TABLE OF CONTENTS

2.6 Geology and Soils 2.6-1
2.6.1 Regional Geology 2.6-1
2.6.1.1 Stratigraphy 2.6-1
2.6.1.2 Structure 2.6-2
2.6.2 Site Geology 2.6-3
2.6.2.1 Stratigraphy 2.6-3
2.6.2.2 Structure 2.6-4
2.6.2.3 Ore Mineralogy and Geochemistry 2.6-4
2.6.2.4 Historic Uranium Exploration Activities 2.6-6
2.6.3 Seismology 2.6-7
2.6.3.1 Historic Seismicity 2.6-7
2.6.3.2 Uniform Building Code and International Building Code ... 2.6-11
2.6.3.3 Deterministic Analysis of Active Fault Systems 2.6-12
2.6.3.4 Maximum Tectonic Province Earthquake "Floating Earthquake" Seismogenic Source 2.6-12
2.6.3.5 Probabilistic Seismic Hazard Analysis and IBC 2.6-13
2.6.4 Soils 2.6-13
2.6.4.1 Soil Survey 2.6-14
2.6.4.2 Field Sampling 2.6-14
2.6.4.3 Results and Discussion 2.6-15
2.6.4.4 Soil Suitability as a Plant Growth Medium 2.6-16
2.6.4.5 Topsoil Protection 2.6-16
2.6.4.6 Prior Surface Disturbances 2.6-17

LIST OF FIGURES

Figure 2.6-1 Regional Geologic Map
Figure 2.6-2a Geologic Cross Section Schematic
Figure 2.6-2b Stratigraphic Column, Upper Battle Spring Formation
Figure 2.6-3 Historical Seismicity Map
Figure 2.6-4 UBC Seismic Zones
Figure 2.6-5 Active Fault Systems in the Vicinity of the Permit Area
Figure 2.6-6 2,500-Year Probabilistic Acceleration Map
Figure 2.6-7a Soils (1:100,000)
Figure 2.6-7b Soils (1:500,000)
Figure 2.6-8 Typical Soil Pit
Figure 2.6-9 Soil Sampling Locations
Figure 2.6-10 Existing Road Disturbance
Figure 2.6-11 Typical Two-Track Road

LIST OF TABLES

Table 2.6-1 Permit Area Stratigraphy
Table 2.6-2 Permit Area Soil Map Units
Table 2.6-3 Permit Area Soil Suitability Ranges
Table 2.6-4 Abandonment Information for Historic Drill Holes

ATTACHMENTS

Attachment 2.6-1 Typical Geophysical Logs
Attachment 2.6-2 Locations, Total Depths, and Completion Dates of Historic Exploration Holes

PLATES

Plate 2.6-1a Cross Section A-A'
Plate 2.6-1b Cross Section B-C
Plate 2.6-1c Cross Section C-D
Plate 2.6-1d Cross Section D-E
Plate 2.6-1e Cross Section F-F'
Plate 2.6-1f Cross Section G-G'
Plate 2.6-1g Cross Section H-H'
Plate 2.6-2a Lost Creek Shale Isopach Map
Plate 2.6-2b HJ Horizon Isopach Map
Plate 2.6-2c Sagebrush Shale Isopach Map
Plate 2.6-2d UKM Sand Isopach Map
Plate 2.6-3 Soil Survey Mapping Units
Plate 2.6-4a Structural Contour Map, FG Sand Unit
Plate 2.6-4b Structural Contour Map, Lost Creek Shale Unit
Plate 2.6-4c Structural Contour Map, HJ Sand Unit
Plate 2.6-4d Structural Contour Map, Sagebrush Shale Unit
Plate 2.6-4e Structural Contour Map, KM Sand Unit

2.6 Geology and Soils

2.6.1 Regional Geology

The Great Divide Basin (Basin) is an oval-shaped structural depression, encompassing some 3,500 square miles in south-central Wyoming. The Basin is bounded on the north by the Wind River Range and Granite Mountains, on the east by the Rawlins Uplift, on the south by the Wamsutter Arch and on the west by the Rock Springs Uplift. The regional geologic map is shown in **Figure 2.6-1**. Geologic development of the Basin began in the Late Cretaceous and continued through much of the Early Eocene.

2.6.1.1 Stratigraphy

The earliest sedimentation in the Basin was the Paleocene (Early Tertiary) Fort Union Formation, which was unconformably deposited on the Lance Formation of Late Cretaceous age. The Fort Union Formation consists mostly of lacustrine shales, siltstones, and thin sandstones, which locally contain lignite beds. The thickness of the Fort Union Formation varies from place to place in the Basin, and it is approximately 4,650 feet thick in the Permit Area.

The Fort Union Formation is unconformably overlain by sediments of Eocene age, making up about 6,200 feet of basin fill. The western and southern portions of the Basin are covered by the Wasatch Group, which consists of sandstone, siltstone, limestone, conglomerate and lignite beds. The rocks in the Wasatch Group are believed to be of fluvial-lacustrine origin. Towards the north and northeast, the Wasatch Group rapidly grades into and inter-tongues with the equally thick, fine- to coarse-grained arkosic sandstones and conglomerates of the Battle Spring Formation, a typical alluvial fan complex. The source of the Battle Spring sediments is believed to be the ancestral Granite Mountains to the north. Pliocene pediment deposits and recent alluvium cover large areas of the surface in the Basin. **Table 2.6-1** and **Figure 2.6.2a** show the general stratigraphy of the Basin.

The upper portion of the Battle Spring Formation is the host to the uranium mineralization in the Permit Area. In the Permit Area, the top 700 feet of the Battle Spring Formation is divided into at least five horizons marked from top to bottom as BC, DE, FG, HJ, and KM. These horizons are separated from one another by various thicknesses of shale, mudstone and siltstone **(Figure 2.6-2b)**.

Aquifers in the Battle Spring Formation typically consist of thick sequences of multiple, medium to coarse-grained, fluvial channel-fill sands. Mapped "sand" units (e.g., the UHJ Sand) may range from five to 50 feet in composite thickness and typically consist of multiple stacked "channel-fills". "Aquifers", in turn, typically consist of multiple stacked sand units. Sand units are commonly separated vertically by locally thick beds of mudstone, claystone, siltstone or fine-grained sands. These interbeds represent local aquitards and aquicludes which can be considered internal to the regional aquifer. Total composite thickness of an aquifer (e.g., the HJ horizon) is commonly in excess of 100 feet.

Aquicludes and aquitards (e.g., the LCS and SBS Shales) represent quiescent floodplain and overbank sedimentary environments between channel fill sequences. Generally referred to as 'shales', they are, in essence, sedimentary sequences dominated by mudstone and claystone lithology; but also may include substantial amounts of siltstone and fine-grained sands. These lithologies can exhibit considerable interfingering, and are often transitional to the aquifers above or below. As a result, dramatic thickening and thinning of the aquicludes can occur locally. In addition, their upper and lower boundaries are often gradational. Aquicludes may even exhibit localized occurrences of mineralization.

2.6.1.2 Structure

The present physiographic feature of the Basin was generated by the Laramide Orogeny. During the Late Cretaceous and Early Tertiary, the structures surrounding the Basin were either rejuvenated or were formed, transforming the area into a bowl-shaped geological structure, the Basin. During this upheaval, the Wind River Mountains and Granite Mountains were uplifted on the north side of the Basin. The Rawlins Uplift formed to the east; the Wamsutter Arch formed to the south; and the Rock Spring Uplift formed to the west. All of these highs formed a ring around the Basin, turning the Basin into a bowl-like structure with drainage being inward. The Continental Divide, extending from the south, splits into two and forms half circles on the east and west sides of the Basin, joining again as one structural high on the north side of the Basin.

The Basin is asymmetrical with its major axis trending west-northwest. Several anticlines and synclines have been mapped within the Basin, and some of these features are oil-bearing (at much deeper levels than the uranium-bearing formations). Noteworthy among these structures is the Lost Soldier anticline in the northeastern part of the Basin, approximately 15 miles northeast of the Permit Area. The Battle Spring and Fort Union Formations, as well as older rocks crop out in the anticline; and the formations on the southwestern flank of the anticline dip 20 to 25 degrees to the southwest. The dip gradually becomes gentler, and, at the Permit Area, it is merely three degrees to the west.

Contemporaneous with the uplift of the mountains surrounding the Basin, there were episodes of normal and thrust faulting within and around the Basin. Most of the major faults are located in the northern part of the Basin, with displacement ranging from a few feet to over 3,000 feet. But, toward the center of the Basin near the Permit Area, faulting seems to be only on a minor scale. For example, the displacement at the Lost Creek Fault (Fault) which traverses the mineralized area from west-southwest to east-northeast is zero to about 80 feet. More details about the Fault are given in **Section 2.6.2.2**.

2.6.2 Site Geology

The Permit Area is located near the north-central part of the Basin, where the Basin fills are predominantly the Eocene Battle Spring Formation and the Paleocene Fort Union Formation. Geological cross sections throughout the Permit Area are presented in **Plates 2.6-1a, b, c, d, e, f, and g)**. **Attachment 2.6-1** contains copies of typical geophysical logs from the Permit Area.

2.6.2.1 Stratigraphy

The entire Permit Area is covered by the upper part of the Battle Spring Formation, which is the host to uranium mineralization. Generally, in the Basin, Battle Spring and Wasatch Formations, which are time equivalent, interfinger with one another. In the Permit Area, the upper half of the lithologic units consists of Battle Spring Formation and the lower half is made up of Wasatch Formation. The total thickness of the Battle Spring and Wasatch Formations under the Permit Area is about 6,200 feet. The Fort Union Formation is 4,650 feet thick beneath the Permit Area and unconformably underlies the Battle Spring/Wasatch Formations. Deeper in the Basin and lying unconformably are various Cretaceous, Jurassic, Triassic, Paleozoic, and Precambrian basement lithologic units (**Table 2.6-1**). A schematic geologic cross section across the Permit Area is shown in **Figure 2.6-2a**, depicting the entire lithologic units that are present under the Permit Area.

The Battle Spring Formation in the Permit Area is part of a major alluvial system, consisting of thick beds of very fine- to coarse-grained arkosic sandstones separated by various layers of mudstones and siltstones. Conglomerate beds may exist locally. The uranium mineralization is associated with finer-grained sandstones and siltstones, which may contain minor organic matter in a few areas. At least five horizons with various amounts of mineralization have been identified. From the surface down, they have been named: BC, DE, FG, HJ, and KM. The two horizons with the most mineralization are HJ and KM, which have been further divided into upper, middle, and lower sub-units of sandstones (UHJ Sand, MHJ Sand, and LHJ Sand; and UKM Sand, MKM Sand, and

LKM Sand). Geological cross sections through the mineralized zones in the Permit Area are presented in **Plates 2.6-1a, b, c, d, e, f, and g)**. Thickness (isopach) maps of the HJ Horizon and UKM Sand, as well as the shales above HJ (Lost Creek Shale) and below HJ (Sage Brush Shale), are presented in **Plates 2.6-2a, b, c,** and **d**. Structural contour maps of the FG Sand, Lost Creek Shale, HJ Sand, Sagebrush Shale, and KM Sand are presented in **Plates 2.6-4a**, **b**, **c**, **d**, and **e**.

The HJ Horizon is 110 to 130 feet thick, averaging about 120 feet. The thinner part of HJ is generally south of the Fault. A thicker part of the HJ Horizon runs parallel to the Fault, trending in a west-southwest to east-northeasterly direction. The mineralization is mostly concentrated in the middle part of the HJ Horizon and occurs as both roll front and tabular deposits. The subdivided Sand units within the HJ Horizon are separated by discontinuous shale, siltstone and mudstones.

The UKM Sand lies under the Sage Brush Shale and is 20 to more than 60 feet thick, averaging about 40 feet. In the eastern part of the Permit Area, the unit is 20 to 50 feet thick; whereas the sand unit in the western portion of the permit area is 40 to more than 60 feet thick, indicating the development of a major paleo-channel. The mineralization occurs as both roll front and tabular deposits.

2.6.2.2 Structure

The geologic structure in the Permit Area is rather simple, as shown in **Plates 2.6-1a, b, c, d, e, f, and g**. The Battle Spring Formation dips gently to the west at three degrees and only one fault (e.g., the Fault) was recognized in the mineralized area. The Fault is a "scissor fault" that extends the length of the Permit Area from the west-southwest to the east-northeast. The maximum displacement at the west end of the Permit Area is around 45 feet, dropping down to the north; whereas the displacement on the east side of the Permit Area is about 80 feet with the down-dropped side to the south, creating the scissor fault. Near the middle of the Permit Area, the displacement is practically zero.

2.6.2.3 Ore Mineralogy and Geochemistry

The age of mineralization in the Battle Spring Formation is considered to be between 35 and 26 million years before present. Uranium mineralization in the Basin generally occurs either as tabular or C-shaped roll-front deposits. Oxygen-rich surface water, carrying dissolved uranium, entered various sandstones in the Basin. The water percolated down dip, oxidizing the sandstones on its way down dip. Upon reaching sites rich in organic matter, the water lost its oxidizing potential and deposited the uranium, forming the two types of mineralization mentioned above.

Tabular deposits may form at the interface between oxidizing and reducing conditions (the redox front), where oxidation, for all practical purposes, stops. Localized tabular deposits may also form up-dip from the redox front in an entirely oxidized zone, where carbonaceous materials have gathered and formed locally reducing conditions.

The C-shaped roll-front deposits normally form just at the redox front, where the water loses its oxidizing potential. The uranium precipitates and accumulates in a "C"-shaped deposit, with the concave side facing up-dip toward the oxidized sand. Uranium usually accumulates in finer-grained sandstones that carry various amounts of organic matter, which provides a reducing condition.

The alteration process not only changes the color, but also alters the mineralogy of the host sandstones. The color of unaltered, reduced sandstone is light to dark grey, with carbon trash, dark accessories, and traces of pyrite. Altered, oxidized, sandstone contains iron oxide staining (where former carbonaceous matter and pyrite were present), kaolinized feldspar, and has a pink to tan-buff, greenish-grey to bleached appearance. The presence of pyrite and carbonaceous material appear to be the major controlling factors for the precipitation of uranium mineralization. Thinning of sandstones and diminishing grain size probably slowed the advance of the uranium-bearing solutions and further enhanced the chances of precipitation.

The main uranium minerals are uraninite, a uranium oxide, and coffinite, a uranium silicate. Russell Honea (1979) and John V. Heyse (1979) studied several core samples by scanning electron microprobe (SEM), polished section and thin section. Their conclusions were that the host sands are fine- to coarse-grained, poorly sorted arkose. The uranium mineralization is of sub-microscopic size and can be seen only in SEM magnification. They are associated and at times intergrown with round pyrite particles. The uranium minerals identified are mostly uraninite and, possibly, coffinite. The uranium, besides occurring with pyrite, also occurs as coating around sand grains and as filling of voids between grains. It also occurs as minute particles within larger clay particles.

The most recent study of the lithology and mineralogy was conducted by Hazen Research under the guidance of Dr. Nick Ferris, Ur-Energy geologist (Ferris, 2007, company report). He concluded that the rocks, represented by a core sample from a depth of 506 to 507 feet of Hole Number LC-64C, are medium- to coarse-grained with interstitial clay and silt. Uranium occurrences are very fine-grained and micron-sized, and are mainly dispersed throughout some of the interstitial clays, and occur similarly in some of the interstitial pyrite as well. Because of the size of uranium mineral particles, it was not certain whether the uranium mineral was coffinite or uraninite. The sample tested, comes from the Upper KM Sand unit and may not be representative of the majority of the mineralization in the overlying HJ Horizon within the Permit Area.

Known mineralized intervals are found at depths ranging from near surface down to 1,150 feet below the surface in the Permit Area. It is possible that deeper mineralization may exist as well. The main mineralization horizons trend in an east-northeast direction for at least three miles, and are up to 2,000 feet wide. The thickness of individual mineralized beds at the Permit Area ranges from five to 28 feet and averages about 16 feet. The mineralization grade ranges from 0.03 percent to more than 0.20 percent equivalent uranium oxide (eU_3O_8). Four main mineralized horizons, from depths of 350 to 600 feet, have been identified. The richest mineralized zone occurs in the middle part of the HJ Horizon (MHJ Sand) and it is about 30 feet thick, 400 to 450 feet deep, and is believed to contain more than 50 percent of the total resource under the Permit Area.

2.6.2.4 Historic Uranium Exploration Activities

Historic exploration activities in the Permit Area can be summarized as follows:

- Pre-1976: Numerous companies held the property; uranium mineralization was discovered by Climax Uranium and Conoco.

- 1976: Texasgulf optioned property from Valley Development Inc.
- 1977 through 1979: Texasgulf optioned property from Valley Development Inc., delineated the main trend of the mineralization, obtained a 50-percent interest in the Conoco claims on the trend to the east, and exercised its option with Valley Development Inc.
- 1986: Power Nuclear Corporation acquired the properties.
- 2000: Power Nuclear Corporation sold its Lost Creek properties to New Frontiers Uranium, LLC.
- 2005: New Frontiers Uranium, LLC transferred its Wyoming properties and data including its Lost Creek property to NFU Wyoming, LLC. (NFU).
- 2005: Ur-Energy USA, Inc. purchased NFU from New Frontiers Uranium, LLC on terms.
- 2007: Ur-Energy USA, Inc. completes the acquisition of NFU from NFU, LLC, and maintains NFU as a wholly owned subsidiary.
- 2007: Ur-Energy USA, Inc. forms LC ISR, LLC to develop the Lost Creek property into an ISR facility and transfers the Lost Creek property from NFU to LC ISR, LLC.

At least 560 uranium exploration holes had been drilled in Permit Area prior to 2000. **Table 2.6-4** lists historic drill holes and their abandonment status, and the plates and table in **Attachment 2.6-2** present the locations and total depths of all the known historic exploration holes drilled in the Permit Area.

Historic and current uranium explorations exist in other areas of the Basin. Historic and current oil and gas exploration drilling are also in the region. There are no current oil and gas activities within the Basin that are completed in the same horizons as those discussed for ISR production in this application. The nearest significant gas fields are approximately ten miles to the southwest; therefore, no interference is anticipated between oil and gas production activities and ISR activities. There is no exploration of coal bed methane or other mineral resources within the Permit Area and the nearby region.

2.6.3 Seismology

The discussion of the seismology of the Permit Area and surrounding areas includes: an analysis of historic seismicity; an analysis of the International Building Code (IBC); 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. The materials presented here are mainly based on the seismologic characterization of Sweetwater, Carbon, Fremont, and Natrona Counties by James C. Case and others from the Wyoming State Geological Survey (Case, et. al., 2002a, 2002b, 2002c and 2003).

2.6.3.1 Historic Seismicity

The Permit Area is located in the north-eastern portion of the Basin, in south-central Wyoming. Historically, south-central Wyoming has had a low to moderate level of seismicity compared to the rest of the State of Wyoming. As shown in **Figure 2.6-3**, most of the historical earthquakes occurred in the west-northwest portion of Wyoming. Significant historical earthquakes adjacent to the Permit Area are described below, and are organized by areas in which they occurred.

Town of Bairoil Area

Bairoil is located about 15 miles northeast of the Permit Area. Historically, there have been only a few earthquakes that have occurred within 20 miles of Bairoil. On August 11, 1916, a non-damaging intensity III earthquake occurred approximately 17 miles northwest of Bairoil. On June 1, 1993, a non-damaging magnitude 3.8, intensity III earthquake occurred four miles north of Bairoil, and was felt by some residents. On December 10, 1996, a non-damaging magnitude 2.6 earthquake occurred approximately ten miles northwest of Bairoil. A few residents also felt that event.

Two recent earthquakes were recorded near Bairoil in 2000. On May 26, 2000, a magnitude 4.0 earthquake occurred, followed by another (magnitude 2.8) four days later, on May 30, 2000. Both earthquakes were located about 3.5 miles southwest of Bairoil. Most residents in Bairoil felt the first earthquake. No significant damage was associated with either seismic event (Cook, 2000).

City of Rawlins Area

Rawlins is approximately 38 miles southeast of the Permit Area. The first recorded earthquake that was felt and reported immediately southwest of Rawlins occurred on March 28, 1896. The intensity IV earthquake shook for about two seconds. On March 10, 1917, an earthquake (intensity IV) was recorded approximately one mile northeast of Rawlins. The earthquake was felt as a distinct shock that caused wooden buildings to noticeably vibrate. Stone buildings were not affected by the event (Rawlins Republican, 1917).

On September 10, 1964, a magnitude 4.1 earthquake occurred approximately thirty miles west of Rawlins. One Rawlins resident reported that the earthquake caused a crack in the basement of his home in Happy Hollow. No other damage was reported (Daily Times, 1964).

Small earthquakes were detected, on April 13, 1973, May 30, 1973, and June 1, 1973, approximately six miles west of Hanna. No one reported feeling this event. On July 11, 1975, Rawlins residents felt an earthquake (intensity II) event. On January 27, 1976, an earthquake (magnitude 2.3, intensity V) occurred approximately 12 miles north of Rawlins. Several people reported that they were thrown out of bed. (Daily Times, 1976). On March 3, 1977, an earthquake (intensity V) was reported approximately 18.5 miles west-northwest of Encampment. Doors and dishes were rattled in southern Carbon County homes; but no significant damage was reported (Laramie Daily Boomerang, 1977).

On April 13, 1991 and April 19, 1991, magnitude 3.2 and magnitude 2.9 earthquakes, respectively, occurred near the center of the Seminoe Reservoir. A magnitude 3.1 earthquake occurred, on December 18, 1991, southwest of the Seminoe Reservoir, approximately 15 miles northeast of Sinclair. No one reported feeling these Seminoe-Reservoir-area earthquakes. On August 6, 1998, a magnitude 3.6 earthquake occurred approximately 13 miles north of Rawlins. Residents in Rawlins reported hearing a sound and then feeling a jolt. On April, 1999, a magnitude 4.3 earthquake occurred approximately 29 miles north-northwest of Baggs. It was felt in Rawlins; and residents reported that pictures fell off the walls.

City of Rock Springs Area

Rock Springs is located approximately 80 air miles southwest of the Permit Area. The first recorded earthquake that was felt in Sweetwater County occurred on April 28, 1888. This intensity IV earthquake, which originated near Rock Springs, did not cause any appreciable damage. On July 25, 1910, an intensity V earthquake occurred at the same time that the Union Pacific Number One Mine in Rock Springs partially collapsed. On July 28, 1930, an intensity IV earthquake, with an epicenter near Rock Springs, was felt in Rock Springs and Reliance (Casper Daily Tribune, 1930). The earthquake awakened many residents; and some merchandise fell off of store shelves.

On March 21, 1942, a non-damaging, intensity III earthquake was felt in Rock Springs area. This event was followed, on September 14, 1946, by an intensity IV earthquake. On October 25, 1947, a small earthquake with no assigned intensity or magnitude occurred southeast of Rock Springs. Two intensity IV earthquakes occurred in the Rock Springs area on September 24, 1948. The events rattled dishes in parts of Rock Springs.

A magnitude 3.9 event was recorded on January 5, 1964, approximately 23 miles south of Rock Springs. The University of Utah Seismograph Stations detected a non-damaging, magnitude 2.4 earthquake on March 19, 1968. This event was centered approximately 17 miles southeast of Rock Springs.

A magnitude 3.2 event occurred on May 29, 1975, approximately 13 miles northeast of Superior. A week later, on June 6, 1975, a magnitude 3.7 earthquake was recorded in the same area. No damage was associated with any of the 1975 events.

The University of Utah Seismograph Stations recorded a non-damaging magnitude 2.7 earthquake on June 5, 1986. This event was located approximately 14 miles southwest of Green River, Wyoming.

On February 1, 1992, the University of Utah Seismograph Stations recorded a non-damaging magnitude 2.3 earthquake, approximately seven miles north of Rock Springs.

City of Lander Area

Lander is about 70 miles northwest of the Permit Area. A number of earthquakes have occurred in the Lander area. The first reported earthquake occurred on January 22, 1889, and had an intensity of III to IV. This was followed by an intensity IV event on November 21, 1895, during which houses were jarred and dishes rattled. On November 23, 1934, an intensity V earthquake was centered approximately 20 miles northwest of Lander. For a radius of ten miles around Lander, residents reported that dishes were thrown from cupboards, and that pictures fell down from the walls. Cracks were found in

buildings along two business blocks; and the brick chimney of the Fremont County Courthouse was separated by two inches from the building. The earthquake was felt at Rock Springs and Green River, Wyoming (Casper Tribune-Herald, 1934).

There were a series of earthquakes in the Lander area in the 1950s that caused little damage. On August 17, 1950, there was an intensity IV earthquake that caused loose objects to rattle and buildings to creak. On January 12, 1954, there was an intensity II event; and on December 13, 1955, there was an intensity IV event near Lander, with no damage reported.

On June 14, 1973, a small earthquake was reported about eight miles east-northeast of Lander. The earthquake has been recently interpreted as a probable explosion. On January 31, 1992, a non-damaging magnitude 2.8 earthquake occurred approximately 20 miles northwest of Lander. This event was followed, on October 10, 1992, by a magnitude 4.0, intensity III earthquake centered approximately 22 miles east Lander.

City of Casper Area

Casper is located about 90 miles northeast of the Permit Area. Two of the earliest recorded earthquakes in Wyoming occurred near Casper. The first was on June 25, 1894, and had an estimated intensity of V. In residences on Casper Mountain, dishes rattled and fell on 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 river banks slumping into the river during the earthquake. On November 14, 1897, an even larger event was felt. An intensity VI to VII earthquake, one of the largest recorded in central and eastern Wyoming, caused considerable damage to a few buildings. As a result of the earthquake, a portion of the Grand Central Hotel was cracked from the first to the third story. Some of the ceilings in the Grand Central Hotel were also severely damaged.

On October 25, 1922, an intensity IV earthquake was reported in the Casper area. The event was felt in Casper; at Salt Creek, 50 miles north of Casper; and at Bucknum, 22 miles west of Casper. Dishes were rattled and hanging pictures were tilted near Salt Creek. No significant damage was reported in Casper (Casper Daily Tribune, 1922). On December 11, 1942, an intensity IV earthquake was recorded north of Casper. Although no damage was reported, the event was felt in Casper, Salt Creek, and Glenrock (Casper Tribune-Herald, 1941). On August 2, 1948, another intensity IV earthquake was reported in the Casper area. No damage was reported (Casper Tribune-Herald, 1948). In the 1950s, two earthquakes caused some concern among Casper residents. On January 24, 1954, an intensity IV earthquake near Alcova did not result in any reported damage (Casper Tribune-Herald, 1954). On August 19, 1959, an intensity IV earthquake was felt in Casper. Most recently, on October 19, 1996, a magnitude 4.2 earthquake was recorded approximately 15 miles north-northeast of Casper. No damage was reported.

2.6.3.2 Uniform Building Code and International Building Code

With safety in mind, the UBC provides Seismic Zone Maps to help identify which building design factors are critical to specific areas of the country. Five UBC seismic zones are recognized, ranging from Zone 0 to Zone 4. These seismic zones are, in part, defined by the probability of having a certain level of ground shaking (horizontal acceleration) in 50 years. The criteria used for defining boundaries on the Seismic Zone Map were established by the Seismology Committee of the Structural Engineers Association of California (SEAOC, 1986). The criteria they developed are as follows:

- Zone 4: ≥ 30 percent gravity (g) effective peak acceleration;
- Zone 3: 20 to ≤ 30 percent g effective peak acceleration;
- Zone 2: 10 to ≤ 20 percent g effective peak acceleration;
- Zone 1: 5 to ≤ 10 percent g effective peak acceleration; and
- Zone 0: ≤ 5 percent g effective peak acceleration.

The Seismology Committee of the Structural Engineers Association of California assumed that there was a 90 percent probability that the above values would not be exceeded in 50 years, or a 100 percent probability that the values would be exceeded in 475 years.

Figure 2.6-4 shows the delineation of UBC seismic zones in Wyoming. The Permit Area is located in Seismic Zone 1. Since effective peak accelerations (90 percent chance of non-exceedance in 50 years) can range from five to ten percent g in Zone 1, it may be reasonable to assume that an average peak acceleration of 7.5 percent g could be applied to the design of a non-critical facility located near the center of Zone 1.

UBC has been used in Wyoming for many years. Recently, the UBC has been replaced by the International Code (IBC). Wyoming also adopted in lieu of the UBC to their regulations in late 2008 (after the submittal of this TR). While the UBC has always been based on seismic zones; the IBC is based on probabilistic analysis (involving a full evaluation of potential earthquake generating fault system of the region), and use ground motion parameters for seismic design. The following sections discuss the fault system of the project region, probabilistic seismic hazard analysis of the Permit Area and nearby region, and presented a 2,500-year probabilistic ground acceleration map used by IBC.

2.6.3.3 Deterministic Analysis of Active Fault Systems

There are two active fault systems in the vicinity of the Permit Area, the Chicken Springs Fault System and the South Granite Mountain Fault System (**Figure 2.6-5**).

The Chicken Springs Fault System, located six miles east of the Permit Area, is composed of a series of east-west trending segments. In 1996, the Wyoming State Geological Survey investigated this fault system, and determined that the most recent activity on the system appears to be Holocene in age. Reconnaissance-level studies indicated that the fault system is capable of generating a magnitude 6.5 earthquake (Case, et. al., 2002a). A magnitude 6.5 earthquake on the Chicken Springs Fault System would generate peak horizontal accelerations of approximately 4.8 percent g at Rawlins (Case, et. al., 2002a). These accelerations would be roughly equivalent to an intensity V earthquake, which may cause some light damage. Bairoil, however, would be subjected to a peak horizontal acceleration of approximately 23 percent g, or an intensity VII earthquake (Case, et. al., 2002a). Intensity VII events have the potential to cause moderate damage.

The South Granite Mountain Fault System is located about 14 miles northeast of the Permit Area. This fault system is composed of several northwest-southeast trending normal and thrust faults in southeastern Fremont County and northwestern Carbon County. The active segments of the system have been assigned a maximum magnitude of 6.75, which could generate peak horizontal accelerations of approximately 20 percent g at Bairoil and 6.1 percent g at the Rawlins (Case, et. al., 2002a). These accelerations would be roughly equivalent to an intensity VII earthquake at the Bairoil and an intensity V earthquake at Rawlins. Bairoil could sustain moderate damage; whereas minor or no damage could occur at Rawlins.

2.6.3.4 Maximum Tectonic Province Earthquake "Floating Earthquake" Seismogenic Source

Tectonic provinces are regions with a uniform potential for the occurrence of earthquakes that are tied to buried faults with no surface expression. 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 most 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.

The USGS identified tectonic provinces in a report titled "Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States" (Algermissen et al, 1982). In that report, Sweetwater County was classified as being in a tectonic province with a "floating earthquake" maximum magnitude of 6.1. Geomatrix (1988) 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 degrees West longitude on the east, 40 degrees North latitude on the south, and 45 degrees North latitude on the north. Geomatrix (1988) estimated that the largest "floating earthquake" in the "Wyoming Foreland Structural Province" would have a magnitude in the 6.0 to 6.5 range, with an average value of magnitude 6.25.

2.6.3.5 Probabilistic Seismic Hazard Analysis and IBC

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 two percent probability that acceleration may be met or exceeded in 50 years is roughly equivalent to a 100 percent probability of exceedance in 2,500 years (and thus commonly referred as the 2,500-year earthquake).

While the UBC intended that structures be designed for "life-safety" in the event of an earthquake with a 10 percent probability of being exceeded in 50 years (commonly referred to as the 475-year, or 500-year earthquake); the IBC intends design for "collapse prevention" in a much larger earthquake, i.e., the 2,500-year earthquake. **Figure 2.6-6** presents the probabilistic peak ground acceleration during a 2,500-year earthquake. The estimated acceleration in the Permit Area is 20 percent g on the 2,500-year map, which would be roughly equivalent to an intensity VII earthquake. As discussed in Section 2.6.3.3, the Chicken Springs and South Granit Mountain fault system could potentially generate an 6.5 and 6.75 earthquake, with peak ground acceleration of 20 and 23 percent (intensity VII) at the Town of Bairoil. The IBC seismic design criteria should be used for facility construction at Lost Creek.

2.6.4 Soils

The Project region had not been previously surveyed by the NRCS or Soil Conservation Service (SCS). Two empirical studies were conducted at 1:100,000 and the 1:500,000 scales (Munn and Arneson, 1998). Both data sets were established based on a simplified five-factor soil formation model. Independent variables for this model were parent material, climate, biota, topography, and time. Parent material was derived from the state geology and surficial geology maps; climate and topography were estimated using the

elevation and relief; the biota was estimated using temperature regimes; and time was estimated using the elevation, surficial geology, and bedrock geology (Munn and Arneson, 1998). The 1:100,000 and 1:500,000 soil maps for the Permit Area are included as **Figures 2.6-7a** and **2.6-7b**.

The closest third-order soil survey to the Permit Area was conducted in 1994 for the permitting of the Kennecott Uranium Company's Sweetwater Mill, which, at the time, was owned by Sweetwater Syndicate Inc. This survey used soil associations as the mapping unit and described six soil associations within a 12-square-mile study area on the Sweetwater property.

2.6.4.1 Soil Survey

A soil survey was conducted according to protocols in the National Soil Survey Handbook (Soil Survey Staff, 1993), which provides major principles and practices for soil surveys.

All preexisting data were used when selecting sites for the primary soil survey, which began in June 2006. Pit locations and the density of the soil pits were determined on the basis of vegetation, landform type, and position within a landform unit. The Permit Area was relatively consistent with respect to vegetation and landforms. Therefore, 19 soil pits were excavated and described to characterize the Permit Area.

Data from the soil profiles were used to create soil map units (SMU) on the base map. SMU boundaries were refined with surface soil pits excavated to a depth of 12 inches. SMUs were numbered from north to south. Because this was the first soil survey to be completed in the Permit Area, the soils were classified to the family level instead of the series level. The descriptions of each family (in this case, each SMU), are discussed below. Prior to the survey, a work plan was presented to and approved by WDEQ.

2.6.4.2 Field Sampling

Field samples were collected from all soil pits in the Permit Area. The pits were excavated with a backhoe to a depth of at least four feet (**Figure 2.6-8**). Soil samples from nine locations in the Permit Area were selected and prepared for the laboratory. Each soil horizon present at the selected locations was analyzed independently. Sampling locations selected for laboratory analysis are shown on the soil map (**Figure 2.6-9**). Samples were analyzed in accordance with the parameters and procedures defined in WDEQ Guideline 1, Topsoil Suitability, Table I-1 (1994).

2.6.4.3 Results and Discussion

General Soil Survey

The soils within the Permit Area are typical of the semiarid areas of the western US. Most of the soil has developed from the sedimentary bedrock of the Permit Area. The precipitation of the region is not enough to leach the majority of calcium and divalent cations from the soil profile. As a result, the soil pH tends to be slightly alkaline. Vegetation is also limited by the amount of precipitation in this region. As a result, the soils tend to have low organic matter.

SMU Interpretation in the Permit Area

The vertical relief of the Permit Area is approximately 260 feet. Due to the relative lack of relief and uniform surficial geology, there are only three exposed soil types within the Permit Area. The three units are very similar in color, depth of horizons, and geomorphic surface. The primary difference between the three soils is the texture; and, therefore, the soil texture is the only difference in the three family names.

All soil units within the Permit Area support similar vegetation types. The Lowland Big Sagebrush Shrubland is present in and immediately surrounding the ephemeral channels; and the Upland Big Sagebrush Shrubland is present over the remainder of the Permit Area. The uniformity in vegetation across the Permit Area indicates that the three soil units are roughly equally productive, and that plant growth is limited by precipitation and not by soil fertility. Each soil unit is described below; and the aerial distribution of the soil units is shown on **Plate 2.6-3**.

Thirty-four percent (1,435 acres) of the Permit Area is Typic Torriorthent, loamy, mixed mesic. The soil is brown to yellowish-brown, and is typically five to 15 inches thick. It generally occurs on the lower foot-slopes, where slopes are less than ten percent, but they can be as steep as 30 percent. The dominant vegetation is low-growing sagebrush with intermittent patches of grasses. The geomorphic surface ranges from bare loamy soil to pebbles and gravel-sized particles. A typical profile of this soil is brown to yellowish-brown sandy loam; and the subsoil is a brown to pale-brown sandy loam that extends to depths greater than 30 inches.

Forty-six percent (1,941 acres) of the Permit Area is Typic Torriorthent, fine-loamy, mixed mesic. This soil is abundant in the down-slope areas of the region, where slopes are very gradual. The dominant vegetation is sagebrush, with scattered grasses and cacti. The geomorphic surface consists of bare, fine sandy loam. The upper profile contains a

dark grayish-brown silt loam to loam that is about nine inches thick. The subsoil is a dark yellowish-brown to light yellowish-brown and extends to a depth of at least 27 inches.

Twenty percent (844 acres) of the Permit Area is Typic Torriorthent, fine-loamy over sandy, mixed mesic. The slopes are less than five percent and the dominant vegetation is low-growth sagebrush and scattered grasses. The geomorphic surface is bare loamy soil with approximately 25 percent gravel. The surface layer consists of a brown loam that is ten to 15 inches thick. The subsoil is a brown to a light yellowish-brown sandy loam that extends to a depth greater than 20 inches.

2.6.4.4 Soil Suitability as a Plant Growth Medium

Based on WDEQ Guideline 1 Topsoil Suitability, Table I-2 (1994), all of the Permit Area samples were within the range for suitable plant growth media for pH, conductivity, sodium adsorption ratio (SAR), texture, selenium, and boron.

Of the 28 Permit Area samples, 11 were classified as marginally suitable for topsoil because of low saturation percentages. The measured saturation percentages of these marginally suitable soils ranged from 16 to 24 percent. These 11 samples were from seven different profiles, and represented all SMUs present in the Permit Area.

One sample from the Permit Area was considered unsuitable for topsoil because the percentage of coarse fragment was 39 percent compared to a 35 percent threshold for unsuitable soil. This sample represented the B horizon of a soil profile in SMU Number Three. Therefore, only the top 11 inches of this SMU should be used as reclamation topsoil. One sample is considered marginally suitable due to a pH more than 8.5 standard units. During reclamation, the use of marginal soils as topsoil will be avoided where possible, except in areas where the undisturbed topsoil is marginally suitable.

2.6.4.5 Topsoil Protection

Disturbance to the general mining area will be surface compaction from drill rigs, trucks carrying supplies and equipment, earth-moving machinery, and light passenger vehicles. In addition, mud pits will be excavated near the location of boreholes. As protection, topsoil from these pit locations will be segregated from the rest of the excavated material. After the pit has been used, the topsoil will be replaced last.

By the nature of ISR operations, there is no need to strip the surface of the general mining area. The majority of topsoil salvage will be restricted to major roadways and building sites. During the delineation drilling, the mine unit installation, and the monitor well ring

installation, the topsoil will be segregated, marked, and replaced contemporaneously. Following the delineation drilling phase, mine unit designs will be prepared that define the extraction or economic limits of the orebody. The mine unit will include injection, recovery, and monitor wells, as well as surface facilities (e.g., header houses, pipelines, and power lines). The soil disturbance caused by these activities is localized; and the topsoil resource management during the mine unit installation and operation is further discussed in **Section 4.3** of the ER.

ISR operations do not require the removal of all topsoil and overburden for mining; therefore, it is very difficult to calculate the volume of topsoil that will be affected by the disturbance. The estimated volume of salvageable topsoil required is 40,000 cubic feet for the development of Mine Unit Number 1. This number was calculated based on **Table 7.1-1**.

Topsoil removal at operations sites will be supervised by a qualified person using the soils mapping and data presented in this report. The percent of each SMU within the corresponding Permit Area is found in **Table 2.6-2**. The estimated suitability ranges for the dominant soil series within the Permit Area are presented in **Table 2.6-3**.

2.6.4.6 Prior Surface Disturbances

There was surface disturbance prior to LC ISR, LLC operations at the Permit Area. Most of this disturbance was due to prior exploration activities for oil and gas, as well as for uranium, and to support livestock and wildlife grazing. The primary activities included vehicle traffic, drilling activities, and stock tank usage. Approximately 26 miles of roads were delineated from 2002 aerial photography of the Permit Area (**Figure 2.6-10**). Field measurements in 2007 indicate that the roads range from 6.9 to 9.4 ft wide. A few of these roads may still be used by grazing lessees, hunters, and for on-going exploration activities. Evidence of abandoned drill sites and stock tanks is more difficult to delineate; but numerous small areas are evident on the aerial photograph.

The roads caused compaction to the soil, which limits infiltration rates and decreases the vegetation regrowth (**Figure 2.6-11**). Active road surfaces have little to no organic matter, and most of the topsoil has been eroded from the road surface.