will fluctuate at a level of 81 percent of the equivalent fluctuation in BP. Additional details on the BE evaluation is provided in the pump test data report for the PZM1 pump test, provided in Addendum 2.7-D.

Figure 2.7B-21 shows a close-up view of water level data in the PZA at early time, as the water level in the well nears the level of maximum drawdown in less than 30 minutes. The drawdown observed in the pumping well is not reflective of the water levels calculated outside of the well completion, as the pumping well is only approximately 10 percent efficient. Based on a Theis prediction of drawdown at a distance of one foot from the well, the predicted drawdown is only 4.6 feet (compared to 46.8 feet drawdown in the pumping well). Additional details of the well efficiency evaluation are presented in Addendum 2.7-D.

It is noted that the drawdown observed does not correspond directly to distance in the observation wells, as greater drawdown is observed in well PZM8 (1.6 feet drawdown; 81 feet from pumping well) versus PZM9 (1.4 feet; 58 feet from pumping well). It is possible that the non-uniform distribution of drawdown is related to depositional heterogeneities present at depth (e.g., sand quality and/or thickness variations), but will be characterized further at a later date during wellfield-scale hydrologic testing.
No drawdown response was observed in the overlying OM1 and underlying UM1 wells, as seen in Figures 2.7B-22 and 2.7B-23, respectively. Hydraulic isolation of the PZA aquifer with respect to the overlying aquifer and underlying unit has thus been demonstrated in the vicinity of PZM1.

Aquifer characteristics of transmissivity (T) and storativity (S) were evaluated in the PZA aquifer and are summarized in Table 2.7B-11. Drawdown data at the observation wells were analyzed by the Theis (1935) method, correcting drawdown data for the partially saturated sand present at this location. A correction for drawdown in a partially saturated aquifer was applied to the drawdown data analyzed, commonly referred to as a Jacob correction. Corrected drawdown (s') for partially saturated conditions is defined by the following relationship between observed drawdown (s) and saturated aquifer thickness (B):

$s' = s^2/2B$ (Kruseman and de Ridder, 1990)

The recovery data were analyzed according to the straight-line Theis (1935) analysis on the observation wells and the pumping well. Table 2.7B-11 summarizes the results of analysis.

Transmissivity (T) results from drawdown data in the observation wells PZM9, PZM8, and PZM10 were 427 ft^2/d, 559 ft^2/d, and 694 ft^2/d. Theis recovery analysis of T for the pumping well PZM1 was calculated to be 389 ft^2/d, and T ranged between 454 ft^2/d to 758 ft^2/d for the three observation wells from recovery data (Table 2.7B-11). Calculated storativity values for the three observation wells ranged between 6.0×10^{-4} to 5.0×10^{-3}. Calculated hydraulic conductivities (based on 94 foot saturated thickness at the pumping well) ranged from 4.5 to 7.4 ft/day from drawdown data, and from 4.1 to 7.6 ft/day from recovery data.

Single-Well Overlying Aquifer Pump Test

A single-well test was conducted in the overlying aquifer at well OM1 on October 5, 2011 and water levels in the pumping well were monitored. The well was pumped at an average rate of 3.3 gpm for 75 minutes, resulting in 19.3 feet of drawdown. A hydrograph of the pump test water level data is presented in Figure 2.7B-24.

Recovery data were evaluated according to Theis (1935) and transmissivity was determined by a straight-line fit, the results of which are summarized in Table 2.7B-11. A T value of 39 ft^2/day was calculated in the aquifer at this location, which indicates that the hydraulic conductivity (K) in the overlying aquifer is approximately one ft/day.

Single-Well Underlying Unit Pump Test

A single-well test was conducted in the underlying unit at well UM1 on October 24, 2011. The well was pumped at an average rate of 6.1 gpm for 12 minutes, resulting in approximately 98 feet of drawdown. Pumping was stopped as water levels approached the level of the pump in the well. Based on the hydrograph of water level during testing presented in Figure 2.7B-25, it appears that much of the water removed during the short test was from wellbore storage. Water levels in the well were also very slow to recovery, only reaching within three feet of the initial static water level after a period of more than two days.

Recovery data were analyzed by a straight-line fit according to Theis (1935), the results of which are presented in Table 2.7B-11. A T value of 0.1 ft^2/d was calculated at the underlying unit at this location. Hydraulic conductivity based on 17 feet of saturated thickness is approximately 0.01 ft/day. Based on the lack of sustainable yield, very slow recovery, and very low transmissivity calculated at UM1, the underlying unit does not meet the definition of an aquifer at this location.

PZM1 Pump Test Summary

Pump testing was conducted in the partially saturated PZA at well PZM1. A drawdown response of 0.5 ft was measured in an observation well 235 feet from the pumping well. No responses were observed in the overlying aquifer and underlying unit, indicating that the PZA in this area is isolated from these adjacent intervals.

Average transmissivity of the PZA at the PZM1 cluster is approximately 560 ft^2/day from drawdown data and 588 ft^2/day from the recovery data analysis. Hydraulic conductivities average approximately 6.0 to 6.3 ft/day. Storativity values range between 6 x 10^{-4} to 5.0 x 10^{-3} (see Addendum 2.7-D for detailed report). Historical testing near the PZM1 cluster was conducted at well RI-5 (see Figure 2.7B-7, located 800 feet east of PZM1), which is summarized in Table 2.7B-9. Transmissivity values from these historical tests are approximately half the values seen at the PZM1 cluster, which may indicate relatively less transmissive sands to the west.

2.7.2.7.2 PZM3 Well Cluster Pump Testing

The PZM3 well cluster is located in the NE ¼, Section 33, T43N, R73W (see Figure 2.7B-6). A multi-well pump test was conducted in the PZA aquifer during October 18 – 21, 2011. Single-well tests of the SM unit, overlying aquifer, and underlying unit were conducted during October 2011. Testing was conducted to evaluate the hydrologic characteristics of the PZA, SM unit, overlying aquifer, and underlying unit, and to demonstrate isolation of the PZA with respect to these adjacent intervals. A more detailed report of these hydrologic investigations is provided in the PZM3 data package, included as Addendum 2.7-D. The results of testing indicate that the PZA at this location is hydraulically connected at the monitoring locations, and no drawdown responses were observed in the overlying aquifer or underlying unit, demonstrating that there is sufficient confinement at this location for the purposes of ISR operations.

A hydrostratigraphic diagram for the PZM3 well cluster integrating geophysical log data and water level data is presented in Figure 2.7B-17. The PZA at the PZM3 well cluster is partially saturated but geologically confined by the predominantly mudstone OA aquitard. A type-log for this area is presented in Figure 2.6A-4 in Addendum 2.6-A, and shows that the PZA is found between depths of approximately 255 feet to 425 feet, with mineralization occurring in the upper and middle portions of the PZM. Depth to water at PZM3 is approximately 302 feet btoc, resulting in a saturated sand thickness of approximately 109 feet.

The overlying aquifer at this location is saturated and approximately 10 feet thick, occurring between depths of approximately 150 to 160 feet bgs at well OM3, with a confining head of approximately 13 feet. The overlying OA aquitard is approximately 85 feet thick. The underlying unit is approximately 14 feet thick at well UM1, occurring at depths of 460 to 474 feet bgs, with a confining head of approximately 146 feet.

For the multi-well pump test conducted at PZM3, three additional PZA observation well were monitored, PZM11, PZM12, and PZM13. These wells are located 52 feet, 102 feet, and 199 feet from the pumping well, respectively. Water levels in the overlying SM3 and OM3 wells and in the underlying UM3R wells were also monitored during testing to demonstrate hydraulic isolation between the PZA and adjacent units.

Short-term single-well pump tests were conducted in wells SM3, OM3, and UM3R to evaluate transmissivity in the water table SM unit and overlying aquifer and underlying unit. The following summary details the results of testing at the PZM3 well cluster.

<u>PZM3 Multi-Well Pump Test</u>

Pumping well PZM3 was pumped at an average rate of 9.9 gpm for 4,149 minutes (2.88 days). Total drawdown observed in the pumping well was 32.1 feet; drawdowns observed in wells PZM11, PZM12, and PZM13 were 3.1 feet, 1.5 feet, and 0.7 feet, respectively, and are summarized in Table 2.7B-12. Figure 2.7B-26 shows the relative water levels of the three observation wells versus the PZM3 pumping well. All data presented have been corrected for barometric pressure (BP) fluctuations. The PZA aquifer at this location is highly efficient with respect to BP. Barometric efficiency (BE) ranges between 0.82 and 0.87 for the wells monitored during testing. Additional details on the BE evaluation are provided in the pump test data report for the PZM3 pump test, provided in Addendum 2.7-D.
Figure 2.7B-27 shows a closeup view of water level data in the PZA at early time, as the water level in the well nears the level of maximum drawdown in approximately five minutes. The drawdown observed in the pumping well (32.1 feet) is not reflective of the water levels calculated outside of the well completion, as the pumping well is only approximately 10.5 percent efficient. Based on a Theis prediction of drawdown at a distance of one foot from the well, the predicted drawdown is only 4.2 feet for the duration of the test. Additional details of the well efficiency evaluation are presented in Addendum 2.7-D.

No drawdown response was observed in the overlying SM3 and OM3 well, as seen in the water level data presented in Figures 2.7B-28 and 2.7B-29. Water level data from well

UM3R from the underlying unit is presented in Figure 2.7B-30 and shows an overall water level decline in the well, but no apparent decline related to pumping in the PZM. The steady decline in water level in this well possibly reflects the impacts of well development by airlifting and shows that the well had yet to reach equilibrium and static water level until approximately October 24, whereupon the water level in the well leveled out at approximately 315.7 ft btoc.

Aquifer characteristics of transmissivity (T) and storativity were evaluated in the PZA aquifer and are summarized in Table 2.7B-13. Drawdown data at the observation wells were analyzed by a Theis (1935) curve match, applying the Jacob correction (previously described in Section 2.7.2.7.1) for the partially saturated PZA aquifer. Straight-line analysis by the Cooper-Jacob method, and correcting drawdown for a partially saturated aquifer, were also evaluated from the PZA observation well drawdown data. Recovery data in the pumping well and observation wells were analyzed according to the straight-line Theis (1935) analysis.

Calculated T results from the Theis drawdown data for wells PZM11, PZM12, and PZM13 were 587 ft^2/day, 830 ft^2/day, and 1327 ft^2/day, respectively, and calculated storativity values were 1.0×10^{-5}, 2.0×10^{-4}, and 8.3×10^{-4}, respectively. Calculated T values from the straight-line Cooper-Jacob analysis for these three observation wells were 535 ft^2/day, 841 ft^2/day, and 1428 ft^2/day, respectively. The calculated S values from these analyses were 2.7×10^{-5}, 1.9×10^{-4}, and 6.2×10^{-4}, respectively (see Addendum 2.7-D for analyses). A comparison of results from the Theis and Cooper-Jacob analytical methods indicate similar values for T and S at each observation well. Recovery data were analyzed for the pumping well and T was calculated at 588 ft^2/day. Transmissivity from recovery data for well PZM11 was slightly higher than calculated from the drawdown data, at 748 ft^2/day. Calculated T from recovery for wells PZM12 and PZM13 was slightly lower at 748 ft^2/day and 1131 ft^2/day, respectively. Calculated hydraulic conductivity for the PZM3 pumping well and observation wells PZM11, PZM12, and PZM13 was 5.4 ft/day, between 4.9 and 6.9 ft/day, and between 6.9 and 7.7 ft/day, respectively.

A comparison to historical pump testing can be evaluated at locations RI-6 and RI-42C (see Figure 2.7B-7), the results of which are summarized in Table 2.7B-9. RI-6, which is located approximately 2,000 feet northeast of PZM3 and within the identified ore body, had a reported T value of between 105 and 109 ft^2/day and a hydraulic conductivity of approximately 1.6 ft/day. The lower T found at this location within the ore body is not unexpected, as ore generally accumulates in the less permeable channel sands. Historical well RI-42C, located approximately 2,000 feet east of PZM3, has a reported transmissivity of 504 ft^2/day and conductivity of 6.8 ft/day, which is similar in scale to the results of testing at the PZM3 cluster.

Single-Well SM Pump Test

A single-well test was conducted in the water table SM unit at well SM3 on September 27, 2011 and water levels in the pumping well were monitored. The well was pumped at an average rate of 0.6 gpm for 19 minutes until water reached below the pump intake, resulting in a drawdown of approximately 8.4 feet. A hydrograph of the pump test water level data is presented in Figure 2.7B-31. Based on this hydrograph, most of the withdrawn water came from wellbore storage, and water level had only recovered to within 4.3 feet of initial static water level after approximately 2.85 days.

Recovery data were evaluated by a straight-line fit according to Theis (1935) to evaluate transmissivity. Transmissivity was calculated to be 0.014 ft^2/day and a calculated hydraulic conductivity of approximately 0.002 ft/day (Table 2.7B-13) in the SM unit at this location. Based on these data, and the lack of sustainable yield in this well, the SM unit does not meet the definition of an aquifer at this location.

Single-Well Overlying Aquifer Pump Test

A single-well test was conducted in the overlying aquifer at well OM3 on September 27, 2011 and water levels in the pumping well were monitored. The well was pumped an average rate of 2.6 gpm for 28 minutes, resulting in approximately 23.7 feet of drawdown. A hydrograph of pump test water level data is presented in Figure 2.7B-32.

Transmissivity by a straight-line fit of recovery data according to Theis was calculated to be 0.049 ft^2/day (Table 2.7B-13). Hydraulic conductivity in the overlying aquifer at this location is approximately 0.005 ft/day.

Single-Well Underlying Unit Pump Test

A single-well test was conducted in the underlying unit at well UM3R on November 4, 2011 and water levels in the pumping well were monitored. The well was pumped an average of 1.9 gpm for 27 minutes, resulting in approximately 104 feet of drawdown. A hydrograph of the pump test water level data is presented in Figure 2.7B-33. Based on this hydrograph, most of the withdrawn water is from wellbore storage. Recovery in this well after just over 3 days was only within approximately one foot of the initial static water level.

Calculated transmissivity of the recovery data according to Theis is 0.074 ft^2/day. Hydraulic conductivity in the underlying unit at this location is approximately 0.005 ft/day (Table 2.7B-13). Based on these data and lack of sustainable yield observed at this well, the underlying unit does not meet the definition of an aquifer at this location.

Well Completion Problems at Well UM3

The initially installed underlying UM3 well was discovered to be in communication with the PZA during a step-rate test conducted in well PZM3 on September 14, 2011. Figure 2.7B-34 illustrates the water level response in well UM3 (located 31 feet from the pumping well) and the response in observation well PZM11 (located 52 feet from the pumping well) versus the water level in the PZM3 pumping well. The scale of drawdown during testing is similar in the responses observed at the PZM11 well and the UM3 well (approximately three feet), which indicates that well UM3 was directly connected to the PZM. This figure is illustrative of a typical response expected resulting from faulty well completion.

Based on field reports by AUC, it was concluded that well UM3 was irreparably damaged during well completion. After the UM3 well casing was cemented and allowed to cure, underreaming was conducted. During the underreaming operations, two blades were severely bent while reaming a four to five feet thick hard carbonate layer immediately above the underlying unit. After completion of the underreaming, the damaged underreaming blades could not be retracted into the bit. Withdrawal of the bit resulted in pressure on the inside of the well casing and caused casing distortion and left continuous grooves inside the well casing, which were visible at the surface. The well was completed, but as the results of the step test conducted at PZM3 show, the intended underlying unit completion interval was compromised by the lack of casing integrity and direct communication with the PZA and underlying unit resulted. Based on this data, the well was plugged and abandoned, and replacement well UM3R was successfully installed to the underlying unit.

It is noted that this response shows what direct communication between adjacent aquifers looks like and has not been seen anywhere else in the project area during any hydrologic investigations.

PZM3 Pump Test Summary

Pump testing was conducted in the partially saturated PZA at well PZM3. A drawdown response was measured at 0.7 feet in an observation well 199 feet from the pumping well. No responses were observed in the overlying aquifer and underlying unit, indicating the PZA in this area is isolated from these adjacent intervals.

Average transmissivity in the PZA at the PZM3 well cluster is approximately 924 ft^2/day from drawdown data and 804 ft^2/day from recovery data analysis. Hydraulic conductivities average approximately 7.4 to 8.4 ft/day. Storativity values range between 1.0×10^{-5} and 8.3×10^{-4} (see Addendum 2.7-D for analyses). Historical testing near the PZM3 cluster was conducted at wells RI-6, RI-7, and RI-42C (see Figure 2.7B-7) which are generally located within the ore body in this vicinity east and northeast of PZM3.

Transmissivity values were less than those calculated at the PZM3 cluster, ranging from approximately 105 to 504 ft^2/day.

2.7.2.7.3 PZM4 Well Cluster Pump Testing

The PZM4 well cluster is located in the SW ¼ of Section 29, T43N, R74W (see Figure 2.7B-6). Multi-well pump testing of the PZA aquifer was conducted in well PZM4D during August 2011, and single-well tests of the overlying aquifer and underlying unit were conducted during September and October 2011. Testing was conducted to evaluate the hydrologic characteristics of the PZA, overlying aquifer, and underlying unit, and to demonstrate isolation of the PZA with respect to these adjacent intervals. A more detailed report of these testing activities is provided in the PZM4 data package, included as Addendum 2.7-D. The results of testing indicate that no drawdown responses were observed in the overlying aquifer or underlying unit, demonstrating that there is sufficient confinement at this location for the purposes of ISR operations.

A hydrostratigraphic diagram for the PZM4 well cluster integrating geophysical log data and water level data is presented in Figure 2.7B-18. The PZA at the PZM4 well cluster is fully saturated and bifurcated by an internal mudstone unit that separates the PZA into upper and lower sand units. Based on potentiometric data in the upper PZA at well PZM4, hydraulic head in the upper PZA is approximately five feet higher than that observed in the lower PZM. Pumping for this test was conducted in the lower PZA at pumping well PZM4D. The upper PZA, as depicted on the geophysical log in Figure 2.6A-8 in Addendum 2.6-A, is approximately 40 feet thick, from depths of 220 to 260 feet bgs. The mudstone unit observed in this well cluster is approximately 40 feet thick, observed between depths of 260 to 300 feet bgs (Figure 2.6A-8). The lower PZA is approximately 80 feet thick from this log, extending to a depth of approximately 380 feet bgs.

The overlying aquifer at this location is approximately 75 feet thick at well OM4, occurring between depths of approximately 95 to 170 feet bgs. Depth to water in the overlying aquifer is approximately 93 feet bgs at this location, and thus the aquifer is partially saturated. The overlying OA aquitard is approximately 35 feet thick, extending to the top of the upper PZM. The underlying unit at well UM4 is approximately 17 feet thick, separated from the lower PZA by approximately 35 feet of the underlying UA aquitard.

For the multi-well pump test conducted at well PZM4D, two additional wells completed in the lower PZA (PZM16 and PZM15) were monitored during testing. Well PZM4, completed in the upper PZA and located 57 feet from the pumping well, was also monitored during testing. Wells PZM17 and PZM14, located approximately 2,800 feet southwest and 6,200 feet northeast of the PZM4D pumping well, respectively, were also monitored during testing. It is noted that the PZA at well PZM17 appears continuous and the mudstone unit observed at the pumping well is not present. At well PZM14, the completion zone appears to correspond to the upper portion of the PZA, but the lateral continuity of the unidentified mudstone that bifurcates the PZA has not been established at distance from the PZM4 cluster.

Water levels in the overlying aquifer at well OM4 and water levels in the underlying unit at well UM4 were monitored during testing to demonstrate hydraulic isolation between the PZA and these aquifer units. Piezometers OAM4S, completed in the upper Felix Coal portion of the OA aquitard, and OAM4D, completed in the lower Felix Coal, were also monitored during testing.

Two short-term single-well tests were conducted in wells OM4 and UM4 in the overlying aquifer and underlying unit, respectively. The following summary details the results of the multi-well and single-well testing conducted at this location.

PZM4D Multi-Well Pump Test

During the pump test conducted in pumping well PZM4D between August 9 and August 16, 2011, there was an issue with the pump at approximately 8,375 minutes into the test (5.82 days, on August 15, 2011). This is visible on the hydrograph of showing water level data from the pumping well in Figure 2.7B-35. Based on water level data, there was a dramatic drop in pumping rate for approximately two hours, and based on the data available from monitoring the pumping rate, it was estimated that the pump slowed down to approximately 6 gpm during this pumping problem. It does not appear that the pump shut off, but no explanation is possible to characterize this problem based on the available field data. The pump test was conducted for a total of 10,050 minutes (6.98 days) until the pump was shut off, and the average pumping rate over this interval is approximately 14.1 gpm. Drawdown data from testing was analyzed for all data up to 8,375 minutes utilizing a pumping rate of 17.6 gpm. The pumping rate utilized for analysis of recovery data was 14.1 gpm.

Total drawdown observed in the pumping well PZM4D was 119.2 feet at the time of test shut-in; drawdowns observed in wells PZM16, PZM15, and PZM17 were 1.2 feet, 4.5 feet, and 0.3 feet, respectively (Table 2.7B-14). Figures 2.7B-35 through 2.7B-38 show the relative water levels of observation wells PZM16, PZM15, PZM17, and PZM14, respectively, versus water level in the pumping well. Figure 2.7B-39 presents water level data in the upper PZA at PZM4 versus water level data in the pumping well PZM4D.

No response was observed in well PZM14, located almost 6,200 feet northeast of the pumping well. All data analyzed and presented has been corrected for barometric pressure fluctuations. The barometric efficiency (BE) of the PZA aquifer ranged between 0.46 to 0.58 at wells PZM16, PZM17, and PZM15. The BE calculated to the northeast at well PZM14 was slightly higher at 0.78. Additional details of the BE evaluation are provided in the pump test data report for the PZM4D pump test, provided in Addendum 2.7-D.

It is noted that the drawdown does not correspond directly with distance in the observation wells (Table 2.7B-14), as the drawdown observed in well PZM15 (approximately 1,800 feet east of PZM4D) was 4.5 feet, but only 1.2 feet in well PZM16 (located approximately 1,300 feet south of PZM4D). Drawdown observed in the upper PZA at well PZM4 (located 57 feet from the pump wells) was only 0.6 feet, indicating that the upper PZA at this location is not in direct hydraulic communication with the lower PZA (which is also supported by potentiometric data and the approximate five feet difference between head in the upper and lower PZM).

No drawdown response was observed in the overlying OM4 well, as seen in Figure 2.7B-40. Piezometers OA4S and OA4D, completed in the two Felix Coal seams in the OA aquitard, also did not show a drawdown response to pumping (Figure 2.7B-41). There is an apparent rise in water level that is coincident with pumping that is likely related to the "Noordbergum effect" or "reverse water-level fluctuation" previously described in Section 2.7.2.7.1. This phenomena is not related to any hydraulic connection of aquifers. No drawdown response was observed in the underlying UM4 well, as seen in Figure 2.7B-42, and this well also exhibited what appears to be a "Noordbergum effect" response (water levels have been observed to rise or fall in response to changing pore pressure) as there was an approximate drop in water level of 0.2 feet that corresponds to the start of pumping, and a similar rise that was coincident with the end of pumping.

Aquifer characteristics of transmissivity (T) and storativity (S) were evaluated in the PZA aquifer and are summarized in Table 2.7B-15. Drawdown data (up to 8,375 minutes, before pump problems) were analyzed according to Theis for wells PZM16 and PZM15. Recovery data were analyzed for the PZM4D pumping well and observation wells. Transmissivity results from the drawdown data at well PZM16 was 229 ft^2/day and a calculated storativity of 8.7 x 10^{-4}. At well PZM15, T from drawdown was 57 ft^2/day, and a calculated S value of 1.3 x 10^{-4} (see Addendum 2.7-D for analyses). Transmissivity evaluated from recovery data was in good agreement with the drawdown data, 286 ft^2/day at PZM16 and 63 ft^2/day at PZM15. Transmissivity from recovery data in the pumping well was 31 ft^2/day, approximately half that observed at PZM15 and significantly less than at PZM16. A definitive analysis of PZM17 could not be conducted due to the later time data (due to pump problems), but the data suggest that the transmissivity in this well is even higher than at well PZM16.

Based on the observed drawdowns and calculated transmissivities, it appears that the PZA is more conductive to the south of pumping well PZM4D (at well PZM16) versus data to the east at well PZM15. The drawdown at PZM16 is almost four times less than that observed at PZM15, even though PZM16 is closer to the pumping well, and transmissivity at PZM16 is approximately four times greater than at PZM15. Preliminary results at PZM17 to the southwest also suggest a more transmissive PZA in this location. The increase in T observed west of PZM4D is likely a function of increasing sand thickness where the bifurcation of the PZA by a mudstone pinches out. The mudstone in the PZA at PZM4 area was not observed in PZM17.

Single-Well Overlying Aquifer Pump Test

A single-well pump test was conducted on September 29, 2011 in the overlying aquifer at well OM4. The well was pumped at an average rate of 3.5 gpm for 95 minutes and subsequently pumped at an average rate of 3.8 gpm for 94 minutes, for a total of 189 minutes, resulting in 100.5 feet of drawdown. A hydrograph of water level data from well OM4 is presented in Figure 2.7B-43.

Recovery data were analyzed by a straight-line fit according to Theis (1935) that accounts for the variable pumping rate in the well, the results of which are presented in Table 2.7B-15. A transmissivity value of 262 ft^2/day was calculated from the data. Calculated hydraulic conductivity based on 82 feet of saturated thickness is approximately 3.2 ft/day.

Single-Well Underlying Unit Pump Test

A single-well pump test was conducted in the underlying unit at well UM4 on October 14, 2011. The well was pumped at an average rate of 6.1 gpm for 23 minutes, resulting in 188 feet of drawdown. A hydrograph of the water level data is presented in Figure 2.7B-44. Based on this hydrograph, most of the withdrawn water is from wellbore storage.

Recovery data were analyzed by a straight-line Theis fit, the results of which are presented in Table 2.7B-15. Calculated transmissivity in the well was determined to be 0.22 ft^2/day, and based on a saturated thickness of 17 feet, hydraulic conductivity was calculated to be 0.013 ft/day. Based on these data and the lack of sustainable yield observed in this well, the underlying unit does not meet the definition of an aquifer at this location.

Felix Coal Piezometers Yield

Piezometers were installed in the Upper and Lower Felix Coal seams (wells OA4S and OA4D, respectively) to evaluate the characteristics in the Felix within the overlying OA aquitard. During development of these wells, the Upper and Lower Felix coal seams yielded less than 0.25 gpm and 1.0 gpm, respectively, and went dry. Based on this, the Upper and Lower Felix Coals are not considered aquifers because:

- The definition of an aquifer per NRC, 10 CFR Part 40 Appendix A, states: "*Aquifer means a geologic formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs*"; and
- The definition of an aquifer per Wyoming DEQ-LQD Guideline 8 Hydrology Coal and Non-Coal states: "*A zone, stratum, or group of strata that stores and transmits water in sufficient quantities for a specific use*".

Based on the lack of sustainable yield in these coal seams, the Felix Coal is not considered an aquifer at the Proposed Project area.

PZM4D Pump Test Summary

Pump testing was conducted in the fully saturated lower portion of the PZA at well PZM4D. Drawdown responses were not radially symmetrical with respect to distance from the pumping well and based on transmissivity evaluations, it is apparent that the PZA is more conductive to the south and southwest in relation to the pumping well. No responses were observed in the overlying aquifer and underlying unit, indicating that the PZA in this area is isolated from these adjacent intervals.

Transmissivity at the pumping well was approximately 31 ft^2/day, slightly higher to the east at well PZM15 (between 57 ft^2/day and 63 ft^2/day), and significantly higher to the south at well PZM16 (between 229 ft^2/day and 286 ft^2/day). Hydraulic conductivities at these three locations ranged between 0.3 and 2.9 ft/day. Calculated storativity values were between 8.7×10^{-4} and 1.3×10^{-4} (see Addendum 2.7-D for analyses). Historical testing near the PZM4 well cluster was conducted at nearby several locations, including RI-28 to the south of PZM4D, RI-1 and RI-2 to the southwest of PZM4D, and MP-09 east of PZM4D (see Figure 2.7B-7, and Table 2.7B-9 for the results summary). Transmissivity at the RI-28 area was between 176 ft^2/day to 217 ft^2/day, which is consistent with the increased T seen at well PZM16. Calculated T at RI-2 (approximately 1,300 feet southwest of PZM4D) ranged between 156 ft^2/day to 189 ft^2/day, and was between 639 ft^2/day and 868 ft^2/day at RI-1 (located approximately one mile southwest of PZM4D). At the MP-09 location east of PZM4D, reported transmissivities ranged between 45 ft^2/day and 62 ft^2/day, which are consistent with the results observed at PZM15.

2.7.2.7.4 PZM5 Well Cluster Pump Testing

The PZM5 well cluster is located in the SW ¼ of Section 36, T43N, R74W (see Figure 2.7B-6). Multi-well pump testing of the PZA was conducted between February 16-24, 2011, and single-well tests of the shallow water table SM unit, overlying aquifer, and underlying unit were conducted in September and October 2011. Testing was conducted to evaluate the hydrologic characteristics of the PZA, SM unit, overlying aquifer, and underlying unit, and demonstrate isolation of the PZA with respect to these adjacent intervals. A more detailed report of these testing activities is provided in the PZM5 data package, included as Addendum 2.7-D. The results of testing indicate that the PZA at this location is hydraulically connected at the PZA monitoring locations, and no drawdown responses were observed in the SM unit, overlying aquifer, or underlying unit, indicating sufficient confinement of the PZA at this location (see Table 2.7B-16).

A hydrostratigraphic diagram for the PZM5 well cluster integrating geophysical log data and water level data is presented in Figure 2.7B-19. The PZA at the PZM5 cluster is fully saturated and occurs between depths of approximately 185 to 330 ft bgs, as seen in the geophysical type log for the area in Figure 2.6A-7, with mineralization present near the middle of the PZM. Depth to water at PZM5 is approximately 129 ft btoc, resulting in approximately 58 feet of confining head at the pumping well. The unidentified mudstone is present at this location (between depths of approximately 250 to 260 ft on Figure 2.6A-7), resulting in a net sand thickness of approximately 132 feet in the pumping well. The PZM5 pumping well is completed across the entire PZA interval, with the screen placed across the lower sand of the PZA and sanded up to the top of the PZM. Observation wells PZM20 and PZM19 (located 499 feet and 1,048 feet north of PZM5, respectively) are completed with 20 foot screen intervals in the lower sand of the PZM. Well PZM18 is located 2,085 feet north of PZM5 and is completed in the upper sand of the PZM. Well PZM6 (2,085 feet northwest of PZM5) is completed in the lower sand of the PZA, but based on the log for this well, the upper sand is not present at well PZM6. The BLM All Night Creek well ANCVSS, located 4,025 feet west of PZM5, was also monitored and is also completed at depths that correspond to the lower sand of the PZM.

Based on the potentiometric surface presented in Figure 2.7B-9, there does not appear to be an observable head differential between the upper and lower sands of the PZM. This is seen by the consistency of hydraulic gradient observed in the general direction of groundwater flow between wells PZM20 and PZM18. Additional characterization of the potentiometry and confining nature of the unidentified mudstone in this vicinity will be conducted at a later date upon initiation of wellfield-scale hydrologic testing.

The water table SM unit is encountered at depths of approximately 30 to 50 feet, with a saturated thickness of 14 feet. The overlying aquifer is approximately 12 feet thick from 70 to 82 feet at well OM1, with a confining head of approximately 35 feet. The overlying OA confining zone is approximately 100 feet thick, as seen in the type log in Figure 2.6-14. The underlying unit is approximately 18 feet thick at well UM1, and isolated from the PZA by the underlying UA aquitard which is approximately 105 feet thick.

For the multi-well pump test at PZM5, five PZA observation wells were monitored during testing, located between 499 and 4,026 feet from the pumping well (see Table 2.7B-16). Water levels in the water table SM unit, overlying aquifer, and underlying unit were also monitored to demonstrate hydraulic isolation between the PZA and adjacent aquifer units.

Single-well pump tests were conducted in wells SM1, OM1, and UM1 to evaluate the aquifer characteristics in the overlying aquifer and underlying unit. The following summary presents the details of testing at the PZM5 cluster.

PZM5 Multi-Well Pump Test

The pump test at PZM5 was initially started on February 7, but was aborted on February 10 due to sub-zero freezing conditions which affected the pump. Water levels were allowed to recover for approximately seven days to static conditions prior to the initiation of the pump test. Pumping well PZM5 was pumped at an average rate of 10 gpm for 11,393 minutes (7.91 days) from February 16-24. Total drawdown observed in the pumping well was 102.1 feet; drawdowns observed in observation wells PZM20, PZM19, PZM18, PZM6, and BLM ANCVSS were 11.7 feet, 4.3 feet, 0.8 feet, 0.9 feet, and 0.2 feet, respectively, and are summarized in Table 2.7B-16. Figures 2.7B-45 and 2.7B-46 shows the relative water levels of these observation wells versus the pumping well. All data presented have been corrected for BP fluctuations. The barometric efficiency (BE) of the PZA aquifer at this location varies between 0 (no apparent trend in pumping well PZM5) to between 0.05 and 0.57 at the PZA observation wells. Additional details regarding the BE evaluation is provided in the pump test data report for the PZM5 pump test, provided in Addendum 2.7-D.

No drawdown response was observed in the water table SM unit, the overlying aquifer, or the underlying unit, indicating that the PZA is isolated hydraulically from these aquifers at this location. Hydrographs of the SM1, OM1, and UM1 wells with respect to water level data in the PZM5 pumping well are presented in Figures 2.7B-47 to 2.7B-50, respectively. The hydrograph response in wells SM1 and OM1 show an apparent rise in water level that is coincident with pumping in PZM5. It is speculated that this is phenomenon is related to the “Noordbergum effect” or “reverse water-level fluctuation” that occurs in layered confined aquifer systems (Hsieh, 1996). Conventional groundwater theory does not account for this effect, and is explained by poroelastic theory. Poroelastic theory considers that “drawing down and aquifer produces time-dependent volumetric contraction and, hence, induced increases in pore pressure in the aquifer, adjacent confining layers, and adjacent aquifers” (Wang, 2000). This observed water level increase is not due to hydraulic communication between the PZA and the overlying aquifer and SM unit.

In order to account for the completion interval of the PZM5 pumping well, which is completed across the entire PZA, an estimated flow was apportioned for the lower sand of the PZM. This was necessary to complete analysis of observation wells PZM20 and PZM19, both of which are completed in the lower PZM. The flow in the lower PZA was estimated at seven gpm (of the total 10 gpm that was pumped) based on the curve match provided by Theis drawdown analysis.

Aquifer characteristics of transmissivity (T) and storativity (S) were evaluated in the pumping well and two closest observation wells PZM20 and PZM19 and are summarized in Table 2.7B-17. Based on the drawdown observed in these two observation wells, it was determined that the drawdown data matches a leaky confined model, as the change in drawdown at later time decreased. Based on geologic information during drilling, it was observed that in the area west of PZM5, the PZA is coarser grained and gravel deposits were noted. It is postulated that at later time, a higher transmissive portion of the aquifer (i.e., more permeable sand) is encountered, thus decreasing the rate of drawdown with time for these observation wells. A Theis curve match was attempted on the data, but a defensible match could not be made to account for the late time data. The Hantush-Jacob analytical method (1954), which assumes a leaky confined aquifer with no aquitard storage, was utilized on the drawdown and this solution provided a good match for mid- to late-time data. A Cooper-Jacob straight-line match was also evaluated on the drawdown data at well PZM20. A straight-line Theis recovery analysis was conducted on the recovery data at the pumping well and PZM20 and PZM19.

Based on the recovery analysis of data at the pumping well PZM5, a transmissivity value of 61.8 ft^2/day was calculated. Based on a sand thickness of 132 feet at this location, the calculated hydraulic conductivity is 0.5 ft/day. For well PZM20, transmissivity from the leaky solution for drawdown is 20.2 ft^2day, the straight-line analysis transmissivity is 26.7 ft^2/day, and the recovery data analysis indicates a transmissivity value of 31.0 ft^2/day. Based on a sand thickness of 47 feet at this well, hydraulic conductivity is between 0.4 and 0.7 ft/day from these analyses. At well PZM19, transmissivity from the leaky solution for drawdown is 26.0 ft^2/day and 47.0 ft^2/day from the recovery analysis. Based on the sand thickness of 56 feet at this well, hydraulic conductivity at PZM19 is between 0.5 ft/day and 0.8 ft/day. Calculated storativity values for the two observations wells range between 6.5×10^{-5} and 1.1×10^{-4} (see Addendum 2.7-D for analyses).

Single-Well SM Pump Test

A single-well pump test was conducted in the water table SM unit on October 4, 2011 and water levels in the pumping well were monitored. The well was pumped at an average rate of 1.7 gpm for nine minutes. A hydrograph of water level data is presented in Figure 2.7B-51. The rapid decline in water level indicates that most of the water removed was from wellbore storage and therefore the water level recovery data were utilized for transmissivity determination.

Transmissivity was determined by a straight-line fit to recovery data according to Theis, the results of which are summarized in Table 2.7B-17. A T value of 0.26 ft^2/day was determined for the SM unit at this location, and hydraulic conductivity was calculated at

0.019 ft/day. Based on these data and the lack of sustainable yield observed at this well, the SM unit does not meet the definition of an aquifer at this location.

Single-Well Overlying Aquifer Pump Test

A single-well pump test was conducted in the overlying aquifer on September 30, 2011 and water levels in the pumping well were monitored. The well was pumped at an average rate of 3.3 gpm for 135 minutes, resulting in 22.7 feet of drawdown. A hydrograph of water level data is presented in Figure 2.7B-52.

Transmissivity was determined by a straight-line fit to recovery data according to Theis, the results of which are summarized in Table 2.7B-17. A T value of 39.1 ft^2/day was determined and hydraulic conductivity is approximately 3.3 ft/day.

Single-Well Underlying Unit Pump Test

A single-well pump test was conducted in the underlying unit on October 18, 2011. The well was pumped at an average rate of 4.3 gpm for 27 minutes. A hydrograph of water level data from well UM1 is presented in Figure 2.7B-53. The rapid decline in water level indicates most of the water withdrawn was from wellbore storage.

Transmissivity was determined by a straight-line fit to recovery data, the results of which are summarized in Table 2.7B-17. A T value of 0.44 ft^2day was determined and hydraulic conductivity in the underlying unit at this location is approximately 0.024 ft/day. Based on these data and the lack of sustainable yield observed in this well, the underlying unit does not meet the definition of an aquifer at this location.

PZM5 Pump Test Summary

Pump testing was conducted in the fully saturated PZA aquifer at well PZM5. Drawdown was observed to a distance greater than 4,000 feet in the PZA aquifer. No responses to pumping were observed in the SM unit, overlying aquifer, or underlying unit, indicating that the PZA in this area is isolated from adjacent aquifers.

Transmissivity in the entire PZA at well PZM5 was approximately 62 ft^2/day. Transmissivity in the lower PZA was approximately 25 ft^2/day from drawdown data and between 31 ft^2/day and 47 ft^2/day from recovery analysis. Hydraulic conductivities from all analyses range between 0.4 and 0.8 ft/day. Storativity values were between 6.5×10^{-5} and 1.1×10^{-4} (see Addendum 2.7-D for analyses).

2.7.2.7.5 Hydrologic Testing Summary and Conclusions

Based on testing conducted by AUC at the Proposed Project area, the following presents a general summary of results that impact the proposed ISR operations.

- The PZA is a discrete and continuous aquifer and is geologically confined across the entire project area;
- The PZA is fully saturated in the western portion of the project and transitions to partially saturated conditions in the eastern third of the site;
- Hydrologic testing completed at four separate locations across the project area provides substantial characterization of the PZA necessary for this license application;
- Calculated transmissivities were found to vary across the site, between 20 ft^2/day to 1,428 ft^2/day; calculated hydraulic conductivities range between 0.3 ft/day and 13 ft/day;
- No drawdown responses were observed during any pump testing in the overlying aquifer and underlying unit, indicating that there is adequate confinement of the PZA for the purposes of ISR operations;
- Based on the results of testing, no hydrologic boundaries were detected in the PZA;
- Transmissivities were evaluated at multiple locations in the water table SM unit, overlying aquifer, and underlying unit. In general, these units have significantly lower transmissivities in relation to the PZA. These units are discontinuous across the project area;
- Based on the lack of sustainable well yields and extremely low values of transmissivity evaluated in the two pump tests conducted in the perched water table SM unit and the four tests conducted in the underlying unit, these intervals do not meet the definition of an aquifer;
- As discussed in Section 3.1.6 of this TR, AUC anticipates monitoring the wells completed in the SM unit and underlying unit for a limited time. No additional wells will be installed in these units in the future, unless they meet the definition of an aquifer; and
- In addition, a site-wide groundwater model based on the hydrologic data collected within the Proposed Project area is presented in Section 4.4.2 of the ER, and is included as Addendum 2.7-C.

2.7.2.8 Powder River Basin CBM Groundwater Study

The Wyoming Geological Survey, in cooperation with the U.S. Bureau of Land Management (BLM), presents a hydrologic study by Clarey (2009) that utilizes data from a basin-wide monitoring well network from 1999 to 2006 to evaluate drawdown in the mined coal seam and adjacent sandstone aquifers. The following discussion is provided to address the potential competing interests of CBM in the area and in-situ uranium production in the Wasatch Formation at the Proposed Project. Results of the study in this vicinity indicate that while there is significant drawdown in the Big George coal seam from local CBM production, drawdown in the adjacent sandstone intervals is an order of magnitude or less than the drawdown observed in the coal seam, and decreases as depths become shallower.

One of the most complete data sets is from the All Night Creek monitor well cluster, which is located in the SW ¼ of Section 36 of T43N, R 74W. This well cluster is located approximately 4,000 feet west of the PZM-5 well cluster (see Figure 2.7B-6). In addition to the monitored Big George coal seam, four sandstone aquifers overlying the Big George have also been monitored for this study. The coal seam is screened from depths of 984 to 1,051 feet below ground surface (feet bgs), the overlying sand above this is screened from depths of 840 to 860 feet bgs (well name ANCS), the next overlying sand is screened from depths of 580 to 640 feet bgs (well ANCSS), the next overlying sand from 350 to 420 feet (well ANCVSS) and the next overlying sand from 200 to 240 feet bgs (well ANCVVSS). The ANCVSS well is completed in the equivalent PZA aquifer of the Proposed Project from 350 to 420 feet bgs, and the ANCVVSS is completed across the overlying aquifer. Figure 2.7B-54 presents a schematic diagram of the completion intervals at this location from a well log run through casing at the ANCSS well, with a comparison to the well log from the RC006 strat hole at the PZM6 well cluster (approximately 2,000 feet east-northeast of the ANCVSS well). It is apparent from the gamma ray spikes indicating mineralization that the sand interval of the ANCVSS well is equivalent to the PZA aquifer.

The results of water level monitoring at the All Night Creek well cluster location indicates that while the maximum drawdown in the coal seam is over 600 feet, there is minimal to no observable drawdown seen in the overlying sand aquifers. Hydrographs of the ANCC (Big George coal) well is presented in Figure 2.7B-55. Figure 2.7B-56 shows water level data in the ANCS and ANCSS wells, which represents the two sandstone aquifers above the Big George. Figure 2.7B-55 shows water level data from the ANCVSS and ANCVVSS wells, which correspond to the PZA and overlying aquifers, respectively. Over 600 feet of drawdown is observed in the Big George coal and only approximately seven to eight feet of water level decline is observed in the ANCS (Deep Sand) well. In the next overlying sandstone (ANCSS), water level declined approximately four to five feet over a period of approximately 10 years (Figure 2.7B-54). As seen in Figure 2.7B-57, there is no observable water level decline in the ANCVSS well (PZA aquifer equivalent) or the shallowest ANCVVSS well (Overlying aquifer equivalent) over a period of approximately nine years.

As the stratigraphic section of the lower Wasatch Formation and upper Fort Union is a complex and heterogeneous system of stratified fluvial deposits, the propagation of drawdown away from the coal seam (if even observed at all) is dampened with vertical distance away from the coal seam through multiple sequences of sand and shale. This behavior is observed near the Proposed Project, and these data indicate that there will be no expected hydraulic communication that will be observed between in-situ uranium production and the underlying groundwater withdrawals associated with CBM development.

2.7.2.9 Groundwater Use

An inventory of groundwater wells within a two mile radius of the Proposed Project area boundary was conducted based on information available from the Wyoming State Engineer's Office (SEO). Table 2.7B-18 summarizes the groundwater wells appropriated for stock, domestic, miscellaneous, and industrial usage. The locations of these wells are shown on Figure 2.7B-58. Table 2.7B-19 summarizes the groundwater wells that are appropriated for coal bed methane (CBM) usage, and the locations of these wells are shown on Figure 2.7B-59. The details and locations of all groundwater wells presented are based on data obtained from the SEO and are a composite of data collected from the Old Water Rights Database (http://seo.state.wy.us/wrdb/index.aspx) on 04/1/2011, a shape file obtained from (ftp://seoftp.wyo.gov/geolibrary_data) on 09/13/2010, and the new e-Permit System (https://seoweb.wyo.gov/e-Permit) on 03/10/2011.

There are 49 identified groundwater wells (non-CBM usage) within two miles of the Proposed Project area indicated as stock, domestic, miscellaneous, and industrial wells (Table 2.7B-18). Based on available depth information on completion intervals from the SEO databases and reviewing available online well record documents, a determination of the aquifer completion zone was made, if possible. This determination was based on the available geologic information within the Proposed Project area on aquifer depths and structural configuration and extrapolated to distance outside of the Proposed Project area if possible.

There are 15 groundwater wells within the Proposed Project area that are noted on Table 2.7B-18. Six of these wells indicate that the water right has been cancelled. Of the nine wells with existing water rights, eight wells are appropriated for stock watering usage. The Taffner #1 well (located in Section 1, 42N, R74W) is the only domestic supply well in the Proposed Project area and is completed to the PZA at this location. AUC will acquire the Taffner property prior to construction and it will not thereafter be used as a residence. The domestic water well located at the Taffner residence will be plugged in accordance with all WDEQ Rules and Regulations and will not be used for consumption once construction begins.

Of the eight stock wells with existing water rights, one is completed to a sandstone interval below the Badger Coal, three are completed in the PZA, and four are completed in the overlying aquifer.

Of the 69 identified non-CBM groundwater wells within three miles of the project area, 56 aquifer determinations were made based on available depth information. Twenty-five of these wells were identified as being completed in the overlying aquifer or above, 23 wells were identified as likely PZA completions, and eight wells were identified as likely having been completed below the PZA.

A discussion regarding the assessment of potential impacts from ISR operations and restoration operations on local groundwater can be found in Sections 7.2.8.1 and 7.2.8.2 of this TR.

There are 324 wells identified as CBM usage or CBM and stock usage within two miles of the Proposed Project area. Based on the available information in the area, the target coal seam for CBM is the Big George Coal within the Fort Union Formation. Reported total depths (when provided) range between 1,424 feet and 631 feet, averaging approximately 1,000 feet (Table 2.7B-19). It is noted that the Big George at the All Night Creek well cluster (see Section 2.7.2.8 on hydrologic impacts of CBM in the project area) is observed between depths of 984 to 1,051 feet. A summary table of all groundwater use can be viewed in Table 2.7B-20 in Addendum 2.7-B.

2.7.2.10 Groundwater Quality

Information related to regional groundwater quality is based upon published literature for the PRB area, related to the aquifers comprising Upper Cretaceous aquifer system and the Lower Tertiary aquifer system. Specific site baseline water quality is based upon the baseline groundwater monitoring program initiated by AUC to collect data required for the WDEQ Permit to Mine as well as the NRC License Application for the Proposed Project.

2.7.2.10.1 Regional Groundwater Quality

Much of the available information on regional water quality is from the relatively shallow Upper Cretaceous and Tertiary formations where sufficient stock and domestic supply can be obtained in most areas of the basin from wells less than 500 feet deep. The following discussion of general water quality is based upon the relatively shallow waters of these formations. In general, wells and springs in the basin utilized primarily for stock water and less domestic supply show consistent total dissolved solids (TDS) concentrations of less than 500 mg/L (Lowry, 1986). Regional analysis of these wells does not include wells determined to be too high in dissolved solids and does not include deeper oil-field related data, and thus is biased toward the higher quality waters with lower dissolved solids.

In general, the length of flow time or flow path from recharge to discharge areas is the dominant factor affecting TDS concentrations in most aquifers. Table 2.7B-21 reports water sampling from the Upper Cretaceous and Lower Tertiary aquifer systems in the Powder River and shows relatively little differences in dissolved solids in the aquifers from the Fox Hills, Lance Formation, Fort Union Formation, and Wasatch Formation. Chemical quality of groundwater is also controlled by the solubility of aquifer rocks and minerals, reactions that occur along groundwater flow paths, the pH and temperature of the water, pressure, and to a lesser degree the length of contact time of the water (Lowry, 1986). The dominant reactions controlling water quality in these aquifers is cation-exchange softening and sulfate reduction. Cation-exchange is a reaction where calcium and magnesium ions are exchanged for sodium from solids such as clay, resulting in softer water. Sulfate reduction occurs due to the presence of organic material to form bicarbonate and sulfide.

Concentrations of manganese and iron in area groundwater samples commonly exceed the National Secondary Drinking Water Regulations standards of 50 and 300 micrograms per liter (ug/L), respectively, which is not an issue for stock watering (Lowry, 1986). Lowry (1986) notes that trace metals concentrations are generally low because these constituents tend to react with sulfide to form relatively insoluble precipitates at natural occurring pH levels. It is noted that concentrations of selenium exceeded the Maximum Contaminant Level (MCL) of 10 ug/L in four of 159 samples tested, and exceeded the MCL for lead (50 ug/L) in six of 165 samples (Lowry, 1986). Single exceedances were reported from available samples for each of the following constituents, including arsenic, barium, and cadmium.

Lance and Fox Hills Water Quality

There are few water quality data in the central portion of the PRB for the Lance/Fox Hills interval. Near the outcrop, there is little difference observed in water quality or major ion concentrations between the waters of the Fox Hills Sandstone and the overlying Lance Formation. Feathers (1981) notes outcrop waters of the Lance and Fox Hills typically have TDS concentrations from 350 to 3,500 mg/L, and having variable major ion composition. Central basin waters typically contain 1,000 to 3,500 mg/L TDS and are typically sodium bicarbonate-sulfate in composition. Feathers (1981) notes that local lithologic variations likely control observed anion composition due to the dissolution of carbonate, gypsum, or pyrite, and cation exchange favors the replacement of sodium for calcium and magnesium. Oil and gas data from the USGS Produced Waters Database and from Wyoming Oil and Gas Conservation Commission (WOGCC) data indicate TDS values for the Lance Formation that range from approximately 1,400 to 2,400 mg/L and from approximately 1,000 to 3,700 mg/L for the Fox Hills.

Rankl and Lowry (1990) describe water quality in the entire Wasatch to Fox Hills sequence. Water from deep wells is soft (sodium plus potassium exceeds calcium plus magnesium) and contain carbonate as well as bicarbonate, with some containing large concentrations of sulfate, while some contain very little. The dominant reaction mechanism controlling water quality is cation exchange and sulfate reduction. Riffenberg (1925) indicated that there is a relationship between water hardness and depth, as water from 100-125 feet is generally soft, and all water below 125 feet is soft. Rankl and Lowry (1990) show a relationship with depth that indicates a decrease in calcium, magnesium, and sulfate and an increase in bicarbonate to a depth of approximately 500 feet. Deeper than 500 feet, the concentration of dissolved solids is relatively uniform. Rankl and Lowry indicate the general decreasing trend in total dissolved solids to a depth of about 500 feet "has not been explained."

Wasatch/FU Water Quality

The Wasatch and Fort Union hydrostratigraphic unit consists of 3,000 feet or more of highly variable lenticular fine-grained sandstones, shales, claystones, and coals. Lithologic variability and the discontinuous and lenticular nature of the sandstones results in a highly variable water quality composition over relatively short distances (Feathers, 1981). Feathers (1981) notes dissolved solids concentrations ranging from 250 to 6,000 mg/L and that there is little correlation between well depth and dissolved solids concentration. Relatively shallow wells in this aquifer show a wide variation in major ion composition, showing either mixed cation concentrations or sodium enrichment (Feathers, 1981). In general, waters less than 500 mg/L dissolved solids are enriched in bicarbonate, while the more saline waters are more enriched with sodium. The major ions concentrations versus well depth (Feathers, 1981) shows an increase in sodium which is attributed to cation exchange of sodium for dissolved calcium or magnesium.

2.7.2.10.2 Proposed Reno Creek Project Groundwater Quality

Water Quality Sampling

AUC installed a large number of ground water monitoring wells to characterize the regional ground water chemistry. The chemical characterization reflects the hydrology and geology within the Proposed Project area. Present within the Proposed Project are two aquifers, the Production Zone and the Overlying Aquifers. The Production Zone is continuous and hydraulically connected across the site. The Overlying Aquifer is the uppermost aquifer within the Proposed Project area and appears continuous on a local scale, but does not correlate with greater distances across the entire Proposed Project site based on geologic and potentiometric data. In addition, there are two units that do not qualify as aquifers due to low yields and transmissivities, which include the shallow water table unit (SM-designated wells) and the deeper underlying unit (UM-designated wells). AUC did, however, install the following monitoring wells in all four units in order to characterize hydrologic and water quality conditions:

- Production Zone Aquifer: 21 wells (designated PZM);
- Overlying Aquifer: 7 wells (designated OM);
- Underlying Unit: 7 wells (designated UM); and
- Surficial (Shallow) Water Table Unit: 4 wells (designated SM; borings were installed and observed to be dry at 3 additional locations).

Water Quality Analysis

Per NUREG 1569 and WDEQ LQD Chapter 11, the objectives of the groundwater characterization required to permit ISR operations included:

- Evaluating the occurrence of groundwater with respect to depth, location and seasonal fluctuations in hydraulic gradient and flow and water quality;
- Determining the dominant water types;
- Assessing potential impacts from non-ISR operations (e.g., CBM production); and
- Assessing how ISR production potentially could impact other water users.

An evaluation of groundwater quality is an important part of the overall groundwater characterization. This evaluation included (a) a general groundwater evaluation (e.g., inorganic concentrations and groupings), (b) review of water quality by formation, and (c) the significance of key indicators to understanding the shallow groundwater system. A summary of groundwater quality results is presented in Tables 2.7B-22 through 2.7B-40.

Proposed Project Aquifers

Because of the large number of ground water samples, several Piper Diagrams were prepared. The Piper diagram uses major ions only (Na+K, Ca, Mg, Cl^-, HCO_3^- + CO_3^{-2}, and SO_4^{-2}) and normalizes concentrations. The purpose of normalization is to show the relative concentrations of the analytes. The normalization also allows for the plotting of these compositions on triangular diagrams. Dilute waters and concentrated waters of similar cation/anion relative abundances will plot at the same locations in the diagram. In preparing a Piper diagram, the relative abundances of cations (as equivalent percentages) are plotted as single points in the left triangle; and the anions are similarly plotted in the right triangle. Because the concentrations are ultimately plotted as percentages of cations or anions on the two triangles, the use of equivalents or milliequivalents will produce the same final result. Figure 2.7B-60 in Addendum 2.7-B shows the Piper diagram for ground water samples from within the Production Zone (PZ). These 15 locations plot in a small area within the red circle. The waters are sulfate dominant and sulfate ranges from about 65 percent to 95 percent when calculated as milliequivalents, with lesser amounts of bicarbonate and chloride percentages less than 5 percent. For the cations, sodium plus potassium represents approximately 50 percent to slightly more than 70 percent of the cation milliequivalents. The similarity of these compositions reflects a continuous and uniform aquifer in the PZA as described in Section 2.7.2.2.

The consistent composition of these waters is related to the geochemical processes responsible for the formation of the ore bodies in the Production Zone. Oxygen bearing ground water reacts with dispersed uranium minerals and causes the uranium to dissolve, the solution continues to migrate and it will react with minerals such as pyrite. The oxidation of pyrite produces the sulfate that is the dominant anion in these waters. Eventually, the available oxygen in these waters is consumed and uranium along with other redox sensitive minerals will precipitate at this boundary. Uranium precipitates as uraninite (UO_2), which is insoluble under anoxic conditions. These redox boundaries can be quite abrupt and result in the precipitation of these minerals over a short distance. Some zonation in the ore body is typically noted, and this may be reflected in differences in the dissolved concentrations of uranium and other trace metals. These differences have been occasionally noted in some samples, but in most cases uranium and trace metal concentrations are consistently low, with most locations within the production zone displaying concentrations less than 0.10 mg/L of U. At this time it is assumed that the concentrations noted in PZM10 (with an average U concentration of 0.47 mg/L) and PZM16 (average U concentration of 0.30 mg/L) reflect some of these redox related processes.

Figure 2.7B-61 in Addendum 2.7-B compares the Overlying Aquifer water samples (designated OM) with the PZ aquifer water samples. For simplicity all but one of the PZ data points have been removed, but the red circle has been retained. PZM3 was selected to represent the PZ waters because it plots near the center of the red circle. The TDS circle (dark brown) has been retained for that point to facilitate comparisons with the OM data points. The OM samples show the greatest variability among the ground water samples at the site. Several samples, specifically OM3, OM2 and OM6 have greater proportions of bicarbonate and more sodium than the PZM samples. Two samples (OM5 and OM7) are similar to the PZM waters and they plot within the red circle. Finally, OM1 and OM4 appear to have greater proportions of calcium than the PZM samples. The variability among the OM samples is likely to be related to the discontinuous nature of this aquifer across the site. OM4 has the greatest proportion of calcium and it appears that the Overlying aquifer in this region is thick and continuous. OM1 is also within a thick aquifer, but it appears to be slightly less continuous. Sodium dominant waters include the OM2 and OM3 samples. Those samples, particularly OM3 appear to be associated more with the aquitard zones rather than the more permeable aquifers. The OM2 sample may be related to a thin aquifer. These samples have lower TDS concentrations than some of the other OM water samples. Using the OM4 and OM3 as “end members”, we can attempt to explain the remaining three samples (OM5, OM6 and OM7). These three samples tend to be associated with the aquitard interval rather than the aquifer. The simplest explanation for the variability among the OM samples is that the samples do not represent one large and continuous formation, which conclusions correlates to the geologic and potentiometric data across the project area that indicates discontinuity within the overlying aquifer.

The variability of the water levels between the OM screened interval and the corresponding PZM well are significant. Using water level data presented by Petrotek (note Table 2.7B-8). The difference in water level (depth) between the OM and PZM levels were calculated. The variability suggests that the OM screened intervals probably represent different water table elevations. There is no evidence to suggest that the OM water elevation represents any type of consistent head. Therefore, at least some of the upper level waters appear to be distinct perched zones reflecting small localized zones.

Proposed Project Water Bearing Non-Aquifer Units

Figure 2.7B-62 is a Piper diagram that presents the shallow SM unit water samples and the underlying unit (designated UM) samples. Several things should be noted. The blue oval represents a range of samples that include all the underlying (UM series) water samples. The oval also would contain several of the overlying aquifer series (e.g., OM3, OM2 and OM6) water samples. Although there is a significant variation in the anion makeup of the waters contained in this oval, the primary cation signature is sodium plus potassium (Na+K). The UM samples are also characterized by more relative chloride than the PZM waters. This may be a reflection of their more dilute nature. The underlying unit is not classified as an aquifer and is discontinuous and lenticular across the site and is included within the underlying aquitard that is predominantly a mudstone with limited thin and discontinuous sand zones. Although UM5 and UM1 are similar to the composition of the CBM waters, these two UM samples have much lower TDS concentrations. The other samples UM2, UM4, UM6 and UM7 are more similar to the PZM compositions.

Geochemical variability for the SM series of samples is most readily apparent in differences in the divalent cations mainly calcium, but the SM3 and SM5 samples also have a greater proportion of Mg than all others except the OM4 sample. The SM5 sample also has the greatest sulfate and corresponding TDS concentrations among the recently collected samples.

Figure 2.7B-63 is a stiff diagram showing a cross section with numerous water samples collected from the well clusters and from some individual wells. The Stiff diagrams use four sets of parameters. For the cations the parameters are, from top to bottom, Na+K, Ca, Mg and Fe. For the anions chloride, bicarbonate plus carbonate, sulfate and fluoride are displayed. Because milliequivalents are employed the area represented by the cations should be similar to the area represented by the anions. Because individual coal bed methane discharge permits have different reporting requirements, iron and fluoride were not included in the surface water Stiff diagrams.

The consistent compositional fingerprint of the PZM wells is apparent. The more dilute nature of the underlying wells is also readily apparent. Finally, the tendency for the shallow water table unit and overlying aquifer well samples to contain a greater proportion of divalent cations (Ca^{+2} and Mg^{+2}) is also apparent.

<u>Historical Groundwater Data</u>

Additional ground water samples collected in 1979 through 1982, as well as additional ground water samples collected in 1993, were also included in the overall evaluation (Figure 2.7B-64). There is limited supporting information available with these results, e.g., confirmation of formation screen depths and intervals, and therefore the results should be used mainly to confirm the previously discussed observations. No assessment of the quality of these data was available, nor are original laboratory reports. Thus the data should be viewed somewhat cautiously. In support of the historical data: (1) most of these locations were sampled numerous times and (2) results from these locations appear to be consistent with respect to sampling events and locations, and (3) the results are representative of the PZ aquifer.

Figure 2.7B-65 is a Piper diagram of the historical samples. Total dissolved solid concentrations were not available for these samples and so the TDS circles are not plotted on the figure. The overall compositions are consistent with the recently collected samples. Several samples plot within or close to the circle originally assigned to the recent PZ well samples. The sample from RI14, although not within the circle is close enough to demonstrate that the well belongs with the other production zone wells.

Historical wells identified with a U (Upper) correspond to the overlying aquifer described previously. Several of these locations, specifically RI25U, RI30U, and RI38U display similar characteristics to some of the recently collected OM samples. The sample from RI2, although assigned to the production zone, contained very low levels of uranium and radium and so it may represent the overlying aquifer. The historical data support the overall conclusions noted in the discussion based upon the recently collected data.

<u>Summary of Groundwater Geochemical Characteristics</u>

Ground waters from the project area have distinctive geochemical characteristics that can be used to identify different aquifers and units. The waters from the PZM aquifer display a consistent composition with sodium and sulfate as the dominant ions. The underlying unit (UM) tends to have greater amounts of sodium and more variation between sulfate and bicarbonate plus carbonate. Waters from overlying (OM) aquifer and the shallow

(SM) unit often have more calcium than the PZM waters, although there is a large degree of variation. The variation in the upper units is related to the discontinuous nature of the more permeable “aquifers” and the abundance of low permeability mudstones.

Comparison of CBM Discharge Waters with Lixiviant

The Piper diagram evaluation described previously showed that there are significant differences between the Production Zone waters and CBM type waters. However, it is expected that the leaching solutions (lixiviants) used in the ISR operation will have greater total bicarbonate and sodium concentrations and the resultant lixiviant compositions will tend to move down the Piper diagram quadrilateral in the direction of CBM waters. Geochemical modeling using PHREEQC (Parkhurst and Appelo, 1999) was used to estimate an expected range of lixiviant compositions. To prepare this solution, compositions from 12 PZM water samples were mixed using PHREEQC to prepare average compositions identified in Table 2.7A-18 as PZM Mixture. These samples represented the four quarterly samples from 10 wells (PZM-2, 6, 7, 8, 10, 14, 15, 16, 17, and 18).

Lixiviant A was prepared assuming a total bicarbonate concentration of approximately 800 mg/L. In the preparation of this solution, 0.01125 moles of $NaHCO_3$ were added to the PZM Mixture. Bicarbonate increased by about 669 mg/L and sodium concentrations increased by about 260 mg/L. Addition of the $NaHCO_3$ also causes a slight decrease in the pH.

For Lixiviant B, 0.0167 moles per liter of $NaHCO_3$ were added to the average composition of the PZM water. This resulted in an increase of nearly 400 mg/L in sodium, and an increase in bicarbonate of approximately 1000 mg/L. Carbonate also increase slightly, some of the increase is offset by the decrease in pH. These two solutions represent compositions prior to injection into the production zone. Consequently, the uranium concentration reflects a pre-mining condition. Identification of a solution that had contacted ore would be facilitated by an elevated uranium concentration typically on the order of 50 to 250 mg/L (Krumhansi et al., 2009). In this regard, the design head grade concentration for the Proposed Project ranges from 40-200 mg/L.

As shown on Figure 2.7B-66, both solutions have sufficient sulfate to plot near the middle of the Piper diagram quadrilateral. The high initial sulfate concentrations in the PZM waters provide a simple and direct method to discriminate between ISR lixiviant and CBM discharge waters. Preparation of Piper diagrams is not necessarily required to identify these waters. But the Piper provides a simple demonstration of the relative differences in these waters.

Another characteristic that can discriminate CBM discharge waters with ISR produced waters is the difference in barium concentrations. The mineral barite ($BaSO_4$) is considered to be insoluble in most ground waters that contain sulfate concentrations above about 50 mg/L. Because of the low sulfate concentrations in the coal bed ground waters, barium cannot precipitate as barite. Therefore, barium concentrations are elevated in CBM discharge waters. For 203 total barium analyses collected from January 2001 through January 2007, as reported in the three-mile buffer data compilation the average concentration of barium (total) was 0.66 mg/L, with a maximum concentration of 1.2 mg/L and a minimum of 0.1 mg/L. An additional 86 total recoverable barium analyses, collected from 2006 to 2011, had an average of 0.530 mg/L, a maximum of 0.894 mg/L and a minimum of 0.124 mg/L. Among 121 dissolved barium analyses representing the various sample levels and surface waters, only one ground water sample was reported to be above 0.1 mg/L; the concentration was 0.2 mg/L from OM-6. A concentration of 0.2 mg/L was also noted in SW3, which is associated with the WY0048526 006 CBM discharge. The lowest values were from PZM-6 at 0.02 mg/L (two samples). All of the remaining samples had values of 0.1 mg/L, this value was also the reporting limit and the majority of these samples (approximately 94 of the 121 samples) were flagged as less than the reporting limit.

CBM wells are also higher in iron; the elevated iron concentrations are also related to the reducing (low Eh) environment. Under Low Eh conditions the more soluble ferrous form of iron is stable. Examination of 256 CBM water samples produced an average dissolved iron concentration of 0.378 mg/L, nearly twice the PZM average. Unfortunately, this parameter is generally not conserved in surface waters because upon exposure to the atmosphere the ferrous iron will oxidize to ferric iron and precipitate as amorphous ferric hydroxide (ferrihydrite). Manganese also demonstrates similar redox behavior, so it is not a reliable indicator if these waters are retained in surface discharge ponds for any period of time.

In summary, two different constituents have been selected as parameters that can be employed to discriminate between ISR derived lixiviants, and CBM discharge waters. Sulfate is the dominant anion in the PZM waters, which will provide the starting solution for the lixiviant, and even with addition of $NaHCO_3$ the sulfate concentration will provide a simple and direct means to discriminate between ISR lixiviants and CBM discharge waters. A secondary parameter to discriminate between these two waters is based upon the elevated barium concentrations present in the low sulfate CBM discharge waters.

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2.8 Ecological Resources

2.8.1 Introduction

This section describes the existing ecological resources within the Proposed Reno Creek Project (Proposed Project). The analysis consists of a review of documents, databases, and reports in conjunction with field surveys. Further discussions regarding ecological resources can be found in:

- Section 5.7.7 of this TR (Airborne Effluent/Environmental Monitoring Programs);
- Section 6.2 of this TR (Plans and Schedules for Reclaiming Disturbed Lands);
- Section 7.1.7, 7.2.7 and 7.3.2.5 of this TR (Environmental Effects);
- Section 3.5 of the ER (Ecological Resources); Addendums 3.5-A through 3.5-H of the ER;
- Section 4.5 of the ER (Environmental Impacts);
- Section 5.7 (Cumulative Impacts);
- Section 6.5 of the ER (Mitigation for Potential Ecological Resources Impacts);
- Section 7.3 of the ER (Ecological Monitoring); and
- Section 8.4.2 of the ER (Long-Term Costs of Habitat Disturbance).

Ecological studies including baseline flora and fauna data were conducted to fulfill the objectives specified in USNRC NUREG-1569, *Standard Review Plan for In Situ Leach Uranium Extraction License Applications*. Ecological surveys were also conducted in accordance with applicable WDEQ-LQD, WGFD, and USFWS established guidelines. These agencies were consulted accordingly during development of survey plans to ensure adequate objectives, methodologies, and survey techniques were utilized.

Vegetation and wetland surveys were conducted by BKS Environmental Associates, Inc. (BKS) of Gillette, Wyoming during the fall of 2010 and the summer of 2011. Initial wildlife surveys were conducted by ICF International (ICF) of Gillette during the spring of 2008 and 2010. Due to access restrictions, the wildlife surveys were limited in coverage in those years. Ultimately, full coverage was obtained and the baseline surveys were completed in their entirety for the complete survey area during spring and summer 2011. A detailed review of these findings can be found in Section 3.5.5.2 of the ER.

2.8.2 Regional Setting

The Proposed Project area is within the Northwestern Great Plains (Level III) ecoregion within the PRB (Level IV) ecoregion (Chapman et al. 2004). Elevation within the Proposed Project area ranges from approximately 5,041 to 5,296 feet above mean sea level. Topography within the Proposed Project area is primarily level to gently rolling, though numerous prominent ephemeral drainages dissect the site and is influenced by previous disturbance from county roads, oil and gas development, and reservoirs. Similar terrain characterizes unearthed lands surrounding the Proposed Project area as described in Section 2.2 of this TR.

Vegetation within the PRB is generally described as mixed grass prairie dominated by rhizomatous wheatgrasses, various bunchgrasses, and shrubs. The Proposed Project area is comprised primarily of sagebrush shrubland and upland grassland. Interspersed among these major vegetation communities, within and along the ephemeral drainages, are less abundant vegetation types of breaks grassland and meadow grassland. Trees within the Proposed Project area were limited in number and extent.

2.8.3 Climate

As noted in NUREG-1910 (GEIS Section 1.4.3), the Proposed Project is located in the Wyoming East Uranium Region. The Proposed Project area features a semi-arid or steppe climate. The region is characterized seasonally by cold harsh winters, hot dry summers, relatively warm moist springs and cool autumns. Temperature extremes range from roughly -25° F in the winter to 100° F in the summer. The “last freeze” occurs during late May and the “first freeze” mid-to-late September.

Yearly precipitation totals are typically near 10 inches. The region is prone to severe thunderstorm events throughout the spring and early summer months and much of the precipitation is attributed to these events. In a typical year, the area will see four or five severe thunderstorm events (as defined by the National Weather Service criteria) and 40 to 50 thunderstorm days. Autumn stratiform rain events also contribute to precipitation totals, but to a lesser degree than those before mentioned. Snow frequents the region throughout winter months (40-50 in/year), but provides much less moisture than rain events. A detailed description of and presentation of regional and site climatologic data is presented in Section 2.5 of the TR.

Wyoming is windy and ranks first in the United States with an annual average speed of 12.9 mph (NUREG-1910, GEIS Section 3.3.6.1). Nearly five percent of the time, hourly wind speed averages exceed 25 mph. In the general vicinity of the Proposed Project, the predominant wind direction is west/southwest with the wind blowing out of that direction 25 percent of the time. A north/northwest secondary mode is also present. Surface wind speeds are relatively high all year-round, with hourly averages 11-15 mph. Higher average wind speeds are encountered during the winter months while summer months experience lower average wind speeds. A detailed description of and presentation of climatologic data is presented in Section 2.5 of the TR.

2.8.4 Terrestrial Ecology

As discussed in Section 2.8.2, the Proposed Project area is within the Northwestern Great Plains and PRB ecoregions, and is generally classified as mixed grass prairie (Chapman, et al. 2004). The elevation within the Proposed Project area ranges from approximately 5,041 to 5,296 feet above mean sea level. Topography is primarily level to gently rolling, though numerous prominent ephemeral drainages dissect the Proposed Project area.

2.8.4.1 Vegetation

As discussed in Section 3.5.2, the Proposed Project area is within the Northwestern Great Plains and PRB ecoregions, and is generally classified as mixed grass prairie (Chapman, et al. 2004). The elevation within the Proposed Project area ranges from approximately 5,041 to 5,296 feet above mean sea level. Topography is primarily level to gently rolling, though numerous prominent ephemeral drainages dissect the Proposed Project area.

2.8.4.1.1 Vegetation Survey Methodology

All sampling procedures were designed according to the WDEQ-LQD Rules and Regulations for Non-Coal Permitting, Guideline 2 (WDEQ 2004), and the methodology approved by the WDEQ (May 2011).

Plant communities were mapped using USDA 2009 National Agricultural Imagery Program (NAIP) true color ortho aerial imagery and verified through field surveys. Disturbed areas within the Proposed Project area were also identified and mapped, based on the scale of the available mapping. All areas within a 0.5 mile vegetation review area within the Proposed Project area were mapped based on review of NAIP true color ortho aerial imagery and known expression of the NAIP true color ortho aerial imagery within the Proposed Project area. Field verification of the plant communities within the 0.5 mile review area was not necessary. The 0.5 mile vegetation review area was approved by the NRC in the Moore Ranch project license application. A more detailed discussion on vegetation survey methodology can be found in 3.5.3.1.1 of the ER.

2.8.4.1.2 Summary of Vegetation Surveys

The total estimated acreage for the Proposed Project area is approximately 6,057 acres. Of these acres, the Big Sagebrush Shrubland plant community was approximately 4,729 acres (78.07 percent), the Meadow Grassland plant community was approximately 484 acres (7.99 percent), the Upland Grassland plant community was approximately 480 acres (7.93 percent), and the Breaks Grassland plant community was approximately 80 acres (1.33 percent). Previously disturbed areas covered approximately 279 acres (4.61 percent) and water covered approximately 4.31 acres (0.07 percent). Refer to Table 3.5-1of the ER for acreage of each plant community within the Proposed Project area and acreage of each plant community within the 0.5 mile vegetation review area. Refer to Addendum 3.5-E of the ER for a map of plant communities within the Proposed Project area.

2.8.4.2 Wildlife

According to the guidance in NUREG-1569 (Section 2.8.3 Acceptance Criteria), the characterization of the site ecology is acceptable if inventories of terrestrial species are compiled by the applicant based on reports or databases of state or federal agencies. The survey types and methods used for the Proposed Project were in compliance with applicable sections of WDEQ-LQD Non-coal Chapters 2, 3, and 11; WDEQ-LQD Guidelines 4 and 5; and the Draft In-Situ Mining Permit Application Requirements Handbook (March 2007 update).

The suite of baseline wildlife surveys was approved by the WGFD (letter dated April 7, 2008 with an updated letter provided June 14, 2010). The USFWS Ecological Services Office (ESO) in Cheyenne, Wyoming, has not typically provided project-specific guidance in recent years, but instead refers project applicants to the list of T&E species for each Wyoming county, as posted on their website. The wildlife survey requirements for the Proposed Project were based on the nature of the expected disturbance and the presence of or potential for unique, critical, or previously unsampled wildlife habitats in or near the project area. The survey requirements were also in keeping with those applied to baseline studies completed at other ISR properties on private surface in Wyoming in recent years.

As indicated, most the habitat disturbance will consist of scattered, confined drill sites for wells that will not result in large expanses of habitat being dramatically transformed from its original character, as in other surface mining operations. Therefore, most indirect impacts would relate to the displacement of wildlife due to increased noise, traffic, or other disturbances associated with the development and operation of the Proposed Project, as well as from small reductions in cover and forage due to habitat alteration, fragmentation, or loss. Indirect impacts typically persist longer than direct impacts. The nature of ISR operations decreases the occurrence of large-scale habitat alterations and, thus, the need for reclamation efforts that can result in dramatic differences between pre-construction and post-construction vegetative communities.

2.8.4.2.1 Raptors

Prior to the 2011 breeding season, a search of all available agency raptor databases indicated three known nests in the Proposed Project area and an additional 10 nests within the one mile review area (Bureau of Land Management [BLM] 2010). All but one of the nests are ferruginous hawk (*Buteo regalis*) ground nests situated on creek banks, hilltops, and rock outcrops throughout the area. However, no nesting activity from ferruginous hawks has been recorded in the area for the last several years. Most of the nests surveyed during the baseline period were in dilapidated condition and showed no signs of recent activity. Individual ferruginous hawks have been observed occasionally during the baseline surveys while soaring and foraging over the general area, but no defensive or territorial behaviors have been observed. One nest, located in a cottonwood tree, was active in 2008 and 2011, and was occupied by red-tailed hawks (*Buteo jamaicensis*) in both years.

2.8.4.2.2 Upland Game Birds

The Proposed Project area does not overlap with any of the core or connectivity areas for greater sage-grouse (*Centrocercus urophasianus*) as designated by the State of Wyoming (Wyoming EO 2011-5). The closest core area ("Thunder Basin") is over 20-miles to the east. According to current Wyoming Game and Fish Department [WGFD] records (WGFD 2010a), no known sage-grouse leks exist within the Proposed Project area, but three occupied leks (160 Acre, Porcupine Creek, and Spring Creek) are present within four-miles. Peak counts of 12 and one displaying male(s) were observed at the Porcupine Creek and Spring Creek leks, respectively, during ground counts conducted in 2011. No grouse have been observed at the 160 Acre lek since 2008.

No new leks were found during the baseline surveys. Outside of the active leks, one sage-grouse was observed during the baseline survey period. In 2011, a female sage-grouse was foraging in moderately dense sagebrush approximately 0.8 mile southwest of the Porcupine Creek lek.

The most recent WGFD records (WGFD 2004) do not reveal any sharp-tailed grouse (*Tympanuchus phasianellus*) leks near the Proposed Project area, as the nearest known lek is located greater than 30-miles from the project.

Habitats within the Proposed Project and associated review area are marginally suitable for sharp-tailed grouse during most of the year. The mosaic of sagebrush-grasslands could provide habitat from April through October. However, cottonwoods (*Populus* spp.) and berry-producing shrubs (e.g., snowberry [*Symphoricarpos* spp.] and chokecherry [*Prunus virginiana*]), which provide winter forage for sharp-tailed grouse, were very limited or absent from the review area.

2.8.4.2.3 Other Animals

No quantitative surveys for big game, lagomorphs (e.g., jackrabbits [*Lepus* spp.] and cottontails [*Sylvilagus* spp.]), breeding birds, waterfowl, small mammals, mammalian predators, furbearers, reptiles, amphibians, or fish were required or conducted specifically for the Proposed Project survey area. However, all sightings of non-targeted animals within the project area and one mile perimeter were recorded, and a species list maintained, during baseline surveys (2008, 2010, and 2011) to document comprehensive wildlife use of the survey area. As requested by the WGFD, big game range maps were used to determine which range delineations overlapped the survey area for future reclamation efforts.

2.8.4.2.4 Waterfowl and Shorebirds

No standardized surveys were targeted for waterfowl, wading bird, or shorebirds, but common species recorded in the Proposed Project survey area include the mallard (*Anas platyrhynchos*), northern pintail, American wigeon (*A. americana*), northern shoveler (*A. clypeata*), green-winged teal (*A. crecca*), eared grebe (*Podiceps nigricollis*), killdeer (*Charadrius vociferous*), and Wilson's phalarope. These wetland birds were observed in the limited ponds and reservoirs throughout the Proposed Project survey area, particularly those along the Belle Fourche River and Spring Creek.

2.8.4.2.5 Reptiles and Amphibians

No standardized surveys targeting reptiles or amphibians were required or conducted specifically for the Proposed Project wildlife baseline. Potential habitat for aquatic reptiles and amphibians is relatively limited within the Proposed Project area and occurs primarily in ephemeral or intermittent habitat associated with small, scattered stock ponds or drainages in the area. However, suitable habitat for snakes and other terrestrial reptiles does exist within the rocky outcrops, especially along the Belle Fourche River drainage. The only amphibian encountered in the Proposed Project survey area during the baseline surveys was the boreal chorus frog, which was heard calling in several of the reservoirs throughout the Proposed Project area. A single short-horned lizard (*Phrynosoma douglassi*) was the only reptile observed. It was observed in sagebrush-grassland uplands within the project area.

2.8.4.2.6 Fish and Microinvertebrates

No quantitative surveys for aquatic species were required or conducted specifically for the Proposed Project. Potential habitat for fish and microinvertebrates is quite limited within the survey area and occurs primarily in the numerous CBM-discharge reservoirs and intermittent wetland habitat associated with small, scattered stock ponds or drainages in the area. Under natural conditions, aquatic habitat in and near the Proposed Project is limited by the ephemeral nature (precipitation events and subsequent run-off) of surface water. Several small reservoirs were present that held water during the baseline survey period. However, the lack of deep-water habitat and extensive water sources precludes the presence of fish, and greatly limits the abundance and diversity of other aquatic species.

2.8.4.3 Threatened and Endangered Species

The USFWS has identified three federally listed species that could occur in Campbell County and require monitoring. Those include two plant species, the Ute ladies'-tresses (*Spiranthes diluvialis*) (threatened) and blowout penstemon (*Penstemon haydenii*) (endangered), and one vertebrate species, the greater sage-grouse (candidate) (USFWS 2010).

No threatened or endangered (T&E) plant species or their potential habitats were observed within the Proposed Project area during surveys in 2011, and available data sets do not indicate the occurrence of any T&E species within the Proposed Project area.

2.8.4.4 Aquatic Resources

Under natural conditions, aquatic habitat in and near the Proposed Project area is limited by the ephemeral nature of surface waters in the survey area. The lack of deep-water habitat and extensive water sources precludes the presence of fish, and limits the abundance and diversity of other aquatic species. As discussed above, water discharged from CBM wells has enhanced the water supply within some drainages in the survey area. However, those enhanced areas are still relatively limited and/or isolated in nature, and no perennial drainages are present in the survey area.

2.8.4.5 Conclusions

The Proposed Project survey area supports an array of common wildlife species, despite the relatively limited variety of habitat types and the presence of existing disturbances within the area.

Likewise, the habitats present within the Proposed Project area and survey area are common in central Wyoming. The project area is dominated by sagebrush shrubland; however, for wildlife utility, the sagebrush habitats are somewhat limited in extent and marginal in quality within most of the survey area. Moderately dense sagebrush stands are largely confined to the eastern third of the area (the area south of Highway 387 and north of Cosner Road). Those areas are likely to support sagebrush obligate species such as the greater sage-grouse and Brewer's sparrow during portions of the year. Lowland grassland (i.e., bottomland) and tree habitats, which often support considerable wildlife diversity, are extremely limited within the Proposed Project area. The natural drainages within the survey area are ephemeral in nature; however, CBM-enhanced reservoirs and some stock ponds provide a few reliable water sources throughout the year. No occupied prairie dog colonies are present within the survey area.

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2.9 Baseline Radiological Survey Characteristics

2.9.1 Introduction

This section presents characterization methods and results for the pre-operational radiological baseline monitoring program conducted at the proposed Reno Creek Project (Proposed Project) from September 2010 through December 2011. Results of the characterization include measurements of naturally-occurring radionuclides in biota, soil, air, surface water and ground water. Baseline conditions described via this characterization are representative of the current radiological environment at the site, and may be used to evaluate future site conditions and potential reclamation obligations during eventual decontamination and decommissioning of operations. Additional discussions concerning site radiological conditions can be found in:

- Addendum 2.9-A of this TR (Sampling and Analysis Plan);
- Addendum 2.9-B of this TR (Digital Air Sampler Calibration Report);
- Addendum 2.9-C of this TR (Proposed Modification To Regulatory Guide 4.14 Pre-Operational Air Sampling Guidance);
- Sections 7.2.4.1 and 7.3 of this TR (Environmental Effects);
- Addendum 7-A of this TR (MILDOS Report);
- Section 3.11 of the ER (Public and Occupational Health);
- Section 4.12 of the ER (Environmental Impacts);
- Section 5.13 of the ER (Cumulative Impacts);
- Section 6.10 of the ER (Mitigation);
- Section 7.1 of the ER (Radiological Monitoring); and
- Section 8.4.4 of the ER (Long-Term External Costs).

The pre-operational radiological baseline program (Figure 2.9-1) was conducted in accordance with recommendations contained in the following documents. Where the documents do not apply to ISR licensing or are out of date with respect to technology improvements, NUREG-1569 or other approaches were applied as noted within this section.

- NRC Regulatory Guide 4.14, Revision 1, “Radiological Effluent and Environmental Monitoring at Uranium Mills” (RG 4.14; NRC 1980);
- NRC Regulatory Guide 3.46, “Standard Format and Content of License Applications, Including Environmental Reports, for In Situ Uranium Solution Mining”, Section 2.9 (Radiological Background Characteristics) (NRC 1982);
- NRC Regulatory Guide 3.8, “Preparation of Environmental Reports for Uranium

Mills" (NRC 1982b); and

- NUREG-1569, "Standard Review Plan For In Situ Leach Uranium Extraction License Applications" (NRC 2003).

The data provided within this TR meet the data quality requirements noted in Regulatory Guide 4.14, and are adequate to support:

- Estimation of maximum potential annual radiation doses to the public from radionuclide releases;
- Evaluation of the performance of effluent control systems;
- Evaluation of environmental impacts during and following operations;
- Establishing baseline data for later decommissioning work, or to guide decontamination after accidental releases; and
- Ascertaining whether relevant regulatory requirements are satisfied.

The Proposed Project covers approximately 6,057 acres. Figure 1-1 presents location and vicinity information. Topography at the site includes low rolling hills, basins and cuts, drainage areas, and man-made ponds. The project's eastern boundary is approximately 7.5 miles southwest of the town of Wright, Wyoming. Figure 2.9-2 presents photos taken at the site during radiological characterization work. Vegetation on the site is largely sagebrush and grassland communities; predominant land uses at the site include livestock grazing and oil and gas extraction activities. No crop farming activities were observed.

2.9.2 Baseline Gamma Radiation Survey

The objective of a baseline gamma radiation investigation is to evaluate current gamma exposure rates and soil radionuclide concentrations. A field investigation was performed by Tetra Tech field engineers from September 9 through September 15, 2010. Follow-up studies were conducted October 13 and 14, 2010, and July 5 and 6, 2011. Activities included recording of GPS-located gamma exposure rates, correlation with gamma dose rates, and collection of soil samples to develop a correlation between exposure rates and soil Ra-226 concentrations.

Regulatory Guide 4.14 (RG 4.14) calls for a pre-operational gamma survey, but was written prior to the availability of portable computers and GPS satellites. The Guide was written to support the licensing of conventional (hard-rock) uranium mills, and calls for the recording of some 80 individual gamma exposure rate measurements at on a radial grid centered on a proposed uranium mill location (NRC, 1980). Portions of the guidance do not apply well to ISR facilities, which have no conventional mill, tailings or ore pile facilities. In keeping with ISR license application and review guidance described in Regulatory Guide 3.46 (NRC, 1982) and NUREG-1569 (NRC, 2003), and with radiological survey guidance specified in the Multi-Agency Radiation Survey and Site Investigation Manual (NRC, 2000), Tetra Tech used GPS-based scanning systems to record baseline gamma exposure rates over the entire site. The resulting set of measurements includes the data specified in RG 4.14.

The gamma scanning system developed by Tetra Tech has been used to characterize a large number of former uranium mine and mill sites and proposed uranium recovery sites (Whicker et al., 2008 & 2006; Johnson et al., 2006). Results from such site studies have been incorporated into other license and permit applications (Uranium One, 2008; EMC, 2007; Lost Creek ISR, LLC, 2007

2.9.2.1 <u>Baseline Gamma Radiation Survey Methods</u>

The radiation survey systems employed vehicle (Yamaha Rhino® ATV, Jeep Rubicon®) and backpack-mounted equipment. The vehicles were configured to minimize terrain damage, and feature roll cages and safety harnesses to reduce worker risk. Figure 2.9-3 presents a photo of the scanning systems.

Both the Jeep and Rhino vehicles employ adjustable systems to carry two Ludlum 44-10 two-inch sodium iodide (NaI) gamma radiation detectors and paired GPS receivers. The detectors are coupled to Ludlum 2350-1 rate meters. The permanently paired instruments are calibrated annually by the manufacturer using Cs-137 sources, and report gamma exposure rate in μR/h. Simultaneous GPS and gamma radiation exposure rate data are recorded once per second by each detector system. Data are recorded on netbook computers using proprietary software (ComReader©, Tetra Tech, 2007). System configuration includes eight foot spacing between the vehicle-mounted detectors, with each detector positioned approximately 3.5 feet above the ground to avoid obstructions. Separate GPS receivers and mapping programs are used to display track data in real-time. Backpack systems use single radiation detectors but are otherwise identical to the vehicle-mounted systems.

Based on previous experience, lateral NaI detector response to significantly above-background gamma source areas extends out to roughly five feet, giving each detector an estimated "field of view" 10 feet in diameter. This does not imply that a detector can discriminate gamma radiation from a small point source five feet away, but does suggest that photons from larger source areas are likely to be detected at that distance. The sensitive track width for each vehicle's two-detector system is therefore estimated to be about 18 feet. Vehicle scanning speeds at the Proposed Project generally ranged between two and 10 mph depending on terrain difficulty, with an average speed of approximately five mph.

Target coverage for the Proposed Project, as for other pre-license facilities where Tetra Tech has performed similar work, was 100 m spacing between the scan vehicles (10 m scan tracks). The tracks were pre-set as computer shape files used to direct the vehicles during scanning. Practical considerations such as steep terrain and obstructions influenced actual courses traversed by the vehicles. Where ore deposits were known to exist, 50 m track spacing was targeted, given the increased likelihood of surface expressions of uranium ore. Where specific study areas were selected to develop correlations with soil samples, scan density was increased to 100 percent (vehicle track spacing less than 18 feet).

2.9.2.1.1 On-site Correlation of NaI vs. Bicron Micro-rem Radiation Detectors

Gamma radiation exposure rates from uranium decay series radionuclides are subject to NaI-detector energy response characteristics, with higher sensitivity at lower gamma energies. To understand this effect at a specific site, NaI-detector measurements were compared to those from a tissue-equivalent detector, the Bicron Micro-rem meter (Bicron). Correlations against NaI-based measurements were made at 13 areas onsite. The onsite correlation process helps to ensure that the results of future gamma radiation surveys can be usefully compared to the pre-operational surveys.

2.9.2.1.2 Gamma/Soil Radionuclide Correlation Methods

Regulatory Guide 4.14 notes that baseline surface soil samples should be collected to a depth of five cm using a consistent technique, at 300 meter intervals in each of the eight compass directions extending in a radial grid pattern out to 1,500 meters from the center of the Proposed Project area. Additional samples are to be collected at the air monitoring stations. NUREG-1569 suggests that 15 cm depths should be sampled, for consistency with decommissioning criteria. The guidance, combined with the large size of the project site, has suggested an alternative: the development of gamma/soil correlations plots at this and other sites. Depending on the statistical strength of the relationship between gamma readings and ^{226}Ra concentrations, such correlations can be used to estimate near-surface radionuclide soil concentrations over an entire site.

Correlation soil sampling was conducted via composite sampling on 100 square meter (10x10 meters) plots. Figure 2.9-4 presents a diagram of the composite sampling scheme, and Figure 2.9-1 shows the sampling locations. Locations were selected using a broader set of earlier radiation survey data, to cover the range of site exposure rates. Each selected plot was scanned to determine average gamma exposure rate, and nine soil sample aliquots were collected to a depth of approximately 15 cm and composited. GPS coordinates were recorded at the center of each sampling plot. Samples were sent to IML in Sheridan, Wyoming for analysis of ^{226}Ra via gamma spectrometry. Samples were dried and homogenized prior to canning, equilibration and analysis.

After receipt of sample data from IML, the average gamma reading over each plot was plotted against the measured ^{226}Ra soil concentration.

2.9.2.1.3 Data Quality Assurance/Quality Control Methods, and Results

Prior to the field work, instrument qualification measurements were performed at background exposure rates for the NaI detector systems likely to be used during the work. Instruments also meeting on-site field QC criteria (background, source and field strip checks) were determined to be qualified, and qualified spare systems could then be used to replace instruments that fail in the field. Data developed using any qualified instrument are considered to be valid.

Field check results: For normally distributed data sets, over 99 percent of measurements are expected to fall within ± 3 standard deviations of the mean (these are the project control limits). Background, field strip and check source standard deviation values were recorded twice daily at the same locations; daily QC plots incorporate results to date. If a detector system exceeds control limits on a field QC check (background, field strip, or source check), it is replaced with a qualified spare system. The daily field strip checks, during which data are collected along the same 100 meter strip each morning and evening, provide an indication of total measurement uncertainty for each complete scanning system (OHV or backpack, power, cabling, computers, GPS receivers and detector systems).

The Ludlum 2350 datalogger systems employ calibration factors to convert detector counts per minute to a gamma exposure rate. If needed, count rates can therefore be calculated using the instrument-specific calibration factors. Factory calibration sheets, including such calibration factors, are provided in this report's appendix.

Figures 2.9-5 through 2.9-7 summarize the QC data acquired during the survey work. All instrument QC results during the field work met the control limit criteria. Daily exposure rate variations within these limits are functions of several variables, including exact locations of detector systems during daily checks, and recent variations in barometric pressure and soil moisture. Differences in detector internal characteristics, including minor NaI crystal issues or photomultiplier tube optical interface minor degradations, may be responsible for the observed differences in instrument response average values.

Note that the backpack scanning systems, used to scan portions of the project area, show background and field strip detector exposure rates that are somewhat higher than those recorded using the OHV-mounted systems. This is due to gamma radiation shielding of a portion of the field of view of the detectors mounted near the OHV's metal components. To correct for this observed difference, coincident scan tracks were run onsite with both OHV and backpack systems; backpack scan data were then corrected, to match the OHV data.

2.9.2.2 Gamma Survey Results

2.9.2.2.1 Baseline Gamma Survey

Raw data were reviewed daily during the field work, and incomplete or error-containing data lines were removed via an automated program, plus inspection. More than 134,000 valid gamma radiation exposure data points, paired with wide area augmentation system (WAAS) corrected GPS data, were collected. Summary statistics for the valid data, including a frequency histogram of the gamma exposure rate data, are provided in Figure 2.9-8. Exposure rates at the Proposed Project ranged from 7.4 to 23 µR/hr. The survey data are mapped in Figure 2.9-9.

2.9.2.2.2 Onsite Correlation: Bicron µRem meter vs. Ludlum NaI Detector

As noted, on the same 10x10 m plots from which soil ^{226}Ra vs. gamma exposure rate correlations were developed, a Bicron µrem meter was used to establish dose rates averaged over each of the correlation plots. Locations are presented in Table 2.9-1.

The dose rates measured at the correlation plot locations ranged from 5.0 to 10.2 µrem/hr. The data are plotted against NaI exposure rates in Figure 2.9-10, and evaluated using a linear equation showing an R^2 of 0.847. Energy dependency characteristics of the Ludlum 44-10 detector are shown in Figure 2.9-11. The equation developed in Figure 2.9-10 can be used to plot estimated dose rates over the entire site, shown in Figure 2.9-12.

2.9.2.2.3 Gamma Exposure Rate vs. Soil Ra-226 Concentrations - Correlation Results

As noted, a total of 13 locations were selected and sampled to develop a correlation curve for the site. Figure 2.9-13 plots the results for these locations. Table 2.9-2 provides the summary data.

2.9.2.2.4 Soil Radon Concentration Mapping

The gamma/^{226}Ra data demonstrate a relatively poor correlation between ^{226}Ra concentrations and gamma exposure rates. It should be noted that, at the very low soil

^{226}Ra concentrations found at this site, other radiation sources including natural ^{230}Th, K-40 and cosmic radiation overshadow radiation from soil ^{226}Ra decay products. Nonetheless, it is still potentially useful to develop a map showing estimates of soil Ra-226 concentrations over the entire site (Figure 2.9-14).

2.9.2.3 Discussion

The baseline gamma exposure and dose rates (gamma scan data) provided in Figures 2.9-9 and 2.9-12 can be used during and after operations to evaluate changes associated with facility operations.

2.9.2.4 Data Uncertainty

Sources of potential measurement uncertainty include:

- Gamma detector variability;
- Variations associated with the random nature of radioactive decay apparent at very low count rates;
- Small-scale spatial variability in gamma exposure rates;
- Temporal variability in gamma exposure rates associated with:
  - Changes in natural shielding or soil ^{222}Rn retention factors, influenced by changes in soil moisture and barometric pressure; and
  - Fluctuations in ambient ^{222}Rn and progeny concentrations in air.
- Inaccuracies in WAAS-enabled GPS readings; and/or
- Errors associated with soil sampling and laboratory sample preparation and analyses methods.

The data presented in Figure 2.9-6 illustrate the resulting range of uncertainty for complete scanning systems used on the project.

2.9.2.5 Gamma Survey Conclusions

The baseline gamma survey of the Proposed Project area provides a detailed characterization of existing gamma exposure rates. The results cover the intent of regulatory guidance for pre-licensing radiological characterization. The information will facilitate later evaluation of potential contamination resulting from ISR activities.

2.9.3 Soil Sampling

In addition to soil sampling performed for the purpose of radiation vs. soil radionuclide correlation, additional soil sampling was conducted at the site in October, 2010. Soil sampling was performed according to recommendations set forth in Regulatory Guide 4.14. That guidance suggests five cm sampling depths for surface soils, supplemented with a few samples taken to depths up to one meter. The Guide specifies that all soil samples should be analyzed for ^{226}Ra, with ten percent (including at least one of the one-meter sample sets) analyzed for natural uranium, ^{230}Th, and ^{210}Pb. Additionally, soil samples should be collected at air particulate sampling stations and analyzed for ^{226}Ra, natural uranium, ^{230}Th, and ^{210}Pb. Baseline soil radionuclide concentration data for both five and 15 cm soil depths are presented in this report, in accordance with RG 4.14 and NUREG-1569 (NCR, 2003) recommendations. Figure 2.9-1 presents sample locations. Table 2.9-3 summarizes analytical methods and target reporting limits. Addendum 2.9-A presents the Standard Operating Procedures and the Sampling and Analysis Plan used during all sampling events.

2.9.3.1 Soil Sampling

2.9.3.1.1 Surface Soil Sampling Methods

The surface soil sampling layout is a radial grid based on Regulatory Guide 4.14 recommendations. Soil samples were collected along transects in eight compass directions from a proposed processing plant location, at 300 meter intervals as illustrated in Figure 2.9-1. In addition, surface soil samples were collected at five air particulate monitoring stations. A total of 40, 5-cm-deep, radial grid samples were collected.

Sample ID information was recorded in a field log book, with GPS coordinates taken at each sampling point. Samples were sent to IML along with chain of custody forms. At IML, samples were dried, crushed, ground and homogenized, prior to analysis after 21 day equilibration.

2.9.3.1.2 Subsurface Soil Sampling Methods

Depth profile sampling locations in the vicinity of a proposed CPP location were selected based on RG 4.14 recommendations. Samples were taken at the center, and at 750 meters north, south, east and west of a potential CPP location. At each location, samples were collected at 1/3 meter increments to a depth of one meter, and were submitted to IML for analysis in accordance with RG 4.14 specifications.

2.9.3.2 Surface Soil Sampling Results

The ^{226}Ra soil concentrations for the 46 surface samples ranged from 0.80 to 1.6 pCi/g, with a mean of 1.24 pCi/g. Concentrations ranged from 0.60 to 1.4 pCi/g for the soil samples collected at the air monitoring stations, with a mean of 1.06 pCi/g. These results are consistent with regional natural background ^{226}Ra concentrations. Summary statistics for surface soil samples are provided in Table 2.9-4.

2.9.3.3 Subsurface Soil Sampling Results

Summary statistics for the subsurface samples analyzed for ^{226}Ra are provided in Table 2.9-5. Results for the subsurface sample analyzed for ^{210}Pb, ^{230}Th and natural uranium are provided in Table 2.9-6. Average ^{226}Ra concentrations ranged from 0.8 to 1.9 pCi/g, again within the region's range of natural background. There were no observed trends in soil concentration with depth.

2.9.3.4 Conclusions

Baseline radiological soil sampling and analysis was performed in accordance with Regulatory Guide 4.14 recommendations. No unusual concentrations or trends were identified.

2.9.4 Sediment Sampling

In September of 2010, baseline sediment sampling was initiated at the site. A total of 18 sediment samples (SED1–18) were collected during the initial sampling event. An additional four sediment samples (SED19–22) were collected in June, 2011. Regulatory Guide 4.14 specifies that one set of sediment samples should also be collected from the surface water sampling locations. For surface water passing through the Site, sediment should be sampled upstream and downstream of the Site (NRC, 1980). Figure 2.9-1 shows the selected sediment sampling locations.

2.9.4.1 Sediment Sampling Methods

At each sediment sampling location, a sample was collected to a depth of five cm. Location ID numbers, date and GPS coordinates for each location were recorded in a field log book. Samples were sent to IML along with chain of custody forms. Samples were dried, crushed, ground and homogenized prior to analysis. Sediment samples were collected during two sampling events. A total of 41 sediment samples were analyzed only for ^{226}Ra concentrations. In addition, a total of 25 sediment samples were analyzed for ^{226}Ra, total uranium, ^{210}Pb and ^{230}Th.

2.9.4.2 Sediment Sampling Results

The results of the sediment sampling and analysis are presented in Table 2.9-7 and Table 2.9-8. A graphical summary is provided in Figure 2.9-15. The ^{226}Rn concentrations were in the range of background for all samples, ranging from <0.2 pCi/g to 1.97 pCi/g, with an average concentration of 1.39 pCi/g. Figure 2.9-16 through 2.9-18 present the results for the subset of sediment samples also analyzed for additional radionuclides. Summary statistics for all sediment samples are presented in Table 2.9-9.

2.9.4.3 Conclusions

Sediment baseline radionuclide concentration data were collected and analyzed in accordance with Regulatory Guide 4.14 guidance. The sediment samples exhibited near-background concentrations, with no unusual concentrations or trends.

2.9.5 Ambient Gamma Dose and Radon Monitoring

Continuous passive monitoring of ambient gamma dose and ^{222}Rn concentration within the Proposed Project site was initiated in the fall of 2010. Regulatory Guide 4.14 calls for 12 consecutive months of quarterly monitoring (NRC, 1980). Although 12 months of data have been collected, certain issues (discussed below) suggest the need to continue data collection during 2012.

Passive devices for the monitoring of quarterly average gamma dose, and ^{222}Rn concentrations in air, are housed at the air particulate monitoring stations in Landauer-provided weather-protection containers. Station locations were selected based on Regulatory Guide 4.14 guidance. Locations of the monitoring stations are shown in Figure 2.9-1.

2.9.5.1 Ambient Gamma Dose and Radon Monitoring Methods

2.9.5.1.1 Ambient Gamma Dose Monitoring Methods

Passive monitoring of gamma dose at the site is being conducted using high-sensitivity optically-stimulated luminescent dosimeters (OSLs) supplied by Landauer, Inc. The badges are stored or in transit prior to and following installation/retrieval at the site;

corrections for the difference in dose rate (site vs. storage location) are calculated using control badges retained at the storage location for the entire period. The correction is calculated as follows:

- Determine the average daily control badge dose rate, by dividing the Landauer-reported control badge dose by the number of days from issuance to read-out; and
- Calculate the field-deployed doses: From each field dosimeter Landauer-reported dose, subtract the control badge dose for the total number of days the field badges were stored or in transit with the controls.

2.9.5.1.2 Ambient Gamma Radiation Exposure Results

The results provided by Landauer are reported in Table 2.9-10. Five stations (AM#2-6) have been in place since fall, 2010, and one station (AM#1) was installed during 2011 after access was granted.

Note that receipt of the third set of OSL detectors was delayed for several weeks after a quarterly package from Landauer was sent to an incorrect addressee. This delayed the field exchange of both the gamma and ^{222}Rn detectors. Monitoring was continuous during the entire period covered by the reported data.

2.9.5.2 Ambient Radon Monitoring Methods

Passive monitoring of average ^{222}Rn air concentrations at the Proposed Project site was conducted with Radtrak® alpha-track ^{222}Rn detectors, also supplied by Landauer Inc. These ^{222}Rn detectors, also housed at the air particulate monitoring stations, are protected from weather and animal disturbance using field containers provided by Landauer (Figure 2.9-19). The ^{222}Rn detectors are supplied by the vendor in sealed packages to minimize ^{222}Rn exposure prior to the beginning of the field monitoring period. Upon completion of the monitoring period, Landauer film-foil sealing stickers are applied to the detector openings to prevent further ^{222}Rn exposure during transit back to the vendor.

2.9.5.2.1 Ambient Radon Results

The data reported by Landauer are presented in Table 2.9-11. Radon concentrations reported for many reporting periods are below Radtrak detection limits. While other pre-license and licensed sites in the region have also reported ^{222}Rn concentration values below Landauer's detection limits, complete quarterly sets of such values suggested that a thorough evaluation of the detector placement, retrieval and lab analysis process should be performed. This review was conducted by Dr. Robert Meyer, Tetra Tech Inc., and Landauer's Dr. Mark Salasky, Radtrak process health physicist. That review has been completed, and indicates that the reported results are correct, and do represent very low concentrations during the two periods of interest.

Because the methods used by Landauer to estimate and subtract detector background counts from deployed, exposed detector counts are subject to significant uncertainty at this site's very low ambient ^{222}Rn concentrations, Landauer has modified its background determination procedure for this project. Sealed, control Radtrak units are now provided with the monitors to be deployed at this site. These control units provide project-detector-specific background correction data, reducing the variability associated with individual batches of the CR-39 detector material, therby increasing sensitivity. Additional details concerning the review process and the modified procedure are available upon request.

2.9.6 Air Particulate Monitoring

Continuous monitoring of air particulate radionuclides was initiated in the fall of 2010. Regulatory Guide 4.14 recommends collection of twelve consecutive months of quarterly monitoring data. Air particulate sampling station locations were selected to conform to RG 4.14 guidance, including consideration of the potential locations of the Proposed Project facilities, prevailing wind directions, adjacent residences, access and future operations. Locations of the air particulate monitoring stations are shown in Figure 2.9-1.

2.9.6.1 Air Particulate Monitoring Methods

The air particulate monitoring program is being conducted using solar powered stations employing Model DF-40L digital air samplers from F&J Specialty Products, Inc. (Figure 2.9-20). These samplers are calibrated by the manufacturer and employ electronic flow control and SD card nonvolatile memory storing all important parameters, and draw approximately 30 liters per minute through glass fiber filters. The calibration reports can be found in Addendum 2.9-B. The six air sampler locations (AM#1 to AM#6) are shown in Figure 2.9-21, and each is housed in protective containers with the air sample filter holder assembly..

Air sampling is continuous. Filters were collected weekly initially, but extended filter replacement testing has been completed, and a gradual change to monthly filter replacement was completed during 2011. To move to monthly filter replacement (an advantage in terms of cost-efficiency, and also in terms of safety for personnel working in the sometimes harsh site environment), filter size was increased to four inches, from 47 mm. A gradual reduction in filter exchange frequency, concomitant with careful observation and documentation of the reliability of the solar-powered air samplers, has shown that monthly filter exchange is feasible in terms of equipment reliability and dust loading. The gradual conversion to an extended filter collection interval was proposed in writing to Mr. Steve Cohen of the NRC in the fall of 2010. The conversion approach was later approved by Mr. Cohen via a telephone conversation with Dr. Robert Meyer, Tetra Tech Inc. A copy of the written report titled, "*Proposed Modification to Regulatory Guide 4.14 Pre-Operational Air-Sampling Guidance*," prepared by Dr. Meyer is included in TR Addendum 2.9-C.

Filters for each station are composited quarterly, and laboratory analyzed to calculate quarterly average radionuclide air concentrations. Analyses are performed by IML for ^{226}Ra, natural uranium, ^{230}Th, and ^{210}Pb.

2.9.6.2 Air Particulate Sampling Results

Results are provided in Tables 2.9-12 through 2.9-15. Note that five stations (AM#2-AM#6) have been in place since late 2010, and one station (AM#1) was installed during the summer of 2011 after access approval by the landowner.

2.9.7 Radon Flux

Regulatory Guide 4.14, written to support development of a conventional uranium mill and tailings pile system, notes that radon flux measurements should be conducted three times at eight locations in a pattern associated with the uranium mill location. Because no uranium mill or tailings impoundment will be created during the Proposed ISR Project, AUC suggests that baseline radon flux measurements are neither appropriate nor necessary to support this application. No flux measurements are planned at this time. Precedent for this decision exists with reference to the current Strata Inc., Ross site ISR license application Technical Report, page 2-286, which notes that the Ross project baseline monitoring program did not include radon flux measurements. Similar precedent exists with reference to the current Uranium One Moore Ranch project, which was approved by NRC without flux measurements.

2.9.8 Ground Water Sampling

Baseline groundwater sampling was conducted at the site, conforming to the intent of Regulatory Guide 4.14 (NRC, 1980). The guidance specifies that ground water should be collected from at least three sampling wells located down-gradient from the tailings area, and from one background well located up-gradient. The samples should be collected monthly through the first year of operation, and quarterly thereafter from the same down-gradient and background wells that were used for preoperational samples. Because there are no tailings impoundments at an ISR project site, the guidance has been interpreted and adapted by AUC. Well locations have been selected based on the potential influence of planned operations on site groundwater. A map showing the selected well locations is presented in Figure 2.9-1.

2.9.8.1 Groundwater Sampling Methods

Prior to sampling a well, static water levels are monitored using a water level meter. Wells are then sampled using EPA-approved low-flow procedures. Rather than purge the equivalent of three well volumes, a low-flow volume of 0.1 L/minute is drawn. This reduces well disturbance dramatically, which in turn reduces variability in sampling results. In-line multipurpose water-quality sensors are used to monitor gradual equilibration of specific parameters. Typically, sampling parameters are stabilized within a few minutes, and sampling begins. Parameters monitored and recorded during equilibration include pH, temperature, and conductivity.

In-line monitoring of the low-flow discharge allows for more representative groundwater field measurements. Additionally, the samples are taken as soon as the well is adequately purged. Where appropriate, sampling containers are filled to exclude air. All equipment used in sampling is decontaminated using deionized water at the conclusion of each individual well sampling. All sampling methods are conducted in compliance with QA/QC guidance specified in applicable NUREGs and Regulatory Guides.

2.9.8.2 Groundwater Sampling Results

AUC began sampling groundwater and domestic wells in August, 2010. Table 2.9-16 presents associated laboratory analysis data for dissolved and suspended ^{226}Ra. For the 17 groundwater samples analyzed, the average ^{226}Ra concentration was 5.7 pCi/L, ranging from 0.5 to 33.1 pCi/L. Sample PZM1 had the highest dissolved ^{226}Ra concentration observed. Samples PZM6 and PZM18 had dissolved ^{226}Ra concentrations of 23.4 and 21.7 pCi/L, respectively. The remaining 14 samples had concentrations ranging from 0.5 to 2.9 pCi/L. Well PZM-1 was sampled again in December and analyzed for total ^{226}Ra and ^{228}Ra; concentrations of 47.2 and 3.0 pCi/l, respectively, were reported.

Table 2.9-17 presents laboratory results for dissolved and suspended ^{210}Po. Fourteen of 15 results for dissolved ^{210}Po were below detection limits. Thirteen of 15 results for suspended ^{210}Po were below detection.

Table 2.9-18 presents the laboratory analysis for dissolved and suspended ^{230}Th. All analyses for dissolved ^{230}Th were below detection limits with the exception of sample UM-1 at 0.3 pCi/L (sample collected on November 16, 2010). Suspended ^{230}Th results for the samples analyzed ranged between <0.2 and 0.3 pCi/L. Three of the 15 samples had detectable, but very low, concentrations of suspended ^{230}Th.

Table 2.9-19 presents laboratory analyses for dissolved and suspended ^{210}Pb. Dissolved ^{210}Pb ranged from <1 to 6.4 pCi/L, with nine of the 15 results below detection limits. Suspended ^{210}Pb results ranged from <1 to 10.5 pCi/L. Nine of 15 results were below detection limits.

Table 2.9-20 presents results for dissolved and suspended uranium in groundwater. Thirteen samples were analyzed for dissolved uranium, and ranged from <0.0003 to 0.0895 mg/L. Suspended uranium concentrations were below detection limits, with the exception of sample PZM18 at a concentration of 0.0023 mg/L.

Table 2.9-21 presents laboratory results for ^{222}Rn in groundwater. Radon was analyzed in six groundwater samples collected during the November sampling event. Concentrations ranged from 133 to 9,300 pCi/L, with a mean concentration of 2,820 pCi/L. Radon concentrations in groundwater vary greatly, influenced by factors including aquifer source concentrations, emanation rates from mineral sources, aquifer porosity and soil/rock permeability (Senior, 1998).

2.9.9 Surface Water Sampling

AUC conducted baseline surface water sampling at four sampling locations beginning in September 2010. Surface water sampling locations are shown in Figure 2.9-1. This sampling included perennial streams, and ephemeral stream drainage channels where surface waters are present at least part of the year. These locations are widely distributed across the site, including locations roughly upstream and downstream from proposed facility locations.

2.9.9.1 Surface Water Sampling Methods

Surface water samples were collected in containers provided by the IML. Field meters were used to measure pH, specific conductance and temperature of water samples, and were calibrated before each day’s use. Sample containers were flushed with the sample water in order to remove potential contaminants from the container. The container was then filled directly from the stream or pond, in a manner designed to minimize collection of debris, or was filled using an alternate clean container. All samples were analyzed by IML and were accompanied by an appropriate chain of custody form. All equipment used in sampling was decontaminated using deionized water, at the conclusion of each sampling. All sampling methods were conducted in compliance with QA/QC requirements as specified within applicable guidance documents.

2.9.9.2 Surface Water Sampling Results

Results for dissolved and suspended radionuclides in surface water are presented in Tables 2.9-22 and 23.

2.9.10 Vegetation Sampling

Regulatory Guide 4.14 calls for three forage vegetation sampling events during the grazing season, in grazing areas at the site in three different sectors likely to have the highest airborne radionuclide concentrations associated with operations (NRC, 1980).

2.9.10.1 Vegetation Sampling Methods

Vegetation grab samples were collected using pruning shears and similar equipment, from mixed, above-ground forage plants across several hundred square meters at each sampling location. Samples were collected in plastic bags and were sent to IML, with chain of custody forms. Analyses requested included all parameters (^{210}Pb, ^{210}Po, ^{226}Ra, 230Th and U-nat) as recommended in Regulatory Guide 4.14. Figure 2.9-1 notes vegetation sampling locations.

2.9.10.2 Vegetation Sampling Results

Vegetation sampling results are presented in Table 2.9-24.

2.9.10.3 Vegetation Sampling Conclusions

Radionuclide concentrations in vegetation exhibit no unusual concentrations or trends.

2.9.10.4 Fish

Fish sampling was not performed because, as discussed in Section 2.8.4.2.6 of this TR, the lack of habitat and persistent water sources on or near the Proposed Project site precludes the presence of fish.

Table 2.9-1: Dose Rate vs. Exposure Rate on 10x10 m Correlation Plots

Soil Correlation ID	Bicron Dose Rate (µrem/hr)	Gamma Radiation Exposure Rate (µR/hr)
RC-CORR1	6.6	14
RC-CORR2	7	14.6
RC-CORR3	7.5	14.6
RC-CORR4	7.1	14.7
RC-CORR5	7.4	15.2
RC-CORR6	6.3	12.6
RC-CORR7	5	12.5
RC-CORR8	5.3	14.1
RC-CORR9	7.1	14.7
RC-CORR10	7.5	13.9
AUXCORR1	10.2	20.2
AUXCORR2	8.8	18.4
AUXCORR3	9.4	18.1

Table 2.9-2: Soil Radium Concentration vs. Exposure Rate: 10x10 m Correlation Plots

Soil Correlation ID	^{226}Ra Soil Concentration (pCi/g)	Gamma Radiation Exposure Rate (µR/hr)
RC-CORR1	1.2	14
RC-CORR2	1.5	14.6
RC-CORR3	0.9	14.6
RC-CORR4	1.4	14.7
RC-CORR5	1.3	15.2
RC-CORR6	1.2	12.6
RC-CORR7	0.9	12.5
RC-CORR8	0.9	14.1
RC-CORR9	0.9	14.7
RC-CORR10	0.8	13.9
AUXCORR1	14.7	20.2
AUXCORR2	3.0	18.4
AUXCORR3	3.6	18.1

Table 2.9-3: Soil Analytical Methods and Target Reporting Limits

Analyte	Analytical Method	Target Reporting Limit (pCi/g)
^{210}Pb	OTW01	1
^{226}Ra	E901.1 mod	0.2
^{230}Th	ACW10	0.2
Total U-Nat	SW-846	0.2

Table 2.9-4: Summary Statistics: Surface Soil Samples

Surface Sample Type	Mean	Standard Deviation	Median	Maximum	Minimum	n
^{226}Ra (pCi/g)						
Radial	1.24	0.23	1.20	1.60	0.80	40
PAS	1.06	0.32	1.10	1.40	0.60	5
All Samples	1.22	0.24	1.20	1.60	0.60	45
U-Nat (mg/kg)						
Radial	0.77	0.15	0.77	0.91	0.61	4
PAS	0.50	0.12	0.48	0.67	0.36	5
All Samples	0.62	0.19	0.61	0.91	0.36	9
^{210}Pb (pCi/g)						
Radial	9.65	2.45	8.80	13.20	7.80	4
PAS	7.66	1.54	7.50	10.00	6.30	5
All Samples	8.54	2.13	8.20	13.20	6.30	9
^{230}Th (pCi/g)						
Radial	0.70	0.24	0.65	1.00	0.50	4
PAS	0.40	0.12	0.40	0.60	0.30	5
All Samples	0.53	0.23	0.50	1.00	0.30	9

Note: PAS refers to Particulate Air Monitoring Station location samples

Table 2.9-5: Summary Statistics: Subsurface Soil Samples

Subsurface Sample Depth Interval (cm)	Mean	Standard Deviation	Median	Maximum	Minimum	n
^{226}Ra (pCi/g)						
0-33	1.08	0.33	0.90	1.60	0.80	5
33-66	1.34	0.34	1.30	1.80	0.90	5
66-100	1.28	0.39	1.30	1.90	0.90	5
All Depths	1.23	0.35	1.20	1.90	0.80	15

Table 2.9-6: Summary: Radionuclide Concentrations, Subsurface Samples

Sample ID	Depth Interval (cm)	U-Nat		^{210}Pb			^{230}Th		
		Conc. (mg/Kg)	RL (mg/Kg)	Conc. (pCi/g)	Precision +/- (pCi/g)	RL (pCi/g)	Conc. (pCi/g)	Precision +/- (pCi/g)	RL (pCi/g)
Center	0-33	0.977	0.001	5.1	1.9	1	0.5	0.2	0.2
Center	33-66	1.54	0.001	7.3	2	1	0.5	0.2	0.2
Center	66-100	1.82	0.001	4.9	2.5	1	0.7	0.2	0.2

Table 2.9-7: Sediment Sample Results: 2010

Sample ID	Collection Date	^{226}Ra (pCi/g)		^{210}Pb (pCi/g)		^{230}Th (pCi/g)		U-Nat (pCi/g)	
		Result	Precision	Result	Precision	Result	Precision	Result	RL
SED 1 0-3"	9/21/2010	1.29	0.36	2.3	0.8	0.797	0.201	1.9	0.9
SED 2 0-3"	9/22/2010	0.999	0.41	-	-	-	-	-	-
SED 3 Composite	9/21/2010	1.07	0.38	-	-	-	-	-	-
SED 4 0-3"	9/22/2010	1.97	0.41	3.2	0.8	1.51	0.286	1.4	0.2
SED 5 0-3"	9/21/2010	1.61	0.43	-	-	-	-	-	-
SED 6 0-3"	9/24/2010	1.64	0.44	-	-	-	-	-	-
SED 7 0-3"	9/22/2010	1.91	0.39	-	-	-	-	-	-
SED 8 0-3"	9/22/2010	1.82	0.39	-	-	-	-	-	-
SED 9 0-3"	9/22/2010	1.56	0.42	-	-	-	-	-	-
SED 10 0-3"	9/21/2010	1.81	0.35	-	-	-	-	-	-
SED 11 Composite	9/21/2010	1.36	0.39	-	-	-	-	-	-
SED 12 0-3"	9/22/2010	1.84	0.47	-	-	-	-	-	-
SED 13 0-3"	9/22/2010	1.06	0.33	-	-	-	-	-	-
SED 14 0-3"	9/21/2010	1.34	0.4	-	-	-	-	-	-
SED 15 0-3"	9/22/2010	1	0.34	-	-	-	-	-	-
SED 16 0-3"	9/22/2010	1.27	0.36	-	-	-	-	-	-
SED 17 0-3"	9/22/2010	1.39	0.38	-	-	-	-	-	-
SED 18 Composite	9/21/2010	1.26	0.37	-	-	-	-	-	-
SED19-001-110623	6/23/2011	1.9	0.4	1.2	0.5	0.8	0.2	1.1	0.3
SED20-001-110623	6/23/2011	1.6	0.4	1.1	0.4	0.8	0.2	3.3	0.2
SED21-001-110623	6/23/2011	1.4	0.4	1.6	0.4	0.4	0.1	0.5	0.3
SED22-001-110623	6/23/2011	1.7	0.5	2.2	0.5	1.2	0.3	2.7	0.2

Table 2.9-8: Sediment Sample Results: 2011

Sample ID	Collection Date	^{226}Ra (pCi/g)		^{210}Pb (pCi/g)		^{230}Th (pCi/g)		U-Nat (pCi/g)	
		Result	Precision	Result	Precision	Result	Precision	Result	RL
SED1-002-110315	3/15/2011	1.2	0.4	1.6	0.4	0.4	0.1	0.8	0.2
SED2-002-110317	3/17/2011	0.9	0.4	2.2	0.4	0.4	0.1	0.7	0.2
SED3-002-110316	3/15/2011	1.2	0.4	1.7	0.4	0.5	0.2	0.5	0.2
SED4-002-110315	3/15/2011	1.3	0.5	3.1	0.5	0.8	0.2	1	0.2
SED5-002-110315	3/15/2011	1.1	0.7	3.7	0.5	1.1	0.3	0.9	0.2
SED6-002-110316	3/16/2011	1.6	0.4	3	0.4	0.8	0.2	0.9	0.2
SED7-002-110316	3/16/2011	1.6	0.4	2.9	0.5	1.3	0.3	1.5	0.2
SED8-002-110316	3/16/2011	1.4	0.4	1	0	1.4	0.4	0.8	0.2
SED9-002-110316	3/16/2011	0.7	0.4	1.6	0.4	0.4	0.1	1	0.2
SED10-002-110315	3/15/2011	<0.2		2	0.4	0.9	0.2	1	0.2
SED11-002-110315	3/15/2011	1.4	0.1	2.3	0.6	0.9	0.2	1.6	0.2
SED12-002-110316	3/16/2011	1.7	0.5	2.9	0.5	0.9	0.2	0.9	0.2
SED13-002-110317	3/17/2011	1.7	0.4	3.4	0.5	0.8	0.2	1	0.2
SED14-002-110317	3/17/2011	1.3	0.4	2.3	0.4	0.6	0.2	0.9	0.2
SED15-002-110317	3/17/2011	0.7	0.3	1.9	0.4	0.3	0.1	0.5	0.2
SED16-002-110317	3/17/2011	1.1	0.4	1.4	0.3	0.5	0.2	0.9	0.2
SED17-002-110317	3/17/2011	1	0.4	2.4	0.4	0.5	0.1	0.5	0.2
SED18-002-110316	3/16/2011	1.6	0.4	2.3	0.4	0.8	0.2	1.1	0.2
GBS-002-110317	3/17/2011	1.4	0.4	1.5	0.4	1.5	0.4	1	0.2

Table 2.9-9: Summary Statistics: Sediment Samples

Summary Statistic	^{226}Ra	^{210}Pb	^{230}Th	U-Nat
# of Samples	41	25	25	25
# of Non-Detects	1	0	0	0
Minimum	<0.2	1	0.3	0.5
Maximum	1.97	3.7	1.51	3.3
Mean	1.39	2.20	0.81	1.14
Standard Deviation	0.33	0.75	0.36	0.66
Median	1.39	2.2	0.8	1

Table 2.9-10: Ambient Gamma Dose Rates: Results Summary

Station ID	OSL Issue Date	Field Install Date	Field End Date	Lab Result (mrem)	Estimated Field Dose (mrem)	Estimated Daily Field Dose (mrem)	Estimated Field Dose Rate (mrem/h)
AM2	10/1/2010	10/13/2010	1/7/2011	29.6	22.9	0.3	0.011
AM3	10/1/2010	10/13/2010	1/7/2011	30.7	24.0	0.3	0.012
AM4	10/1/2010	10/13/2010	1/7/2011	30.5	23.8	0.3	0.012
AM5	10/1/2010	10/13/2010	1/7/2011	29.7	23.0	0.3	0.011
AM6	10/1/2010	10/13/2010	1/7/2011	29.7	23.0	0.3	0.011
Control avg	10/1/2010			28.2			
AM2	1/1/2011	1/7/2011	5/4/2011	41.4	29.1	0.2	0.010
AM3	1/1/2011	1/7/2011	5/4/2011	40.1	27.8	0.2	0.010
AM4	1/1/2011	1/7/2011	5/4/2011	40.1	27.8	0.2	0.010
AM5	1/1/2011	1/7/2011	5/4/2011	41.9	29.6	0.3	0.011
AM6	1/1/2011	1/7/2011	5/4/2011	40.7	28.4	0.2	0.010
Control avg	1/1/2011			53.4			
AM2	4/1/2011	5/4/2011	7/6/2011	38.2	21.5	0.3	0.014
AM3	4/1/2011	5/4/2011	7/6/2011	35.9	19.2	0.3	0.013
AM4	4/1/2011	5/4/2011	7/6/2011	38.6	21.9	0.3	0.014
AM5	4/1/2011	5/4/2011	7/6/2011	38.6	21.9	0.3	0.014
AM6	4/1/2011	5/4/2011	7/6/2011	38.8	22.1	0.4	0.015
Control avg	4/1/2011			40.0			
AM2	7/1/2011	7/6/2011	10/18/2011	43.8	35.4	0 .35	0.015
AM3	7/1/2011	7/6/2011	10/18/2011	45.4	37	0.37	0.015
AM4	7/1/2011	7/6/2011	10/18/2011	42.2	33.8	0.34	0.014
AM5	7/1/2011	7/6/2011	10/18/2011	38.6	30.2	0.3	0.13
AM6	7/1/2011	7/6/2011	10/18/2011	41.2	32.8	0.33	0.14
Control avg	7/1/2011			51.0			
4th Q 2011							
AM1	10/1/2011	10/18/2011	1/4/2012	35.1	25.2	.32	.013
AM2	10/1/2011	10/18/2011	1/4/2012	40.0	30.1	.38	.016
AM3	10/1/2011	10/18/2011	1/4/2012	36.9	27	.35	.015
AM4	10/1/2011	10/18/2011	1/4/2012	41.2	31.3	.40	.017
AM5	10/1/2011	10/18/2011	1/4/2012	38.1	28.2	.36	.015
AM6	10/1/2011	10/18/2011	1/4/2012	36.6	26.7	.34	.014
Control avg	10/1/2011			44.8			

Table 2.9-11: Ambient Radon Air Concentration Averages: Summary

Monitoring Station ID	Start Date	End Date	Result (pCi/L)-d	Concentration (pCi/L)
Q4 2010				
AM2	10/13/2010	1/7/2011	8.9	0.1
AM3	10/13/2010	1/7/2011	15.4	0.2
AM4	10/13/2010	1/7/2011	13.7	0.2
AM5	10/13/2010	1/7/2011	26.2	0.3
AM6	10/13/2010	1/7/2011	23.8	0.3
Q1 2011				
AM2	1/7/2011	5/4/2011	6.0	0.05
AM3	1/7/2011	5/4/2011	6.0	0.05
AM4	1/7/2011	5/4/2011	6.0	0.05
AM5	1/7/2011	5/4/2011	6.0	0.05
AM6	1/7/2011	5/4/2011	6.0	0.05
Q2 2011				
AM2	5/4/2011	7/6/2011	6.0	0.10
AM3	5/4/2011	7/6/2011	6.0	0.10
AM4	5/4/2011	7/6/2011	6.0	0.10
AM5	5/4/2011	7/6/2011	6.0	0.10
AM6	5/4/2011	7/6/2011	6.0	0.10
Q3 2011				
AM2	7/6/2011	10/18/2011	59.5	0.6
AM3	7/6/2011	10/18/2011	38.5	0.4
AM4	7/6/2011	10/18/2011	22.9	0.2
AM5	7/6/2011	10/18/2011	56.8	0.5
AM6	7/6/2011	10/18/2011	45.0	0.4
Q4 2011				
AM1	10/18/2011	1/4/2012	15.3	0.2
AM2	10/18/2011	1/4/2012	6.6	0.1
AM3	10/18/2011	1/4/2012	6	0.08
AM4	10/18/2011	1/4/2012	25	0.3
AM5	10/18/2011	1/4/2012	34.9	0.4
AM6	10/18/2011	1/4/2012	44.3	0.6

Table 2.9-12: Air Particulate Monitoring Results: Quarter 1

Air Station ID	Collection-Date	Air Volume Sampled (L)[1]	Air Volume Sampled (mL)	Analyte	Filter Conc. (pCi/filter)	Reporting Limit (pCi/filter)	Concentration (µCi/mL)	Reporting Limit (µCi/mL)
AM2-Composite	12/31/2010	5.77E+06	5.77.E+09	^{210}Pb	131	2	2.3E-14	2.0.E-15
		5.77E+06	5.77.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		5.77E+06	5.77.E+09	^{230}Th	0.5	0.3	ND	1.0E-16
		5.77E+06	5.77.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM3-Composite	12/31/2010	5.07E+06	5.07.E+09	^{210}Pb	107	2	2.1E-14	2.0.E-15
		5.07E+06	5.07.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		5.07E+06	5.07.E+09	^{230}Th	0.4	0.3	ND	1.0E-16
		5.07E+06	5.07.E+09	U-Nat	0.3	0.3	ND	1.0E-16
AM4-Composite	12/31/2010	4.76E+06	4.76.E+09	^{210}Pb	110	2	2.3E-14	2.0.E-15
		4.76E+06	4.76.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.76E+06	4.76.E+09	^{230}Th	0.6	0.3	1.3E-16	1.0E-16
		4.76E+06	4.76.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM5-Composite	12/31/2010	4.87E+06	4.87.E+09	^{210}Pb	119	2	2.4E-14	2.0.E-15
		4.87E+06	4.87.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.87E+06	4.87.E+09	^{230}Th	1	0.3	1.2E-16	1.0E-16
		4.87E+06	4.87.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM6-Composite	12/31/2010	4.42E+06	4.42.E+09	^{210}Pb	68.2	2	1.5E-14	2.0.E-15
		4.42E+06	4.42.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.42E+06	4.42.E+09	^{230}Th	2.2	0.3	5.0E-16	1.0E-16
		4.42E+06	4.42.E+09	U-Nat	6	0.3	1.2E-15	1.0E-16

[1]Presented by mistake as m^3 in the laboratory reports

Table 2.9-13: Air Particulate Monitoring Results: Quarter 2

Air Station ID	Collection Date	Air Volume Sampled (L)[1]	Air Volume Sampled (mL)	Analyte	Filter Concentration (pCi/filter)	Reporting Limit (pCi/filter)	Concentration (µCi/mL)	Reporting Limit (µCi/mL)
AM2-Composite	3/25/2011	4.24E+06	4.24.E+09	^{210}Pb	27	2	6.4E-15	2.0.E-15
		4.24E+06	4.24.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.24E+06	4.24.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.24E+06	4.24.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM3-Composite	3/25/2011	3.85E+06	3.85.E+09	^{210}Pb	47	2	1.2E-14	2.0.E-15
		3.85E+06	3.85.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		3.85E+06	3.85.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		3.85E+06	3.85.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM4-Composite	3/25/2011	4.10E+06	4.10.E+09	^{210}Pb	30	2	7.4E-15	2.0.E-15
		4.10E+06	4.10.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.10E+06	4.10.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.10E+06	4.10.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM5-Composite	3/25/2011	4.18E+06	4.18.E+09	^{210}Pb	26	2	6.2E-15	2.0.E-15
		4.18E+06	4.18.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.18E+06	4.18.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.18E+06	4.18.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM6-Composite	3/25/2011	9.62E+06	9.62.E+09	^{210}Pb	19.6	2	2.0E-15	2.0.E-15
		9.62E+06	9.62.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		9.62E+06	9.62.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		9.62E+06	9.62.E+09	U-Nat	ND	0.3	ND	1.0E-16

Table 2.9-14: Air Particulate Monitoring Results: Quarter 3

Air Station ID	Collection-Date	Air Volume Sampled (L)[1]	Air Volume Sampled (mL)	Analyte	Filter Concentration (pCi/filter)	Reporting Limit (pCi/filter)	Concentration (µCi/mL)	Reporting Limit (µCi/mL)
AM2-Composite	6/24/2011	4.50E+06	4.50.E+09	^{210}Pb	43	2	9.4E-15	2.0.E-15
		4.50E+06	4.50.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.50E+06	4.50.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.50E+06	4.50.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM3-Composite	6/24/2011	4.17E+06	4.17.E+09	^{210}Pb	44	2	1.1E-14	2.0.E-15
		4.17E+06	4.17.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.17E+06	4.17.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.17E+06	4.17.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM4-Composite	6/24/2011	4.38E+06	4.38.E+09	^{210}Pb	45	2	1.0E-14	2.0.E-15
		4.38E+06	4.38.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.38E+06	4.38.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.38E+06	4.38.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM5-Composite	6/24/2011	4.53E+06	4.53.E+09	^{210}Pb	44	2	9.7E-15	2.0.E-15
		4.53E+06	4.53.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.53E+06	4.53.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.53E+06	4.53.E+09	U-Nat	ND	0.3	ND	1.0E-16
AM6-Composite	6/24/2011	4.53E+06	4.53.E+09	^{210}Pb	41.0	2	9.1E-15	2.0.E-15
		4.53E+06	4.53.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.53E+06	4.53.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.53E+06	4.53.E+09	U-Nat	ND	0.3	ND	1.0E-16

Table 2.9-15: Air Particulate Monitoring Results: Quarter 4

Air Station ID	Collection Date	Air Volume Sampled (L)[1]	Air Volume Sampled (mL)	Analyte	Filter Concentration (pCi/filter)	Reporting Limit (pCi/filter)	Concentration (µCi/mL)	Reporting Limit (µCi/mL)
AM1-Composite	9/30/2011	5.67E+06	5.67.E+09	^{210}Pb	48.9	2	8.6E-15	2.0E-15
		5.67E+06	5.67.E+09	^{226}Ra	0.4	0.3	ND	1.0E-16
		5.67E+06	5.67.E+09	^{230}Th	0.4	0.3	ND	1.0E-16
		5.67E+06	5.67.E+09	U-Nat	0.5	0.3	ND	1.0E-16
		5.67E+06	5.67.E+09	^{210}Pb	48.9	2	8.6E-15	2.0E-15
AM2-Composite	9/30/2011	4.67E+06	4.67.E+09	^{210}Pb	105.0	2	2.2E-14	2.0.E-15
		4.67E+06	4.67.E+09	^{226}Ra	0.3	0.3	ND	1.0E-16
		4.67E+06	4.67.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.67E+06	4.67.E+09	U-Nat	0.8	0.3	1.6E-16	1.0E-16
AM3-Composite	9/30/2011	4.31E+06	4.31.E+09	^{210}Pb	89.3	2	2.1E-14	2.0.E-15
		4.31E+06	4.31.E+09	^{226}Ra	ND	0.3	ND	1.0E-16
		4.31E+06	4.31.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.31E+06	4.31.E+09	U-Nat	0.4	0.3	ND	1.0E-16
AM4-Composite	9/30/2011	4.59E+06	4.59.E+09	^{210}Pb	92.7	2	2.0E-16	2.0.E-15
		4.59E+06	4.59.E+09	^{226}Ra	0.5	0.3	1.1E-16	1.0E-16
		4.59E+06	4.59.E+09	^{230}Th	0.3	0.3	ND	1.0E-16
		4.59E+06	4.59.E+09	U-Nat	0.4	0.3	ND	1.0E-16
AM5-Composite	9/30/2011	4.73E+06	4.73.E+09	^{210}Pb	101	2	2.1E-14	2.0.E-15
		4.73E+06	4.73.E+09	^{226}Ra	0.4	0.3	ND	1.0E-16
		4.73E+06	4.73.E+09	^{230}Th	ND	0.3	ND	1.0E-16
		4.73E+06	4.73.E+09	U-Nat	0.4	0.3	ND	1.0E-16
AM6-Composite	9/30/2011	4.76E+06	4.76.E+09	^{210}Pb	97.5	2	2.0E-14	2.0.E-15
		4.76E+06	4.76.E+09	^{226}Ra	0.4	0.3	ND	1.0E-16
		4.53E+06	4.53.E+09	230Th	ND	0.3	ND	1.0E-16
		4.53E+06	4.53.E+09	U-Nat	ND	0.3	ND	1.0E-16

Table 2.9-1: Groundwater: Laboratory Analytical Results for Radium

Sample Name	Sample Date	Result	Precision +/- (pCi/g)	RL	Units
^{226}Ra (Dissolved)					
PZM5-PT1	8/25/2010	2.9	0.3	0.2	pCi/L
PZM5b	9/15/10	2.2	0.8	0.2	pCi/L
TAF 1	9/29/10	0.7	0.1	0.2	pCi/L
TAF 2	9/29/10	0.5	0.1	0.2	pCi/L
GW 5	9/29/10	0.6	0.1	0.2	pCi/L
GW 3	9/29/10	0.6	0.1	0.2	pCi/L
GW 2	9/29/10	0.6	0.1	0.2	pCi/L
PRI 1	9/29/10	1.3	0.2	0.2	pCi/L
PZM1	10/21/10	33.1	0.6	0.2	pCi/L
SM5	10/29/10	2.0	0.2	0.2	pCi/L
OM5	11/1/10	0.553	0.086	0.2	piC/L
UM5	11/2/10	0.234	0.056	0.2	piC/L
PZM5	11/2/10	1.73	0.15	0.2	piC/L
PZM6	11/3/10	23.4	0.55	0.2	piC/L
PZM18	11/9/10	21.7	0.6	0.2	pCi/L
UM1	11/16/10	2.4	0.2	0.2	pCi/L
PZM4	12/14/10	2.5	0.2	0.2	pCi/L
^{226}Ra (Suspended)					
PZM5-PT1	8/25/2010	<0.2		0.2	pCi/L
TAF 1	9/29/10	<0.2		0.2	pCi/L
TAF 2	9/29/10	<0.2		0.2	pCi/L
GW 5	9/29/10	<0.2		0.2	pCi/L
GW 3	9/29/10	<0.2		0.2	pCi/L
GW 2	9/29/10	<0.2		0.2	pCi/L
PRI 1	9/29/10	0.7	0.1	0.2	pCi/L
SM5	10/29/10	<0.2		0.2	pCi/L
OM5	11/1/10	<0.2		0.2	piC/L
UM5	11/2/10	<0.2		0.2	piC/L
PZM5	11/2/10	<0.2		0.2	piC/L
PZM6	11/3/10	0.323	0.083	0.2	piC/L
PZM18	11/9/10	0.721	0.3	0.2	pCi/L
UM1	11/16/10	0.259	0.38	0.2	pCi/L
PZM4	12/14/10	<0.2		0.2	pCi/L

Table 2.9-2: Groundwater: Laboratory Analytical Results for Polonium

Sample Name	Sample Date	Result	Precision +/- (pCi/g)	RL	Units
^{210}Po (Dissolved)					
PZM5-PT1	8/25/2010	<1		1	pCi/L
TAF 1	9/29/10	<1		1	pCi/L
TAF 2	9/29/10	<1		1	pCi/L
GW 5	9/29/10	<1		1	pCi/L
GW 3	9/29/10	<1		1	pCi/L
GW 2	9/29/10	<1		1	pCi/L
PRI 1	9/29/10	<1		1	pCi/L
SM5	10/29/10	<1		1	pCi/L
OM5	11/1/10	1.0	0.8	1	pCi/L
UM5	11/2/10	<1		1	pCi/L
PZM5	11/2/10	<1		1	pCi/L
PZM6	11/3/10	<1		1	pCi/L
PZM18	11/9/10	<1		1	pCi/L
UM1	11/16/10	<1		1	pCi/L
PZM4	12/14/10	<1		1	pCi/L
^{210}Po (Suspended)					
PZM5-PT1	8/25/2010	<1		1	pCi/L
TAF 1	9/29/10	<1		1	pCi/L
TAF 2	9/29/10	<1		1	pCi/L
GW 5	9/29/10	<1		1	pCi/L
GW 3	9/29/10	<1		1	pCi/L
GW 2	9/29/10	<1		1	pCi/L
PRI 1	9/29/10	<1		1	pCi/L
SM5	10/29/10	<1		1	pCi/L
OM5	11/1/10	<1		1	pCi/L
UM5	11/2/10	<1		1	pCi/L
PZM5	11/2/10	<1		1	pCi/L
PZM6	11/3/10	3.8	1.4	1	pCi/L
PZM18	11/9/10	<1		1	pCi/L
UM1	11/16/10	<1		1	pCi/L
PZM4	12/14/10	1.1	0.7	1	pCi/L

Table 2.9-18: Groundwater: Laboratory Analytical Results for Thorium

Sample Name	Sample Date	Result	Precision +/- (pCi/g)	RL	Units
^{230}Th (Dissolved)					
PZM5-PT1	8/25/2010	<0.2		0.2	pCi/L
TAF 1	9/29/10	<0.2		0.2	pCi/L
TAF 2	9/29/10	<0.2		0.2	pCi/L
GW 5	9/29/10	<0.2		0.2	pCi/L
GW 3	9/29/10	<0.2		0.2	pCi/L
GW 2	9/29/10	<0.2		0.2	pCi/L
PRI 1	9/29/10	<0.2		0.2	pCi/L
SM5	10/29/10	<0.2		0.2	pCi/L
OM5	11/1/10	<0.2		0.2	pCi/L
UM5	11/2/10	<0.2		0.2	pCi/L
PZM5	11/2/10	<0.2		0.2	pCi/L
PZM6	11/3/10	<0.2		0.2	pCi/L
PZM18	11/9/10	<0.2		0.2	pCi/L
UM1	11/16/10	0.3	0.1	0.2	pCi/L
PZM4	12/14/10	<0.2		0.2	pCi/L
^{230}Th (Suspended)					
PZM5-PT1	8/25/2010	<0.2		0.2	pCi/L
TAF 1	9/29/10	0.3	0.4	0.2	pCi/L
TAF 2	9/29/10	<0.2		0.2	pCi/L
GW 5	9/29/10	<0.2		0.2	pCi/L
GW 3	9/29/10	0.3	0.4	0.2	pCi/L
GW 2	9/29/10	0.2	0.2	0.2	pCi/L
PRI 1	9/29/10	<0.2		0.2	pCi/L
SM5	10/29/10	<0.2		0.2	pCi/L
OM5	11/1/10	<0.2		0.2	pCi/L
UM5	11/2/10	<0.2		0.2	pCi/L
PZM5	11/2/10	<0.2		0.2	pCi/L
PZM6	11/3/10	<0.2		0.2	pCi/L
PZM18	11/9/10	<0.2		0.2	pCi/L
UM1	11/16/10	<0.2		0.2	pCi/L
PZM4	12/14/10	<0.2		0.2	pCi/L

Table 2.9-19: Groundwater: Laboratory Analytical Results for Lead

Sample Name	Sample Date	Result	Precision +/- (pCi/g)	RL	Units
^{210}Pb (Dissolved)					
PZM5-PT1	8/25/2010	4.0	1	1	pCi/L
TAF 1	9/29/10	<1		1	pCi/L
TAF 2	9/29/10	<1		1	pCi/L
GW 5	9/29/10	<1		1	pCi/L
GW 3	9/29/10	<1		1	pCi/L
GW 2	9/29/10	<1		1	pCi/L
PRI 1	9/29/10	<1		1	pCi/L
SM5	10/29/10	<1		1	pCi/L
OM5	11/1/10	<1		1	pCi/L
UM5	11/2/10	<1		1	pCi/L
PZM5	11/2/10	1.3	0.5	1	pCi/L
PZM6	11/3/10	6.4	0.7	1	pCi/L
PZM18	11/9/10	2.65	0.83	1	pCi/L
UM1	11/16/10	1.07	0.62	1	pCi/L
PZM4	12/14/10	4.5	0.1	1	pCi/L
^{210}Pb (Suspended)					
PZM5-PT1	8/25/2010	<1		1	pCi/L
TAF 1	9/29/10	1.4	0.5	1	pCi/L
TAF 2	9/29/10	<1		1	pCi/L
GW 5	9/29/10	<1		1	pCi/L
GW 3	9/29/10	<1		1	pCi/L
GW 2	9/29/10	<1		1	pCi/L
PRI 1	9/29/10	<1		1	pCi/L
SM5	10/29/10	<1		1	pCi/L
OM5	11/1/10	<1		1	pCi/L
UM5	11/2/10	1.3	0.5	1	pCi/L
PZM5	11/2/10	<1		1	pCi/L
PZM6	11/3/10	9.1	0.9	1	pCi/L
PZM18	11/9/10	10.5	3.7	1	pCi/L
UM1	11/16/10	4.1	2.2	1	pCi/L
PZM4	12/14/10	5.0	0.1	1	pCi/L

Table 2.9-20: Groundwater: Laboratory Analytical Results for Uranium

Sample Name	Sample Date	Result	RL	Units
U-Nat (Dissolved)				
PZM5-PT1	8/25/10	0.088	0.001	mg/L
TAF 1	9/29/10	0.0745	0.0003	mg/L
TAF 2	9/29/10	0.0004	0.0003	mg/L
GW 5	9/29/10	<0.0003	0.0003	mg/L
GW 3	9/29/10	<0.0003	0.0003	mg/L
GW 2	9/29/10	<0.0003	0.0003	mg/L
PZM1	10/21/10	0.0043	0.0003	mg/L
OM5	11/1/10	0.0011	0.0003	mg/L
UM5	11/2/10	0.0014	0.0003	mg/L
PZM5	11/2/10	0.0895	0.0003	mg/L
PZM6	11/3/10	0.0139	0.0003	mg/L
PZM18	11/9/10	0.0074	0.0003	mg/L
PZM4	12/14/10	0.0638	0.0003	mg/L
U-Nat (Suspended)				
PZM5-PT1	8/25/10	<0.001	0.001	mg/L
TAF 1	9/29/10	<0.0003	0.0003	mg/L
TAF 2	9/29/10	<0.0003	0.0003	mg/L
GW 5	9/29/10	<0.0003	0.0003	mg/L
GW 3	9/29/10	<0.0003	0.0003	mg/L
GW 2	9/29/10	<0.0003	0.0003	mg/L
PRI 1	9/29/10	<0.0003	0.0003	mg/L
SM5	10/29/10	<0.0003	0.0003	mg/L
OM5	11/1/10	<0.0003	0.0003	mg/L
UM5	11/2/10	<0.0003	0.0003	mg/L
PZM5	11/2/10	<0.0003	0.0003	mg/L
PZM6	11/3/10	<0.0003	0.0003	mg/L
PZM18	11/9/10	0.0023	0.0003	mg/L
PZM4	12/14/10	<0.0003	0.0003	mg/L

Table 2.9-3: Groundwater: Laboratory Analytical Results for Radon

Sample Name	Sample Date	Result	Precision +/- (pCi/g)	RL	Units
^{222}Rn					
OM5	11/1/10	156	28	50	pCi/L
UM5	11/2/10	133	26	50	pCi/L
PZM5	11/2/10	2150	250	50	pCi/L
PZM6	11/3/10	9300	1100	50	pCi/L
PZM18	11/9/10	3960	460	50	pCi/L
UM1	11/16/10	1240	63.2	100	pCi/L

Table 2.9-22: Dissolved Radionuclides in Surface Water (September 2010)

Sample Name	Result	Precision +/- (pCi/g)	RL	Units
^{226}Ra (Dissolved)				
SW 18	0.245	0.079	0.2	piC/L
SW 3	0.5	0.1	0.2	pCi/L
SW 11	0.4	0.1	0.2	pCi/L
SW 16	0.3	0.1	0.2	pCi/L
^{210}Po (Dissolved)				
SW 18	<1		1	piC/L
SW 3	<1		1	pCi/L
SW 11	<1		1	pCi/L
SW 16	<1		1	pCi/L
^{230}Th (Dissolved)				
SW 18	<0.2		0.2	pCi/L
SW 3	<0.2		0.2	pCi/L
SW 11	<0.2		0.2	pCi/L
SW 16	<0.2		0.2	pCi/L
^{210}Pb (Dissolved)				
SW 18	1.3	0.9	1	pCi/L
SW 3	<1		1	pCi/L
SW 11	<1		1	pCi/L
SW 16	<1		1	pCi/L
Total U-Nat (Dissolved)				
SW 18	0.0137		0.0003	mg/L
SW 3	0.0092		0.0003	mg/L
SW 11	0.0057		0.0003	mg/L
SW 16	0.0011		0.0003	mg/L

Table 2.9-23: Suspended Radionuclides: Surface Water (September 2010)

Sample Name	Result	Precision +/- (pCi/g)	RL	Units
^{226}Ra (Suspended)				
SW 18	0.3	0.1	0.2	piC/L
SW 3	2.8	0.2	0.2	pCi/L
SW 11	0.4	0.1	0.2	pCi/L
SW 16	<0.2		0.2	pCi/L
^{210}Po (Suspended)				
SW 18	<1		1	piC/L
SW 3	<1		1	pCi/L
SW 11	<1		1	pCi/L
SW 16	<1		1	pCi/L
^{230}Th (Suspended)				
SW 18	<0.2		0.2	piC/L
SW 3	0.296	0.161	0.2	pCi/L
SW 11	<0.2		0.2	pCi/L
SW 16	0.218	0.165	0.2	pCi/L
^{210}Pb (Suspended)				
SW 18	<1		1	piC/L
SW 3	6.3	0.7	1	pCi/L
SW 11	1.2	0.4	1	pCi/L
SW 16	<1		1	pCi/L
Total U-Nat (Suspended)				
SW 18	<0.0003		0.0003	mg/L
SW 3	0.0021		0.0003	mg/L
SW 11	<0.0003		0.0003	mg/L
SW 16	<0.0003		0.0003	mg/L

Table 2.9-24: Vegetation Sampling Results

Sample ID	Sample Date	^{210}PB (pCi/kg)			^{210}Po (pCi/kg)			^{226}Ra (pCi/kg)			^{230}Th (pCi/kg)			Total U-Nat (pCi/kg)	
		Result	Precision +/-	RL	Result	Precision +/-	RL	Result	Precision +/-	RL	Result	Precision +/-	RL	Result	RL
3rd Quarter 2010															
RC-RAD-1	9/16/2010	93.5	8.0	1	<1		1	9.3	0.4	0.05	0.2	0.5	0.2	1.9	0.2
RC-RAD-2	9/13/2010	266	14	1	1.56	1.6	1	10.6	0.4	0.05	1.3	1.0	0.2	2.4	0.2
RC-RAD-3	9/13/2010	132	17	1	1.15	1.4	1	6.8	0.3	0.05	<0.2		0.2	1.1	0.2
2nd Quarter 2011															
RC-RAD-1	6/15/2011	100	8.5	4	<1		1	11.0	1.3	0.05	1.4	0.7	0.2	3.7	0.2
RC-RAD-2	6/15/2011	110	8.2	4	2.50	4.20	1	12.0	1.3	0.05	2.3	1.0	0.2	3.6	0.2
RC-RAD-3	6/15/2011	74.0	17	4	<1		1	13.0	1.5	0.05	1.2	0.7	0.2	2.4	0.2

DAC

PROPOSED RENO CREEK PROJECT
CAMPBELL COUNTY, WYOMING

Figure 2.9-1
Baseline Radiological Sampling Locations

REV #	BY	DATE	DESCRIPTION
0	RHK	12/08/2011	Initial Draft for Review
1	RHK	01/19/2012	Approved
2	RHK	06/15/2012	Revised Project Boundary

Prepared For:
AUC LLC
LAKEWOOD, COLORADO

Prepared By:
TREC, Inc.
Engineering & Environmental Management
900 Werner Court
Suite 150
Casper, WY, 82601
Phone (307)265-0696
Fax (307)265-2498
www.treccorp.com

Contour Interval = 10 feet
0 0.2 0.4 0.8 Miles
0 1,400 2,800 5,600 Feet
NAD 1983 StatePlane Wyoming East FIPS 4901 Feet — 1:17,000

This map (or data product) is for assessment and planning purposes only. It is not intended to be used for description, conveyance, authoritative definition of legal boundary, or property title. This is not a survey product.

Legend
- Proposed Central Processing Plant Location
- Ground Water Well Sample Location
- Surface Water & Sediment Sample Location
- Stock Well Sample Location
- Soil Sample Location
- Air Particulate Monitor Location
- Vegetation Sample Location
- Meteorological Station
- Soil Correlation Plot Location
- Proposed Reno Creek Project Boundary
- Ephemeral Stream
- Ore Body

Road Classification
- Major Road (Paved)
- Minor Road (Unpaved)

Figure 2.9-2 Selected Photos of Reno Creek Project

Figure 2.9-3 Vehicle Scanning Systems

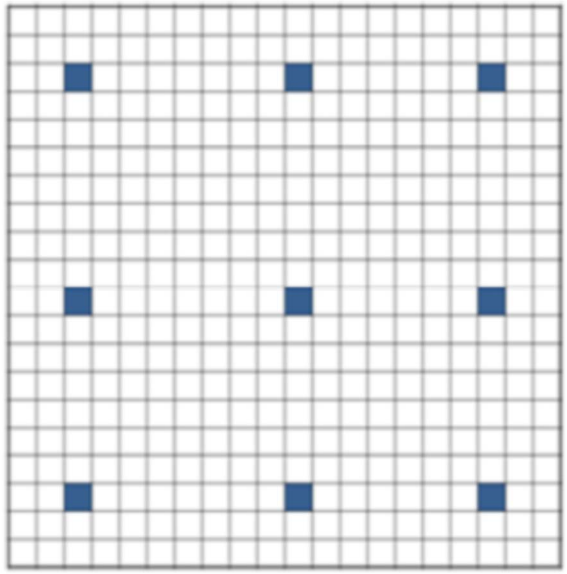


Figure 2.9-4 Correlation Sampling Composite Layout

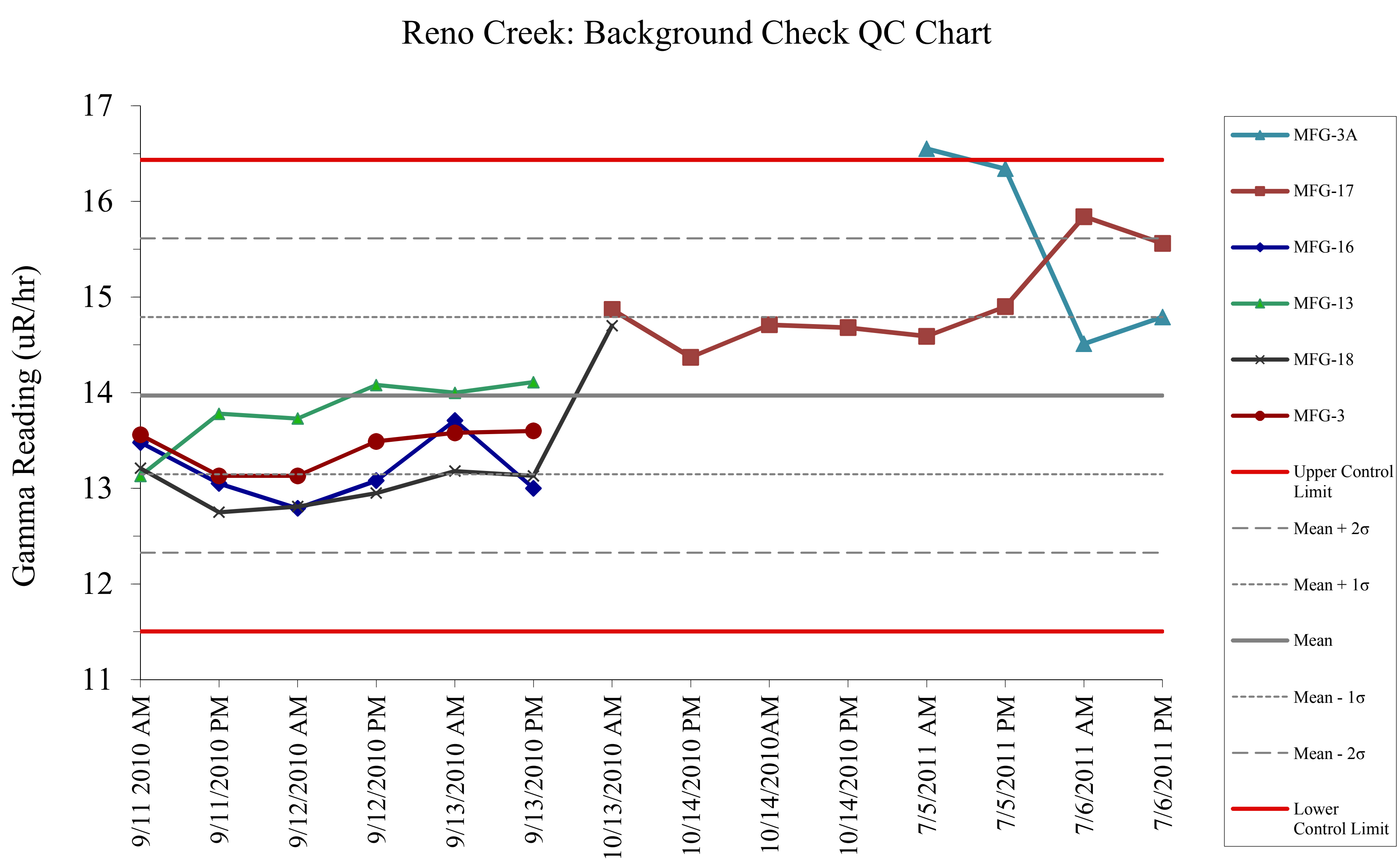


Figure 2.9-5 Instrument QA/QC Background Chart

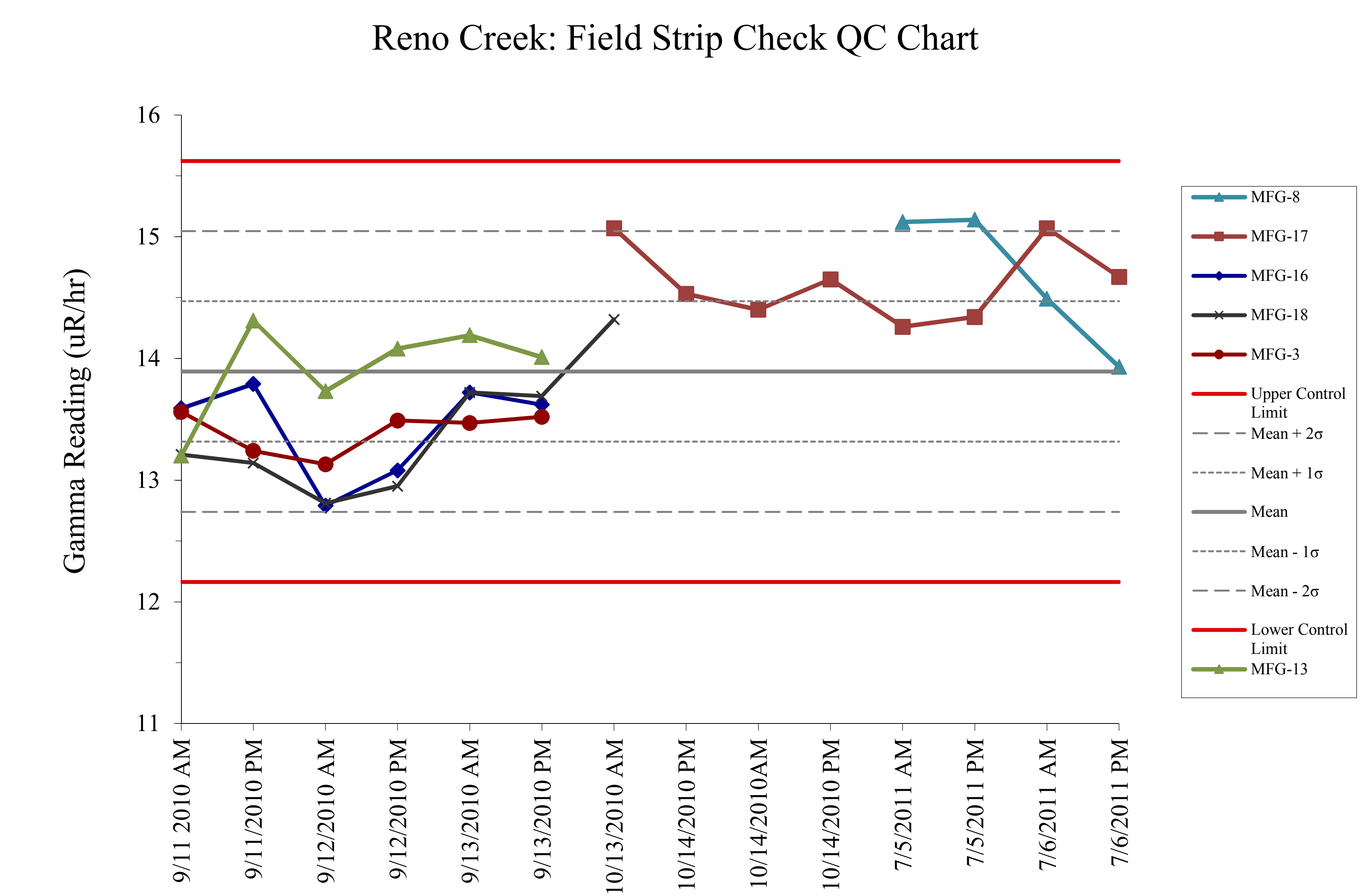


Figure 2.9-6 Instrument QA/QC Field Strip Chart

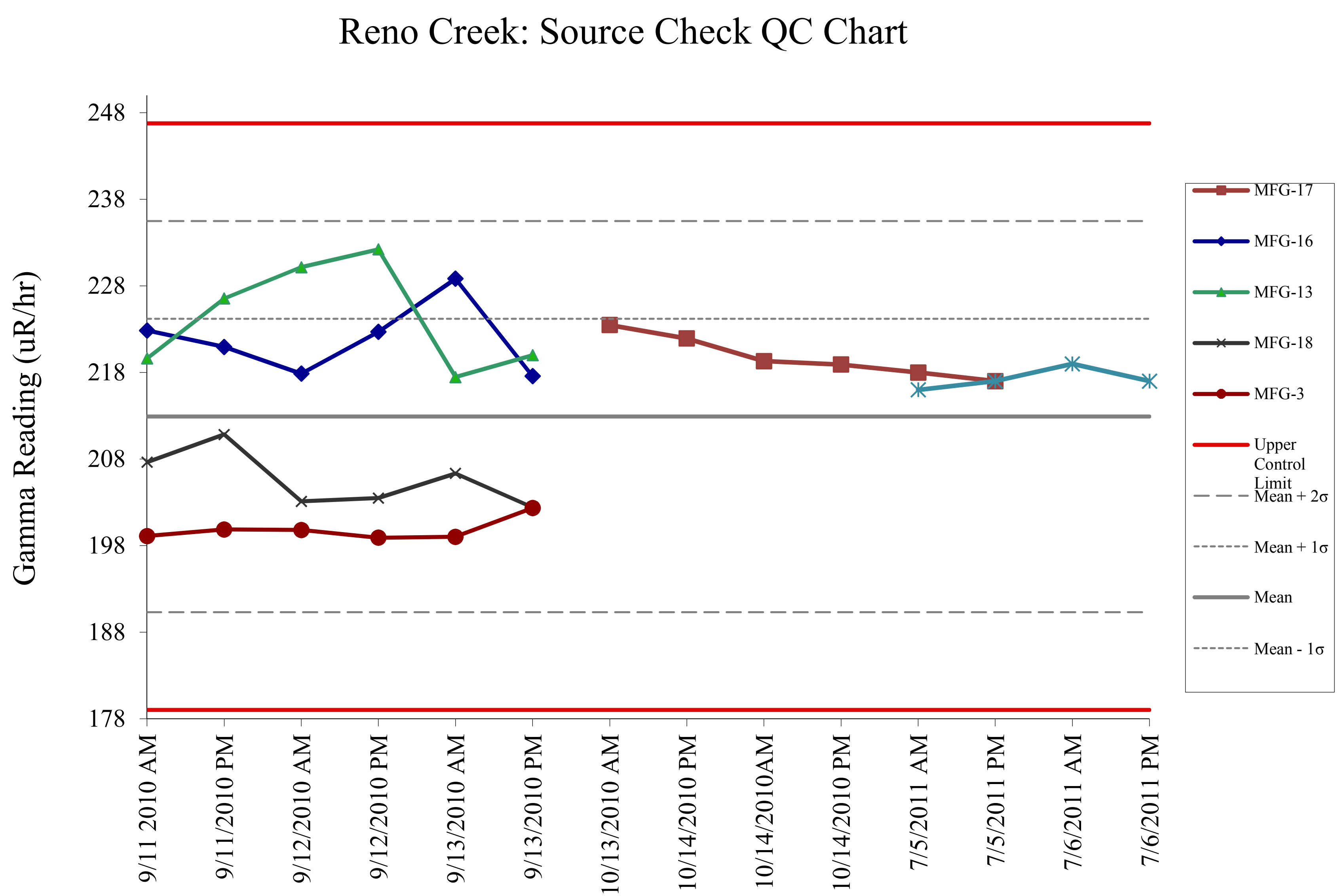


Figure 2.9-7 Instrument QA/QC Source Chart

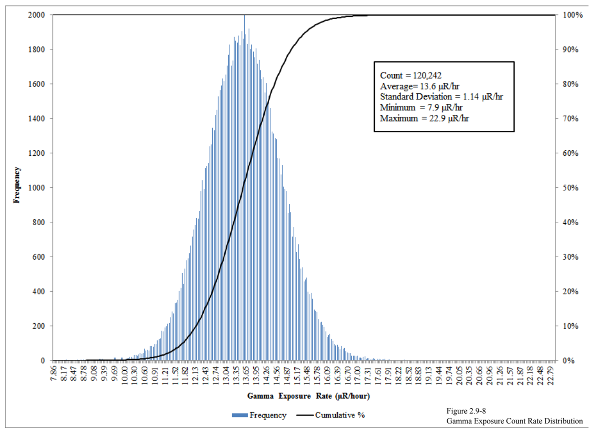
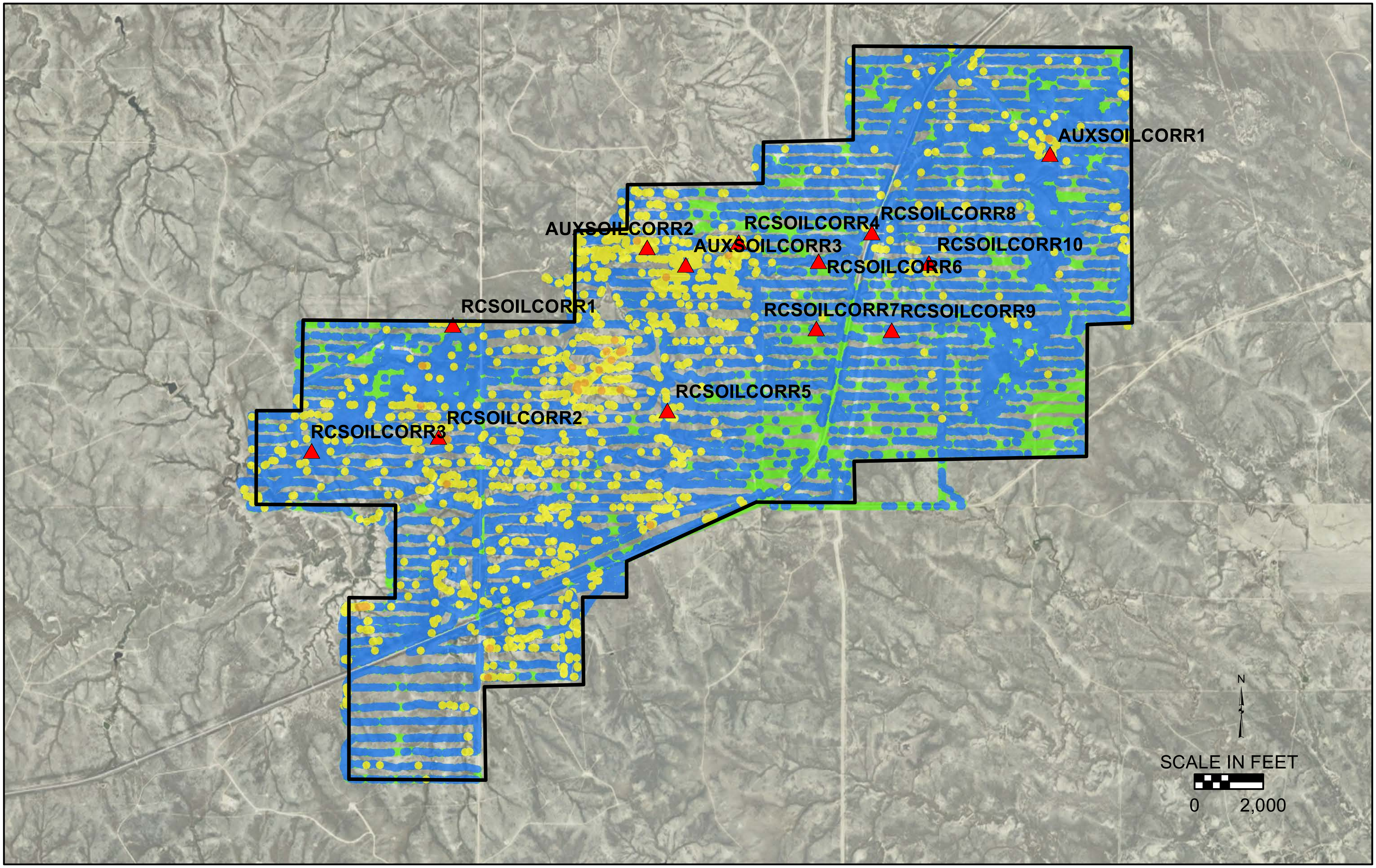


Figure 2.9-8 Gamma Exposure Count Rate Distribution

P:\182068 Reno Creek\GIS Mapping\2011 MXDs\Figure2.9-10_GammaSoil_Corr_NEW.mxd



Gamma Exposure Rate (uR/hr)

- <14
- 14-16
- 16-18
- 18-20
- >20

Project Boundary

Soil Correlation Plot Location

February, 2012

Figure 2.9-9
Gamma Exposure Rate Map and Soil Correlation Plot Locations
Reno Creek

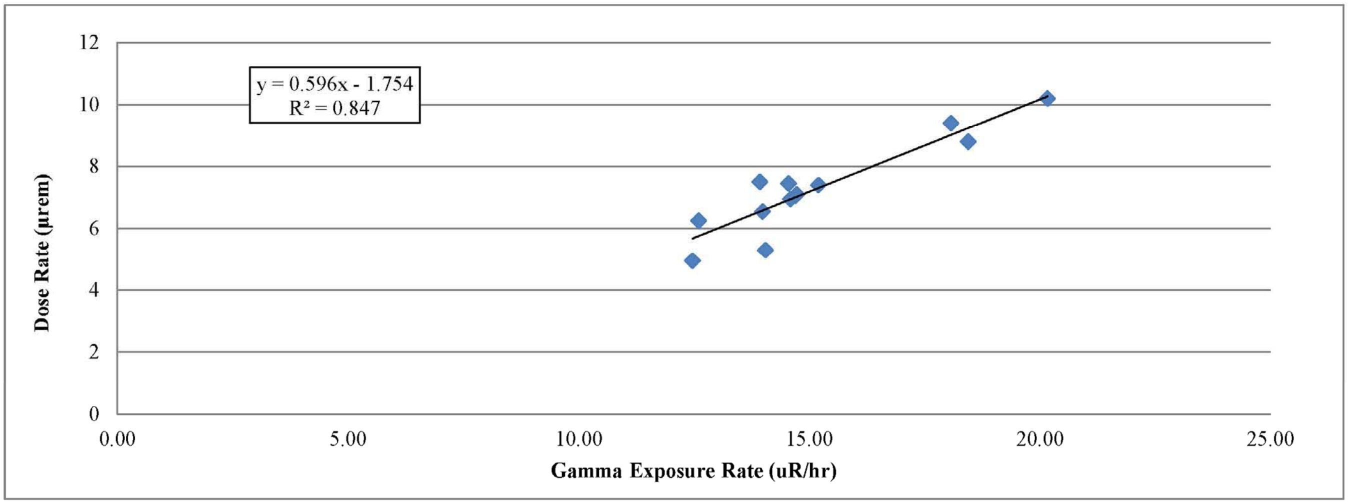


Figure 2.9-10 Dose Rate and Gamma Exposure Rate Correlation

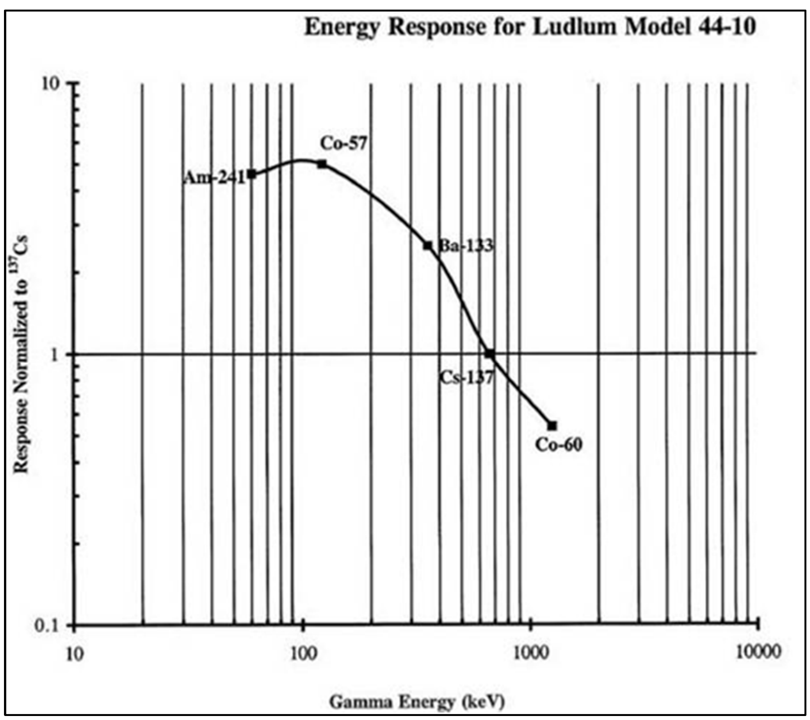


Figure 2.9-11 Energy Response Characteristics of the Ludlum Model 44-10 Detector

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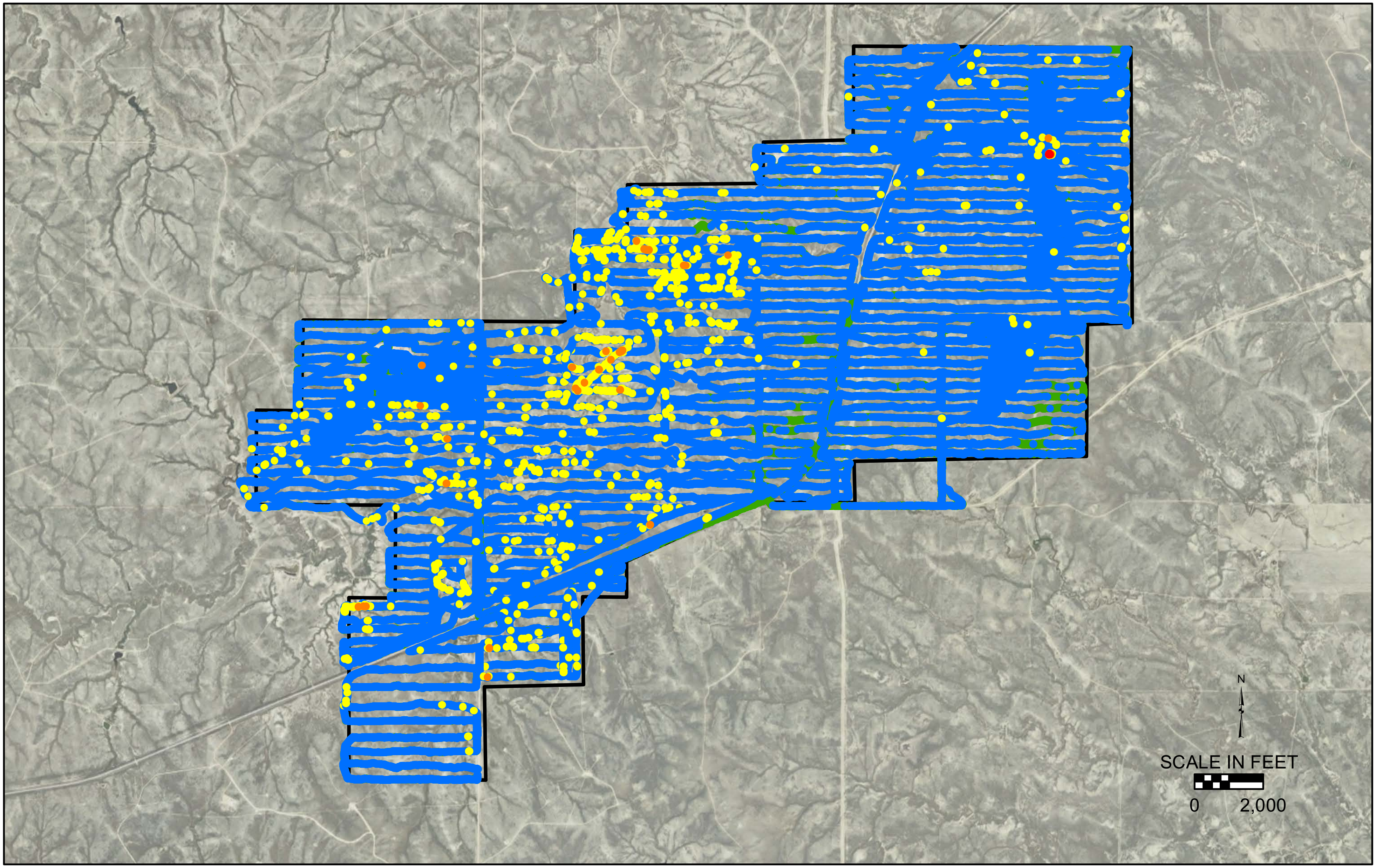

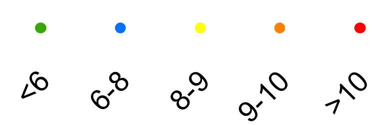

February, 2012

Figure 2.9-12
Estimated Dose Rate Map
Reno Creek

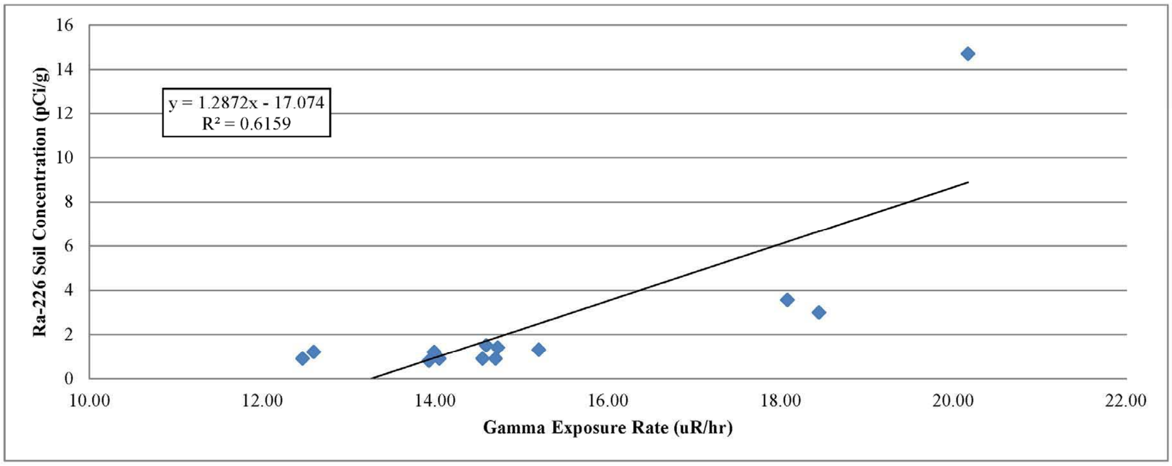

Figure 2.9-13 Radium-226 and Gamma Exposure Rate Correlation

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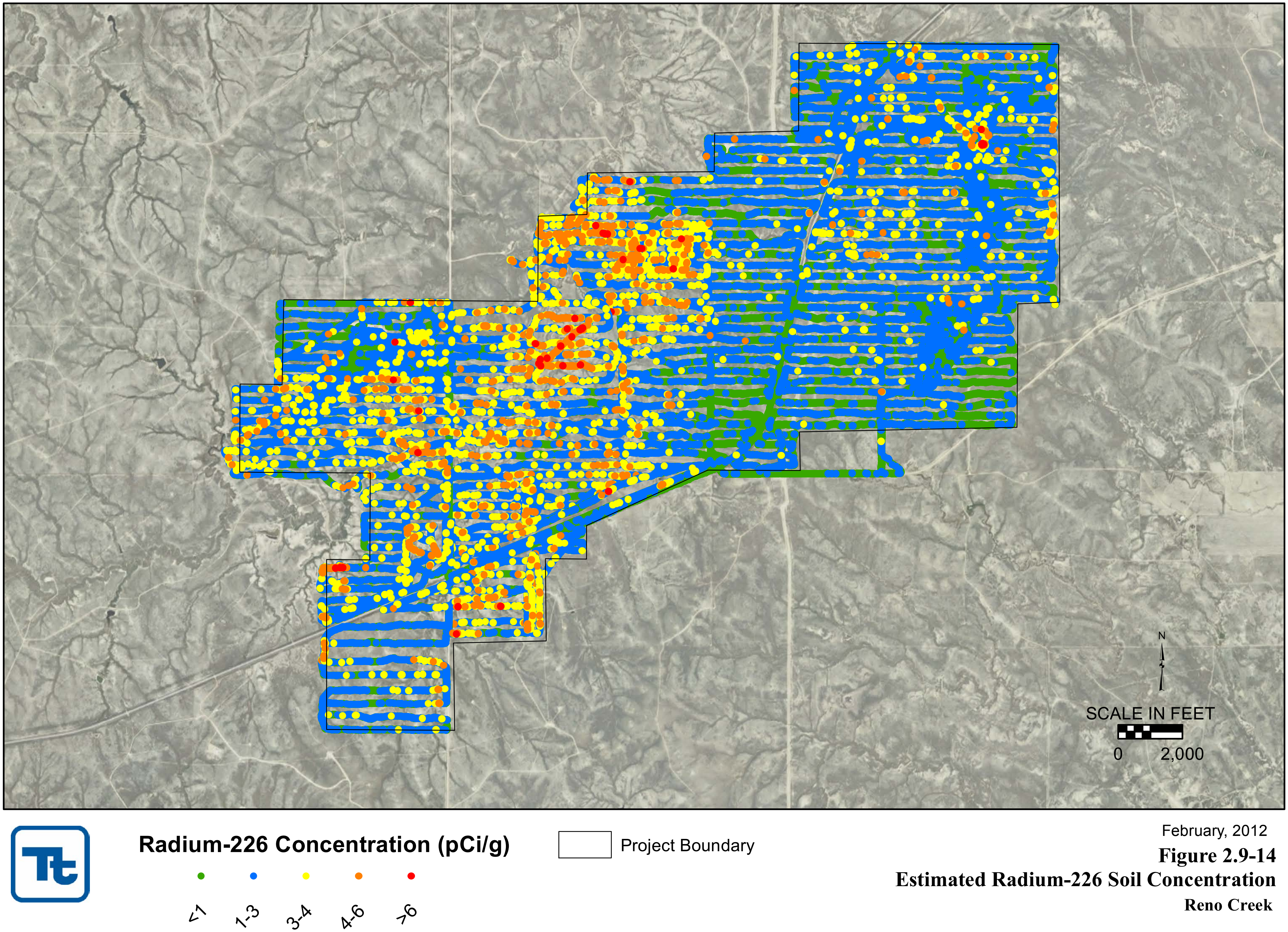

February, 2012

Figure 2.9-14
Estimated Radium-226 Soil Concentration
Reno Creek

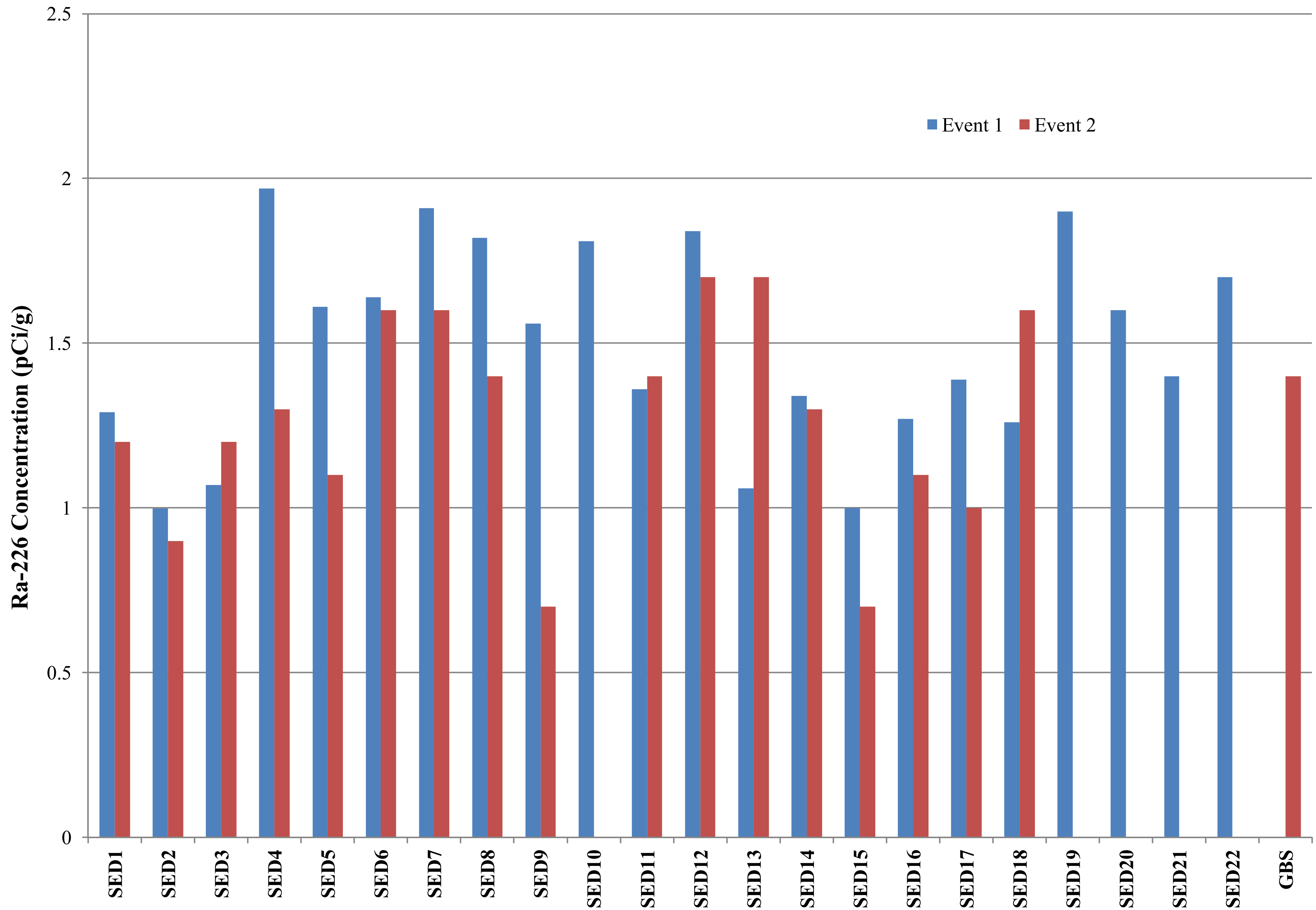

Figure 2.9-15 Sediment Sampling Radium-226 Concentrations for Event 1 & 2

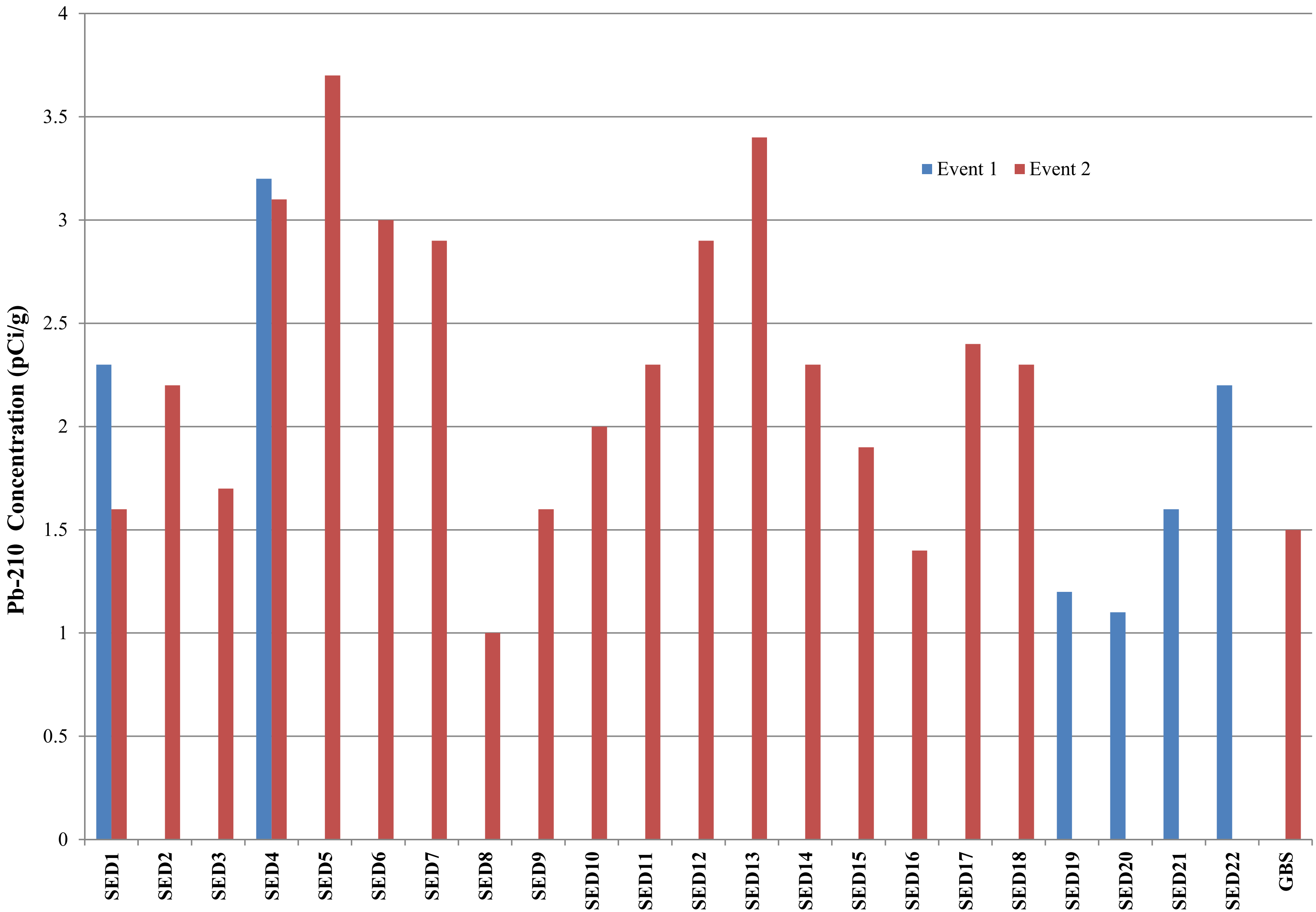

Figure 2.9-16 Sediment Sampling Pb-210 Concentrations for Event 1 & 2

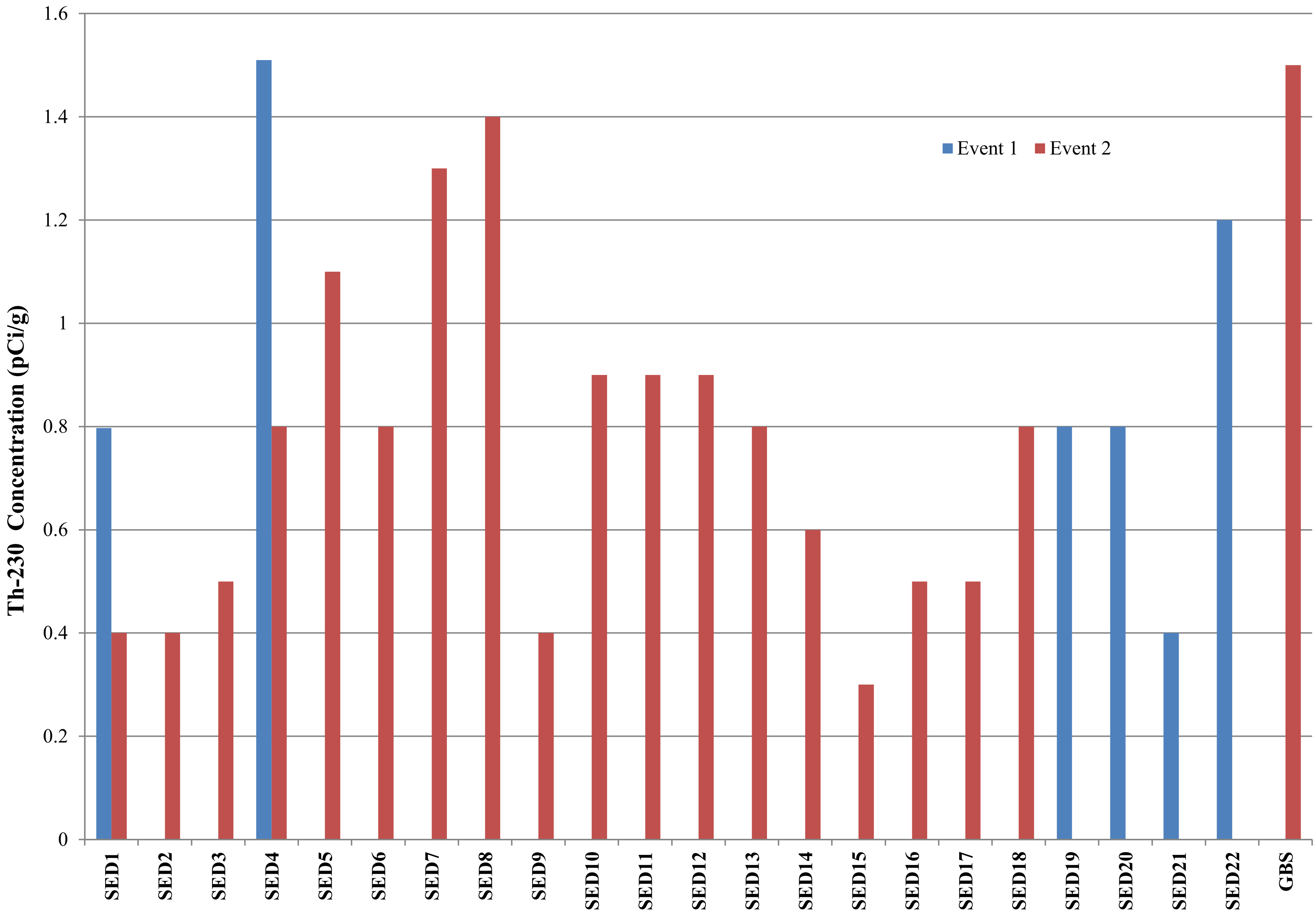

Figure 2.9-17 Sediment Sampling Th-230 Concentrations for Event 1 & 2

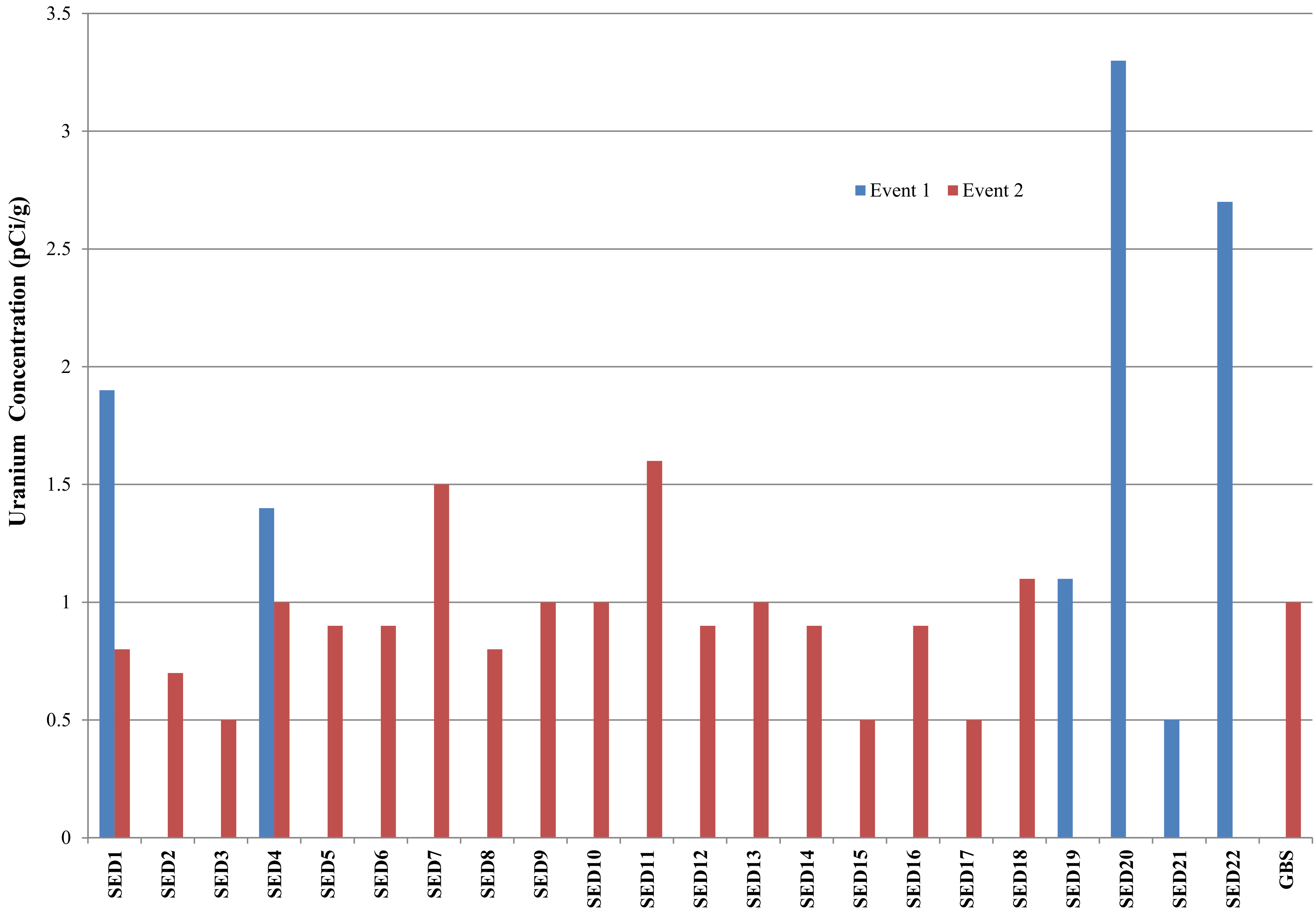

Figure 2.9-18 Sediment Sampling Total Uranium Concentrations for Event 1 & 2

Figure 2.9-19 Air Monitoring Station and Radon Monitor

Figure 2.9-20 F&J Air Particulate Sampler Pump

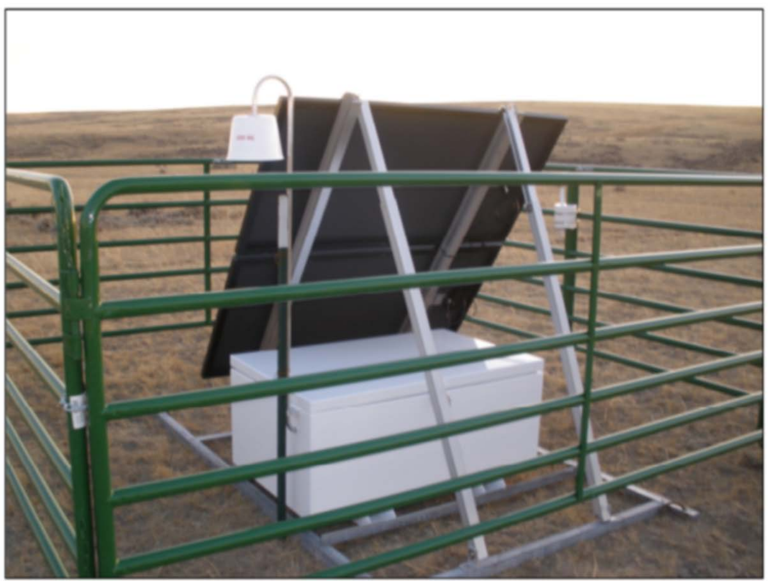

Figure 2.9-21 Solar Powered Air Sampler Configuration

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