POWERTECH (USA) INC.

Revised Dewey-Burdock Project Underground Injection Control Permit Application

February 2010

Prepared for

Department of Environment & Natural Resources
Groundwater Quality Program
Joe Foss Building
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Appendices

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K	Surface Water Quality Data and Statistics
L	Restoration and Reclamation Cost Estimate

List of Abbreviations and Acronyms

µmhos/cm	micromhos per centimeter
µR/hr	microroentgens per hour
AEB	aquifer exemption boundary
ALARA	as low as reasonably achievable
AOR	area of review
ARSD	Administrative Rules of South Dakota
ASTM	American Society for Testing and Materials
bgs	below ground surface
BLM	U.S. Bureau of Land Management
BME	Board of Minerals and Environment
BMP	Best Management Practice
Bq/g	becquerels per gram
CBA	central Burdock Area
CFR	Code of Federal Regulations
CI	Completeness Issue
cm	centimeter
cm/sec	centimeters per second
cpm	counts per minute
CPP	Central Processing Plant
D&D	Decontamination and Decommissioning
DCGL	derived concentration guideline level
DES	Draft Environmental Statement
EFN	Energy Fuels Nuclear
eH	measure of oxidation potential
EH&S	Environmental Health and Safety
EPA	U.S. Environmental Protection Agency
ERG	Environmental Restoration Group
ft	feet
ft/day	feet per day
ft^2/day	square feet per day
gpd/ft	gallons per day per foot
gpm	gallons per minute
GPS	global positioning system
GWPB	Ground Water Protection Branch
ha	hectares
HPRCC	High Plains Regional Climate Center
HS&E	health, safety and environmental
HAS	historical site assessments
IQR	inter-quartile range
ISL	In Situ Leach also referred to as in situ recovery

ISR	In Situ Recovery
IX	ion exchange
LLD	lower limit of detection
M	million
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
Max WHP	maximum well head pressure
MCL	maximum contaminant level
md	millidarcy
MDL	minimum detection limit
meq/l	milliequivalents per liter
mgd	million gallons per day
mg/kg	milligram per kilogram
mg/L	milligrams per liter
MIP	maximum injection pressure
MIT	mechanical integrity test
mRem	millirems
mSv	millisievert
MVS	Mining Visualization System
NAS/NAE	National Academy of Science / National Academy of Engineering
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NVLAP	National Voluntary Laboratory Accreditation Program
NRC	Nuclear Regulatory Commission
NWS	National Weather Service
OSHA	Occupational Safety and Health Administration
PA	Proposed Action
PAA	Proposed Action Area
pCi/f	picocuries per filter composite
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pH	measure of acidity
PNL	Pacific Northwest Laboratory
PQL	Practical Quantitation Limits
psi	pounds per square inch
psi/ft	pounds per square inch per foot
psig	pounds per square inch gauge
PV	pore volume
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
QC	quality control
RCM	recording current meter

RCRA	Resource Conservation and Recovery Act
RER	Replicate Error Ratio
RG	Regulatory Guide
RO	reverse osmosis
SCFM	standard cubic feet per minute
SDCL	South Dakota Codified Laws
SD DENR	South Dakota Department of Environment and Natural Resources
SDGF&P	South Dakota Game Fish and Parks
SDSU	South Dakota State University
SDWA	Safe Drinking Water Act
SERP	Safety and Environmental Review Panel
SMCL	secondary drinking water standards
SWMP	Storm Water Pollution Management Plan
TDS	total dissolved solids
TLD	thermoluminescent detectors
TRG	target restoration goals
TSX	Toronto Stock Exchange
TVA	Tennessee Valley Authority
TWRI	USGS “National Field Manual for the Collection of Water-Quality Data; Techniques of Water-Resources Investigations Book 9”
UCL	upper control limit
UIC	Underground Injection Control
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USACE	US Army Corps of Engineers
USDW	underground source of drinking water
USGS	United States Geological Survey
VSP	visual sampling plan
WHP	well head pressure
wt%	weight percent

Glossary

Aquifer Exemption: The process by which an aquifer, or portion of an aquifer, that meets the criteria for an underground source of drinking water, for which protection under the Safe Drinking Water Act has been exempted under the criteria in 40 CFR 146.4. Injection of fluids through a Class I, II, or III injection well into any aquifer that meets the classification as an underground source of drinking water (USDW) requires a demonstration that the aquifer is not currently serving a drinking water system and is not expected to do so in the future.

Bleed: A small flow of water from a process flow stream for the purpose of affecting process pressure; also referred to as "purge."

Brine Solution: A concentrated solution containing dissolved minerals (usually greater than 100,000 milligrams per liter [mg/L]), especially chloride salts.

Central Processing Plant: The main processing facility that typically includes the ion exchange system, elution and precipitation circuits, settling and holding tanks, dewatering equipment, vacuum dryer and effluent control systems.

Confining Bed (layer): A geologic formation, group of formations, or a part of a formation of low permeability above and below an aquifer that confine groundwater to flow within the aquifer.

Elution: The process of extracting (or eluting) one material from another by washing with a solvent (eluant) to remove adsorbed material (such as uranium) from an adsorbent such as an ion exchange resin.

Excursion: Any unwanted and unauthorized movement of a recovery fluid detected and confirmed at the monitoring well ring.

Flare: A proportionality factor designed to estimate the amount of aquifer water outside of the pore volume that has been impacted by lixiviant flow during the extraction phase. The flare is usually expressed as a horizontal and vertical component to account for differences between the horizontal and vertical hydraulic conductivity of an aquifer material.

Ion Exchange: A chemical process used to recover uranium from solution by the exchange of dissolved uranium ions between a lixiviant (leach solution) and a solid, either a mineral surface or, more commonly, a synthetic polymer resin.

Injection Well: A well in which fluids are injected rather than produced, the primary objective typically being to maintain reservoir pressure. Two main types of injection are common: gas and liquid. Liquid-injection wells are common offshore in the oil and gas industry, and in solution (in-situ) mining.

In Situ Leach: The in-place recovery of a mineral resource without removing overburden or ore. This method of mining is typically accomplished by installing a well and recovering the resource directly from the natural deposit by exposing it to the injection and recovery of the lixiviant that causes leaching, dissolution and recovery of the mineral. The term in situ leach (ISL) is synonymous with the term in situ recovery (ISR) for the purpose of this document.

Lixiviant: A leachate solution pumped underground to recover the uranium from the ore body.

Mining Unit: A determinate area(s) within well fields used for scheduling development.

Monitor Well: A well used to obtain water quality samples or measure groundwater levels; also referred to as Monitoring Well.

Ore Horizon: An interface indicative of the uppermost position of an ore body in a stratigraphic sequence.

Picocurie: One one-trillionth (1/1,000,000,000,000) of a curie: a measure of radioactivity based on the observed decay rate of approximately one gram of radium. The curie was named in honor of Pierre and Marie Curie, pioneers in the study of radiation.

Pore Volume (PV): Volume of water required to replace the water in the volume of aquifer that was mined.

Production Well: Also known as 'extraction well' for in situ recovery, usually located in the center of a 5 or 7 spot well pattern; used to pump the metal-laden solution to the surface for further treatment.

Production Zone: The uranium-bearing portion of a geological formation or part of a formation that is the target of ISL uranium recovery by underground injection and production of lixiviant.

Radionuclide: An unstable form of a nuclide that decays or disintegrates spontaneously emitting radiation. Nuclide: a general term applicable to all atomic forms of an element. Nuclides are characterized by the number of protons and neutrons in the nucleus as well as by the amount of energy contained within the atom.

Safe Drinking Water Act (SDWA): The main federal law that ensures the quality of Americans' drinking water. The SDWA sets the framework for the Underground Injection Control (UIC) Program to control the injection of fluids. EPA and states implement the UIC Program, which sets standards for safe injection practices and bans certain types of injection.

Satellite Plant: A remote plant consisting of an ion exchange system, pumps, reverse osmosis unit and transportation vehicles (tanker trucks) to transport loaded resins to the central processing plant.

Underground Source of Drinking Water (USDW): An aquifer or portion of an aquifer that supplies any public water system or that contains a sufficient quantity of ground water to supply a public water system, and currently supplies drinking water for human consumption, or that contains fewer than 10,000 mg/L total dissolved solids and is not an exempted aquifer.

Well field: The area of an ISL operation that encompasses the array of injection, recovery (or production), and monitoring wells and interconnected piping employed in the leaching process.

Yellowcake: A mixture of uranium oxides that can vary in proportion and in color from yellow to orange to dark green (blackish) depending on the temperature at which the material was dried (level of hydration and impurities). Higher drying temperatures produce a darker, less soluble material. Yellowcake is commonly referred to as U_3O_8. This fine powder is packaged in drums and sent to a conversion plant that produces uranium hexafluoride (UF_6) as the next step in the manufacture of nuclear fuel.

Powertech (USA) Inc.
Dewey-Burdock Project
Revised Underground Injection Control
Permit Application

Section 1.0 - Owner/Operator Information

1.1 General

Name of person legally responsible for Class III operation (owner/operator): Powertech (USA) Inc.

Address: 5575 DTC Parkway, Suite # 140
Greenwood Village, CO 80111

Telephone: (303) 790-7528

Local representative or contact person if different from above: Richard Blubaugh

Address: 5575 DTC Parkway, Suite # 140
Greenwood Village, CO 80111

Telephone: (303) 790-7528

This Underground Injection Control (UIC) Permit application is being submitted by Powertech (USA) Inc. (Powertech), a South Dakota Corporation and a USA subsidiary of the Canadian parent company, Powertech Uranium Corporation. Powertech Uranium Corp. is a mineral exploration and development company that, through its Denver-based subsidiary, Powertech (USA) Inc., holds the Dewey-Burdock uranium deposit in South Dakota, the Centennial Project in Colorado and the Dewey Terrace and Aladdin projects in Wyoming. The company's key personnel have over 200 years of experience in the uranium industry throughout the United States, and have permitted more than a dozen in situ recovery operations in the United States for production. For more information, refer to Powertech's website at http://www.powertechuranium.com.

The corporate office is located in Vancouver, British Columbia and the United States headquarters office is located Greenwood Village, Colorado. Powertech maintains an exploration office in Hot Springs, South Dakota, an administrative/exploration office in Albuquerque, New Mexico and operations offices in Wellington, Colorado and Edgemont, South Dakota (addresses shown below in Table 1.1-1). Powertech is a publicly traded company on the Toronto Stock Exchange (TSX) as PWE and the Frankfurt Stock Exchange as P8A.

Table 1.1-1 Powertech (USA) Inc. Office Locations

COLORADO-DTC Powertech (USA) Inc. 5575 DTC Parkway, Suite 140 Greenwood Village, CO 80111	SOUTH DAKOTA - Edgemont Powertech (USA) Inc. 310 2nd Avenue P.O. Box 812 Edgemont, SD 57735	NEW MEXICO Powertech (USA) Inc. 8910 Adams Street NE Albuquerque, NM 87113
COLORADO - Wellington Powertech (USA) Inc. 8305 6th Street P.O. Box 1066 Wellington, CO 80549	SOUTH DAKOTA - Hot Springs Powertech (USA) Inc. 145 N. Chicago, Suite C P.O. Box 723 Hot Springs, SD 57747	

1.2 Health, Safety and Environmental Responsibilities

Powertech is committed to managing health, safety and environmental (HS&E) matters as an integral part of the proposed action (PA). In particular, it is the company's policy to assure the HS&E integrity of activities and facilities associated with the PA at all times. Powertech will adhere to its principles of Compliance, Prevention, Communication and Continuous Improvement.

The company will implement programs to ensure strict compliance with all applicable laws and regulations.

Powertech's pre-operational and operational procedures are designed and implemented in such a way as to prevent or minimize releases to the atmosphere, land and water. The amount and toxicity of generated waste will be minimized and treated and disposed of properly.

Powertech's management has extensive technical and practical experience in permitting, operations and reclaiming in situ leach (ISL) facilities. With the combined experience of Powertech working in conjunction with regulators, all necessary controls to assure that the highest HS&E standards are met, will be implemented.

Management systems and procedures specifically designed to prevent activities and/or conditions that pose a threat to human health, safety or the environment will be implemented. Risk will be minimized, and employees and the nearby communities will be protected by employing measures from the umbrella of safe technologies and operating procedures. Powertech will institute training and emergency preparedness in order to be prepared and to provide the local communities information and awareness that Powertech has a commitment to open and transparent operations.

1.3 Implementation of the Health and Safety Program

Implementation of the health and safety program will be accomplished through the Environmental Health and Safety (EH&S) department within Powertech. Support for Powertech's principles of compliance, prevention, communication and continuous improvement of the EH&S program will be accomplished via Powertech's (USA) Safety and Environmental Review Panel (SERP) to be established under Nuclear Regulatory Commission (NRC) requirements. The SERP will consist of at least three members. One member will be the RSO. Another member will be someone with authority to implement managerial and

financial changes (e.g., the Mine Manager). Another member will be someone with authority to make operational changes (e.g., the Production Superintendent). The SERP may include others on a temporary or permanent basis whenever the SERP requires additional technical or scientific expertise and may be other employees or consultants. At least one member of the SERP shall be designated as chairman.

The purpose of the SERP will be to evaluate, discuss, approve, and record any changes to any SOP, the facility, or tests and experiments involving safety or the environment. For example, the SERP will review hydrologic test results and documentation to demonstrate that the monitoring wells are not hydrologically connected to the injection or production wells. Based on current knowledge of site lithology and processes of the production area, and industry proven practices, the number and spacing of overlying and underlying monitoring wells meets criteria to protect human health and the environment. Wells completed in overlying and underlying aquifers will be subject to sampling, remedial action, and reporting requirements pertinent to the Environmental Protection Agency (EPA) and South Dakota Department of Environment and Natural Resources (SD DENR) rules.

1.3.1 Radiation Safety

The bedrock of the EH&S department program is built from past guidance, rules and laws proven effective in providing a safe environment for workers, public and the environment. During operations principles such as “as low as reasonably achievable” (ALARA) will be implemented with regards to maintaining potential occupational and public exposures to ionizing radiation as low as reasonably achievable. Powertech will implement the principles of compliance, prevention, communication and a continuous effort to improve the health and safety program via such requirements as 10 CFR 40.32 and 40.45 also objectives set forth in 10 CFR 20.

1.3.2 General Safety

Powertech’s basic principle concerning safety in general is that our entire work force - from board members to the most recent hires - recognizes that the safety and health of our workers and visitors is a core value held by the company. This core value is crucial to our mission and is the key to the profitability of the corporation. Developing a program built around the following will ensure not only a safe working environment, but will encourage higher employee morale, therefore generating higher productivity, which is considered by Powertech to be good business practice.

- Safety-minded management leadership and employee team participation (communication and effort to improve safety on a continuous basis)
- Worksite analysis to eliminate potential hazards (prevention)
- Training and Implementation of safe work procedures (compliance)

Section 2.0 - Legal Location of Class III Facility

2.1 Legal Description

Legal descriptions for the Proposed Action Area (PAA) are presented below in Table 2.1-1.

Table 2.1-1 Legal Descriptions for the Proposed Action Area (PAA) Comprised of All Properties Included within the PAA

T6S-R1E, Custer County	T7S-R1E, Fall River County
Section 20: E2NE4, E2SE4, SW4SE4, S2NW4SE4, SE4SW4, S2NE4SW4 Section 21: W2, W2W2NE4, W2NW4SE4 Section 27: S2 Section 28: N2NW4, SW4NW4, SW4 Section 29 Section 30 Section 31: E2 Section 32 Section 33: NW4, SW4, SE4, S2NE4 Section 34 Section 35	T7S-R1E, Fall River County Section 1 Section 2 Section 3 Section 4: W2W2 Section 5 Section 10 Section 11 Section 12 Section 14: NW4, W2NE4, NE4NE4 Section 15: N2

Section 3.0 - Name of Proposed Facility and Estimated Project Life

3.1 Proposed Project Information

Dewey-Burdock Project
Powertech (USA) Inc. (Powertech) proposes to mine uranium at the Dewey-Burdock Site (hereafter the "Proposed Action Area" [PAA]) using In Situ Leach (ISL) technology.

Estimated Life of the Project: 15 years

Type of Class III Operation: Uranium Mining Area Permit

This UIC permit application is being submitted to the SD DENR. This UIC Class III application has been prepared in accordance with the requirements of the UIC Program promulgated under the federal Safe Drinking Water Act (SDWA) and South Dakota Administrative Rules §74:55:01 for the Proposed Dewey-Burdock Project (hereafter referred to as the "Proposed Action" [PA]).

3.2 Permitting Requirements

The EPA has primary enforcement authority for Class III wells in South Dakota. The SD DENR also regulates Class III wells. Therefore, this application is intended to satisfy both EPA and SD DENR regulatory requirements. Also, due to addition of the approximate 240 acres managed by the Bureau of Land Management (BLM), a plan of operation has been prepared and submitted for its review and approval.

This permit application has been prepared in accordance with the requirements of the SDWA. The Safe Drinking Water Act was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supplies. This Act authorizes the EPA to set national health-based standards to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and groundwater wells which serve fewer than 25 individuals. The EPA, states and water districts work together to ensure protection against naturally-occurring and anthropogenic contaminants. The UIC Program found in Title 40 Code of Federal Regulations (CFR) Parts 144-147 is one such program designed to implement the SDWA by regulating underground injection practices to protect underground sources of drinking water (USDWs). In addition, this application has met applicable rules promulgated by both the South Dakota Board of Minerals and Environment under the South Dakota Mined Land Reclamation Act (South Dakota Codified Laws [SDCL] 45-6B), and the requirements from SD DENR Class III UIC regulations (74:55:01).

3.2.1 Regulatory Guidance

The following statues and guidelines were utilized in development of this application:

- South Dakota Codified Laws Title 45, Chapter 6B and South Dakota Administrative Rules 74:55:01
- South Dakota Administrative Rules 74:55:01 (Class III wells)
- 10 CFR Part 40 Appendix A as relevant and appropriate
- 40 CFR Part 144 Underground Injection Control Program
- 40 CFR Part 146 Underground Injection Control Program Criteria and Standards
- United States Nuclear Regulatory Commission Documents:
  - NUREG-1569 "Standard Review Plan for In Situ Leach Uranium Extraction License Applications" (NRC, 2003)

- NUREG-1748 "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs" (NRC, 2003)
- NUREG-1910 "Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities (Draft Report)" (NRC, 2008)
- NUREG/CR 6733 "A Baseline Risk-Informed, Performance-Based Approach for In Situ Leach Uranium Extraction Licensees" (NRC, 2001)
- NUREG/CR-6870 "Consideration of Geochemical Issues in Groundwater Restoration at Uranium In-Situ Leach Mining Facilities" (NRC, 2007)
- NRC Regulatory Guide 8.30 "Health Physics Surveys in Uranium Recovery Facility," Revision 1 (NRC, 2002)
- NRC Regulatory Guide 4.14 "Radiological Effluent and Environmental Monitoring at Uranium Mills," Revision 1 (NRC, 1980)

3.2.2 Required Approvals and Submittals in Association with the In Situ Leach Mine Permit

A number of applications for licenses, permits and/or approvals are necessary for the various phases of the PA, which include evaluation, planning, construction, operation and reclamation. In addition to the UIC Class III permit application submitted to SD DENR under the Underground Injection Control Program (SDCL 34A-2 and Chapter 75:55), applications to other state and federal will be prepared and submitted in order to obtain authorizations under the following programs:

- In Situ Leach Permit submitted under Article 74:29 chapter §45:6B of SD DENR
- The state hazardous waste management program under SDCL chapter 34A-11
- The state solid waste permit program under SDCL chapter 34A-6, article 74:27, and chapters 74:54:01 and 74:54:02
- The state surface water quality program under SDCL chapter 34A-2 and article 74:52
- The state underground storage tank and aboveground storage tank program under SDCL chapter 34A-2 and article 74:56
- The state water rights permit program under SDCL title 46 and article 74:02
- The new source review, Prevention of Significant Deterioration, or Title V permit program under the Clean Air Act 42 U.S.C. § 7401 et seq. as amended through November 15, 1990, and under SDCL chapter 34A-1 and article 74:36, or minor source construction and operating air quality permit program under SDCL chapter 34A-1 and article 74:36
- The U.S. Army Corps of Engineers dredge and fill permit program under Section 404 of the Clean Water Act, as amended to January 1, 2008
- The U.S. Nuclear Regulatory Commission source material license program under 10 CFR Part 40 (January 1, 2007)
- Other relevant permitting programs, including other state and local permits or approvals

In addition to submitting this Class III UIC application to SD DENR, Powertech has submitted the Class III UIC Application to the U. S. Environmental Protection Agency (EPA) and the Source Materials License application to the Nuclear Regulatory Commission. At the State level, Powertech has submitted the required request for the department to determine whether or not the lands included in the proposed mining operation constitute special, exceptional, critical, or unique lands by submitting a notice of intent to operate to the Department. The Board of Minerals and Environment (BME) agreed with Powertech's determination and subsequently denied an opposing petition. Powertech received approval of two exploration permits submitted in 2007 and 2008 (pending placement financial assurance for the latter).

Section 4.0 - Regional and Site Description and Analysis

4.1 Project Background

Uranium was first discovered in the Edgemont Uranium District in 1951, and recovery was accomplished for a number of years using conventional surface and underground mining methods. In the mid-1970s, the Tennessee Valley Authority (TVA) bought a major interest in the District and focused their main exploration target in the Dewey-Burdock area, where approximately 4,000 exploration holes were drilled. Silver King Mines, a TVA wholly owned subsidiary, was the operator for TVA, who continued drilling until the early 1980s when depressed uranium prices led to a halt in exploration activities. A draft environmental statement (DES) was prepared by TVA to address the impact of a proposed underground mine in the Dewey-Burdock area, but the National Environmental Policy Act (NEPA) process was never completed by TVA. TVA had relinquished all leases and claims and withdrew from uranium exploitation by the late 1980s. In 1994, Energy Fuels Nuclear (EFN) acquired the project but relinquished it in the late 1990s due to low uranium prices. In 2005, Powertech acquired the property.

The PAA is located approximately 13 miles north-northwest of Edgemont, South Dakota and straddles the area between northern Fall River and southern Custer County line. The PAA encompasses approximately 10,580 acres (4,282 ha) of private land on either side of County Road 6463 and includes portions of Sections 1-5, 10-12, 14 and 15, Township 7 South, Range 1 East and Sections 20, 21, 27, 28, 29 and 30-35, Township 6 South, Range 1 East. Approximately 240 acres (97.1 ha) are under the control of the BLM located in portions of sections 3, 10, 11, and 12. Figure 4.1-1 depicts a regional view of: project location, permit boundary, the Pine Ridge Reservation boundary, public highways, nearest towns, national landmarks, state and county lines, and railroads.

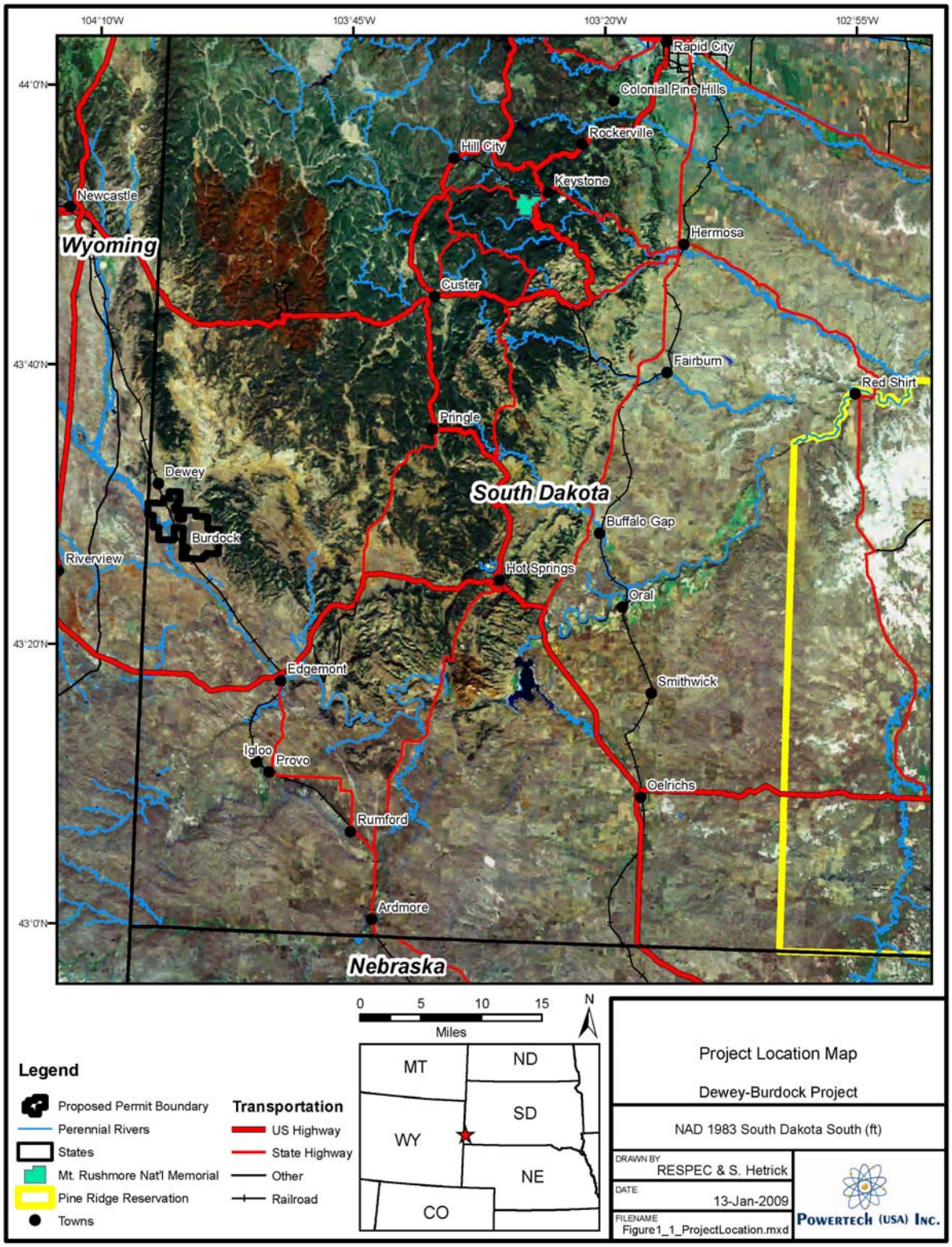

Figure 4.1-1 Project Location Map

The Dewey-Burdock uranium deposit occurs in both the Fall River and Lakota formations of the lower Cretaceous age that make up the Inyan Kara group. The Fall River and Lakota formations consist of permeable sandstones deposited in a major sand channel system that comprises two groundwater aquifers separated by the Fuson Shale Aquitard. The Lakota formation includes the Fuson shale and the Chilson sandstone units. The uranium occurs in the sandstones as classic roll front deposits with both oxidized and reduced zones located at both the Dewey and Burdock localities. Uranium minerals are deposited from down gradient flow of soluble oxidized uranium ions which encounter reducing chemical conditions within the aquifer causing precipitation of the uranium. At this interface of the oxidized groundwater and reduced groundwater, the uranium minerals precipitate, and coat the sand grains. Uranium mineralization can occur in several horizons within the aquifers resulting in multiple roll fronts. These roll fronts are typically "C" shaped in cross section, a few tens of feet wide and often thousands of feet long.

This paragraph has been updated to reflect current estimated mineable resource as stated in "Updated Technical Report on the Dewey-Burdock Uranium Project, Custer and Fall River Counties, South Dakota" (June, 2009). The National Instrument 43-101 Standards of Disclosure for Mineral Projects (NI 43-101) estimated mineable resources totaled 10.8 million pounds of U_3O_8 with an average grade of 0.182 percent. Subsequent to the publishing of the 43-101, Powertech has acquired properties with potential additional historical resources. The potential ISL mineable resources within the permit area were historically estimated by TVA at approximately 20 million pounds of U_3O_8. This resource is based on evaluation of approximately 4,000 exploration drill holes within the PAA. Evaluation of the lab and pumping hydrologic tests of the deposits indicate that the uranium is amenable to ISL mining techniques.

4.2 Topographic Maps

This section addresses **Completeness Issue CI–4 (1), (7).**

The maps provided within this section locate and identify features within the proposed permit boundary and adjacent areas of interest on regional and local scale. Regional maps utilize a LANDSAT base layer (Figure 4.1-1).

United States Geological Survey (USGS) topographic base layers are used for larger scale (site specific) maps that identify buildings, dwellings and other structures, existing wells within a one-mile radius of the proposed permit boundary, proposed location of first two well fields, process facilities, chemical storage areas, existing utilities and easements, and aquifer exemption boundary (AEB) (Exhibit 4-1).

Chemical storage areas are more closely defined in Exhibits 4-2 and 4-3 for both the Central Processing Plant (CPP) and the Satellite Facility (SF). For further discussion concerning proposed mining operations see Section 10.0 of this application.

Powertech proposes two methods for disposal of well field generated wastewater at the Dewey-Burdock project. These include:

- Deep well injection
- Land application with pre-treatment ion exchange and co-precipitation of radium

For both applications, holding ponds will be required. The design criterion for both systems is such that it would allow continuous disposal of three percent bleed as well as simultaneous operation of restoration activities. Proposed disposal options - deep well with associated ponds and land application with associated ponds, utilities, and easements are depicted on Exhibits 4-4 and 4-5.

Exploration holes and abandoned wells are identified within Figures 4.2-1 and 4.2-2 respectively. Wells that may require corrective action are depicted on Figure 4.2-3. Well and hole data consist of known existing water wells, producing wells, injection wells, abandoned wells, and exploration holes, providing location, depth, (Table 7.6-1) producing intervals, type of use (Exhibit 4-1), condition of casing, plugging date, procedures (Section 7.0 "Well Installation and Maintenance") and date of completion for each well or drill hole within the Area of Review (AOR) to the extent such information is available in public records and from a reasonable inspection of the property; for further detail concerning casing condition and aquifer refer to Appendix F "Groundwater Wells".

Preliminary depictions of a header house design, a well field design with injection, and production and monitoring wells are depicted in Exhibits 10-1, 10-2 and 10-3. Proposed future production areas and the first two well field locations are depicted in Exhibit 10-4. (Addresses **CI–4 (12) (a)**)

There are no adjudicated groundwater rights within the PAA. Groundwater and surface water rights are presented in Figure 4.2-4. For the discussion regarding potential impacts to water resources and water rights see Sections 10.5.2, 11.4.1, 11.5.1 of this application. Appendix A, Surface and Groundwater Rights provides the tabular form of water rights for cross reference with Figure 4.2-4.

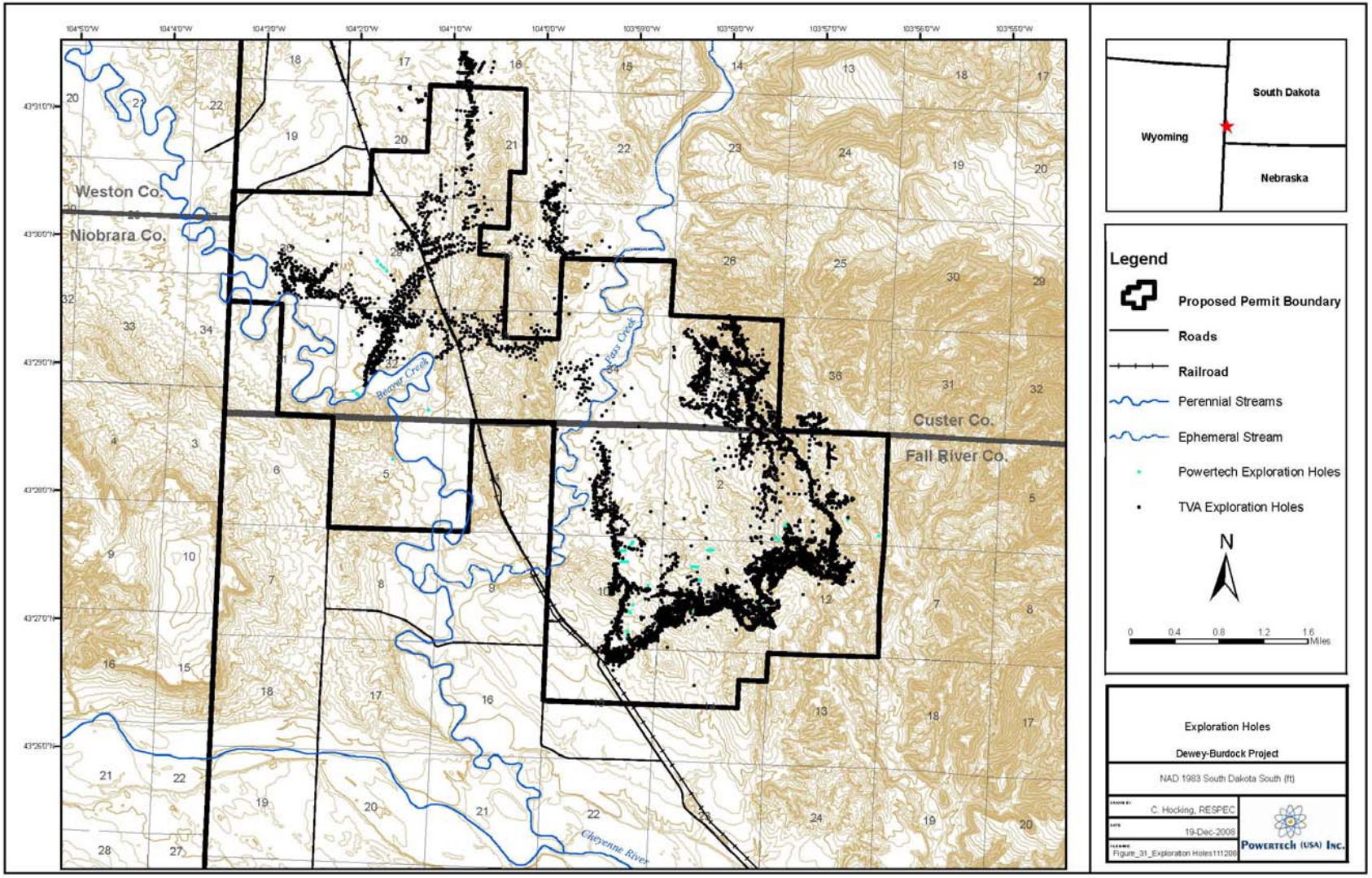

Figure 4.2-1 Exploration Holes

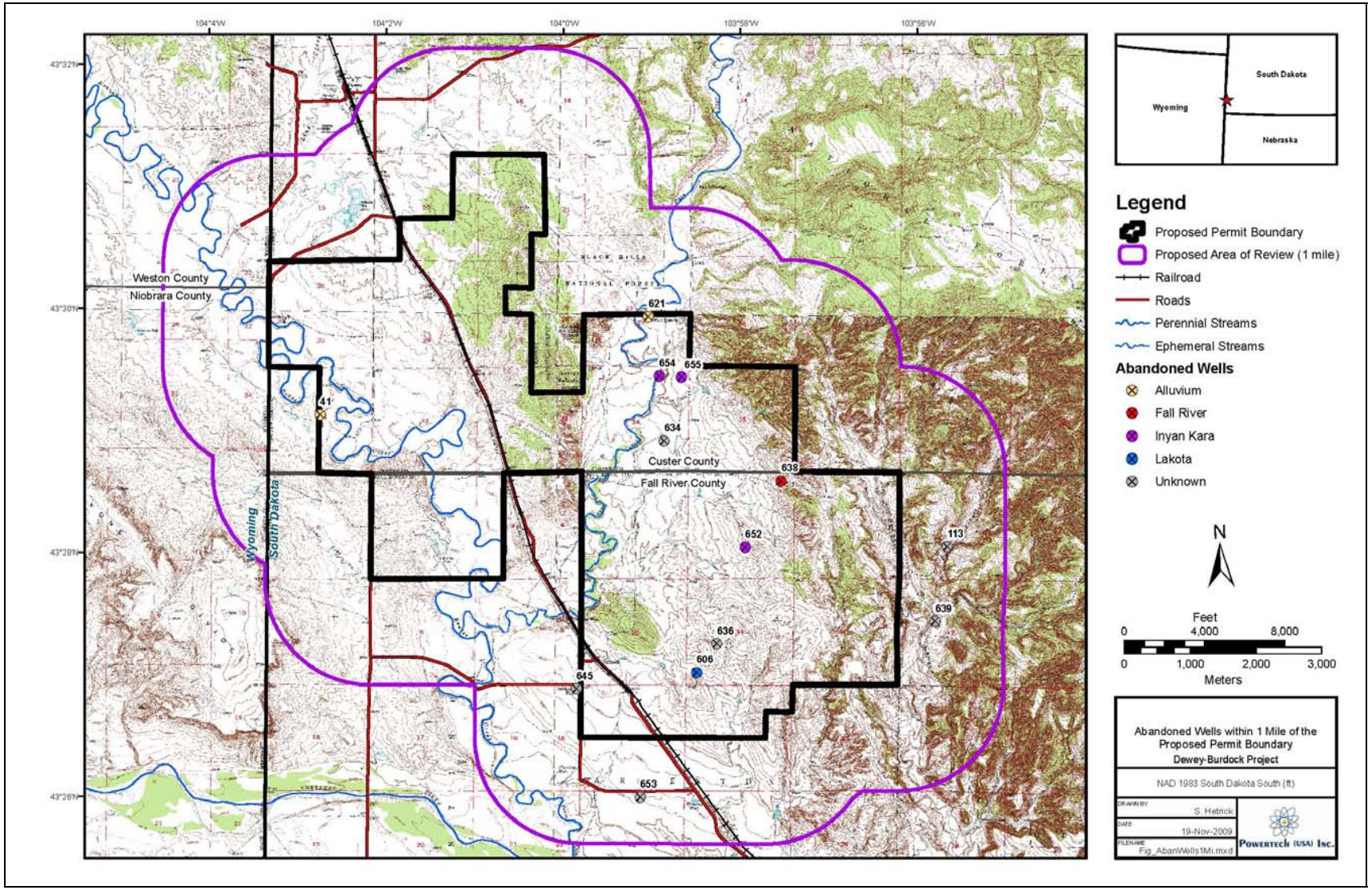

Figure 4.2-2 Abandoned Wells within 1 Mile of the Proposed Permit Boundary

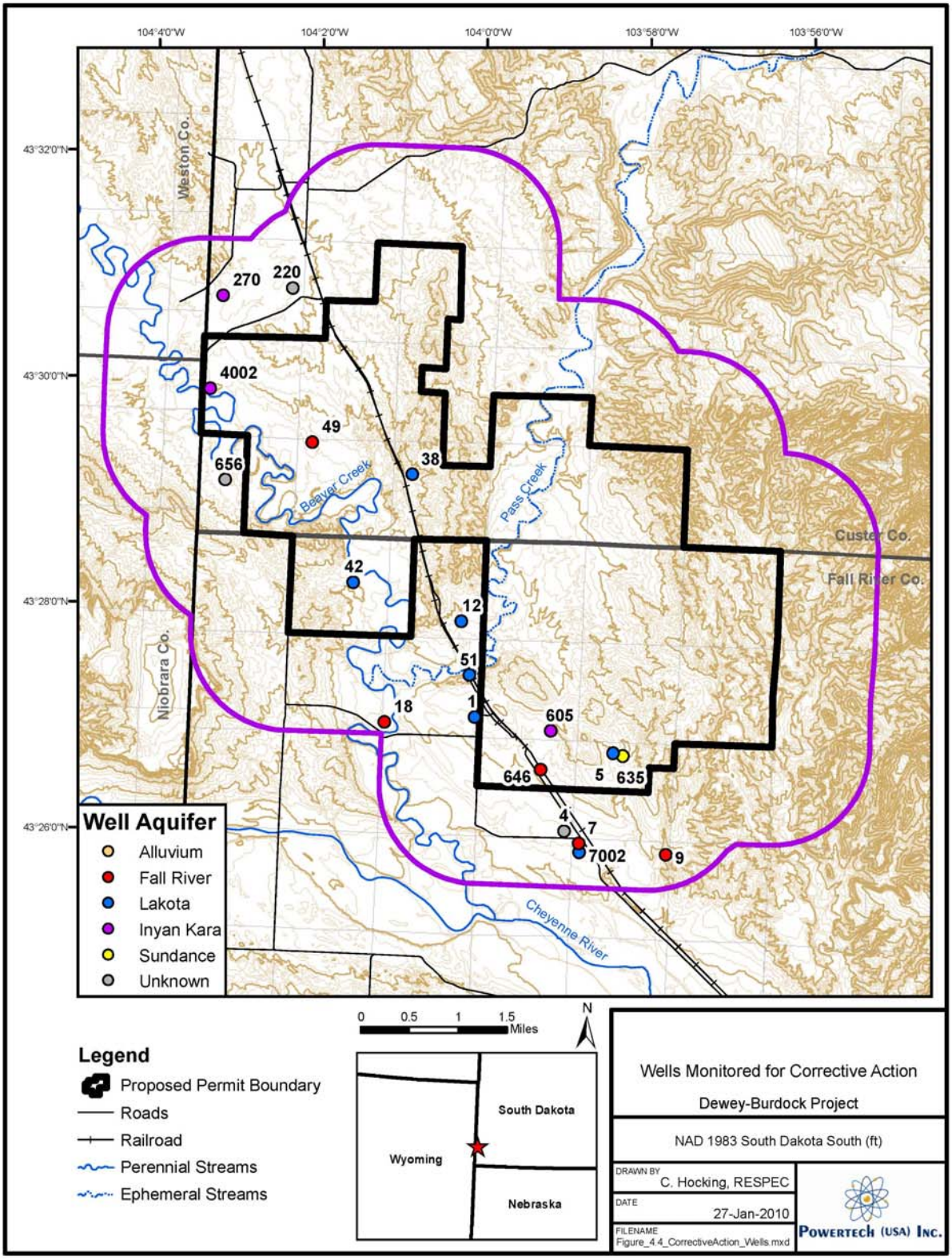

Figure 4.2-3 Wells Monitored for Potential Corrective Action

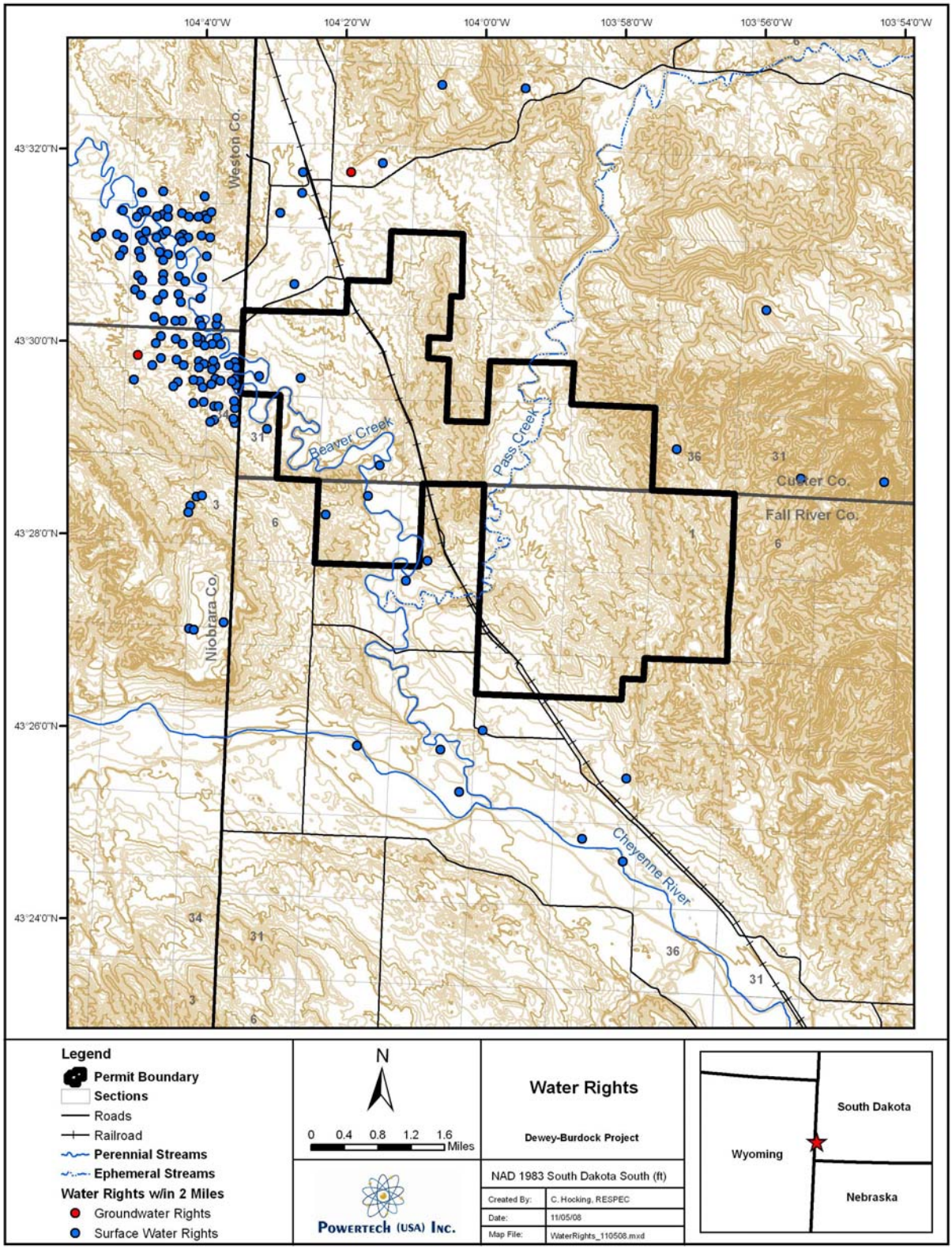

Figure 4.2-4 Groundwater and Surface Water Rights

4.3 Area of Review

4.3.1 Introduction

The AOR is established to maximize the data to be described before an Aquifer Exemption is granted in order to prove the integrity of the injection zones and their relationship to surrounding USDWs. The AOR normally specified by the EPA is ¼ mile from the proposed permit boundary. Powertech chose an area of review more extensive than that required by the EPA due to the fact that the NRC specifies a review area of 1.2 miles or (2.0 kilometers). The abundance of data from TVA on prior pumping tests performed for its planned Draft Environmental Statement (DES) yields excellent regional hydrologic information. After reviewing the TVA data in conjunction with other regional water well data (including pumping test data in Appendix B from TVA and Powertech), Powertech believes that the integrity of the units within the Inyan Kara geologic group will be maintained; thereby minimizing the opportunity for loss of fluids to any protected USDW either above or below the operating zone.

4.3.2 Proposed Project Features within the PAA

All available information concerning wells, dwellings, utilities, any existing easements within the PAA and adjacent lands in relation to all proposed affected lands and proposed activities associated with the in situ leach operation is contained in Exhibit 4-1.

Drinking water wells and other producing wells are color coded to designate which aquifer the wells are completed into and the depth of completion. Powertech is aware of four wells historically used for drinking water within the AOR, one of which, the Daniel's well, is located within the horizontal extent of the proposed AEB and completed within the mineralized aquifer. Powertech subsequently replaced the Daniel's well with a well completed in a deeper non-mineralized aquifer, the Unkpapa/Sundance; this domestic well is not within the vertical extent of the proposed AEB. The original well was not plugged or abandoned as the owner may utilize this water for cattle. Neither of these wells was used for the state approved baseline groundwater quality study performed within the PA. Powertech has agreements in place with all landowners concerning water wells. Figure 4.3-1 presents an excerpt from the original agreement. Powertech will be in close communications with landowners as the separate phases of the mining project are developed and initiated. Should a determination result in a well having the potential to interfere with operations, Powertech will remedy this circumstance with the landowner via the written agreement in place. Groundwater quality information required for permitting purposes is included within Appendix C. Powertech suggests the SD DENR contact private landowners to obtain water quality information regarding wells not utilized for the state approved baseline study.

9. **Water Wells.** DENVER URANIUM shall compensate LESSOR for water wells owned by LESSOR at the execution of this Lease, follows:

A. Any such water which falls within an area to be mined by DENVER URANIUM shall be removed from LESSOR's use. Prior to removal, DENVER URANIUM shall arrange for the drilling of a replacement water well or wells, outside of the mining area, in locations mutually agreed upon between LESSOR and DENVER URANIUM, as may be necessary to provide water in a quantity equal to the original well and of a quality which is suitable for a all uses the original water well served at the time such well was removed from LESSOR's use.

B. If any water well on the Property outside of a mining area or well field is materially and substantially diminished in quantity or quality due to DENVER URANIUM's exploration, development or mining activities, DENVER URANIUM will provide LESSOR with such additional water well or wells as may be necessary to provide water in a quantity equal to the original well and of a quality which was suitable for all uses the diminished well served.

C. Prior to commencement of any exploration or mining activities on the Property, DENVER URANIUM shall sample and/or test all of the water wells owned by LESSOR on the Property and all adjacent property owned by LESSOR within one-forth (1/4) mile of any planned operations. The purpose of these tests will be to establish baseline data regarding the quantity and quality of the water in each such well. Periodically thereafter during the term of this Lease, DENVER URANIUM shall have the right to sample and/or test wells at any frequency required by the State of South Dakota. All water quality and quantity data submitted to the State of South Dakota shall be provided to LESSOR upon his written request. If LESSOR claims that a well has been substantially and materially diminished, Denver Uranium shall have the right to verify such damage by testing the well in question.

Figure 4.3-1 Excerpt from Water Well Agreement

No injection wells, intake structures, discharge structures, hazardous waste treatment, storage, or disposal facilities have been identified in the AOR or within one mile of the proposed permit boundary. Springs identified on USGS topographical maps outside the AOR but within one mile of the project were not found during field investigations. No quarries are located within one mile of the proposed permit boundary; however, a quarry is located on the GCC Dacotah property to the north of the PAA boundary.

Additional information pertaining to drill holes and wells within the AOR is provided in Section 5.2 "Site Geology."

4.3.3 Population and Land Use

This section addresses **CI–4 (8 & 9)**.

Current land use is presented in Exhibit 4-6. This map is representative of each section and the designated land use according to the National Land Cover Database, 2001, zone 29, produced by the Multi-Resolution Land Characteristics Consortium (MRLC) at www.mrlc.gov and the NLCD 2001 land cover mapping team at the USGS/EROS, Sioux Falls, South Dakota. It is Powertech's presupposition that Exhibit 4-6 serves to depict current land use for all land within a one mile area of the proposed mine boundary and serves as a representation of land use section by section.

Within a 6.2 mile (10 km) radius of the approximate center of the PAA, which encompasses the AOR, a determined number of 38 people reside (Knight Piésold, 2008). Three people reside within the AOR on a permanent basis and one dwelling within the AOR is used as a vacation home.

Table 4.3-1 lists the distance to the nearest occupied dwellings from the center of the PAA according to 22.5-degree sectors centered on the 16 cardinal compass points in accordance with NRC guidance. Exhibit 4-1 and Table 4.3-2 present all occupied dwellings within a one mile radius of the permit boundary in accordance with Administrative Rules of South Dakota (ARSD) 74:55:01:26 (9). The nearest occupied dwelling is 0.9 miles to the west south-west of the PAA and is the only occupied dwelling within one mile of the boundary of the PA.

Table 4.3-1 Distance to Nearest Occupied Dwelling from Center of the Proposed Project

Sector	Distance from PAA Center	
	Miles	Km
N	7.2	11.6
NNE	8.3	13.3
NE	6.7	10.8
ENE	13.1	21.1
E	6.8	11.0
ESE	10.7	17.3
SE	7.5	12.1
SSE	5.9	9.4
S	0.9	1.4
SSW	3.4	5.5
SW	21.0	33.7
WSW	1.7	2.7
W	20.3	32.6
WNW	6.2	10.0
NW	3.5	5.6
NNW	4.2	6.7

Table 4.3-2 Occupied Dwellings within One Mile of Proposed Boundary of PAA

Name on Exhibit 4-1	Township	Range	Section	QrtQrt
Peterson	7	1	16	SESE
Morrison	7	1	15	SESE
Kennobie	7	1	23	NWNW
Spencer	7	1	4	NENE
Daniels	7	1	1	NESW
Don Anderson	7	1	9	SWSW
Putnam	7	1	5	SWNE
Stodart	41	60	22	SWSW
Cook	6	1	17	NENW
Beaver Creek Ranch HQ	6	1	30	NWSW

Land within the PAA is predominantly privately owned (97.5 percent) and the remaining 2.5 percent is managed by the BLM. Current land use within the PAA consists of agriculture related to grazing, alfalfa hay production, hunting and historical mining. Historical mine sites exist along the eastern portion of the proposed permit area.

There is no commercial crop production within the permit area, although approximately 388.79 acres of land are irrigated for alfalfa periodically in Section 5, T 7S, R 1E and Sec. 32, T 6S, R. 1E along Beaver Creek. The majority of agricultural production is related to grazing. Most of the land serves as grazing land for wildlife, cattle, and a few horses. The applicant would direct the reviewer's attention to Exhibit 4-6 that depicts:

- Land Use
- Section Grid with Township and Range
- Initial Well Fields
- 1 mile Area of Review
- Rural Residents
- CPP
- SF
- Proposed Permit Boundary
- Known Easements and/or Right of Ways
- Historical Mine Area
- Streams

Between 1951 and 1964, approximately 1,500,025 pounds (680,400 kilograms) of U_3O_8 was produced from underground and open pit mines in the Edgemont Uranium District (TVA, 1979). The Darrow, Spencer Richardson and Triangle uranium mine pits are located within the PAA boundary. The Freezeout and Lucky Strike uranium mine pits are located just northeast of the PAA (Table 4.3-3).

Table 4.3-3 Mines within One Mile of the Proposed Dewey-Burdock Boundary

Name	Township	Range	Section	Qrt Section	SD State Plane 1983		Area (acres)
					East (ft)	North (ft)	
Triangle	6	1	34	NE	1001770.6	442659.63	69
Spencer Richardson1	6	1	35	SE	1005548.3	440243.66	28
Darrow	7	1	1 and 2	NA	1007656.8	435455.66	217
Freezeout	6	1	36	SW	1009842.1	439075.66	ND
Lucky Strike	6	1	36	NE	1011383.1	442490.03	ND

Notes:
ND = Not Determined
NA = Not Applicable
1Partially reclaimed

Recreational use within the PAA is limited primarily to large game hunting. Within the project area, hunting is currently open to the public on approximately 5,689 acres. Approximately 240 acres are owned by the BLM; the South Dakota Game Fish and Parks (SDGF&P) lease approximately 3,069 acres annually of privately owned land and currently designate this acreage as walk-in hunting areas. GCC Dacotah, Inc owns 2,380 acres, designated as a SDGF&P Special Management unit that currently allows hunting. Fishing and other water-based recreational activities on streams within the project vicinity are limited due to low flows and turbid water conditions. Upon receipt of applicable permits and prior to commencing project activities, all hunting will be prohibited within the Permit Boundary.

Main access to the PAA is gained via the Dewey Road (County Road 6463), a gravel road, leading north from Edgemont. Other, mostly unimproved gravel roads crisscross the project at irregular intervals. A major rail line, Burlington Northern Santa Fe Railroad, lies across the center of the permit area. This railroad is a primary transportation corridor for Powder River Basin coal. Powertech is aware of Dakota Minnesota & Eastern rail plans in the area. According to the Dakota, Minnesota & Eastern Railroad, "As of today, no decision has been made on whether or not Canadian Pacific–DM&E's parent company–will build the extension" (http://www.dmerail.com/About_Us/Poweder%20River%20Basin/Project-Background.html; accessed 11/12/2009).

4.4 Corrective Action Plan

This section addresses **CI–12**.

Corrective action will be taken on a case by case basis, and will be appropriate for the situation and existing conditions. Any improperly completed, plugged and abandoned wells or holes identified within the monitoring well ring that may have potential to allow fluids to migrate into a USDW will be properly evaluated. Wells requiring corrective action will be identified and their locations will be provided to the EPA and SD DENR. Efforts will be made to re-enter and repair these wells. If repair is unsuccessful, the wells will be plugged and abandoned according to ARSD 74:02:04:67 to prevent the migration of fluids into a USDW according to the procedures outlined in Section 7 – Well Installation and Maintenance.

Extent of corrective action will include known wells designated by Powertech hydrologists having a degree of potential affect upon mining operations within the project area. If a well lacks mechanical integrity or is in a condition that precludes the use of that well for injection, or extraction corrective action to prevent the movement of fluids into USDWs will be implemented in accordance with 40 CFR Part 144.55. There are currently no existing Class III injection wells in South Dakota; however, corrective action for new wells is covered under ARSD 74:55:01. Powertech's Corrective Action Plan covers

methods concerning existing and new injection wells that comply with both EPA and South Dakota rules. The following details the steps or modifications necessary to prevent movement of fluid into unauthorized zones. A corrective action plan to prevent the migration of fluid into any USDW from PA wells is detailed in Section 11.4 – Contingency Plan for Well Failures.

4.4.1 Wells Monitored for Potential Corrective Action

For decades, it has been common practice in the area to allow free-flowing wells to continually discharge, largely to prevent freezing during winter. The attached map shows artesian wells within the AOR that will be monitored to determine if corrective action will be needed (Figure 4.2-3). This determination will be made during well field design phase.

4.5 Operational Pumping Tests

Prior to the start-up of a well field, pumping tests will be conducted to demonstrate that communication between the production zone and the underlying or overlying aquifers is not occurring. In some cases there may not be an underlying aquifer as the Morrison formation contains approximately one hundred feet of shale and therefore is a confining unit. If pumping test results indicate that leakage between aquifers has occurred, the leakage will be addressed according to accepted Best Management Practices (BMPs) by modification of operational practices as warranted.

Section 5.0 - Geologic Description

The following information includes project scale maps and cross sections that show detailed geologic structure affecting local stratigraphy, lithology of injection intervals and lithology of confining intervals. Supporting information is provided.

5.1 Regional Geology

The PA is located in the Great Plains Physiographic province on the south-western flank of the Black Hills uplift in south-western South Dakota. To the west of the project area is the Powder River Basin of Wyoming. The regional geologic map of this region is shown in Figure 5.1-1.

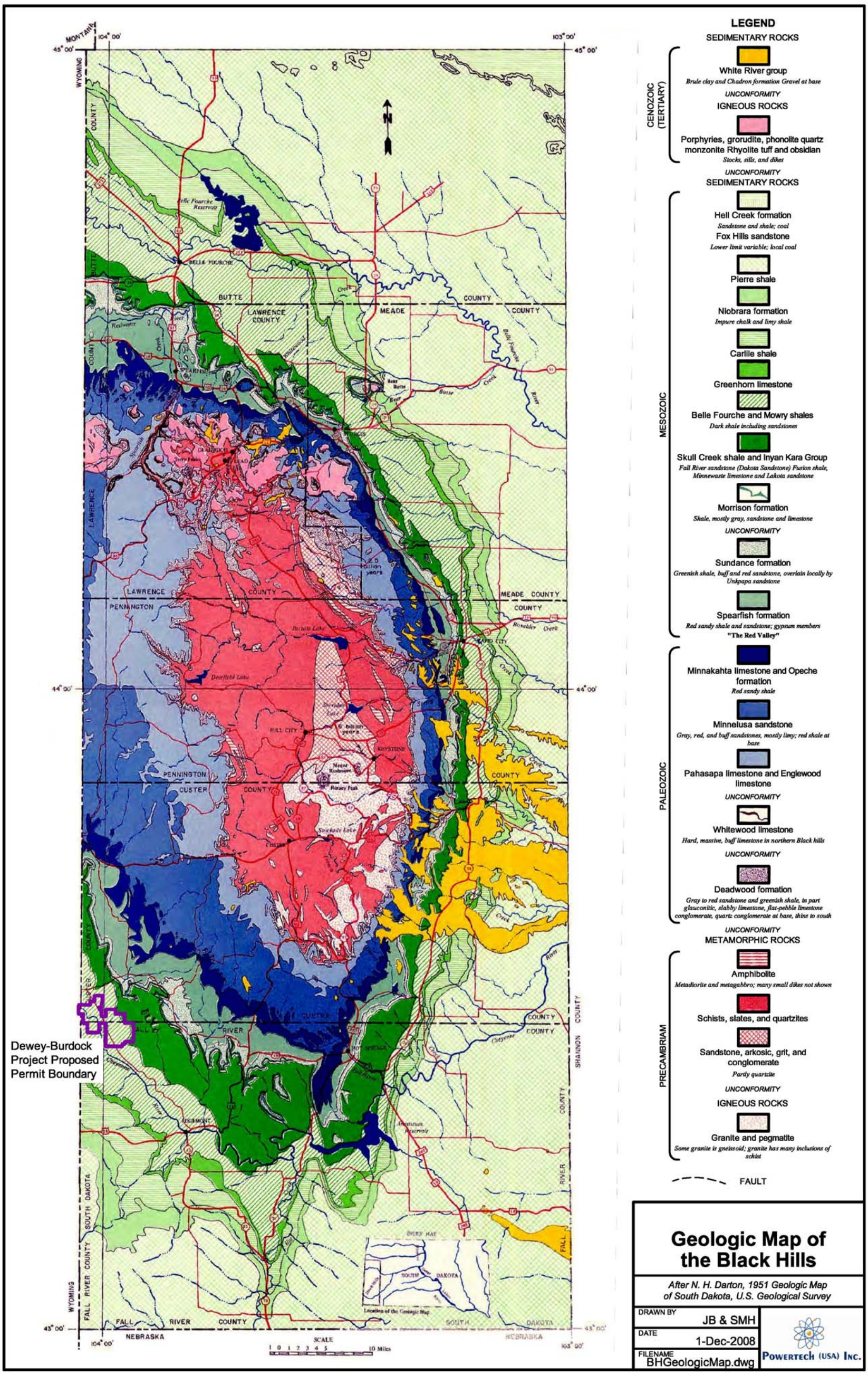

Figure 5.1-1 Geologic Map of the Black Hills

5.2 Site Geology

The site geology is shown in Figure 5.2-1. The Fall River Formation outcrops across the eastern part of the project and the Skull Creek Shale Mowry Shale, and Belle Fourche Shale outcrop across the western part of the project. The formations dip west and southwest at 2 to 6 degrees.

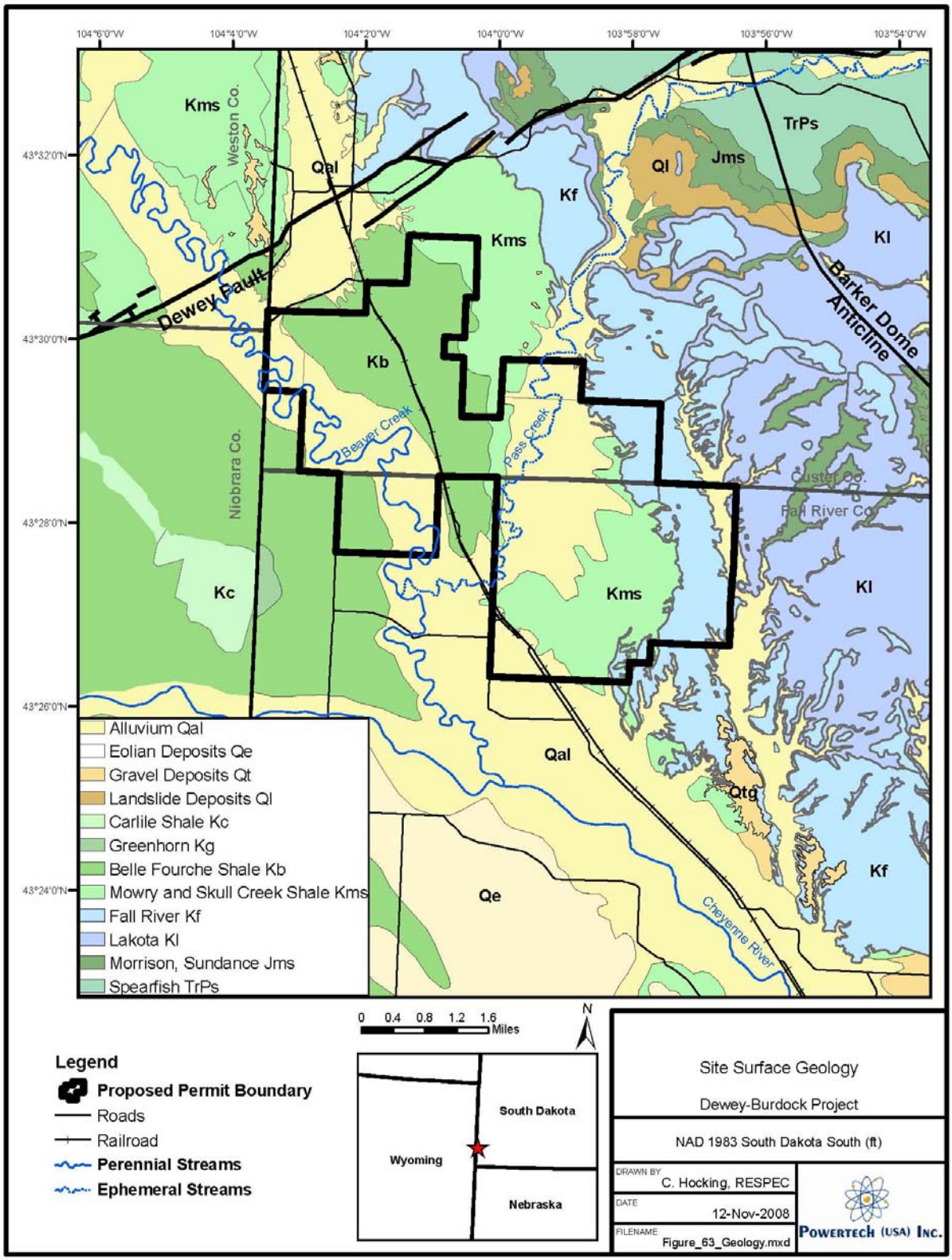

Figure 5.2-1 Site Surface Geology

The geology of the PAA was developed through the interpretation of data gathered from thousands of exploration drill holes. For each drill hole there was a suite of down-hole electric logs run to characterize natural radioactivity and the lithology (rock type) of the sediments in the subsurface. Resistivity and spontaneous potential depict the rock types encountered in the subsurface (sandstone, siltstone, shale, etc.). This is further enhanced by a geologist's description of the drill cuttings. Exhibit 5-1 is an example of a "type log" from the PAA.

Cross sections were generated using a 3-D geologic model, C'Tech's Mining Visualization Systems (MVS) (CTECH, 2008). MVS is a software program that allows a variety of data to be displayed in three dimensions. The objective of this model was to provide detailed geologic maps and cross-sections across the project area.

Cross sections from exploration logs were developed along each ore body and illustrate the aerial distribution of the sandstones across the project. Exhibit 5-2 depicts the locations of the four cross sections in an index map. The cross sections were generated in the MVS model and show the stratigraphy across the project area with the ore in the sandstones. The Belle Fourch, Mowry, and Skull Creek shales thicken from the east to the west (Exhibit 5-3). The Fall River Formation is continuous across the area and dips to the west (Exhibit 5-4). The Fuson Member of the Lakota ranges from 30 to 80 feet across the area (Exhibit 5-5). The Chilson Member of the Lakota is continuous across the area and thickens and thins due to channels (Exhibit 5-6). The ore in the Fall River mainly occurs in the lower sandstone unit while the ore in the Chilson Member of the Lakota occurs throughout the sandstone channels of the member.

5.3 Structural Geology

5.3.1 Regional Structure

The dominant structural feature in this region is the Black Hills Uplift. This uplift is of Laramide age (65 million years ago) and is an elongate northwest trending dome about 125 miles long and 60 miles wide. Igneous and metamorphic Precambrian-age rocks are exposed in the core of the uplift and are surrounded by outward-dipping Palaeozoic and Mesozoic rocks that form cuestas and hogbacks around the core of the uplift. Folds constitute the major structural features in the Black Hills. In early Cretaceous time minor deformation along concealed northeast trending structures of Precambrian age affected the courses of the northwest flowing streams and their tributaries, thereby influencing the location of the fluvial sandstone deposits of the Inyan Kara Group.

5.3.2 Local Structure

The structure across the project is simple and shows sediments dipping gently 2 to 6 degrees to the southwest. This is illustrated by structure contour maps of the top of the Fall River Formation (Exhibit 5-7), the Chilson Member of the Lakota Formation (Exhibit 5-8) and the top of the Unkpapa Formation (Exhibit 5-9).

The Dewey Fault, a northeast to southwest trending fault zone, is present approximately one mile north of the north and northwest parts of the project area. The Dewey Fault is a steeply dipping to vertical normal fault with the north side uplifted approximately 500 feet by a combination of displacement and drag. The USGS considers an area 7 miles southeast of the project as the Long Mountain Structural Zone. This northeast – southwest trend contains several small shallow surface faults in the Inyan Kara. No faults were identified along this trend on subsurface structure maps of the underlying Madison Formation, Minnelusa Formation or the Deadwood Formation. Despite the presence of faulting north and south of the site, there are no identified faults within the PAA.

There is some folding in the areas adjacent to the PAA. East of the project is a northwest – southeast trending anticline that ends in a closed structure called the Barker Dome. To the west is the Fanny Peak

Monocline. This monocline is the structural boundary between the Black Hills and the Powder River Basin.

There are no known geologic structural issues within the PAA that would compromise the surface or subsurface concerning development of the proposed action. South Dakota has a comparatively higher rate of seismicity than other areas in the northern plains states, although earthquakes in the area tend to be relatively rare and of low to moderate magnitude, and no active faults have been mapped in the vicinity (Hammond, 1992). This statement is made to generally summarize the results of the seismicity research. If one looks at a seismicity map of the U.S., it becomes apparent that seismic events are more frequent in the southern half of South Dakota, comparatively, than other northern plain states. Most of the seismicity and earthquake data was collected from the USGS Quaternary Fault and Fold Database and website, the Geological Survey of South Dakota, and Hammond (1992). The section continues on to explain magnitude and proximity of historical earthquakes to the project site.

There are no capable faults (i.e., active faults) with surface expression mapped within a radius of 100 kilometers (62 miles) from the center of the PAA, according to the 2002 U.S. Geological Survey's Quaternary Fault and Fold Database. In addition, there are no capable faults mapped in the entire state of South Dakota. The closest capable faults to the site are located in central Wyoming, nearly 345 kilometers (200 miles) to the west-southwest.

5.4 Stratigraphy

5.4.1 Regional Stratigraphy

The oldest rocks in the region are Precambrian metamorphic rocks and granites. These form the core of the Black Hills Uplift and are exposed at the surfaced of this structural feature. Overlying these crystalline rocks are 2000-3000 feet of Palaeozoic sediments. This sedimentary sequence contains several regional aquifers, to include the Deadwood Formation of Cambrian age, the Mississippian Madison Limestone and the Pennsylvanian/Permian-age Minnelusa Formation.

Mesozoic sediments include the Triassic age Spearfish Formation and the Sundance, Unkpapa and Morrison Formations of Jurassic age. The Sundance Formation is a minor aquifer in the southern Black Hills region. A thick sequence of Cretaceous age sediments completes the Mesozoic section.

The Early Cretaceous sediments of the Inyan Kara Group consist of the Lakota Formation and the Fall River Formation and is a transitional unit, exhibiting a change from terrestrial to marine deposition. The basal Lakota Formation (Chilson Member) is a fluvial sequence, which grades upward into marginal marine sediments as the Cretaceous Seaway inundated a stable land surface. Basal units of the Lakota Formation scour into clays of the underlying Morrison Formation and display the depositional nature of a large braided stream system, crossing a broad, flat coastal plain and flowing toward the northwest. Younger fluvial sand units of the Lakota become progressively thinner and less continuous and are separated by thin deposits of overbank and flood plain silts and clays. The mid-Lakota Minnewaste Limestone Member is a lacustrine deposit that occurs only in the southern Black Hills, but does not occur within the project boundary. At the top of the Lakota is the Fuson Member. The Fuson consists of shale with minor beds of fine grained sandstone and siltstone. The Fuson separates the underlying Lakota Formation from the overlying Fall River Formation. The Fall River consists of thick, widespread fluvial sands in the lower portion, grading to thinner, less continuous, marginal sands in the upper part. The Cretaceous Lakota and Fall River Formations are the hosts of the roll front uranium mineralization in the Black Hills region.

Following deposition of the Fall River, this region was covered by the North American Cretaceous Seaway, which resulted in the accumulation of vast thicknesses of marine sediments. From 3000-5000 feet of these marine sediments are represented by the Skull Creek Shale, Newcastle Sandstone, Mowry

Shale, Belle Fourche Shale, Greenhorn Formation, Carlisle Shale, Niobrara Formation and Pierre Shale. In Late Cretaceous time, the modern Rocky Mountain Uplift began, forcing the retreat of the Cretaceous seaway.

Unconformably overlying the Cretaceous sediments in the Black Hills region is the Tertiary-age (Oligocene) tuffaceous White River Formation. This thick, tuffaceous sequence was the result of volcanic eruptions to the west and was rich in volcanic fragments. The White River sediments have primarily been removed by erosion and can be found only as erosional remnants. This unit is thought to be the source of the uranium deposits found in the Black Hills region and the Powder River Basin of Wyoming.

The most recent sediments in the region are Quaternary-age deposits consisting of local material derived as a result of post-Laramide-uplift erosion. Recent deposits include alluvium and floodplain terrace deposits.

A stratigraphic column of the Black Hills is illustrated in Figure 5.4-1.

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ERATHEM	SYSTEM	ABBREVIATION FOR STRATIGRAPHIC INTERVAL	STRATIGRAPHIC UNIT	THICKNESS IN FEET	DESCRIPTION
CENOZOIC	QUATERNARY & TERTIARY (?)	QTac	UNDIFFERENTIATED ALLUVIUM AND COLLUVIUM	0-50	Sand, gravel, boulder, and clay.
		Tw	WHITE RIVER GROUP	0-300	Light colored clays with sandstone channel fillings and local limestone lenses.
	TERTIARY	Tui	INTRUSIVE IGNEOUS ROCKS	--	Includes rhyolite, latite, trachyte, and phonolite
MESOZOIC	CRETACEOUS	Kps	PIERRE SHALE	1,200-2,700	Principal horizon of limestone lenses giving teepee buttes. Dark-gray shale containing scattered concretions. Widely scattered limestone masses, giving small teepee buttes. Black fissile shale with concretions.
			NIOBRARA FORMATION	[1]80-300	Impure chalk and calcareous shale.
			CARLILE SHALE: Turner Sandy Member	[1]350-750	Light-gray shale with numerous large concretions and sandy layers.
			CARLILE SHALE: Wall Creek Member		Dark-gray shale
			GREENHORN FORMATION	225-380	Impure slabby limestone. Weathers buff. Dark-gray calcareous shale, with thin Orman Lake limestone at base.
			GRANEROS GROUP: BELLE FOURCHE SHALE	150-850	Gray shale with scattered limestone concretions. Clay spur bentonite at base.
			GRANEROS GROUP: MOWRY SHALE	125-230	Light-gray siliceous shale. Fish scales and thin layers of bentonite.
			GRANEROS GROUP: MUDDY SANDSTONE / NEWCASTLE SANDSTONE	0-150	Brown to light-yellow and white sandstone.
			GRANEROS GROUP: SKULL CREEK SHALE	150-270	Dark-gray to black siliceous shale.
		Kik	INYAN KARA GROUP: FALL RIVER FORMATION	10-200	Massive to thin-bedded, brown to reddish-brown sandstone.
			INYAN KARA GROUP: LAKOTA FM: Fuson Shale	10-190	Yellow, brown, and reddish brown massive to thinly bedded sandstone, pebble conglomerate, siltstone, and claystone. Local fine-grained limestone and coal.
			INYAN KARA GROUP: LAKOTA FM: Minnewaste Limestone	0-25	
			INYAN KARA GROUP: LAKOTA FM: Chilson Member	25-485	
	JURASSIC	Ju	MORRISON FORMATION	0-220	Green to maroon shale. Thin sandstone.
			UNKPAPA SS	0-225	Massive fine-grained sandstone.
			SUNDANCE FORMATION: Redwater Member, Lak Member, Hulett Member, Stockade Beaver Mem., Canyon Spr. Member	250-450	Greenish-gray shale, thin limestone lenses. Glauconitic sandstone; red sandstone near middle.
			GYPSUM SPRING FORMATION	0-45	Red siltstone, gypsum, and limestone.
	TRIASSIC	TRPs	SPEARFISH FORMATION / Goose Egg Equivalent	375-800	Red silty shale, soft red sandstone and siltstone with gypsum and thin limestone layers. Gypsum locally near the base.
PALEOZOIC	PERMIAN	Pmk	MINNEKAHTA LIMESTONE	[1]25-65	Thin to medium-bedded, fine-grained, purplish gray laminated limestone.
		Po	OPECHE SHALE	[1]25-150	Red shale and sandstone.
		PIPm	MINNELUSA FORMATION	[1]375-1,175	Yellow to red cross-bedded sandstone, limestone, and anhydrite locally at top. Interbedded sandstone, limestone, dolomite, shale, and anhydrite. Red shale with interbedded limestone and sandstone at base.
	PENNSYLVANIAN				
	MISSISSIPPIAN	MDme	MADISON (PAHASAPA) LIMESTONE	[1]<200-1,000	Massive light-colored limestone. Dolomite in part. Cavernous in upper part.
	DEVONIAN		ENGLEWOOD FORMATION	30-60	Pink to buff limestone. Shale locally at base.
	ORDOVICIAN	Ou	WHITEWOOD (RED RIVER) FORMATION	[1]0-235	Buff dolomite and limestone.
			WINNIPEG FORMATION	[1]0-150	Green shale with siltstone.
	CAMBRIAN	O€d	DEADWOOD FORMATION	[1]0-500	Massive to thin-bedded buff to purple sandstone. Greenish glauconitic shale flaggy dolomite and flat-pebble limestone conglomerate. Sandstone, with conglomerate locally at the base.
PRECAMBRIAN		p€u	UNDIFFERENTIATED IGNEOUS AND METAMORPHIC ROCKS		Schist, slate, quartzite, and arkosic grit. Intruded by diorite, metamorphosed to amphibolite, and by granite and pegmatite.

[1]Modified based on drill-hole data

STRATIGRAPHIC COLUMN OF THE BLACK HILLS AREA
(from Driscoll et al.)

DEWEY-BURDOCK PROJECT

DRAWN	L. Tafoya
DATE	12-Nov-2008
SCALE	NONE
FILENAME	Figure 6.2.dwg

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Figure 5.4-1 Stratigraphic Column of the Black Hills Area

5.4.2 Local Stratigraphy

The sedimentary rocks of primary interest that underlie the PAA range in age from Upper Jurassic to Early Cretaceous. The Upper Jurassic Morrison Formation is considered to be the Lower Confining Unit for the project. The uranium mineralization is contained within the Inyan Kara Group (Lakota and Fall River Formations). The Skull Creek Shale is the Upper Confining Unit. Exhibit 5-10 is a generalized cross section of the project area, illustrating the relationship between these sedimentary units, as well as their position to underlying rocks, ranging in age from Jurassic to Precambrian.

5.4.2.1 Overlying Units: Belle Fourche Shale, Mowry Shale and Skull Creek Shale Formations

5.4.2.1.1 Alluvium

The most recent sedimentary units deposited within the PAA area are the Quaternary age alluvium deposits. Alluvium is present in the major drainages and their tributaries and consists of silt, clay sand and gravel.

5.4.2.1.2 Terrace Deposits

Along the sides of drainages are relatively flat terrace deposits representing floodplains and former levels of streams. The terraces are primarily overbank deposits of clay and silt with gravel beds. Gravel deposits consist of boulders and pebbles of chert, sandstone, and limestone.

5.4.2.1.3 Belle Fourche Shale

The Belle Fourche Shale conformably overlies the Mowry Shale and is present in the western (Dewey) side of the PAA. In the eastern (Burdock) side of the PAA this unit has been eroded away. The Belle Fourche Shale is a dark gray to black marine shale. It is also the uppermost member of the Graneros Group which also includes the Mowry Shale, Newcastle Sandstone (not present within PAA), and the Skull Creek Shale.

5.4.2.1.4 Mowry Shale

At the PAA the Skull Creek Shale is directly overlain by the Mowry shale and is also considered to be part of the Upper Confining Unit. Normally, the Newcastle Sandstone is present between the Skull Creek Shale and the Mowry Shale, but is absent across the project area. The Mowry Shale consists of light gray marine shale with minor amounts of siltstone, fine grained sandstone, and a few thin beds of bentonite. Dark-gray to purple and black iron and manganese concretionary zones are common within the shale. The combined Skull Creek Shale – Mowry Shale reaches a thickness of 400 feet in the western part of the PAA. Exhibit 5-11 is an isopach map showing the combined thickness of these two shale units. In the north-eastern portion of the PAA, these units outcrop and have been eroded.

5.4.2.1.5 Skull Creek Shale Formation

The Skull Creek Shale directly overlies the Fall River Formation and consists of dark-grey to black shale, organic material, and some silt sized quartz grains. The Skull Creek Shale has an average thickness of approximately 200 feet and is the Upper Confining Unit for the project. Analyses of core samples demonstrate that the Skull Creek clays have extremely low vertical permeabilities, in the range of 6.8×10^{-9} centimeters per second (cm/sec) (0.007 millidarcies). The Skull Creek Shale is eroded from the eastern parts of the project.

5.4.2.2 Production Zone Units: Fall River and Lakota Formations

5.4.2.2.1 Inyan Kara Group

The Early Cretaceous Inyan Kara Group consists of two formations, The Lakota and the Fall River. The Inyan Kara is composed of interbedded sandstone siltstone and shale. Sandstones within these two

formations are hosts to all the uranium mineralization for the PA. The depositional environment of the Inyan Kara is fluvial to marginal marine.

5.4.2.2.2 Fall River Formation

The Fall River formation is composed of carbonaceous interbedded siltstone and sandstone, channel sandstones, and a sequence of interbedded sandstone and shale. The lower part of the Fall River consists of dark carbonaceous siltstone interbedded with thin laminations of fine-grained sandstone. Channels were cut into this interbedded sequence by northwest flowing rivers and fluvial sandstones were deposited. These channel sandstones occur across various parts of the PAA and generally contain the uranium deposits. Overlying the channel sandstones is another sequence of alternating sandstone and shales. The sandstones are cross-bedded to massive, fine to medium-grained, and well-sorted. Analysis from core indicated the Dewey Fall River sandstone unit has a horizontal hydraulic conductivity of 2.2×10^{-3} cm/sec (6.1 feet per day [ft/day]).

The isopach map of the Fall River Formation (Exhibit 5-12) shows a range of thickness of 120 to 160 feet. The thickening of the formation indicates the presence channel sandstones. Along the north eastern portion of the project area, this formation is exposed on the surface and erosion has taken place.

5.4.2.2.3 Lakota Formation

The Lakota Formation consists of three members; from lower to upper, they are the Chilson Member, the Minnewaste Limestone Member and the Fuson Member.
The Minnewaste Limestone Member is not present in the PAA.

The Chilson Member (commonly referred to as the Lakota Sandstone) is composed largely of fluvial deposits. These deposits consist of sandstone, shale, siltstone, and shale. The member consists of a complex of channel sandstone deposits and their laterally fine-grained equivalents. The Chilson Member consists of two units; a basal carbonaceous black mudstone and an overlying unit of channel sandstones with laterally fine-grained equivalents and interbedded shales. The sandstones are very fine to medium-grained and well sorted and were deposited by a northwest flowing river system. Analyses of core samples of these sandstones indicate these units exhibit high horizontal permeabilities, ranging from 2.6 x 10-3 cm/sec to 4.1 x 10-3 cm/sec (2697 millidarcies to 4161 millidarcies). The massive sandstone is made up of numerous individual sand filled channels, which contain the uranium deposits.

The isopach map of the Chilson Member (Exhibit 5-13) of the Lakota Formation shows the thickness of the channel sandstones and interbedded shales within the Chilson Member. Thicknesses vary from 100 to 240 feet. The total sand thicknesses are adequately documented from drill hole information. Drilling was usually stopped in the lower carbonaceous shale unit of the Chilson Member and did not penetrate the Morrison Formation.

The Fuson Member is the uppermost member of the Lakota Formation and the shale-siltstone portion of the Fuson has been used to divide the Lakota Formation from the Fall River Formation. Analyses of core samples of these lithologies demonstrate low vertical permeabilities, ranging from 2.2 x 10-7 cm/sec to 7.8 x 10-9 cm/sec (0.228 millidarcies to 0.008 millidarcies).

The Fuson Member is described as having a lower discontinuous sandstone unit at its base and upper discontinuous sandstone at the top of the member. If present, the lower sandstone unit was mapped as Lakota sandstone. Similarly, if the upper sandstone was present it was mapped as Fall River sandstone. The isopach map of the Fuson Member (Exhibit 5-14) shows the thickness of the shale – siltstone unit ranging from 30 to 80 feet. It shows thinning of the shale under the overlying channel sandstones of the Fall River Formation. The isopach map (Exhibit 5-15) of the underlying unit (the Morrison Shale) shows the thickness of the shale ranging from 90 to 115 feet.

5.4.2.3 Underlying Unit: Morrison

5.4.2.3.1 Morrison Formation

The Upper Jurassic Morrison Formation was deposited as flood plain deposits. It is composed of waxy, unctuous, calcareous, noncarbonaceous massive shale with numerous limestone lenses and a few thin fine grained sandstones. Below the site, this formation has an average thickness of approximately 100 feet and is the Lower Confining Unit for the project. Analyses of core samples demonstrate that the Morrison clays have extremely low vertical permeabilities, ranging from 4.2 x 10-8 cm/sec to 3.9 x 10-9 cm/sec (0.043 millidarcies to 0.004 millidarcies).

5.5 Lithology and Mineralogy of Receiving Formations and Confining Units

The following presents information pertaining to mineralogical and lithology of the receiving formations the confining units of the proposed project area and addresses **CI–7**.

5.5.1 Morrison Confining Unit

The Morrison consists of gray to green (rarely red or purple), non-carbonaceous mudstone. The lower portion of the Morrison is often more calcareous with thin, discontinuous beds or lenses of gray clayey limestone, chert, and sandstone (Braddock, 1963). Because of its unresistant nature, the formation is poorly exposed in the outcrop and commonly forms steep grass covered slopes (Brobst, 1961). The thickness of the Morrison within the Jewel Cave SW Quadrangle (NE of the site) ranges from 60 to 120 feet with individual beds typically less than two feet thick (Braddock, 1963). The formation was deposited in a nonmarine lowland environment in channels, floodplains, and ponds or lakes (Braddock, 1963).

5.5.2 Lakota Receiving Formation

This basal-Cretaceous, fluvial sequence was deposited within a broad, northwest trending braided channel system. The sandstone units are poorly-sorted, with grain sizes ranging from fine-grained to cobbles. Surrounding the Black Hills, quartz and chert grains account for 80% to 95% of the mineralogical composition of the sandstone units. In the Dewey-Burdock area, studies of core samples in the Blake master's thesis determined that the SiO_2 content (quartz and chert) of these sedimentary units exceeded 95% - classifying them as "quartz arenites" or "chert arenites". The remaining mineralogical composition of these units includes approximately 1% feldspar, which can be altered to kaolinite clay, and a heavy mineral suite consisting of rounded zircon and tourmaline grains and authigenic pyrite, which can be coated with hematite or limonite. Geochemical analyses for trace elements within the core show high iron values (up to 1%) and lesser amounts of uranium, vanadium and selenium. The source of the mineralogical components in these sediments is pre-existing sedimentary rocks located to the south.

5.5.3 Fuson Confining Unit

The Fuson member tends to be approximately 60 to 100 feet thick and is mainly comprised of a noncarbonaceous, nonfissile, mudstone and siltstone with abundant calcareous concretions. The beds are gray, green, and occasionally maroon in color. Due to its nonresistant nature, the Fuson tends to weather to steep grass-covered slopes. Waage (1959) stated that the "use of the name Fuson as a member of the Lakota is considered permissible only where the Minnewaste Limestone member is present." His reasoning is based on the fact that in the absence of the Minnewaste, it is difficult, if not impossible in the subsurface, to differentiate between Chilson and Fuson sandstone beds. For this reason, this geologic model of this study refers to the Fuson as only the shale facies of the member.

Numerous sources, though, describe two fluvial units (S_3 and S_4) within the Fuson. Where present, the lower S_3 sandstone is 20 to 30 feet of fine grained, gray quartz sandstone (Braddock, 1963). The S_3 unit also has numerous cross beds indicating deposition in a north to northeast flowing stream (Brobst, 1961). Where present, the S_4 sandstone forms a channel up to l.5 miles wide and 70 feet deep (Braddock, 1963).

Although similar to the S_3 sandstone, the S_4 sandstone was deposited in northwest flowing streams, contains petrified logs, and has many sets of foreset crossbeds (Gott et al,1974). On outcrops, "the upper few inches to few feet of the Fuson is bleached, resulting in a strong color contrast between the rocks" (Gott et al, 1974). In subsurface exploration, however, his color contrast is not evident hence the reason for delineation of the Fuson in the geologic model.

5.5.4 Fall River Receiving Formation

This Cretaceous sedimentary sequence was deposited in fluvial and marginal marine systems on the southern flank of the transgressive North America Cretaceous Seaway. The sandstone units are fine to medium-grained and well-sorted. Quartz grains account for 80% to 95% of the mineralogical composition. The remaining composition contains approximately 1% feldspar (can be altered to kaolinite clay), 1% chert, 3% muscovite and 3% metamorphic (schist) fragments. The heavy mineral suite consists of angular zircon and tourmaline grains, small amounts of garnet, chloritite and hornblende, along with authigenic pyrite, which can be coated with hematite or limonite. Geochemical analyses for trace elements within the core show high iron values (up to 1%) and lesser amounts of uranium, vanadium and selenium. Vanadium values appear to be higher in the Fall River Fm. than in the Lakota Fm. The source of the mineralogical components in these sediments remains predominantly pre-existing sedimentary rocks located to the south. However, deeper erosion (as evidenced by the schist fragments) cut down into underlying meta-sedimentary units.

5.5.5 Graneros Confining Unit

The Graneros Group (Early through Late Cretaceous) consists of four conformable formations: the Skull Creek Shale, Newcastle Sandstone, Mowry Shale, and Belle Fourche Shale. Extending westward across the site above the top of the Fall River Formation, the formations of the Graneros Group are exposed and weathered into gentle slopes.

5.5.5.1 Skull Creek Shale

The Cretaceous (Albian) Skull Creek Shale is the basal formation of the Graneros Group and erodes into gentle slopes west of the Inyan Kara hogback. The type locality of the Skull Creek is southeast of Osage, WY (Braddock, 1963). In the Dewey-Burdock area, the Skull Creek is a medium-gray mudstone with abundant septarian and cone-in-cone type concretions. Near the base of the Skull Creek there are bentonite beds from 0.25 to 4 inches thick (Braddock, 1963). The upper 50 feet of the formation is characterized by abundant sandstone dikes; their emplacement is uncertain although they may be related to the Newcastle Sandstone (Brobst, 1961). The Skull Creek shale was deposited in a quiet, shallow, and somewhat brackish environment and is approximately 250 feet thick at the site (Gries and Martin, 1985).

5.5.5.2 Newcastle Sandstone

Within the area, the Newcastle Sandstone is only present in very isolated lenses and pods. Where present, the Newcastle forms a thin ledge of sandstone that serves as a marker bed between the Skull Creek and Mowry Shales. In this area, the Newcastle is between zero and ten feet thick and does not represent an aquifer (Brobst, 1961).

5.5.5.3 Mowry Shale

Deposited in the uppermost lower Cretaceous, the Mowry Shale overlies the Skull Creek and underlies the Bell Fourche Shale. The type locality of Mowry Formation is at Mowrie Creek northeast of Buffalo, WY (Braddock, 1963). The Mowry is a light-gray mudstone and siliceous shale that weathers into platy chips. Dark-gray to purple and black, iron and manganese concretionary zones are common within the shale. Around the Black Hills, abundant fish scales are found within the Mowry often within a thin sandy zone about 50 feet above the base of the formation. The upper contact with the Belle Fourche is marked by a 5

foot bed of bentonite known locally as the Clay Spur (Brobst, 1961). The Mowry can often be distinguished from other Graneros Group shale based on the vegetation; typically the easily erodible Mowry will have little or no vegetation although more silicified areas often form small pine-covered mounds. Within the Dewey Quadrangle, adjacent to the project site, the Mowry is approximately 130 feet thick (Brobst, 1961).

5.5.5.4 Belle Fourche Shale

The Belle Fourche Shale (Cenomanian–upper Cretaceous) is the uppermost formation of the Graneros Group and consists of dark brownish-black shale. Within the Belle Fourche there are also concretionary beds of oligonite, an iron-manganese carbonate, and popcorn texture bentonite [Brobst, 1961]. The Belle Fourche Shale was estimated to be over 136 feet thick in the Dewey Quadrangle [Brobst, 1961].

5.5.6 Acid Rock Drainage

This section addresses **CI–7**.

The phenomena of acid rock drainage (ARD) has been observed in historic mining regions where pyrite and other sulphide minerals present in crushed rock tailings have been exposed to atmospheric oxygen. In these circumstances, oxidation of sulphide to sulphate will solubilize ferrous iron (Fe^{+2}), which, in a strong surface oxidizing environment, will oxidize to ferric iron (Fe^{+3}). Ferric iron will continue to oxidize additional sulphides in a chain reaction. The net effect is the release of hydrogen ion, which lowers the pH of the water and keeps the ferric iron active. When this process continues over extended time periods of many years, this effect is termed “acid rock drainage,” and is due to both the large rock surface area exposure and the availability of oxygen to that rock surface from extended exposures to air.

The uranium deposits at Dewey-Burdock, similar to other roll-front deposits in Wyoming, Nebraska and Texas, were precipitated in a reduced environment below the water table. The conditions for acid rock drainage is absent during and after in-situ leach operations: Rocks are not crushed, and more importantly, because they are located below the water table, rocks are not exposed to atmospheric oxygen for extended time periods. During in-situ mining, oxygen and carbon dioxide are injected into the uranium deposit. The oxygen solubilizes the uranium, but because of the strong reducing environment in the subsurface, the uranium has a tendency to quickly re-precipitate. The carbon dioxide is introduced with the oxygen, to complex with the solubilized uranium and to keep it in solution so it can be pumped to the surface. During mining operations, sulphides in the subsurface will be oxidized to sulfates by the injected oxygen, forming ferrous iron. But because of the strong reducing environment in the subsurface, the oxidation chain reaction that occurs on the surface does not take place and ferric iron is not formed. Without the oxidation chain reaction, insufficient hydrogen ion is generated to lower the pH of the groundwater in the subsurface. Furthermore, the restoration operations to be conducted immediately following the recovery operations will reduce the oxidizing nature of the lixiviant, leading to re-precipitation of constituents that were mobilized by oxidation during the mining operation.

5.6 Subsidence

This section addresses **CI–4 (12) (f)**.

South Dakota’s UIC Class III Well regulations (Chapter 74:55:01) address the in situ mining of sulfur, salts, trona, potash and uranium. The in situ mining of chemical rocks (i.e., sulfur, salts, trona and potash), resulting in the dissolution and removal of a lithologic unit from the subsurface may result in minor subsidence within overlying units. This phenomena, however, does not apply to sandstone-hosted uranium deposits at the Dewey-Burdock Project.

The lithologic units containing uranium at the Dewey-Burdock Project are early Cretaceous-aged fluvial sandstones of the Lakota and Fall River Formations. These sands were deposited 120-140 million years ago and were subsequently overlain and buried by thousands of feet of marine shales derived from the

North American Cretaceous Seaway. This deep burial caused a high degree of compaction within these sandstones. During the uplifting of the Black Hills, 65 million years ago, these highly-compacted sandstones were brought to the surface and near-surface. Recent drilling and coring operations on the project confirm that these sandstones are compacted, well-consolidated lithologic units.

Uranium was introduced into these consolidated sands at the outcrop and was emplaced through the down dip migration of meteoric water. Uranium oxide was precipitated as coatings on sand grains and fillings of pore spaces between sand grains. During the proposed in situ mining process, oxygenated groundwater, circulated through these sands, will take this uranium oxide into solution. Individual sand grains are not affected by this process, therefore the integrity of the lithologic unit is unchanged. As a result of the chemical and physical stability of these host sandstone units, there will be no subsidence within overlying sedimentary units.

Section 6.0 - Hydrologic Description

6.1 General

The following information includes regional scale maps and cross sections that show the geologic structure and overlying and underlying USDWs relevant to the PAA. Supporting details are provided in the following sections. Terms aquifer and subaquifer may be used interchangeably in discussion(s) concerning the Inyan Kara, Fall River and Lakota aquifers.

6.2 Hydrogeologic Description

6.2.1 Regional Hydrogeology

Five major aquifers are utilized as groundwater resources in the Black Hills. These main aquifers are the Precambrian fractured granite and metamorphics, Deadwood sedimentary rocks, Madison limestone, Minnelusa sedimentary and evaporative units, and the Inyan Kara Group of sandstones. The groundwater hydrology is influenced by its location relative to the Black Hills uplift and variation in recharge, leakage between overlying and underlying hydrogeologic units, lateral flow within the aquifers, and discharge to pumping wells, artesian wells, and springs.

Figure 6.2-1 provides an overview of the hydrologic setting and general hydrogeologic flow within the Black Hills. Regionally, the general direction of groundwater flow is downdip or radially away from the central part of the Black Hills where the aquifers are recharged via infiltration from local precipitation. The aquifers transition from unconfined at the outcrop areas to confined away from the central highlands. At some distance away from the highlands the groundwater often is under sufficient pressures for artesian conditions and flowing artesian wells to exist.

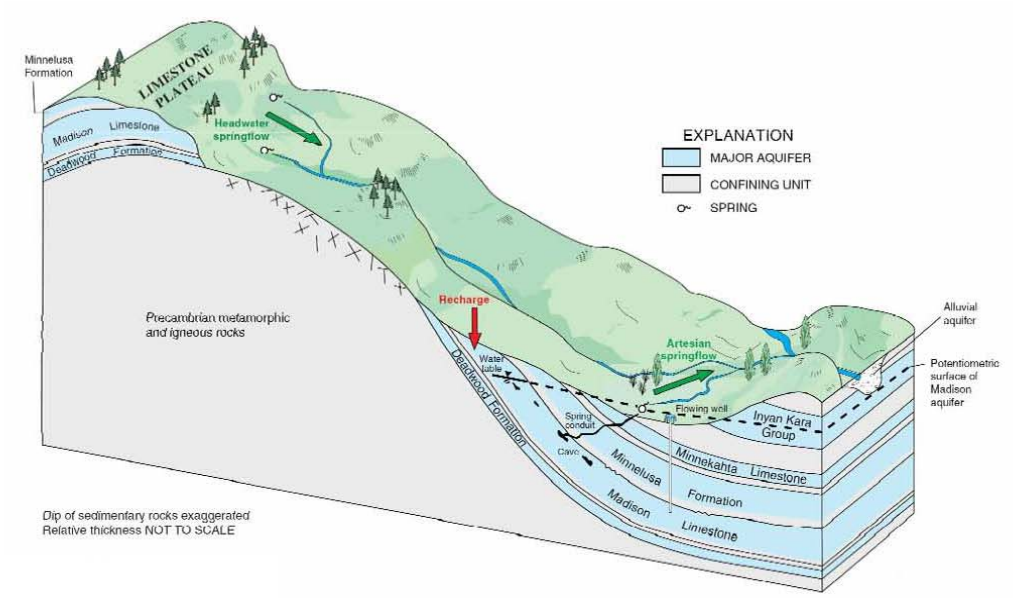

DIAGRAM SHOWING A SIMPLIFIED VIEW OF THE HYDROGEOLOGIC SETTING OF THE BLACK HILLS AREA (modified from Driscoll et al, 2002)

DEWEY-BURDOCK PROJECT

DRAWN	L. Tafoya
DATE	12-Nov-2008
SCALE	NONE
FILENAME	Figure 5.1.dwg

POWERTECH (USA) INC.

Figure 6.2-1 Diagram Showing a Simplified View of the Hydrogeologic Setting of the Black Hills Area

6.2.1.1 Regional Hydrostratigraphic Units

This section summarizes the aquifers in the Black Hills, including general characteristics and hydraulic properties. Geologic units of interest within the Black Hills area are shown on the stratigraphic column in Figure 5.4-1 and detailed information on the geologic units is provided in Section 5. Note to reader: Within this application permeability in reference to intrinsic permeability such as the discussion of core, milidarcy (md) units are used; within discussions concerning pumping tests intrinsic permeabilities were converted to hydraulic conductivity. The conversion from intrinsic permeability measurements on core to permeability/hydraulic conductivity in cm/sec or ft/day is provided in a table in the pumping test write up in Section 6.2.2.7.1.

6.2.1.1.1 Precambrian Aquifer

The Precambrian rocks that make up the core of the Black Hills consist of various rock types including metamorphosed sedimentary rocks and granites. Precambrian aquifers are not continuous and have little to no primary porosity; "groundwater flow is mainly controlled by secondary permeability caused by fracturing and weathering" (Driscoll et al., 2002). The greater the fracture density, the greater the porosity and permeability that exists, Rahn (1985) estimated the effective porosity of the Precambrian aquifers to be 0.01. In general only the upper 500 feet has been developed, although deeper wells have been completed within the Precambrian (Driscoll et al., 2002). Strobel and Galloway (2000) found that the transmissivity of the Precambrian ranged from 450 to 1,435 square feet per day (ft^2/day). According to Driscoll et al. (2002), "the Precambrian aquifer is mostly unconfined within the center of the Black Hills Uplift, but may have locally confined conditions." In the area of the PAA the Precambrian is several thousand feet below the operating horizons.

6.2.1.1.2 Deadwood Aquifer

Overlying the Precambrian, the Cambrian Deadwood Formation consists of basal conglomerates, sandstone, limestone, and mudstone. The thickness of the Deadwood is between 0 and 500 feet (Driscoll et al., 2002). Rahn (1985) estimated the effective porosity of the aquifer to be 0.05. In the northern Black Hills the effective porosity is presumably lower, in areas where the formation has undergone extensive hydrothermal alteration. The transmissivity of the Deadwood within the region ranges from 250 to 1,000 ft^2/day (Table 2.1, Downey, 1984). Regionally, "the Precambrian rocks act as a lower confining unit to the Deadwood aquifer," although local connection can exist (Williamson and Carter, 2001). Local connection between the Deadwood Aquifer and underlying Precambrian rocks could occur in areas where fracturing and/or weathering has increased the secondary permeability of the basement rocks. It is currently unknown if this type of a connection exists within the project boundary but the contact lies several thousand feet below the operating horizon and is isolated by several fairly impermeable shale formations. The Deadwood aquifer is in contact with the overlying Madison aquifer except where the Whitewood and Winnipeg formations are present (Strobel et al., 1999).

6.2.1.1.3 Madison Aquifer

Within the Black Hills, the Madison Limestone, also known as the Pahasapa Limestone, could be considered the most important aquifer because it is the source of municipal water in numerous communities including Rapid City and Edgemont. The Madison aquifer is mainly a dolomite unit characterized by extensive secondary porosity resulting from fractures and associated karstic features (Williamson and Carter, 2001). The thickness of the Madison ranges from 200 feet in the southern Black Hills to 1,000 feet regionally. In the Rapid City area, Greene (1993) found the transmissivity to vary widely between 1,300 and 56,000 ft^2/day. The aquifer varies from unconfined at its outcrop areas to confined, where reported storativity values range from 10-3 to 10-6 (Table 2.1, Driscoll et al., 2002). Regionally a paleosol and low permeability layers within the overlying Minnelusa Formation act to confine the Madison. The Madison may be in connection with the underlying Deadwood aquifer when the Whitewood and Winnipeg confining units are absent.

6.2.1.1.4 Minnelusa Aquifer

The Minnelusa Formation consists of interbedded siltstone, sandstone, anhydrite, and limestone (SDSM&T, 1963). The Minnelusa aquifer occurs primarily in saturated sandstone and anhydrite beds within the upper part of the formation (Williamson and Carter, 2001). Within the Black Hills, the Minnelusa ranges in thickness from 375 to 1,175 feet (Driscoll et al., 2002). The porosity is dominantly primary porosity within the sandstone beds, although secondary porosity is present in association with fractures and dissolution features (Williamson and Carter, 2001). Various studies have found the transmissivity of the Minnelusa to range from 1 to 12,000 ft^2/day. The Minnelusa aquifer is confined above by the Opeche Shale and below by lower permeability layers at the base of the Minnelusa formation.

6.2.1.1.5 Inyan Kara Aquifer

Away from the central Black Hills, the Inyan Kara is typically the first significant aquifer encountered. The Inyan Kara aquifer is comprised of two (2) sub-aquifers, the Lakota and the Fall River, which are separated by the Fuson shale confining unit. Regionally, the Inyan Kara ranges from 250 to 500 feet. The Inyan Kara is a very heterogeneous formation, which results in the two (2) aquifers exhibiting a large variation in local characteristics. Regionally, the Inyan Kara exhibits a large effective porosity (0.17) and the aquifer can yield considerable water from storage (Driscoll et al., 2002). Within the Black Hills, transmissivity of the Inyan Kara ranges from 1 to 6,000 ft^2/day. This high variability is an indication of the complex heterogeneity of the Inyan Kara formation. The Inyan Kara is confined below by the Morrison Formation (50-100 feet thick) and above by Cretaceous Graneros Group shale.

6.2.1.2 Minor Aquifers

In addition to the major aquifers, minor aquifers around the Black Hills include the Minnekahta Limestone, Sundance/Unkpapa, Newcastle Sandstone, and alluvium. Where present and saturated, these units may yield small amounts of water. Typically, these minor aquifers are not heavily utilized because of more reliable sources in adjacent aquifers.

6.2.1.3 Regional Hydraulic Connection of Aquifers

Because of the geologic variability across the Black Hills, several mechanisms can serve to create hydraulic connection between aquifers. Most interconnection appears to be associated with the thinning or absence of confining units between aquifers, which has been documented in local and regional geologic studies (Miller, 2005). Analyses of regional aquifer tests conducted around the Black Hills provide direct evidence of aquifer interconnection. A few examples are mentioned below:

- Recent pumping tests within the Deadwood aquifer near Jewel Cave indicate that vertical leakage through a confining layer is occurring in that area (Valder, 2006).
- In Rapid City, Rahn (1989) points to different artesian pressures reported in Sioux Park wells, installed into different hydrogeologic units, as evidence that the units are hydraulically separated.
- Studies by Long and Putnam (2002) of paired Madison and Minnelusa wells at the City Quarry site indicate hydraulic connection between these units. The variations in yields between areas indicate that locally the interlaying layers may not provide hydraulic separation between the two units. Both well tests and outcrop observations show the variability of hydraulic connection between the Deadwood, Madison, and Minnelusa aquifers.
- Various sources have also suggested that breccia pipes serve as a path between aquifers. The majority of these features are believed to originate within the Minnelusa Formation and extend upward as high as the Inyan Kara (Gott et al., 1974). These breccia pipes are the result of dissolution of significant thicknesses of anhydrite from the upper Minnelusa and subsequent collapse. The greatest concentration of these breccia pipes has been noted within a few miles of the outcrop, although groups of pipes can be concentrated along joints and may extend as “high in the stratigraphic section as the

Lakota Formation" (Braddock, 1963). The historical and recent drilling activities and pumping tests indicate the breccia pipes are not present within the project area Exhibit 6-1.

6.2.1.4 Regional Potentiometric Surfaces

As part of the Black Hills Hydrology Study, the USGS developed 1:100,000-scale potentiometric maps for five aquifers including the Inyan Kara, Minnekahta, Minnelusa, Madison, and Deadwood. The purpose of these maps is to show the potentiometric surface of the aquifers and be a tool for evaluating groundwater flow directions and hydraulic gradients in the Black Hills area. The potentiometric maps were created by contouring altitudes of water levels completed in their respective aquifers. Structural features such as folds and faults were also considered in the contouring of the potentiometric surfaces. In areas where the potentiometric contours have been inferred (dashed), deviations between the map and actual water levels may occur.

The regional potentiometric surfaces generated by the USGS are provided in Appendix D.

6.2.2 Local Hydrogeology

This section focuses on site hydrogeology in comparison to documented regional values. Regional characteristics of hydrostratigraphic units are presented above; detailed geology is provided in Section 5. Only hydrogeologic units younger than and including the Spearfish Formation (Permo-Triassic age) are described here for two reasons:

1. With the exception of the town of Edgemont, which has two Madison wells, deeper aquifers are not used as a source of water in this area.

2. Federal and State permit guidance requires the assessment focus on the mined unit and hydrogeologic units immediately above and below the proposed mined unit.

6.2.2.1 Local Characteristics of the Hydrostratigraphic Units

The site hydrostratigraphic units are generally consistent with regional units discussed above. However, the recent pumping tests have not indicated any communication with the Unkpapa within the proposed permit area. The reviewer is directed to Section 6.2 of Appendix B for explanation of the conversion from intrinsic permeability units to permeability/hydraulic conductivity units.

6.2.2.2 Breccia Pipes

The USGS Gott report (Gott, 1974) described the location of a number of breccia pipes formed from solution collapse of the underlying evaporative sequences along the flank of the Black Hills uplift. Powertech has reviewed the location of the identified breccia pipes and their origin and offers the following observations and conclusions about the probability of this occurrence.

In reviewing the location of the breccia pipes, the majority of the locations are associated with the Dewey Fault zone that occurs to the north of the Project Area boundary (Exhibit 6-1, Breccia Pipe Map) These breccia pipes are associated with dissolution within the Minnelusa Formation. The Minnelusa Formation in the Southern Black Hills contains thick sequences of evaporites, such as anhydrite and gypsum. These units are believed to form breccia pipes where structural deformation allows migration of dissolving solutions into the evaporite sequence.

The detailed geology mapped throughout the proposed operating areas demonstrates that there are no structural displacements found within the PAA boundary, and the probability of unknown breccia pipes being present within the PAA from the creation of solution caverns is highly unlikely. Without the fracture permeability formed along major fault systems trending downdip from the uplift, it is highly unlikely that

dissolving solutions would penetrate through the evaporative units in such a quantity that caverns would develop.

The large number of exploration drill holes (over 4000) within the PAA without any indication of brecciation lends credence to the hypothesis that no solubilizing solutions penetrated the underlying evaporative strata to such an extent that caverns were created that disrupted the operating zone. If the possibility of brecciation occurred within the PAA, evidence of their presence would be observed in the correlation of the electric logs or from the structure maps based on the Fuson Shale aquitard at the top of the Lakota sequence. See Exhibits 5-7 (Fall River) and 6-2 (Fuson).

Pumping tests performed by Powertech within the initial operating areas, at Dewey and Burdock, show the low permeability character for the Fuson Shale and that it is capable of acting as an aquitard. The three day pumping tests would have readily discovered the presence of a collapse feature or a conduit for fluids within the confining unit. None was shown during Powertech's tests, which again confirms there is no indication of the presence of breccia pipes as a conduit for operating solutions to migrate away from the Aquifer Exemption Boundary and the presence of such is highly unlikely, if not totally disproven.

6.2.2.3 Spearfish Formation Confining Unit

In general, the Spearfish Formation is characterized by a thick sequence (250 to 450 feet) of red siltstone, gypsum, and dolomite. Both the overlying Gypsum Springs Formation and gypsum beds within the Spearfish Formation have been observed in outcrops approximately 5 miles north of the project area. It is assumed that the gypsum beds are present within our project boundary since there are no known faults and/or breccia pipes within our project. However, known drilling has not confirmed this. Based on the few exploration holes that have penetrated the entire thickness of the formation in the Dewey-Burdock area, the Spearfish is an average of 320 feet thick. This thick sequence of shale serves as a hydrologic barrier or confining unit preventing nearly all vertical flow between the Paleozoic aquifers and the Jurassic/Cretaceous aquifers. Within the proposed permit area, one deep oil and gas test was found to penetrate the Minnelusa Formation. This drill hole is located in Section 2 T 7S, R 1E, S1/2, SE. It appears from the electric log that the Spearfish section is comprised dominantly of interbedded shale and siltstone. Any evaporative units within the section would be finely banded as shown by the e-log character, and therefore, not readily dissolved from intralayer ground water migration. However, it is also recognized from the e-log that the basal unit of the Sundance Formation, which lies directly above the Spearfish, consists of a thick (55 foot) shale unit which in addition to the poor vertical permeability of the Spearfish will form a reliable aquitard. This, of course is dependent on the shale unit being continuous throughout the project area.

6.2.2.4 Sundance and Unkpapa Aquifers

Overlying the Spearfish formation, the Sundance and Unkpapa aquifers are considered aquifers of minor importance within the Black Hills. These aquifers are a source of water within the Dewey-Burdock area. The Sundance Formation is composed primarily of shale and sandstone with an average thickness of 280 feet thick near Dewey-Burdock. Where present, the Unkpapa is 50 to 80 feet of well sorted, fine-grained, eolian sandstone. For the purpose of this study, the Sundance and Unkpapa aquifers are considered equivalent, as there is no intervening confining unit separating the two.

6.2.2.5 Morrison Formation Confining Unit

Overlying the Sundance and Unkpapa aquifers is the Morrison Formation. The Morrison is a shale layer approximately 100 feet thick, which serves as an underlying confining unit between the Inyan Kara and the Sundance aquifers (and the Unkpapa where it exists). Analyses of core samples demonstrate that the Morrison clays have extremely low vertical permeabilities, ranging from 0.043 millidarcies to 0.004 millidarcies.

6.2.2.6 Inyan Kara Group

This section addresses **CI–8**.

The Inyan Kara Group is the principal aquifer in the region of the PAA. Locally, the Cretaceous Inyan Kara Group is consistent with its regional characteristics and is composed of two formations the Lakota (Fuson and Chilson members) and Fall River. In general, the Inyan Kara consists of interbedded sandstone, siltstone, and shale. Based on several measured outcrop sections within the Dewey Quadrangle, the Inyan Kara Group averages 350 feet thick. The Fuson member of the Lakota, underlying the Fall River, varies in thickness from 40 to 70 feet. Throughout most of the region, the Fuson is expected to be an effective confining unit. It is possible that, “interaquifer connection shown in the TVA tests were are result of extreme stressing of the aquifer by pumping sufficient water to completely dewater the Inya Kara resulting in temporary fracturing of the aquitard. This test was designed to gather information on the requirements to dewater the Inya Kara for Underground mining. We do not stress aquifers anywhere near this degree as we must maintain a relatively high water level in our wells to operate as opposed to an underground mine that must completely dewater the aquifer. The Inyan Kara is treated in the TVA 1979 reports as one aquifer with the Fall River and Lakota representing sub-aquifers.

Gott and Wolcott, in their U.S. Geological Survey Professional Paper 763 (p. 9), describe the two fluvial units of the Fuson Member (Unit 3 and Unit 4) as follows: "Fluvial unit 4, the youngest rock unit in the Fuson Member, was deposited in channels eroded by north-west flowing streams during partial dissection of the underlying variegated mudstone. The streams in places incised as much as 150 feet below the surface and cut completely through the variegated mudstone and into units 2 and I of the Chilson Member."

While there are distinct sand channels within the Upper Fuson in the Black Hills region (Gott’s Fluvial unit 4), these sands occur as lenticular sand bodies that were deposited only along axes of stream channels. The above description seems to imply that these sands are always present in the Upper Fuson. This is not the case. Throughout most of the Dewey-Burdock Project area, based on geological reviews of the subsurface via 4,000 exploration holes, the Fuson consists entirely of low-permeability clays.

However, as shown in the Fall River and Fuson isopach maps of the project area (Exhibits 5-12 and 5-14), there is channeling within the Fuson Member in the Burdock area. The Fall River isopach shows a 30-foot increase in the thickness of the Fall River Formation along a mile-wide, northwest trending channel system in this area. This increase in sand thickness has been interpreted as the development of a lower Fall River channel system that has scoured into the underlying Fuson Member. This lower Fall River sand could correlate to an upper Fuson sand, but through the use of drill cuttings samples and electric logs, it is impossible to make this differentiation. An examination of the Fuson isopach shows a corresponding 30-foot decrease in the thickness of the Fuson clays in this area. This scouring was recognized by Powertech, but at no point does it penetrate the entire thickness of the Fuson Member. The minimum thickness of the Fuson Member within the Dewey-Burdock Project area is 30-40 feet.

The detailed delineation drilling that is conducted prior to the final well field design would easily identify such cut and fill style channel sands. Channel sand of this type are very often found in a fluvial environment. Potential for communication between the Lakota and the Fall River is one of the reasons that the Inyan Kara is considered as one aquifer. The monitoring of the operations in the vicinity of an overlying or underlying incised channel unit is accomplished via methods described within the monitoring plan for monitoring potentially interconnected sands with minor shale breaks above and below the operating zone.

The Inyan Kara is confined above by the Graneros Group, a thick sequence of dark shale that varies in thickness from zero (0) feet where the Inyan Kara crops out to more than 500 feet thick in the plains, preventing the vertical migration of water between the Inyan Kara and alluvial aquifers.

6.2.2.7 Fluid Pressure of the Receiving Strata

This section addresses **CI–6 (1)**.

The range of the receiving strata formation fluid within the Fall River and Lakota were estimated utilizing water level and elevation of the base of the receiving strata.

The fluid pressure of the receiving aquifer of the Inyan Kara has been broken down for Fall River and Lakota.

Fall River fluid pressure generally varies from approximately 100-630 ft of H_2O across the project area from NE to SW following the hydraulic gradient. This pre-mining fluid pressure is estimated utilizing the elevation at the base of the Fall River and water levels measured within the project area. For potentiometric surface of the Fall River see Figure 2.3, "Potentiometric Surface, Fall River Aquifer, 2008" within the Pump Test Report Appendix B. Near out crop areas the pressure could approach zero.

Lakota fluid pressure generally varies from approximately 150-850 ft of H_2O across the project area from NE to SW following the hydraulic gradient. This pre-mining fluid pressure is estimated utilizing the elevation at the base of the Lakota and water levels measured within the project area. For potentiometric surface of the Lakota see Figure 2.4, "Potentiometric Surface, Lakota Aquifer, 2008" within the Pump Test Report Appendix B. Near out crop areas the pressure could approach zero.

6.2.2.7.1 Hydraulic Connection Description of Receiving Units

This section addresses **CI–8**.

In 2008, Knight Piesold, Powertech's engineering contractor, conducted two 72-hour pump tests on the Dewey-Burdock project. In these tests, a hydraulic stress was applied to a borehole connected to a single, permeable sand, and the distribution of flow induced by that stress monitored in adjacent boreholes. The transient flow responses were compared to type curves computed for several different types of fluid connections. The shape of the transient flow response indicates the type of fluid connection, and the fit of the data to the type curve yields an estimate of its transmissivity and storage coefficient. These pump tests demonstrated that both the Lakota and Fall River Formations behave as single, confined aquifers.

6.2.2.7.1.1 Lakota Formation

One pump test was conducted within the lower Lakota Formation at the proposed initial well field in the Burdock area. Within the lower Lakota formation, the test results indicate a response between pumping and observation wells up to 250 ft apart with 10 to 17 ft of ultimate drawdown starting in 4 to 140 minutes; ultimate response was nearly 3 ft of drawdown at 1,290 ft distance starting at 280 minutes; these results and good matches to type curves indicate the aquifer was sufficiently stressed during the test to produce good quality analytical results, including the following:

- The mean value of transmissivity was determined to be 150 ft^2/day.
- The mean value for storativity was determined to be 1.2×10^{-4}.
- The observation well in the upper Lakota aquifer at 50 feet radial distance and 100 feet upward vertical distance from the pumping well took 160 minutes to first respond and produced a relatively limited 3.4 feet ultimate drawdown.

This test indicates that the lower and upper portions of the Lakota formation behave as a single, confined, leaky aquifer, although the upper and lower portions are not perfectly connected. Within the Lakota formation, vertical hydraulic connection throughout the entire formation is indicated by the delayed and muted response at the upper Lakota observation well. The 160-minute delay in response at the upper

Lakota observation well is attributed to lateral and vertical anisotropy due to the shale interbeds seen on the conceptual stratigraphic cross-sections for the pumping test site

6.2.2.7.1.2 Fall River Formation

A second pump test was conducted within the lower Fall River Formation at the proposed initial well field at the Dewey site. Within the lower Fall River formation, the test results indicates a rapid response (starting in two to three minutes) between pumping and observation wells up to 467 ft apart with 10 to 14 ft of ultimate drawdown; response in the upper Fall River was nearly 9 ft ultimate drawdown at 1,400 ft distance starting within 40 minutes; and response in the lower Fall River was 1.5 ft ultimate drawdown at 2,400 ft distance in starting in 0.6 days; these results and good matches to type curves indicate the aquifer was sufficiently stressed during the test to produce good quality analytical results, including the following:

- The mean value of transmissivity was determined to be 255 ft^2/day.
- The mean value for storativity was determined to be 4.6×10^{-5}.
- A vertical hydraulic connection throughout the entire Fall River formation is indicated by the near instantaneous responses in the lower Fall River production zone wells followed by a delayed response at the upper Fall River observation well. The 11-minute delay in response at the upper observation well is attributed to lateral and vertical anisotropy due to the shale interbeds seen on the conceptual stratigraphic cross-sections for the pumping test site.

This test indicates that the lower and upper sandstone portions of the Fall River formation behave as a single, confined, aquifer with some form of lateral barrier due changing lithology, such as a channel boundary. Apparently, both the Lakota and Fall River formations in the general Dewey project area show barrier boundaries attributable to lithologic changes, suggesting the project ore zone area is a locally thick sedimentary section thinning laterally.

6.2.2.7.2 Production Zone Overlying and Underlying Units

Individual horizons within both the Fall River and the Lakota are interconnected hydrologically due to lateral discontinuity of overlying and underlying confining shale layers co-deposited with the channel sandstones. This was demonstrated by the pumping tests that showed the intercommunication of all units within the formations. However, the company plans on monitoring the overlying and, potentially, the underlying sandstone units in the vicinity of the producing well fields to demonstrate and maintain control of mining solutions and to minimize the assumed volume for required restoration. These monitor wells will be drilled and completed as part of the well field development program after the company conducts its delineation drilling program for well pattern planning. The maximum subsurface control will be available for placing injection and extraction wells directly into the ore bodies after delineation drilling. Once the well field is drilled the perimeter monitor wells and appropriate overlying and underlying monitor wells will be situated to give maximum control information for operations. The actual locations of the wells and intervals opened for observation can only be determined after all well field data has been collected. Refer to Section 6.2.2.5 “Morrison Formation Confining Unit” for more concerning underlying confining unit.

6.2.2.8 Graneros Group Confining Unit

The Graneros Group is composed of several geologic formations including the Skull Creek, Newcastle, Mowry, and Belle Fourche. The group acts as a single unit that confines the Inyan Kara aquifer. The Skull Creek and Mowry are overlying in the project area, however, the Newcastle is missing and the Belle Fourche crops out to the west. The Skull Creek is truncated by erosion due to the Black Hills uplift to the east and the thickness increases westward from zero (0) where the Fall River outcrops to more than 500 feet thick at the Wyoming Border. Within the project area the Skull Creek Shale has an average thickness of approximately 200 feet and is the upper confining unit for the Project. Core samples were collected from the lower Skull Creek shale; analyses of these core samples demonstrate that the Skull

Creek clays have extremely low vertical permeabilities, in the range of 6.8 x 10^{-9} cm/sec (0.007 millidarcies).

6.2.2.9 Alluvial Aquifers

For the purpose of this report, the alluvial aquifers in the vicinity of the Dewey-Burdock Site consist of any saturated alluvial material along Pass Creek, Beaver Creek, and the Cheyenne River. In general, the thickness of the alluvial material varies from zero (0) to 25 feet, although it can reach 40 feet. Based on water level measurements in five alluvial piezometers, the upper 10 to 15 feet of the alluvium is unsaturated. The alluvial material is typically unconfined although localized areas of confinement may exist where weathered shale and other material has slumped on top of the alluvium.

6.2.3 Relevance of Historical Studies to the Dewey-Burdock Project

6.2.3.1 Groundwater Velocity Evaluation

In a 1974 U.S. Geological Survey Professional Paper No.763, Gott Wolcott and Bowles (Gott, et al., 1974) presented detailed results and interpretations related to the stratigraphy and uranium mineralization of the Inyan Kara Group within and near the proposed Dewey-Burdock project area. Gott, et al., utilized measured tritium concentrations obtained from Inyan Kara groundwater well samples to support their interpretation that the Inyan Kara aquifer is recharged through collapse structure and breccia pipe hydrogeologic connections with the underlying Minnelusa Formation. Groundwater samples were obtained during 1965, and although some samples were obtained as far as 4 miles down-dip from the Inyan Kara outcrop particularly in the area near Burdock, tritium concentrations in groundwater were consistent with tritium concentrations in the atmosphere. Because the tritium levels in the tested water wells displayed concentrations consistent with the atmosphere, Gott, et al., hypothesized that groundwater recharge and groundwater velocity was rapid enough to transport atmospheric tritium from the location in which meteoric precipitation entered into geologic formations to the screened intervals of the tested groundwater wells. In this study it was concluded that Inyan Kara groundwater velocity in the area of Burdock is approximately 15 feet/day.

Powertech has collected extensive amounts of data related to the Inyan Kara aquifer and other adjacent aquifers to the Inyan Kara in the Burdock area. Site specific data and analysis have led Powertech to conclusions different from the interpretations presented in Gott, et al., report. Although the Gott, et al., report presents a thorough and comprehensive set of groundwater geochemical data, the presented interpretations related to Inyan Kara aquifer recharge and groundwater velocity are not verified by Burdock site specific geologic and hydrogeologic investigations conducted by Powertech.

6.2.3.2 Exploration Drilling

Extensive exploration conducted by companies such as Kerr- McGee, Westinghouse, Tennessee Valley Authority from 1963 to 1981 and then again by Powertech from 2007-2008 drilling resulted in an excess of 4,000 boreholes that were advanced and logged by aforementioned exploration companies in and around the Burdock area. Powertech has compiled and utilized this data to construct a more defined structural and stratigraphic framework of the subsurface geology present at Burdock. Tritium based calculations of Inyan Kara groundwater velocity in the Burdock area presented in the Gott, et al., report are predicated on a hypothetical hydrogeologic connection, and thus groundwater recharge of the Inyan Kara aquifer, from underlying aquifers such as the Minnelusa Formation via vertical collapse structure and breccia pipe flow pathways. The recent and historical exploration drilling conducted in the area by Powertech and other companies has not led to the identification of any such structural features (refer to Section 6.2.2.2 – Breccia Pipes).

6.2.3.3 Groundwater Levels

Groundwater wells have been constructed into underlying aquifers at the Dewey-Burdock project area, and water levels have been monitored by Powertech. Groundwater wells at both Dewey and Burdock are completed within the Inyan Kara Group aquifers as well as the underlying Unkpapa Formation aquifer. Throughout the entire project area, including the same area studied by Gott, et al, the groundwater potentiometric surface elevation of the Unkpapa aquifer is 65 feet (Burdock) to 79 feet (Dewey) higher than that of the Inyan Kara aquifer. If such a hydrogeologic connection existed between the Inyan Kara aquifer and other underlying aquifers, such as the Minnelusa, as suggested in the 1974 Gott, et al., report, the potentiometric surface of the Inyan Kara aquifer would be consistent with the Unkpapa aquifer, particularly in the area near Burdock. The inconsistent potentiometric surface elevations directly refute the interpretations of the 1974 Gott report.

6.2.3.3.1 Groundwater Monitoring & Pump Test Results

This section also addresses **CI–8**.

Powertech has conducted two separate aquifer pumping tests of Inyan Kara Group subaquifers at both the Dewey and Burdock areas. Aquifer pumping tests were conducted in the Lakota Formation at Burdock and the Fall River Formation at Dewey. For the purposes of this section, the Lakota aquifer properties at Burdock will be utilized to evaluate Inyan Kara groundwater velocity at Burdock, and compare the results with conclusions presented in the 1974 Gott, et al., report.

Based on aquifer parameters determined through pumping tests and groundwater level monitoring of observation wells, an accurate estimate of Inyan Kara groundwater flow velocity can be calculated using Darcy's Law of groundwater flow through a porous media. The effective porosity of the Inyan Kara aquifer is rather large as evidenced by its ability to produce large volumes of water from storage (Driscoll and others, 2002), and for the purposes of this velocity estimate is assumed to be 17%. Below is the calculation of Inyan Kara groundwater velocity and the average linear groundwater velocity, using empirically derived aquifer parameters from site specific aquifer testing and monitoring at Burdock.

Darcy Velocity = (Hydraulic Conductivity) x (Hydraulic Gradient)
Darcy Velocity = (15 ft/day) x (0.0026965 ft/ft)*
Darcy Velocity = 0.0404475 ft/day
Average Linear Groundwater Velocity = (Darcy Velocity) / (Effective Porosity)
Average Linear Groundwater Velocity = (0.0404475 ft/day) / (0.17)
Average Linear Groundwater Velocity = 0.2379 ft/day

*Hydraulic Gradient derived from Burdock water well level measurements.

During aquifer pumping tests conducted by Powertech at the Dewey and Burdock areas, water level monitoring of the underlying Unkpapa aquifer took place concurrently with pumping. During pumping of the Inyan Kara subaquifers there was no response observed in the Unkpapa aquifer. This is an important observation because it further demonstrates that there are no hydraulic communicative pathways between the Inyan Kara and other underlying aquifers at the pumping test locations.

6.2.3.4 Summary

Data collected and analyzed by Powertech adequately demonstrates that Inyan Kara groundwater flow velocity near Burdock, South Dakota is far less than that suggested in past published documents by Gott, et al., in 1974 as well as Bowles, et al., in 1980. The geochemical evidence presented in published documents is comprehensive, but the groundwater aquifer physical characteristics and calculations presented by Powertech in this section, as well as in the DENR UIC section on Dewey-Burdock aquifer pumping tests, is a more reliable indication of Inyan Kara groundwater flow within the proposed project area. Powertech has collected extensive site-specific geologic and hydrogeologic data using state-of-the-

art techniques and analyses in the Dewey-Burdock project area that calls into question the suggested findings presented in the 1974 Gott, et al., report.

Section 7.0 - Well Installation and Maintenance

7.1 Well Drilling Features for Operation

This section addresses the essential well drilling features for injection, recovery, and monitor wells.

7.1.1 Well Construction Materials

This section addresses **CI–5**.

Well casing material will typically be thermoplastic such as polyvinyl chloride (PVC) with SDR 17 wall thickness. Table 7.1-1 below depicts the range of casing sized that could be used at PAA with the corresponding drill hole size to ensure annular sealing.

Table 7.1-1 Range of PVC Specifications

Casing	I.D.	O.D.	Bit Size
4.5”	4.454	4.950	7-7/8
5.0”	5.047	5.563	8-3/4
6.0”	6.065	6.625	9-7/8

The annular seal will be pressure-grouted and sealed with either neat cement grout or bentonite grout. Cement grout will be composed of high sulfate resistant Portland cement using adequate cement to yield a slurry weight of approximately 11 pounds per gallon. Water used to make the cement grout will not contain oil or other organic material. Cement grout could contain adequate bentonite to maintain the cement in suspension in accordance with Halliburton cement tables. Bentonite grout will be composed of commercially manufactured sodium bentonite material specifically formulated for well casings. Bentonite grout will be mixed according to manufacturer’s recommendations and will contain a minimum of 20 percent solids by weight and have a minimum slurry density of 9.4 pounds per gallon.

Casing will be joined by fittings or using methods recommended by the casing manufacture. PVC casing joints approximately 20 feet apart will be connected with glue or bonded with PVC cement and self-tapping screws, or will be joined mechanically (with pipe threads or a water tight o-ring seal with a high strength nylon spline) to ensure watertight joints above the perforations or screens. Casings and annular material will be maintained throughout the operating life of the wells.

7.1.1.1 Well Completion

This section addresses **CI–4 (21) and CI–11**.

All injection, production, and monitoring wells will be strictly constructed by Powertech or its contractors in accordance with ARSD outlined in 74:02:04. Test holes will be abandoned, or in some cases converted to water wells immediately following data collection. Another well conversion scenario that may take place would be if Powertech converted a monitoring well or a pumping test well into a production of injection well during well field design or during operations. Water wells may be plugged and abandoned due to an end in their use, mechanical failure, or problems encountered during drilling activities. All test holes and water wells will be plugged and abandoned in strict accordance to ARSD outlined in 74:02:04:67, 74:02:04:69, or 74:02:04:70, as applicable, in a manner that will not allow the movement of fluids either into or between water bearing strata, including underground sources of drinking water.

Typical well completion schematics for injection, production and monitor wells are depicted in Figures 7.1-1, 7.1-2 and 7.1-3, respectively.

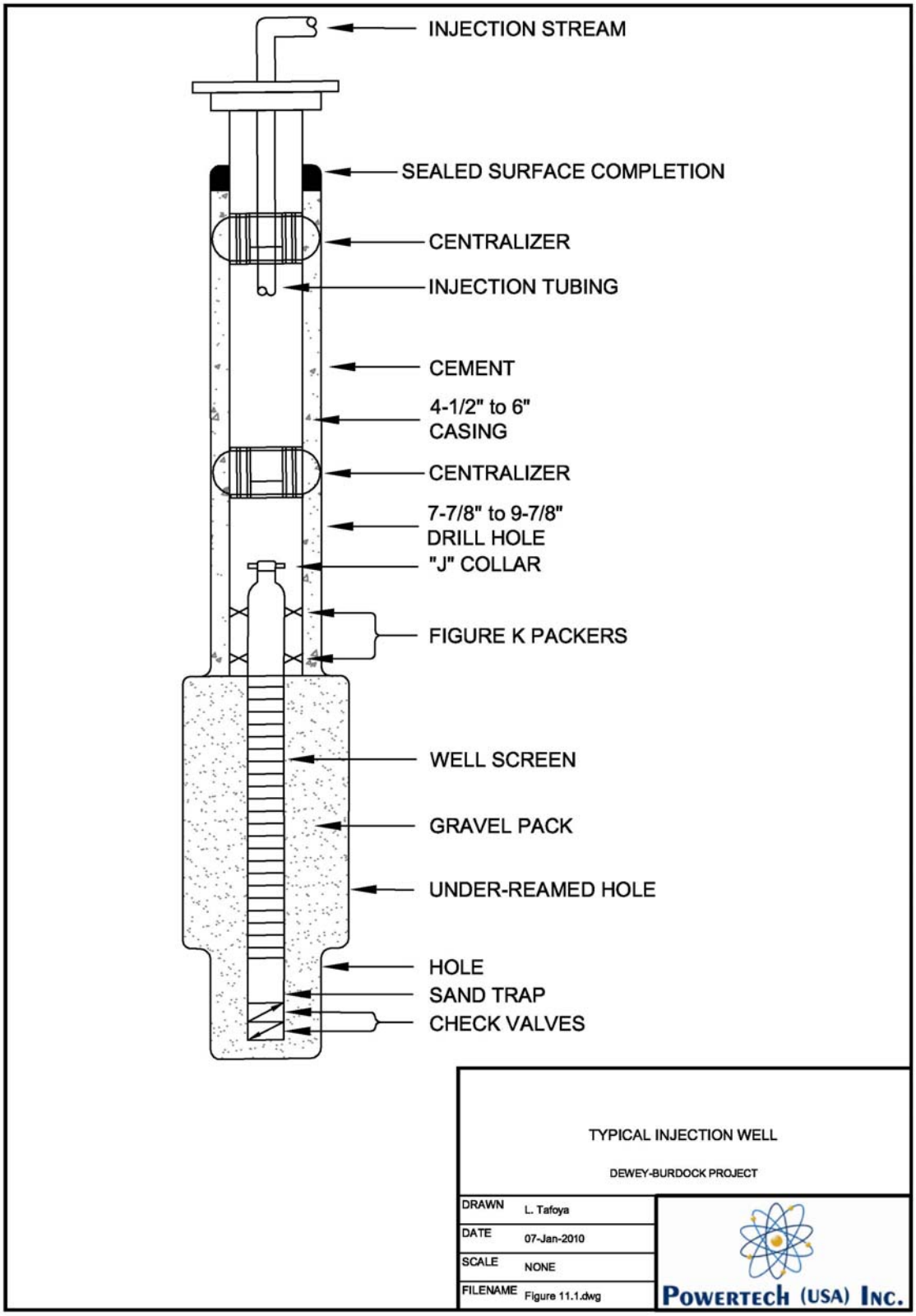

Figure 7.1-1 Diagram of a Typical Injection Well

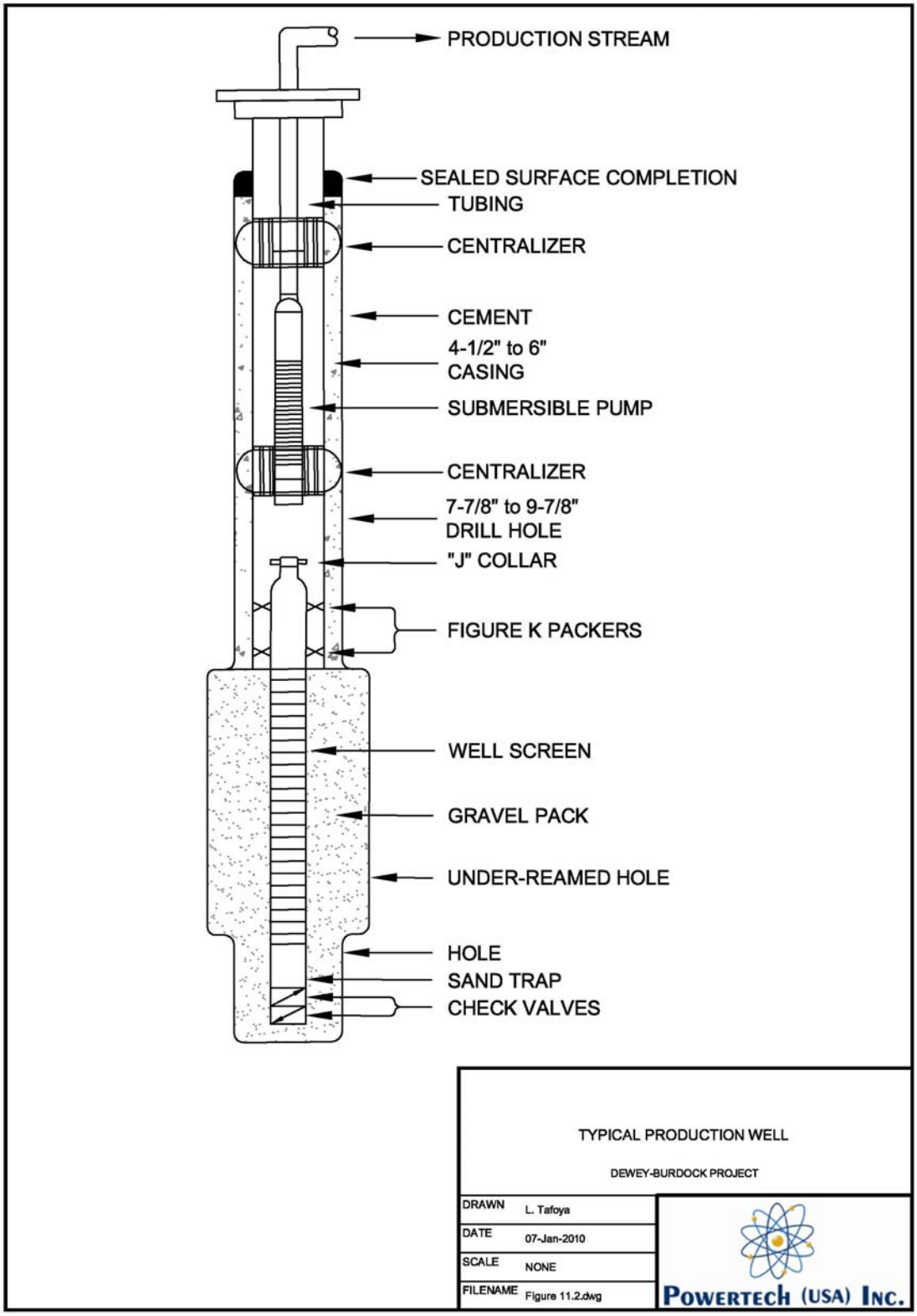

Figure 7.1-2 Diagram of a Typical Production Well

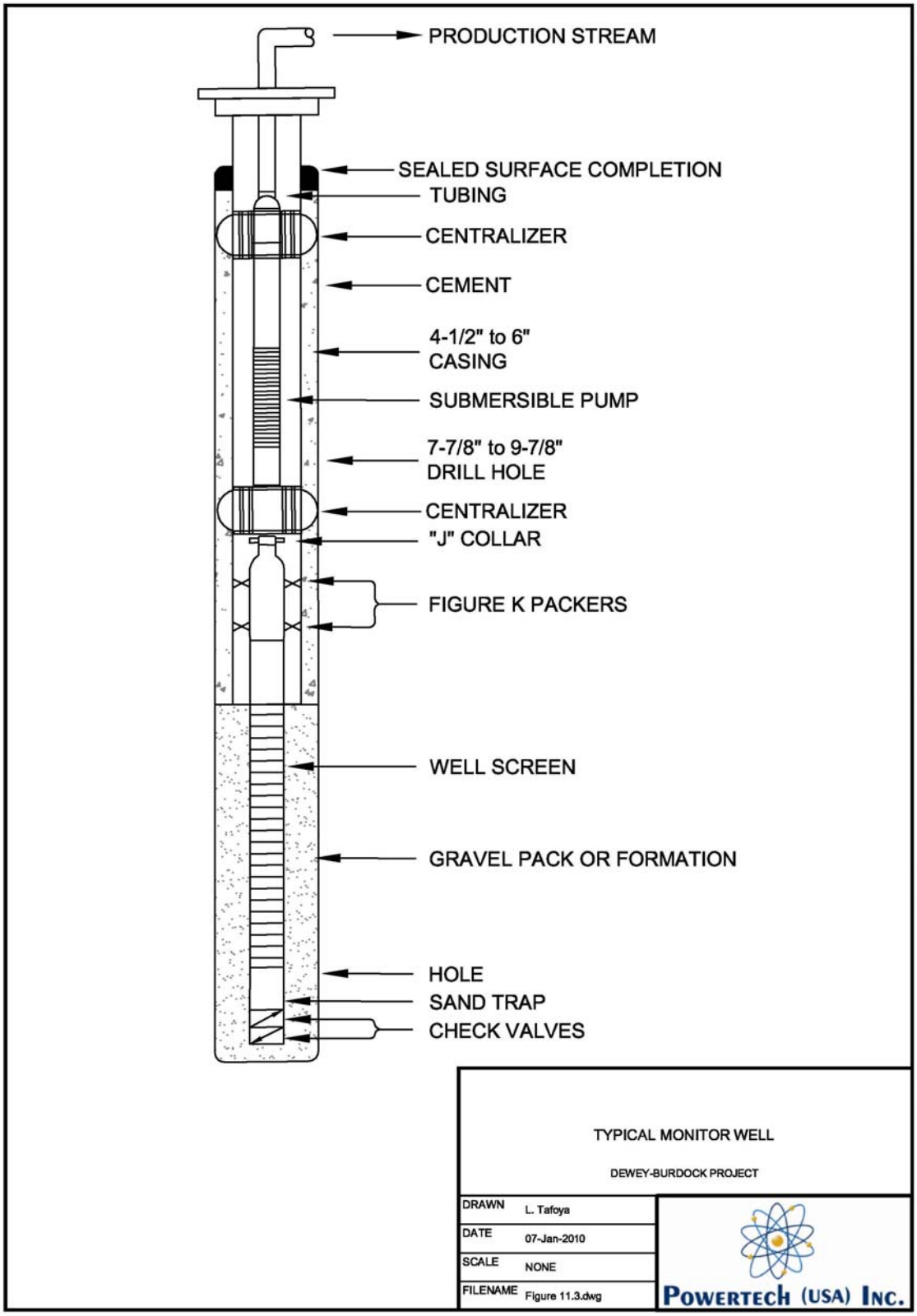

Figure 7.1-3 Diagram of a Typical Monitoring Well

Injection, production and monitoring wells will first be drilled as pilot holes (less than full diameter) to the bottom of the target completion interval with a truck mounted rotary drilling unit using bentonite or polymer drilling mud with pH adjusted water and mixed to control the viscosity as recommended by the drilling supervisor. Each hole will be logged to precisely determine the ore interval and to determine the characteristics of the sand unit. To complete the well, the hole will be reamed to full diameter to just above the ore zone, reamed and the casing will be set and cemented to isolate the completion interval from all other aquifers. The reamed drill holes shall be of sufficient diameter for adequate sealing and, at least two inches greater in nominal diameter than the outside diameter of the outer casing at that depth. The two inches is protects equivalent with regards to ARSD 74:55:01:31:

- Mechanical integrity testing (MIT)
- Cementing to surface – exceeds construction standards
- Cementing records
- Use of centralizers for stabilization; also provides uniform annulus

Best Management Practices – According to the NRC's historical data review attached as a Memorandum dated July 10, 2009, subject: STAFF ASSESSMENT OF GROUNDWATER IMPACTS FROM PREVIOUSLY LICENSED IN-SITU URANIUM RECOVERY FACILITIES - "The data indicate that excursions have been controlled by the pumping and injection processes" (Appendix C-1; USNRC 2009).

Cement or other approved sealing materials will be used to stabilize and strengthen the casing and the annulus of the well so as to prevent vertical migration of solutions to unauthorized zones. Effective sealing materials will consist of cement grout or bentonite clay mixtures as described above. Cement will be placed by pumping it down the casing and displacing the cement with water forcing the cement out the bottom of the casing and back up the casing drill hole annulus. The cementing material will be circulated up the annulus, until return of uncut cementing agent is visible at the surface. The volume of cement used in each well will be determined by estimating the volume required to fill the annulus and ensure cement returns to the surface. However, drilling could result in a larger annulus volume than anticipated and cement may not return all the way to the surface. In these cases the upper portion of the annulus will be cemented from the surface to backfill as much of the well annulus as possible and stabilize the wellhead. With experience at the location the percent excess cement to ensure returns to the surface can be closely estimated.

After the well is cemented to the surface and the cement has set, the well will be drilled out and completed with a screen assembly (screen liner), which may have a gravel pack installed between the screen and the under-reamed formation as shown on the well completion schematics (see Figures 7.1-1, 7.1-2 and 7.1-3). The well will then be surged with water or washed with the stinger pipe or another accepted development technique will be used to remove any remaining drilling mud and/or cuttings until well fluids are clear and to fully develop the flow capacity of the well. A submersible pump may be run in the well for final clean-up and sampling. If sand production or hole stability problems are anticipated, a slotted liner, wire wrapped screen or similar device may be installed across the completion interval to minimize the problem.

7.1.1.2 Additional Construction Requirements

Ore grade Gamma log, self potential and single point resistivity electric logs will be run in the pilot holes which will be drilled prior to reaming the hole to final diameter to run casing. These logs will determine the location and grade of uranium and the sand and clay units' depths to properly plan each pattern.

7.1.1.3 Well Development

The primary goals of well development are to allow formation water to enter the well screen and flush out drilling mud, or cement filtrate water and to develop the well bore to remove the finer clays and silts to

reduce the pressure drop between the formation and the well screen. This process is necessary to allow representative samples of groundwater to be collected, if applicable, and to ensure efficient injection and recovery operations. Wells will be developed immediately after construction using air lifting, swabbing, pumping or other accepted development techniques which will remove water and drilling fluids from the casing and borehole walls along the screened interval. Prior to obtaining baseline samples from monitor or restoration wells, additional well development will be conducted to ensure that representative formation water is sampled. The water will be pumped sufficiently to show stabilization of pH and conductivity values prior to sampling and used to indicate that development activities have been effective.

A stimulation program is not currently being proposed for the PA injection wells. Well development, which will include swabbing, will be used to improve well yield by enhancing hydraulic pressure between the undisturbed aquifer and the well and by reducing well bore damage by use of improved well completion techniques.

7.1.1.4 Mechanical Integrity Testing

This section addresses **CI–4 (21)**.

Field testing of all injection, production, and monitoring wells will be performed to demonstrate the mechanical integrity of the well casing. An initial pressure test will be performed on each cased well after cementing and before the cement is drilled out of the casing. The casing should be full of water when the cement head is removed indicating a good cement job.

After drilling out the cement, under-reaming and completing, the well will be re-tested. The MIT will be performed using pressure packer tests. The bottom of the casing will be sealed with a plug, down-hole packer, or other suitable device. The casing will be filled with water and the top of the casing will be sealed with a treaded cap or mechanical seal. The well casing will then be pressurized with water or air and monitored with a pressure gauge. Internal casing pressure will be increased to 125 percent of the maximum operating pressure of the well field (which is always less that the maximum pressure rating of the pipe). A well must maintain 90 percent of this pressure (which equates to approximately 1 pounds per square inch per foot [psi/ft] of overburden above the bottom of casing), whichever is less for a minimum of 10 minutes to pass the MIT test.

At least once every five (5) years during the life of each well, a demonstration of mechanical integrity will be conducted. In addition, a MIT will be conducted on a well prior to plugging and abandonment.
If there are obvious leaks, or the pressure drops by more than 10 percent during the 10 minute period, the seals and fittings on the packer system will be checked and/or reset and another test will be conducted. If the pressure drops less than 10 percent, the well casing will have demonstrated acceptable mechanical integrity.

7.1.1.5 Loss of Mechanical Integrity

Failure of a well casing to meet the MIT criteria will result in the casing being repaired and re-tested. A well will be used for its intended purpose provided it passes the MIT. A well defect occurring at depth may result in the well being plugged back and recompleted for use in a shallower zone provided it passes the MIT. DENR will be notified of any well that fails the MIT. If a repaired well passes the MIT, it will be employed in its intended service following approval from the EPA and/or DENR that the well has demonstrated mechanical integrity. A well that cannot pass the MIT after repairs will be plugged and abandoned in the manner discussed in the Plugging and Abandonment Plan.

7.1.1.6 Injection Pressure Limitation

During well field operations, pressure at the injection well heads will not exceed the maximum MIT pressure. Injection wells will only be used for injection purposes if they demonstrate mechanical integrity.

Injection pressure at the wellhead will be calculated to ensure that the pressure in the production zone does not initiate fractures. Accordingly, maximum estimated injection pressures will be approximately 125 pounds per square inch (psi) at the header houses located in deepest ore areas. Notwithstanding this restriction, the maximum injection operating wellhead pressures shall not exceed 90 percent of the production zone fracture pressure calculated or 95 percent of the American Society for Testing Materials (ASTM) maximum recommended operating pressure at 75 degrees Fahrenheit for the well casing, whichever is lesser.

According to the EPA Maximum Injection Pressure (MIP) is defined as: The term "maximum injection pressure" generally refers to the maximum permitted injection pressure, that is, the maximum value of injection pressure at which an operator can inject into an injection well. Title 40 of the Code of Federal Regulations (40 CFR) Section 146.13(a)(1) requires that the MIP in Class I and Class III wells be set so as to assure that, except during stimulation, "the pressure in the injection zone during injection does not initiate new fractures or propagate existing fractures in the injection zone. In no case shall injection pressure initiate fractures in the confining zone ...."

7.2 Drill Cuttings Disposal Plan

7.2.1 Drill Cuttings Plan

This section addresses **CI–4 (19)**.

Powertech will dispose of and bury drill cuttings in a pit at the well site, such as the mud pit used to circulate drilling fluids once the drilling operation has been completed. The following rules outlined in ARSD 74:29:11:15, disposal of drill cuttings, will be met:

- The drill cuttings are generated from the well at the well site;
- The drill cuttings are not contaminated with brines, oil, production fluids, or drilling fluids other than top-hole water or fresh water;
- The pit is backfilled with topsoil replaced, and the site is graded to promote runoff with no depression that would accumulate or pond water on the surface. The stability of the backfilled pit shall be compatible with the adjacent land;
- The surface of the backfilled pit area is re-vegetated in accordance with the approved reclamation plan to stabilize the soil surface;
- For wells into uranium ore deposits, the surface of the backfilled drill cutting pit will not exceed the following limits:
  - The concentration of radium-226 or radium-228 in soil may not exceed the background level by more than 5 picocuries per gram (pCi/g) or 0.185 becquerels per gram (Bq/g), averaged over the first 15 centimeters (cm) of soil below the surface; and
  - The concentration of natural uranium in soil, with no radioactive decay products present may not exceed the background level by more than 300 pCi/g or 1.11 Bq/g, averaged over the top 15 cm of soil below the surface; and 150 pCi/g or 5.55 Bq/g, average concentration at depths greater than 15 cm below the surface, so that no individual member of the public will receive an effective dose equivalent in excess of 0.1 rem per year or 1 millisievert (mSv) per year.

7.3 Well Plugging and Abandonment – Existing and Historical

7.3.1 Wells and/or Holes Improperly Plugged

This section addresses **CI–4 (17)**.

It is Powertech's determination that improperly plugged wells or holes do not presently exist within the proposed production area. With that stated, the DENR recognizes the determination may not be possible for all wells and holes within the proposed production area until additional pump tests are conducted. However, based upon field work to date this determination pertains to identified wells and is submitted in compliance with SD DENR 74:55:01:26 (17).

The majority of exploration holes at Dewey Burdock were drilled in 1970 and 1980. The state of South Dakota had plugging rules in effect at the time these holes were drilled and plugged and the holes were plugged according to the state's requirements.

It is not always possible by observation in the field to determine whether a former well was properly plugged. Example, it is not uncommon for a historical drilling site to have holes and/or wells recorded in file, yet not observed in the field due to anthropogenic influences and weather events through the years or recording errors. Data available through state record or wells listed within documentation in Powertech's possession has been thoroughly evaluated in the field. Information obtained by Powertech suggests that historic drill holes within the proposed production area were abandoned using either abandonment bentonite, drilling mud or a combination of bentonite and drilling mud. In addition, it is well documented that most abandoned drill holes that are completed with drilling muds, swell shut in a few days due to natural clay swelling and formation weight. However, if improperly abandoned drill holes are detected during well field installation (e.g., communication is detected during a pump test), Powertech will plug the drill holes in accordance with the procedures outlined in Section 7.4 of this application. Appendix E summarizes the available information for historic drill holes within the AOR.

Exploration holes and abandoned wells are identified within Figures 4.2-1 and 4.2-2 respectively. Wells that will be monitored for potential corrective action are depicted on Figure 4.2-3.

7.4 Existing and Historical Wells

7.4.1 Well Re-Plugging and Abandonment Plan

No Re-plugging plan is submitted at this time due to aforementioned determination (ARSD 74:55:01:26 (17)). Over 5,800 exploration drill holes are known to have been drilled and abandoned within the one mile perimeter around the PAA prior to acquisition of the property by Powertech in 2005. If at any time during pumping tests or field observation, Powertech becomes aware of a well or hole that would require proper plugging and abandonment within the project area that may possibly interfere with operations, Powertech will plug the well or hole according to plugging requirements of SD DENR (ARSD 74:11:08).

7.5 Well Maintenance

This section addresses **CI–4 (16) (a) and (b)**.

7.5.1 Well Maintenance for Surface Completion and Monitoring Equipment

7.5.1.1 Subsequent Mechanical Integrity Testing

In addition to the initial testing after well construction, a MIT will be conducted on wells after any repair where a downhole drill bit or under-reaming tool is used. Injection wells that exhibit potential subsurface damage will pass a new MIT prior to being returned to service. All wells used for injection of lixiviant, or injection of fluids for restoration operations will be subjected to a MIT at least once every five years.

7.5.1.2 Reporting

MIT documentation will include the well designation, test date, test duration, beginning and ending pressures, and the signature of the individual responsible for conducting each test. Results of each MIT will be available for inspection by the EPA and SD DENR. MIT results will be reported on a quarterly basis

to EPA and SD DENR. A well completion report will be completed for each well. These reports will be made available for review by the EPA and the SD DENR.

7.5.1.3 Well Covers

This section addresses **CI–4 (16) (a)**.

Groundwater wells will be strictly constructed by Powertech or its contractors in accordance with ARSD 74:02:04. All injection, production, and groundwater monitoring well heads will be sealed with a water tight flange fitted with a gasket to protect against undesirable material entering into the well. Wells will be constructed to have a locking and tamper resistant cover over the well head. In addition, all well covers will be insulated in order to insure fluids within exposed pipes and at the well heads underneath the covers do not freeze under extreme cold weather conditions.

7.5.1.4 Wells Visibly Marked

This section addresses **CI–4 (16) (b)**.

Groundwater wells will be strictly constructed by Powertech or its contractors in accordance with ARSD 74:02:04 (Well Construction Standards). Each injection, production, and monitoring groundwater well will be clearly labeled in two separate locations. A stainless steel band will be permanently imprinted on the upper portion of the water well casing. In addition, each water well head cover will be labeled with its respective identification code using highly visible labels. The water well cover identification code will be maintained on a regular basis to insure the identification code is legible at all times. All water well head covers will be colored in such a way that they are highly visible during every season and every shade of ground cover to individuals working in the well fields. All groundwater well heads will be surveyed in using a GPS survey instrument capable of sub meter accuracy in the x-y-z coordinate system. All groundwater well survey data will be submitted to the appropriate regulatory authorities and maintained in an on-site database.

7.5.1.5 Maintenance and Servicing of Area and Equipment

Good housekeeping surrounding wells will be incorporated into the daily inspections of well fields. Areas will be kept clear of brush, tall grass and debris to insure minimizing the potential for accidents such as running into a well head with a motor vehicle. Well monitoring equipment is housed within header houses. Well field workers will inspect well monitoring equipment daily and ensure it is operating properly; workers will also maintain good housekeeping practices in and around the header houses.

7.6 Operator Wells and Holes

7.6.1 Plugging and Abandonment Plan

This discussion pertains to plugging plans for injection, recovery, monitor wells and exploration holes.

7.6.1.1 Pre-operational Plugging and Abandonment

As of August 2008, Powertech has drilled, plugged and abandoned 94 verification drill holes within the AOR. Well and hole data consist of known existing water wells, producing wells, injection wells, abandoned wells, and exploration holes, giving location, depth, producing intervals, type of use, condition of casing, plugging procedures and date of completion for each well or drill hole within the permit area and on adjacent lands to the extent such information is available in public records and from a reasonable inspection of the property. (Refer to Figures: 4.2-1, 4.2-2, 4.2-3 and Appendices E “Abandoned Wells” and F “Groundwater Wells”).

The following Table 7.6-1 summarizes Powertech's plugging and abandonment activities and addresses **CI–4 (7)**. Some wells currently utilized for monitoring are also listed.

Exploration Holes drilled by Powertech were plugged according to ARSD 74:02:04:67:

> "with bentonite grout if the weight of the bentonite grout column is sufficient to overcome the bottom hole pressure or must be plugged with cement grout placed from the bottom of the well or hole to within eight feet of the ground surface. Cement grout must be placed from eight feet below ground surface to within three feet of the ground surface. The top three feet may be filled with native material. If a pipe cannot be lowered inside the well casing to place grout from the bottom to the top, the well may be plugged by making a tight connection to the top of the casing and pumping a volume of cement grout, sufficient to fill the well, under pressure into the well. "

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Table 7.6-1 Powertech Drill Holes Plugged and Abandoned within the One Mile Perimeter around the PAA

Powertech Drill Hole Number	RESPEC Drill Hole Number	SD State Plane 1983 Easting Surveyor	SD State Plane 1983 Northing Surveyor	Section-Township-Range	Starting Date Drilled	Date Logged	Total Depth Driller	Total Depth Logger	Date Plugged
DB 07-1-1		1039398.5	433963.91	1-7S-1E	7/8/2007	7/8/2007	430	424	7/8/2007
DB 07-1-2		1039352.5	433841.27	1-7S-1E	7/10/2007	7/10/2007	470	467	7/10/2007
DB 07-1-3		1039274	433796	1-7S-1E	7/11/2007	7/11/2007	450	454	7/16/2007
DB 07-1-4		1038963.9	433190.41	1-7S-1E	7/16/2007	7/16/2007	460	444	7/17/2007
DB 07-1-5		1038849	433279.54	1-7S-1E	7/18/2007	7/18/2007	380	379	7/18/2007
DB 08-6-1	3026	1043742	433344.21	1-7S-1E	3/24/2008	3/24/2008	250	244	NA
DB 08-1-7	703	1042271.3	434136.81	1-7S-1E	4/14/2008	4/18/2008	575	575	NA
DB 08-2-1	698	1035918.6	436952.4	2-7S-1E	3/21/2008	3/21/2008	247	246	NA
DB 07-3-1		1031018	434086	3-7S-1E	11/28/2007	11/29/2007	660	642	11/29/2007
DB 07-3-2		1031080	434187	3-7S-1E	11/30/2007	12/3/2007	680	659	12/3/2007
DB 07-3-3		1031113	434264	3-7S-1E	12/10/2007	12/12/2007	635	632	12/13/2007
DB 07-3-4		1031478	435151	3 7S-1E	12/16/2007	12/19/2007	650	649	12/19/2007
DB 08-3-5		1031714.7	434958.77	3-7S-1E	1/7/2008	1/11/2008	670	666	1/11/2008
DB 08-3-6		1031701.3	434957.77	3-7S-1E	4/2/2008	4/4/2008	620	615	4/4/2008
DB 08-3-7		1031629.1	435017.7	3-7S-1E	4/4/2008	4/5/2008	610	552	4/5/2008
DB 08-3-8		1031577.2	435089.64	3-7S-1E	4/6/2008	4/7/2008	610	609	4/7/2008
DB 08-5-1	704	1020684.4	437010.11	5-7S-1E	4/16/2008	4/1/2008	990	990	NA
DB 07-10-1		1031778.4	428440.23	10-7S-1E	5/9/2007	5/9/2007	677	570	5/10/2007
DB 07-10-2		1031772.2	428533.73	10-7S-1E	5/11/2007	5/11/2007	560	556	5/12/2007
DB 07-10-3		1031777.3	428616.61	10-7S-1E	5/12/2007	5/12/2007	570	565	5/12/2007
DB 07-10-4		1032055.1	430989.9	10-7S-1E	5/26/2007	6/6/2007	624	624	6/6/2007
DB 07-10-5		1031788.4	428852.24	10-7S-1E	5/13/2007	5/14/2007	580	579	5/16/2007
DB 07-10-6		1031964	430913	10-7S-1E	5/15/2007	5/16/2007	610	607	5/16/2007
DB 07-10-7		1031880.4	430912.46	10-7S-1E	5/21/2007	5/24/2007	604	615	5/24/2007
DB 07-10-8		1031804.2	430907.7	10-7S-1E	5/24/2007	6/7/2007	620	499	6/7/2007
DB 07-10-9		1032767	430777.24	10-7S-1E	5/14/2005	5/15/2007	600	600	5/15/2007
DB 07-10-10		1032775.7	430908.59	10-7S-1E	5/13/2007	5/14/2007	620	617	5/14/2007
DB 07-10-11		1032783.5	431036.95	10-7S-1E	5/12/2007	5/12/2007	552	552	5/12/2007
DB 07-10-12		1031491.3	432153.73	10-7S-1E	6/7/2007	6/9/2007	600	595	6/9/2007
DB 07-10-13		1031589.9	432147.37	10-7S-1E	6/11/2007	6/12/2007	620	617	6/12/2007
DB 07-10-14		1031679.3	432148.5	10-7S-1E	6/9/2007	6/10/2007	620		6/10/2007
DB 07-10-15		1031786.1	432141.79	10-7S-1E	6/18/2007	6/19/2007	630	620	6/19/2007
DB 07-10-17		1031437.9	432686.08	10-7S-1E	6/19/2007	6/20/2007	660	663	6/20/2007
DB 07-10-19		1031531.7	432687.02	10-7S-1E	6/24/2007	6/25/2007	670	630	6/25/2007
DB 07-10-20		1031583.8	432679.66	10-7S-1E	6/22/2007	6/23/2007	660	628	6/24/2007
DB 07-10-21		1031633.3	432680.53	10-7S-1E	7/6/2007	7/7/2007	670	624	7/7/2007
DB 07-10-22		1031683.4	432678.33	10-7S-1E	6/21/2007	6/22/2007	660	654	6/22/2007
DB 07-10-23		1031935.5	429714.24	10-7S-1E	6/5/2007	6/6/2007	604	559	6/6/2007
DB 07-10-24		1031836	429768.27	10-7S-1E	6/7/2007	6/8/2007	630	630	6/8/2007
DB 07-10-25		1031759.8	429814.18	10-7S-1E	6/9/2007	6/10/2007	630	623	6/10/2007

Table 7.6-1 Powertech Drill Holes Plugged and Abandoned within the One Mile Perimeter around the PAA (concl.)

Powertech Drill Hole Number	RESPEC Drill Hole Number	SD State Plane 1983 Easting Surveyor	SD State Plane 1983 Northing Surveyor	Section-Township-Range	Starting Date Drilled	Date Logged	Total Depth Driller	Total Depth Logger	Date Plugged
DB 07-10-26		1031665.4	429865.96	10-7S-1E	6/10/2007	6/11/2007	630	616	6/11/2007
DB 07-10-27		1032769.1	430843.01	10-7S-1E	5/28/2007	5/30/2007	620	619	5/30/2007
DB 07-10-28		1032051.7	430071.93	10-7S-1E	6/12/2007	6/13/2007	620	621	6/13/2007
DB 07-10-40		1031920.5	432883.75	10-7S-1E	6/25/2007	6/26/2007	670	665	6/27/2007
DB 07-10-41		1031966	432960.8	10-7S-1E	10/6/2007	10/7/2007	675	674	11/7/2007
DB 07-10-42		1032004.3	433026	10-7S-1E	7/10/2007	7/11/2007	675	673	7/11/2007
DB 07-10-43		1032044.2	433094.17	10-7S-1E	7/5/2007	7/6/2007	675	654	7/6/2007
DB 07-11-1		1035258	431256.77	11-7S-1E	5/24/2007	5/25/2007	593	585	5/25/2007
DB 07-11-2	682	1035138.1	431266.07	11-7S-1E	5/23/2007	5/24/2007	592	585	5/23/2007
DB 07-11-3		1035023.4	431277.18	11-7S-1E	5/21/2007	5/22/2007	590	590	6/22/2007
DB 07-11-4C		1035074.6	429984.9	11-7S-1E	6/18/2007	6/22/2007	575	557	5/29/2007
DB 07-11-5		1034857.3	431899.58	11-7S-1E	5/28/2007	5/29/2007	620	615	5/27/2007
DB 07-11-6		1034981.9	431895.13	11-7S-1E	5/26/2007	5/27/2007	634	624	5/26/2007
DB 07-11-7		1035116.8	431891.25	11-7S-1E	5/25/2007	5/26/2007	600	592	5/30/2007
DB 07-11-8		1035612.3	432704.57	11-7S-1E	5/29/2007	5/30/2007	650	628	6/5/2007
DB 07-11-9		1035718.2	432695.88	11-7S-1E	6/4/2007	6/5/2007	630	592	6/7/2007
DB 07-11-10		1035836.1	432692.74	11-7S-1E	6/6/2007	6/7/2007	610	607	5/25/2007
DB 07-11-11C	680	1035077.2	429975.67	11-7S-1E	10/8/2007	10/10/2007	450	449	NA
DB 07-11-12		1037708.8	430209.15	11-7S-1E	10/16/2007	10/17/2007	445	446	10/17/2007
DB 07-11-13		1037715.7	430384.16	11-7S-1E	10/17/2007	10/18/2007	455	456	10/19/2007
DB 07-11-14C	684	1035190	429752.86	11-7S-1E	10/30/2007	11/2/2007	458	452	NA
DB 07-11-15	686	1034969.4	429757.45	11-7S-1E	11/3/2007	11/4/2007	495	490	NA
DB 07-11-16C P&A		1035126.4	429971.49	11-7S-1E	11/12/2007	11/17/2007	710	701	11/18/2007
DB 08-11-17	688	1035038.3	429982.44	11-7S-1E	3/25/2008	3/25/2008	270	268	NA

Baseline Wells
Pump Test Wells
Water Wells
Handheld GPS

Powertech applied for two variances and received approvable, to the states required plugging. On non flowing holes, bentonite grout was pumped from the bottom of the hole to surface displacing the drilling mud out of the hole. After the plugging gel set up the remaining open hole was filled with plugging chips to the surface.

Flowing holes were plugged with cement grout from the bottom of the hole to the surface. After the cement had set, the remaining hole was filled with plugging chips to the surface. If an unplugged exploration hole is observed, the hole will be washed out and plugged according to 74:02:04:67.

A Natural Resource Project Engineer of the SD DENR Waste Management Division was on-site and witnessed the plugging of Powertech's exploration holes. Continue reading in the following section for a more detailed discussion on plugging and abandonment

7.6.1.2 Operational Plugging and Abandonment Plan

The plan addresses the plugging and abandonment of wells in a manner which will prevent movement of fluids through the well, out of the injection zone either into or between USDWs or to the land surface.

Key topics covered in the proposed Plugging and Abandonment Plan includes the following:

- Method of placement of the plugs
- Procedure used to plug and abandon each well
- Type, number, and placement (including elevation of the top and bottom) of plugs to be used
- Type, and quantity of plugging material to be used
- Information demonstrating that a well within the AOR that underlies or is in an exempted aquifer provides adequate protection of USDWs

Prior to plugging, each well will undergo MIT to demonstrate the integrity of casing and cement that will be left in the ground after closure. Alternatively, cementing records will be used to show that an adequate quantity of cement is present to prevent upward fluid movement within the borehole outside of the casing. If it cannot be verified that a well casing is grouted properly, an effort will be made to plug the annulus from the bottom of the annulus to the ground surface, using the same materials required for plugging the inside of the casing as described below.

Wells will be opened and debris and downhole equipment such as the tubing and pumps will be removed to prevent obstacles from interfering with plugging operations. The wellhead and casing will be removed to 3 feet below ground surface. A tremie pipe will be used to add grout to wells that are more than 40 feet deep.

Injection, production and monitoring wells that are completed into a confined or unconfined aquifer or multiple aquifers will be plugged with bentonite grout provided the weight of the bentonite grout column will be sufficient to overcome the bottom hole pressure. If bentonite grout will not be sufficient, cement grout will be placed from the bottom of the well to within 8 feet of the ground surface. Cement grout will be placed from 8 feet below ground surface to within 3 feet of the ground surface. The top 3 feet of the well will be backfilled with native material and reclaimed. If a tremie pipe cannot be lowered inside the well-casing for grout placement, a tight connection will be made to the top of the casing in order to pump a sufficient volume of cement grout down to fill the well under pressure. Bentonite grout will not be used if the tight connection method is used. Figure 7.6-1 shows a generalized schematic of a plugged and abandoned well completed into a confined or unconfined aquifer or multiple aquifers.

Bentonite grout, composed of commercially manufactured sodium bentonite material specifically formulated for well casings, will be mixed according to manufacturer's recommendations and will contain a minimum of 20 percent solids by weight and have a minimum slurry density if 9.4 pounds per gallon. Cement plugs will consist of cement grout prepared in the same manner as used for well construction. Specifically, cement grout will be composed of Portland cement and mixed with appropriate amounts of bentonite and accelerator in accordance with Halliburton cementing tables to yield a minimum slurry weight of approximately 11 pounds per gallon. Water used to make the cement grout will not contain oil or other organic material.

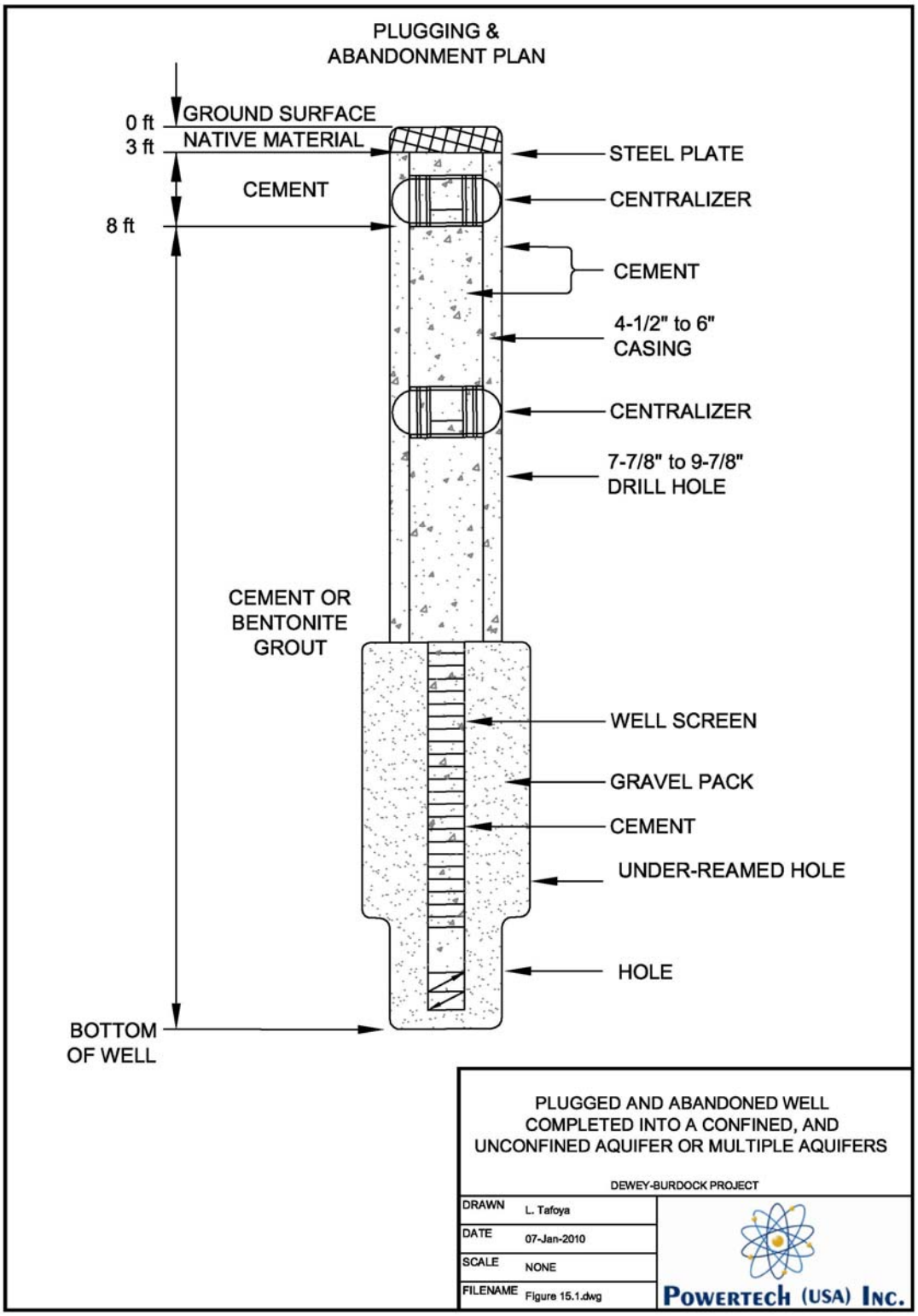

Figure 7.6-1 Plugged and Abandoned Well Completed into a Confined, and Unconfined Aquifer or Multiple Aquifers

A steel plate will be placed on top of the sealing mixture with the permit number, date of plugging and well identification number clearly displayed. The tag will be affixed to the top of the plug at a minimum depth of 2 feet below ground surface. The locations of the abandoned wells will be identified by recording the boundaries of each well field and the location of the monitor well ring around each well field as a deed notice with the appropriate county.

Wells in which water is not encountered or only low-permeability formations such as clays, shales, or till are encountered will be backfilled with material free of contamination. In order to restore the natural conditions as much as possible, the fill will have a permeability less than or equal to the permeability of the formations encountered. The wells will be backfilled with bentonite or cement.

The EPA will be notified according to conditions in 40 CFR §144.51 and the SD DENR will be notified based on conditions in ARSD 74:55.

7.6.1.3 Plugging and Abandonment Report

According to EPA 144.51(p) and ARSD 74:29:11:44 the operator is to notify the agencies within 60 days after plugging or at the time of the next quarterly report (whichever is less), a Plugging and Abandonment Report will be submitted to the EPA. The person that performs the plugging operation will certify the report as accurate. The report will contain either:

- A statement that the well was plugged in accordance with the approved Plugging and Abandonment Plan, or
- If the actual plugging differed from the Plugging and Abandonment Plan, a statement specifying the different procedures followed will be submitted.

Documentation will be provided to verify that the quantity of sealing material placed in the well is at least equal to the volume of the empty hole.

The Plugging and Abandonment Reports will be retained for at least 3 years from the date of the submission unless the EPA requests an extension. If requested, at the conclusion of the retention period, the reports will be delivered to the EPA.

7.6.2 Well Data

Appendix F contains all known available well data from public records or from the company's field investigations and communications with local land owners, including:

- Well type
- Ownership information
- Construction data
- Location (latitude/longitude)
- Total depth
- Completion formation
- Date drilled
- Condition of cementing
- Source of completion or plugging and abandonment information
- Additional information related to any tendency or characteristic that many cause or prevent a breach in the confining zone

Figure 4.2-2 illustrates wells that have been plugged and abandoned within 1 mile of the proposed permit boundary.

7.6.3 Necessary Resources

Table 7.6-2 provides a breakdown of the costs for plugging and abandoning the injection, extraction and monitor wells associated with the first well field planned for production in the Burdock area. The cost estimate is based on a total of 377 wells and includes a cost per well line item. The plugging costs are based on the diameter of wells, a nominal 5 inches, and the depth, approximately 600 feet, and the number of wells.

Table 7.6-2 Well Plugging and Abandonment Cost Estimate

Unit cost per well (assume average depth of 650 feet)			
Materials			
5" diameter casing =		0.136	Cubic ft/ft
Average well depth =		650	ft
Cubic ft per well =		88.4	CF
Cement grout cost =		9.00	$/cubic ft
Cement grout cost/well		795.60	$/well
Equipment and Labor			
Contractor crew and equipment - estimated at $125/hour			
Mobilization/Demob ($11,000 over 377 wells)		30.00	$/well
Well plugging		375.00	
Demolition of well heads and backfill		95.00	
Equipment and Labor cost/well		500	$/well
Total abandonment cost/well =		1,300	$/well
1st Well Field			
Monitoring wells #wells =	140	182,000	$
Production and Injection wells #wells =	237	308,100	$
Total Estimated Well Abandonment		490,000	$

Following review and approval of the plugging and abandonment cost estimate, a surety instrument acceptable to EPA (40 CFR Part 144.52) and SD DENR (ARSD 74:55:01:25) will be submitted to the EPA to assure the required plugging and abandonment activities will be completed to safeguard potential USDWs.

The proposed action is potentially subject to multiple surety requirements. In addition to SD DENR, the EPA and the NRC have surety requirements that must be satisfied. The applicant will submit one surety instrument for well plugging and the agencies must agree who is the lead agency responsible. The suggestion of the applicant is that the SD DENR will be the lead agency with the EPA and the NRC

negotiating a Memorandum of Understanding with the SD DENR to consolidate the surety requirements with the SD DENR. The NRC allows the licensee the following options:

Financial surety arrangements generally acceptable to the Commission are:

- Surety bonds
- Cash deposits
- Certificates of deposits
- Deposits of government securities
- Irrevocable letters or lines of credit
- Combinations of the above or such other types of arrangements as may be approved by the Commission. However, self insurance, or any arrangement which essentially constitutes self insurance (e.g., a contract with a State or Federal agency), will not satisfy the surety requirement since this provides no additional assurance other than that which already exists through license requirements. (10 CFR Part 40, Appendix A, Criterion 9)

The State of South Dakota provides similar options. (SD Mined Land Reclamation Act, Chapter 45-6B-21 through 24) The State of South Dakota is willing to consider surety arrangements with federal agencies. "The board [Minerals and Environment] shall also consider any surety or cash bond for the proposed mining operation required by an agency of the federal government which surety is required for reclamation purposes." (45-6B-21)

Considering the potential for multiple bond requirements by two federal agencies and one state agency, Powertech is unable to commit to a specific surety instrument at this time. However, upon approval of the UIC Class III Permit, or shortly thereafter, Powertech will provide the approved surety, or evidence thereof (as allowed by 40 CFR Part 144.65), to the EPA.

Section 8.0 - Climate Description

8.1 Climatic Data

The proposed project is located in an area in southwestern South Dakota that can be characterized as a semiarid or steppe climate. It lies adjacent to the southwestern extension of the Black Hills. The area experiences abundant sunshine, low relative humidity, and sustained winds which lead to high evaporative demand. There are also large diurnal and annual variations in temperature.

Precipitation in the PAA is generally light. Migratory storm systems that originate in the Pacific Ocean release a majority of their moisture over the Rocky or Cascade Mountains. Major precipitation events can occur when these systems regain moisture already present in the area or moisture advected from the Gulf of Mexico. Localized summer convective storms, caused by the Black Hills, can produce heavy precipitation events.

To complete the site specific analysis, a weather station was installed in coordination with the South Dakota State Climatology office at approximately the center of the PAA in July 2007. This site collects temperature, humidity, solar radiation, wind speed/direction, barometric pressure, and precipitation at 1-minute, 5-minute, and hourly time steps. To determine whether this period of data collection (July 18, 2007, to July 17, 2008) was representative of long-term meteorological conditions, weather data from the nearest National Weather Service (NWS) site at Chadron, Nebraska, for the same period was compared to data collected at the site from years 1978–2007.

The data compiled from several sites (listed and shown in Appendix G) surrounding the PAA from the High Plains Regional Climate Center (HPRCC) and South Dakota State University (SDSU) was used to represent the long-term meteorological conditions of the Proposed Action region. All the sites were used to characterize regional trends of temperature and precipitation along with growing, heating, and cooling degree days. Only the SDSU sites had sufficient data available to analyze regional patterns of humidity, and only the Oral, South Dakota, site had adequate data to characterize wind speed/direction and evapotranspiration.

Data were analyzed at each site by time of day, month, and season of the year. The seasons for this analysis are defined as: winter (December, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November). Refer to Appendix G for details concerning regional and site specific climatic data.

Section 9.0 - Site Monitoring Program

9.1 Introduction

The following information details the baseline groundwater quality sampling program for the PA and the proposed monitoring program for individual well fields in accordance with 74:55:01:26(10) where applicable. ARSD 74:54:01:04 was consulted during preparation of this application. For additional radiological water quality sampling and results information see Section 12.1.9.

TVA sponsored a groundwater sampling investigation within the Burdock area, in support of a Draft Environmental Statement (DES) in order to quantify groundwater quality within the Edgemont Uranium Mining Project area. The investigation was conducted over the one year period of November 1976 through November of 1977. The groundwater data represents the Fall River and Lakota Formations that form the Inyan Kara Group. In summary of the investigation, a brief discussion is provided in support of current groundwater quality data.

9.1.1 Summary of Investigation

The TVA groundwater investigation observed the water from Fall River and Lakota intermixed within some of the wells, thus representing a composite sample of the two formations. Dissolved solids averaged 1,000 milligrams per liter (mg/L) and rated very hard; principle cations for both formations of the Burdock area were observed to be calcium and sodium; principle anions were sulfate and bicarbonates. Concentrations of dissolved solids, sulfates, iron and manganese exceeded the EPA secondary water quality standards. Lead exceeded the EPA standard (1,600 g/L) in one non-flowing well.

9.2 Groundwater Quality

This section addresses **CI - 3 of 6** and has been written in accordance with ARSD 74:54:01:04.

Powertech conducted a general groundwater quality baseline sampling program. Upon receiving all required licenses and permits, well field specific groundwater baseline studies will be performed as part of well field design and development. This section presents water quality information obtained during the baseline characterization study required pre-licensing. Also, presented is the proposed site monitoring plan post licensing.

Groundwater quality for non ore-bearing sand lenses within the Inyan Kara are not mapable at this level of study and therefore is beyond the scope of a Class III application. However, all well field specific data will be presented within a well field package to the SD DENR and the NRC for approval. The well field package will contain among other information, water quality baseline data, geologic and hydrologic data within the dimensions outlined for each specific well field.

9.2.1 Groundwater Quality Baseline for the Propose Action Area

The groundwater characterization study was conducted for the PAA in 2008. The groundwater sampling program is summarized in the Baseline Sampling Plan (Respec, 2008a). To support the Baseline Sampling Plan, a Quality Assurance Project Plan (QAPP) has been implemented following the guidance provided by the U.S. Environmental Protection Agency (USEPA, 2002b and 2006) (Respec, 2008b) and the U.S. Nuclear Regulatory Commission (NUREG 1569, June 2003).

For the baseline groundwater study, 19 groundwater wells (14 existing and 5 newly drilled) were selected as a representative sampling group for the area (Figure 9.2-1). Initial baseline sampling of these wells was conducted quarterly from July 2007 through June 2008. Also as required by the SD DENR (rule

ARSD 74:29), an additional 12 wells were sampled monthly beginning in March 2008 and continued to be sampled through February 2009 (Figure 9.2-2).

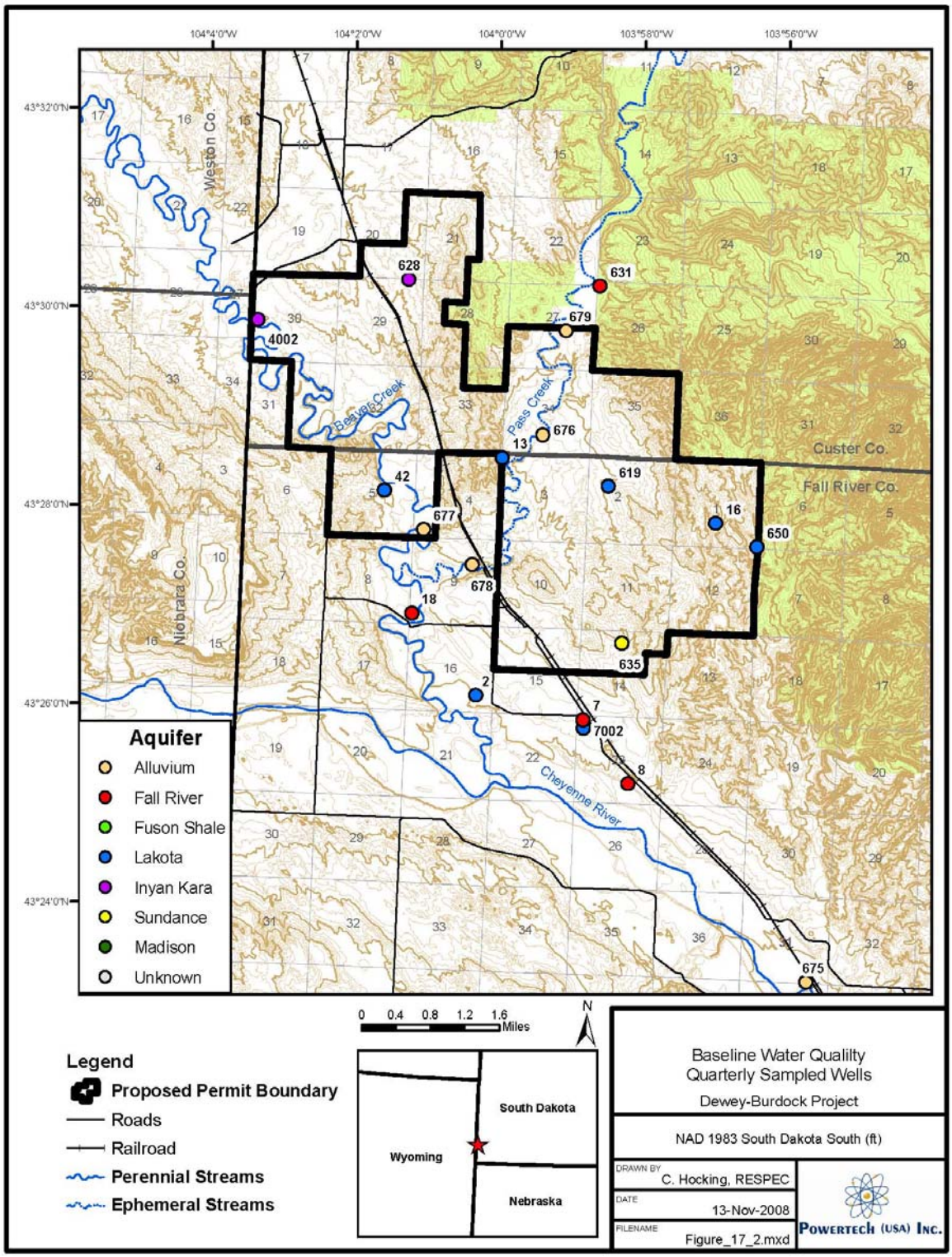

Figure 9.2-1 Baseline Water Quality Quarterly Sampled Wells

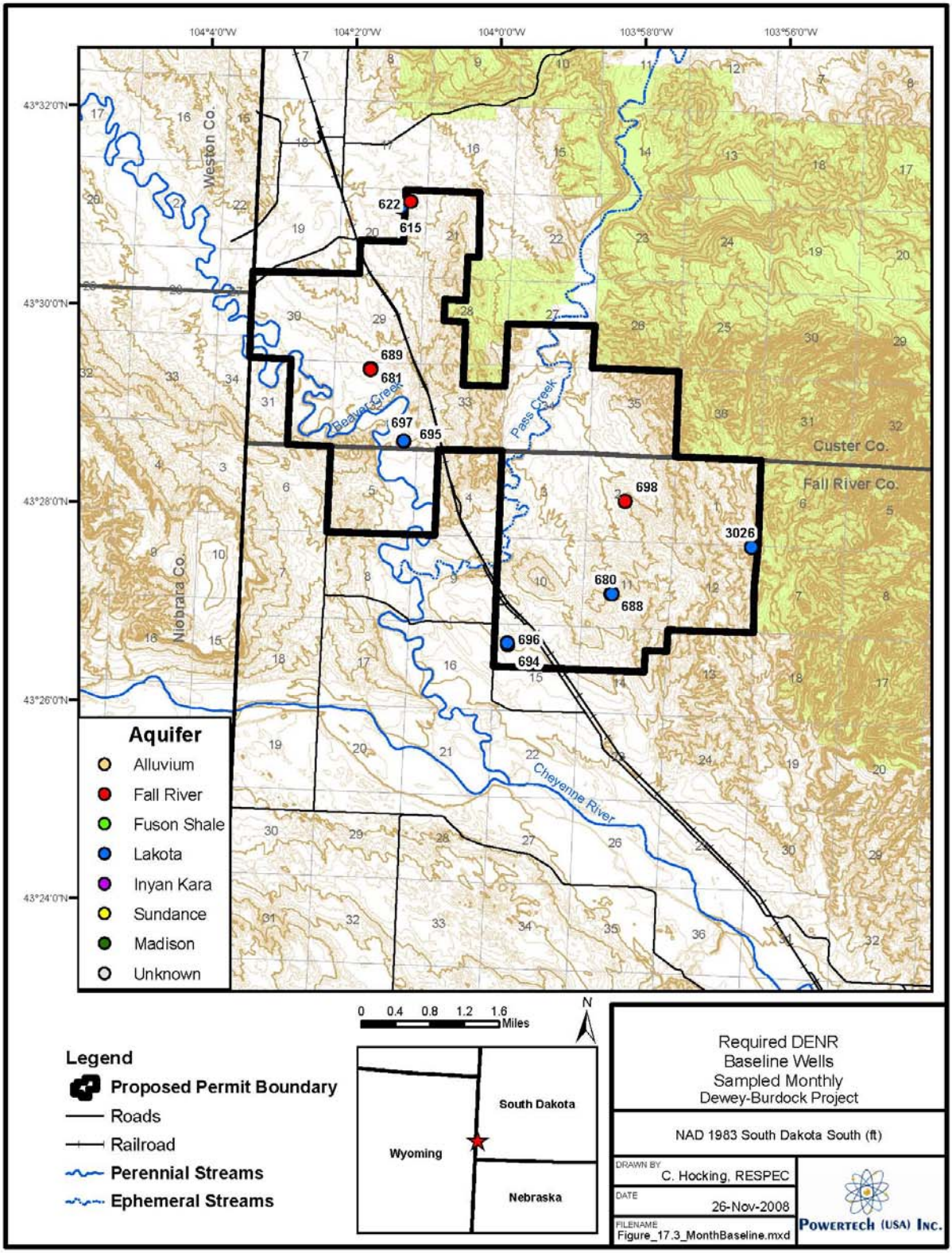

Figure 9.2-2 Baseline Water Quality Monthly Sampled Wells

Table 9.2-1 contains the water quality parameters analyzed for the groundwater sampling program. Please refer to Table 9.2-2, Water Quality Regulatory Limits for the EPA associated with key baseline water quality parameters. The analytical methods utilized and minimum detection limits (MDLs) are consistent with the MDLs provided by Region 8 EPA (Table 9.2-2). Table 9.2-3 provides the water quality parameters and methods used for analyses.

Table 9.2-1 Powertech Baseline Water Quality Monitoring Parameters

Test Analyte/Parameter	Units	PQL	Method
BULK PROPERTIES			
pH	pH Units	0.01	A4500-H B
Total Dissolved Solids (TDS)	mg/L	5	A1030 E1, A2540 C*
Conductivity	µmhos/cm	5	A2510B
CATIONS/ANIONS			
Calcium	mg/L	0.5-1.0	E200.7
Chloride	mg/L	12	E300.0
Fluoride	mg/L	0.1	E300.0
Magnesium	mg/L	0.5	E200.7
Oxygen reduction potential	mV		A2580B
Potassium	mg/L	0.5	E200.7
Sodium	mg/L	8-0.8	E200.7
Sulfate	mg/L	5	E300.0
Total Alkalinity (as CaCO3)	mg/L	5	A2320 B
Bicarbonate Alkalinity (as CaCO3)	mg/L	5	A2320 B (as HCO3)
Carbonate Alkalinity (as CaCO3)	mg/L	5	A2320 B
Nitrogen (Ammonia as N)	mg/L	0.1	A4500-NH3 G
Nitrate, NO3- (as Nitrogen)	mg/L	0.1	E300.0
Nitrite, NO2- (as Nitrogen)	mg/L	0.1	E300.0
Anion/Cation Balance			A1030 E
TRACE METALS			
Antimony, Sb	mg/L	0.003	E200.8
Aluminum, Al	mg/L	0.1	E200.8
Arsenic, As	mg/L	0.001	E200.8
Barium, Ba	mg/L	0.1	E200.8
Beryllium, Be	mg/L	0.001	E200.7, E200.8
Boron, B	mg/L	0.1	E200.7
Cadmium, Cd	mg/L	0.0053	E200.8
Chromium, Cr	mg/L	0.05	E200.8
Copper, Cu	mg/L	0.01	E200.8
Iron, Fe	mg/L	0.03	E200.7
Lead, Pb	mg/L	0.001	E200.8

Table 9.2-1 Powertech Baseline Water Quality Monitoring Parameters (concl.)

Test Analyte/Parameter	Units	PQL	Method
Manganese, Mn	mg/L	0.01	E200.8
Mercury, Hg	mg/L	0.0014	E200.8
Molybdenum, Mo	mg/L	0.1	E200.8
Nickel, Ni	mg/L	0.05	E200.8
Selenium, Se	mg/L	0.001	E200.8, A3114 B5
Silica	mg/L	0.5	E200.7
Silver, Ag	mg/L	0.0056	E200.8
Sodium Adsorption Ratio	unitless	0.1	Calculation
Strontium, Sr	mg/L	0.02	E200.7, E200.8
Thallium, Tl	mg/L	0.002	E200.8
Uranium, U	mg/L	0.0003	E200.8
Vanadium	mg/L	0.1	E200.7, E200.8
Zinc, Zn	mg/L	0.01	E200.8
RADIONUCLIDES			
Gross Alpha=Alpha Particles	pCi/L	1.0	E900.0
Gross Beta=Beta Particles and Photons	mRem/Year	2.0	E900.0
Gross Gamma	pCi/L	20	E901.1
Radium-226	pCi/L	0.2	E903.0
Lead-210	pCi/L	1.0	E909.0M
Polonium-210	pCi/L	1.0	RMO 3008
Thorium-230	pCi/L	0.2	E907.0
Thorium-232	pCi/L	0.0057	E200.8
Radon-222	pCi/L	100	D5072-92

Notes: PQL - Practical Quantitation Limit

* TDS & 180 C and TDS Balance (0.80 - 1.20)

1 A1030 E Method does not reference a PQL

2 Samples from 09/28/07 DewBurdGW 677 had a PQL of 8 mg/L

3 Samples from 09/26/07 DewBurd GW 18,02,08,631 had a PQL of 0.01

4 Samples from 09/26/07-09/28/07 list a PQL for T-Hg of 0.001 and D-Hg of 0.0002

5 Selenium IV and VI - PQL of 0.0010

6 Samples from 9/26/07 DewBurd GW 18,02,08,631 had a PQL of 0.01

7 Samples from 9/26/07 DewBurd GW 18,02,08,631 had a PQL of 0.001

Table 9.2-2 Total Metals, EPA Testing Methods and Permit Limits Identified by Region 8 EPA

Constituent	Regulatory Limit (mg/L)	Standard Type	Applicable EPA Methods	Minimum Detection Limit (mg/L)
Antimony	0.006	MCL	200.8, 200.9	0.003
Arsenic	0.01	MCL	200.7, 200.8, 200.9	0.005
Barium	2	MCL	200.7, 200.8	1
Beryllium	0.004	MCL	200.7, 200.8, 200.9	0.002
Boron	1.4	HA-Lifetime	200.7, 212.3	0.7
Cadmium	0.005	MCL	200.7, 200.8, 200.9	0.0025
Chromium (Total)	0.1	MCL	200.7, 200.8, 200.9	0.05
Copper	1.3	MCL-TT	200.7, 200.8, 200.9	0.65
Iron	5	Region 8 Permit Limit	200.7, 200.9	2.5
Lead	0.015	MCL-TT	200.8, 200.9	0.0075
Manganese	0.8	Region 8 Permit Limit	200.7, 200.8, 200.9	0.4
Mercury (Inorganic)	0.002	MCL	245.1, 245.2, 200.8	0.001
Molybdenum	0.04	HA-Lifetime	200.7, 246.1, 246.2	0.02
Nickel	0.1	HA-Lifetime	200.7, 200.8, 200.9	0.05
Selenium	0.05	MCL	200.8, 200.9	0.025
Silver	0.1	HA-Lifetime	200.7, 200.8, 200.9	0.05
Strontium	4	HA-Lifetime	272.1, 272.2, 200.7	2
Thallium	0.002	MCL	200.8, 200.9	0.001
Uranium	0.03	MCL	200.8, 908.0, 908.1	0.015
Zinc	2	HA-Lifetime	200.7, 200.8	1

Notes:
MCL = Maximum Contaminant Level
HA-Lifetime = Health Advisory-Lifetime
MCL-TT = Action level which if exceeded triggers treatment
Region 8 = Region 8 Permit Limit

Table 9.2-3 Baseline Water Quality Parameters and Indicators for Groundwater

Test Analyte/Parameter	Units	Method
BULK PROPERTIES		
pH	pH Units	A4500-H B
Total Dissolved Solids (TDS)	mg/L	A1030 E1, A2540 C
Conductivity	µmhos/cm	A2510B
CATIONS/ANIONS		
Chloride	mg/L	E300.0
Sulfate	mg/L	E300.0
Total Alkalinity (as $CaCO_3$)	mg/L	A2320 B
TRACE METALS		
Arsenic, As	mg/L	E200.8
Iron, Fe	mg/L	E200.7
Lead, Pb	mg/L	E200.8
Manganese, Mn	mg/L	E200.8
Strontium	mg/L	E200.8
Uranium, U	mg/L	E200.8
Vanadium	mg/L	E200.7, E200.8
RADIONUCLIDES		
Gross Alpha=Alpha Particles	pCi/L	E900.0
Gross Beta=Beta Particles and Photons	mRem/Year	E900.0
Radium-226	pCi/L	E903.0
Radon-222	pCi/L	D5072-92

Four drinking water wells were present that had been completed into the Lakota within the Permit boundary (Exhibit 4-1) prior to implementation of the baseline groundwater sampling program for the PA. One of these wells is located within the AEB (Exhibit 4-1). Powertech has replaced the Lakota water well located within the AEB with wells completed in the Unkpapa for the Daniel Ranch. The Daniel Ranch drinking water well (16), shown on Exhibit 4-1, was completed into the Lakota and in close proximity to the ore body at the Burdock site. Since the beginning of October 2006, water samples have been collected and submitted to Energy Laboratories Inc. for analysis. Table 9.2-4 summarizes the analytical results for total dissolved solids (TDS), total sulfate, and total chloride; from wells sampled on a quarterly basis; Table 9.2-5 presents the same analytical results from wells sampled on a monthly basis. Sample results were compared to EPA National Primary Drinking Water Standards (Table 9.2-2) and are discussed in the following sections.

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Table 9.2-4 Summary of Key Groundwater Constituents Concentrations From Quarterly Sampled Wells

Parameter	Aquifer	Total Dissolved Solids @ 180C				Sulfate-Total				Chloride-Total			
Units		mg/L				mg/L				mg/L			
Sampling Quarter / Well ID		3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008
Domestic Wells													
2	Lakota	1100	1100	1100	1100	583	577	639	579	10	11	26	9
7	Fall River	1000	1000	990	960	586	567	583	514	12	12	11	11
8	Fall River	962	973	879	973	540	594	455	514	13	12	12	11
13	Lakota	890	890	850	880	488	520	499	442	11	11	10	10
16	Lakota	810	760	780	780	448	428	449	401	5	5	5	4
18	Fall River	990	960	960	940	513	536	537	492	13	13	14	12
4002A	Other Inyan Kara	NS	6.7	6.7	6.8	717	799	842	834	7	7	7	6
7002	Lakota	NS	2.7	2.4	2.6	1620	1750	1750	1780	10	11	9	9
Domestic/Stock Wells													
42	Lakota	960	940	980	930	505	519	505	466	12	13	12	11
Stock Wells													
619	Lakota	2100	1900	2100	2000	1440	1180	1310	1230	9	10	12	9
628	Other Inyan Kara	1800	1300	920	980	1030	635	651	515	82	35	29	42
631	Fall River	1900	2000	2000	2000	1240	1220	1250	1250	10	10	8	10
635	Sundance / Unkpapa	2200	2300	2300	2200	1500	1370	1470	1430	24	23	26	20
650	Lakota	2000	1600	1300	1400	1320	1000	801	825	17	16	19	19
Piezometer													
675	Alluvial	5900	6100	6100	5700 (Rep 4800)	3600	3420	3810	3810 (Rep 3840, 3840)	64	60	75	64 (Rep 64, 64)
676	Alluvial	3000	2900	2500	2600	1790	1720	1670	1760	15	16	14	13
677	Alluvial	8900	9700	9600	9100	4390	4590	4310	4410 (Rep 4410)	1720	1780	1290	1710 (Rep 1710)
678	Alluvial	6000	6100	6000	5400	3220	3440	3620	3740 (Rep 3740)	64	61	96	54 (Rep 94)
679	Alluvial	2500	2600	2500	2500	1580	1500	1420	1440	12	12	13	11

Notes:

Yellow highlights designate concentrations over the EPA MCL

Green highlights designate concentrations over the EPA "Secondary" guideline value above which use of water may give rise to complaints by consumers

ND = Not detected

NS = No sample

Rep = duplicate analysis

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Table 9.2-5 Summary of Key Groundwater Constituents Concentrations from Monthly Sampled Wells

Parameter	Aquifer	Total Dissolved Solids @ 180C												Sulphate-Total											
Units		mg/L												mg/L											
Sampling Quarter / Well ID		Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09
615	Fall River	675	750	710	680	710	740	670	720	700	700	720	730	374	371	399	369	430	401	421	414	391	388	389	398
622	Fall River	800	940	890	900	950	920	910	920	890	880	925	900	470	487	493	481	478	504	528	510	480	476	495	495
680	Lakota	2200	2300	2300	2500	2300	2300	2300	2300	2300	2300	2200	2300	1280	1360	1290	1410	1260	1430	1400	1365	1330	1310	1370	1400
681	Fall River	910	940	895	880	920	920	890	880	900	900	940	900	478	466	457	449	538	489	515	491	478	453	465	479
688	Lakota	690	690	740	755	785	810	790	810	780	780	800	830	428	390	398	403	429	425	422	450	421	435	436	460
689	Fall River	720	760	730	700	720	710	700	730	660	750	780	690	421	374	400	366	387	399	362	392	379	408	399	380
694	Lakota	970	995	970	960	980	990	950	1100	985	960	960	970	531	512	493	486	528	540	533	519	495	507	508	518
695	Lakota	870	910	920	920	950	900	880	1100	940	890	910	910	476	504	530	442	534	466	514	478	481	483	500	494
696	Lakota	880	930	930	920	930	930	920	950	790	900	920	920	475	475	505	456	526	495	506	493	476	459	483	470
697	Lakota	800	810	790	810	825	840	810	1000	820	810	820	820	452	430	456	409	481	452	435	560	430	442	444	436
698	Fall River	2200	2300	2150	2100	2300	2300	2200	2300	2200	2200	1700	2200	1365	1450	1315	1470	1530	1290	1470	1380	1360	1340	1340	1310
3026	Lakota	2300	2300	2400	2700	2800	2800	2300	1700	2300	2300	2100	2300	1470	1520	1480	1790	1700	1770	1560	1360	1370	1290	1310	1390

Notes:

Yellow highlights designate concentrations over the EPA MCL

Green highlights designate concentrations over the EPA "Secondary" guideline value above which use of water may give rise to complaints by consumers

ND = Not detected

NS = No sample

Rep = duplicate analysis

Table 9.2-5 Summary of Key Groundwater Constituents Concentrations from Monthly Sampled Wells (concl.)

Parameter	Aquifer	Chloride-Total											
Units		mg/L											
Sampling Quarter / Well ID		Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09
615	Fall River	6	4	5	5	5	5	5	5	5	5	5	5
622	Fall River	12	10	10	10	10	10	10	10	11	10	10	10
680	Lakota	15	11	12	12	12	13	12	14	14	13	13	13
681	Fall River	17	13	16	15	17	16	16	17	16	15	13	13
688	Lakota	13	10	11	11	11	11	11	12	12	12	11	11
689	Fall River	7	5	5	5	5	5	5	5	5	6	5	5
694	Lakota	11	9	9	9	9	9	9	9	9	9	9	9
695	Lakota	14	11	11	11	12	12	12	13	13	12	12	12
696	Lakota	15	12	12	12	13	13	12	13	13	13	12	12
697	Lakota	10	8	8	8	8	8	8	8	9	8	8	8
698	Fall River	12	9	9	9	10	10	9	10	10	10	10	9
3026	Lakota	37	16	15	15	15	15	15	17	17	16	16	16

Notes:

Yellow highlights designate concentrations over the EPA MCL

Green highlights designate concentrations over the EPA "Secondary" guideline value above which use of water may give rise to complaints by consumers

ND = Not detected

NS = No sample

Rep = duplicate analysis

9.2.1.1 Exceedances of Primary Drinking Water Standards

A number of groundwater samples collected at the project site exceeded the National Primary Drinking Water Standards. Constituents with samples exceeding the standards include arsenic (Table 9.2-6), lead (Table 9.2-7), uranium (Table 9.2-8), radium-226 (Table 9.2-9 to 9.2-11), and gross alpha particles (Table 9.2-12); these tables provide constituent concentrations, well ID, and sample date for regulated constituents detected at or above MCL levels. Complete groundwater quality data results, including original laboratory data and quality assurance/quality control (QA/QC) summaries are available in Appendix C.

About 70 percent of the samples exceeded the MCL for gross alpha particles (15 picocuries per liter [pCi/L]), with the exceedances occurring in samples from the Inyan Kara aquifer and alluvial aquifer. The range of gross alpha particles in alluvial wells was 13.3 to 129 pCi/L. The range of gross alpha particles in Inyan Kara wells was 1.4 to 6730 pCi/L. Four of the six wells (680, 681, 684, and 692) having gross alpha concentrations over 1000 pCi/L are known to be directly within an orebody. One well (698) is downgradient of open pit mines within the Fall River Formation.

Each sample collected from well 615 exceeded the MCL for arsenic. Each sample from well 698 exceeded the MCL for total uranium. Thirty-five percent of all uranium exceedances are from alluvial aquifer samples.

Table 9.2-6 Arsenic (Total) MCL Exceedances

Well	Sample Date	Result, mg/L	Well Use
615	1-Apr-08	0.025	Monitoring
615	20-Oct-08	0.024	Monitoring
615	20-Jan-09	0.024	Monitoring
615	25-Jun-08	0.024	Monitoring
615	1-Apr-08	0.024	Monitoring
615	21-Apr-08	0.024	Monitoring
615	28-May-08	0.024	Monitoring
615	17-Dec-08	0.023	Monitoring
615	14-Jul-08	0.023	Monitoring
615	24-Feb-09	0.022	Monitoring
615	18-Nov-08	0.022	Monitoring
615	22-Sep-08	0.022	Monitoring
615	20-Aug-08	0.021	Monitoring
622	14-Jul-08	0.027	Monitoring
676	5-Feb-08	0.021	Alluvial Monitoring
679	18-May-08	0.011	Alluvial Monitoring
681	14-Jul-08	0.024	Monitoring
684	7-Jul-08	0.040	Monitoring
688	28-Jul-08	0.015	Monitoring
695	23-Sep-08	0.016	Monitoring
3026	13-Jul-08	0.044	Monitoring
3026	28-May-08	0.028	Monitoring
3026	24-Jun-08	0.025	Monitoring
3026	30-Mar-08	0.023	Monitoring
3026	22-Apr-08	0.022	Monitoring
3026	19-Aug-08	0.022	Monitoring
3026	19-Aug-08	0.021	Monitoring

Table 9.2-7: Lead (Total) MCL Exceedances

Well	Sample Date	Result, mg/L	Well Use
622	25-Jun-08	0.0300	Monitoring
622	21-Apr-08	0.0260	Monitoring
622	28-May-08	0.0230	Monitoring
650	24-Mar-08	0.0500	Discontinued Stock
676	5-Feb-08	0.0600	Alluvial Monitoring
679	18-May-08	0.0220	Alluvial Monitoring
689	25-Jun-08	0.0170	Monitoring
690	7-Jul-08	0.0190	Monitoring
691	1-Jul-08	0.0350	Monitoring

Table 9.2-8 Uranium (Total) MCL Exceedances

Well	Sample Date	Result, pCi/L	Well Use
675	29-Apr-08	0.0516	Monitoring
675	29-Apr-08	0.0502	Monitoring
675	5-Feb-08	0.0387	Monitoring
676	5-Feb-08	0.0687	Monitoring
676	29-Apr-08	0.0591	Monitoring
677	29-Apr-08	0.0471	Monitoring
677	5-Feb-08	0.0414	Monitoring
678	29-Apr-08	0.0387	Monitoring
678	5-Feb-08	0.0379	Monitoring
678	5-Feb-08	0.0352	Monitoring
680	31-Mar-08	0.0541	Monitoring
684	7-Jul-08	0.336	Monitoring
698	20-Oct-08	0.132	Monitoring
698	30-Mar-08	0.123	Monitoring
698	30-Mar-08	0.122	Monitoring
698	28-May-08	0.119	Monitoring
698	22-Apr-08	0.119	Monitoring
698	14-Jul-08	0.116	Monitoring
698	28-May-08	0.116	Monitoring
698	24-Feb-09	0.113	Monitoring
698	24-Jun-08	0.113	Monitoring
698	17-Dec-08	0.112	Monitoring
698	24-Feb-09	0.11	Monitoring
698	20-Jan-09	0.108	Monitoring
698	17-Dec-08	0.107	Monitoring
698	18-Nov-08	0.103	Monitoring
698	22-Sep-08	0.102	Monitoring
698	19-Aug-08	0.101	Monitoring
3026	28-May-08	0.0322	Monitoring

Table 9.2-9 Radium-226 (Dissolved) MCL Exceedances

Well	Sample Date	Result, mg/L	Well Use
16	12-Nov-07	8.1	Domestic
16	30-Jun-08	6.4	Domestic
16	3-Oct-06	33.6	Domestic
16	27-Sep-07	26.2	Domestic
16	30-Mar-08	15.3	Domestic
18	3-Oct-06	5.8	Domestic
42	28-Sep-07	96.5	Domestic
42	3-Oct-06	87.6	Domestic
42	12-Nov-07	102	Domestic
42	30-May-08	100	Domestic
42	5-Feb-08	100	Domestic
615	25-Jun-08	7.2	Monitoring
619	24-Mar-08	99.7	Stock
619	27-Sep-07	120	Stock
619	17-Jun-08	110	Stock
619	12-Nov-07	100	Stock
622	24-Feb-09	7.9	Stock
628	20-Feb-08	9	Stock
628	28-Sep-07	7.4	Stock
628	29-May-08	6.1	Stock
628	14-Nov-07	20.7	Stock
631	14-Nov-07	9.5	Stock
631	19-May-08	22.1	Stock
631	20-Feb-08	19.4	Stock
631	26-Sep-07	12.9	Stock
680	22-Sep-08	1440	Monitoring
680	18-Nov-08	1430	Monitoring
680	13-May-08	1430	Monitoring
680	22-Sep-08	1420	Monitoring
680	10-Jun-08	1410	Monitoring
680	20-Jan-09	1360	Monitoring
680	24-Feb-09	1330	Monitoring
680	7-Jul-08	1280	Monitoring
680	20-Aug-08	1270	Monitoring
680	21-May-08	1240	Monitoring
680	20-Oct-08	1230	Monitoring
680	21-Apr-08	1230	Monitoring
680	20-Oct-08	1190	Monitoring
680	30-Jan-08	1180	Monitoring
680	31-Mar-08	1150	Monitoring

Table 9.2-9 Radium-226 (Dissolved) MCL Exceedances (cont'd)

Well	Sample Date	Result, mg/L	Well Use
680	17-Dec-08	1110	Monitoring
681	23-Sep-08	445	Monitoring
681	25-Jun-08	434	Monitoring
681	18-May-08	423	Monitoring
681	30-Jan-08	421	Monitoring
681	14-Jul-08	418	Monitoring
681	30-Mar-08	414	Monitoring
681	12-May-08	407	Monitoring
681	18-Nov-08	398	Monitoring
681	21-Apr-08	377	Monitoring
681	19-Aug-08	362	Monitoring
681	1-Jul-08	357	Monitoring
681	20-Oct-08	356	Monitoring
681	24-Feb-09	336	Monitoring
681	17-Dec-08	291	Monitoring
681	20-Jan-09	258	Monitoring
684	7-Jul-08	543	Monitoring
687	1-Jul-08	25.7	Monitoring
688	24-Feb-09	7.9	Monitoring
688	7-Jul-08	6.7	Monitoring
689	30-Mar-08	7.9	Monitoring
689	1-Jul-08	7.7	Monitoring
689	23-Sep-08	7.5	Monitoring
689	18-Nov-08	6.6	Monitoring
689	20-Oct-08	6.4	Monitoring
689	17-Dec-08	6.2	Monitoring
689	14-Jul-08	6.1	Monitoring
689	20-Jan-09	6.1	Monitoring
689	28-May-08	5.7	Monitoring
689	25-Jun-08	5.5	Monitoring
689	24-Feb-09	5.4	Monitoring
692	7-Jul-08	484	Monitoring
695	31-Mar-08	6.3	Monitoring
695	24-Jun-08	5.2	Monitoring
695	23-Sep-08	10.4	Monitoring
697	24-Feb-09	5.6	Monitoring
698	24-Jun-08	429	Monitoring
698	14-Jul-08	423	Monitoring
698	28-May-08	413	Monitoring
698	28-May-08	412	Monitoring
698	22-Sep-08	410	Monitoring

Table 9.2-9 Radium-226 (Dissolved) MCL Exceedances (concl.)

Well	Sample Date	Result, mg/L	Well Use
698	18-Nov-08	403	Monitoring
698	30-Mar-08	398	Monitoring
698	30-Mar-08	387	Monitoring
698	20-Jan-09	386	Monitoring
698	19-Aug-08	372	Monitoring
698	22-Apr-08	370	Monitoring
698	17-Dec-08	363	Monitoring
698	24-Feb-09	355	Monitoring
698	24-Feb-09	349	Monitoring
698	20-Oct-08	347	Monitoring
698	17-Dec-08	335	Monitoring
3026	28-May-08	9.6	Monitoring
3026	19-Aug-08	9.5	Monitoring
3026	19-Aug-08	8.7	Monitoring
3026	23-Sep-08	5.9	Monitoring
3026	13-Jul-08	10.1	Monitoring
4002	27-Sep-07	63.6	Stock
4002	27-Sep-07	60	Stock
4002	12-Feb-08	57	Stock
4002	14-Nov-07	54.2	Stock
4002	19-May-08	52.3	Stock
7002	20-Feb-08	8.8	Stock
7002	28-Sep-07	8.5	Stock
7002	12-Nov-07	8.1	Stock
7002	29-May-08	8	Stock

Note: Radium-228 was not analyzed due to the absence of Thorium-232 in samples

Table 9.2-10 Radium-226 (Suspended) MCL Exceedances

Well	Sample Date	Result, pCi/L	Well Use
42	05-Feb-08	5.1	Domestic
619	24-Mar-08	11.4	Stock
619	17-Jun-08	8.8	Stock
676	05-Feb-08	11.4	Alluvial Monitoring
679	03-Feb-08	9	Alluvial Monitoring
680	30-Jan-08	9	Monitoring
680	20-Oct-08	6.9	Monitoring
680	20-Oct-08	6.4	Monitoring
680	24-Feb-09	5.9	Monitoring
680	22-Sep-08	5.1	Monitoring
680	22-Sep-08	13.3	Monitoring
680	20-Jan-09	13.2	Monitoring
680	13-May-08	13.1	Monitoring
680	17-Dec-08	12.7	Monitoring
681	30-Jan-08	9.9	Monitoring
684	7-Jul-08	44.1	Monitoring
692	7-Jul-08	96.1	Monitoring
698	18-Nov-08	9	Monitoring
698	20-Oct-08	7.4	Monitoring
698	20-Jan-09	7.3	Monitoring
698	22-Apr-08	6.4	Monitoring
698	14-Jul-08	6.3	Monitoring
698	17-Dec-08	21.6	Monitoring
698	30-Mar-08	15.3	Monitoring
698	28-May-08	14	Monitoring
698	28-May-08	13.5	Monitoring
698	24-Feb-09	12.5	Monitoring
698	30-Mar-08	12.4	Monitoring
698	24-Jun-08	11.6	Monitoring
698	24-Feb-09	11	Monitoring
4002	19-May-08	8.4	Stock
4002	12-Feb-08	37	Stock
4002	27-Sep-07	19.4	Stock

Note: Radium-228 was not analyzed due to the absence of Thorium-232 in samples

Table 9.2-11 Radium-226 (Total) MCL Exceedances

Well	Sample Date	Result, pCi/L	Well Use
16	27-Sep-07	17.4	Domestic
42	28-Sep-07	79.7	Domestic
619	27-Sep-07	120	Stock
628	28-Sep-07	6.8	Stock
631	26-Sep-07	15.2	Stock
4002	27-Sep-07	62.7	Stock
4002	27-Sep-07	79.4	Stock
7002	28-Sep-07	6.3	Stock

Note: Radium-228 was not analyzed due to the absence of Thorium-232 in samples

Table 9.2-12 Gross Alpha (Total) MCL Exceedances

Well	Sample Date	Result, pCi/L	Well Use
7	3-Oct-06	17	Domestic
7	20-Feb-08	15.5	Domestic
13	20-Feb-08	19.5	Domestic
16	30-Mar-08	85.7	Domestic
16	27-Sep-07	62.7	Domestic
16	30-Jun-08	28.3	Domestic
16	3-Oct-06	110	Domestic
18	3-Oct-06	37	Domestic
18	12-Feb-08	31.7	Domestic
18	30-May-08	27.5	Domestic
18	12-Nov-07	20	Domestic
18	12-Nov-07	18.9	Domestic
18	26-Sep-07	15.7	Domestic
42	3-Oct-06	560	Domestic
42	30-May-08	558	Domestic
42	5-Feb-08	526	Domestic
42	12-Nov-07	375	Domestic
42	28-Sep-07	371	Domestic
135	13-Mar-08	66.5	Domestic
615	25-Jun-08	38.3	Monitoring
615	17-Dec-08	21.7	Monitoring
615	22-Sep-08	21.5	Monitoring
615	20-Jan-09	21.1	Monitoring
615	20-Oct-08	20.9	Monitoring
615	1-Apr-08	18.2	Monitoring
615	1-Apr-08	17.7	Monitoring
615	20-Aug-08	17.3	Monitoring
615	14-Jul-08	15.3	Monitoring
615	28-May-08	15.3	Monitoring
615	21-Apr-08	15.1	Monitoring

Table 9.2-12 Gross Alpha (Total) MCL Exceedances (cont'd)

Well	Sample Date	Result, pCi/L	Well Use
619	24-Mar-08	438	Stock
619	17-Jun-08	398	Stock
619	27-Sep-07	367	Stock
619	12-Nov-07	341	Stock
622	24-Feb-09	44.3	Monitoring
622	20-Jan-09	37.6	Monitoring
622	20-Jan-09	36.4	Monitoring
622	25-Jun-08	36.4	Monitoring
622	18-Nov-08	32.6	Monitoring
622	28-May-08	32.6	Monitoring
622	14-Jul-08	31.2	Monitoring
622	20-Oct-08	29.3	Monitoring
622	20-Aug-08	27.7	Monitoring
622	21-Apr-08	22.6	Monitoring
622	1-Apr-08	15	Monitoring
622	22-Sep-08	1470	Monitoring
628	14-Nov-07	83.9	Stock
628	20-Feb-08	64.5	Stock
628	29-May-08	39	Stock
628	28-Sep-07	29.9	Stock
631	19-May-08	60.7	Stock
631	26-Sep-07	51	Stock
631	14-Nov-07	46.5	Stock
631	20-Feb-08	162	Stock
675	29-Apr-08	55.2	Monitoring
675	29-Apr-08	51.1	Monitoring
675	5-Feb-08	29.3	Monitoring
675	28-Sep-07	18.8	Monitoring
675	27-Nov-07	18.3	Monitoring
676	5-Feb-08	95.5	Monitoring
676	29-Apr-08	51.6	Monitoring
676	28-Sep-07	37.1	Monitoring
676	27-Nov-07	31.9	Monitoring
677	29-Apr-08	43.1	Monitoring
677	28-Sep-07	41	Monitoring
677	27-Nov-07	38.7	Monitoring
677	5-Feb-08	129	Monitoring
678	29-Apr-08	54.7	Monitoring
678	5-Feb-08	41.5	Monitoring
678	5-Feb-08	30.2	Monitoring
678	28-Sep-07	23.2	Monitoring
678	27-Nov-07	18.9	Monitoring

Table 9.2-12 Gross Alpha (Total) MCL Exceedances (cont'd)

Well	Sample Date	Result, pCi/L	Well Use
679	18-May-08	22.4	Monitoring
679	28-Sep-07	19.9	Monitoring
679	3-Feb-08	18.4	Monitoring
680	20-Jan-09	6730	Monitoring
680	13-May-08	6500	Monitoring
680	31-Mar-08	6440	Monitoring
680	22-Sep-08	5620	Monitoring
680	22-Sep-08	5470	Monitoring
680	24-Feb-09	5140	Monitoring
680	17-Dec-08	5140	Monitoring
680	21-May-08	4500	Monitoring
680	18-Nov-08	4410	Monitoring
680	10-Jun-08	4370	Monitoring
680	20-Aug-08	4330	Monitoring
680	7-Jul-08	4280	Monitoring
680	21-Apr-08	4270	Monitoring
680	20-Oct-08	4200	Monitoring
680	30-Jan-08	4090	Monitoring
680	20-Oct-08	3700	Monitoring
681	30-Jan-08	656	Monitoring
681	12-May-08	2220	Monitoring
681	14-Jul-08	2170	Monitoring
681	30-Mar-08	2170	Monitoring
681	18-Nov-08	1850	Monitoring
681	17-Dec-08	1560	Monitoring
681	24-Feb-09	1460	Monitoring
681	20-Oct-08	1440	Monitoring
681	19-Aug-08	1430	Monitoring
681	21-Apr-08	1400	Monitoring
681	25-Jun-08	1390	Monitoring
681	18-May-08	1220	Monitoring
681	20-Jan-09	1210	Monitoring
681	23-Sep-08	1180	Monitoring
681	1-Jul-08	1180	Monitoring
682	7-Jul-08	50.3	Monitoring
684	7-Jul-08	1890	Monitoring
685	1-Jul-08	23.8	Monitoring
687	1-Jul-08	114	Monitoring

Table 9.2-12 Gross Alpha (Total) MCL Exceedances (cont'd)

Well	Sample Date	Result, pCi/L	Well Use
688	7-Jul-08	29.8	Monitoring
688	24-Feb-09	28.7	Monitoring
688	20-Jan-09	25.6	Monitoring
688	10-Jun-08	17.3	Monitoring
688	18-Nov-08	15	Monitoring
689	30-Mar-08	64.3	Monitoring
689	17-Dec-08	54.6	Monitoring
689	20-Jan-09	52.8	Monitoring
689	20-Oct-08	40	Monitoring
689	18-Nov-08	37.9	Monitoring
689	25-Jun-08	36.5	Monitoring
689	19-Aug-08	36.4	Monitoring
689	14-Jul-08	36	Monitoring
689	28-May-08	34.9	Monitoring
689	1-Jul-08	33.4	Monitoring
689	23-Sep-08	30.9	Monitoring
689	21-Apr-08	25.5	Monitoring
689	24-Feb-09	23.9	Monitoring
692	7-Jul-08	1450	Monitoring
694	20-Jan-09	25.9	Monitoring
694	24-Jun-08	23.7	Monitoring
694	21-Apr-08	19.2	Monitoring
694	21-Apr-08	18.1	Monitoring
694	14-Jul-08	15.1	Monitoring
695	31-Mar-08	52.2	Monitoring
695	23-Sep-08	44	Monitoring
695	24-Jun-08	39.7	Monitoring
695	20-Jan-09	35.8	Monitoring
695	22-Apr-08	29.4	Monitoring
695	14-Jul-08	28.2	Monitoring
695	21-Oct-08	27.8	Monitoring
695	17-Dec-08	26.8	Monitoring
695	21-May-08	25.6	Monitoring
695	20-Aug-08	21.6	Monitoring
695	18-Nov-08	19.2	Monitoring
695	24-Feb-09	18.7	Monitoring
696	24-Jun-08	23.9	Monitoring
696	20-Jan-09	20.2	Monitoring
697	20-Jan-09	21.7	Monitoring
697	24-Feb-09	18.2	Monitoring
698	22-Sep-08	36.3	Monitoring
698	22-Apr-08	2110	Monitoring

Table 9.2-12 Gross Alpha (Total) MCL Exceedances (concl.)

Well	Sample Date	Result, pCi/L	Well Use
698	20-Jan-09	1960	Monitoring
698	30-Mar-08	1880	Monitoring
698	14-Jul-08	1790	Monitoring
698	24-Jun-08	1790	Monitoring
698	30-Mar-08	1750	Monitoring
698	17-Dec-08	1730	Monitoring
698	18-Nov-08	1680	Monitoring
698	17-Dec-08	1570	Monitoring
698	19-Aug-08	1560	Monitoring
698	24-Feb-09	1490	Monitoring
698	28-May-08	1390	Monitoring
698	20-Oct-08	1330	Monitoring
698	24-Feb-09	1270	Monitoring
698	28-May-08	1210	Monitoring
3026	28-May-08	92.4	Monitoring
3026	13-Jul-08	80.1	Monitoring
3026	19-Aug-08	79	Monitoring
3026	19-Aug-08	77.5	Monitoring
3026	20-Jan-09	51.6	Monitoring
3026	30-Mar-08	47.6	Monitoring
3026	22-Apr-08	43.8	Monitoring
3026	20-Oct-08	36	Monitoring
3026	17-Dec-08	23.9	Monitoring
3026	18-Nov-08	19.7	Monitoring
3026	23-Sep-08	15.9	Monitoring
3026	24-Feb-09	15.4	Monitoring
3026	24-Jun-08	116	Monitoring
4002	12-Feb-08	314	Stock
4002	14-Nov-07	227	Stock
4002	27-Sep-07	141	Stock
4002	19-May-08	127	Stock
4002	27-Sep-07	120	Stock
7002	20-Feb-08	91.4	Stock
7002	28-Sep-07	45.6	Stock
7002	12-Nov-07	39.8	Stock
7002	29-May-08	29.5	Stock

9.2.1.2 Exceedances of Other Drinking Water Standards

In addition to primary drinking water standards established by the EPA, EPA Region 8 has set primary standards for some constituents. There are also a number of constituents (including radon-222) that have proposed standards which have not yet been adopted. However, SD DENR has adopted the EPA recommended standard for radon-222 in drinking water. Secondary drinking water standards (SMCL) set

by the EPA are designated for constituents that alter the color, taste, and odor of water; these constituents are not considered health risks but may deter human consumption. These constituents, along with the number of samples that exceed these guidelines, are presented in Table 9.2-13.

Bulk water quality properties with SMCLs include pH and TDS. For samples collected as part of the baseline study, nine wells exceeded the SMCL for pH with values ranging from 8.6 to 12.4 and one well had a sample below the SMCL with a pH of 6.49. All of the samples exceeded the recommended concentration of TDS. Values of TDS ranged from 660 to 9700 mg/L with the highest values obtained from alluvial well samples.

A number of samples also exceeded the SMCL for sodium and sulfate. A total of 111 samples exceeded the secondary standard for sodium with values ranging from 200 to 2140 mg/L. Again, the highest values of sodium were from alluvial well samples. All but one of the samples exceeded the SMCL for sulfate of 250 mg/L; 146 of these samples were over double the limit (over 500 mg/L), and 89 samples were over 1000 mg/L sulfate. Fourteen samples had concentrations of sulfate over 3000 mg/L, all of which were from the alluvial aquifers.

Exceedances were noted for trace metals including boron, iron, manganese, and strontium. The three exceedances for boron were all collected from well 678 with values from 1.4 to 1.6 mg/L. Over half of the samples collected exceeded the SMCL of 0.3 mg/L for iron; 29 samples exceeded the Region 8 limit of 5.0 mg/L. The only water supply wells exceeding the Region 8 limit for iron are stock wells 619 and 650. The SMCL for manganese was exceeded by 186 of 215 samples; the Region 8 limit of 0.8 mg/L was exceeded by 38 samples. Values of manganese over the secondary guideline range from 0.05 to 3.4 mg/L. Strontium was exceeded in 69 of 215 samples analyzed with values ranging from 4.2 to 11.6 mg/L. The alluvial wells had the highest values for SMCL exceeded trace metals including boron, iron, manganese, and strontium.

Currently, there is no federal primary drinking water standard for Radon-222. However, SD DENR has adopted the proposed EPA MCL of 300 pCi/L. Of the 245 samples analyzed for Radon-222 as part of the project baseline sampling program, 197 samples exceed the recommended level. Values of samples exceeding the limit range from 304 to 590,000 pCi/L. Sixty-seven samples have over 10 times the recommended concentration of radon-222; 46 of these samples are over 100 times the proposed MCL. The wells with the highest concentration include wells 680 and 681, which are directly in a known orebody, and well 42, a private well recently used for domestic and stock water.

Table 9.2-13 Water Quality Regulatory Limits for Public Drinking Water Supply Systems

Test Analyte/Parameter	Units	EPA Maximum Contaminant Level (MCL)	Number of Samples Analyzed*	Number of Detections	Number of Detections equal to or above MCL
BULK PROPERTIES					
pH	pH Units	6.5- 8.5 [1]	266	266	13
Total Dissolved Solids (TDS)	mg/L	500 [1]	266	266	265
CATIONS/ANIONS					
Sodium, Na	mg/L	200 [1]	240	266	111
Chloride, Cl	mg/L	250 [1]	266	266	4
Fluoride, F	mg/L	4; 2[1]	266	260	0
Sulfate, SO4	mg/L	250 [1]	266	266	264
Nitrate (as Nitrogen)	mg/L	10	260	30	0
Nitrite (as Nitrogen)	mg/L	1	266	1	0
TRACE METALS (total)**					
Antimony, Sb	mg/L	0.006	215	1	0
Arsenic, As	mg/L	0.01	215	170	27
Barium, Ba	mg/L	2	215	7	0
Beryllium, Be	mg/L	0.004	215	3	1
Boron, B	mg/L	1.4 [2]	215	56	3
Cadmium, Cd	mg/L	0.005	215	0	0
Chromium, Cr	mg/L	0.1	215	2	1
Copper, Cu	mg/L	1.0 [1]; 1.3 [3]	215	8	0
Iron, Fe	mg/L	0.3 [1]; 5 [4]	215	210	120 [1], 29 [4]
Mercury, Hg	mg/L	0.002	304	1	0
Manganese, Mn	mg/L	0.05 [1]; 0.8 [4]	215	213	186 [1], 38 [4]
Molybdenum, Mo	mg/L	0.04 [2]	215	8	2
Nickel, Ni	mg/L	0.1 [2]	215	1	1
Lead, Pb	mg/L	0.015 [3]	215	33	10
Selenium, Se	mg/L	0.05	215	47	0
Silver, Ag	mg/L	0.1 [1], [2]	215	0	0
Strontium, Sr	mg/L	4 [2]	215	214	69
Thallium, Tl	mg/L	0.002	215	1	0
Uranium, U	mg/L	0.030	219	163	29
Zinc, Zn	mg/L	5 [1]; 2 [2]	215	60	0
RADIONUCLIDES					
Beta Particles and Photons	mRem/ Year	4	266	262	N/A
Radium 226 and 228 (Combined)	pCi/L	5			
Radon-222 (total)	pCi/L	300 [5]	245	245	197

Notes:
[1] "Secondary" guideline value above which use of water may give rise to complaints by consumers
[2] Health Advisory-Lifetime
[3] Action level which if exceeded triggers treatment
[4] Region 8 Permit Limit
[5] Proposed MCL
N/A – Not available
* Number of samples includes results for only those wells that were sampled quarterly or monthly as part of the baseline sampling plan.

**Number of samples analyzed under trace metals is based on samples that were analyzed for total trace metals.

9.2.1.3 Not Fit for Human Consumption

Based on the baseline sampling results, the groundwater contained within the ore zones has concentrations of radionuclides beyond levels that are practical to render fit for human consumption. The aquifer does not presently, and will not in the future, serve as a source of drinking water because the concentrations of radionuclides in groundwater are well in excess of EPA MCLs and TDS concentrations significantly exceed SMCLs in all wells (Tables 9.2-4, 9.2-5, 12.1-26 and 12.1-27). Therefore, rendering the water fit for human consumption would be economically and technologically impractical.

No drinking water wells are extracting water from the Fall River or Lakota formations in the area requested for exemption. During initiation of baseline sampling program, a single domestic well completed into the Lakota formation was present within less than one mile of the proposed aquifer exemption boundary. Water quality samples from this well (16), (E 1009827.637, N 434446.9008) were elevated above the EPA MCLs for alpha particles, radium-226 and radon-222 (Table 12.1-26). Powertech replaced the well with a well completed into the Unkpapa aquifer.

9.3 Comparison of Historical and Recent Groundwater Quality near the Project

An analysis was conducted to determine if the well chemistry data collected at the PAA by the Tennessee Valley Authority (TVA) between May 1979 and April 1984 is representative of current water quality conditions and could therefore be used to expand the current Powertech data set. Nine wells were selected for analysis based on TVA and Powertech data sets being available for each well, time period, and constituent (Figure 9.3-1). All nine wells are completed into the Inyan Kara Group, which is composed of the Lakota and Fall River formations. Five of the wells are completed into the Lakota formation, three in the Fall River formation, and one is classified as simply the Inyan Kara formation.

Powertech and TVA data comparison consisted of two phases: (1) computing basic statistics on selected data, and (2) plotting Piper diagrams. The same set of wells was used in both analyses. Table 9.3-1 lists wells, the aquifer they are completed into, and the number of sample results available for analysis from monitoring programs done by TVA and Powertech. Table 9.3-2 shows the constituents sampled for during TVA data collection and those used in the comparison analysis either with statistics or Piper diagrams. Because the Powertech program is ongoing, the sample number is the number of samples analyzed through August 2008. Data selection process, analysis details, and results from statistical analyses and Piper plots are summarized independently in the following sections.
The following procedures were followed in completing the analyses:

- The analytical data was reviewed to define the chemical constituents that were similar between the monitoring programs with a focus on bulk properties.
- The reported values of alkalinity, conductivity, pH, and total dissolved solids (TDS) were compared from nine wells that were sampled during both project periods.
- Statistics calculated included mean, minimum, and maximum.
- Comparison was made by graphical representation of the mean value of reported parameters from TVA and Powertech data.
- At well 2, mean was computed and graphed both with an outlier included and without an outlier included for Alkalinity, TDS, and conductivity.

The number of samples analyzed during the current monitoring program limited the sample size available for statistical analysis. Therefore the analyses techniques available were limited to less rigorous qualitative and quantitative techniques. Comparison statistics reported are mean, minimum, and maximum, with relative percent difference (RPD) calculated for each statistic, where RPD is the absolute difference divided by the average (Table 9.3-3). Complete groundwater quality data results are available in Appendix C (Powertech results) and Appendix H (TVA results).

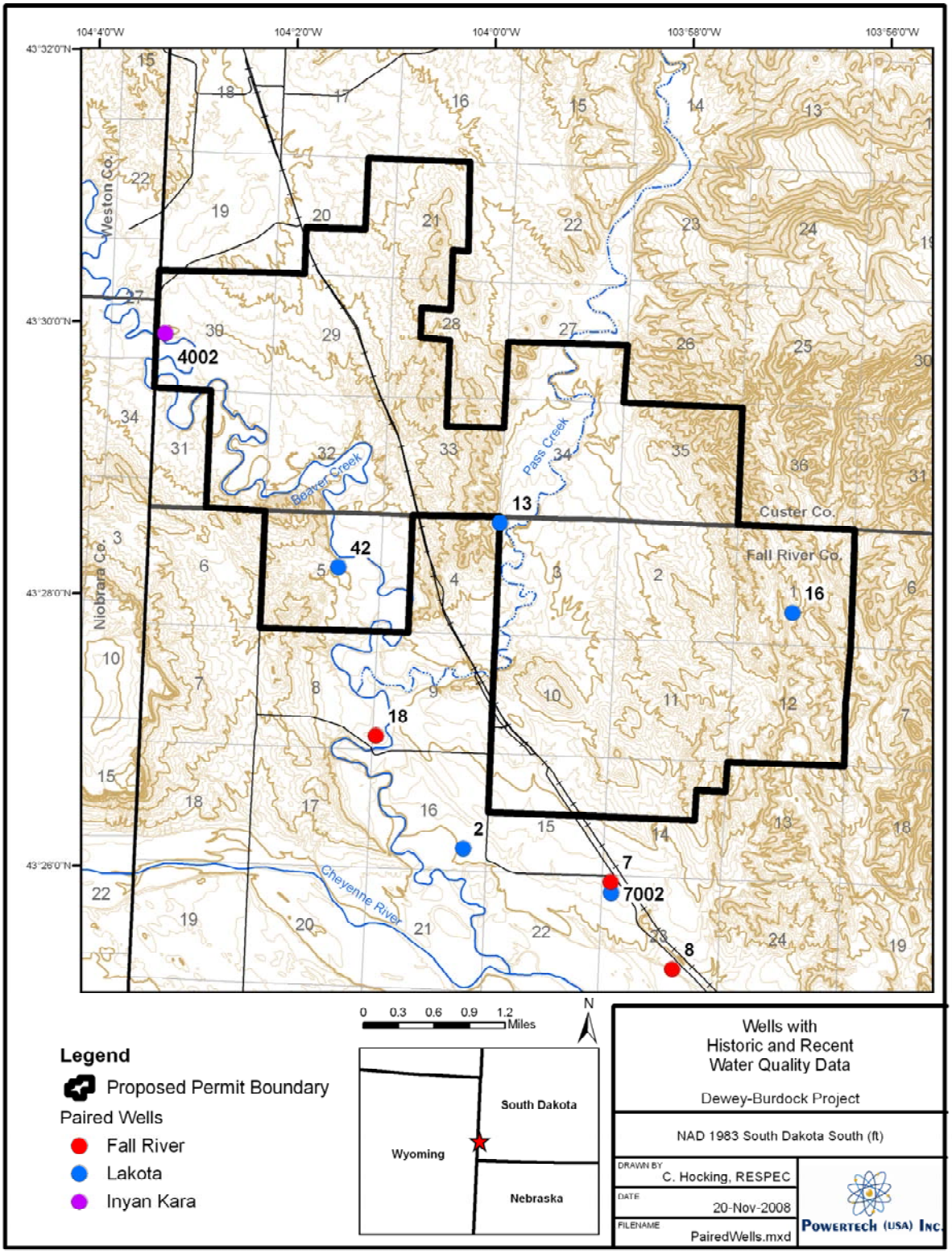

Figure 9.3-1 Wells with Historic and Recent Groundwater Quality Data

Table 9.3-1 Groundwater Quality Sampling from Previous Uranium Exploration Era as well as from Recent Exploration

Well No.	Aquifer	Number of TVA samples (1979 – 1984)	Number of Powertech samples (2006 – 2008)
2	Lakota	10	4
7	Fall River	2	5
8	Fall River	11	5
13	Lakota	11	5
16	Lakota	3	5
18	Fall River	11	6
42	Lakota	10	5
4002	Inyan Kara	5	5
7002	Lakota	11	4

Table 9.3-2 Parameters Analyzed During TVA Water Quality Monitoring

Test Analyte/Parameter	Units	Notes	Used in Historic/Recent Comparison
BULK PROPERTIES			
pH	pH Units	Field and Laboratory Program	X
Total Dissolved Solids (TDS)	mg/L		X
Total Suspended Solids (TSS)	mg/L		
Water Level	ft		
Conductivity	µmhos/cm	Field and Laboratory Program	X
Hardness			
CATIONS/ANIONS			
Calcium	mg/L		X
Alkalinity	mg/L		X
Bicarbonate (as HCO_3)	mg/L		X
Carbonate (as $CaCO_3$)	mg/L		X
Magnesium	mg/L		X
Potassium	mg/L		X
Sodium	mg/L		X
Sulfate	mg/L		X
Chloride	mg/L		X
Phosphate	mg/L		
Nitrogen	mg/L		
Cation/Anion Balance	%		
TRACE METALS			
Arsenic, As	mg/L	Dissolved	
Boron, B	mg/L	Dissolved	
Iron, Fe	mg/L	Dissolved	
Manganese, Mn	mg/L	Dissolved	
Lead, Pb	mg/L	Dissolved	
Selenium, Se	mg/L	Dissolved: Speciated	
Silcon-SiO_2	mg/L		
Uranium, U	mg/L	Total	
Vanadium, V	mg/L		
Zinc, Zn	mg/L	Dissolved	
RADIONUCLIDES			
Radium-226	pCi/L	Total	

Average alkalinity decreased slightly for all wells sampled except for No. 16 and No. 7002 which had essentially the same mean alkalinity in both time periods. The average absolute difference of the mean value of alkalinity was approximately 7 percent in the two data sets. The minimum value statistic at No. 2 showed the greatest RPD (78 percent) between TVA and Powertech data; one sample had an alkalinity of 88 mg/L while the other three ranged from 208 mg/L to 214 mg/L. A plot comparing average alkalinity between TVA and Powertech data is given in Figure 9.3-2; this plot both includes and excludes the low value at No. 2 well in the mean calculation.

Conductivity was overall slightly greater (8 percent) than in previous sampling years. It decreased slightly in No.16 and was essentially the same in No. 13 and No. 7002. The greatest increase in conductivity was found in No.2 (from 1547 to 2285 umhos/cm); although with the exclusion of an outlier (4400 umhos/cm) the mean of Powertech samples is 1580 umhos/cm. Figure 9.3-3 is a plot of average conductivity compared between historic TVA and current Powertech data both including and excluding the outlier value at No. 2 well in the mean calculation.

Values of pH were slightly higher in Powertech samples than in TVA samples, with the exception of wells No.2 and No. 7002 (Figure 9.3-4). Mean pH values varied from 7.44 to 8.11 at wells with greater than five samples. The greatest difference in pH was at well No. 7, with mean pH of 8.5 for TVA data and mean pH of 8.11 for Powertech data.

The TDS values from the two different sampling periods were also very similar. The greatest difference was once again at well No.2 that had a mean of 1043 mg/L in the TVA era compared to 1750 mg/L in the current sampling period. One Powertech sample collected at No. 2 well had a TDS value of 3700 mg/L, while the other Powertech samples were the same at 1100 mg/L. Figure 9.3-5 gives a comparison between historic TVA and current Powertech mean TDS, showing the mean calculated both including and excluding the outlier value at well No. 2.

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Table 9.3-3 Comparison of Statistics for Selected Constituents between Historic TVA Data and Current Powertech Data

		Mean			Minimum			Maximum		
	Well	Powertech	TVA	RPD	Powertech	TVA	RPD	Powertech	TVA	RPD
Alkalinity as CaCO3, mg/L	2	181	219	19%	88	200	78%	214	242	12%
	7	171	181	6%	170	171	1%	176	191	8%
	8	166	178	7%	156	166	6%	178	194	9%
	13	159	173	8%	142	160	12%	170	196	14%
	16	153	152	1%	148	144	3%	160	157	2%
	18	179	196	9%	172	180	5%	184	238	26%
	42	178	188	5%	174	179	3%	180	204	13%
	4002	140	158	12%	138	144	4%	144	202	34%
	7002	261	261	0%	250	210	17%	280	300	7%
Conductivity, uS/cm	2	2285	1547	39%	1500	1450	3%	4400	1750	86%
	7	1542	1338	14%	1440	1325	8%	1650	1350	20%
	8	1450	1385	5%	1420	1285	10%	1560	1450	7%
	13	1292	1274	1%	1140	1100	4%	1420	1400	1%
	16	1063	1162	9%	925	1150	22%	1260	1175	7%
	18	1412	1379	2%	1330	1300	2%	1470	1420	3%
	42	1408	1353	4%	1310	1200	9%	1510	1400	8%
	4002	1220	1161	5%	1130	1100	3%	1340	1195	11%
	7002	2328	2339	0%	2200	1925	13%	2480	2500	1%
pH	2	7.91	7.7	3%	7.85	7.16	9%	7.94	8.2	3%
	7	8.11	8.5	5%	8.05	8.3	3%	8.17	8.7	6%
	8	7.95	7.87	1%	7.93	7.59	4%	7.97	8.5	6%
	13	7.9	7.76	2%	7.75	7.48	4%	8.05	8.1	1%
	16	7.46	7.34	2%	7.38	7.31	1%	7.57	7.39	2%
	18	8.08	7.94	2%	8.02	7.69	4%	8.11	8.4	4%
	42	8.02	7.94	1%	7.95	7.67	4%	8.08	8.4	4%
	4002	7.83	7.75	1%	7.65	7.51	2%	8.02	8.5	6%
	7002	7.36	7.44	1%	7.22	7.14	1%	7.56	8	6%
	2	1750	1043	51%	1100	1004	9%	3600	1113	106%
	7	999	1081	8%	896	1058	17%	1050	1104	5%
	8	1000	965	4%	940	860	9%	1100	1130	3%
	13	878	886	1%	850	792	7%	890	1006	12%
	16	814	846	4%	760	796	5%	940	894	5%
	18	958	909	5%	940	520	58%	990	1118	12%
	42	950	939	1%	930	888	5%	980	1033	5%
	4002	818	773	6%	790	740	7%	850	805	5%
	7002	1875	1843	2%	1800	1690	6%	1900	1970	4%

RPD (Relative Percent Difference) = The absolute difference divided by the average.

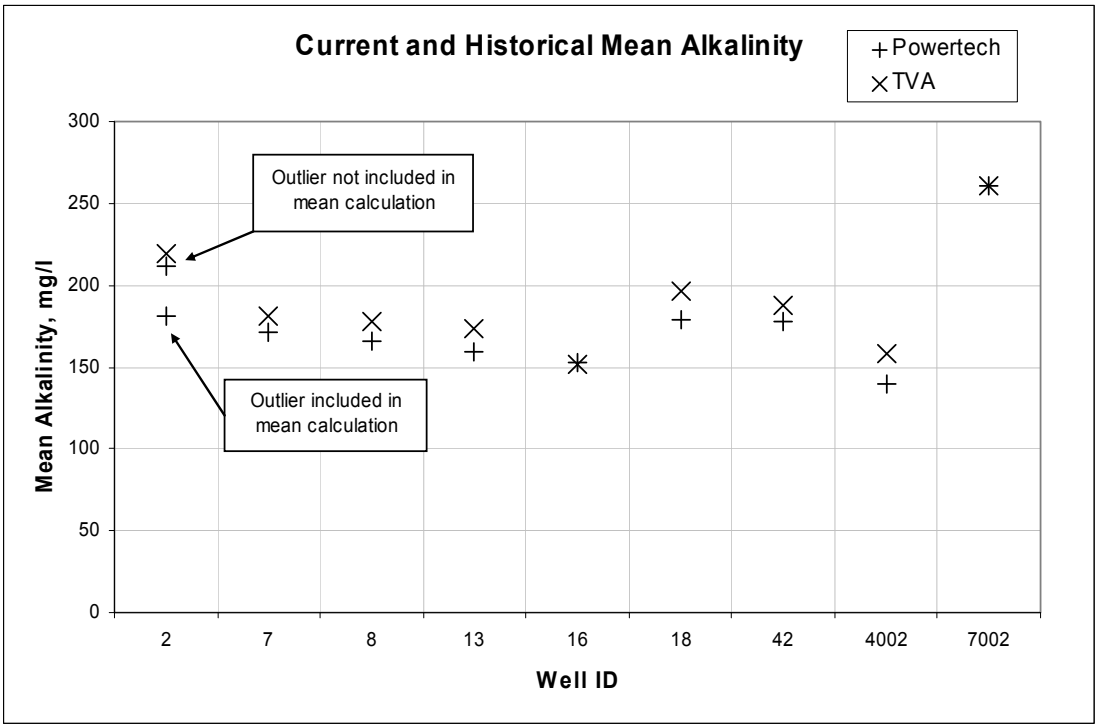

Figure 9.3-2 Mean Alkalinity Comparison between Historic TVA and Current Powertech Data

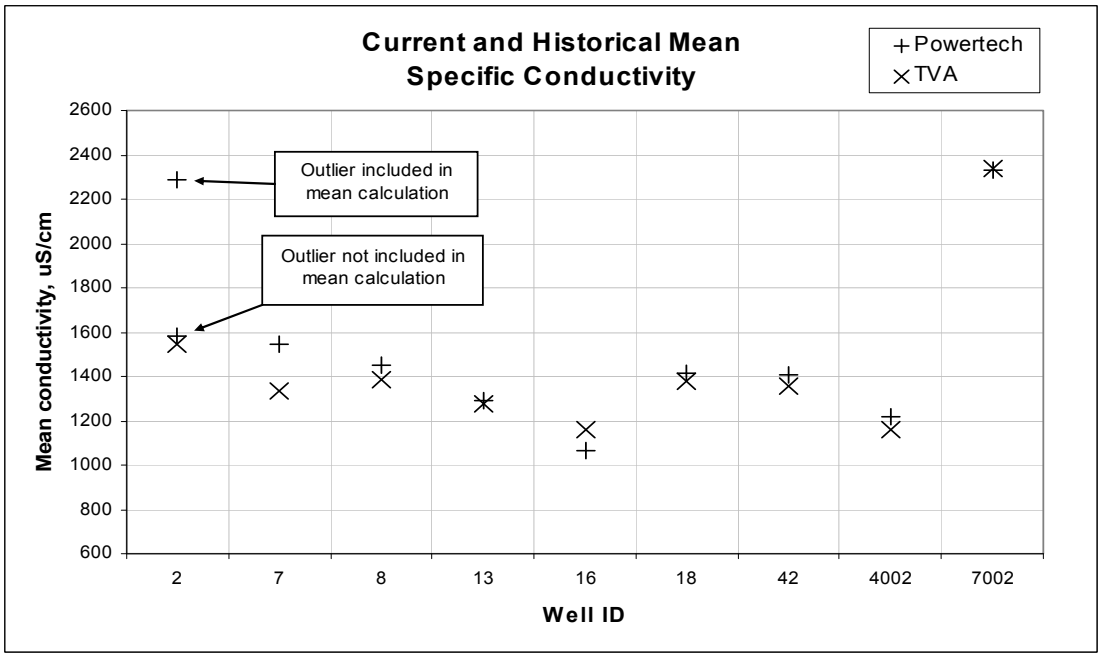

Figure 9.3-3 Mean Conductivity Comparison between Historic TVA and Current Powertech Data

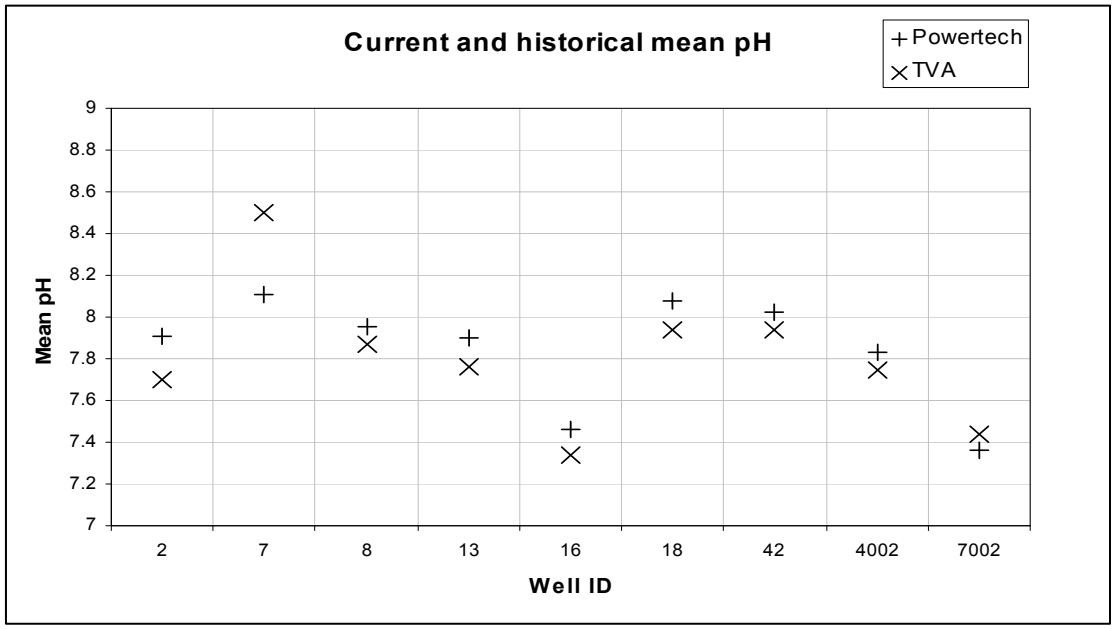

Figure 9.3-4 Mean pH Comparison between Historic TVA and Current Powertech Data

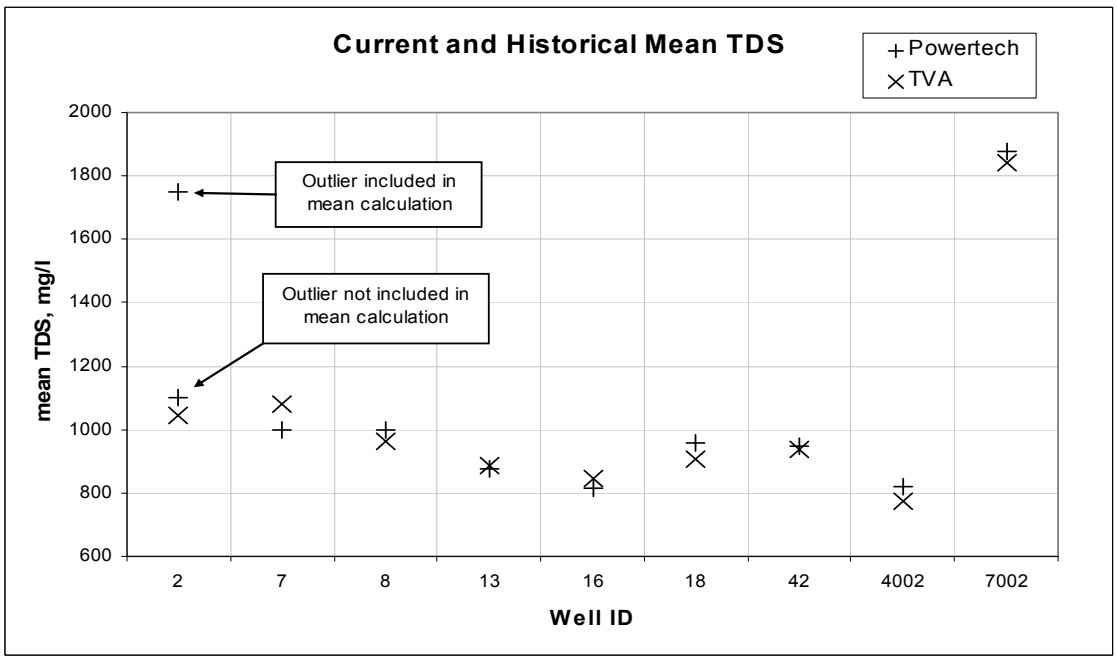

Figure 9.3-5 Mean TDS Comparison between Historic TVA and Current Powertech Data

Piper diagrams were constructed for this group of wells with both historic and recent samples to determine if the general water quality type has changed over the course of the last 30 years (Figures 9.3-6 through 9.3-10). Piper diagrams are a useful tool to evaluate overall water quality as they provide a visual representation of the proportional concentrations of major ions. These figures consist of two trilinear diagrams (one for each cations and anions) and a comprehensive quadrilateral diagram. The trilinear diagrams illustrate the relative concentrations of cations (left diagram) and anions (right diagram) in each sample plotted as percent of total in milliequivalents per liter (meq/l). Cations included on the

diagram include sodium (Na+) plus potassium (K+), calcium (Ca++), and magnesium (Mg++). Anions plotted include bicarbonate (HCO3-) plus carbonate (CO3--), sulfate (SO4--), and chloride (Cl-). Each sample is represented by a point in each trilinear diagram. The quadrilateral field at the top of the Piper diagram is designed to show both anion and cation groups and is used to assign a general water type.
Inspection of the resulting Piper diagrams reveals that water quality within both the Fall River and Lakota formations display a similar distribution. For both formations, sulfate is by far the dominant anion accounting for 70 to 80 percent meq/l (Figure 9.3-6). Relative abundance of calcium and magnesium are fairly even though most samples have a slightly higher percentage of calcium. Most samples contain between 55 and 85 percent meq/l sodium although water from the Lakota has a greater fluctuation with a group of samples having only 20 to 30 percent meq/l of sodium. Figures 9.3-7 and 9.3-8 display the water major ion concentrations sorted by aquifer and historical and recent data sets. In general, both the historic and recent data sets display the same trends and range in water type grading between a calcium-magnesium sulfate to sodium sulfate type.

Figures 9.3-9 and 9.3-10 display the proportional concentrations of major ions symbolized by well. These diagrams illustrate that samples for a particular well form a cluster, and hence it can be said that water quality has not greatly varied by sampling event. It is also apparent that the water type is variable from well to well. The geographical location and distance from the outcrop are therefore believed to be the main influences on water type, although well depth and screened interval may also have an effect. Wells that are located on or near the Inyan Kara outcrop (well 16 for example) yield a more calcium-magnesium sulfate type water, whereas wells further downgradient evolve to a sodium sulfate type water. This finding is consistent with that of Gott et al. (1974), who believed the difference in water type distribution resulted from recharge to the Inyan Kara from upward leaking Minnelusa aquifer water. It can be concluded that relative ion concentration of Inyan Kara formation water is similar today to what it was during TVA sampling in the PAA.

Powertech and TVA well chemistry data shows that the general water quality parameters in the aquifers has demonstrated good consistency over time. Therefore, the Powertech data set can be supplemented with the previously collected TVA data to expand the knowledge of baseline water quality conditions and the time period of data collection from one to almost 30 years. Future monitoring is anticipated to demonstrate the continuing stability of water chemistry.

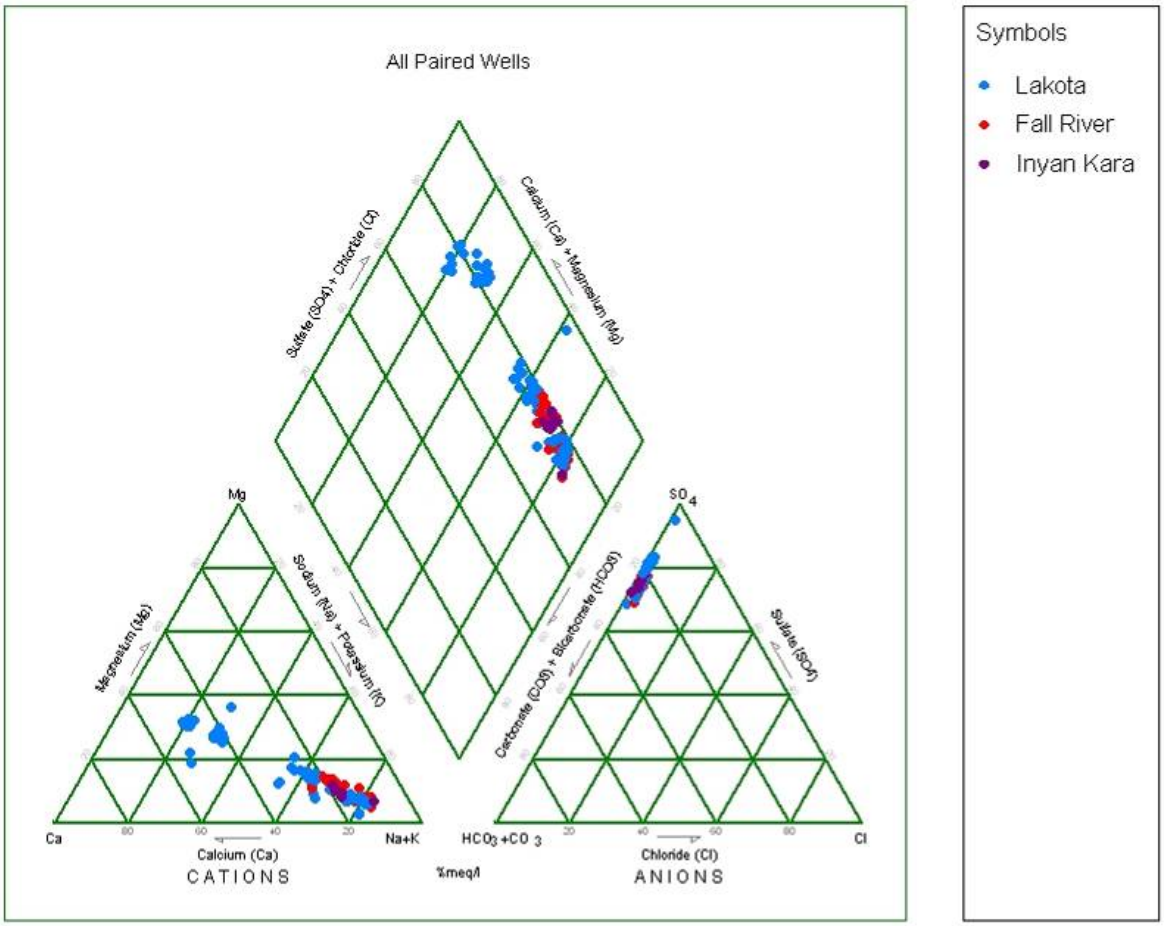

Figure 9.3-6 Piper Diagram of Well Data Grouped by Formation for Wells Sampled by TVA and Powertech

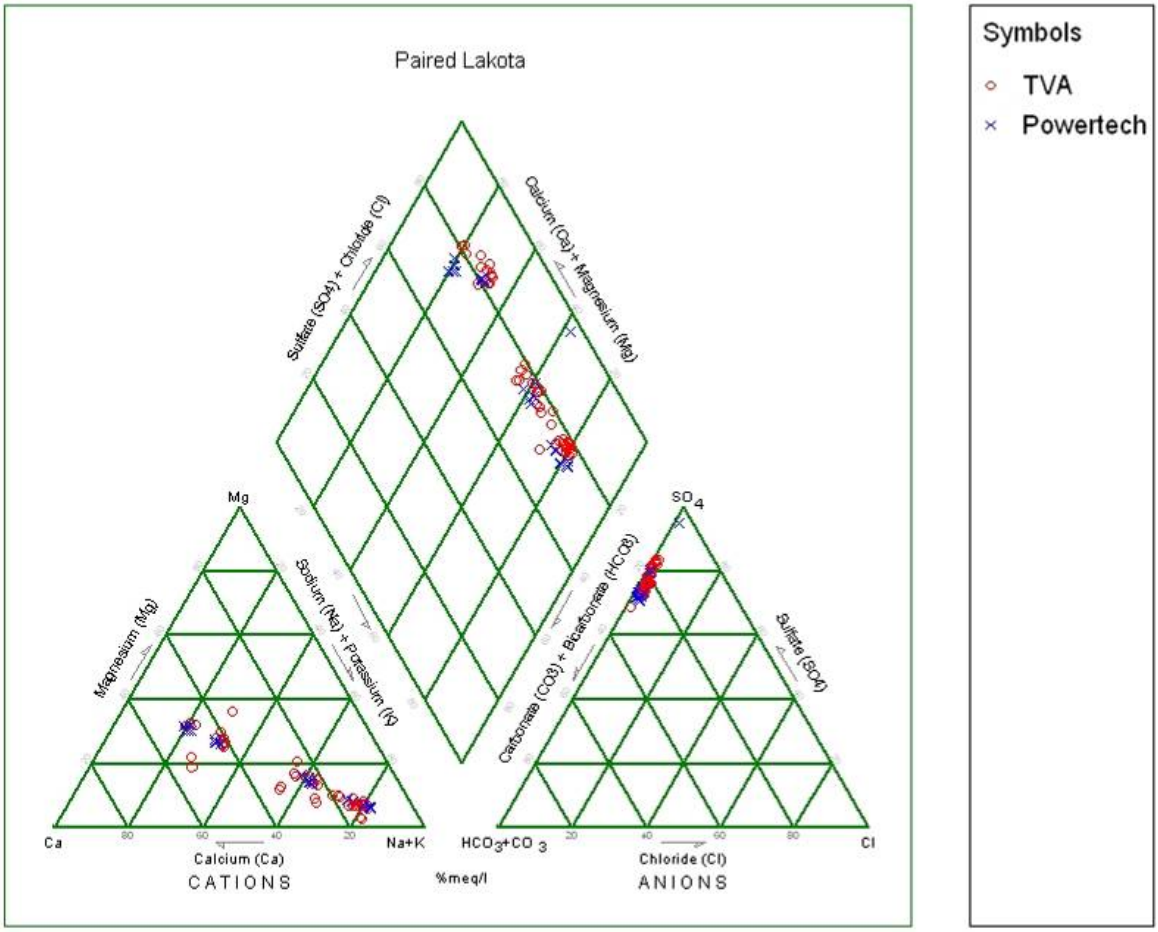

Figure 9.3-7 Piper Diagram of Sample Results from Lakota Wells Grouped by Vintage

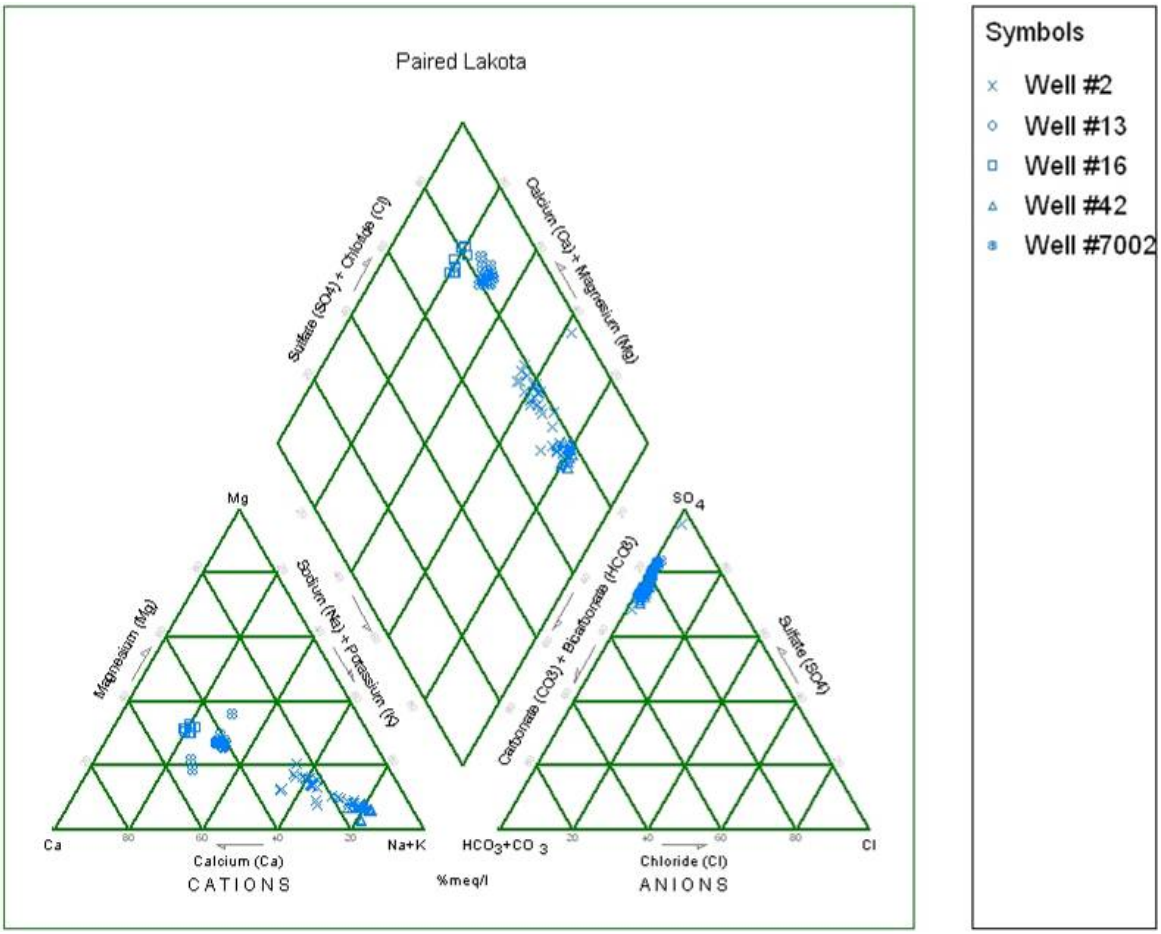

Figure 9.3-8 Piper Diagram of Sample Results from Wells Sampled in the Lakota Formation by TVA and Powertech Grouped by Well

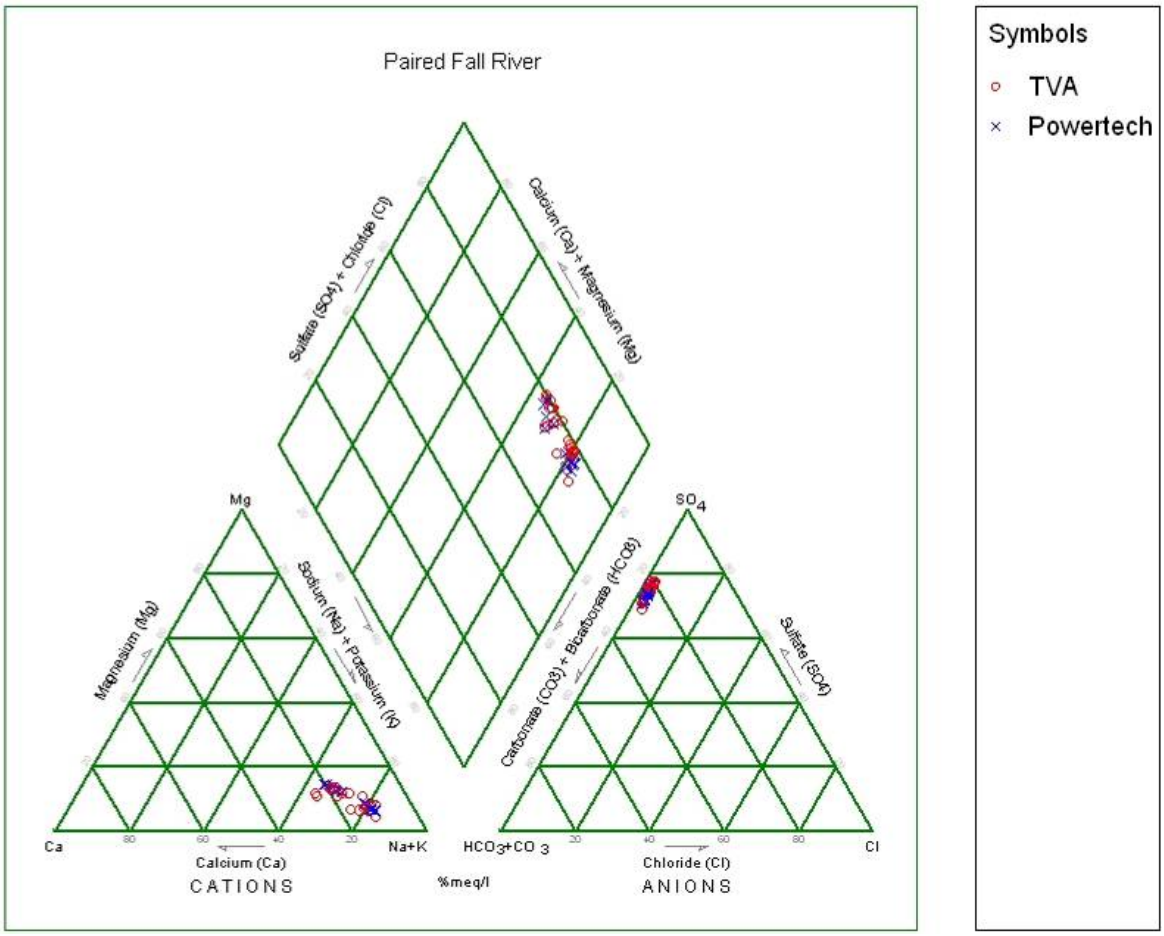

Figure 9.3-9 Piper Diagram of Sample Results from Fall River Wells Grouped by Vintage

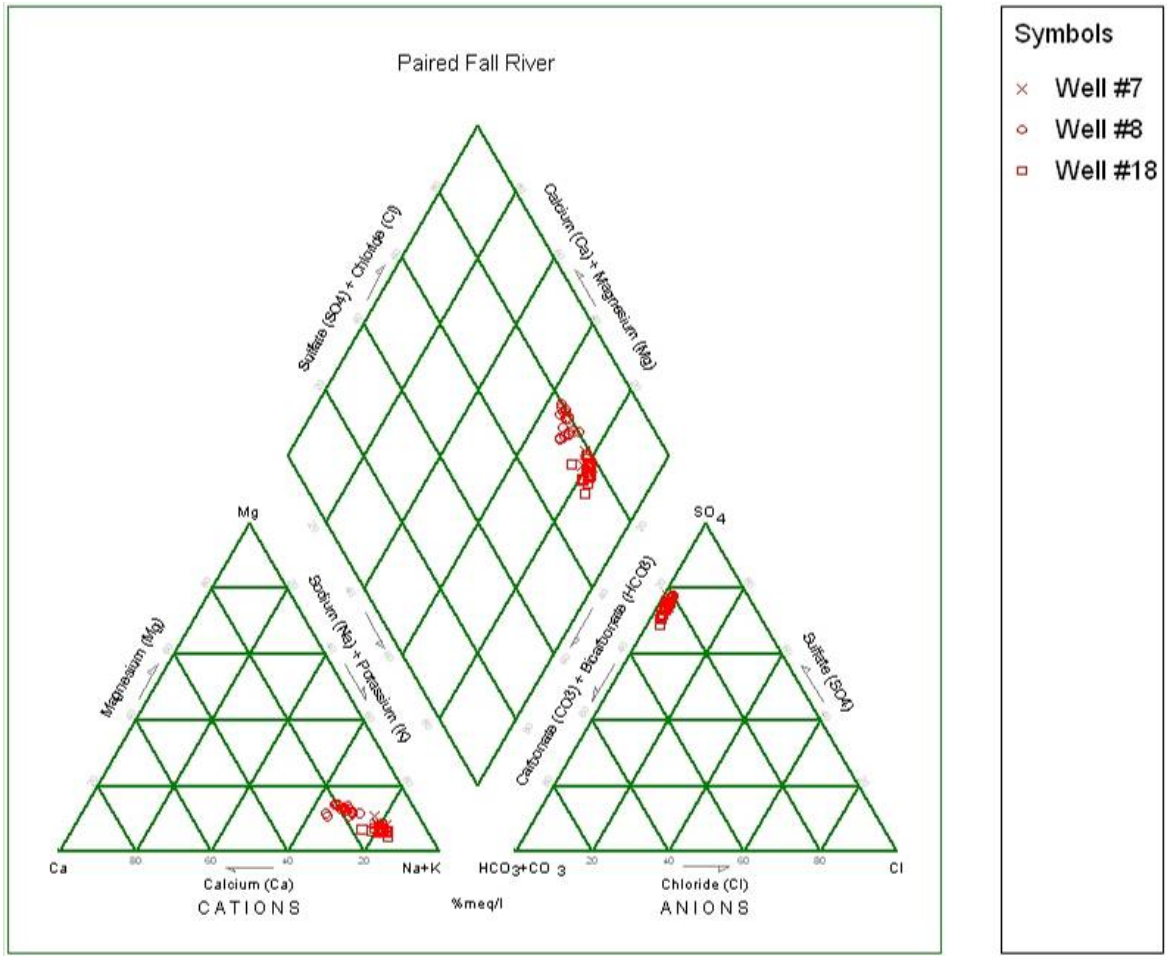

Figure 9.3-10 Piper Diagram of Sample Results from Wells Sampled in the Fall River Formation by TVA and Powertech Grouped by Well

9.3.1.1 Conclusions

The radiological baseline sampling results indicate that the groundwater contained within the ore zones of the Inyan Kara Group has concentrations of radionuclides that greatly exceed EPA MCL concentrations at levels and, therefore, are not acceptable for human consumption. That portion of the aquifer within the proposed AEB does not presently, and will not in the future, serve as a source of drinking water.

9.4 Proposed Operational Groundwater Monitoring Plan

During the Proposed Action, an extensive groundwater sampling program specific to each well field will be conducted prior to, during, and following ISL operations to identify any potential impacts to water resources of the area. The groundwater monitoring program is designed to: 1) establish well field baseline water quality prior to mining, 2) detect excursions of lixiviant either horizontally or vertically outside of the target mineralization zone, 3) demonstrate compliance with groundwater quality standards, and 4) determine when the mined sandstone aquifer has been adequately restored following ISL operations. Objectives 1 (partially) and 4 will be accomplished using injection and recovery wells. Objectives 1 (partially), 2, and 3 will be accomplished using two types of dedicated monitoring wells consisting of perimeter, and internal monitoring wells.

9.5 Monitoring Well Locations and Spacing

The proposed design and placement of monitoring wells, including the production zone monitor ring and overlying and underlying monitor wells, is but one of the safeguards employed to detect and recover a potential breach outside the production zone. Technology has enabled substantial advances in the operational management of monitoring systems that are typically applied to monitoring of in situ operations. This monitoring program will be implemented in a manner that maximizes and combines the expertise of qualified operators and engineers with proven technologies.

Some features considered in the design of monitoring programs include but are not limited to: hydrostratigraphic units and their lateral and vertical continuity; information on the geometry of the boundaries and boundary conditions; physical form of constituents in potential migrating fluid (i.e., dissolved, suspended); structural features of the geology; and chemical properties and potential reactions of groundwater, the aquifer matrix, and lixiviant. Processes that are considered include but are not limited to: steady-state and transient flow conditions; advection, dispersion; sorption, and precipitation. The objective of monitoring is to indicate the presence of lixiviant movement outside the production zone in either a horizontal direction via a production zone monitoring well ring, or in a vertical direction via overlying and underlying groundwater monitoring wells. The monitoring program is designed based on factors such as groundwater flow direction and travel time, and continuity and characteristics of hydrostratigraphic units. Further, it is designed to strategically place monitor wells around, above and below the production zone to allow prompt detection of possible horizontal and vertical migration of lixiviant or production and restoration related fluids. Well fields of large size and more complex hydrogeology may require a greater number of suitably designed and positioned wells in order to ensure adequate migration detection capability. The design of monitoring well programs must be flexible enough to allow for additional installation of monitoring wells if the primary monitoring effort indicates there is a need to further delineate the horizontal or vertical extent of migration (NRC, NUREG–1757, Vol. 2). Well field monitoring is designed according to site specific scientific and technical conditions that provide safeguards to humans and the environment. Refer to Exhibits 10-2 and 10-4 which illustrate the monitoring well layout for a typical well field of the PA. Powertech does not intend to locate any wells within the easement (approximately 100 ft. on either side of the rail line) of the Burlington Northern Santa Fe Railroad.

9.5.1 General Monitoring Procedure

Production zone monitoring wells are installed around the periphery of each production area to monitor for any fluids that might escape the hydraulic controls (Hunkin, G. G., 1977 and Dickinson, K. A., and J. S. Duval, 1977) with a screened interval open to the sand unit containing the production zone. This monitoring “ring” design serves two purposes: 1) to monitor any horizontal migration of fluid within the sand unit or aquifer where production is occurring, 2) to determine baseline water quality data and characterize the area outside the production pattern area. The Operational monitoring program will require periodic sampling and analysis from these wells with respect to site specific parameters (lixiviant indicators) that may be specified within the Class III UIC Permit. Well field baseline concentrations will be determined and Upper Control Limits (UCLs) will be established for particular constituents indicative of a possible process water excursion. By establishing UCLs, the operator is allowed the capability of early detection of an excursion and then has the time to apply corrective action before water quality outside the aquifer exemption boundary is affected (NUREG/CR-6733, 2001). Production zone monitor wells will be located approximately 400 feet from the production area, and will be spaced approximately 400 feet between production zone monitoring wells. Production zone monitoring wells are installed before the start of production activities in order that required baseline sampling and hydrologic tests (as required) can be conducted.

Non-production monitoring wells consist of two types of monitor wells termed “overlying” and “underlying”. The screened intervals of overlying wells are located in the sand unit or aquifer immediately above the ore-bearing stratum. The overlying non-production monitoring wells are designed to provide monitoring of

any upward movement of production fluids that may occur from the production zone and to guard against potential leakage from production and injection well casing into any overlying aquifer. The overlying wells are used to obtain baseline water quality data and are used in the development of UCLs for the overlying zones that will be used to determine if vertical migration of production fluids is occurring. Vertical monitoring is generally designed with a density of wells ranging from one every three to five acres and where confining layers are very thick and permeabilities are negligible, requirements for vertical excursion monitoring can be relaxed or eliminated for underlying aquifers (NUREG/CR-6733, 2001). The screened zone for the overlying wells is determined from electric logs by qualified geologists or hydrogeologists. The first layer of overlying non-production zone monitoring wells will be evenly distributed through the production area with a minimum of one well for every four acres of production area. Should additional aquifers exist above the first monitoring layer; additional overlying monitors will be located in these aquifers with a minimum of one well positioned for every eight acres of production area.

A single layer of underlying monitor wells will be completed in the first sand unit or aquifer underlying the ore-bearing stratum similarly based on the local lithology. The underlying monitor wells are used to obtain baseline water quality data and are used in the development of UCLs for the underlying aquifer that will be used to determine if vertical migration of production fluids is occurring. The screened zone for the underlying monitor wells is determined from electric logs by qualified geologists or hydrogeologists. Underlying non-production monitoring wells will be evenly distributed through the production area with a minimum of one well for every four acres of production area. Underlying wells will not be installed below the Lakota formation, primarily due to the presence of the approximately 100-foot-thick and relatively impermeable Morrison formation immediately below the Lakota formation.

All of the non-production zone monitoring wells will be designed and installed for detection of potential excursions of lixiviant, if such an excursion were to occur. Design of the monitor ring and overlying and underlying monitor wells for each well field will be based on site specific lithology and hydrogeochemical processes of the production zone(s) of each well field. Powertech will present each monitoring well program to EPA and the SD DENR before installation of proposed well placement to ensure administrative approval is obtained. After completion of the required hydrologic test, it may be necessary to revise the location and/or number of wells proposed.

South Dakota UIC Class III rules were promulgated in April 2008. ARSD 74:55:01:42 addresses non-production zone monitoring. The rule provides for alternative non-production zone monitoring well location and spacing to be considered if the operator demonstrates that the proposed location or spacing will adequately provide monitoring coverage. Based on industry experience in locating and spacing overlying monitor wells and the low probability of any upward fluid migration going undetected, along with considerations of local lithology, Powertech believes the proposed locations and spacing are sufficient for the monitoring of any potential upward migration of production fluids. The monitoring program is designed in to satisfy Title 40: Protection of Environment PART 146—Underground Injection Control Program: Criteria and Standards and Chapter 74:55:01 Underground Injection Control -- Class III Wells for the state of South Dakota.

Each well field will be handled on a case-by-case basis in consultation with the EPA and SD DENR. Powertech's Safety and Environmental Review Panel (SERP) to be established under NRC requirements will review hydrologic test results and documentation to ensure that the monitoring wells are properly located. Well field packages will be evaluated based on current knowledge of site lithology and processes of the production area, and industry proven practices, the number and spacing of overlying and underlying monitoring wells to ensure number and spacing meets criteria to protect human health and the environment. All wells completed in the production zone monitor ring, and overlying and underlying aquifers will be subject to remedial action and reporting requirements pertinent to EPA and SD DENR rules.

9.6 Flow Monitoring

This section addresses **CI–10 (2)**.

Oxygen is injected into the barren solution in the header house as an oxidant and the oxygen flow rate is metered via an recording current meter (RCM) (or rotameter on individual injection meter runs) which reads out in standard cubic feet per minute (SCFM). The meters are calibrated for a given pressure. CO2 addition is metered by a gas flow meter, which is calibrated for CO_2 at a specific pressure. The calibration and maintenance of all monitoring and recording equipment will occur on a regular basis to ensure that all equipment is in proper working order.

Monitoring safeguards utilized during operational phase include monitoring and recording the rates, volumes and wellhead pressures of production and injection wells daily. Monitor well sampling will also be conducted during restoration, including stabilization monitoring at the end of the restoration activities to determine the achievement of acceptable water quality.

9.6.1 Water Monitoring Network

This section addresses **CI–10 (6)**.

The groundwater monitoring network is comprised of private wells in the vicinity of the proposed permit area, perimeter production zone monitoring wells surrounding the well field, baseline production zone wells within the interior of the well field, and the non-production zone monitor wells within the overlying and underlying aquifers (if deemed appropriate).

Overlying and underlying wells within the production zone and monitor wells in the monitoring well ring, which is only 400 feet from the production site, will be monitored twice a month for the express purpose of detecting potential migration of recovery fluids. Powertech is willing to consult with the Department to identify wells within one-quarter mile of the production site that may be monitored quarterly. However, at this time, it is not clear that there is any protective benefit to quarterly monitoring within one-quarter mile when there is a complete monitoring system that is monitored every two weeks within 400 feet of the production site.

9.6.1.1 Private Wells

All private wells within 0.62 miles (1.0 kilometer) of the well field boundary that Powertech has received landowner authorization to sample will be sampled annually with the initial sampling event occurring prior to mining operations. Analytes for these wells will consist of natural uranium and radium-226.

9.6.1.2 Perimeter Production Zone Monitoring Wells

Subsequent to delineation of the well field boundary, a ring of production zone monitoring wells will be installed around the perimeter of the well field area. These wells will be designed primarily for the detection of lixiviant excursion from the production area well field. Refer to Section 7.0 for further information on the well design and Section 9.0 for locations.

9.6.1.3 Baseline Production Zone Wells

Baseline production zone wells will be uniformly distributed across the production area. These wells are utilized for establishment of pre-mining water quality within the production zone. The minimum number of production zone wells to be sampled for baseline analysis within a production area will be five. These wells will be sampled three times each at intervals of two weeks to provide repeatability of the data. They will be sample prior to mining and after restoration of the ground water is complete as demonstration of restoration.

9.6.1.4 Non-Production Zone Monitor Wells

Non-production zone monitoring wells will be installed in the overlying and underlying (if present and deemed necessary) aquifers related to the production zone aquifer. They will be designed to detect migration of lixiviant outside the production zone aquifer. Non-production zone wells will be located within the production zone pattern. At the minimum, these wells will be completed in the overlying aquifer to the production aquifer. Refer to Section 7.0 for further information on the well design and Section 9.0 for location.

9.7 Hydrostatic Monitoring

This section addresses **CI–10 (2)**.

Additional excursion preventative techniques incorporated into Powertech's monitoring program include fluid volume and flow rate monitoring and wellhead pressure monitoring as described below.

9.7.1 Fluid Volume and Flow Rate

Accurate assessment of water balance for a well field is achieved by monitoring the extraction (production) and injection rates and volumes. A bleed system will be employed that will result in less solution injection than total volume of fluids (native groundwater and lixiviant) extracted. A bleed of at least 0.5 percent will be maintained during production. This 0.5 percent bleed will cause an inflow of groundwater into the production area and prevent the loss of lixiviant solution. Fluid volume and flow will be metered and recorded daily.

9.7.2 Wellhead Pressure

Wellhead pressure will be monitored at all injection wells. Pressure gauges installed at each injection wellhead or on the injection manifold will be monitored at least daily. The maximum injection pressure at the wellhead will not exceed 120 psi, nor will it exceed the manufacturer's recommended pressure for the piping material. Injection rates will be adjusted to maintain wellhead pressure below that level.

Nonproduction zone monitoring wells will be located laterally within the production area. In the first overlying aquifer above the production zone, a minimum of one (1) monitoring well monitoring well will be completed for every four (4) acre of production area. If an additional overlying aquifer is present, a minimum of one (1) well for every four (4) acres of the production area will be completed. In the first underlying aquifer, a minimum of one (1) monitoring well will be completed for every eight (8) acres of production area.

9.8 Water Quality Sampling and Analysis

The sampling frequency and parameters measured are addressed in the following subsections. Water quality sampling will serve as a safeguard to detect excursions of lixiviant outside the production area during mining operations, and will determine when a production zone aquifer has been acceptably restored following mining.

9.8.1 Groundwater Quality

Powertech will establish the baseline groundwater quality before beginning operations in a well field. Production and monitoring zone wells will be sampled at least four times over a sufficiently spaced interval to indicate well field baseline. Wells will be selected based on a density of one well per 4.0 acres of mine unit, all wells in the monitoring ring, and wells in aquifers above and below the confining layers of the production zone. Wells will be sampled for proposed parameters as shown in Table 9.8-1.

Based on statistical analysis of the data following ASTM Standard D 6312 (ASTM, 2001) to determine the baseline range of statistical variability of an indicator constituent, target restoration goals (TRG) will be established, which will be used to assess the effectiveness of groundwater restoration activities. Powertech will consult with SD DENR concerning the specific groundwater suite of constituents prior to well field baseline evaluation.

Sampling will follow the appropriate QA/QC procedures. Samples will be analyzed by a National Voluntary Laboratory Accreditation Program (NVLAP) accredited laboratory. Results will be submitted to the EPA and SD DENR on a quarterly basis as described below in Section 9.10 – Reporting.

Subsequent to establishing well field baseline, a groundwater monitoring program will be designed to specifically address each individual well field's lithology, and groundwater chemistry. Using designated analytes, UCLs will be established and monitored for during operations and TRGs will be established and monitored for during and subsequent to restoration.

Table 9.8-1 Baseline Water Quality Parameters and Indicators for Groundwater

Test Analyte/Parameter	Units	Method
BULK PROPERTIES		
pH	pH Units	A4500-H B
Total Dissolved Solids (TDS)	mg/L	A1030 E1, A2540 C
Conductivity	µmhos/cm	A2510B
CATIONS/ANIONS		
Chloride	mg/L	E300.0
Sulfate	mg/L	E300.0
Total Alkalinity (as $CaCO_3$)	mg/L	A2320 B
TRACE METALS		
Arsenic, As	mg/L	E200.8
Iron, Fe	mg/L	E200.7
Lead, Pb	mg/L	E200.8
Manganese, Mn	mg/L	E200.8
Strontium	mg/L	E200.8
Uranium, U	mg/L	E200.8
Vanadium	mg/L	E200.7, E200.8
RADIONUCLIDES		
Gross Alpha=Alpha Particles	pCi/L	E900.0
Gross Beta=Beta Particles and Photons	mRem/Year	E900.0
Radium-226	pCi/L	E903.0
Radon-222	pCi/L	D5072-92

9.9 Excursions

This section addresses **CI–10 (3)**.

The monitoring program described above will be used to protect USDWs in the event that well casings fail. Monitoring of wells, completed into the aquifers above and below the mining zone, will occur twice a month to check fluid levels and changes in water quality. During operations, lixiviant will enter the ore-bearing formation through the injection wells and is drawn to the recovery/production wells. Each individual well field within a production zone monitor well ring will produce a localized cone of depression

by recovering more groundwater than is injected. This induced gradient in groundwater movement from the surrounding area toward the well field will serve as a control over lixiviant excursions. If an excursion occurs, an increase of the cone of depression to pull back fluid is the first line of defense. If concentrations decline within 60 days after the excursion is verified, no further corrective action will be implemented. Additional measures will be implemented, such as drilling and pumping of wells inside the monitor well ring near the well that is on excursion to pull back the excursion inside the monitor well ring, if a declining trend does not occur in a reasonable time period, i.e., 60 to 90 days. After a significant declining trend is established, normal operations will resume and be maintained as long as the declining trend continues and concentrations return to acceptable levels. Best Management Practices and Best Practicable Technology will be employed throughout the excursion detection and response phases. Powertech has proposed an extensive monitoring plan that will ensure early detection of possible lixiviant escaping from the well field(s), see Sections 9.5 and 9.8 also. Therefore, Powertech is proposing that due to the extent of monitoring for both horizontal and vertical movement near and within the location of mining that to monitor a quarter mile via an arbitrary well, would not serve to add a protective element to the proposed monitoring program.

9.9.1 Injection Fluid Characterization

The injection fluid will be sampled monthly. Samples will be collected from or before the wellhead following the appropriate QA/QC procedures. Changes to the injection fluid composition will result in an additional sampling event followed by regular monthly sampling and analysis. Samples will be submitted to an EPA certified commercial laboratory for the analyses detailed above in Section 9.8.1 – Groundwater Quality.

9.10 Reporting

At minimum, the quarterly monitoring reports will include the following information:

- Physical, chemical and other relevant characteristics of injection fluids
- Monthly average, maximum and minimum values for injection pressure, flow rate and volume
- Additional monitoring results as discussed above
- Periodic MIT results
- Any well maintenance activities

Appendix I contains an example of the quarterly monitoring report form (EPA Form 7520-8, Rev. 8-01) required by the EPA.

Signed quarterly reports will be submitted electronically unless otherwise directed by the EPA. If required, a signature letter from the Project Manager will accompany the disk to certify the report. Reports will consist of monthly summary information for the project. Monitoring reports will include raw data and graphical analysis for the current reporting period to date. Each calendar quarter, the maximum, minimum, and average monthly values for each monitored parameter specified for the injection wells will be tabulated. A narrative description of any deviations from permit limitations will be given. Maintenance activities, MITs, or other significant events that took place during the reporting period will be described. If an excursion is detected by an increase in upper control limits of the excursion detection parameters of uranium, sulfate or chlorides is detected, it will be reported verbally within 24 hours and followed up in written form.

In accordance with South Dakota requirements casing MIT or resistivity logs will be implemented every 5 years.

9.11 Recordkeeping

All monitoring information, including calibration and maintenance records and data from the continuous monitoring instrumentation will be retained for at least 3 years after all wells have been plugged and abandoned. Other information to be retained is as follows:

- Information on the nature, volume, and composition of all injected fluids until three years after all the wells have been plugged and abandoned
- Results of MITs, any other tests required by EPA and/or SD DENR, and any well work-overs completed

The records discussed above (originals or copies) will be retained on site unless written approval to discard the records is provided by the EPA and SD DENR.

Copies of these records (or originals) will be maintained for all observation records throughout the operating life of each well. These records will be made available for inspection at the facility and retained unless written approval to discard the records is provided by the EPA and SD DENR.

9.12 Groundwater Sample Collection Methods

This section has been prepared in accordance with ARSD 74:55:01:26(10).

9.12.1 Ground Water Monitoring

Powertech's groundwater monitoring program is designed to establish baseline water quality prior to mining and along with other production zone wells, determine when production zone aquifer has been adequately restored following mining.

9.12.1.1 Collection Methods

The water quality sampling and analysis requirements were determined based upon references listed in ARSD 74:54:01:06. The USGS "National Field Manual for the Collection of Water-Quality Data; Techniques of Water-Resources Investigations Book 9" (TWRI) methods employed for cleaning of equipment, collection of water samples, and field measurements. This manual can be found using the reference listed within the Reference section of this document or obtained via the USGS website: http://water.usgs.gov/owq/FieldManual/.

9.12.1.2 Preservation Procedures

The preservation procedures utilized are the measures Powertech takes to prevent reduction or loss of target constituents. There are physical, chemical and biological processes that can result in precipitation, adsorption, oxidation, reduction, ion exchange, degassing, or degradation of a sample. Therefore, proper preservation techniques to stabilize the constituent concentrations for a specified holding time are vital for proper analysis. Sample preservation protocol in the TWRI; Chapter A5. (Wilde, F.D., 2004) was utilized during the baseline water quality sampling effort.

9.12.1.3 Quality Control

Quality control is included into each procedure. Elements contained within the quality assurance program include but are not limited to:

- The organizational structure, responsibilities, and qualifications of both the management and the operational personnel
- Specification and qualifications of personnel
- The SOPs used in the monitoring programs

- The records of samples, from collection to shipping to analysis
- The records of quality control of the sample analyses, including results of quality
- control blanks, duplicates, and cross-checks performed by other laboratories
- The calibration and operation of equipment used in obtaining samples, measuring radiation, etc.
- Data verification and validation procedures
- The data and calculations used to determine concentrations of radioactive materials, radiation doses due to occupational exposure, etc.

9.12.1.4 Minimum Detection Levels

The analytical methods utilized and minimum detection limits (MDLs) are consistent with the MDLs provided by Region 8 EPA (Table 9.2-2).

9.12.1.5 Laboratory Information and Signature(s)

Energy Laboratories Inc. preformed the analysis for baseline characterization. Laboratory Identification Numbers are as follows: main laboratory in Casper, Wyoming has an EPA ID of WY00002; the radiochemistry laboratory in Casper, Wyoming has an EPA ID of WY00937; the laboratory in South Dakota has an EPA ID of SD00012 (see Figure 9.12-1 for signatures and laboratory verification letter, in accordance with ARSD 74:55:01:26(10).

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March 20, 2009

Cory Foreman
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Energy Laboratories Inc. was the analytical laboratory that conducted the Dewey Burdock preoperational surface water and groundwater analysis from July 2007 through February 2009. The project was managed out of the Rapid City Branch at 2821 Plant St. in Rapid City, SD. Our Casper Branch at 2393 Salt Creek Hwy in Casper, Wyoming conducted the metal and radiological analysis. All sample runs were accompanied by quality control and quality assurance practices. Rapid City Energy Laboratory EPA code is SD00012. Casper's EPA code is WY00002.

Linda Larson

Branch Manager
Energy Laboratories Inc
2821 Plant St
Rapid City, SD 57702
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Figure 9.12-1 Energy Laboratory Identification and Signature Sheet

Section 10.0 - Method of Operation

This section addresses **CI–4 (11) (b)**.

The Project will consist of well fields, comprised of injection, production, and monitor wells, satellite ion exchange (IX) production facilities, and a central processing plant (CPP), consisting of an elution (resin stripping) system and precipitation and drying and packaging processes to produce a final uranium product (yellowcake). In addition, the Proposed Action will include, waste management facilities, office buildings and other structures or facilities to house work areas and equipment.

It is anticipated that the well fields at each site will operate at an estimated flow rate of between 1500 gallons per minute (gpm) to 2000 gpm. Uranium will be extracted and loaded onto ion exchange resin at both the Dewey and Burdock locations (Refer to Exhibit 10-1 for the preliminary Future Well Fields diagram). Uranium extracted and loaded onto the ion exchange resin at the Dewey site will be transported via truck to the CPP at the Burdock site for elution, precipitation, drying and packaging. The uranium extracted and loaded onto the ion exchange resin at the Burdock site will be pumped to the central ion exchange stripping columns at the Burdock CPP (same building) for elution (stripping), precipitation, drying and packaging. The barren resin will be returned to the appropriate portion of the ion exchange circuit. Total production from both sites is expected to produce approximately 1,000,000 pounds of U_3O_8 per year, approximately evenly divided into 500,000 pounds per year at each processing site from the well fields located in each area.

10.1 Description of Proposed Injection Solution

10.1.1 Proposed Lixiviant

This section addresses **CI–4 (11) (b)**.

The general process of in situ recovery involves the oxidation of reduced uranium from an ore-bearing aquifer using a leaching solution (lixiviant) to solubilize the uranium ion. In the U.S., lixiviant, most commonly used are alkaline solutions prepared using natural groundwater fortified with a carbonate/bicarbonate complexing agent and gaseous oxygen as an oxidizing agent. The uranium-rich (pregnant) lixiviant is pumped back to the surface through recovery wells. After recovery of the uranium on ion exchange resin, the then barren lixiviant is pumped back to the well field to be reinjected into the injection wells in the well field, thus recycling the natural groundwater.

The pregnant lixiviant is pumped to the ion exchange columns located in the central processing plant or in the satellite facility. In the ion exchange columns, the uranium is adsorbed onto resin beads that selectively remove uranium from solution. At the central processing facility, the uranium is eluted (stripped) from the resin with a solution of salt (NaCl) and soda ash (Na_2CO_3), precipitated by hydrogen peroxide (H_2O_2), filtered, dried and packaged as yellowcake (U_3O_8). Barren lixiviant is recharged with carbonate/bicarbonate and oxygen and returned through the injection wells to dissolve additional uranium. The efficiency of uranium ISL will, in part, depend on proper selection of the solution lixiviant used to recover uranium from the ore body. The ideal lixiviant will oxidize uranium in the ore and will contain a complexing agent that will dissolve and form strong aqueous complexes that interact little with the host rock (Davis and Curtis, 2007).

The PA proposes to use an alkaline lixiviant that is based on carbonate/bicarbonate added as sodium bicarbonate or carbon dioxide gas as the complexing agent and gaseous oxygen gas as the oxidizing agent. Native groundwater will be circulated through the ore zone and the ion exchange columns with the addition of carbon dioxide and oxygen to oxidize and to complex the uranium to Uranyl Carbonate which

is both soluble and recoverable on the ion exchange resin. The PA proposed lixiviant is presented in Table 10.1-1.

Table 10.1-1 Typical Lixiviant Composition

Constituent	Units	Concentration Range	
		Minimum	Maximum
Calcium	mg/L	≤20	1,000
Sodium	mg/L	≤400	6,000
Magnesium	mg/L	≤3	200
Potassium	mg/L	≤15	300
Chloride	mg/L	≤200	5,000
Carbonate	mg/L	≤0.5	2,500
Bicarbonate	mg/L	≤400	5,000
Sulfate	mg/L	≤400	5,000
Uranium	mg/L	≤0.01	900
Vanadium	mg/L	≤0.01	100
pH	Std units	≤6.5	10.5
Total Dissolved Solids, TDS	mg/L	≤1650	12,000

Notes: Table adapted from USNRC (2008) Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities-Draft Report for Comment. NUREG-1910. July 2008.

Preliminary results regarding leach tests are useful in determining general water quality post mining, yet, there is the potential for high variability to exist from one well field to another. This is one of the reasons each well field will be submitted in its own specific package (containing the well field water quality results from leach testing within the designated portion of the aquifer containing ore) separately to agencies for administrative review and approval. Refer to (Table 11.6-1) for the estimated preliminary post mine water quality.

10.1.2 Chemical Storage

The ISL process requires chemical storage and feeding systems to store and feed chemicals at various stages in the extraction, processing and waste treatment processes. Each chemical storage system will be designed to safely store and accurately deliver process chemicals to their intended delivery point in the process. Design criteria for chemical storage and feeding systems include applicable sections of the international building code, international fire code, Occupational Safety and Health Administration (OSHA) regulations, Resource Conservation and Recovery Act (RCRA) regulations, and Homeland Security rules. Both the Dewey and Burdock sites will have outside storage tanks for carbon dioxide and oxygen (Exhibits 4-2 and 4-3). At the Burdock site, additional outside storage tanks will be provided for storage of hazardous chemicals including acids, hydrogen peroxide, propane and sodium hydroxide. Additional storage tanks inside the central processing plant will be provided for the more innocuous elution salts that are transported to the site as dry solids.

10.2 Possible Chemical Reactions During Operations

10.2.1 Chemical Reactions

Insoluble minerals such as uraninite (UO_2(solid)) and coffinite ($USiO_4$(amorphous)) will undergo oxidation from the U_4^+ to U_6^+ oxidation state following injection of lixiviant into the ore body. The oxidation of uraninite can be written in the following reaction:

$$UO_2(s) + ½O_2. \leftrightarrows UO_3(s) \qquad [1]$$

Gaseous carbon dioxide forms both bicarbonate and carbonate ions in solution according to the following pH dependent reactions, where bicarbonate is the predominant carbon-containing specie at slightly alkaline pH values and carbonate the predominant form in more alkaline solutions.

$$CO_2(g) \leftrightarrows CO_2(aq.) \quad [2]$$

$$CO_2(aq.) + H_2O \leftrightarrows H_2CO_3 \quad [3]$$

$$H_2CO_3 \leftrightarrows HCO_3^- + H^+ \quad [4]$$

$$HCO_3^- \leftrightarrows CO_3^{2-} + H^+ \quad [5]$$

The use of sodium bicarbonate as a complexing agent produces dissolved bicarbonate ion directly, as shown in reaction 6. Once dissolved, the bicarbonate ion can then participate in reactions [2] through [5].

$$NaHCO_3 \rightarrow Na^+ + HCO_3^- \quad [6]$$

The sodium added through the addition of sodium bicarbonate is expected to remain in solution since the sodium salts of most compounds are highly soluble.

Once oxidized to the U^{6+} oxidation state, the uranium (VI) oxide is soluble as a carbonate complex by the following reactions.

$$UO_3(s) + 2HCO_3^- \rightarrow UO_2(CO_3)_2^{2-} + H_2O \quad [7]$$

$$UO_3(s) + CO_3^{2-} + 2HCO_3^- \rightarrow UO_2(CO_3)_3^{4-} + H_2O \quad [8]$$

The oxidation and dissolution reaction for coffinate is represented in Reaction 9

$$USiO_4 + 2HCO_3^- + 0.5O_2 + H_2O \rightarrow UO_2(CO_3)_2^{2-} + H_4SiO_4 \quad [9]$$

The solubility of each uranyl carbonate species is a function of pH (measure of acidity), Eh (measure of oxidation potential) and the concentration of carbonate/bicarbonate ions in the leaching water (lixiviant). The aqueous uranium complexes will be recovered by passing the pregnant lixiviant, containing 10 to 900 mg/L uranium in solution, through columns containing ion exchange resin beads. The complexed uranium is exchanged with another anionic species (usually chloride, Cl^-) at the reactive resin sites (represented as R^+ where $R^+ + Cl^- = RCl$) as shown in Reaction 10 using the uranyl dicarbonate complex ($UO_2(CO_3)_2^{2-}$):

$$UO_2(CO_3)_2^{2-} + 2RCl = R_2UO_2(CO_3)_2 + 2Cl^- \quad [10]$$

10.3 Proposed Injection Rate and Fluid Compatibility

This section addresses **CI–6 (5)**.

10.3.1 Injection Rate

Accurate assessment of water balance for each well field is achieved by monitoring the extraction (production) and injection rates and volumes. A bleed system will be employed that will result in less solution injected than total volume of fluids (native groundwater and lixiviant) extracted. A bleed of at least 0.5 percent will be maintained during production. This bleed will cause an inflow of groundwater into the production area and prevent the loss of lixiviant solution. At each site, a bleed stream of 0.5-1.0 will be removed from the production fluid prior to reinjection, at 1.0 percent bleed and a nominal production

flow rate of 2000 gpm at each site, these bleed streams will be 20 gpm each. The bleed streams may be increased to as high as three percent if necessary to pullback an excursion. The primary purpose of removing the bleed stream is to produce the cone of depression that confines the mining solution to the ore zone, but a secondary purpose is the removal of sulfate and chloride ions, with accompanying cations, which will be present at elevated concentrations as a result of the mining process. This removal of ions will be significantly higher under the deep disposal option due to the use of reverse osmosis units.

Injection rate is equivalent to corresponding production rate minus the bleed taken at any given time. 4,000 gpm is the expected daily average for the entire project. This production rate will be divided between the two sites as previously stated above. Average daily injection will be equivalent to the production rate minus a bleed between 0.5 and 3% of the total production flow.
On an annual basis, maximum injection rates are not expected to exceed the nominal rate by more than 20%.

10.3.2 Injection Fluid Compatibility

ISL uses the formation fluids as the injection fluids this negates any concern of compatibility issues. The additives to the injection fluid are Oxygen and Carbon Dioxide; both occur naturally in the oxygenated side of the roll front. While the injection fluid will cause minerals to oxygenate in the reduced area, there will be nothing created that does not naturally occur on the oxygenated side of the redox boundary. The injection and formation fluids will be fully compatible.

10.3.2.1 Ore Amenability to Solution Mining

The uranium deposit within the PAA has the geologic and hydrologic features that make a uranium deposit suitable for ISL as detailed in the Nuclear Regulatory Commission Draft Generic Environmental Impact Statement (USNRC, 2008) based on Holen and Hatchell (1986), specifically:

- Deposit geometry is generally horizontal and of sufficient size and lateral continuity to economically extract uranium.
- The sandstone host rock is permeable enough to allow the mining solutions to access and interact with the uranium mineralization.
- The confining layers (Skull Creek Shale and Morrison Formation) will prevent lixiviant from vertically migrating into overlying or underlying aquifers.
- The mineralization to be mined is located in a hydrologically saturated zone.

The amenability of the PA mine zone to ISL methods is demonstrated by the pumping test results presented in Section 13.2 and the operating information provided in Section 10.0. Additional information is provided in the following subsection.

10.3.2.2 Lixiviant Compatibility with Ore Body

Laboratory bottle roll tests have been conducted by Energy Laboratories of Casper Wyoming on ore samples from both the Fall River formation and Lakota formation using a simulated lixiviant composed of hydrogen peroxide and sodium bicarbonate dissolved in deionized water.

In the tests, a crushed ore sample was successively contacted with five pore volumes (PVs) of fresh lixiviant for a total of six leach cycles comprising a total of 30 PVs of lixiviant. After each leach cycle, uranium and other dissolved specie concentrations were measured. Results of these leach studies are shown in Table 10.3-1. Four separate tests were conducted, with one ore sample from the Lakota formation and three ore samples from a single hole in the Fall River formation. The ore samples had ore grades ranging from 0.07 to 0.70 weight percent (wt%) uranium, and produced pregnant lixiviants with

uranium concentrations as high as 1600 mg/L. Over the course of the 30 PV test, analysis of the resulting leach solutions indicated uranium recoveries of 59 to 90 percent.

Table 10.3-1 Results of Laboratory Leach-Amenability Study

		Hole 11-4C	Hole 32-2C		
	Formation	Lakota	Fall River		
Ore Grade	Wt% U	.07	.20	.74	.14
U Recovery	%	76.6	58.6	73.5	89.9

10.3.2.2.1 Mineralogy of the Uranium Ore

The uranium mineralization is present as a coating on the sand grains and within the pore spaces of Inyan Kara sandstone. Within the Edgemont Uranium District, the dominant uranium minerals are coffinite and uraninite with minor paramontroseite, haggite, fourmarierite, carnotite, and tyuyamunite (Schnabel, 1963). Based on TVA core assays, the uranium is often associated with vanadium in a ration of 1:1.5. The samples tested come from several different mineralized zones but may or may not be representative of the majority of the mineralization throughout the project site.

10.4 Proposed Volume of Fluid Injected

Refer to Section 10.9.4.3 for more information regarding proposed injection fluid volume and flow rates.

10.5 Proposed Injection and Extraction Procedure

The well field will consist of either 5-spot or 7-spot patterns or other regular geometric shapes. A typical 5-spot pattern contains four injection wells at the corners of a square and one production well in the center. A typical 7-spot pattern is in the shape of a hexagon with the production well in center. The well fields will be based on 70x70-foot or 100x100-foot grids where injection wells will be spaced 70 or 100 feet apart depending on the chosen grid. The wells will be completed so that they can be used as either injection or production wells. The production well will be equidistant from all injection wells serving that production well and equidistant from each other.

10.5.1 Injection Procedure Description

Barren lixiviant will be injected into the injection wells and pregnant lixiviant will be recovered through the production wells. A cone of depression in the well field will be maintained by recovering a greater volume of solution than is injected. The cone of depression will help to control the movement of lixiviant away from the well field. The bleed will be approximately 0.5 - 1 percent of the total well field production rate but may be up to 3 percent. The bleed will be disposed of using holding ponds and land application, or deep disposal well, or a combination of both. The bleed will be treated to remove uranium and radium to acceptable levels. It is anticipated that trace metal concentrations will be at or below EPA Primary Drinking Water Standards. In addition, the effluent concentration limits for the release of radionuclides to the environment as contained in 10 CFR Part 20, Appendix B will be met. Specific details of estimated land application water quality are beyond the scope of a Class III UIC application, however, land application water quality will be discussed with the DENR and addressed within a groundwater discharge plan. The design of the land application system was developed based on modeling using the SPAW model, which is described in Section 4.0 of the Technical Report submitted to NRC. Based upon preliminary data modeled, estimated land application water quality is depicted in Table 10.5-1. Oxygen will be added to the barren lixiviant prior to injection. The oxygen will be fed into the barren lixiviant header via a common connection or through the individual injection well pipes. Solenoids will automatically shut off the oxygen supply during power failure to reduce the risk of oxygen leaks in the lixiviant injection piping.

Carbon dioxide will be added to the barren lixiviant under pressure downstream of the ion exchange resin vessels and the barren solution injection pumps.

Provisions for spills are described in Section 11.3.1. The manifolds will be visually inspected once a day. Meters and control valves will be installed in the individual well lines to monitor flow rates and pressures. The individual well flows and pressures will be monitored and adjusted daily. Flow meters will also be installed on the main pipelines entering and exiting each header house and monitored continuously. The pipeline pressures will be monitored continuously for indications of spills and leaks. The wellheads will be visually inspected once a month.

10.5.2 Extraction Procedure Description

Approximately 0.5 to 3.0 percent of the barren lixiviant, referred to as the production bleed, is removed from the circuit, and sent to wastewater disposal. The production bleed ensures that more groundwater is extracted than re-injected, maintaining a cone of depression surrounding the network of wells. Maintaining this negative water balance serves to ensure that there is a net inflow of groundwater into the well field to prevent the potential movement of lixiviant and the associated contaminants out of the well field.

Table 10.5-1 Estimated Land Application Water Quality

Parameter	Units	Dewey Land Application	Burdock Land Application
pH	s.u.	6.5-7.5	6.5-7.5
Eh	mV	350	350
cond.	mS/cm	4	4
Major Ions			
Bicarbonate	mg/L	<50	<50
Calcium	mg/L	270	330
Carbonate	mg/L	<1	<1
Chloride	mg/L	300-1200	300-1200
Fluoride	mg/L	0.4	0.3
Nitrate	mg/L	<0.1	<0.1
Nitrite	mg/L	0	0
Sodium	mg/L	260	230
Sulfate	mg/L	600	1100
Solids	mg/L	4000-5000	4000-5000
Minor Ions			
Antimony	mg/L	0.002	0.002
Arsenic	mg/L	<0.01	<0.01
Barium	mg/L	<0.1	<0.1
Beryllium	mg/L	<0.001	<0.001
Bromate	mg/L	NA	NA
Cadmium	mg/L	0.3	0.3
Chlorite	mg/L	NA	NA
Chromium	mg/L	0.3	0.3
Copper	mg/L	0.3	0.3
Iron	mg/L	1	1
Lead 210	mg/L	<10	<10
Magnesium	mg/L	120	220
Mercury	mg/L	<0.001	<0.001
Molybdenum	mg/L	<0.1	<0.1
Nickel	mg/L	0.05	0.05
Potassium	mg/L	10	20
Radium 226	pCi/L	<60	<60
Radon	pCi/L	<300	<300
Selenium	mg/L	<0.2	<0.2
Silver	mg/L	<0.005	<0.005
Thallium	mg/L	<0.001	<0.001
Thorium 230	pCi/L	<100	<100
U-Nat	pCi/L	<300	<300
Uranium	mg/L	<0.2	<0.2
Vanadium	mg/L	<10	<10

Table 10.5-1 Estimated Land Application Water Quality (Post-Treatment) (concl.)

Parameter	Units	Dewey Land Application	Burdock Land Application
Sodium Absorption Ratio		5.4	3.8
Cations	meq/L	29	39
Anions	meq/L	22	26
Zinc	mg/L	0.01	0.01
A/C balance	%	14	19
TDS Calc.	mg/L	1500	2100
Gross alpha particle activity, excluding radon and uranium	pCi/L	<15	<15

Notes: 1) Estimates of land application water quality were based on the results of laboratory scale leach tests conducted on ore samples from the Dewey (Fall River) and Burdock (Lakota) sites, as well as from historical end-of-production water quality data from other ISL sites in Wyoming and Nebraska, with adjustments as necessary to account for planned post-production water treatments.
2) For the anion computation, a chloride concentration of 300 mg/L was used.
3) For the calculated TDS computation, a chloride concentration of 800 mg/L was used.

The bleed stream will be separated from the bulk flow of lixiviant in a reverse osmosis process that separates a portion of the lixiviant flow into two streams: A relatively clean permeate stream and a reject brine that contains a higher level of dissolved solids, including radium and other contaminants. The reverse osmosis permeate stream is combined with the barren lixiviant for re-injection into the well field, while the reject brine will be directed to disposal in a Class V disposal well; physical proposed locations can be reviewed in Exhibit 4-4. Details of a specific injection formation will be discussed with EPA and DENR and specifically addressed within a UIC Class V application. Any deep disposal well located within the proposed project boundary will be located below the Inyan Kara. If no disposal wells are available within or nearby the permit boundary, the alternate waste water disposal method of land application will be used. In this latter case, the bleed stream will not be concentrated through a reverse osmosis process, but will be treated with additional ion exchange to remove residual uranium, followed by contact with barium chloride to remove radium.

As groundwater is re-circulated via the ISL process, subsidence (near surface or deep) impacts from the project are expected to be negligible or non-existent due to the compaction of the cretaceous system within the PAA. The project is not expected to have a significant effect on subsidence or matrix compression because the net withdrawal of fluid (bleed) from the extraction zone is generally on the order of 3 percent or less, and the ISL process does not remove matrix material or structure. After restoration is complete, the groundwater levels are expected to return to pre-operational levels, and therefore, should not cause any near surface or deep subsidence (See Section 5 “Geologic Description” for more discussion on subsidence).

10.6 Well Field Schedule and Map

10.6.1 Well Field Map

Please refer to Exhibit 10-1 for a map of the first two well fields and proposed injection sequence.

10.6.2 Dewey-Burdock Well Field Schedule Summary

Figure 10.6-1 below, presents the Operations Summary Schedule, which addresses **CI–4 (12) (b) and (18) (b)**.

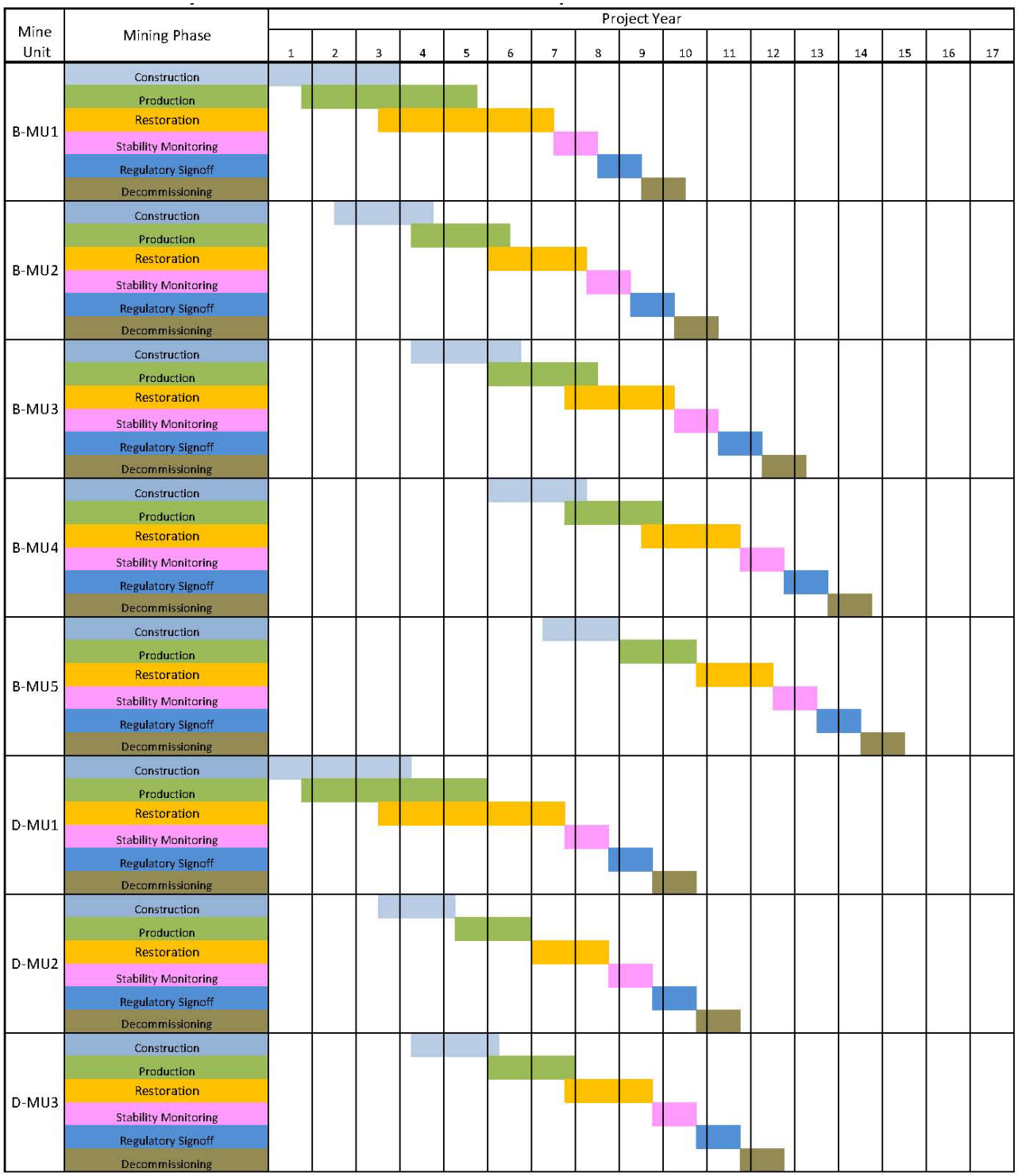

Figure 10.6-1 Operations Summary Schedule

10.7 Changes in Fluid Pressure

The following sections address anticipated changes in pressure, native groundwater displacement, and the direction of movement of injection fluid. Refer to Section 11.5.1 for a discussion on impacts from the proposed action to water resources and water rights inside the permit area and on adjacent lands and the proposed mitigation steps.

10.7.1 Changes in Fluid Pressure

This section addresses **CI–4 (12) (c)**.

Well patterns consist of production wells that are surrounded by injection wells. Initially native groundwater is withdrawn from the production wells and brought to the surface so it can be chemically treated in such a way that it will serve as the uranium mobilizing lixiviant. The treated solution will then be injected back into the production zone and drawn across the uranium ore body. As the treated solution comes in contact with the ore body, uranium goes into solution and is mobilized to the production wells and brought to the surface for extraction.

All well patterns will be designed in such a way that the amount of production fluid always exceeds the amount of fluid being injected into the well pattern. The difference in the rate of fluid production and fluid injection within a well pattern is referred to as the bleed stream, and depending on the site specific hydrology, typically ranges from about 0.5% to 3%. The production bleed insures that more groundwater is extracted than that being injected maintaining a negative pressure gradient (cone of depression) in the direction of production wells. Monitoring and maintaining this negative pressure gradient serves to ensure that there is always a net inflow of groundwater into the well field to prevent the potential movement of lixiviant and the associated contaminants out of the well field.

10.7.1.1 Changes in Bleed Stream

A median bleed stream of one percent of 2,000 gpm, or 20 gpm from each well field, will be used to control increase in sulfate and chloride ions and equivalent cations by withdrawing the sulfate and chloride ions at the rate of addition. The withdrawal will increase with the concentration to come in balance with the generation of the ions. Well field formation water from the mining zone will be the source of the injection fluid, so fluid displacement will be minimal. The bleed stream will create a small (0.5 to 3 percent) flow of surrounding groundwater into the mining zone (Table 10.7-1).

Table 10.7-1 Changes in Bleed Stream

Percent Bleed	Utilization Purpose
0.5	Low
1.0	Medium
3.0	Maximum
0.5-3.0	Design Range
0.5-1.0	Typical Operating Range
1.0-3.0	Excursion Control

10.8 Estimated Native Groundwater Displacement

10.8.1 Recharge and Consumptive Use Estimates

The Project area encompasses about 10,580 acres or 16.5 square miles, and extends for about 38,500 ft along a northwest-southeast trend parallel to the mountain front and recharge area where the Lakota and Fall River aquifers outcrop. To make water balance estimates, a distance of 64,000 ft, or about 1.7 times the length of the Project area along parallel to the outcrop, was used to for calculation of recharge and aquifer discharge in and near the Project area. The Fall River Formation has an outcrop recharge area

(including overlying alluvial material and excluding isolated outcrops) of about 13 square miles, and the Lakota Formation (including the Fuson Member and overlying alluvium) has an outcrop area of 20 square miles (RESPEC, personal communication, 2008).

Estimates of aquifer recharge are based on analysis of hydrologic data for the Black Hills area by the U.S. Geological Survey (Carter et al., 2001). Average annual precipitation over the outcrop area adjacent to the Project is about 16.5 to 17.5 inches per year (see Figure 12 in Carter et al., 2001). Figure 16 in Carter et al. (2001) indicates that about 2 to 3 percent of precipitation is available to bedrock aquifers as recharge. Thus recharge estimates for the Fall River and Lakota formation aquifers can be calculated as follows:

- Fall River: 0.33 to 0.525 inches per year times 8,320 acres = 230 to 365 acre-ft/year
- Lakota: 0.33 to 0.525 inches per year times 12,800 acres = 350 to 560 acre-ft/year

The above annual recharge estimates correspond to about 140 to 225 gpm for the Fall River Formation and 215 to 345 gpm for the Lakota Formation. Existing discharge estimates were prepared by tabulating 73 known wells in the Project area. Based on the census, it estimated that 52 gpm is withdrawn from the Fall River Formation due to well discharge, and about 80 gpm existing well discharge was estimated for the Lakota Formation (RESPEC, personal communication, 2008).

10.8.1.1 Flare Factor

According to the NRC, flare factor is defined as *a proportionality factor designed to estimate the amount of aquifer water outside of the pore volume that has been impacted by lixiviant flow during the extraction phase. The flare is usually expressed as a horizontal and vertical component to account for differences between the horizontal and vertical hydraulic conductivity of an aquifer material* (USNRC, 2003). Horizontal and vertical flares are usually expressed as a multiple of the calculated pore volume. However, according to NUREG/CR-6870, zones with low permeabilities have proven more of a concern than in a well field where the balance is maintained. Operator will balance well fields on an individual pattern basis. Powertech believes this is the most effective way to mine an in situ well field and is the most effective way to restore groundwater. The operator will balance individual wells that are in operation and production every day. This method reduces the pore volumes for mining and for restoration and minimizes excursions beyond the flare zone. The restoration volumes are based on historical experience and are in relation to this method of operation. Upon well field development, inclusive of detailed delineation drilling and completion of well field design, the applicant will be in a position to calculate flare, however, due to the protective processes in practice during mining and restoration to control potential displacement, estimation of vertical and horizontal flare may not be required. Protective processes include maintaining a hydrologic bleed in each mine unit to prevent lateral movement of mining fluid and utilizing the monitor well ring around the well fields and monitoring during restoration to ensure containment of any potentially displaced mining fluid. In addition, the operator will correct any observed displacement of mining fluids in a timely manner as required by regulations. Vertical displacement is of less concern due to the presence of overlying and underlying aquitards.

10.9 Direction of Movement of Mining Solution

This section addresses **CI–4 (12) (c)** and **CI–6 (4)**.

10.9.1 Discharge Estimate – Fall River Aquifer

To generally quantify the aquifer properties for the Fall River Formation the following assumptions were used:

- Formation thickness: average 120 feet

- Formation hydraulic conductivity: 0.5 ft/d
- Formation transmissivity: 60 ft^2/d
- Formation storativity: 4 x 10^{-5}
- Average hydraulic gradient (0.005 to 0.01 ft/ft)

The overall transmissivity of 60 ft^2/day for the Fall River Formation assumed for the project area impact modeling is considerably less than the 255 ft^2/day determined in the 2008 pumping test at the Dewey project area (Knight Piesold, 2008). However, a barrier boundary that was attributed to decrease in transmissivity surrounding the pumping well was also noted in the 2008 test. The aquifer transmissivity and horizontal hydraulic conductivity of 0.5 ft/day are verified with an estimate of discharge and water balance.

The Project area water balance for the Fall River aquifer compares recharge less existing consumptive use to estimated aquifer discharge. The aquifer discharge equals transmissivity times regional hydraulic gradient times width (64,000 ft). Hydraulic gradients based on recent measurements in the Fall River aquifer in the Project area range from about 0.005 to 0.01 ft/ft (Knight Piesold, 2008). The transmissivity of 60 ft^2/day yields a range of calculated aquifer discharge from 100 to 200 gpm. This balances with recharge estimates of 140 to 225 gpm less 50 gpm of consumptive use.

Thus the transmissivity of 60 ft^2/day is appropriate for modeling the Fall River aquifer, recognizing that there are locally much thicker and more transmissive areas. This is substantiated by examination of regional cross-sections based on oil well logs (RMAG, 1972), and an isopach map for the lowermost Cretaceous formations, which finds that the northern portion of the project area is a local isopach maximum, and that the thickness of the Fall River Formation decreases to 100 feet or less west of the project area.

10.9.2 Discharge Estimate – Lakota Aquifer

To generally quantify the aquifer properties for the Lakota Formation the following assumptions were used:

- Formation thickness: average 150 feet
- Formation hydraulic conductivity: 2.0 ft/day
- Formation transmissivity: 300 ft^2/d
- Formation storativity: 4 x 10^{-4}
- Average hydraulic gradient (0.003 ft/ft)

The overall transmissivity of 300 ft^2/day (2,240 gallons per day per foot [gpd/ft]) for the Lakota Formation assumed for the Project area impact modeling is greater than the 2008 pumping test value of 140 ft2/day at the Burdock site (Knight Piesold, 2008). The assumed transmissivity is at the upper end of the range reported for the 1979 TVA pumping test at Burdock (Boggs and Jenkins, 1980), but is less than 4,400 gpd/ft reported in 1982 TVA test north of the present project's Dewey site (Boggs, 1983). The aquifer transmissivity and horizontal hydraulic conductivity of 2.0 ft/day is verified with an estimate of discharge and water balance.

The Project area water balance for the Lakota aquifer compares recharge less existing consumptive use to estimated aquifer discharge. The aquifer discharge equals transmissivity times regional hydraulic gradient times width (64,000 ft). Hydraulic gradients based on recent measurements in the Lakota aquifer in the Project area are about 0.003 ft/ft (Knight Piesold, 2008). The transmissivity of 300 ft^2/day

yields a calculated aquifer discharge of 300 gpm. This approximately balances with the upper end of the range of recharge estimates of 215 to 345 gpm less 80 gpm of consumptive use.

Thus the transmissivity of 300 ft^2/day is appropriate for modeling the Lakota aquifer, recognizing that there are locally much thicker and more transmissive areas, particularly at the Dewey Project site. This is substantiated by examination of regional cross-sections based on oil well logs (RMAG, 1972), and an isopach map for the lowermost Cretaceous formations, which finds that the northern portion of the project area is a local isopach maximum, and that the thickness of lower Cretaceous units including the Lakota Formation decreases west of the project area.

10.9.3 Drawdown Estimates

The Theis analytical solution includes the following assumptions (Driscoll, 1986):

- The aquifer is homogeneous and isotropic (same hydraulic conductivity everywhere)
- The aquifer is confined with uniform thickness and has infinite extent,
- No recharge to the aquifer occurs,
- The pumping well is fully penetrating and receives water from the full thickness of the formation,
- All water removed from the well comes from aquifer storage which is discharged instantaneously when the head is lowered,
- The piezometric surface is horizontal prior to pumping,
- The well is pumped at a constant rate,
- The pumping well diameter is small so well bore storage is negligible.

Possible barrier boundaries for the aquifer system include the respective outcrops of the Fall River and Lakota formations generally east and north of the property boundary, as well as the Dewey Fault to the north and east of the property boundary. However, the Dewey Fault is considered likely to terminate both the Fall River and Lakota aquifers at some distance to the west. Therefore, just the outcrop was assumed to be a straight line barrier boundary and modeled with “image” pumping wells (e.g., Fetter, 1988) having the same pumping rates as the production wells for the Fall River and Lakota aquifers. A spreadsheet developed by the U.S. Geological Survey to calculate drawdown (Halford and Kuniansky, 2002) was used to make the confined aquifer prediction calculations.

10.9.4 Dewey-Burdock Well Field Operation

The PA will operate uranium ISL production facilities at both the Dewey and Burdock sites with a central processing plant located at the Burdock site. The Dewey-Burdock ISL well fields will consist of either 5-spot or 7-spot patterns. A typical 5-spot pattern contains four injection wells and one production well. The well fields will be based on 70x70-foot or 100x100-foot grids where injection wells will be spaced 70 or 100 feet apart depending on the chosen grid. The wells will be completed so that they can be used as either injection or production wells. A typical (100 x 100-foot grid) well field is shown on Exhibit 10-2. Each well field layout is designed to maximize the production of the specific delineation of ore located in the mining zone. Therefore, a 5-spot pattern may be utilized in one well field, while a 7-spot pattern may be utilized for a separate well field. These types of details will be submitted to regulatory agencies within individual well field packages.

The estimated maximum instantaneous injection flow rate is 4,200 gpm; the system is designed to operate at 4,000 gpm (2,000 at Dewey and 2,000 at Burdock) to produce 1 million pounds of U_3O_8 per year at the estimated average uranium concentration. However, the flow rate will be adjusted to maintain desired production levels. The fluid injection pressure is calculated and designed to be less than

formation fracture pressure and not exceed pressure rating of pipe used in well fields. The flow is nominal and controlled via injection booster pumps and manual flow control valves on the injection wells.

Injection pressure of the fluid will not exceed the formation fracture pressure and 80 percent of the minimum material strength of piping components. Pressure at the header house will be limited to the lowest mechanical integrity test passing pressure; therefore, will not exceed the published operating pressure for any piping component in the system. Average injection pressure at the pump discharge is estimated at 82 pounds per square inch gauge (psig).

It is anticipated that the ISL well fields at each site (Dewey or Burdock) will operate at an estimated flow rate between 1500 gpm to 2000 gpm; see pump test and step test information in Appendix B for additional information in support of pumping rates. Uranium extracted from well fields at the Dewey site will be loaded onto ion exchange resins and transported via truck to the Burdock site for elution, precipitation, drying and packaging.

10.9.4.1 Header House Control

Within each well field, injection and production wells will be connected to manifolds in a nearby header house (Exhibit 10-3). The manifolds will be connected to a series of pipelines that will carry solutions to and from the satellite facility or central processing plant (Exhibit 10-3). The manifolds will be visually inspected once a day. The wellheads will be visually inspected once a day. Meters and control valves will be installed in the individual well lines to monitor flow rates and pressures. The individual well flows and pressures will be monitored and adjusted daily with a digital recorder in order to balance individual patterns so that the flow rate from a pattern is more than the flow rate to the pattern, thus maintaining uniform distribution of leach solution and a cone of depression for each individual pattern. Flow meters will also be installed on the main pipelines entering and exiting each header house and monitored daily. The pipeline pressures will be monitored daily for indications of spills and leaks.

10.9.4.2 Detection and Cleanup of Piping Leaks

Leak detection will be performed by daily visual inspection of all above-ground pipe, connections, and fittings by field personnel during their daily site inspections. Operating pressures of all injection wells, recovery wells, and associated buried piping systems will also be monitored during these inspections. In addition, the pressure and flow in each line will be continuously monitored with results relayed to a central processing unit that is connected to a central alarm at the CPP. Should pressure/flow significantly fluctuate from established operating ranges, controls will cause deactivation of the affected component of the piping system. These controls will involve either operator oversight and/or automated systems. An operator will then inspect the troubled component and determine the root cause and extent of the problem. The troubled component will then be repaired, tested, and returned to service, as appropriate, and preventative measures will be implemented to prevent a recurrence.

Cleanup will involve characterizing the extent of release via visual observation coupled with sampling of soils for constituents of concern in accordance with a standard operating procedure.
Impacted material will be consolidated into a centralized area.

10.9.4.3 Pressure and Flow Rate

This section addresses **CI–10 (2)**.

The individual well field patterns are balanced daily by adjusting injection and production well flow rates and pressures. Production flow rates will be maintained greater than injection in each pattern and so that flow will be uniformly distributed in each pattern. Each pattern will have withdrawal greater than the injection to prevent outward flow of leach solution from each pattern. The fluid volume for each well will be determined by monitoring the individual pressure and flow meters daily.

- Production flow rates are estimated at 20 to 30 gpm per well.
- Fluid Volume – Daily maximum volume would not exceed 6.05 million gallons per day (mgd).
- The estimated maximum instantaneous injection flow rate is 4,200 gpm; most of the time the system will be maintained at a rate of 4,000 gpm.

The maximum injection pressure at the wellhead will not exceed formation fracture pressure. This pressure will not initiate new fractures or propagate existing fractures in the injection or confining zone or cause the migration of injection or formation fluids into any USDW.

10.9.5 Fracture Pressure

Powertech does not intend to utilize hydraulic fracturing within the company's ISL process. Consequently, no testing is intended. Powertech intends to operate its injection wells below the fracture pressure of formations where injection occurs. It is crucial for effective operation to maintain the native state of the formations in order to control lixiviant, especially within the existing confining units. This approach reduces the potential for damaging the formation layers and aids in preventing additional pathways for lixiviant. Therefore, due to the fact that such testing tends to increase the probability of creating confinement issues within the well field and the ISL mining process in general, no fracture testing is planned.

Fracture pressure varies with depth of well, specific gravity of rock type within the formation, and the pressure of overburden. Hydraulic pressure is the sum of surface pressure and pressure of the weight of the fluids contained in the wellbore. This sum is multiplied by depth:

Downhole psig = surface psig + (fluid gradient, psi/ft) (depth, feet)

Downhole injection pressures will be maintained below the formation fracture pressure.

Lixiviant used in this mining process has very near the same specific gradient as water (0.433 psi/ft). Therefore, maximum well head pressure (Max WHP) will not exceed the formation fracture pressure and will be calculated utilizing the industry accepted formula:

Max WHP= (fracture gradient – wellbore fluid gradient) (depth to open interval)

Fracture gradient is defined by the EPA as "a measure of how the pressure required to fracture rock in the earth changes with depth. It is usually measured in units of pounds per square inch per foot (psi/ft) and varies with the type of rock and the stress history of the rock. The default value used by Region 5 in Michigan is 0.8 psi/ft. This means, for example, that at a depth of 100 ft, a pressure of 80 psi would be required to fracture the rock, while at a depth of 500 ft, the required pressure would be 400 psi; at 1000 ft, 800 psi. The fracture gradient is used in the calculation of the maximum injection pressure."

The maximum allowable well head pressure (WHP) will be calculated on a well-by-well basis and operational controls will be put in place to prevent exceeding designated pressures. The maximum WHP accepted will be the lesser value determined for calculated WHP via fracture gradient and depth or that determined from MIT casing results. Wellhead surface injection pressure will be determined for each header house and posted near the injection trunk line gauge nearest to the injection wellhead and used to monitor injection pressure. This practice will ensure the formation fracture pressure is not exceeded according to ARSD 74:55:01:44. The formation fracture pressure proposed to be used for the project is 0.70 psi for every 1 foot of depth to the top of the screened interval. The depth to the top of the anticipated screened interval varies from approximately 200 to 600 feet in well fields at the PAA.

Section 11.0 - Groundwater Protection and Restoration

11.1 Procedures to Protect Over and Underlying Aquifers

This section addresses **CI–4 (12) (d)**.

11.1.1 Injection, Production and Monitoring Well Placement

Procedures implemented to ensure that the installation of recovery, injection, and monitor wells will not result in hydraulic communication between the production zone and overlying or underlying stratigraphic horizons include the following steps:

- Delineation of the well field
- Design of the well field; this includes injection, production, overlying and underlying monitoring wells
- Design of the production zone monitoring system; this includes the monitoring well ring outside of the well field
- Installation of all injection, production and monitoring wells
- Perform pumping test(s) to ensure there is no connection between injection and production wells to the overlying and underlying monitoring wells.

11.2 Procedures to Ensure Production Zone Monitoring Well Placement

This section addresses **CI–4 (12) (e)**.

11.2.1 Production Zone Monitoring Well Placement Procedure

Procedures implemented to ensure that the installation of recovery, injection, and monitor wells will result in hydraulic communication between the production zone and the placement of the production zone monitoring wells include the following steps:

- Delineation of the well field
- Design of the well field; this includes injection, production, overlying and underlying wells
- Design of the production zone monitoring system; this includes the monitoring well ring outside of the well field
- Installation of all injection, production and monitoring wells
- Perform pumping test(s) to ensure there is connection between injection and production wells to the monitoring wells located in a ring enclosing the well field.

11.3 Spill Contingency Plan

This section addresses **CI–4 (12) (g)**.

11.3.1 Spill Provision Plans

Procedures to assess and respond to potential spills will be the responsibility of the radiation safety department; engineers and operations supervisors will also assist in development of procedures. The Safety and Environmental Review Panel (SERP) will review the procedure(s) for effectiveness.

Procedures developed will implement appropriate protocol to handle potential spills of radioactive materials. Nine responsibilities comprise basic activities:

- Resources and manpower assigned
- Material and Inventory
- Identification of potential spill sources
- Spill reporting and visual inspection program established
- Review of past spill incidents
- Coordination among all departments for containment of spills
- Emergency response protocol established
- Program implementation, review and updating
- New construction and changes in process relative to prevention and control of spills will be reviewed
  - If a spill were to occur, there are basic procedures to follow that include:
    - Flag maximum extent of the spill
    - Sample medium where spill occurred
    - If contamination is above the maximum allowable concentration,
    - The contamination is removed and disposed of in a NRC licensed disposal facility.

There are two types of spills that may result from an in situ operation, surface releases and subsurface releases.

11.3.1.1 Surface Releases

Potential surface releases may be the result of a tank failure, ruptured pipe, or transportation incident. Erosion of existing soils has the potential to lead to a release of undesirable elements in addition to the aforementioned spills. The greatest likely hood of this type of release may occur during the construction phase of the project. Two types of Best Management Practices (BMPs) will be employed to minimize the effects of runoff during precipitation events. One type is erosion prevention practices and the second type is sediment control practices.

Erosion Prevention Practices utilize ground covers that prevent different types of erosion from occurring. Ground covers include but are not limited to:

- Vegetation
- Riprap
- Mulch
- Blankets

Sediment control practices prevent soil particles that are being carried in storm water from leaving the site. These types of controls may consist of:

- Silt fence
- Sediment traps
- Sediment basins
- Vegetative cover

Leaving as much of the vegetation in place for as much of the construction period as possible will reduce the potential for a precipitation event to cause significant erosion and soil loss on-site. Utilizing erosion prevention and sediment controls in combination will prevent sediment loss during a major precipitation event. In addition to the above mentioned controls, engineering design and administrative controls will also minimize and control erosion and runoff. Should a pipeline failure coincide with a precipitation event, there is potential for a release. Relative soil saturation beneath the leak area would be a determining factor to what extent the material would be able to be absorbed. In any event with rapid detection and quick spill response a pipeline failure and migration of solutions due to runoff would be minimal.

Failure of a process vessel will be contained within the CPP via berms and directed into a sump (equipped with a level alarm) that will allow the solution to be transported to appropriate tank or disposal system.

Piping system leaks is the most common source of surface releases that occur at an in situ facility. Generally these spills are small due to visual inspections each day and engineering controls set up to detect changes in pressure within the piping systems. Operators are alerted via an alarm system when pressure changes occur. Well field piping systems are constructed of PVC or high density polyethylene (HDPE) materials with butt welded joints or the equivalent. All pipelines will be pressure tested at operating pressures before put online. No additional stress is placed on the buried pipes so it is improbable a break would occur. The underground portions of the pipes are protected from vehicles and exposed pipes only occur at the wellheads and header houses. Trunkline flows and wellhead pressures will be monitored for process control. Spill response is specifically addressed in the Emergency Response Procedures.

In the event a spill from a pipeline occurs via leak or rupture, licensee will initiate immediate spill responses through onsite standard operation procedure (USNRC, 2003, Section 5.7). For example, immediate spill response may include shutting down the affected pipeline, recovering as much of the spilled fluid as possible, and collecting samples of the affected soil for comparison to background values for uranium, radium and other metals.

As part of the monitoring requirements the licensee must report certain spills to the SD DENR and NRC within 24 hours. These spills include those that cause unplanned contamination that meets the criteria of 10 CFR 40.60 and those spills that could cause exposures that exceed the dose limits established in 10 CFR 20 Subpart M. Additional reporting requirements may be imposed by the state or within the NRC license conditions. All reports and documentation of spills and corrective action will aid in final site decommissioning activities. Powertech will comply with applicable SD DENR permitting requirements for spill response and reporting.

Any spills that may occur of non-radiological materials is primarily reportable to the appropriate state agency (SD DENR) and/or the EPA.

Spills related to transportation will be addressed in Powertech's (USA) Emergency Response Action Plan. Specific actions involving response to a radioactive materials shipment will include instructions for appropriate packaging, documentation, driver emergency and accident response procedures and cleanup and recovery protocol. Any accident resulting in yellowcake or loaded ion exchange resin spills will result in immediate corrective action and reported to both the NRC and the SD DENR.

11.3.1.2 Subsurface Releases

Potential subsurface releases such as a well excursion may result in the minor migration of process fluids. Monitoring wells will be installed enclosing the well field for detection of any leach fluids that may potentially migrate away from the production zone. The monitoring well detection system is a proven method historically among ISL operations. Powertech (USA) proposes to locate a ring of monitoring wells no farther than 400 feet from the well field. These monitoring wells will be screened in the same zone as

the production well. There will be additional wells monitoring the aquifers above and potentially below the ore-bearing aquifer. Sampling of monitoring wells will occur on a weekly or bi-weekly basis. Recovery and monitoring work in conjunction, as a coordinated effluent control system, and has proven effective in early detection of recovery fluids for a number of reasons:

- Close proximity of monitoring wells to well field
- Low flow of production wells
- Cone of depression created from production bleed

The overall effect of the system makes non-detection highly unlikely.

Effluent controls for preventing migration of recovery solutions to overlying and underlying aquifers consist of:

- Plugging and Abandonment of all delineation holes .
- Conducting Mechanical Integrity Tests (MITs) on each well before it is put on line.
- Sampling the monitoring wells located within the overlying and underlying aquifers on a frequent schedule.

These controls work together to prevent and detect production fluid migration. Plugging exploration holes prevents connection of the ore-bearing aquifer to overlying and underlying aquifers. The EPA UIC requirement of MITs assures proper well construction and is the first line of defense for maintaining appropriate pressure without leakage. Sampling the monitor wells will enable early detection of any production solutions should an excursion occur.

11.3.2 Excursion Prevention

The endangerment of USDWs may occur via any combination of at least six contamination pathways in which fluids can escape the injection zone and enter USDWs (USEPA, 2002a). These pathways include:

- Migration of fluids through a faulty injection well casing
- Migration of fluids upward through the annulus located between a well casing and the drilled hole
- Migration of fluids from an injection horizon through the confining zone
- Vertical migration of fluids through improperly abandoned or constructed wells or test holes
- Lateral migration of fluids from the injection zone beyond the exempted area into a USDW
- Direct injection of fluids into or above a USDW

The extent to which a USDW is threatened will depend on a number of factors including:

- The nature of the fluids being injected
- The volume of the fluid being injected
- The effectiveness of the well field monitoring program
- The amount of fluid that may enter the USDW via one or more of the pathways

Proper construction of PA wells as outlined in Section 7.0 will reduce the likelihood that any USDWs will be threatened.

11.3.2.1 Excursion Prevention Steps

As stated in Section 7.0 “Well Installation and Maintenance” choosing proper well construction materials, following proven and acceptable methods of completion and development, and testing the mechanical integrity of the well(s) are the primary steps taken for excursion prevention.

11.3.2.2 Mechanical Integrity Testing of Wells

Each new injection, production and monitoring well will be pressure tested to confirm the integrity of the casing prior to being used for ISL operations. Mechanical integrity is demonstrated after a well is constructed and before it is put into use. The casing adjacent to or below the confining layer above the injection zone is sealed with a suitable device such as a plug, or downhole packer. The top of the casing is sealed and a pressure monitoring gauge is installed to measure pressure inside the casing. Pressure is increased to 125 percent of the maximum operating pressure rating of the well casing (which is always less that the maximum pressure rating of the pipe), or 90 percent of the formation fracture pressure (which equates to approximately 1 psi per foot of overburden above the bottom of casing), whichever is less and all fittings are checked for leaks. Upon stabilization of pressure, readings are recorded at two-minute intervals for ten minutes. A well passes the test if it holds 90 percent of the original pressure for ten minutes. Wells that fail the pressure test will be repaired or plugged and abandoned and replaced as necessary.

All three types of wells (injection, production and monitoring) must demonstrate mechanical integrity before being put into service. Mechanical integrity will be documented by including the well designation, date and duration of the test, beginning and ending pressures, and the signature of the individual responsible for conducting the test. The results of integrity testing of wells will be maintained onsite and available for inspection by the appropriate regulatory agency.

11.3.2.3 Shutdown

11.3.2.3.1 General

Well fields consist of production wells, injection wells, and monitor wells. These wells either pump water from a section of the ore-bearing formation or inject and return water into a section of the ore-bearing formation or monitor for excursion of leach fluids outside the well field. These wells are constructed of well casing that is cemented on the exterior to prevent vertical migration of the leach fluid up the annulus between the outside hole diameter and the casing. Each of these wells are piped into a collection header inside a header house.

A production well will have a circuit breaker in the header house associated with a submersible pump installed in the well that will be labeled by its production well number (e.g., P-100). Each breaker has a start and stop switch that can be used to energize or de-energize the pump motor. The circuit breaker is the main source of electrical power and can be used to de-energize and lock out the pump motor.

Each metered injection well will have a block valve between the header and the meter so that the injection well maybe blocked off to service the meter and the well. There will be a manual flow control valve and a flow meter on each production and injection well to regulate the flow to and from each well and to balance the individual well patterns. The flow meters will be labeled with a designated well identification number. The block valves will be closed for the appropriate injection or production well for shutdown and tag out.

11.3.2.3.2 Emergency Shutdown

External and internal shutdown controls will be installed in the header houses for operator safety and spill control. The external shutdown will consist of a shutdown switch and an internal shutdown control will be located within the header house sump. The external and internal shutdown controls are designed for automatic and remote shut down of the header house power. Some header houses may have a

disconnect at the transformer pole which will, when activated, shut down all electrical power to the header house. The result of this method is to shutdown all electrical power to the header house and mitigate potential electrical hazards while de-energizing the operating equipment including the production sumps.

The sump will also be designed with an automatic shutdown switch. If water level approaches the full level, the switch will cause immediate shutdown of the production well pumps. This will prevent leaks from production wells. A flashing alarm light will activate outside the building to indicate the sump shut-down switch has tripped.

11.3.3 Excursion Control

During operations, lixiviant is pushed into the ore-bearing formation through the injection wells and is withdrawn by the submersible pumps in the recovery/production wells. Recovering more groundwater than is injected, allows for a localized cone of depression to be maintained for each individual well field. This induced gradient in groundwater movement from the surrounding area toward the well field serves as a control over lixiviant movement and minimizes the potential for excursions of leach fluids to the monitor well ring.

Pre-operational excursion preventative measures include, but are not limited to:

- Proper well construction and mechanical integrity testing of each well before use
- Monitoring well design schema for production and non-production monitoring wells based upon detailed borehole or core logging
- Pre-operational pump test with monitoring system in place to determine detailed understanding of local hydrogeology and to demonstrate the suitability of the monitoring system

Operational excursion preventative measures include, but are not limited to:

- Regular monitoring of flow and pressure on each production and injection well
- Regular flow balancing and adjustment of all production and injection flows appropriate for each production pattern
- Operation of bleed, and continuous measurement of bleed rate
- Monitoring of hydrostatic water levels in all monitor wells to maintain cone of depression
- Regular collection of samples from all monitors to determine presence of any indicators of lixiviant travel

Monitoring wells will be set up around the well field for detection of any mining solutions that may potentially migrate away from the mining zone due to an imbalance in well field pressure. The monitoring well detection system is a proven method historically among ISL operations. Powertech proposes to locate a ring of monitoring wells no farther than 400 feet from the well field. The angle between adjacent monitor wells and the nearest injection well in the enclosed well field will be no greater than 70 degrees or 400 feet (closer if necessary to maintain the 70 degree angle) between adjacent monitor wells to prevent an excursion from moving out of the monitor well ring undetected. These monitoring wells will be screened in the same zone as the production well. Prior to injecting chemicals into the well field, a pump test will be conducted showing that the exterior monitor wells are connected to the mining zone and this data will be provided to demonstrate the effectiveness of the monitor well ring prior to injecting chemicals within the monitor well ring. There will be additional overlying monitoring wells within aquifers above the ore-bearing aquifer. The pump test conducted prior to injection of chemicals into the well field will demonstrate that the overlying monitor wells are not connected to the mine zone wells demonstrating confinement. Sampling of monitoring wells will occur on a bi-weekly basis. The monitoring system and operational procedures have proven effective in early detection of mining fluids for a number of reasons:

- Regular sampling for indicator parameters (such as chloride) that are highly mobile can detect lixiviant at low levels well before excursion is created.
- Hydrostatic water levels from production monitor ring provide immediate monitoring of the cone of depression, draw rapid attention, and provide ability for measurement and implementation of corrective response.
- Bleed and cone depression always create flow of native groundwater inward to the mining area.
- The natural groundwater gradient and slow rate of natural groundwater flow is less significant relative to mining activities and gradient caused by the well field bleed.
- Fluids within the well field do not typically have the natural tendency to travel outward.

The combination of these parameters provide minimal chance for the occurrence of non-detection of any excursions.

Effluent controls for preventing migration of mining solutions to overlying and underlying aquifers consist of:

- Regular monitoring of hydrostatic water levels and sampling for analysis of indicator species
- Routine mechanical integrity test of all wells on regular basis (every 5 years) to reduce any possibility of casing leakage
- Completion of mechanical integrity test on all wells before putting into service or after work which involves drilling equipment inside of the casing
- Proper plugging and abandonment of all wells which do not pass mechanical integrity testing, that become unnecessary for use
- Proper plugging and abandonment of exploration holes

Sampling the monitoring wells located within the overlying and underlying aquifers on a frequent schedule.

These controls work together to prevent and detect production fluid migration. Plugging exploration holes prevents connection of the ore-bearing aquifer to overlying and underlying aquifers. The EPA and SDENR UIC requirement of MITs assures proper well construction and is the first line of defense for maintaining appropriate pressure without leakage. Sampling the monitor wells will enable early detection of any production solutions should an excursion occur. Additional preventative measures are included in Section 9.0 “Site Monitoring Program”.

Powertech will place a well on excursion status after two or more of the excursion indicators exceed their respective upper control limits (UCLs). After analytical results from a verifying sample has confirmed exceedances, Powertech will identify, and implement as necessary proper reporting, monitoring and response measures that will be taken to:

- Recover the excursion into the well field
- Remove the well from excursion status

Most wells placed on excursion status were restored below their designated UCLs within 1 to 6 months (NUREG-1910, 2008). The specific indicator species will be determined during well field baseline assessment.

Powertech proposes the following species and parameters be used as indicators to monitor lixiviant travel and excursion control: Uranium, Chloride, Sulfate, Total Dissolved Solids. It is recommended that these be set as a function of the difference between baseline water quality outside of the ore bearing zone and anticipated lixiviant concentrations.

An NRC-sponsored study conducted by Pacific Northwest Laboratory (PNL) presented significant evidence concerning the best way for operators to determine indicator constituents for detection of excursions. According to the PNL study the best indicators of an excursion of process fluids are determined by site specific analysis of typical concentrations of groundwater surrounding the ore-zone (NUREG/CR-3136, 1983). After typical baseline of a well field has been established the lixiviant solution should be considered and constituent types such as dissolved major anions within the lixiviant that are not significantly susceptible to ion exchange, for example, chloride and sulfate would serve as good indicator constituents (NUREG/CR-3136, 1983).

If an excursion was verified through confirmatory sampling and analyses of the designated indicators, the operator will immediately notify proper authorities and implement excursion controls and increase the monitoring efforts in order to monitor the progress of excursion control procedures.

The PA is subject to permit and license requirements from three federal agencies, EPA, BLM and NRC, and a state agency, SD DENR. All four agencies have requirements and responsibilities regarding monitoring for excursions and the corrective action for any such excursion detected.

For example, the SD DENR requirement for remedial action for excursion (ARSD 74:55:01:53) requires the operator to: 1) verify with additional analyses that an excursion has occurred and, 2) to submit a report and remedial action plan for review and approval. “Following review by the secretary of the SD DENR, the operator shall use methods judged necessary and prudent to define the extent of the excursion and to clean up recovery fluids in an expeditious manner” (ARSD 74:55:01:53). Considering that there are four regulatory agencies that are involved in this process, Powertech proposes to develop a single, coordinated procedure with all four agencies during the permitting and licensing process.

11.4 Contingency Plan for Well Failures

This section addresses **CI–4 (21)**.

The following section outlines contingency plans to cope with all system shut-ins or failures so as to prevent migration of fluids into any USDWs.

11.4.1 Well Casing Failure

In the event that well failure occurs, the potential for environmental impacts will depend on the type of well (e.g., injection, production, monitoring). With proper casing, cementing, and testing procedures, the probability of such a failure is very low.

Following the identification of a leak in an injection well casing, the well will be examined to verify that well casing failure is the cause of the leak. If possible, a MIT will be conducted. A resistivity log or a video log will be obtained if it will prove useful for identifying the location of the leak. The leak will be repaired if possible; if not possible the well will be plugged and abandoned as detailed in Section 7.0 – Well Installation and Maintenance.

It is improbable that failure of a production well casing will result in contamination of a USDW because the production well operates by pumping the water from the submersible pump to the surface through tubing. As a result, annulus between the casing and the tubing operates below formation pressure, and there is not a hydraulic gradient for flow out of the casing. Any potential failure would likely result in water

entering the well casing due to the pressure in the production well being lower than the pressure in the underlying or overlying aquifers.

Following identification of a defective well casing, the well will be repaired as described in Section 4.4 - Corrective Action Plan and Well Data or plugged and abandoned as described in Section 7.0 – Well Installation and Maintenance. The mechanical integrity of all well casings will be tested prior to use and after any repair that involves entering the wells with a cutting tool such as a drill bit or under-reamer.

The monitoring program described in Section 9.0 – Site Monitoring Program will be used to protect USDWs in the event that well casings fail. Monitoring wells, completed into the aquifers above and below the mining zone, will be routinely sampled twice a month to check fluid levels and changes in water quality as indicated by changes to the upper control limits on the excursion detection parameters of uranium, chloride and sulfate. Should a vertical excursion be detected, surveillance of the well condition by using a camera, a sonic log, electric log or mechanical integrity testing would be conducted. If the well is determined to be damaged beyond repair, the well would be replaced with a new well. If the excursion well is an injection well (which is more likely to have an excursion associated with it instead of an extraction/production well) the well would be packed off at the bottom, a pump would run down the hole and the use would change from an injection to an extraction well and the excursion would be pulled back into the proper zone.

For horizontal excursions, surveillance of the well condition will also be determined and the well replaced if damaged beyond repair. Well field flow rates will be adjusted to pull the excursion that is detected back to the well field until the indicator parameters (i.e., chloride, sulfate and uranium) are reduced to acceptable levels. If the flow adjustment fails to correct the excursion, wells will be drilled and pumped inside the monitor well ring adjacent to the well that is on excursion to pull back the excursion inside the monitor well ring.

11.4.1.1 Historic Exploration Drill Holes

In general, historic exploration drill holes are believed to have been abandoned using either abandonment mud, drilling mud or a combination of bentonite and drilling mud. These materials are likely to have provided an effective seal against fluid communication between aquifers penetrated by exploration drill holes. Also, the presence of native clays and their potential for swelling can act as a natural mechanism for plugging holes. However, some drill holes may not have been properly abandoned. If inadequately abandoned wells are identified during well field pumping tests, Powertech will require plugging and abandonment to be conducted as detailed in the South Dakota plugging standards (ARSD 74:11:08).

11.5 Impacts and Mitigation Measures

This section addresses **CI–4 (15)**.

11.5.1 Potential Water Resource Impacts

A Table of all adjudicated groundwater and surface water rights are presented in Appendix A. There are no groundwater water rights within the permit boundary and only two groundwater rights within 2 miles of the permit boundary. The majority of water rights in this area are surface water rights with 5 surface water rights existing within the permit boundary and an additional 139 within 2 kilometers of the PAA. The majority of the surface water rights are located along Beaver Creek within Wyoming.

11.5.1.1 Potential Surface Water Impacts

The average annual runoff for this region is higher than that for the Wyoming West Region, therefore potential surface water impacts may be slightly higher in the Proposed Action Area (USGS, 2008 in NUREG-1910, 2008). The water quality of storm water is regulated under permits issued by South

Dakota's Surface Water Quality Program in Pierre. Impacts to wetlands are negligible (See Environmental Report; Section 3.5.5.2) and will be addressed through consultations and the permitting process (NUREG-1910, 2008). The surface water impacts overall would be small to moderate. All activities that could potentially affect surface water will be undertaken in such a way as to comply with applicable state and federal regulations and conditions of permit; through the use of best management practices and mitigation measures impacts to water quality will be reduced to small and/or moderate and determined by site specific conditions (NUREG-1910, 2008).

11.5.1.1.1 Potential Surface Water Impacts from Construction

Construction activities within the well fields, along the pipeline courses and roads, and at the process plant have the potential to increase the sediment yield of the disturbed areas. The impacts from increased sedimentation will be minimal because of the short-term nature of the disturbance (areas will be concurrently reclaimed) and the area of disturbance is small compared to the total drainage basin of Angostura Reservoir (total area 7143 mi^2) and because of the lack of dependable surface water supplies. A slight increase in sediment yields and total runoff can be expected during final reclamation; however, well field decommissioning and reclamation activities via best management practices and mitigation measures utilized throughout the life of the project will help to reduce the impacts. No direct disturbance to any wetlands or water sources is planned at this time. If, in the future, the proposed action should involve an impact to a jurisdictional wetland area or water source, the appropriate actions will be taken in accordance with Section 404 of the Clean Water Act and US Army Corps of Engineers (USACE) regulations.

"Potential indirect impacts of ISL operations could include increased sediment deposition in streams, which could alter stream morphology and degrade the suitability of channel substrate for aquatic organisms. However, as stated previously, this issue is addressed by NPDES storm water requirements, and good management practices likely will minimize, if not eliminate, any such potential impacts" (NUREG-1910, 2008). Indirect impacts to surface water will be limited to uncommon precipitation or runoff events (e.g., a flood event).

There were 20 potential wetland sites evaluated by the USACE; the determination rendered four of the 20 evaluated as Jurisdictional sites (see Environmental Report; Appendix 3.5-H). Descriptions of the jurisdictional determination: Ephemeral Tributary to Beaver Creek, Ephemeral Tributary to Pass Creek, Pass Creek (Non RPW), Beaver Creek (Perennial RPW). Beaver Creek is the only perennial stream within the proposed PAA and the rest of the natural water flow is ephemeral. Of the jurisdictional determinations within the Proposed Action Area, impact is expected to be small and none are expected to experience direct impact from the pre-operational or operational activities. Erosion potential is present due to the possible construction of the wells near the drainage area; however, disturbance is expected to be mild and short-term.

An old mine pit located at Waypoint 37 was determined to be a non-wetland area. Although surface water was present, there was no hydrophytic vegetation or hydric soils. This old mine pit is also located along a disturbance area. The concentration of old mine pits along the eastern edge of the permit area contained small PUB wetlands (0.175 acres) that are a product of the old mine pits, that could be impacted by disturbance areas located along the old mine pits.

Mitigation measures employed in order to minimize potential impacts may include: best soil management practices (i.e., silt fencing, straw bales) if crossing the water body is necessary, timing of crossing will be evaluated, and only temporary crossing may be necessary, and type of equipment working near water body will be considered. Potential impacts to surface waters from the construction of an ISL facility would be expected to be SMALL based on the application of federal and state clean water regulations in conjunction with the use of best management practices (NUREG-1910, 2008).

ISL operations do not involved the consumption of surface waters. Nor do the operations proposed require a long- term discharge to surface waters. For these reasons, no significant impacts to surface water quantity and use are anticipated.

11.5.1.1.2 Potential Surface Water Impacts from Operations

Potential impacts from accidental spills or permitted temporary discharge to surface water may include the release of process materials into the environment or a release or spill from the operation or well field (e.g., handling of fuels, lubricant, oily wastes, chemical wastes, sanitary wastes, herbicides, and pesticides). Surface water monitoring and spill response procedures will limit the impact of potential spills to surficial aquifers. The impact that may result from a spill is dependent upon several considerations such as: size of spill, remediation success, designated use of the surface water, location of spill relative to surface water, and any relative contribution an aquifer discharge may have to the surface water (NUREG-1910, 2008). A Storm Water Pollution Management Plan (SWMP) will be part of the NPDES permit issued and will describe potential sources of storm water contamination from the facility. The SWMP will include routes by which spills may leave the facility and the best management practices to be implemented as preventative measures to control storm water contamination (NUREG-1910, 2008).

Most ISL operations extract slightly more groundwater than they re-inject into the uranium bearing formation. The groundwater extracted from the formation could result in a depletion of flow in nearby streams and springs if the ore-bearing aquifer is hydraulically connected to such features. However, because most, if not all ISL operations are expected to occur where the ore-bearing aquifers are confined, local depletion of streams and springs is unlikely, and potential impacts would be anticipated to be SMALL (NUREG-1910, 2008).

Any water disposed of via land application methods must be treated in compliance with any established state and federal established concentration levels for specified constituents. According to 10 CFR Part 20, the NRC requirement is that the public and occupation dose limits are met during and post land application. An accumulation of some constituents and dissolved solids may develop within the soils and may potentially have an indirect impact on surface water. The degree of the potential impacts again, would depend on factors such as actual evapotranspiration rates, irrigation rates, precipitation quantities and sorpitive properties of specific soils with respect to constituents considered (NUREG-1910, 2008). Permit requirements will be in place to assure mitigation should any accumulations of residuals remain upon completion of the operations. At that time the land application areas would be subject to land surveys during decontamination efforts. If accumulation occurs, that does not meet permit conditions is discovered, the areas in exceedance will be remediated to meet the NRC regulations, consequently; potential impacts from permitted land application will be SMALL (NUREG-1910, 2008).

11.5.1.1.3 Potential Groundwater Impacts from Production Operations

During ISL operations, the following is a list of potential impacts to groundwater: (1) Alteration of groundwater quality from the addition of the proposed lixiviant oxygen and carbon dioxide to the groundwater in the exempted aquifer, (2) the addition of chloride to the groundwater by displacement from the ion exchange resin during the uranium loading process, (3) and the interaction of these chemicals with the mineral and chemical constituents of the aquifer being mined, primarily the oxidation of the pyrite in the ore body to form solubilized sulfate ion. The result is that during the proposed action, the concentration of most of the naturally occurring dissolved constituents in the ore zone(s) will be higher than their concentrations in the pre production groundwater. The ISL process does not introduce any constituents that are not already present within the groundwater. Procedures proposed in this application are designed to provide early detection of and to provide for remediation any excursions of leach fluids to adjacent non exempt USDWs. These procedures are consistent with those recommended in NUREG-1910 to address potential groundwater impacts; therefore will be no adverse impacts on human health and the environment from affected groundwater within the production zone.

11.5.1.1.4 Potential Impacts of Production on Ore Zone Groundwater Quality

Potential environmental impacts to groundwater are changes to water quality in well fields within the exempted aquifer. The impact is low, due to the fact that the pre-existing groundwater quality degraded prior to ISL operations; due to the presence of naturally occurring radionuclides, heavy metals, and other constituents that exceed EPA and/or state MCLs for drinking water. Accordingly, the exempted aquifer is not and can never serve as a USDW (HRI, 1997; NMA, 2007).

Powertech (USA) has proposed to use native groundwater combined with gaseous oxygen and carbon dioxide lixiviant. The interaction of the lixiviant with the mineral constituents of the exempted ore zone results in a slight increase in trace elements and primary constituents of sulfate, chloride, cations and TDS above pre production levels. There is no introduction of non-naturally occurring constituents from the leach fluids into the ore body.

The uranium present in the ore zone pre-operations is solubilized by oxidation via the ISL process. Uranium, when oxidized to the soluble valence, reacts with the bicarbonate ions to form a stable, soluble anion, uranyl bicarbonate. The dissolved oxygen in the leach fluid also oxidizes the pyrites (sulfides) to increase the concentration of sulfate (SO_4) ions in solution. The loading of uranyl bicarbonate ions onto the resin displaces chloride ions into the leach solution. Therefore, the leach process which recycles groundwater back to the ore zone increases the concentration of sulfate and chloride anions into the leach solution. The increase in sulfate and chloride anions in the leach solution increases the concentrations of sodium, calcium, potassium and magnesium cations in solution. These cations are exchanged off the clays within the ore body to balance the ion charges in the leach solution. Since these cations and anions are the principal constituents of TDS, therefore the TDS increases.

11.5.1.1.5 Potential Groundwater Impacts from Land Application

The wastewater applied to the land will be treated to meet EPA Primary Drinking Water Standards and NRC effluent criteria for radionuclides as referenced in 10 CFR part 20 Appendix B. Therefore, potential adverse impacts to groundwater are not anticipated.

Data from test pits 1, 2 and 5 were used to develop the soil profile used in the SPAW modeling for the Dewey site. The logs for these test pits indicated that bedrock was encountered at depths of 9 feet, 11 feet, and 8.5 feet respectively below the ground surface. The composite soil profile used to model the soil at the Dewey site had a total depth of 9.83 feet. The results of the SPAW modeling indicated that the soil moisture content at the base of this soil profile was less than field capacity for all cases that were modeled (28 15-year simulations) and that there was no percolation beyond the base of the soil profile (Environmental Report; Appendix 4.6-A). Therefore, it is assumed that there would be no lateral movement of water along the bedrock surface, and no vertical movement of water into the bedrock, and therefore no leaching of trace elements beyond the base of the soil profile.

Data from test pits 8, 9 and 10 were used to develop the soil profile used in the SPAW modeling for the Burdock site. The logs for these test pits indicated that bedrock was encountered at depths of 7 feet and 5 feet below the ground surface in test pits 8 and 9. Test pit 10 was excavated to a total depth of 12 feet, with a clayey silt layer from 2 feet to 12 feet below the ground surface. The composite soil profile used to model the soil at Burdock had a total depth of 8 feet. The results of the SPAW modeling indicated that the soil moisture content at the base of this soil profile was also less than field capacity for all cases that were modeled (28 15-year simulations) and that there was no percolation beyond the base of the soil profile. Again it is assumed that no lateral movement of water would occur along the bedrock surface, and that water would not move vertically into the bedrock, and therefore there would be no leaching of trace elements beyond the base of the soil profile.

Based on the above information, there will be no migration pathway of waste water constituents to groundwater beneath the land application sites, thereby eliminating any potential of exposure and risk to human health and the environment.

11.5.1.1.6 Potential Groundwater Impacts from Deep Well Disposal Below Production Aquifer

Deep well injection involves the pumping of waste fluids into a deep confined aquifer. Aquifer water quality in the deep confined aquifer is often poor (e.g., high salinity or total dissolved solids) and does not meet drinking water standards. Licensees must obtain an UIC permit from EPA or the appropriate state agency. The approval process verifies that site-specific and regional characteristics limit the potential for contamination of local drinking water sources. This is accomplished by the licensee providing data that the aquifer is hydraulically separated from the overlying aquifer systems. "Under these conditions, the potential environmental impacts would be SMALL" (NUREG-1910, 2008). NRC staff may also review the UIC application, even though the EPA or state give final approval. NRC has approved deep well injection for specific ISL sites as a method to dispose of particular process fluids such as reverse osmosis brine."

The potential environmental impacts of injection of leaching solutions into deep aquifers below ore-bearing aquifers would be expected to be SMALL, if water production from deep aquifers is not economically feasible or the groundwater quality from these aquifers is not suitable for domestic or agricultural uses (e.g., high salinity), and they are confined above by sufficiently thick and continuous low permeability layers. The impacts of discharging wastes to deep disposal well during restoration are expected to be similar to the impacts of these waste management practices during operations (SMALL) (NUREG-1910, 2008)

11.5.1.1.7 Potential Groundwater Impacts from Aquifer Restoration

Groundwater consumption is the primary impact of concern when considering aquifer restoration and waste management.

Groundwater transfer has minimal impact concerning groundwater consumption by replacing recovered well field groundwater with near baseline quality water. Whereas groundwater sweep has a larger impact since the process involves extracting the recovered well field water and pulling unaffected water into the aquifer to take its place. When utilizing reverse osmosis (RO), 70 percent to 99 percent of the water is suitable for reinjection into the formation depending on whether brine concentrate is used or not. This lowers groundwater consumptive use substantially during aquifer restoration.

All well fields do not undergo restoration simultaneously. A deliberate phased approach is utilized to keep groundwater impacts to a minimum throughout the life of the operation. Potential environmental impacts are affected by the restoration techniques chosen, the severity and extent of the contamination, and the current and future use of the production and surrounding aquifers in the vicinity of the ISL facility. The potential environmental impacts of groundwater consumption during restoration could be SMALL to MODERATE depending on site-specific conditions. Site-specific impacts also would depend on the proximity of water users' wells to the well fields, the total volume of water in the aquifer, the natural recharge rate of the production aquifer, the transmissivity and storage coefficient of the production aquifer, and the degree of isolation of the production aquifer from aquifers above and below (NUREG-1910, 2008).

Deep well injection is one of the most common methods to dispose of the more heavily concentrated wastewater. Brine water treated via RO may also be disposed of via deep well injection. Aquifers utilized for deep disposal must meet federal and state standards such as: the aquifer must have poor water quality, low water yields, or be economically infeasible for production. Underground injection of wastewater requires an EPA permit and approval from the NRC. Impacts from deep well disposal are expected to be SMALL (NUREG-1910, 2008).

11.5.1.1.8 Potential Impacts of Groundwater Consumption During Operations and Restoration

The majority of groundwater used in the ISL process will be treated and re-injected. Based on a median case of bleed of one percent of 2,000 gpm (20 gpm), the potential impacts from consumptive use of groundwater in the Fall River and Lakota aquifers are calculated below. There are separate calculations

for the Fall River aquifer assuming pumping at the first proposed well field at the Dewey Site, and for the Lakota aquifer assuming pumping at the first proposed well field at the Burdock Site.

The potential impacts due to drawdown are calculated at the locations of the nearest wells outside the proposed Permit Boundary Area that are expected to remain active during the life of the Project

11.5.1.1.8.1 Drawdown Estimates

The Theis analytical solution includes the following assumptions (Driscoll, 1986):

- The aquifer is homogeneous and isotropic (same hydraulic conductivity everywhere).
- The aquifer is confined with uniform thickness and has infinite extent.
- No recharge to the aquifer occurs.
- The pumping well is fully penetrating and receives water from the full thickness of the formation.
- All water removed from the well comes from aquifer storage which is discharged instantaneously when the head is lowered.
- The piezometric surface is horizontal prior to pumping.
- The well is pumped at a constant rate.
- The pumping well diameter is small so well bore storage is negligible.

Possible barrier boundaries for the aquifer system include the respective outcrops of the Fall River and Lakota formations generally east and north of the property boundary, as well as the Dewey Fault to the north and east of the property boundary. However, the Dewey Fault is considered likely to terminate both the Fall River and Lakota aquifers at some distance to the west. Therefore, just the outcrop was assumed to be a straight line barrier boundary and modeled with “image” pumping wells (e.g., Fetter, 1988) having the same pumping rates as the production wells for the Fall River and Lakota aquifers. A spreadsheet developed by the U.S. Geological Survey to calculate drawdown according to the Theis equation (Halford and Kuniansky, 2002) was used to make the confined aquifer prediction calculations.

11.5.1.1.8.1.1 Drawdown Impact – Fall River Aquifer

The following is a summary of available aquifer parameter (transmissivity, storativity) determination in successful pumping tests:

- 1979 TVA tests at Burdock area (Boggs and Jenkins, 1980):
  - Formation transmissivity: 54 ft2/day
  - Formation storativity: 1.4 x 10-5
- 2008 Powertech (USA) tests at Dewey area (Knight Piésold, 2008c):
  - Formation transmissivity: 255 ft2/day
  - Formation storativity: 4.6 x 10-5

To quantify the impact of the Project on the Fall River Formation aquifer the following assumptions were used together with the range of aquifer parameters above:

- Production/restoration: 8 years
- Average net consumptive use: 20 gpm
- Location of pumping centroid: NW ¼ of Section 32, T6S, R1E

- Distance from pumping well to barrier boundary (Fall River outcrop): 14,610 ft
- Observation radius: 15,075 feet (nearest domestic well, Hydro ID = 18), SW ¼ of SW ¼ of Section 9, T7S, R1E
- Image well observation radius: 39,350 ft

For the 1979 TVA test parameters, the calculated drawdown at the nearest domestic well after 8 years of pumping at 20 gpm due to the pumping well alone is 26.8 feet. The calculated drawdown at the nearest domestic well due to the image well is 16.0 feet. Thus the estimated drawdown at the nearest domestic well is 42.8 feet after 8 years of continuous pumping at a rate of 20 gpm. For the 2008 Powertech (USA) test parameters, the calculated drawdown at the nearest domestic well after 8 years of pumping at 20 gpm due to the pumping well alone is 6.1 feet. The calculated drawdown at the nearest domestic well due to the image well is 3.8 feet. Thus the estimated drawdown at the nearest domestic well is 9.9 feet after 8 years of continuous pumping at a rate of 20 gpm.
Therefore, based on available pumping test data, the range of possible drawdown estimates at the nearest domestic well, located 15,075 feet from the approximate center of pumping is 9.9 to 42.8 feet.

11.5.1.1.8.1.2 Drawdown Impact – Lakota Aquifer

The following is a summary of available aquifer parameter (transmissivity, storativity) determination in successful pumping tests:

- 1979 TVA tests at Burdock area (Boggs and Jenkins, 1980):
  - Formation transmissivity: 190 ft2/day
  - Formation storativity: 1.8 x 10-4
- 1982 TVA tests at Dewey area (Boggs, 1983):
  - Formation transmissivity: 590 ft2/day
  - Formation storativity: 1.0 x 10-4
- 2008 Powertech (USA) tests at Burdock area (Knight Piésold, 2008):
  - Formation transmissivity: 150 ft2/day
  - Formation storativity: 1.2 x 10-4

To quantify the impact of the Project on the Lakota Formation aquifer the following assumptions were used:

- Production/restoration: 8 years
- Average net consumptive use: 20 gpm
- Location of pumping centroid: SW ¼ of Section 11, T7S, R1E
- Distance from pumping well to barrier boundary (Lakota outcrop): 17,610 ft
- Observation radius: 10,915 feet (nearest domestic well, Hydro ID = 13) NE ¼ of NE ¼ of Section 4, T7S, R1E
- Image well observation radius: 36,170 ft.

For the 1979 TVA test parameters, the calculated drawdown at the nearest domestic well after 8 years of pumping at 20 gpm due to the pumping well alone is 6.6 feet. The calculated drawdown at the nearest domestic well due to the image well is 2.9 feet. Thus the estimated drawdown at the nearest domestic well is 9.5 feet after 8 years of continuous pumping at a rate of 20 gpm.

For the 1982 TVA test parameters, the calculated drawdown at the nearest domestic well after 8 years of pumping at 20 gpm due to the pumping well alone is 3.0 feet. The calculated drawdown at the nearest domestic well due to the image well is 1.8 feet. Thus the estimated drawdown at the nearest domestic well is 4.9 feet after 8 years of continuous pumping at a rate of 20 gpm.

For the 2008 Powertech (USA) test parameters, the calculated drawdown at the nearest domestic well after 8 years of pumping at 20 gpm due to the pumping well alone is 8.7 feet. The calculated drawdown at the nearest domestic well due to the image well is 3.9 feet. Thus the estimated drawdown at the nearest domestic well is 12.6 feet after 8 years of continuous pumping at a rate of 20 gpm.

Therefore, based on available pumping test data, the range of possible drawdown estimates at the nearest domestic well, located 10,915 feet from the approximate center of pumping is 4.9 to 12.6 feet.

11.5.1.1.9 Potential Impacts from Simultaneous Operational and Restorational Groundwater Consumption

11.5.1.1.9.1 Operational Water Use

During ISL operations (including both production and restoration) nominal bleed rates of .5-1 percent are expected to be maintained over the life of the project. Instantaneous rates may vary in the range of 0.5 percent to 3 percent for short durations, from days to months. All effluent systems for treating bleed streams are designed for continuous operation at the maximum bleed rate of 3 percent. However, over the life of the project, a reasonable estimate of .5-1 percent, or slightly less, bleed is believed appropriate and sufficient to maintain a the cone of depression necessary within any production or restoration activity In situ mining circulates significant quantities of water through the ore zone but consumes only a small fraction of that amount because most water is reinjected back into the deposit. During operations, 0.5 to 3 percent of the solution extracted from the aquifer will be “bled” from the system to ensure a cone of depression is maintained and that no leach fluids are released from the production area.

It is anticipated that no more than two well fields, typically one at the Dewey site and one at the Burdock site will be in production at one time, with another two in restoration. Reclamation will begin as soon as each mining unit has been depleted of uranium, beginning approximately two years after the start of operations. When one well field is depleted, it will be reclaimed at the same time production continues in another well field along the ore front.

11.5.1.1.9.2 Water Requirements for the Proposed Action Facilities

Water requirements of the CPP and other facilities are estimated to have a maximum requirement of 65 gpm. As this requirement is relatively large, it is expected that most of this water will be derived from a water supply well in the Madison formation. Some of this water may be withdrawn from the Inyan Kara formation, but if so, it will not occur in a fashion to affect any well field operations.

11.5.1.1.9.3 Water Usage with Reverse Osmosis and without Reverse Osmosis

Total net water use for production operations (as well field purge) will be in the range 20-120 gpm from the Inyan Kara. Each production site will consume between 10 and 60 gpm as well field purge. During restoration operations, water consumption will be greater from the Inyan Kara. However, net withdrawal from the Inyan Kara formation will also remain at the range of 0.5 to 3% of total restoration flow during groundwater treatment via RO method of restoration (Table 11.5-1). It is expected that the restoration activities will also be split between the two sites. Net withdrawal during these restoration operations (as well field purge) is expected to be a total of 2.5 to 15 gpm from the Inyan Kara. At each site, Dewey and Burdock, 1.25 to 7.5 gpm will be the net withdrawal during restoration operations. Net water usage from the Maddison using a (RO) unit to restore groundwater following production, approximately 167 gpm of the 500 gpm (without RO utilization; Table 11.5-2), will need to be made up with Madison aquifer water.

The actual flow rates of water leaving the Inyan Kara formation during restoration operations is expected to be in the range of 150-500 gpm. Nearly all of this water will be "made-up" by injection of water from these two sources:

11.5.1.1.9.3.1 Madison formation

The Madison aquifer is a source of fresh water and could potentially be utilized for the Project. Powertech (USA) would utilize the Madison Limestone, which occurs at depth throughout the entire project boundary, as a source of fresh make-up water for restoration purposes. As described below, it is very likely that the Madison aquifer can provide a source of water at the desired rate and quality sufficient for the needs of Powertech (USA) to ensure timely and successful ISL restoration goals. Depending on the exact aquifer restoration process Powertech (USA) may need to produce up to 500 gpm from the Madison aquifer. In the case of land application disposal of water during restoration, 500 gpm of make-up water will be required from the Madison aquifer. Utilizing RO, approximately one-third (or 167 gpm) of the 500 gpm will need to be made up with Madison aquifer water.

11.5.1.1.9.3.2 Inyan Kara formation

This is providing that make-up water is withdrawn from wells that are located far enough from operating well fields so as to not affect the cone of depression within the operating well fields.

The actual net difference between fluid produced and fluid injected must be maintained at a rate equivalent to the 0.5-3 percent bleed rates described above. With RO process used for treating well field bleed streams, permeate will be reinjected and will substantially lower the requirement for makeup waterform the Madison; such use of RO typically reduces make-up water requirements to approximately 1/3 of the water that would be required without RO (Table 11.5-2).

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Table 11.5-1 Net Water Usage with Reverse Osmosis

Net Water Usage at nominal bleed rate (with RO in restoration)											Cumulative	Percentage of Recharge	
INYAN KARA											**water Usage**	**350 gpm**	**520 gpm**
Years	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**(million gallons)**	**recharge**	**recharge**
Production operations													
production flow	4000	4000	4000	4000	4000	4000	4000						
injection flow	3965	3965	3965	3965	3965	3965	3965						
net production withdrawal	35	35	35	35	35	35	35	0	0	0			
bleed rate	0.88%	0.88%	0.88%	0.88%	0.88%	0.88%	0.88%						
Restoration operations													
restoration flow	0	0	500	500	500	500	500	500	500	500			
injection flow			495	495	495	495	495	495	495	495			
Permeate flow			350	350	350	350	350	350	350	350			
Recharge from Madison			145	145	145	145	145	145	145	145			
net restoration withdrawal			5	5	5	5	5	5	5	5			
bleed rate			1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%			
Net Usage from Iyan Kara	35	35	40	40	40	40	40	5	5	5	150	8%	5%
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**			
INYAN KARA	Consumptive Usage - with RO and re-injection of permeate												
Production operations	35	35	35	35	35	35	35	0	0	0	129	7%	5%
Restoration operations*	0	0	150	150	150	150	150	150	150	150	631	34%	23%
Inyan Kara Total	35	35	185	185	185	185	185	150	150	150	759	41%	28%
MADISON	Consumptive Usage - with RO and re-injection of permeate												
Process Water	65	65	65	65	65	65	65	65	65	65	342		
Recharge of Inyan Kara	0	0	145	145	145	145	145	145	145	145	610		
Madison Total	`	65	210	210	210	210	210	210	210	210	917		
* assumes all restoration make-up water from outside of INYAN KARA													

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Table 11.5-2 Net Water Usage without Reverse Osmosis

	Net Water Usage at nominal bleed rate (without RO in restoration)										Cumulative	Percentage of Recharge	
INYAN KARA											**water Usage**	**350 gpm**	**520 gpm**
Years	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**(million gallons)**	**recharge**	**recharge**
Production operations													
production flow	4000	4000	4000	4000	4000	4000	4000						
injection flow	3965	3965	3965	3965	3965	3965	3965						
net production withdrawal	35	35	35	35	35	35	35	0	0	0			
bleed rate	0.88%	0.88%	0.88%	0.88%	0.88%	0.88%	0.88%						
Restoration operations													
restoration flow	0	0	500	500	500	500	500	500	500	500			
injection flow			495	495	495	495	495	495	495	495			
Permeate flow			0	0	0	0	0	0	0	0			
Recharge from Madison			495	495	495	495	495	495	495	495			
net restoration withdrawal			5	5	5	5	5	5	5	5			
bleed rate (%)			1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%			
Net Usage from Iyan Kara	35	35	40	40	40	40	40	5	5	5	150	8%	5%
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**			
INYAN KARA	Consumptive Usage - without RO and re-injection of permeate												
Production operations	35	35	35	35	35	35	35	0	0	0	129	7%	5%
Restoration operations*	0	0	500	500	500	500	500	500	500	500	2102	114%	77%
Inyan Kara Total	35	35	535	535	535	535	535	500	500	500	2231	121%	82%
MADISON	Consumptive Usage - without RO and re-injection of permeate												
Process Water	65	65	65	65	65	65	65	65	65	65	342		
Recharge of Inyan Kara	0	0	495	495	495	495	495	495	495	495	2081		
Madison Total	65	65	560	560	560	560	560	560	560	560	2423		
* assumes all restoration make-up water from outside of INYAN KARA													

11.5.1.1.10 Potential Groundwater Quality Impacts from Accidents

11.5.1.1.10.1 Potential Excursions

Monitoring wells within the monitoring well ring are designed and installed to detect an excursion of leach fluids outside the well field within the aquifer exempted area. Neither historical excursions nor excursions within active ISL projects have "resulted in any significant adverse impacts to USDWs" (NMA, 2007). This demonstrates the protective capabilities of operators to detect and control excursions. Operators are mandated by permitting conditions to employ practices to protect adjacent, non-exempted aquifers. With that stated, importance is placed upon the understanding that the UIC Class III permits issued by the EPA and DENR and the uranium recovery license issued by the NRC are written and enforced to protect USDWs. The permit and license also ensures the operational processes such as: monitoring, pump tests, and maintenance of well field bleed are all geared toward protecting USDWs (NMA, 2007).

Well field imbalance is the most common cause of excursions. Imbalance can cause lixiviant to migrate outside the well field pattern toward the monitoring well ring; therefore it is crucial to characterize the groundwater within each separate well field before lixiviant is introduced into the groundwater. This well field specific groundwater data is then used to establish UCLs used for determination of properly functioning well field. One example of how an excursion is declared is "if any two excursion indicators in any monitor well exceed their respective UCLs, or a single excursion indicator exceeds its UCL by 20 percent (NMA, 2007; NUREG-1910, 2008).

Common procedure during routine sampling of monitoring wells is:

- If two of the three UCL values are exceeded in a monitor well, or if one UCL value is exceeded by 20 percent, the well will be re-sampled within 48 hours and analyzed for the excursion indicators. If the second sample does not exceed the UCLs, a third sample will be taken within 48 hours. If neither the second or third sample results exceeded the UCLs, the first sample will be considered in error.
- If the second or third sample verifies an exceedance, the well in question is placed on excursion status. Upon verification of the excursion, NRC Project Manager is notified by telephone or email within 48 hours and notified in writing within thirty (30) days.
- If an excursion is verified, the following methods of corrective action will be instituted (not necessarily in the order given) dependent upon the circumstances:
  - A preliminary investigation will be completed to determine the probable cause.
  - Extraction and/or injection rates in the vicinity of the monitor well will be adjusted as necessary to generate an effective net over-recovery, thus forming a hydraulic gradient toward the production zone.
  - Individual wells will be pumped to enhance recovery of leach fluids.
  - Injection into the production zone area adjacent to the monitor well may be suspended, while extraction continues, thus increasing the overall bleed rate and the recovery of ore zone solutions.
  - In addition to the above corrective actions, sampling frequency of the monitor well on excursion status is increased to weekly. An excursion will be considered resolved when the concentrations of excursion indicators do not exceed the criteria defining an excursion for three consecutive one-week samples. Accordingly, while a real potential short-term impact, excursions during operations can be identified and controlled such that impacts are expected to be minimal.

Impacts of excursions include the potential to contaminate groundwater outside of the well field or in aquifers above or below the production zone. However, it is noted that, in spite of excursions at virtually every operating ISL site, no significant, adverse impacts to USDWs have been documented throughout the history of ISL operations in the United States, which indicates that operators have the capability to recover errant solutions (NMA, 2007).

There are two types of excursions: vertical and horizontal. A vertical excursion is movement of solution into overlying or underlying aquifers. A horizontal excursion is a lateral movement of leach fluids outside the ore zone of the ore-body aquifer.

Maintaining injection pressures below casing and formation rupture pressures prevent the well casing from rupturing and potentially causing a vertical excursion. Well field operating pressures are monitored at the header houses via instrumentation equipped with alarms and interlocks to prevent an excursion due to excessive pressure. Consistent monitoring of well field pressures minimizes the potential for impacts to shallow and deep aquifers. MITs have all but eliminated potential impacts from excursions to shallow aquifers (NMA, 2007).

In general, the potential environmental impacts of vertical excursions to groundwater quality in surrounding aquifers would be SMALL, if the vertical hydraulic head gradients between the production aquifer and the adjacent aquifer are small, the vertical hydraulic conductivity of the confining units is low, and the confining layers are sufficiently thick. To limit the likelihood of vertical excursions, licensees must conduct MIT to ensure that lixiviant would remain in the well and not escape into surrounding aquifers. Licensees also must conduct pre-operational pump tests to ensure adequate confinement of the production zone. In addition, licensees must develop and maintain programs to monitor above and below the ore-bearing zone to detect both vertical and horizontal excursions and flow rates, and must have operating procedures to analyze an excursion and determine how to remediate it (NUREG-1910, 2008).

During normal ISL operations, inward hydraulic gradients are maintained by production bleed such that groundwater flow is towards the production zone from the edges of the well field. This inward gradient prevents the chance of a horizontal excursion occurring. To reduce the likelihood and minimize the consequences of potential horizontal excursions, a ring of monitoring wells are installed encircling the well field pattern to enable early detection of excursions. Monitoring will be conducted for both vertical and horizontal excursions. Thus, potential non-radioactive contamination of groundwater beyond the production zone can have short-term impacts, but such impacts likely will be minimal and readily controllable (NMA, 2007).

11.5.1.1.10.2 Potential Spills

Types of spills that could potentially impact groundwater during operations include: a leak in a storage pond, a release of pregnant and/or barren lixiviant, a release of injection or production solutions from associated piping, spills and potential well rupture. Potential impacts of contamination to shallow aquifers and surrounding soils may result from one or a combination of these types of spills. The likelihood of spills is minimized by way of rigorous safety training, and employing all necessary preventative procedures such as maintaining injection pressures below casing and formation rupture pressures, monitoring pressure in the header houses with instrumentation equipped with alarms and interlocks for early warning, and maintaining operating pressures so as to minimize the likelihood for potential impacts to shallow aquifers. The potential environmental impacts from spills and mitigation measures are discussed in further detail in Sections 11.5.1 and 11.5.2.

11.5.2 Proposed Mitigation Measures for Surface Water Impacts from the Proposed Action

Potential surface water impacts due to storm events during all phases of the Proposed Action include increased sedimentation and changes in water quality. The following procedures will be used to minimize the impacts to surface waters as discussed in Section 11.5.1:

- Minimize disturbance of surface areas and vegetation which, in turn, will minimize erosion and run-off rates.
- Minimize physical changes to drainage channels unless changes are made to upgrade drainage.

- Use erosion and run-off control features such as proper placement of pipe, grading to direct run-off away from water bodies, and use of riprap (broken rock and/or concrete) at these intersections to make bridges or culverts more effective, if necessary.
- Use sediment trapping devices such as hay or straw bales, fabric fences, and devices to control water flow and discharges to trap sediments moved by run-off.
- Train employees in the handling, storage, distribution, and use of hazardous materials.
- Maintain natural contours as much as possible, stabilizing slopes and avoiding unnecessary off-road travel with vehicles; maintaining natural contours as much as possible, stabilizing slopes and avoiding unnecessary off-road travel with vehicles.
- Provide rapid response cleanup and remediation capability, techniques, procedures, and training for potential spills.
- The land application of treated waste water will be applied in a manner consistent with local conditions to avoid excess irrigation run-off into surface water.
- Ponds will be designed with underdrains and leak detection systems to detect and mitigate any impact from a potential leak.
- Fueling operations and storage of hazardous materials and chemicals will be conducted in bermed/curbed areas and in a manner that minimizes potential impacts to surface water.
- Prepare and implement a Storm Water Pollution Prevention Plan that is consistent with state and federal standards for construction activities.
- Surface piping will avoid any identified 100-year or 500-year flood plain levels.
- Curbing relevant facilities and structures at CPP to minimize or eliminate escape of process fluids during spills.

Best management practices will be utilized in all phases of the Proposed Action.

11.5.2.1 Proposed Mitigation Measures for Potential Groundwater Impacts from the Proposed Action

Potential groundwater impacts during all phases of the Proposed Action include the following: groundwater consumption (Section 11.5.1.1.8), alteration of ore zone groundwater quality (Section 11.5.1.1.4), potential groundwater quality impacts from accidents (Section 11.5.1.1.10), potential groundwater impacts from land application (Section 11.5.1.1.5), and potential aquifer restoration impacts (Section 11.5.1.1.7). The following is a list of potential mitigation measures to mitigate impacts to groundwater:

- Minimize groundwater use during operations.
- Monitor well pressures to detect leaks.
- Install monitoring wells as an early warning system for potential lixiviant excursions or leaks from the relevant CPP or SF.`
- Maintain pumping and injection rates (well field balance) to ensure radial hydraulic flow into and through the production zone.
- Monitor to detect and define unanticipated surface spills, releases, or similar events that may infiltrate into the groundwater system.
- Implement a spill prevention and cleanup plan to minimize impacts to groundwater, including rapid response cleanup and remediation capability, techniques, procedures, and training;
- Recycle groundwater collected for use in dust suppression and other activities;
- Monitor closest private domestic, livestock, and agricultural wells as appropriate during operations;

- Provide alternate sources of water to landowners in the event of significant drawdown impacts from the proposed action, to domestic wells adjacent to the PAA;
- Select restoration method to minimize water consumption during groundwater restoration;
- Monitor area downgradient from land application sites to determine potential vertical and lateral seepage.

During restoration, monitor groundwater using standard industry practices to determine the progression and effectiveness of restoration.

11.6 Groundwater Restoration Methods

This section addresses **No.3 of Cover Letter** dated 08/06/2009.

11.6.1 Groundwater Restoration Method(s)

For ISL operations, a typical commercial groundwater restoration program consists of a restoration stage and a monitoring stage. The proposed project restoration schedule, Table 10.7-2, shows the estimated schedule for restoration. This is a preliminary schedule based on current knowledge of the area, and is based on completion of the production activities for both the Dewey and Burdock sites. As the project is developed, the restoration schedule will be further refined. The restoration stage commonly consists of groundwater sweep and groundwater treatment. The methods of water disposal will provide two options during the ground water treatment stage and some variations exist between the two options. The expected waste disposal method during restoration could be any or all of the following:

- Deep well injection
- Land application with pre-treatment
- Any combination of deep well injection and land application

Potential use of deep disposal well(s) will allow use of reverse osmosis (RO) in the treatment phase with permeate from the RO being re-injected into the well field being restored. In the case of land application as a disposal method, a fresh water source is required for injection into the well field during restoration. The reasons for this are that deep disposal wells are expected to allow disposal of RO reject which has TDS levels that are expected to be unsuitable for land application.

11.6.2 Estimate of Post-Production Groundwater Quality

This section addresses **CI–18 (a)**.

According to ARSD 74:55:01:26(18)(a) The proposed methods to restore ground water quality are based on the geochemistry of the production zone and the chemistry of the injection solutions and are to include: A proposed restoration table for all ground water quality restoration values... ARSD 74:55:01:45.01 concerns ground water restoration tables and requires: information submitted in accordance with subdivision 74:55:01:26(18), the department shall develop a ground water restoration table with assigned ground water quality restoration values that are the compliance requirements for restoration of the production and nonproduction zones. The restoration values shall be based on pre-mining baseline conditions.

The intention of the rule concerning pre-mining baseline refers to well field baseline pre-mining water quality. Before the pre-mining baseline water quality can be assessed, it must be obtained via specific well field testing and sampling. Therefore, it is not appropriate at this point in the permitting process to

prepare restoration tables that are intended to set standards for restoring well field groundwater. This information is to be provided upon consultation with agencies during the development of well field packages.

This section addresses **CI–9**.

Powertech is willing to develop groundwater restoration tables in conjunction with SD DENR as stated in our response to Completeness Issue 4-18 (a), above. However, additional well field specific data is required. Also it is our understanding from ARSD 74:55:01:26(18) that DENR sets the restoration table values.

In order to estimate post-production water quality from ISL operations at the site, Powertech (USA) has reviewed operational restoration water quality data from six ISL operations in the western United States. These sites include:

- Irigaray/Christensen Ranch (Wyoming)
- Crownpoint (New Mexico)
- Crow Butte (Nebraska)
- Bison Basin (Wyoming)
- Smith Ranch/Highland (Wyoming)
- Ruth (Wyoming)

Based on this review, the Crow Butte site was selected for the estimate because of the proximity and similar geologic conditions to the project site, available water quality data, reasonable pore volume estimates to achieve restoration and overall restoration success. The water quality data for the Crow Butte site is extensive with baseline, post-production, post-restoration, and stabilization period data. Baseline water quality, post-production water quality, post-restoration average water quality and stabilization period average water quality data are provided in Table 11.6-1 for the Crow Butte Mine Unit No.1. Powertech (USA) may expect similar baseline and post-production water quality results at the project site.

Table 11.6-1 Crow Butte Post Mining Water Quality Data Summary

Parameter	Baseline Water Quality	Post-Mining Water Quality	Post-Restoration Average Water Quality	Stabilization Period Average Water Quality
BULK PROPERTIES				
Specific Cond.	1947	5752	1620	1787
pH	8.5	7.35	7.95	8.18
TDS	1170.2	3728	967	1094
CATIONS/ANIONS				
Alkalinity	293	875	321	347
Chloride	204	583	124	139
Sulfate	356.2	1128	287	331
TRACE METALS				
Manganese	0.11	0.075	0.01	0.02
Arsenic	0.002	0.021	0.024	0.017
Iron	0.044	0.078	<0.05	0.09
Lead	0.031	<0.05	<0.05	<0.01
Uranium	0.092	12.2	0.963	1.73
Vanadium	0.066	0.96	0.26	0.11
RADIONUCLIDES				
Radium-226	229.7	786	246.7	303

Notes: All units in mg/L except for pH (standard units), radium (pCi/L), and specific conductivity (µmhos/cm).

11.6.3 Groundwater Treatment

The groundwater treatment method of restoration is similar to the injection sweep method in that uncontaminated water is injected in perimeter wells. In this method of restoration, the groundwater removed during restoration is treated by reverse osmosis to divide it into a permeate stream containing most of the water, but little of the dissolved solids in the restoration flow, and a reject stream containing a relatively small portion of the volumetric flow, but a large fraction of the dissolved solids. The permeate stream is relatively uncontaminated and is a suitable source for a portion of the uncontaminated water injected at the perimeter of the well field. In addition to this permeate recycle, a make-up stream of fresh water from an outside well will be required, as described in the injection sweep method, but requiring a much smaller amount of this water from an outside source. The reject stream is then disposed of in a suitable deep disposal well, as described in Section 10.5.2.

The wastewater system, disposal well injection and land application descriptions are discussed in further detail in Section 10.0.

11.6.4 Estimated Groundwater Restoration Schedule

See Figure 10.6-1 Operations Summary Schedule.

11.6.5 Effectiveness of Ground Water Restoration Techniques

The groundwater restoration methods described in this application have been successfully applied at other uranium ISL facilities in the US, including Irigaray/Christensen Ranch in Wyoming and Crow Butte in Nebraska. According to the NRC's historical data review (Appendix C-1, USNRC 2009), "The data show that over 60 percent of the constituents were restored to their pre-operational concentrations. Although the remaining constituents were restored to concentrations that were above baseline levels, they were all restored to levels that NRC staff found to be protective of public health and the environment."

11.6.5.1 Irigaray/Christensen Ranch

The Irigaray/Christensen Ranch ISL sites are located in the Powder River Basin approximately 50 miles to the southeast of Buffalo, Wyoming (USEPA, 2008). The ore mineralization occurs as a roll-front deposit in the Eocene Wasatch Formation.

Reverse osmosis was used to treat well field bleed water for use in restoration. Water quality of the Irigaray ore zone after production was measured by sampling each of the designated restoration wells and comparing results to baseline water quality data. Most of the 30 parameter concentrations in the post-production data exceeded the baseline means. Several of these parameters did not meet Restoration Target Values (RTV) established for the site (EMC, 2007).

Groundwater restoration results at the Irigaray/Christensen Ranch site were approved by the NRC and WDEQ following commercial operations and groundwater restoration at well fields 1 through 9. Post-production water quality in the nine production units was described above. Restoration water quality data were not available for this report. After restoration, twenty-seven of twenty-nine constituents were restored below the restoration target values as approved by the WDEQ using 9.5 to 18.4 pore volumes (USNRC, 2008). Bicarbonate and manganese were the only constituents that exceeded baseline ranges. However, WDEQ ruled that these constituents met the criteria of pre-production class of use. Therefore, the WDEQ determined that post restoration groundwater conditions did not significantly differ from the background water quality and groundwater, as a whole, had been returned to its pre-production class of use. In 2006, the NRC concurred with WDEQ's determination that groundwater restoration was complete at the site.

11.6.5.2 Crow Butte

The Crow Butte ISL site is located in Dawes County Nebraska just southeast of the town of Crawford (Collins and Knode, 1984). Roll-front ore deposits are concentrated in the Basal Chadron Sandstone, which is a member of the Paleocene White River Group. Coffinite is the major uranium mineral associated with the deposit. Matrices minerals include quartz, feldspar, mafic minerals, pyrite, and clays.

Restoration of commercial Mine Unit No. 1 took approximately five years after beginning in 1994 (USNRC, 2007). The restoration process consisted of groundwater transfer (0.89 pore volumes), groundwater sweep (0.09 pore volumes), groundwater treatment with IX (26.62 pore volumes), groundwater treatment with reverse osmosis (6.02 pore volumes) and well field recirculation (2.85 pore volumes). Thus, a total 36.47 pore volumes was processed in the restoration steps listed above (Crow Butte Resources, 2000). The NRC originally denied restoration approval for Mine Unit No. 1 due to concentrations of ammonium, iron, radium-226, selenium, total dissolved solids, and uranium that showed increasing trends during the six-month stability monitoring period. Therefore, the NRC requested additional stability monitoring for these parameters which was performed and submitted by Crow Butte Resources (Crow Butte Resources, 2001). The NRC then approved the restoration of Mine Unit No. 1 in 2003 (USNRC, 2007).

The NRC approved the completion of groundwater restoration program for Well field No. 2 after the removal of approximately 19 pore volumes and recirculation of approximately 16.4 pore volumes (USNRC, 2007).

Section 12.0 - Radiological Environmental Measures and Monitoring Programs

12.1 Background Radiological Data

12.1.1 Radiological Monitoring

For radiological characterization of the PAA three primary guides were utilized, NUREG-1569 "Standard Review Plan (SRP) for In Situ Leach Uranium Extraction License Applications" (USNRC, 2003), "NRC Regulatory Guide (RG) 4.14" (Revision 1), "Radiological Effluent and Environmental Monitoring at Uranium Mills" (USNRC, 1980) to provide an acceptable basis for pre-operational radiological baseline evaluations, NUREG-1575, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), 2000 was also considered where relevant.

Sample placement prescribed by RG 4.14 was modified in order to ensure the effort put forth in characterization of the PAA is adequate and assures an appropriate baseline determination of background radiation. Modification of the sampling program described in RG 4.14 is appropriate as RG 4.14 was developed to be used in design of an environmental monitoring program for conventional uranium mill and tailings sites and was not specifically intended to address ISL operations. The modified sampling program adequately characterized radiological aspects of the environment at the PAA and assists the applicant in the proper placement of operational monitoring sites to ensure standards for protection against radiation will be met during licensed operations. The sampling protocol was designed to achieve the goal of adequately protecting the public and the environment from unacceptable levels of radiation or radioactive materials that exceed background levels. See Section 12.1 for additional details.

Responsible operators achieve this goal, in part, by consulting NRC guidance documents such as NUREG-1575. By conducting a detailed environmental site survey, sampling and analysis program; the operator is able to establish baseline background levels and assess possible derived concentration guideline levels (DCGLs) via both historical site assessments (HAS) and the most recent site characterization. Historical and current data will be assessed prior to commencement of the Proposed Action's D&D (Decontamination and Decommissioning) program. By utilizing the immense experience of the industry, consultation with the appropriate regulators and utilization of applicable guidance, the licensee will be able to clean up any contamination that may result from ISL operations and release the site for unrestricted use.

12.1.1.1 Approval of Pre-operational Radiological Plan

This section addresses **CI–4 (13)** and **CI–4 (10) (a)**.

Powertech and its consultants met with NRC staff in a public meeting on August 22,2007 to present and review the baseline characterization plan (also referred to as the sampling and analysis plan) for the Dewey-Burdock Project. A similar meeting was also held with the SD DENR August, 2007. Below is a bullet list of the meetings held with the SD DENR related to the baseline sampling plan:

- Draft Baseline Sampling Plan dated Aug 2007
- Original Baseline Sampling Plan dated Sept 2007 and sent to DENR by Dan Hoyer on 9/18/2007
- Meeting w/ DENR in Pierre to discuss Baseline Sampling Plan on 9/27/07 1PM
- Formal response from DENR's Natural Resource Engineering Director of the Minerals and Mining Program, dated: February 11, 2008.
- Memo response to DENR comments Dec 11, 2007
- Revision 1 dated Jan 2008

- Meeting on 1/8/07 at Edgemont (USGS, EPA, NRC, DENR, etc.)
- Meeting on 1/9/07 10AM @ USGS office in Rapid City

While the NRC does not request a formal submittal or issue approval of the baseline sampling and analysis plan, it encourages all prospective applicants to present and review their baseline characterization plan with them. The modified radiological characterization plan was discussed and no objections were raised by NRC. However, the NRC did offer comments for consideration regarding the addition of alluvial monitor wells and expression of the gamma survey to include the railroad right-of-way and access/egress roadways potentially used by historical operations. Powertech and its consultants incorporated these components into the radiological characterization plan (Letter dated February 11, 2008; Section 4.0; item 1). After consultation with the SD DENR in 2007, Powertech was requested to add groundwater baseline wells by SD DENR. These, too, were incorporated into the radiological characterization plan. A second request for two more additional wells were requested by SD DENR and Powertech has incorporated these two "SD DENR Up gradient wells" into the data compilation effort. See Appendix F for well data.

12.1.2 Introduction

This section provides baseline radiological data for surface soils (0-5 and 0-15 cm), subsurface soils to a depth of 1 m, vegetation, cattle, direct gamma radiation, and radon-222 flux rates radon-222 in air representative of the project property. See Section 9.2.1 "Groundwater Quality Baseline for the Proposed Action Area"; Tables 12.1-26 and 12.1-27 for radiological data. The work was performed by Environmental Restoration Group (ERG) between August 2007 and July 2008.

Field investigations, sample collection, and other quality-related work performed were conducted in accordance with applicable ERG SOPs, listed below:

- SOP .010 Radon Flux Canister Deployment
- SOP 1.05 Calibration of Scale, Ratemeters
- SOP 1.22 Determining the Concentration of Airborne Radioactive Particles
- SOP 1.51 Correlation between Gamma-Ray Count Rate and Exposure Rate
- SOP 2.02 General Equipment Decontamination
- SOP 2.07 Function Check of Equipment
- SOP 2.09 Correlation between Gamma-Ray Measurements and Radium-226 in Soil
- SOP 3.02 Sample Control and Documentation
- SOP 5.01 Setup and Operation of Trimble Pro XRS GPS Receiver with Trimble TSCe Data logger
- SOP 5.02 Download, Correction, and Export of GPS Survey Data
- SOP 5.06 Creating, Uploading, and Navigating to Waypoints
- SOP 7.08 Surface and Shallow Subsurface Soil Sampling
- SOP 7.09 Vegetation Sampling
- The baseline radiological field investigation consisted of the following activities:
- A GPS-based gamma survey conducted at 100 to 500 m transects spanning the PAA
- A second GPS-based gamma survey of two, collective land application areas conducted at 100 m transects
- Collecting surface soil (0-15 cm) samples at 75 randomly selected and at five biased locations spanning the PAA

- Collecting subsurface soil samples at nine randomly selected locations taken at depth intervals of 15-30 cm and 30-100 cm
- Collecting surface (0-15 cm) and subsurface samples at the same depth intervals at 17 randomly selected locations in the land application areas
- Collecting shallow (0-5 cm) surface soil samples at the eight AMS
- Vegetation sampling at each AMS during the summer, fall and spring
- Air monitoring at one background and seven additional locations
- Radon monitoring in air
- Radon flux measurements at locations coinciding with the subsurface samples
- Exposure rate monitoring, using a PIC and thermoluminescent detectors (TLDs)
- Collecting three samples of locally grazed livestock

Table 12.1-1 summarizes the scope of the field investigation and Exhibit 12-1 shows the sampling location and type of sampling performed in the PAA. All samples were shipped under chain-of-custody to a National Environmental Accreditation Conference-certified laboratory, Energy Laboratories, in Rapid City, South Dakota.

The units reported in the body, tables, and figures related to this section vary. NRC Regulatory Guide (RG) 4.14, Radiological Effluent and Environmental Monitoring at Uranium Mills, has specific requirements for unit reporting in tables. For example, it recommends that radionuclide soil concentrations be reported in units of microcuries per gram (µCi/g). Where applicable, the tables adopt this unit. The main body of Section 6.2.1, however, adopts the unit pCi/g for this parameter, as this unit is used more generally and consistently by the uranium industry and public.

Table 12.1-1 Summary of Baseline Radiological Investigation Scope

Task Method/Endpoint	Baseline Investigation Scope	Parameters Evaluated
A.GPS-Based Gamma Surveys	GPS-based unshielded gamma-ray readings along 100 or 500 meter transects at <1.5 meters per second. A second survey covered proposed land application areas along 100 meter transects.	Serve as basis to estimate pre-operational gamma emissions from land areas and exposure rates, surface soil radium-226 concentrations, and identify areas for biased soil sampling.
B. Biased Soil Sampling	Biased samples at five locations, all collected from 0 to 15 cm	Radium-226 for all samples Thorium-230, natural uranium, lead-210 for 2 locations
C. Random Soil Sampling	Random samples at 75 locations Nine of the 75 locations were sampled at depth (15-30 cm and 30-100 cm) Ten duplicates at 0 to 15 cm. One duplicate each at 15 to 30 cm and 30 to 100 cm.	Radium-226 for all samples Thorium-230, natural uranium, lead-210 (8 from 0 to 15 cm and one each at 15 to 30 cm and 30 to 100 cm
D. Soil sampling in land application areas	Random samples at 17 locations, all but one of which were sampled at 0 to 15, 15 to 30 and 30 to 100 cm. Refusal was encountered at 45 cm in the exceptional location. One duplicate each at 0 to 5, 15 to 30, and 30 to 100 cm.	Radium-226, thorium-230, natural uranium, and lead-210 for all samples
E. Exposure Rate Monitoring	Exposure rate determinations based on TLD and PIC measurements. TLD measurements collected for four quarters.	Exposure rates
F. Soil and Vegetation Sampling at Air Monitoring Stations	Eight locations: seven on-site (AMS-01 through AMS-07) and one located approximately 1.9 miles west of the southwest corner of the PAA (AMS-BKG). Vegetation samples collected for four quarters.	Vegetation: radium-226, thorium-230, natural uranium, lead-210 and polonium-210 Soil: All of the above except polonium-210
G. Air Particulate Sampling	Eight locations: seven on-site (AMS-01 through AMS-07) and one located approximately 1.9 miles west of the southwest corner of the PAA (AMS-BKG). Air particulate samples collected for four quarters.	Air filters: radium-226, thorium-230, natural uranium, lead-210 and polonium-210
H. Radon in air	16 locations: eight AMS and eight additional locations. Radon in air measurements taken for four quarters.	Radon-222
I. Radon Flux Measurements	Radon flux measurements at nine locations (collected at the biased subsurface soil sample locations in Task C) in summer, fall, and spring.	Radon-222
I. Locally Grazed Livestock Sampling	Three samples collected from one locally grazing cow.	Radium-226, thorium-230, natural uranium, lead-210 and polonium-210

12.1.3 Surface Gamma Survey

12.1.3.1 Methods

12.1.3.1.1 Baseline GPS-Based Gamma Survey

GPS-based gamma surveys were conducted within the PAA and the historical surface mine areas of the project from September 13-27, 2007 and completed on July 14, 2008. Unshielded Ludlum Model 44-10 2”x 2” sodium iodide (NaI) detectors were coupled to Ludlum Model 2221 ratemeter/scalers (set in ratemeter mode) and a Trimble Pro XRS GPS Receiver with Trimble TSCe Datalogger. Survey transects were spaced at approximately 500-m intervals in the PAA and 100 m in the surface mine area. The transect spacing was reduced in the surface mine area in anticipation of finding a greater variation in gamma-ray emissions, due to historical mining in the area. The survey speed was maintained between 2 and 5 feet per second with x- and y-coordinates and gamma-ray count rates recorded every second. The detector height was held relatively constant at approximately 18 inches above ground surface. Depending on the terrain, field personnel surveyed using ATVs or by walking with the equipment in backpacks. See example of utilization of best technology available in regards to conducting the roving gamma survey at the PAA in Figure 12.1-1.

A second GPS-based gamma survey was conducted over the land application areas from July 17-19, 2008, using the Ludlum gamma-ray detection system described above with the same response characteristics as used in the initial survey. The scanning speed and detection height were unchanged from the initial survey and the transect spacing was 100 m.

The areas subject to GPS-based gamma surveys are shown on Figure 12.1-2.

Figure 12.1-1 Example of Best Technology Available Utilized for the Roving Gamma Survey at the Dewey-Burdock Project by ERG

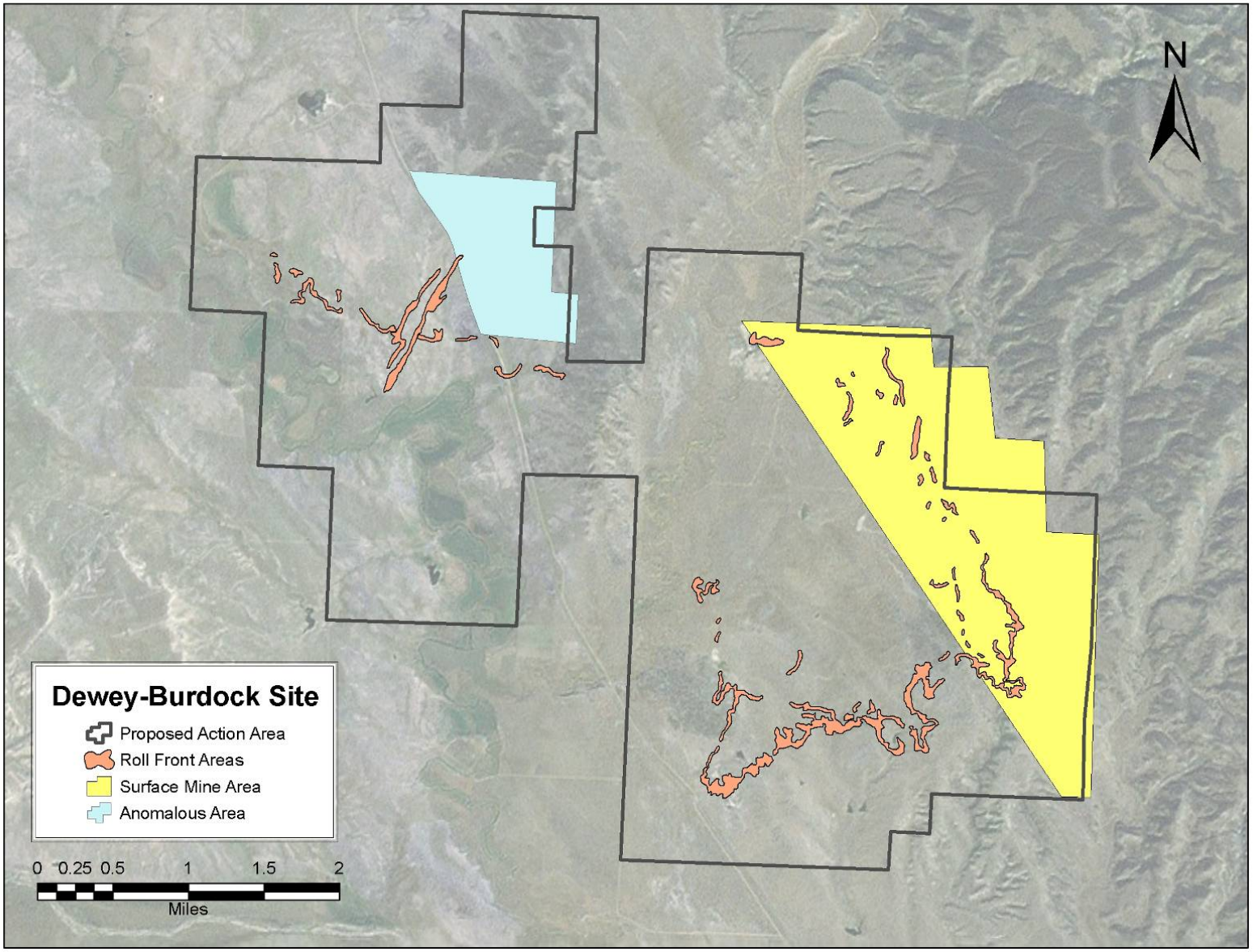

Figure 12.1-2 Areas Subject to GPS-Based Gamma Surveys

12.1.3.1.2 Cross-Calibration of Sodium Iodide Detectors and a High-Pressure Ionization Chamber

Both the sodium iodide detector and PIC measure gamma radiation. The sodium iodide detection system measures the rate that the gamma rays interact with the detector in counts per minute (cpm), has a lower sensitivity than the PIC and is energy dependent. The PIC is a highly accurate ionization chamber for measuring exposure rate in microroentgens per hour (μR/hr) but requires a longer count time. The PIC was used because it measures exposure rates directly and is considered a primary standard by the National Institute of Standards and Technology (NIST), when calibrated. The PIC measures gamma, X-rays, and cosmic radiation without discrimination. It is highly stable, relatively energy independent, and serves as an excellent tool to calibrate other survey equipment to measure exposure rates. Because of its portability and shorter measurement times, the sodium iodide detector is more efficient than the PIC for use in large area surveys. By performing the large area gamma surveys with sodium iodide detectors, then developing a correlation between the two instruments, exposure rates derived from the sodium iodide measurements can represent site wide gamma emissions from surface soils.

Powertech collected 12 co-located static gamma counts and exposure rate measurements to develop the correlation between gamma counts and exposure rates. The locations were biased towards areas where gamma shine was not relatively high; that is, where gamma count rates remained relatively constant at 18 inches, 1 m, and 2 m above ground surface. In addition, locations were chosen to encompass most of the range of sodium iodide detector readings observed in the GPS-based gamma surveys. The sodium iodide measurements were taken using one of the 2-inch by 2-inch sodium iodide detectors that were used in the baseline gamma survey. A 1-minute integrated count was taken at each of the 12 locations with the detector suspended at 18 inches above the ground surface. Exposure rate measurements were then collected at a 1-m height at each location, directly above the location where the sodium iodide detector was held. Exposure rates were determined after 20-minute integrated counts. The PIC and gross gamma measurements were performed on July 14 to 16, 2008 at the locations shown on Figure 12.1-3.

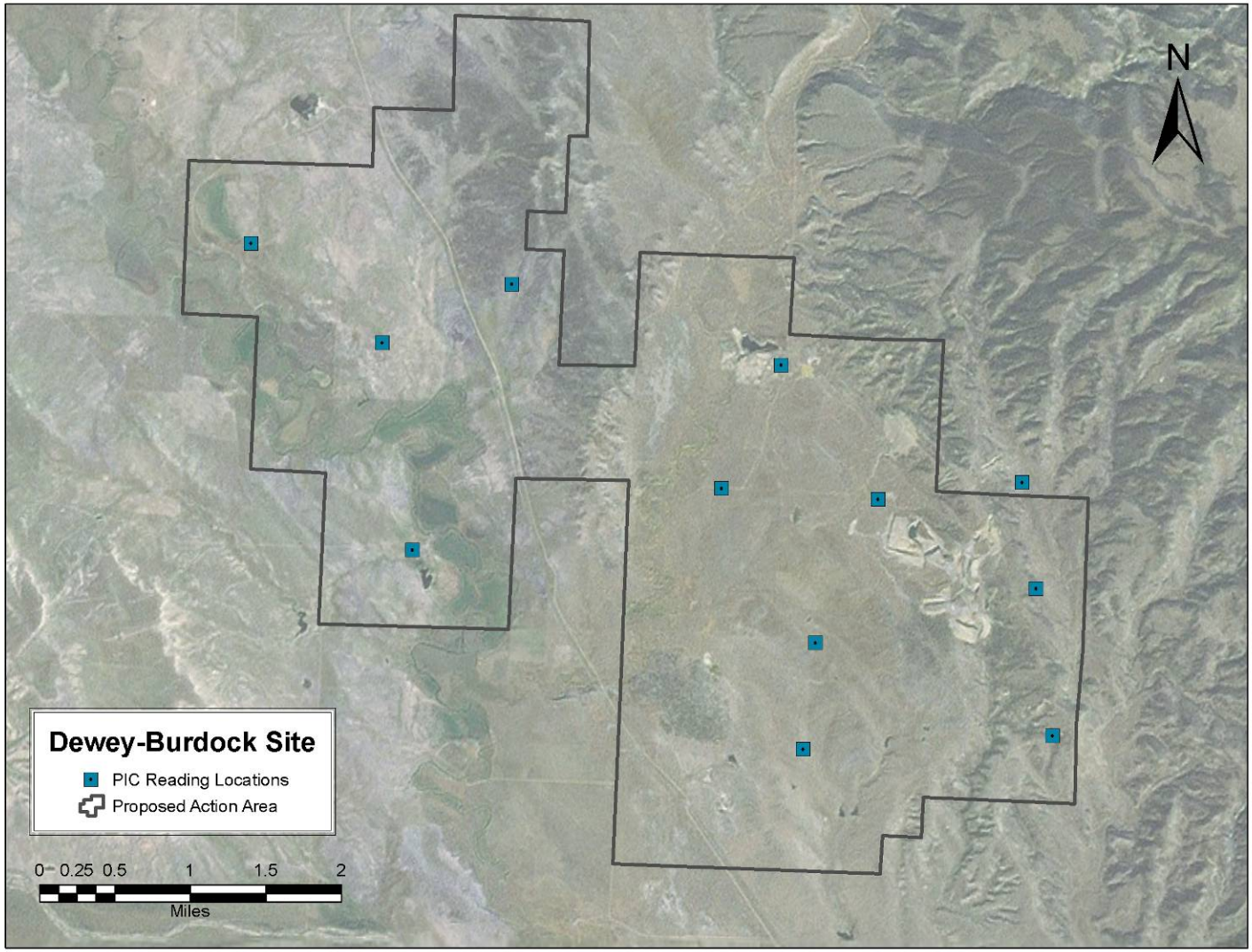

Figure 12.1-3 Locations of High Pressure Ion Chamber and Sodium Iodide Detector Measurements

12.1.3.1.3 Gamma/Radium-226 Correlation Grids

To estimate site-wide radium-226 concentrations at each of the GPS-based gamma survey points, a correlation was established by performing a regression between the surface soil analytical results for radium-226 in the 80 surface (0-15 cm) soil samples and one-minute integrated direct radiation measurements collected at each of these locations prior to sample collection. The measurements were collected with the same Ludlum 44-10/2221 2-in by 2-in sodium iodide gamma detection systems used in the GPS-based gamma survey.

The correlation was used to translate each of the gamma-ray count rates obtained in the GPS-based survey to predicted radium-226 concentrations. ArcView GIS then was used to generate average predicted radium-226 concentrations in 700 by 700 foot grid blocks covering the site.

12.1.3.1.4 Data Quality Assurance/Quality Control

All survey instruments were calibrated. The function of survey instruments was checked at the beginning and end of each work day using a National Institute of Standards and Technology-traceable cesium-137 source. Calibration sheets and function check data are provided in Appendix A of Appendix J.

12.1.3.2 Surface Gamma Survey Results

12.1.3.2.1 Baseline Surface Gamma Survey Results

The gamma-ray count rate data obtained in the initial survey were first evaluated as an entire set and then subdivided into the main permit (the entire data set less the surface mine area) and surface mine areas.

The observed gamma-ray count rates are presented as colors representing ranges of counts in Figure 12.1-4. Three areas are shown on the figure: the main permit and surface mine areas, and an area of anomalous gamma-ray count rates located in the northern portion of the PAA.

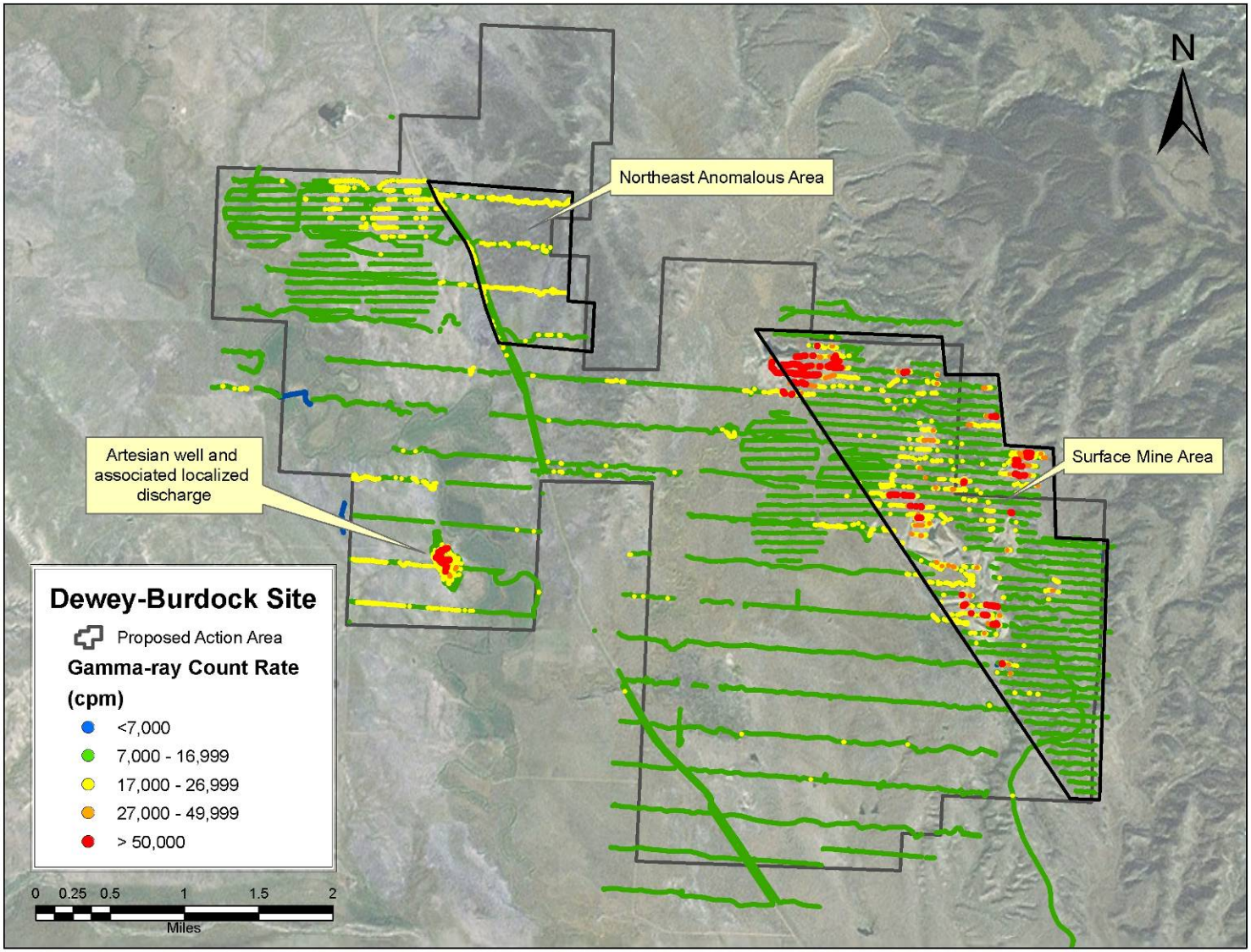

Figure 12.1-4 Gamma-Ray Count Rates Obtained During Initial GPS-Based Gamma Survey

None of the data sets: including the entire PAA and gamma data obtained in the main permit and surface mine areas are normal, lognormal, or exponentially distributed. Furthermore, normalizing data transformations were conducted and the transformed data did not follow standard distributions. For these reasons, data analysis and summaries were performed using non-parametric statistical methods, which are less sensitive to extreme observations typical of skewed data distributions.

The median and inter-quartile range (IQR) are non-parametric measures of central tendency and variability, respectively. The IQR is the difference between the first (Q1) and third (Q3) quartiles, i.e., 25 and 75 percent of the data are less than Q1 and Q3, respectively. Any datum that is outside the range of 1.5 times the IQR lower than Q1 and 1.5 times the IQR higher than Q3 is considered an outlier. Extreme outliers, or extremes, are those exceeding three times the IQR to the left and right from the first and third quartiles respectively (Ott and Longnecker, 2001).

The summary statistics of the GPS-based gamma-ray survey are listed in Table 12.1-2. The median of the gamma-ray count rates for the overall data set was 12,687 cpm. Field personnel collected 157,075 readings ranging from 5,550 to 460,485 cpm.

Table 12.1-2 Statistical Summary of Gamma-Ray Count Rates in Entire Data Set, Main Permit and Surface Mine Areas

	Gamma-Ray Count Rate (cpm)		
Estimator/Endpoint	**Entire Data Set**	**Main**	**Surface Mine Area**
Mean	15,025	13,073	16,823
Standard Deviation	17,095	2,995	23,377
Median	12,687	12,664	12,717
Mode	12,487 (n=53)	12,585 (n=35)	12,138 (n=31)
Minimum	5,550	5,883	5,550
Maximum	460,485	171,243	460,485
Q1	11,395	11,598	11,125
Q3	14,437	14,137	14,783
IQR	3,042	2,539	3,658
No. of Counts	157,075	75,345	81,757

Notes:
Entire data set does not include gamma-ray counts obtained along the eastern haul road. In addition, the sum of the counts in the main permit and surface mine areas is 27 counts greater than the counts in the entire data set, due to an overlap in counts within the two shapes placed as a layer in ArcView GIS to select the data sets.

12.1.3.2.1.1 Proposed Action Area

As shown in Table 12.1-2, the median gamma-ray count rate for the PAA data set was 12,664 cpm for 75,345 observations. The count rates ranged from 5,883 to 171,243 cpm. Low outliers in the PAA data set, count rates below 7,790 cpm, appear to be limited to two clusters. High outliers in the data set, count rates exceeding 17,946 cpm, appear to be limited to an approximately 600-acre area located at the north end of the PAA, the area identified as an anomalous area on Figure 12.1-4.

Approximately 0.1 and 2 percent of the gamma-ray count rates observed in the PAA are comprised of low and high outliers, respectively.

The majority of high outliers are located in the north section of the PAA. The distribution of these anomalous gamma-ray count rate data is unknown. The count rates ranged from 8,863 to 22,130 cpm and the median was 15,503 cpm.

12.1.3.2.1.2 Surface Mine Area

In the surface mine area, the gamma-ray count rates ranged from 5,550 to 460,485 cpm and the median was 12,717 cpm. In general, clusters of higher readings are associated with un-reclaimed open pit uranium mines, waste rock, rocky outcrops, and drainages in the surface mine area. Approximately 0.004 and 9 percent of the gamma-ray count rates observed in the surface mine area are low and high outliers, respectively.

12.1.3.2.1.3 Discussion

There is sufficient evidence for the variances in the main permit and surface mine area gamma-ray count rates being distinct and thus represent distinct data populations. The variances in the main permit anomalous area are also distinct.

It is clear that the surface mine area in the eastern quarter of the site exhibits radiological impacts from historic and/or current anthropogenic activities within the area. In addition, gamma-ray count rates in the anomalous north area also are clearly distinct from those in the wider main PAA. The precise sources of the differences are not relevant in the context of this investigation since they are part of the baseline or background radiological characteristics of the site.

12.1.3.2.1.4 Land Application Areas

The summary statistics of the GPS-based gamma-ray survey of the proposed land application areas are listed in Table 12.1-3. The gamma-ray count rates obtained in the main PAA are listed in the table to facilitate comparison between the proposed land application areas and area in which they occur. The data are shown as ranges of count rates on Figure 12.1-5.

Gamma-ray count rates in the proposed land application areas are similar to those obtained in the larger main PAA. In the Dewey land application area, the median of the gamma-ray count rates was 12,523 cpm. Field personnel collected 23,480 readings ranging from 6,798 to 20,422 cpm. In the smaller, Burdock land application area, the median of the gamma-ray count rates was 12,232 cpm. Field personnel collected 13,647 readings ranging from 8,498 to 24,248 cpm.

Table 12.1-3 Statistical Summary of Gamma-Ray Count Rates in Proposed Land Application Areas

	Gamma-Ray Count Rate (cpm)		
		Land Application Area	
Estimator/Endpoint	**Main**	**Dewey**	**Burdock**
Mean	13,073	12,815	12,308
Standard Deviation	2,995	1,940	1,318
Median	12,664	12,523	12,232
Mode	12,585 (n=35)	11,778 (n=15)	12,266 (n=16)
Minimum	5,883	6,798	8,498
Maximum	171,243	20,422	24,248
Q1	11,598	11,437	11,504
Q3	14,137	13,993	12,958
IQR	2,539	2,556	1,454
No. of Counts	75,345	23,480	13,647

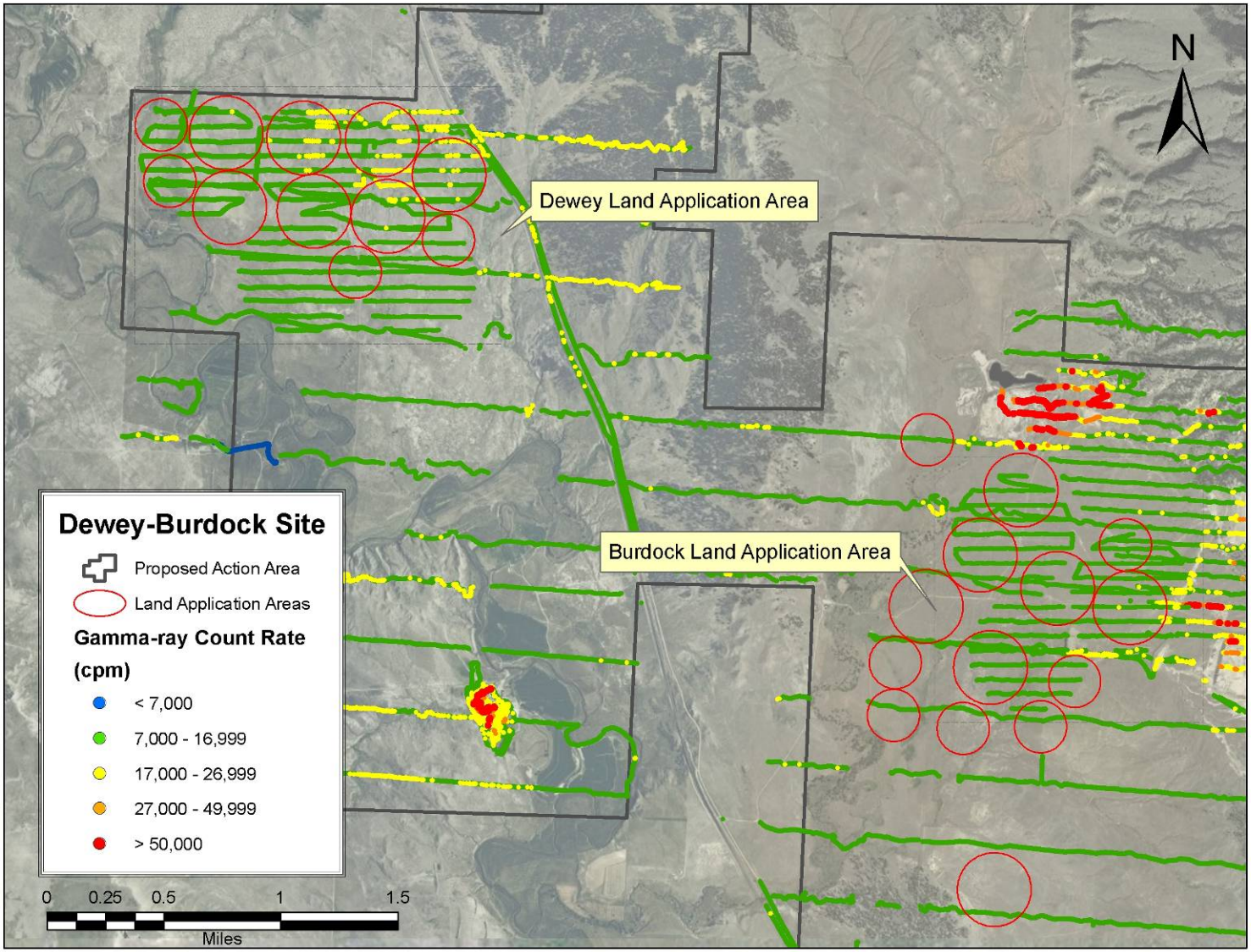

Figure 12.1-5 GPS-Based Gamma-Ray Count Rates in the Land Application Areas

12.1.3.2.1.5 Cross-Calibration of Sodium Iodide Detectors and a High-Pressure Ionization Chamber

The linear equation representing the correlation between exposure rates and gamma-ray count rates, determined using the PIC and average of the two sodium iodide detectors is:

Exposure Rate = 0.0007 x Gamma Count Rate + 2.02

where the exposure rate is in gross µR/hr and the gamma count rate is in gross cpm.

The linear regression model for the average is a good fit, with an R2 of 0.96. Nearly all of the data align along the slope of the line, as shown in Figure 12.1-6. The correlations are similar for the individual sodium iodide detectors and not discussed further.

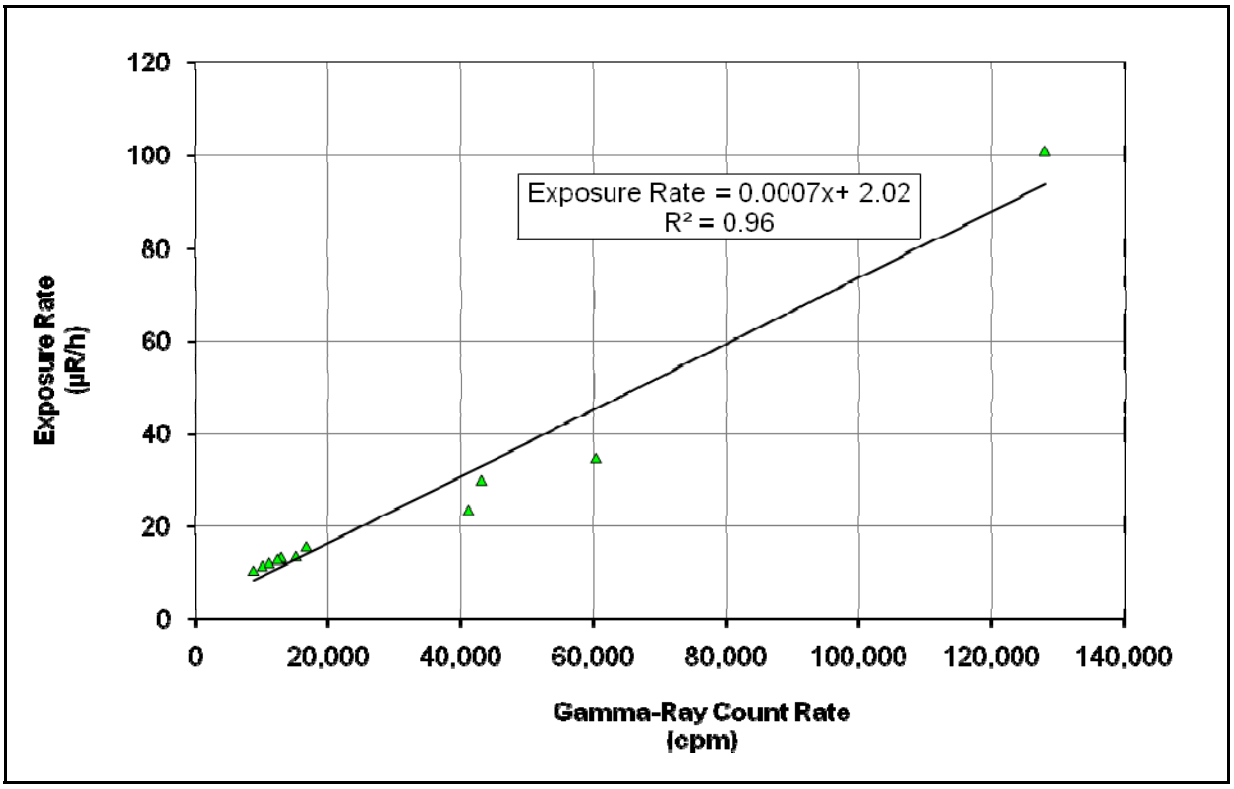

Figure 12.1-6 Linear Regression Model: Exposure Rates Correlated to Gamma-Ray Count Rates

The linear regression model predicts an average exposure rate of 10.9 µR/hr for the site. The range of predicted exposure rates is 5.9 to 324 µR/hr, based on the observed gamma-ray count rates at the site. The predicted site-wide exposure rates are shown as ranges of colors in 700 by 700 foot grid block averages on Figure 12.1-7.

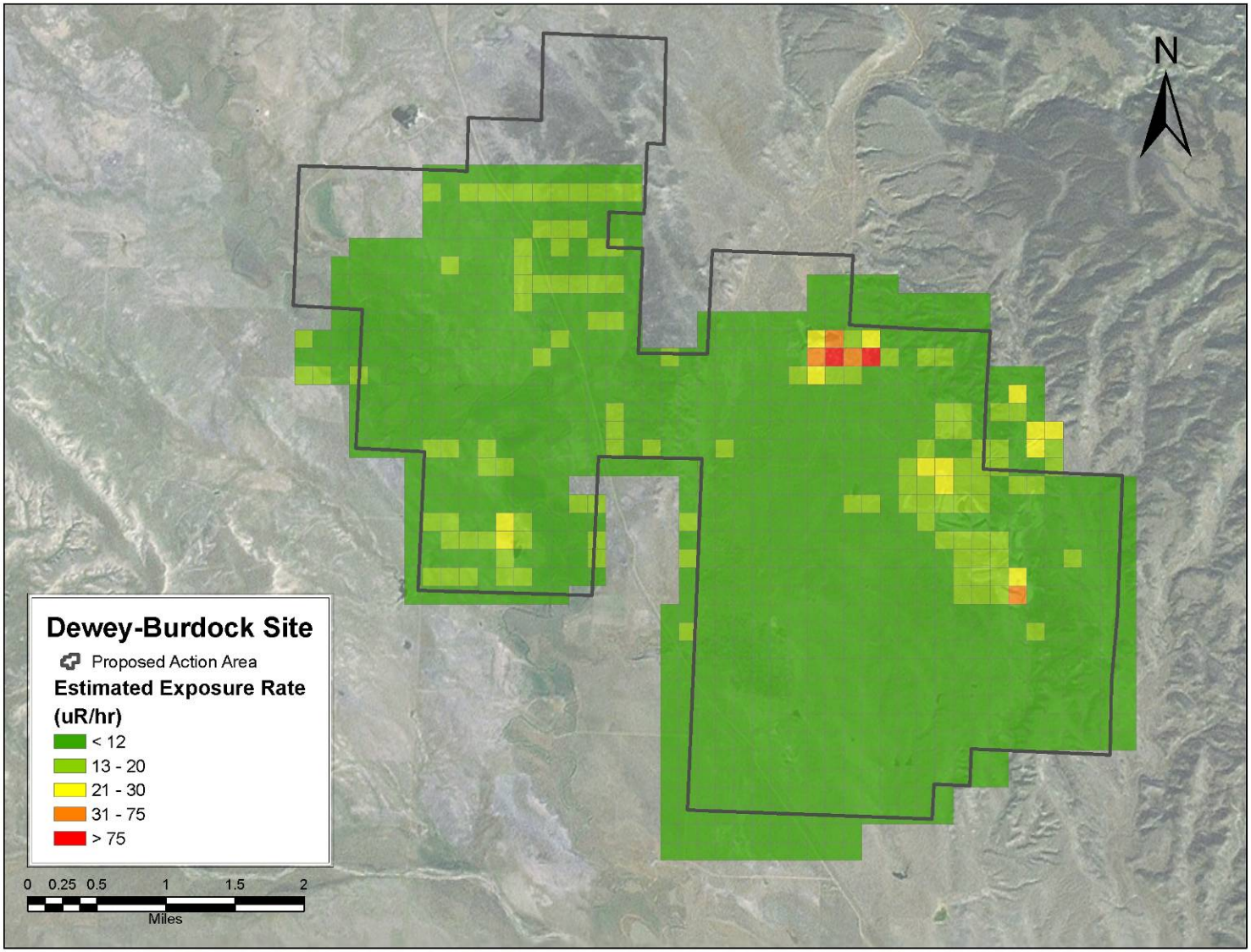

Figure 12.1-7 Predicted Site-Wide Exposure Rates, Grid Block Averages

12.1.3.2.1.6 Gamma-Ray Count Rate-Soil Ra-226 Concentration Correlation Grid Results

The relationship between gamma-ray count rates and radium-226 concentrations was determined to be appropriate after five outliers were removed from the set of 80 data points. The equation of the linear fit is:

*Radium-226 = 1.9*10-4 x Gamma-Ray Count Rate -1.04*

where the radium-226 concentration is in pCi/g and the gamma-ray count rate is in gross cpm.

This model has an R2 of 0.43, with 0.43 accounting for 43 percent of the variance in the data set. Table 12.1-4 lists summary data for the predicted radium-226 concentrations in each of the major areas.

Of the 1,015 grid blocks covering the entire PAA, the majority (approximately 78 percent) of the interpolated surface radium-226 concentrations is less than 1.5 pCi/g. In the overall data set, the median predicted radium-226 concentration is 1.1 pCi/g and the range is 0.0 to 24.9 pCi/g. In the main PAA (excluding the anomalous area), the median predicted radium-226 concentration is 0.0 pCi/g and the range is 0.0 to 9.0 pCi/g. In the surface mine area, the median predicted radium-226 concentration is 1.5 pCi/g and the range is 0.0 to 24.9 pCi/g. In the anomalous portion of the main PAA, the median predicted radium-226 concentration is 1.4 pCi/g and the range is 0 to 2.3 pCi/g.

Table 12.1-4 Summary of Predicted Radium-226 Concentrations in Grid Blocks

		Predicted Radium-226 Concentration Based on Average of Counts Within Grid Block (pCi/g)					
Data Set	**No. of Grid Blocks**	**Median**	**Minimum**	**Maximum**	**Q1**	**Q3**	**IQR**
All Data	1,015	1.1	0	24.9	0	1.4	1.4
Surface Mine Area	171	1.5	0	24.9	1.1	1.8	0.7
Main without Anomalous Area	791	1.0	0	9.0	0	1.3	1.3
Anomalous Area	53	1.4	0	2.3	0	1.8	1.8

12.1.3.2.1.7 Final Gamma Exposure Rate Mapping

The linear regression model correlating sodium iodide detector readings to PIC measurements predicts a site-wide average exposure rate of 10.9 µR/hr. The range of predicted exposure rates is 5.9 to 324 µR/hr, based on the observed gamma-ray count rates at the site. As indicated on Figure 12.1-7, predicted exposure rates ranging from 21 to greater than 75 µR/hr occur in the open pit mine areas, near the artesian well in Section 5 and its localized discharge areas, and in rocky outcrop areas in the northwest corner of the surface mine area. Predicted exposure rates in the anomalous area in the northern portion of the main PAA range from less than 12 to 30 µR/hr.

12.1.3.2.1.8 Soil Ra-226 Concentration Mapping

Predicted radium-226 concentrations in soil are shown as grid block averages on Figure 12.1-8. It is important to acknowledge that discrepancies between measured soil radium-226 concentrations reported by the laboratory and corresponding radium-226 concentrations estimated by gamma surveys are inevitable in a characterization survey of this nature and magnitude, given the heterogeneity of the site (at least in some areas) and differing detector-source geometry at various sample/survey locations.
At the same time, Figure 12-3-8 shows that without a gamma survey, reliance on a random soil sampling program alone would not have identified elevated areas of radioactivity at the site.

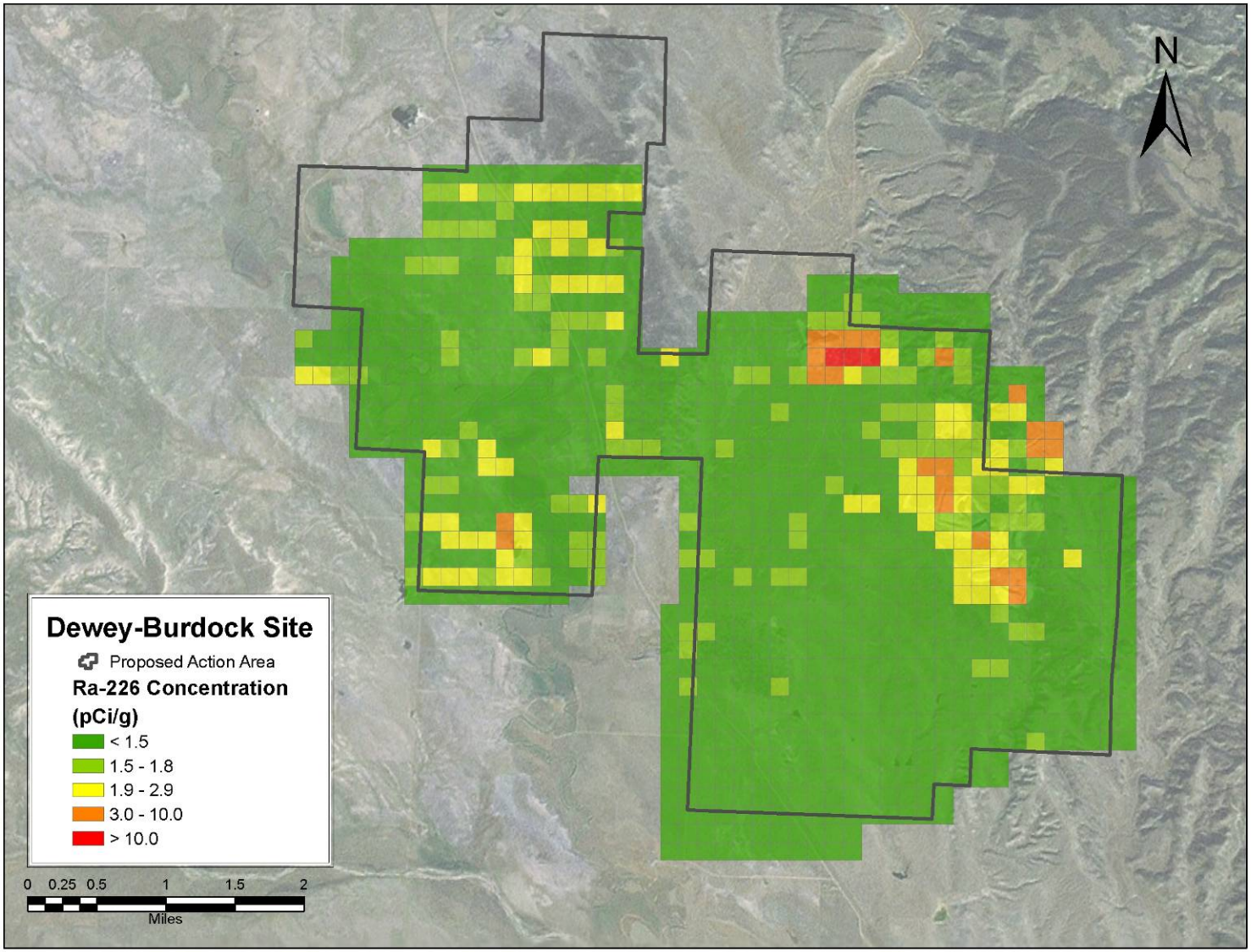

Figure 12.1-8 Predicted Site-Wide Radium-226 Concentrations, Grid Block Averages

12.1.4 Soil Sampling

12.1.4.1 Methods

12.1.4.1.1 Surface Soil Sampling

In the case of surface soil radiological characterization, sample placement prescribed by RG 4.14 was modified. RG 4.14 states that soil sampling locations start at a point halfway between proposed tailings and process areas, and 0-5 cm samples are collected every 300 m out to 1500 m in eight compass directions (40 samples) and one at each air monitoring station. This prescribed spacing largely ignores potentially varying site features such as soil types, drainages, outcrops, the affects of historical activities and the less centralized layout of the ISL operations. In addition, the soil sampling depth of 0-5 cm does not coincide with applicable cleanup standards. The NUREG-1569 requirements include collecting 0-15 cm samples to be consistent with the radium-226 cleanup standard of 5 pCi/g above background for the 0-15 cm soil horizon (10 CFR 40, Appendix A, Criterion 6(6)).

RG 4.14 suggests the collection of 40 samples from 0-5 cm and NUREG-1569 suggests the collection of samples at 0-15 cm. To avoid any ambiguity in the interpretation of these guidance documents, Powertech chose to collect 80 samples at 0-15 cm and supplementing the sampling effort with Global Positioning System (GPS)-based gamma radiation surveys. This sample size was determined to be adequate based on criteria in NUREG-1575. The GPS-based surveys allow orders of magnitude more data to be obtained with a similar effort. Owners of uranium recovery sites that have or are undergoing decommissioning are finding that extensive baseline data are invaluable. In conjunction with soil sampling and analysis and cross-reference to PIC measurements, the GPS-based gamma surveys can be used to predict site-wide concentrations of gamma-emitting radionuclides and/or exposure rates. Spatial trends in gamma emissions (and radionuclide concentrations as surrogates) are also far more apparent through the use of GPS-based gamma surveys than soil sampling alone. As will be shown below, reliance on a random soil sampling program alone would not have identified elevated areas of radioactivity at the site.

12.1.4.1.1.1 Main Permit and Surface Mine Areas

The soil sampling strategy for the main permit and surface mine areas of the project site consisted of biased and random sampling at the eight AMS locations shown in Figure 12.1-9 (this figure also shows the locations of the radon flux and track etch detector measurements, discussed below) and 80 additional locations shown in Figure 12.1-10. Biased samples were collected at five of the 80 locations; the remainder was placed randomly, using Visual Sampling Plan (VSP), Version 5.0. The biased samples were obtained in the surface mine area and selected to bound the upper range of radionuclide concentrations. The five biased samples are not sufficient to characterize radium-226 concentrations in impacted areas.

The additional 80 surface soil samples were collected from 0-15 cm below ground surface. Seventy-one of these samples were collected using a hand shovel. A hand auger was used to collect samples at 0-15, 15-30, and 30-100 cm at nine of the 80 locations. All of the soil samples were analyzed for radium-226. Ten of the 80 samples were also analyzed for natural uranium, lead-210, and thorium-230. Thirteen duplicate samples were collected: 11 with the surface set and 2 with the subsurface set. All duplicate samples were analyzed for radium-226 while two were also analyzed for natural uranium, thorium-230, and lead-210. The analytes and corresponding analytical methods were:

- Radium-226 via gamma spectroscopy or radon emanation: EPA Methods 901.1 and 903.1, respectively. Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032), August 1980. The majority of radium-226 analyses were performed using EPA Method 901.1.
- Thorium-230: EPA 907.0 Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032), August 1980.

- Natural Uranium: EPA 6020 ICP-MS, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846), June 2007
- Lead-210: EPA 909.0M Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032), 1980.

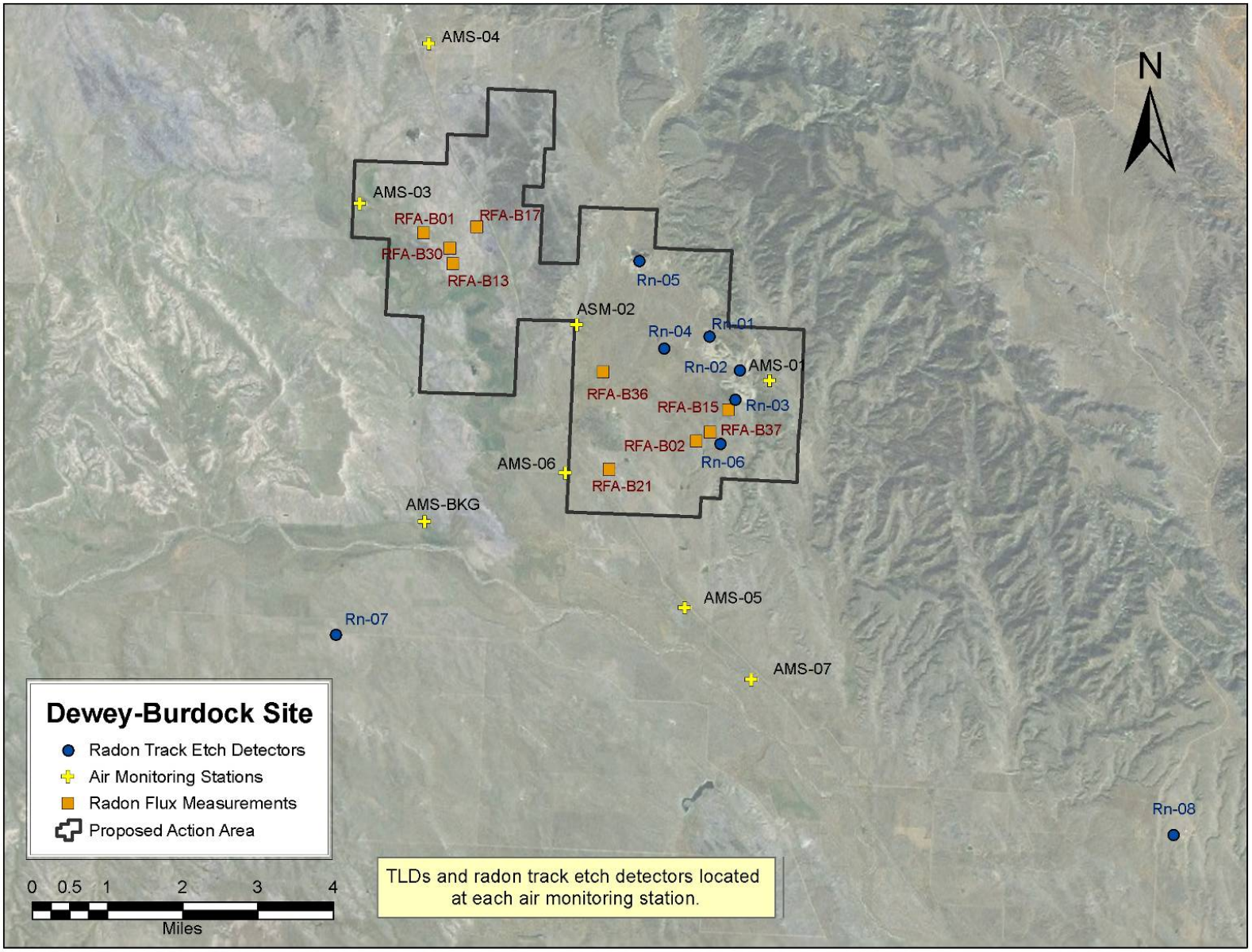

Figure 12.1-9 Air Monitoring Station, Ambient Radon, and Radon Flux Measurement Locations

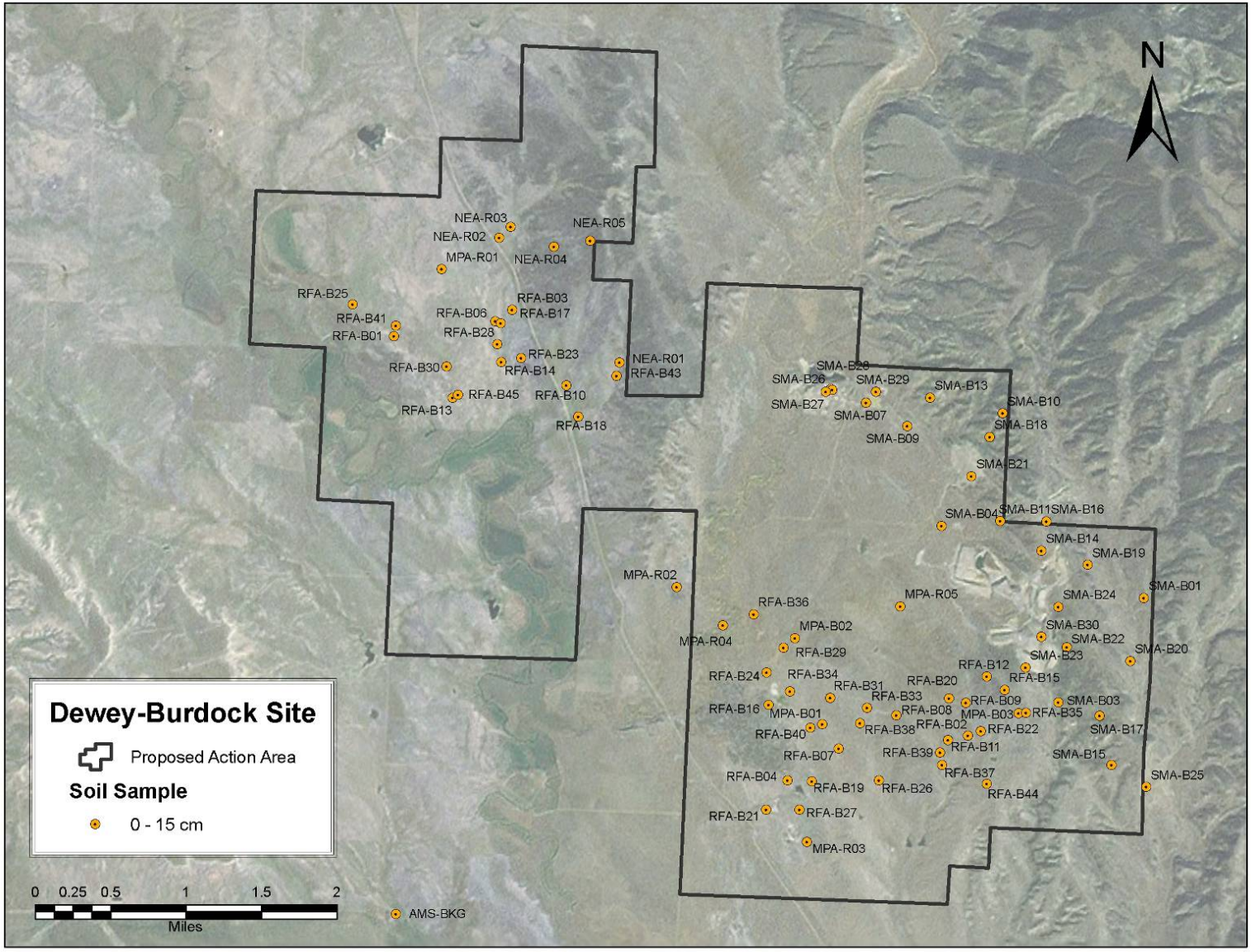

Figure 12.1-10 Surface Soil Sample Locations (80 Locations)

12.1.4.1.1.2 Land Application Areas

To characterize baseline radionuclide concentrations in soils in the land application areas, samples were collected at 17 locations, 10 in the northern and 7 in the southern area, from three intervals: 0-15, 15-30, and 30-100 cm. Refusal was encountered at 10 inches below ground surface (bgs) in LAN-008 and the lower interval was not collected. The sample locations, selected randomly using VSP Version 5.0, are shown on Figure 12.1-11. The samples were analyzed for radium-226, natural uranium, thorium-230, and lead-210.

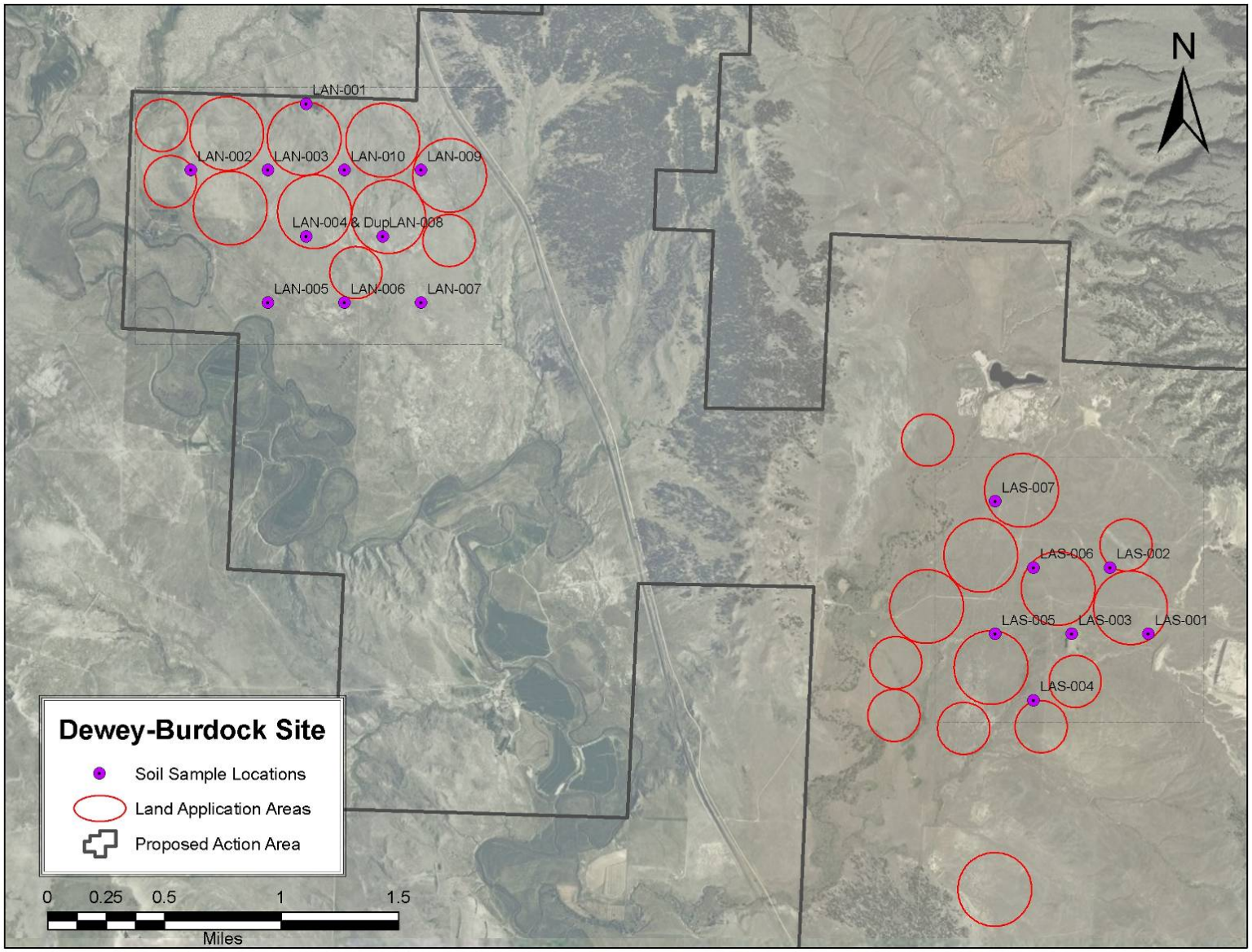

Figure 12.1-11 Soil Sample Locations in Proposed Land Application Areas

12.1.4.1.1.3 Soil Sampling Results

Table 12.1-5 presents the radium-226 concentrations in the soil samples collected in the main permit, surface mine, and land application areas. The results described in this section are those determined using only EPA Method 901.1. The laboratory analytical data reports are provided in Appendix B of Appendix J.

Samples are identified as follows, with duplicates labeled as “dup”:

- AMS: air monitoring station
- SMA: surface mine area
- MPA: main
- NEA: northeast area
- RFA: roll front area
- LAN: land application area north (Dewey)
- LAS: land application south (Burdock)

Table 12.1-5 Radionuclide Concentrations in All Soil Samples

Sample ID	Date Collected	Depth (cm)	1-minute Gamma-Ray Count Rate (cpm)	U-nat (µCi/g)	Pb-210 (µCi/g)	Pb-210 Error (µCi/g)	Th-230 (µCi/g)	Th-230 Error (µCi/g)	Ra-226 (µCi/g)	Ra-226 Error (µCi/g)
AMS-1	9/27/2007	0-5	-	9.6E-07	2.0E-06	3.0E-07	4.0E-07	1.0E-07	1.4E-06	2.0E-07
AMS-2	9/27/2007	0-5	-	9.5E-07	3.0E-06	3.0E-07	5.0E-07	1.0E-07	1.1E-06	2.0E-07
AMS-3	9/27/2007	0-5	-	8.2E-07	2.0E-06	2.0E-07	4.0E-07	1.0E-07	1.5E-06	2.0E-07
AMS-4	9/27/2007	0-5	-	1.4E-06	2.0E-06	2.0E-07	8.0E-07	2.0E-07	1.5E-06	3.0E-07
AMS-5	9/27/2007	0-5	-	6.8E-07	2.0E-06	2.0E-07	6.0E-07	1.0E-07	1.3E-06	3.0E-07
AMS-6	9/27/2007	0-5	-	5.5E-07	1.0E-06	2.0E-07	4.0E-07	1.0E-07	8.0E-07	2.0E-07
AMS-7	9/27/2007	0-5	-	5.8E-07	2.0E-06	2.0E-07	3.0E-07	8.0E-08	1.1E-06	2.0E-07
AMS-BKG	9/27/2007	0-5	-	1.9E-06	2.0E-06	2.0E-07	9.0E-07	1.0E-07	2.4E-06	4.0E-07
MPA-B01	9/25/2007	0-15	13824	-	-	-	-	-	1.4E-06	3.0E-07
MPA-B02	9/25/2007	0-15	14176	-	-	-	-	-	1.1E-06	2.0E-07
MPA-B03	9/25/2007	0-15	13006	-	-	-	-	-	1.3E-06	3.0E-07
MPA-R01	9/24/2007	0-15	13749	-	-	-	-	-	1.4E-06	2.0E-07
MPA-R02	9/24/2007	0-15	16059	-	-	-	-	-	2.6E-06	3.0E-07
MPA-R03	9/24/2007	0-15	10796	7.5E-07	7.0E-07	1.0E-07	4.0E-07	1.0E-07	1.1E-06	2.0E-07
MPA-R04	9/24/2007	0-15	10810	-	-	-	-	-	9.0E-07	2.0E-07
MPA-R04-Dup	9/24/2007	0-15	-	-	-	-	-	-	8.0E-07	2.0E-07
MPA-R05	9/24/2007	0-15	11850	-	-	-	-	-	1.2E-06	2.0E-07
NEA-R01	9/24/2007	0-15	12302	9.1E-07	7.0E-07	2.0E-07	6.0E-07	1.0E-07	1.1E-06	2.0E-07
NEA-R02	9/24/2007	0-15	13176	-	-	-	-	-	1.3E-06	2.0E-07
NEA-R03	9/24/2007	0-15	16393	-	-	-	-	-	2.2E-06	3.0E-07
NEA-R04	9/24/2007	0-15	17356	-	-	-	-	-	2.3E-06	3.0E-07
NEA-R04-Dup	9/24/2007	0-15	-	-	-	-	-	-	2.5E-06	3.0E-07
NEA-R05	9/24/2007	0-15	17269	-	-	-	-	-	2.8E-06	3.0E-07
RFA-B01A	9/26/2007	0-15	13115	8.7E-07	1.0E-06	2.0E-07	7.0E-07	1.0E-07	1.2E-06	2.0E-07
RFA-B01A-Dup	9/26/2007	0-15	-	9.0E-07	8.0E-07	1.0E-07	7.0E-07	1.0E-07	1.1E-06	2.0E-07
RFA-B02A	9/26/2007	0-15	13360	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B03	9/25/2007	0-15	14253	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B04	9/25/2007	0-15	13963	-	-	-	-	-	1.5E-06	3.0E-07
RFA-B06	9/25/2007	0-15	13819	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B07	9/25/2007	0-15	12700	-	-	-	-	-	1.7E-06	2.0E-07
RFA-B08	9/25/2007	0-15	13433	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B08-Dup	9/25/2007	0-15	13528	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B09	9/25/2007	0-15	14825	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B10	9/25/2007	0-15	13366	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B11	9/25/2007	0-15	14253	8.8E-07	1.0E-06	2.0E-07	5.0E-07	1.0E-07	1.8E-06	3.0E-07
RFA-B12	9/25/2007	0-15	13135	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B13A	9/26/2007	0-15	13987	-	-	-	-	-	1.8E-06	3.0E-07
RFA-B02A	9/26/2007	0-15	13360	-	-	-	-	-	1.6E-06	2.0E-07
RFA-B14	9/25/2007	0-15	13872	-	-	-	-	-	1.7E-06	3.0E-07
RFA-B15A	9/26/2007	0-15	13535	-	-	-	-	-	1.4E-06	3.0E-07
RFA-B16	9/25/2007	0-15	13675	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B17A	9/26/2007	0-15	16283	-	-	-	-	-	2.0E-06	3.0E-07

Table 12.1-5 Radionuclide Concentrations in All Soil Samples (cont'd)

Sample ID	Date Collected	Depth (cm)	1-minute Gamma-Ray Count Rate (cpm)	U-nat (µCi/g)	Pb-210 (µCi/g)	Pb-210 Error (µCi/g)	Th-230 (µCi/g)	Th-230 Error (µCi/g)	Ra-226 (µCi/g)	Ra-226 Error (µCi/g)
RFA-B19	9/25/2007	0-15	13689	-	-	-	-	-	1.2E-06	2.0E-07
RFA-B20	9/25/2007	0-15	13113	8.8E-07	1.0E-06	2.0E-07	5.0E-07	1.0E-07	1.3E-06	3.0E-07
RFA-B21A	9/26/2007	0-15	16641	-	-	-	-	-	5.6E-06	4.0E-07
RFA-B22	9/25/2007	0-15	14087	-	-	-	-	-	1.5E-06	2.0E-07
RFA-B23	9/25/2007	0-15	19674	-	-	-	-	-	3.6E-06	4.0E-07
RFA-B24	9/25/2007	0-15	12766	-	-	-	-	-	1.3E-06	2.0E-07
RFA-B25	9/25/2007	0-15	10300	6.7E-07	1.0E-06	2.0E-07	4.0E-07	1.0E-07	1.2E-06	2.0E-07
RFA-B26	9/25/2007	0-15	11791	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B27	9/25/2007	0-15	13794	-	-	-	-	-	1.5E-06	2.0E-07
RFA-B28	9/25/2007	0-15	15246	-	-	-	-	-	2.4E-06	3.0E-07
RFA-B28-Dup	9/25/2007	0-15	-	-	-	-	-	-	1.8E-06	3.0E-07
RFA-B29	9/25/2007	0-15	14345	-	-	-	-	-	1.7E-06	3.0E-07
RFA-B30A	9/26/2007	0-15	12461	-	-	-	-	-	1.8E-06	2.0E-07
RFA-B31	9/25/2007	0-15	12221	-	-	-	-	-	1.3E-06	2.0E-07
RFA-B33	9/25/2007	0-15	13221	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B34	9/25/2007	0-15	13408	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B35	9/25/2007	0-15	12290	-	-	-	-	-	1.2E-06	2.0E-07
RFA-B36A	9/25/2007	0-15	12465	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B37A	9/26/2007	0-15	11170	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B38	9/25/2007	0-15	11852	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B39	9/25/2007	0-15	11478	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B40	9/25/2007	0-15	12629	5.6E-07	1.0E-06	2.0E-07	3.0E-07	1.0E-07	1.1E-06	2.0E-07
RFA-B41	9/25/2007	0-15	11806	-	-	-	-	-	1.2E-06	2.0E-07
RFA-B43	9/25/2007	0-15	13264	-	-	-	-	-	1.7E-06	3.0E-07
RFA-B44	9/25/2007	0-15	11436	-	-	-	-	-	1.4E-06	2.0E-07
RFA-B45	9/25/2007	0-15	12242	-	-	-	-	-	1.6E-06	3.0E-07
SMA-B01	9/24/2007	0-15	10459	1.2E-06	6.0E-07	1.0E-07	5.0E-07	1.0E-07	9.0E-07	2.0E-07
SMA-B01-Dup	9/24/2007	0-15	-	1.5E-06	2.0E-06	2.0E-07	6.0E-07	1.0E-07	1.4E-06	3.0E-07
SMA-B03	9/24/2007	0-15	22410	-	-	-	-	-	1.5E-06	2.0E-07
SMA-B04	9/24/2007	0-15	15263	-	-	-	-	-	1.0E-06	2.0E-07
SMA-B07	9/24/2007	0-15	22925	-	-	-	-	-	3.2E-06	3.0E-07

Table 12.1-5 Radionuclide Concentrations in All Soil Samples (cont'd)

Sample ID	Date Collected	Depth (cm)	1-minute Gamma-Ray Count Rate (cpm)	U-nat (µCi/g)	Pb-210 (µCi/g)	Pb-210 Error (µCi/g)	Th-230 (µCi/g)	Th-230 Error (µCi/g)	Ra-226 (µCi/g)	Ra-226 Error (µCi/g)
SMA-B09	9/24/2007	0-15	12879	-	-	-	-	-	1.2E-06	2.0E-07
SMA-B09-Dup	9/24/2007	0-15	-	-	-	-	-	-	1.7E-06	2.0E-07
SMA-B10	9/25/2007	0-15	13184	-	-	-	-	-	1.4E-06	2.0E-07
SMA-B11	9/24/2007	0-15	17346	-	-	-	-	-	2.3E-06	3.0E-07
SMA-B13	9/25/2007	0-15	13252	-	-	-	-	-	1.7E-06	3.0E-07
SMA-B14	9/24/2007	0-15	14483	-	-	-	-	-	1.4E-06	3.0E-07
SMA-B14-Dup	9/24/2007	0-15	-	-	-	-	-	-	1.6E-06	2.0E-07
SMA-B15	9/24/2007	0-15	8474	-	-	-	-	-	8.0E-07	2.0E-07
SMA-B16	9/24/2007	0-15	10235	-	-	-	-	-	9.0E-07	2.0E-07
SMA-B17	9/24/2007	0-15	10139	-	-	-	-	-	1.0E-06	2.0E-07
SMA-B18	9/25/2007	0-15	8511	-	-	-	-	-	5.0E-07	1.0E-07
SMA-B18-Dup	9/25/2007	0-15	-	-	-	-	-	-	4.0E-07	1.0E-07
SMA-B19	9/24/2007	0-15	10074	-	-	-	-	-	1.2E-06	2.0E-07
SMA-B20	9/27/2007	0-15	10897	-	-	-	-	-	9.0E-07	2.0E-07
SMA-B21	9/24/2007	0-15	16712	-	-	-	-	-	1.4E-06	2.0E-07
SMA-B22	9/24/2007	0-15	10618	-	-	-	-	-	8.0E-07	2.0E-07
SMA-B23	9/24/2007	0-15	16233	-	-	-	-	-	2.7E-06	3.0E-07
SMA-B23-Dup	9/24/2007	0-15	-	-	-	-	-	-	2.8E-06	3.0E-07
SMA-B24	9/24/2007	0-15	12662	-	-	-	-	-	1.3E-06	2.0E-07
SMA-B25	9/24/2007	0-15	9991	-	-	-	-	-	1.0E-06	2.0E-07
SMA-B26	9/28/2007	0-15	73243	-	-	-	-	-	1.1E-05	5.0E-07
SMA-B27	9/28/2007	0-15	130293	6.7E-05	3.0E-05	8.0E-07	3.0E-05	8.0E-07	4.0E-05	1.1E-06
SMA-B28	9/29/2007	0-15	39061	-	-	-	-	-	6.4E-06	4.0E-07
SMA-B29	9/28/2007	0-15	231041	1.6E-05	2.0E-05	7.0E-07	2.0E-05	6.0E-07	2.9E-05	9.0E-07
SMA-B30	9/28/2007	0-15	89139	-	-	-	-	-	3.4E-05	9.0E-07
LAN 001A	7/18/2008	0-15	-	1.8E-06	2.4E-06	2.3E-06	1.2E-06	6.0E-07	8.0E-07	9.0E-08
LAN 002A	7/18/2008	0-15	-	8.6E-07	3.4E-06	2.3E-06	9.0E-07	5.0E-07	9.0E-07	1.0E-07
LAN 003A	7/18/2008	0-15	-	7.8E-07	8.0E-07	2.2E-06	7.0E-07	6.0E-07	1.2E-06	1.0E-07
LAN 004A	7/18/2008	0-15	-	6.9E-07	1.0E-06	1.4E-06	6.0E-07	6.0E-07	1.9E-06	2.0E-07
LAN 004A-DUP	7/18/2008	0-15	-	7.2E-07	5.0E-07	1.4E-06	4.0E-07	3.0E-07	7.0E-07	1.0E-07
LAN 005A	7/18/2008	0-15	-	8.4E-07	1.2E-06	1.4E-06	9.0E-07	5.0E-07	4.4E-06	3.0E-07
LAN 006A	7/18/2008	0-15	-	7.1E-07	-5.0E-09	1.4E-06	3.0E-07	5.0E-07	1.1E-06	1.0E-07
LAN 007A	7/18/2008	0-15	-	8.1E-07	6.0E-07	1.4E-06	3.0E-07	5.0E-07	7.0E-07	1.0E-07
LAN 008A	7/18/2008	0-15	-	2.1E-06	1.0E-06	1.4E-06	1.0E-06	7.0E-07	9.0E-07	1.0E-07
LAN 009A	7/18/2008	0-15	-	1.1E-06	-4.0E-07	1.4E-06	3.0E-07	6.0E-07	8.0E-07	1.0E-07
LAN 010A	7/18/2008	0-15	-	1.6E-06	1.8E-06	1.2E-06	1.2E-06	6.0E-07	1.2E-06	2.0E-07
LAS 001A	7/19/2008	0-15	-	1.2E-06	1.6E-06	1.2E-06	6.0E-07	5.0E-07	9.0E-07	1.0E-07
LAS 002A	7/19/2008	0-15	-	4.8E-07	1.4E-06	1.2E-06	1.0E-07	5.0E-07	7.0E-07	1.0E-07

Table 12.1-5 Radionuclide Concentrations in All Soil Samples (cont'd)

Sample ID	Date Collected	Depth (cm)	1-minute Gamma-Ray Count Rate (cpm)	U-nat (µCi/g)	Pb-210 (µCi/g)	Pb-210 Error (µCi/g)	Th-230 (µCi/g)	Th-230 Error (µCi/g)	Ra-226 (µCi/g)	Ra-226 Error (µCi/g)
LAS 003A	7/19/2008	0-15	-	5.0E-07	1.4E-06	1.2E-06	3.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 004A	7/19/2008	0-15	-	1.1E-06	1.2E-06	1.2E-06	6.0E-07	5.0E-07	8.0E-07	1.0E-07
LAS 005A	7/19/2008	0-15	-	1.2E-06	1.6E-06	1.2E-06	4.0E-07	3.0E-07	9.0E-07	1.0E-07
LAS 006A	7/19/2008	0-15	-	3.7E-07	7.0E-07	1.1E-06	6.0E-07	6.0E-07	7.0E-07	1.0E-07
LAS 007A	7/19/2008	0-15	-	4.3E-07	6.0E-07	1.5E-06	6.0E-07	1.0E-07	8.0E-07	1.0E-07
RFA-B01B	9/26/2007	15-30	13115	1.1E-06	2.0E-06	2.0E-07	9.0E-01	2.0E-01	1.7E-06	2.0E-07
RFA-B01B-Dup	9/26/2007	15-30	-	9.9E-07	9.0E-07	2.0E-07	9.0E-01	2.0E-01	1.5E-06	2.0E-07
RFA-B02B	9/26/2007	15-30	-	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B13B	9/26/2007	15-30	-	-	-	-	-	-	1.8E-06	2.0E-07
RFA-B15B	9/26/2007	15-30	-	-	-	-	-	-	1.5E-06	2.0E-07
RFA-B17B	9/26/2007	15-30	-	-	-	-	-	-	2.2E-06	3.0E-07
RFA-B21B	9/26/2007	15-30	-	-	-	-	-	-	1.3E-06	2.0E-07
RFA-B30B	9/26/2007	15-30	-	-	-	-	-	-	2.1E-06	3.0E-07
RFA-B36B	9/26/2007	15-30	-	-	-	-	-	-	1.1E-06	2.0E-07
RFA-B37B	9/26/2007	15-30	-	-	-	-	-	-	7.0E-07	2.0E-07
LAN 001B	7/18/2008	15-30	-	1.9E-06	4.6E-06	2.3E-06	1.4E-06	6.0E-07	8.0E-07	1.0E-07
LAN 002B	7/18/2008	15-30	-	7.5E-07	1.5E-06	2.3E-06	4.0E-07	4.0E-07	1.0E-06	1.0E-07
LAN 003B	7/18/2008	15-30	-	1.1E-06	2.4E-06	2.3E-06	8.0E-07	5.0E-07	1.2E-06	1.0E-07
LAN 004B	7/18/2008	15-30	-	7.9E-07	2.2E-06	1.4E-06	2.0E-07	5.0E-07	1.3E-06	2.0E-07
LAN 004B-DUP	7/18/2008	15-30	-	6.8E-07	-3.0E-07	1.4E-06	5.0E-07	4.0E-07	7.0E-07	1.0E-07
LAN 005B	7/18/2008	15-30	-	7.1E-07	9.0E-07	1.4E-06	6.0E-07	4.0E-07	1.6E-06	2.0E-07
LAN 006B	7/18/2008	15-30	-	7.5E-07	5.0E-07	1.4E-06	6.0E-07	4.0E-07	1.3E-06	1.0E-07
LAN 007B	7/18/2008	15-30	-	1.5E-06	6.0E-07	1.4E-06	4.0E-07	4.0E-07	7.0E-07	1.0E-07
LAN 008B	7/18/2008	15-30	-	3.5E-06	1.0E-07	1.4E-06	9.0E-07	7.0E-07	1.0E-06	1.0E-07
LAN 009B	7/18/2008	15-30	-	1.8E-06	-3.0E-07	1.4E-06	7.0E-07	5.0E-07	4.1E-06	3.0E-07
LAN 010B	7/18/2008	15-30	-	1.5E-06	1.1E-06	1.1E-06	7.9E-06	1.2E-06	1.4E-06	2.0E-07
LAS 001B	7/19/2008	15-30	-	8.6E-07	1.1E-06	1.2E-06	4.0E-07	5.0E-07	8.0E-07	1.0E-07
LAS 002B	7/19/2008	15-30	-	7.1E-07	7.0E-07	1.2E-06	4.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 003B	7/19/2008	15-30	-	1.2E-06	1.1E-06	1.1E-06	5.0E-07	4.0E-07	9.0E-07	1.0E-07
LAS 004B	7/19/2008	15-30	-	9.5E-07	1.3E-06	1.2E-06	5.0E-07	4.0E-07	8.0E-07	1.0E-07
LAS 005B	7/19/2008	15-30	-	1.6E-06	1.4E-06	1.1E-06	4.0E-07	4.0E-07	1.0E-06	2.0E-07
LAS 006B	7/19/2008	15-30	-	4.8E-07	1.4E-06	1.2E-06	3.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 007B	7/19/2008	15-30	-	4.5E-07	6.0E-07	1.5E-06	6.0E-07	1.0E-07	7.0E-07	1.0E-07
LAN 008B	7/18/2008	15-30	-	3.5E-06	1.0E-07	1.4E-06	9.0E-07	7.0E-07	1.0E-06	1.0E-07
LAN 009B	7/18/2008	15-30	-	1.8E-06	-3.0E-07	1.4E-06	7.0E-07	5.0E-07	4.1E-06	3.0E-07
LAN 010B	7/18/2008	15-30	-	1.5E-06	1.1E-06	1.1E-06	7.9E-06	1.2E-06	1.4E-06	2.0E-07
LAS 001B	7/19/2008	15-30	-	8.6E-07	1.1E-06	1.2E-06	4.0E-07	5.0E-07	8.0E-07	1.0E-07

Table 12.1-5 Radionuclide Concentrations in All Soil Samples (concl.)

Sample ID	Date Collected	Depth (cm)	1-minute Gamma-Ray Count Rate (cpm)	U-nat (µCi/g)	Pb-210 (µCi/g)	Pb-210 Error (µCi/g)	Th-230 (µCi/g)	Th-230 Error (µCi/g)	Ra-226 (µCi/g)	Ra-226 Error (µCi/g)
LAS 002B	7/19/2008	15-30	-	7.1E-07	7.0E-07	1.2E-06	4.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 003B	7/19/2008	15-30	-	1.2E-06	1.1E-06	1.1E-06	5.0E-07	4.0E-07	9.0E-07	1.0E-07
LAS 004B	7/19/2008	15-30	-	9.5E-07	1.3E-06	1.2E-06	5.0E-07	4.0E-07	8.0E-07	1.0E-07
LAS 005B	7/19/2008	15-30	-	1.6E-06	1.4E-06	1.1E-06	4.0E-07	4.0E-07	1.0E-06	2.0E-07
LAS 006B	7/19/2008	15-30	-	4.8E-07	1.4E-06	1.2E-06	3.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 007B	7/19/2008	15-30	-	4.5E-07	6.0E-07	1.5E-06	6.0E-07	1.0E-07	7.0E-07	1.0E-07
RFA-B01C	9/26/2007	30-100	-	1.5E-06	6.0E-07	1.0E-07	8.0E-01	1.0E-01	1.2E-06	2.0E-07
RFA-B01C-Dup	9/29/2007	30-100	-	1.3E-06	1.0E-06	2.0E-07	1.0E+00	2.0E-01	1.7E-06	3.0E-07
RFA-B02C	9/26/2007	30-100	-	-	-	-	-	-	9.0E-07	2.0E-07
RFA-B13C	9/26/2007	30-100	-	-	-	-	-	-	1.6E-06	2.0E-07
RFA-B15C	9/26/2007	30-100	-	-	-	-	-	-	1.5E-06	3.0E-07
RFA-B17C	9/26/2007	30-100	-	-	-	-	-	-	2.5E-06	3.0E-07
RFA-B21C	9/26/2007	30-100	-	-	-	-	-	-	1.2E-06	2.0E-07
RFA-B30C	9/26/2007	30-100	-	-	-	-	-	-	1.7E-06	3.0E-07
RFA-B36C	9/26/2007	30-100	-	-	-	-	-	-	1.0E-06	2.0E-07
RFA-B37C	9/26/2007	30-100	-	-	-	-	-	-	1.1E-06	2.0E-07
LAN 001C	7/18/2008	30-100	-	1.9E-06	1.9E-06	2.2E-06	1.6E-06	7.0E-07	9.0E-07	1.0E-07
LAN 002C	7/18/2008	30-100	-	1.5E-06	1.1E-06	2.2E-06	3.0E-07	3.0E-07	1.2E-06	1.0E-07
LAN 003C	7/18/2008	30-100	-	2.0E-06	2.6E-06	2.3E-06	6.0E-07	3.0E-07	1.0E-06	1.0E-07
LAN 004C	7/18/2008	30-100	-	1.5E-06	8.0E-07	1.4E-06	7.0E-07	5.0E-07	1.0E-06	1.0E-07
LAN 004C-DUP	7/18/2008	30-100	-	1.3E-06	1.2E-06	1.4E-06	5.0E-07	4.0E-07	8.0E-07	1.0E-07
LAN 005C	7/18/2008	30-100	-	7.1E-07	6.0E-07	1.4E-06	5.0E-07	4.0E-07	1.5E-06	2.0E-07
LAN 006C	7/18/2008	30-100	-	1.1E-06	7.0E-07	1.4E-06	5.0E-07	3.0E-07	1.4E-06	2.0E-07
LAN 007C	7/18/2008	30-100	-	2.5E-06	1.0E-07	1.4E-06	8.0E-07	6.0E-07	4.0E-07	1.0E-07
LAN 009C	7/18/2008	30-100	-	1.6E-06	5.0E-07	1.4E-06	1.1E-06	6.0E-07	3.9E-06	3.0E-07
LAN 010C	7/18/2008	30-100	-	2.7E-06	1.9E-06	1.2E-06	1.9E-06	8.0E-07	1.5E-06	2.0E-07
LAS 001C	7/19/2008	30-100	-	6.1E-07	9.0E-07	1.1E-06	1.0E-07	3.0E-07	8.0E-07	1.0E-07
LAS 002C	7/19/2008	30-100	-	6.3E-07	4.0E-07	1.1E-06	4.0E-07	4.0E-07	7.0E-07	1.0E-07
LAS 003C	7/19/2008	30-100	-	9.3E-07	7.0E-07	1.2E-06	1.0E-06	5.0E-07	8.0E-07	1.0E-07
LAS 004C	7/19/2008	30-100	-	1.3E-06	1.2E-06	1.1E-06	5.0E-07	3.0E-07	9.0E-07	1.0E-07
LAS 005C	7/19/2008	30-100	-	9.8E-07	1.2E-06	1.1E-06	7.0E-07	5.0E-07	1.1E-06	2.0E-07
LAS 006C	7/19/2008	30-100	-	6.5E-07	-3.0E-07	1.5E-06	3.0E-07	9.0E-08	6.0E-07	1.0E-07
LAS 007C	7/19/2008	30-100	-	7.2E-07	-7.0E-07	1.5E-06	5.0E-07	1.0E-07	7.0E-07	1.0E-07

Notes:
All errors reported are ± 2σ.

12.1.4.1.1.4 Surface Soil Sample Results

12.1.4.1.1.4.1 Radium-226 Concentrations in the First Set of 80 Locations

In the set of 80 surface samples, the mean and median radium-226 concentrations are 2.9 and 1.3 pCi/g, respectively. Q1 and Q3 are 1.1 and 1.7 pCi/g, respectively. The IQR is 0.6. The mode is 1.1 pCi/g (12 observations). One result (0.45 pCi/g, Sample Location SMA-18) was a low outlier. Thirteen values exceeded 2.3 pCi/g, the cutoff for high outliers.

The soil data were fitted to normal and lognormal distributions. The p-values for both distributions are less than 0.005, indicating that at a 95 percent confidence level (p = 0.05), the distributions are non-normal and non-lognormal.

Considering that the data do not fit normal or lognormal distributions, and clear differences in the gamma-ray count rates obtained in the surface mine and main PAAs are indicative of differences in the levels of gamma-emitting radionuclides therein, the set of surface soil data was divided into surface mine and main PAA subsets, as discussed in the following sections.

12.1.4.1.1.4.2 Radium-226 Concentrations in the Surface Mine Area

Twenty-five surface soil samples were collected in the surface mine area. The data did not fit a parametric distribution. The median radium-226 concentration was 1.4 pCi/g. Five of the concentrations were outliers, exceeding a cutoff (1.5 times Q3) of 5.9 pCi/g. The outliers are the radium-226 concentrations in the five biased samples, all collected in the surface mine area.

The data set with the outliers removed fit a lognormal distribution. The central tendency and variability of a lognormal distribution are best represented by the geometric mean and geometric standard deviation, each of which is 1.3 pCi/g radium-226 in the case of the surface mine area data set. The data lie within a population range of 0.76 to 2.2 pCi/g.

12.1.4.1.1.4.3 Radium-226 Concentrations in the Main Area

Fifty-five surface soil samples were collected in the main PAA. The data did not fit a parametric distribution. The median radium-226 concentration was 1.3 pCi/g. Three of the concentrations were outliers, exceeding a cutoff (1.5 times Q3) of 2.6 pCi/g.

The data set with the outliers removed fit a lognormal distribution. The geometric mean and geometric standard deviation of the set of main PAA radium-226 concentrations are each 1.3 pCi/g. The data lie within a population range of 0.76 to 2.2 pCi/g.

12.1.4.1.1.4.4 Radium-226 Concentrations in the North Section of Main PAA

It was stated above that elevated gamma-ray count rates were observed in an approximately 600-acre area located at the north end of the main PAA. Considering that the elevated levels are likely due to relatively higher increased levels of one or more gamma-emitting radionuclides, radium-226 concentrations in soil samples collected from this area were evaluated.

Eight surface soil samples were collected in this area (MPA-R01, NEA-R02, NEA-R03, NEA-R04, NEA-R05, RFA-03, RFA-06, and RFA-17). One of these samples was considered an outlier of the main PAA data set (NEA-R05).

There are too few soil samples collected in this area to characterize it statistically. However, the gamma-ray count rates therein differ from the main PAA, with statistical significance.

12.1.4.1.1.4.5 Radium-226 Concentrations in the Proposed Land Application Areas

Radium-226 concentrations in surface soils in the land application areas are summarized as follows:

- Averaged 1.1 pCi/g and ranged from 0.7 to 4.4 pCi/g in both areas
- Averaged 1.3 pCi/g in the Dewey land application area
- Averaged 0.8 pCi/g in the Burdock land application area

The concentrations of surrogate radionuclides, uranium, lead-210, and thorium-230 concentrations are consistently lower in the Burdock than in the Proposed Dewey Land Application Area, indicating that the lower radium-226 concentration is not a laboratory artifact.

12.1.4.1.1.4.6 Discussion of Radium-226 Concentrations

Although the distributions of the main permit and surface mine area radium-226 concentration data sets are similar, the gamma-ray count rate distributions in these two areas differ, with statistical significance. The gamma-ray count rates observed in the anomalous portion of the main area also differ from the main area.

With outliers removed, both the surface mine and main area radium-226 concentration data sets fit a lognormal distribution. The geometric mean and geometric standard deviation of both data sets is 1.3 pCi/g. The data lie within a population range of 0.76 to 2.2 pCi/g. The mean of 1.3 pCi/g is representative of a general background value in the majority of the PAA surface soils. Exceptional areas include those in and around the artesian well discharge and historical open pit mines. At this time, radium-226 concentrations are not well characterized in the northern anomalous area in the main area and along the northwest edge of the surface mine area.

The range of radium-226 concentrations in the land application areas lies within the range of overall radium-226 concentrations, averaging 1.3 and 0.8 pCi/g in the Dewey and Burdock areas, respectively.

Other Radionuclides

Table 12.4.1 summarizes the analytical results for all samples analyzed for the extended suite of radiological parameters (all locations and depths combined). Although the sample number isn't sufficient to allow any definitive conclusions to be drawn regarding distributional characteristics or trends of non radium-226 parameters, a positive relationship between the concentrations of radium-226 and natural uranium, thorium-230, and lead-210 is apparent.

12.1.4.1.1.4.7 Limits of Detection

A summary of the results with respect to reporting limits and minimum detectable concentrations (MDCs) is as follows:

- The radium-226, lead-210, and thorium-230 lower limits of detection (LLD) (reported as MDCs or reporting limits) in the NEA, MPA, RFA, and SMA soil samples were all 1*10-7 µCi/g.
- The natural uranium LLDs in the NEA, MPA, RFA, and SMA samples ranged from 1.7*10-8 to 2.0*10-8 µCi/g.
- None of the results NEA, MPA, RFA, and SMA samples were below their respective LLDs.
- The lead-210 LLDs for the LAN and LAS samples ranged from 1.9*10-6 to 3.8*10-6 µCi/g. In all but one case, the lead-210 results were lower than their respective LLDs.
- The radium-226 LLDs for the LAN and LAS samples ranged from 4.0*10-8 to 1.0*10-7 µCi/g. All of the LAN and LAS results exceeded their respective LLDs.

- The thorium-230 LLD for the LAN and LAS samples was 1.0*10-7 µCi/g. Results for 17 of the 53 (surface and subsurface) samples were reported below 1.0*10-7 µCi/g.
- The natural uranium LLD for the LAN and LAS samples was 7.0*10-9 µCi/g. All of the results exceeded the LLD.

The LLD recommended in RG 4.14 for natural uranium, thorium-230, radium-226, and lead-210 in soils is 2*10-7 µCi/g. The only case for which the guidance was not followed was the LLD for lead-210 in the LAN and LAS samples.

12.1.4.1.1.5 Subsurface Soil Sample Results

Table 12.1-5 lists the subset of subsurface biased samples that were collected at depth in the project roll front areas: RFA-B01, RFA-B02 RFA-B13 RFA-B15, RFA-B17, RFA-B21, RFA-B30, RFA-B36, and RFA-B37. The table also lists results obtained in subsurface samples collected in the two land application areas: LAN-001 through LAN-009 and LAS-001 through LAS-007.

12.1.4.1.1.6 Data Uncertainty

This section briefly summarizes the results of the quality control (QC) samples collected for the baseline soil sampling program. The results of this QC effort are documented in Table 12.1-6, which lists the errors and LLDs for each duplicate pair. Table 12.1-6 documents associated comparisons, presenting the corresponding RPD (in the case of natural uranium) and/or Replicate Error Ratio (RER) for each QC pair. The calculation of RPDs and RERs is a standard technique used to evaluate laboratory precision.
The RPD is calculated as follows:

$$RPD = \frac{|A - B|}{\frac{A + B}{2}}$$

Where A and B are the sample and duplicate results, respectively.
The RER is calculated as follows:

$$RER = \frac{|S - R|}{\sqrt{(Sx0.15)^2 + (E_s)^2} + \sqrt{(Rx0.15)^2 + (E_R)^2}}$$

Where S and R are the sample and duplicate concentrations, respectively. ES and ER are the sample (ES) and duplicate errors (ER). The factor of 0.15 accounts for any inherent systematic error which cannot be quantified. The acceptance criteria are an RPD and RER of less than 40 and 1 percent for data above the MDC, respectively, as established in a QAPP (ERG 2006). This data set shows four cases where the RER for lead-210 was greater than 1 and five cases where the RPD exceeded 40. There are three cases where the RER and RPD for radium-226 are exceeded (two concurrently).

Table 12.1-6 Quality Control Analyses for Soil Samples

		Relative Percent Difference (%)				Replicate Error Ratio		
Sample ID	**Depth (cm)**	**U-nat**	**Pb-210**	**Th-230**	**Ra-226**	**Pb-210**	**Th-230**	**Ra-226**
MPA-R04+Duplicate	0-15	-	-	-	11.8	-	-	0.2
NEA-R04+Duplicate	0-15	-	-	-	8.3	-	-	0.2
RFA-B01A+Duplicate	0-15	3.4	22.2	0.0	8.7	0.0	0.0	0.2
RFA-B01B+Duplicate	15-30	10.5	75.9	0.0	12.5	1.8	0.0	0.3
RFA-B01C+Duplicate	30-100	14.3	50.0	22.2	34.5	1.0	0.5	0.8
RFA-B08+Duplicate	0-15	-	-	-	0.0	-	-	0.0
RFA-B28+Duplicate	0-15	-	-	-	28.6	-	-	0.7
SMA-B01+Duplicate	0-15	22.2	107.7	18.2	43.5	2.8	0.4	0.8
SMA-B09+Duplicate	0-15	-	-	-	34.5	-	-	0.8
SMA-B14+Duplicate	0-15	-	-	-	13.3	-	-	0.3
SMA-B18+Duplicate	0-15	-	-	-	22.2	-	-	0.4
SMA-B23+Duplicate	0-15	-	-	-	3.6	-	-	0.1
LAN-004A+Duplicate	0-15	-4.3	66.7	40.0	92.3	0.5	0.6	8.5
LAN-004B+Duplicate	15-30	15.0	263.2	-85.7	60.0	2.5	0.9	4.2
LAN-004C+Duplicate	30-100	14.3	-40.0	33.3	22.2	0.4	0.6	1.4

Notes: The radium-226, lead-210, and thorium-230 LLDs were all 1*10-7 µCi/g. All results are greater than 5 times their respective MDC, with the exception of radium-226 in Sample Location SMA-B18-Dup.
The natural uranium LLDs ranged from 1.7*10-8 to 2.0*10-8 µCi/g.
None of the results were below their respective LLDs.
Bolded values are anomalous QC results.

The consequences of one radium-226 and three lead-210 results exceeding the acceptance criteria are minimal since in each case the concentrations are low. In addition, lead-210 largely has no impact when addressing the impact of the baseline radiological characteristics of the site and potential impacts from site operations.

There is close agreement for all other analytical results reported for each duplicate pair collected for all parameters. Overall, duplicate results are generally comparable for the majority of QC samples collected. Considering the low level of radioactivity observed in most of the QC pairs, the laboratory performance on blind duplicates is satisfactory.

12.1.4.1.1.7 Conclusions

12.1.4.1.1.7.1 Main permit and Surface Mine Areas

Main permit and surface mine areas' subsurface radium-226 concentrations, ranging from 0.7 to 5.6 pCi/g, are comparable to those observed in the 0-15 cm surface samples in the samples. There is no apparent trend with depth.

12.1.4.1.1.7.2 Land Application Areas

Subsurface concentrations in the land applications can be summarized as follows:

- Radium-226 concentrations range from 0.4 to 4.1 pCi/g, with a median of 0.9 pCi/g.
- Radium-226 concentrations in the Dewey land application area have a median of 1.0 pCi/g.
- Radium-226 concentrations in the Burdock land application area have a median of 0.8 pCi/g.

The subsurface results in both land application areas are comparable to those observed in the 0-15 cm surface samples. There is no apparent trend with depth.

12.1.5 Sediment Sampling

In June and August of 2008, baseline sediment sampling was conducted at the proposed project site in accordance with NRC Regulatory Guide 4.14 (USNRC, 1980), which requires stream sediment samples during both seasonal runoff and low-flow conditions and one sediment sample at each impoundment to characterize radionuclide content. Stream sediment samples were collected at the same locations at which surface water quality sampling sites were located: upstream and downstream sites on Pass Creek, Beaver Creek, and the Cheyenne River, and one site on each of two ephemeral drainages located within the proposed project boundary. Impoundment sediment samples were collected in the same impoundments at which surface water chemistry was sampled. Figure 12.1-12 and Table 12.1-7 provide sediment sampling locations.

Stream sediment samples were collected upstream and downstream sites on three primary streams (Pass Creek, Beaver Creek, and the Cheyenne River) and sites on two other ephemeral drainages.
Sediment samples were collected in June 2008 from 11 surface water impoundments located in the area. Impoundments primarily consist of stockponds but also include historical open pit mines within the proposed permit boundary. At the time of sampling, the majority of subimpoundments had water present. As indicated by NRC Regulatory Guide 4.14, a one-time sampling event is sufficient to document radiological conditions of surface water impoundment sediments.

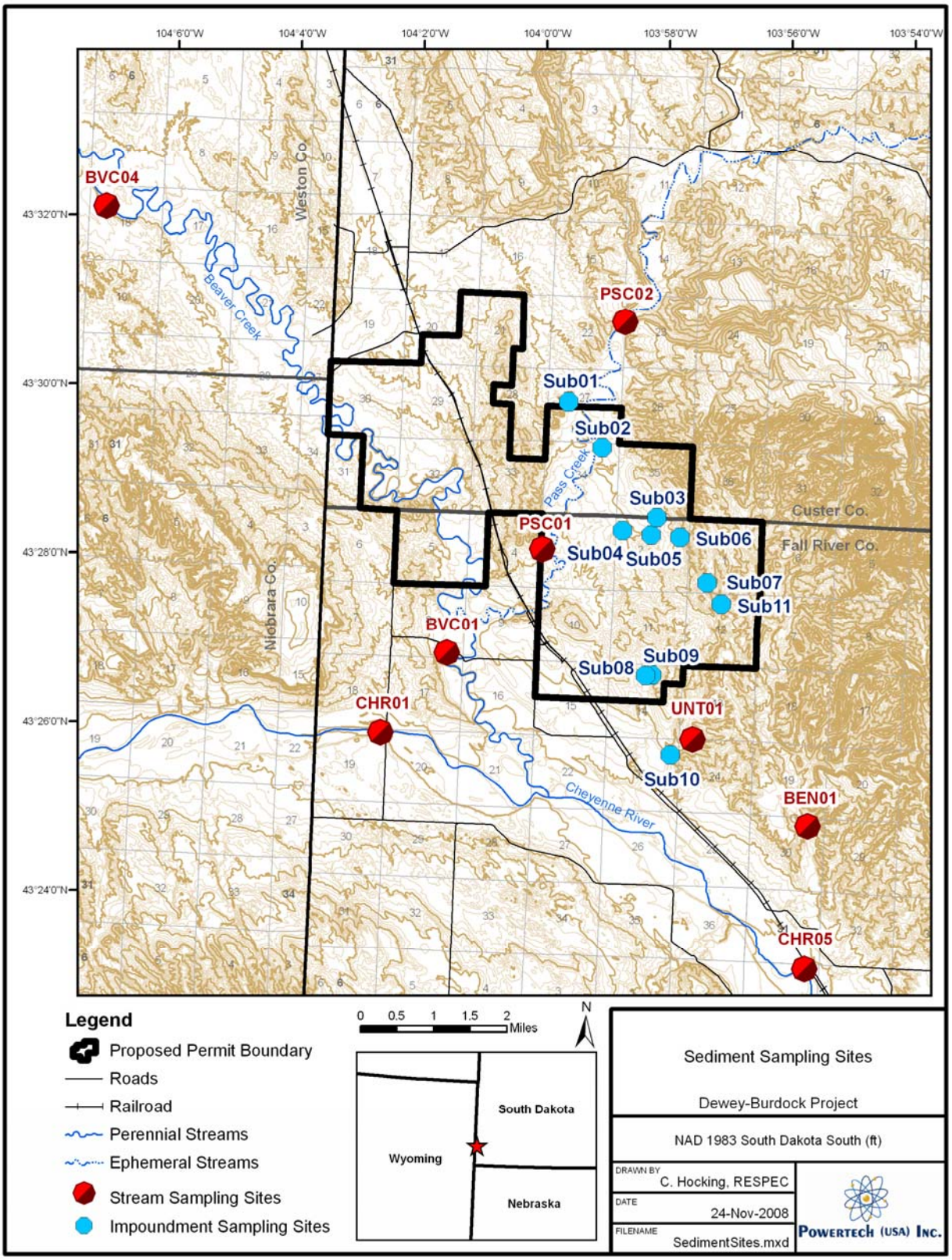

Figure 12.1-12 Sediment Sampling Sites

Table 12.1-7 Sampling Locations - Stream and Impoundment Sediment Sampling Locations

	Site ID	SD State Plane 1983		Type / Name	Groundwater Influence
		East (ft)	North (ft)		
Subimpoundments	Sub01	998654	446816	stock pond	
	Sub02	1001071	443526	Triangle Mine Pit	x
	Sub03	1005005	438448	mine dam	
	Sub04	1002542	437518	stock pond	
	Sub05	1004591	437191	mine dam	
	Sub06	1006665	437019	Darrow Mine pit - Northwest	
	Sub07	1009312	434360	stock dam	
	Sub08	1004195	427057	stock pond	x
	Sub09	1004640	427089	stock pond	
	Sub10	1005961	421367	stock pond	
	Sub11	1009659	432225	stock pond	
Streams	BVC01	989871	428716	Beaver Creek downstream	
	BVC04	965366	460922	Beaver Creek upstream	
	CHR01	985098	423010	Cheyenne River upstream	
	CHR05	1015626	405925	Cheyenne River downstream	
	PSC01	996764	436205	Pass Creek downstream	
	PSC02	1002722	452563	Pass Creek upstream	
	BEN01	1015872	416196	Bennet Canyon	
	UNT01	1007565	422482	Un-named Tributary	

12.1.5.1 Methods

12.1.5.1.1 Stream Sediments Sampling

At each location, four sediment sub-samples were collected with a plastic hand trowel to a depth of 5 cm each, along a transect spanning the width of the channel in areas where active sediment deposition was occurring. Prior to sampling at each site, the trowel was cleaned by rinsing with a liquid Alconox solution followed by a deionized water rinse. To represent the average radionuclide concentration across the channel, the four sub-samples were composited into a single sample. The composite sample was placed in a plastic zipper bag labeled with site ID, date, and time of collection, which was then placed into another plastic zipper bag and into a cooler with ice.

Samples were hand-delivered to ELI in Rapid City, SD along with the chain of custody forms. At the lab, samples were dried, crushed, ground, and thoroughly homogenized prior to analysis. All samples were analyzed for natural uranium, thorium-230, radium-226, and lead-210 by wet radiochemical methods.

12.1.5.1.1.1 Surface Water Impoundment Sediment Sampling

Sediment sampling locations for surface water impoundments were the same as the subset of impoundments selected for water quality analysis. Impoundments were identified on aerial photographs and topographic maps and then field verified (Figure 12.1-13). A subset of 11 of the total 48 impoundments within a 2 km radius of the proposed permit boundary were chosen based on presence of water at commencement of water-quality sampling activities and their spatial distribution. The sampled impoundments include two open pit uranium mines and nine stock dams, one of which is fed by a free-flowing artesian Sundance well.

At each of the 11 sampled impoundments, a single sample was collected with a trowel to a depth of 5 cm. Prior to sampling at each site, the trowel was cleaned by rinsing with a liquid Alconox solution followed by a deionized water rinse. Samples were collected near the waters edge in a location appearing relatively undisturbed. In dry impoundments samples were collected near the upstream side of the impoundment in an area that would be submerged if water was present. The samples were placed in a plastic zipper bag labeled with site ID, date, and time of collection, then placed into another plastic zipper bag and into a cooler with ice.

Samples were hand-delivered to ELI in Rapid City, SD along with the chain of custody forms. At the lab, samples were dried, crushed, ground, and thoroughly homogenized prior to analysis. All samples were analyzed for natural uranium, thorium-230, radium-226, and lead-210 by wet radiochemical methods.

12.1.5.1.2 Sediment Sampling Results

Results of the stream sediment data for each stream channel sampling location and impoundment location are provided in Table 12.1-8. Beaver Creek sediment sample results from the historical TVA survey (TVA EIS, 1980) are provided in Table 12.1-9.

Figure 12.1-13 Surface Water Impoundments

Table 12.1-8 Radionuclide Concentrations in Stream Sediment Samples

Site ID	Date	U-nat, Total	Ra-226, Total		Pb-210, Total			Th-230, Total	
		Result	Result	Precision	Result	Precision		Result	Precision
		mg/kg-dry	pCi/g-dry	+/- pCi/g-dry	pCi/g-dry	+/- pCi/g-dry	Qualifier	pCi/g-dry	+/- pCi/g-dry
BEN01	6/23/2008	1.8	0.6	0.1	2.3	2.1	U	0.6	0.2
	8/21/2008	2.4	0.6	0.1	2.0	0.7		0.5	0.02
BVC01	6/17/2008	2.0	1.3	0.2	0.5	2	U	0.8	0.2
	8/21/2008	2.0	0.6	0.1	2.6	0.7		1.2	0.03
BVC04	6/17/2008	2.0	1.5	0.2	1.9	2.1	U	0.7	0.2
	8/21/2008	2.0	1.0	0.1	1.8	0.7		1.0	0.03
CHR01	6/17/2008	1.7	1.0	0.2	0.2	2	U	0.6	0.2
	8/21/2008	2.7	0.9	0.1	1.7	0.6		1.4	0.03
CHR05	6/17/2008	6.2	2.1	0.2	1.7	2	U	1.9	0.4
	8/21/2008	1.2	0.6	0.1	1.3	0.7		0.5	0.02
PSC01	6/17/2008	3.9	2.9	0.3	4.7	2.1		2.0	0.5
	8/21/2008	6.5	1.8	0.2	4.0	0.7		4.1	0.06
PSC02	6/17/2008	1.1	0.6	0.1	1.2	2	U	0.4	0.1
	8/21/2008	1.0	0.4	0.1	0.4	0.6	U	0.4	0.02
UNT01	6/23/2008	2.0	0.8	0.1	2.2	2.1	U	0.5	0.2
	8/21/2008	2.5	0.7	0.1	1.7	0.7		1.0	0.03
Sub01	6/18/2008	2.2	1.2	0.2	0.5	2	U	0.7	0.2
	8/21/2008	3.3	1.1	0.1	1.0	0.7	U	1.0	0.03
Sub02	6/18/2008	18	3.9	0.3	2.8	2.1	U	2.9	0.7
	8/21/2008	19	1.3	0.2	3.1	0.7		6.8	0.07
Sub03	6/18/2008	7.2	4.1	0.3	3.9	2.1		2.1	0.6
	8/21/2008	4.2	1.1	0.2	3.2	0.7		1.9	0.04
Sub04	6/17/2008	6.5	2.5	0.2	1.2	2	U	0.9	0.2
	8/21/2008	5.1	0.7	0.1	2.1	0.7		1.8	0.04

Table 12.1-8 Radionuclide Concentrations in Stream Sediment Samples (concl.)

SiteID	Date	U-nat, Total	Ra-226, Total		Pb-210, Total			Th-230, Total	
		Result	Result	Precision	Result	Precision		Result	Precision
		mg/kg-dry	pCi/g-dry	+/- pCi/g-dry	pCi/g-dry	+/- pCi/g-dry	Qualifier	pCi/g-dry	+/- pCi/g-dry
Sub05	6/18/2008	8.5	4.2	0.3	4.2	2.1		2.4	0.5
	8/21/2008	6.0	3.0	0.2	2.8	0.7		2.3	0.04
Sub06	6/23/2008	37	8.6	0.4	9.6	2.2		7.8	1.6
	8/21/2008	32	5.2	0.3	4.0	0.7		5.9	0.07
Sub07	6/23/2008	1.7	0.7	0.1	0.6	2	U	0.5	0.2
	8/21/2008	2.2	0.4	0.1	1.9	0.7		0.9	0.03
Sub08	6/23/2008	1.2	0.6	0.1	0.6	2.1	U	0.4	0.1
	8/21/2008	1.9	0.4	0.1	1.7	0.7		0.8	0.02
Sub09	6/23/2008	2.4	1.0	0.2	1.5	2	U	0.7	0.2
	8/21/2008	2.3	0.6	0.1	1.7	0.7		0.9	0.03
Sub10	6/23/2008	1.5	0.8	0.1	1.5	2.1	U	0.7	0.3
	8/21/2008	2.1	0.6	0.1	0.9	0.7	U	0.7	0.03
Sub11	6/23/2008	2.7	0.8	0.1	2.1	2.1	U	0.5	0.2
	8/21/2008	1.8	0.6	0.1	1.5	0.7		0.8	0.03

Table 12.1-9 Historical Radionuclide Concentrations in Beaver Creek Sediment Samples (TVA DES, 1980)

Sampling Location	Date Collected	Natural U µg/g	Ra-226 pCi/g	Pb-210 pCi/g	Th-230 pCi/g
Beaver Creek at Old Hwy 85 Bridge	7/31/1975	-	1.06 ± 0.04	-	-
	5/5/1976	2.57	1.29 ± 0.03	-	0.3 ± 0.2
	8/25/1976	1.48	1.06 ± 0.03	-	1.5 ± 0.2
	11/12/1976	1.12	0.98 ± 0.03	-	2.1 ± 0.2
	4/27/1977	1.42	1.15 ± 0.03	-	0.3 ± 0.1
	7/21/1977	3.4	0.91 ± 0.03	-	-0.05 ± 0.07
	11/15/1977	0.02	0.44 ± 0.02	3.3 ± 0.4	0.8 ± 0.2
Beaver Creek at Mouth	5/5/1976	2.65	1.25 ± 0.03	-	0.06 ± 0.2
	8/25/1976	2.23	1.71 ± 0.04	-	0.4 ± 0.1
	11/12/1976	0.86	0.84 ± 0.03	-	2.6 ± 0.3
	4/27/1977	0.87	1.31 ± 0.03	-	0.2 ± 0.1
	7/21/1977	4.1	2.45 ± 0.05	-	0.5 ± 0.2
	11/15/1977	0.72	0.83 ± 0.02	5.5 ± 0.5	0.2 ± 0.1
Beaver Creek Upstream	5/5/1976	4.37	1.03 ± 0.03	-	0.4 ± 0.3
	8/25/1976	3.01	1.23 ± 0.03	-	0.9 ± 0.2
	11/12/1976	1.5	1.01 ± 0.03	-	2.9 ± 0.3
	4/27/1977	0.89	1.34 ± 0 03	-	0.02 ± 0.07
	7/21/1977	3.7	1.41 ± 0.04	-	0.02 ± 0.08

12.1.5.1.3 Conclusions

The radionuclide concentrations in sediments at the project site are generally consistent with observed US soil concentrations (Myrick 1983). Exceptions are the Darrow Mine Pit (Sub 06) and the Triangle Mine Pit (Sub 02), both of which appear to contain radionuclide concentrations in sediments considerably higher than observed in soil by Myrick, 1983. The Darrow and Triangle Mine Pits are historical open pit uranium mines and elevated radionuclide concentrations in sediments would be expected.

Radionuclide concentrations in sediment at downstream locations of Pass Creek (PSC02) and the Cheyenne River (CHR05) are elevated compared to upstream locations for the same surface water bodies indicating potential impacts from mineralized areas on and adjacent to the site. Radionuclide concentrations in sediment at the downstream location on Beaver Creek (BVCO1) are similar to the upstream location (BVC04).

12.1.6 Ambient Gamma and Radon Monitoring

12.1.6.1 Methods

12.1.6.1.1 Ambient Gama Does Rate Monitoring

Ambient exposure rates were determined for three periods, using TLDs supplied and analyzed by Landauer, Inc. The monitoring periods were: August 18, 2007 to February 4, 2008, February 4 to May 17, 2008, and May 17 to July 17, 2008.

The TLDs were deployed at each of the eight AMS locations. Duplicates were deployed at AMS-01 and the background location (AMS-BKG).

Five of the nine TLDs deployed in the August 2007 to February 2008 period were lost, presumably by way of cattle consumption and/or disturbance.

12.1.6.1.1.1 Ambient Radon-222 Monitoring

Radtrak passive track etch detectors were placed at each of the eight AMS locations and an additional eight biased locations to measure radon-222 concentrations in air. For QC purposes, one duplicate detector was placed at each of two locations during each sampling event. The locations of the passive radon detectors are shown on Figure 12.1-9.

The detector measures average radon-222 concentrations in air over the measurement period. The results are reported in picocuries per liter (pCi/L).

With an overlap in time across the group of detectors, but not on an individual location basis, the four quarterly measurement periods were: August 14 to September 27, 2007; September 27, 2007 to February 1 through 12, 2008; February 1 through 12, 2008 to May 17, 2008; and May 17 to July 17, 2008.

12.1.6.2 Results

12.1.6.2.1 Ambient Gamma Dose Rate Monitoring

The ambient gamma dose rate monitoring results are listed in Table 12.1-10. The results for the TLDs reported in mrem ambient dose equivalents are as follows:

- AMS-01: 94.9 for 303 monitored days, projected to 114 mrem/year
- AMS-02: 54.0 for 61 monitored days, projected to 323 mrem/year
- AMS-03: 38.6 for 103 monitored days, projected to 137 mrem/year
- AMS-04: 152.8 for 303 monitored days, projected to 184 mrem/year
- AMS-05: 123.7 for 303 monitored days, projected to 149 mrem/year
- AMS-06: 88.0, for 164 monitored days projected to 196 mrem/year
- AMS-07: 145.3 for 303 monitored days, projected to 175 mrem/year
- AMS-BKG: 167.8 for 303 monitored days, projected to 202 mrem/year

Excluding the result at AMS-02, the range of exposure rates, 114-202 mrem/year, is similar to average worldwide exposures to natural radiation sources comprised of cosmic radiation, cosmogenic radionuclides, and external terrestrial radiation reported in the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) Report to the General Assembly, Sources and Effects of Ionizing Radiation, Annex. The typical ranges of average worldwide exposures reported in this reference document are to 60 to160 mrem/year.

Table 12.1-10 Ambient Gamma Dose Rates

Location	Starting Date	End Date	Dose (mrem)	Projected Doses (mrem)
AMS-01	9/18/07	2/4/08	-	114
	2/4/08	5/17/08	37.2a	
	5/17/08	7/17/08	57.7a	
AMS-02	9/18/07	2/4/08	-	323
	2/4/08	5/17/08	-	
	5/17/08	7/17/08	54.0	
AMS-03	9/18/07	2/4/08	-	137
	2/4/08	5/17/08	38.6	
	5/17/08	7/17/08		
AMS-04	9/18/07	2/4/08	62.4	184
	2/4/08	5/17/08	36.1	
	5/17/08	7/17/08	54.3	
AMS-05	9/18/07	2/4/08	50.6	149
	2/4/08	5/17/08	36.7	
	5/17/08	7/17/08	36.4	
AMS-06	9/18/07	2/4/08	-	196
	2/4/08	5/17/08	36.9	
	5/17/08	7/17/08	51.1	
AMS-07	9/18/07	2/4/08	73.7	175
	2/4/08	5/17/08	35.5	
	5/17/08	7/17/08	36.1	
AMS-BKG	9/18/07	2/4/08	68.8a	202
	2/4/08	5/17/08	40.5a	
	5/17/08	7/17/08	58.5a	

Notes:
Result is average of measurement plus duplicate.

12.1.6.2.2 Ambient Radon-222 Monitoring

The ambient radon monitoring results are listed in Table 12.1-11. Period 1 ambient radon concentrations ranged from 1.0 to 9.8, averaging 2.4 pCi/L. Period 2 concentrations ranged from 0.4 to 1.8, averaging 1.2 pCi/L. Period 3 concentrations ranged from 0.4 to 3.3, averaging 1.8 pCi/L. Period 4 concentrations ranged from 0.5 to 0.8, averaging 0.5 pCi/L.

Table 12.1-11 Radon Concentrations in Air

Location	Starting Date	Ending Date	Radon-222 Conc. (µCi/ml)	Error ± (µCi/ml)	LLD (µCi/ml)	Average Rn-222 Conc. (µCi/ml)	Standard Deviation of Average (µCi/ml)	Minimum Rn-222 Conc. (µCi/ml)	Maximum Rn-222 Conc. (µCi/ml)	Percent Effluent Conc.
AMS-1	8/14/07	9/27/07	1.00E-09	-	6.82E-10	7.23E-10	2.09E-10	4.92E-10	1.00E-09	1000
	9/27/07	2/1/08	7.00E-10	-	2.00E-10					700
	2/1/08	5/17/08	7.00E-10	7.1E-11	2.83E-10					700
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
AMS-1[a]	8/14/07	9/27/07	1.00E-09	-	6.82E-10	5.73E-10	2.88E-10	4.00E-10	1.00E-09	1000
	9/27/07	2/1/08	4.00E-10	-	2.00E-10					400
	2/1/08	5/17/08	4.00E-10	5.2E-11	2.83E-10					400
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
AMS-2	8/15/07	9/27/07	2.20E-09	-	6.98E-10	1.70E-09	7.62E-10	4.92E-10	2.20E-09	2200
	9/27/07	2/1/08	1.20E-09	-	2.00E-10					1200
	2/1/08	5/17/08	7.00E-10	7.0E-11	2.83E-10					700
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
AMS-3	8/14/07	9/27/07	1.20E-09	-	6.82E-10	1.20E-09	9.30E-10	4.92E-10	2.70E-09	1200
	9/27/07	2/4/08	1.20E-09	-	2.00E-10					1200
	2/4/08	5/17/08	2.70E-09	7.9E-11	2.91E-10					2700
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
AMS-4	8/14/07	9/24/07	1.20E-09	-	7.32E-10	1.20E-09	9.98E-10	5.75E-10	2.90E-09	1200
	9/27/07	2/4/08	1.20E-09	-	2.00E-10					1200
	2/4/08	5/17/08	2.90E-09	7.8E-11	2.91E-10					2900
	5/17/08	7/17/08	5.75E-10	-	4.92E-10					575
AMS-5	8/15/07	9/27/07	2.20E-09	-	6.98E-10	1.60E-09	7.16E-10	4.92E-10	2.20E-09	2200
	9/27/07	2/1/08	1.00E-09	-	2.00E-10					1000
	2/1/08	5/17/08	1.20E-09	7.9E-11	2.83E-10					1200
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492

Table 12.1-11 Radon Concentrations in Air (cont'd)

Location	Starting Date	Ending Date	Radon-222 Conc. (µCi/ml)	Error ± (µCi/ml)	LLD (µCi/ml)	Average Rn-222 Conc. (µCi/ml)	Standard Deviation of Average (µCi/ml)	Minimum Rn-222 Conc. (µCi/ml)	Maximum Rn-222 Conc. (µCi/ml)	Percent Effluent Conc.
AMS-6	8/17/07	9/27/07	2.60E-09	-	7.32E-10	1.80E-09	8.40E-10	6.89E-10	2.60E-09	2600
	9/27/07	2/1/08	1.00E-09	-	2.00E-10					1000
	2/11/08	5/17/08	1.30E-09	7.6E-11	2.83E-10					1300
	5/17/08	7/17/08	6.89E-10	-	4.92E-10					689
AMS-7	8/14/07	9/27/07	1.10E-09	-	6.82E-10	1.30E-09	4.15E-10	4.92E-10	1.50E-09	1100
	9/27/07	2/1/08	1.50E-09	-	2.00E-10					1500
	2/1/08	5/17/08	1.00E-09	7.2E-11	2.83E-10					1000
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
AMS-BKG	8/14/07	9/24/07	2.00E-09	-	7.32E-10	1.80E-09	6.58E-10	4.95E-10	2.00E-09	2000
	9/27/07	2/1/08	1.60E-09	-	2.00E-10					1600
	2/1/08	5/17/08	1.70E-09	8.1E-11	2.83E-10					1700
	5/17/08	7/17/08	4.95E-10	-	4.92E-10					495
AMS-BKG[a]	8/14/07	9/27/07	2.70E-09	-	6.82E-10	2.10E-09	9.03E-10	4.92E-10	2.70E-09	2700
	9/27/07	2/1/08	1.50E-09	-	2.00E-10					1500
	2/1/08	5/17/08	1.50E-09	8.1E-11	2.83E-10					1500
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
Rn 01	8/14/07	9/23/07	2.00E-09	-	7.50E-10	1.65E-09	8.35E-10	5.00E-10	2.40E-09	2000
	9/23/07	2/11/08	1.30E-09	-	2.00E-10					1300
	2/11/08	5/17/08	2.40E-09	8.5E-11	3.13E-10					2400
	5/17/08	7/17/08	5.00E-10	-	4.76E-10					500
Rn 02	8/14/07	9/23/07	9.80E-09	-	7.50E-10	3.86E-09	5.15E-09	5.75E-10	9.80E-09	9800
	9/23/07	2/11/08	1.20E-09	-	2.00E-10					1200
	no data	-	-	-	-					-
	5/17/08	7/17/08	5.75E-10	1.5E-10	4.92E-10					575

Table 12.1-11 Radon Concentrations in Air (concl.)

Location	Starting Date	Ending Date	Radon-222 Conc. (µCi/ml)	Error ± (µCi/ml)	LLD (µCi/ml)	Average Rn-222 Conc. (µCi/ml)	Standard Deviation of Average (µCi/ml)	Minimum Rn-222 Conc. (µCi/ml)	Maximum Rn-222 Conc. (µCi/ml)	Percent Effluent Conc.
Rn 03	8/14/07	9/23/07	1.20E-09	-	7.50E-10	1.05E-09	9.63E-10	4.92E-10	2.70E-09	1200
	9/23/07	2/11/08	9.00E-10	-	2.00E-10					900
	2/11/08	5/17/08	2.70E-09	8.6E-11	3.13E-10					2700
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
Rn 04	8/14/07	9/23/07	2.00E-09	-	7.50E-10	1.70E-09	6.34E-10	5.00E-10	2.00E-09	2000
	9/23/07	2/1/08	1.40E-09	-	2.00E-10					1400
	2/11/08	5/17/08	1.00E-09	7.7E-11	2.83E-10					1000
	5/17/08	7/17/08	5.00E-10	-	4.92E-10					500
Rn 05	8/14/07	9/23/07	1.50E-09	-	7.50E-10	1.30E-09	7.82E-10	8.18E-10	2.60E-09	1500
	9/23/07	2/12/08	1.10E-09	-	2.00E-10					1100
	2/11/08	5/17/08	2.60E-09	8.6E-11	3.16E-10					2600
	5/17/08	7/17/08	8.18E-10	-	4.92E-10					818
Rn 06	8/19/07	9/23/07	3.30E-09	-	8.57E-10	2.30E-09	1.35E-09	4.92E-10	3.30E-09	3300
	9/23/07	2/11/08	1.30E-09	-	2.00E-10					1300
	2/11/08	5/17/08	3.00E-09	8.5E-11	3.13E-10					3000
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492
Rn 07	8/15/07	9/23/07	3.00E-09	-	7.69E-10	2.40E-09	1.18E-09	7.21E-10	3.30E-09	3000
	9/23/07	2/12/08	1.80E-09	-	2.00E-10					1800
	2/12/08	5/17/08	3.30E-09	8.3E-11	3.16E-10					3300
	5/17/08	7/17/08	7.21E-10	-	4.92E-10					721
Rn 08	8/14/07	9/23/07	1.50E-09	-	7.50E-10	1.40E-09	4.39E-10	4.92E-10	1.50E-09	1500
	9/23/07	2/1/08	1.30E-09	-	2.00E-10					1300
	9/23/07	2/1/08	1.00E-09	7.2E-11	2.83E-10					1000
	5/17/08	7/17/08	4.92E-10	-	4.92E-10					492

Notes:
[a]Duplicate track etch detector
[a]Seal potentially compromised

With the exception of one location (AMS-3), Period 1 concentrations exceeded Period 2 concentrations. On average, the radon concentrations decreased by an average of 35 percent. The range in the data sets decreased from 2.1 (Period 1) to 0.3 pCi/L (Period 2), as the largest value in Period 1, 9.8 pCi/L, decreased to 1.2 pCi/L.

Figure 12.1-14 presents the ambient radon concentrations in relation to the radium-226 concentrations predicted from the gamma-ray count rate data. One expects higher radon concentrations in the mined areas. However, there is only one case where this is true: the Q1 observation at Rn-02, located adjacent to the edge of an open pit mine, is 9.8 pCi/L. There appear to be no spatial trends in the current data set, other than the levels are within the same order of magnitude across the site, i.e., all less than 10 pCi/L and averaging 2.4, 1.2, 1.8, and 0.5 pCi/L in Periods 1 through 4, respectively.

Duplicates were collected at AMS-01 and AMS-BKG in all periods. The QC summary for the radon monitoring is as follows:

- AMS-01: In Period 1, each concentration was 1.0 pCi/L and the relative percent difference (RPD) was 0. In Periods 2 and 3, the concentrations of the sample and its duplicate were 0.7 and 0.4 pCi/L. The RPD was 55.5. In Period 4, each concentration was 0.49 pCi/L and the RPD was 0.
- AMS-BKG: In Period 1, the concentrations of the sample and its duplicate were 2.0 and 2.7 pCi/L. The RPD was 29.8. In Period 2, the concentrations of the sample and its duplicate were 1.6 and 1.5 pCi/L, with an RPD of 6.5. In Period 3, the concentrations of the sample and its duplicate were 1.7 and 1.5 pCi/L, with an RPD of 12.5. In Period 4, the concentrations of the sample and its duplicate were 0.5 and 0.49 pCi/L, with an RPD of 0.7.

There are two cases where the RPDs do not meet the project acceptance criterion of 40: AMS-01 in Period 2 and 3.

12.1.6.3 Conclusions

In terms of effluent limits, the measured values exceed the 10 CFR 20 limit of 0.1 pCi/L for radon-222 with daughters present. However, on average the measured values are within the range of reported worldwide ambient background radon concentrations, 0.027 to 2.7 pCi/L (United Nations Scientific Committee on the Effects of Atomic Radiation [UNSCEAR], 2000).

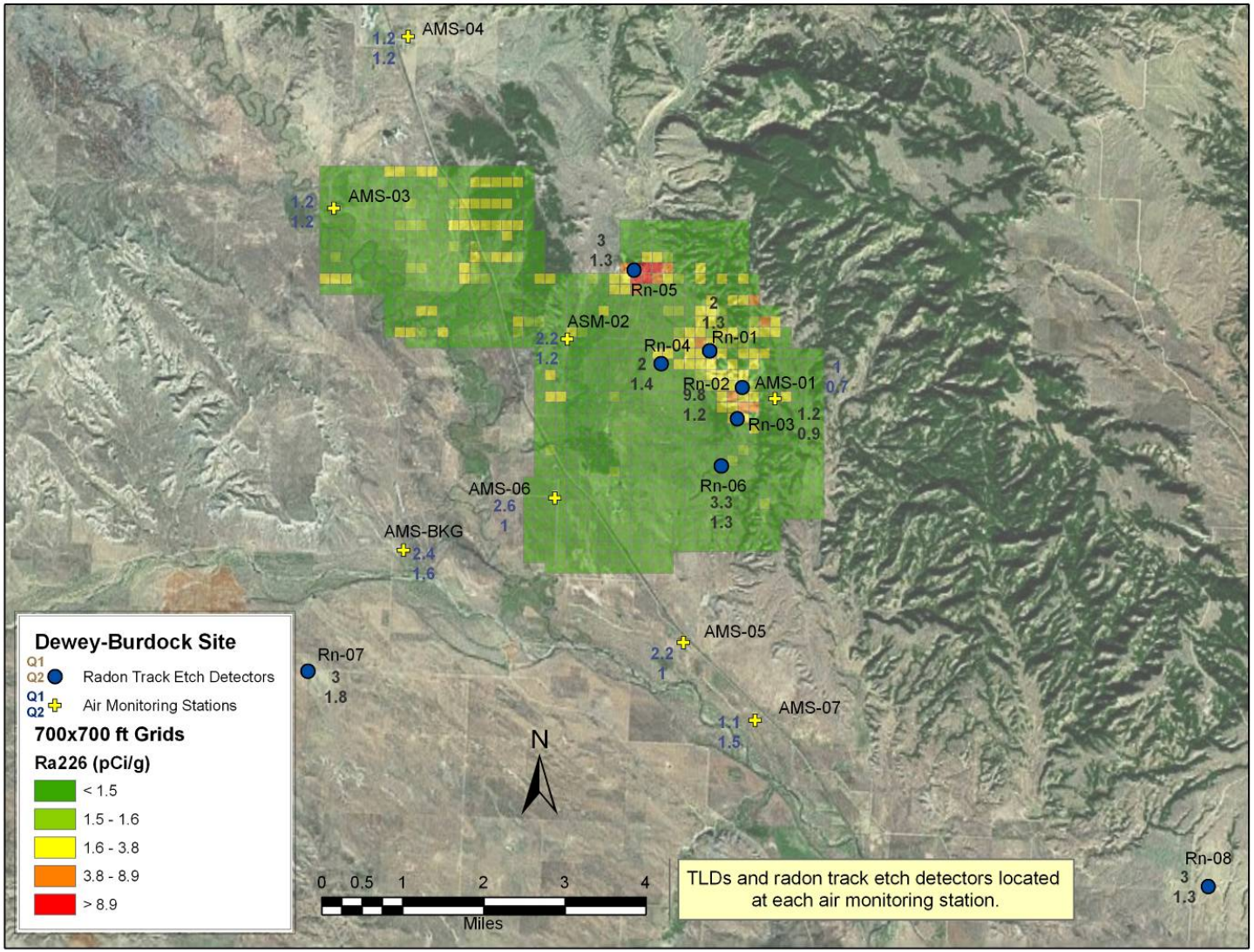

Figure 12.1-14 Radon Concentrations in Air in Relation to Predicted Radium-226 Concentrations

12.1.7 Air Particulate Monitoring

Air particulate monitoring was conducted at the project for one year. Particulates were collected using high volume air samplers.

12.1.7.1 Methods

Eight Hi-Q Model HVP-4200AFC high volume air samplers were established within and surrounding the proposed PAA. The samplers operated from August 2007 to August 2008. The locations of the air samplers are shown on Figures 12.1-15 and 12.1-16.

Each high volume air sampler was equipped with an 8-in. by 10-in. 0.8 micron glass fiber filter paper. The air filters were collected approximately bi-weekly, prior to saturation, from each of the eight air samplers. Flow rate and total flow data were recorded at the same time. The samples were collected as follows:

- Period 1: August 28 to October 2, 2007
- Period 2: October 2, 2007 to January 1, 2008
- Period 3: January 4 to April 1, 2008
- Period 4: April 1 to July 9, 2008
- Period 5: July 9 to August 13, 2008

The samples were composited and digested by the external independent analytical laboratory. The samples were analyzed for radium-226, thorium-230, natural uranium, and lead-210, using the same methods as listed for the soil samples.

The laboratory data were reported in units of picocuries per filter composite (pCi/f). The data were converted to units of microcuries per milliliter (µCi/ml), as follows:

$$Concentration,\ \mu Ci/ml = \frac{Filter\ Concentration}{Total\ Flow}(1*10^{-12})$$

The units of total flow and filter concentration in the equation are cubic meters and pCi/f, respectively. The resulting concentrations for each radionuclide and high volume sampler were compared to effluent concentration limits listed in Table 2 of 10 CFR 20 Appendix B and reported in Table 12.1-12 as percentages of the respective effluent limits. The most conservative effluent limits were applied to thorium-230 (3*10-12 µCi/ml) and lead-210 (6*10-13 µCi/ml). The Class D and W limits were applied to natural uranium (3*10-12 µCi/ml) and radium-226 (9*10-13 µCi/ml), respectively.

12.1.7.2 Air Particulate Sampling Results

In general and relative to one another (e.g., natural uranium to radium-226), the average concentrations of radionuclides were consistent at each location from period to period. The lowest average concentration was radium-226, followed by thorium-230, natural uranium, and lead-210. Average radium-226 concentrations were five orders of magnitude lower than lead-210 concentrations. The data are listed in Table 12.1-12 and summarized as averages and ranges in Table 12.1-13.

Site-wide, the data can be summarized as follows:

- Natural uranium concentrations ranged from -3.0*10-17 to 9.1*10-15 µCi/ml and averaged 7.5*10-16 µCi/ml.

- Thorium-230 concentrations ranged from -9.5*10-19 to 5.6*10-17 µCi/ml and averaged 1.2*10-17 µCi/ml.
- Radium-226 concentrations ranged from -4.9*10-17 to 4.7*10-17 µCi/ml and averaged 8.9*10-19 µCi/ml.
- Lead-210 concentrations ranged from -1.1*10-16 to 4.1*10-14 µCi/ml and averaged 1.4*10-14 µCi/ml.

There are no clear patterns in the data, in terms of radionuclide concentrations, when evaluating them spatially or temporally. Natural uranium concentrations at each location were on the order of 10^{-16} µCi/ml over the course of monitoring. Thorium-230 concentrations fluctuated between the orders of 10^{-17} and 10^{-18} µCi/ml. Radium-226 concentrations fluctuated between the orders of 10^{-17} and 10^{-19} µCi/ml. Finally, lead-210 concentrations at each location were all on the order of 10^{-14} µCi/ml over the course of monitoring.

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Table 12.1-12 Radionuclide Concentrations in Air

Location	Monitoring Period[a]	Concentration (µCi/ml)							% of Effluent Concentration				Lower Limit of Detection (µCi/ml)			
		U-nat	Th-230	Th-230 2σ Error	Ra-226	Ra-226 2σ Error	Pb-210	Pb-210 2σ Error	U-nat	Th-230	Ra-226	Pb-210	U-nat	Th-230	Ra-226	Pb-210
AMS-01	1	-1.3E-17	3.4E-18	1.0E-17	1.8E-17	1.7E-17	2.1E-14	2.4E-16	0.00%	0.00%	0.00%	3.54%	1.7E-18	1.7E-18	1.2E-17	2.1E-16
	2	2.4E-17	1.3E-17	9.8E-18	1.4E-17	9.7E-18	2.1E-14	4.9E-16	0.00%	0.00%	0.00%	3.51%	1.5E-18	1.5E-18	8.3E-18	4.2E-16
	3	3.7E-15	1.3E-17	4.2E-17	1.2E-17	5.7E-17	1.9E-14	9.8E-16	0.12%	0.00%	0.00%	3.13%	3.9E-15	2.3E-18	5.7E-17	3.7E-16
	4	0.0E+00	1.6E-18	1.1E-17	7.2E-18	9.1E-18	4.1E-14	6.9E-16	0.00%	0.00%	0.00%	6.78%	1.6E-16	1.6E-18	1.6E-18	7.9E-18
	5	-1.7E-17	6.5E-18	2.5E-17	-3.1E-17	2.7E-17	1.0E-14	6.5E-16	0.00%	0.00%	0.00%	1.74%	4.3E-18	4.3E-18	5.6E-17	6.7E-16
AMS-02	1	-2.0E-17	4.7E-18	1.1E-17	-8.6E-18	1.3E-17	8.9E-15	2.5E-16	0.00%	0.00%	0.00%	1.49%	1.6E-18	1.6E-18	1.1E-17	1.9E-16
	2	4.2E-18	0.0E+00	7.4E-18	-4.2E-18	7.4E-18	8.2E-15	4.2E-16	0.00%	0.00%	0.00%	1.37%	1.4E-18	1.4E-18	7.6E-18	3.9E-16
	3	2.9E-15	1.8E-18	2.5E-17	-2.6E-17	3.3E-17	1.2E-14	7.5E-16	0.10%	0.00%	0.00%	1.96%	3.1E-15	1.8E-18	4.1E-17	3.0E-16
	4	0.0E+00	1.6E-17	1.1E-17	-2.3E-18	7.0E-18	2.0E-14	4.7E-16	0.00%	0.00%	0.00%	3.26%	1.5E-16	1.5E-18	1.5E-18	7.6E-18
		-1.3E-17	0.0E+00	8.0E-18	-4.9E-17	2.3E-17	1.5E-14	6.5E-16	0.00%	0.00%	0.01%	2.44%	4.0E-18	4.0E-18	5.3E-17	6.2E-16
AMS-03	1	-3.0E-17	9.3E-18	1.2E-17	-1.4E-17	1.3E-17	9.2E-15	2.5E-16	0.00%	0.00%	0.00%	1.53%	1.5E-18	1.5E-18	1.2E-17	1.9E-16
	2	1.8E-17	8.9E-18	9.0E-18	9.6E-18	9.5E-18	8.0E-15	4.4E-16	0.00%	0.00%	0.00%	1.34%	1.5E-18	1.5E-18	8.9E-18	4.1E-16
	3	2.8E-15	6.9E-18	2.2E-17	-4.8E-18	3.7E-17	1.2E-14	7.5E-16	0.09%	0.00%	0.00%	1.98%	2.9E-15	1.7E-18	3.6E-17	2.8E-16
	4	0.0E+00	9.3E-18	1.0E-17	5.4E-18	8.8E-18	1.3E-14	3.9E-16	0.00%	0.00%	0.00%	2.16%	1.6E-16	1.6E-18	1.6E-18	7.8E-18
	5	-1.6E-17	1.9E-17	9.7E-18	-3.2E-18	3.1E-17	1.2E-14	6.5E-16	0.00%	0.00%	0.00%	1.99%	4.2E-18	4.2E-18	5.0E-17	6.6E-16
AMS-04	1	-2.6E-17	2.5E-18	1.1E-17	-2.8E-17	1.2E-17	8.5E-15	2.6E-16	0.00%	0.00%	0.00%	1.42%	1.7E-18	1.7E-18	9.9E-18	2.0E-16
	2	1.9E-17	6.6E-18	9.0E-18	1.2E-17	9.5E-18	1.0E-14	4.6E-16	0.00%	0.00%	0.00%	1.74%	1.5E-18	1.5E-18	8.1E-18	4.1E-16
	3	3.0E-15	-9.5E-19	3.0E-17	2.5E-17	4.7E-17	-1.1E-16	7.0E-16	0.10%	0.00%	0.00%	0.02%	3.2E-15	1.9E-18	4.4E-17	3.1E-16
	4	0.0E+00	9.4E-18	1.1E-17	2.3E-18	8.3E-18	2.2E-14	5.1E-16	0.00%	0.00%	0.00%	3.66%	1.6E-16	1.6E-18	1.6E-18	7.8E-18
	5	-1.0E-18	2.7E-17	9.7E-18	-5.2E-18	3.3E-17	1.3E-14	6.7E-16	0.00%	0.00%	0.00%	2.23%	4.2E-18	4.2E-18	5.5E-17	6.6E-16

Table 12.1-12 Radionuclide Concentrations in Air (concl.)

Location	Monitoring Period	Concentration (µCi/ml)							% of Effluent Concentration				Lower Limit of Detection (µCi/ml)			
		U-nat	Th-230	Th-230 2σ Error	Ra-226	Ra-226 2σ Error	Pb-210	Pb-210 2σ Error	U-nat	Th-230	Ra-226	Pb-210	U-nat	Th-230	Ra-226	Pb-210
AMS-05	1	1.0E-18	4.7E-18	1.1E-17	1.1E-17	1.5E-17	1.0E-14	2.3E-16	0.00%	0.00%	0.00%	1.66%	1.6E-18	1.6E-18	1.1E-17	1.9E-16
	2	2.7E-17	1.5E-17	1.0E-17	1.5E-17	9.9E-18	1.1E-14	4.8E-16	0.00%	0.00%	0.00%	1.91%	1.5E-18	1.5E-18	8.5E-18	4.3E-16
	3	2.8E-15	3.6E-17	2.3E-17	-1.3E-17	4.0E-17	1.0E-14	7.2E-16	0.09%	0.00%	0.00%	1.68%	2.9E-15	1.7E-18	4.3E-17	2.8E-16
	4	0.0E+00	2.0E-17	1.4E-17	4.7E-17	1.3E-17	2.5E-14	5.3E-16	0.00%	0.00%	0.01%	4.09%	1.5E-16	1.5E-18	1.5E-18	7.7E-18
	5	2.4E-17	5.6E-17	9.5E-18	2.2E-17	3.4E-17	1.1E-14	6.3E-16	0.00%	0.00%	0.00%	1.85%	4.1E-18	4.1E-18	4.9E-17	6.4E-16
AMS-06	1	-1.4E-17	9.4E-18	1.2E-17	0.0E+00	1.4E-17	6.0E-15	2.2E-16	0.00%	0.00%	0.00%	1.00%	1.6E-18	1.6E-18	1.1E-17	1.9E-16
	2	1.7E-17	5.5E-18	1.0E-17	-5.5E-18	8.4E-18	1.1E-14	4.9E-16	0.00%	0.00%	0.00%	1.80%	1.6E-18	1.6E-18	9.5E-18	4.4E-16
	3	2.9E-15	1.0E-17	2.4E-17	-2.0E-17	3.9E-17	1.7E-14	8.2E-16	0.10%	0.00%	0.00%	2.89%	3.1E-15	1.8E-18	4.2E-17	2.9E-16
	4	0.0E+00	1.4E-17	1.2E-17	2.3E-17	1.0E-17	2.1E-14	4.8E-16	0.00%	0.00%	0.00%	3.56%	1.5E-16	1.5E-18	1.5E-18	7.3E-18
	5	-2.6E-18	2.0E-17	9.1E-18	6.9E-18	3.3E-17	1.9E-14	6.9E-16	0.00%	0.00%	0.00%	3.25%	4.0E-18	4.0E-18	4.9E-17	6.2E-16
AMS-07	1	-1.1E-17	6.4E-18	9.1E-18	-1.3E-17	1.1E-17	7.2E-15	2.2E-16	0.00%	0.00%	0.00%	1.20%	1.4E-18	1.4E-18	9.2E-18	1.7E-16
	2	2.0E-17	7.9E-18	8.1E-18	-6.6E-19	7.5E-18	1.3E-14	4.4E-16	0.00%	0.00%	0.00%	2.13%	1.3E-18	1.3E-18	7.3E-18	3.7E-16
	3	9.1E-15	2.0E-17	2.6E-17	3.9E-18	4.2E-17	1.7E-14	7.8E-16	0.30%	0.00%	0.00%	2.85%	2.9E-15	1.7E-18	4.3E-17	2.8E-16
	4	0.0E+00	1.3E-17	1.2E-17	2.9E-17	1.0E-17	2.8E-14	5.4E-16	0.00%	0.00%	0.00%	4.66%	1.4E-16	1.4E-18	1.4E-18	7.0E-18
	5	-9.2E-19	1.7E-17	8.5E-18	1.4E-17	3.0E-17	1.3E-14	5.9E-16	0.00%	0.00%	0.00%	2.10%	3.7E-18	3.7E-18	4.6E-17	5.8E-16
AMS-BKG	1	1.6E-18	2.0E-17	1.3E-17	-5.6E-18	1.4E-17	8.3E-15	2.5E-16	0.00%	0.00%	0.00%	1.38%	1.6E-18	1.6E-18	1.2E-17	2.2E-16
	2	2.1E-17	2.0E-18	1.2E-17	3.0E-18	1.1E-17	1.8E-14	6.6E-16	0.00%	0.00%	0.00%	3.05%	2.0E-18	2.0E-18	1.2E-17	5.7E-16
	3	3.0E-15	2.8E-17	2.9E-17	-5.1E-18	4.0E-17	1.3E-14	7.7E-16	0.10%	0.00%	0.00%	2.18%	3.2E-15	1.9E-18	4.1E-17	2.5E-16
	4	0.0E+00	-7.8E-19	9.4E-18	1.2E-17	9.5E-18	2.0E-14	4.8E-16	0.00%	0.00%	0.00%	3.29%	1.6E-16	1.6E-18	1.6E-18	7.8E-18
	5	-8.1E-18	2.4E-17	9.3E-18	-1.7E-17	2.4E-17	1.2E-14	6.3E-16	0.00%	0.00%	0.00%	2.00%	4.0E-18	4.0E-18	4.0E-17	5.3E-16

Notes:

a. The laboratory reported no blank assay data for Period 5. Blank assays in the sample concentration calculation were assumed to be 50 percent of the values for blanks reported for the previous period. The assumption is based on the relative, approximate run-time of the air samplers in both periods.

NR = Not reported by the laboratory.

Table 12.1-13 Summary of Radionuclide Concentrations in Air

Location	U-nat Concentration (µCi/ml)				Th-230 Concentration (µCi/ml)				Ra-226 Concentration (µCi/ml)				Pb-210 Concentration (µCi/ml)			
	Avg	σ	Min	Max	Avg	σ	Min	Max	Avg	σ	Min	Max	Avg	σ	Min	Max
AMS-01	7.3E-16	1.6E-15	-1.7E-17	3.7E-15	7.4E-18	5.2E-18	1.6E-18	1.3E-17	4.0E-18	2.0E-17	-3.1E-17	1.8E-17	2.2E-14	2.0E-17	9.1E-18	5.7E-17
AMS-02	5.8E-16	1.3E-15	-2.0E-17	2.9E-15	4.5E-18	6.7E-18	0.0E+00	1.6E-17	-1.8E-17	2.0E-17	-4.9E-17	-2.3E-18	1.3E-14	1.1E-17	7.0E-18	3.3E-17
AMS-03	5.5E-16	1.2E-15	-3.0E-17	2.8E-15	1.1E-17	4.7E-18	6.9E-18	1.9E-17	-1.4E-18	9.2E-18	-1.4E-17	9.6E-18	1.1E-14	1.3E-17	8.8E-18	3.7E-17
AMS-04	6.0E-16	1.3E-15	-2.6E-17	3.0E-15	9.0E-18	1.1E-17	-9.5E-19	2.7E-17	1.2E-18	2.0E-17	-2.8E-17	2.5E-17	1.1E-14	1.7E-17	8.3E-18	4.7E-17
AMS-05	5.6E-16	1.2E-15	0.0E+00	2.8E-15	2.6E-17	2.0E-17	4.7E-18	5.6E-17	1.6E-17	2.2E-17	-1.3E-17	4.7E-17	1.3E-14	1.4E-17	9.9E-18	4.0E-17
AMS-06	5.8E-16	1.3E-15	-1.4E-17	2.9E-15	1.2E-17	5.4E-18	5.5E-18	2.0E-17	8.6E-19	1.6E-17	-2.0E-17	2.3E-17	1.5E-14	1.4E-17	8.4E-18	3.9E-17
AMS-07	1.8E-15	4.1E-15	-1.1E-17	9.1E-15	1.3E-17	5.7E-18	6.4E-18	2.0E-17	6.6E-18	1.6E-17	-1.3E-17	2.9E-17	1.6E-14	1.5E-17	7.5E-18	4.2E-17
AMS-BKG	5.9E-16	1.3E-15	-8.1E-18	3.0E-15	1.5E-17	1.3E-17	-7.8E-19	2.8E-17	-2.5E-18	1.1E-17	-1.7E-17	1.2E-17	1.4E-14	1.2E-17	9.5E-18	4.0E-17

In terms of comparison to 10 CFR 20 Appendix B effluent limits, the data can be summarized as follows:

- Natural uranium concentrations were 0.0 to 0.3 percent of its effluent limit.
- Thorium-230 concentrations were 0.0 percent of its effluent limit.
- Radium-226 concentrations were -0.01 to 0.01 percent of its effluent limit.
- Lead-210 concentrations were -0.02 to 6.78 percent of its effluent limit.

The LLDs, in pCi/f, reported by the laboratory for each radionuclide were converted to µCi/ml by multiplying pCi/f by $1*10^{-12}$. In no cases were the LLDs higher than their respective 10 CFR 20 effluent concentration limits. The LLDs reported in Period 2 by the laboratory for uranium exceeded the recommendation in NRC Regulatory Guide 4.14.

The LLDs for each of the radionuclides are listed in Table 12.1-12.

12.1.7.3 Conclusions

With the exception of natural uranium, the values determined above are similar to U.S. background concentrations reported in the UNSCEAR Report to the General Assembly, Sources and Effects of Ionizing Radiation, Annex B. The regional concentrations reported in this reference document are: uranium-238 ($2.4*10^{-17}$ to $1.4*10^{-16}$ µCi/ml), thorium-230 ($1.6*10^{-17}$ µCi/ml), radium-226 ($1.6*10^{-17}$ µCi/ml), and lead-210 ($2.7*10^{-15}$ to $2.7*10^{-14}$ µCi/ml).

12.1.8 Radon Flux Measurements

Radon flux rates were measured at nine locations on three occasions in the Dewey and Burdock roll front areas. The locations are shown on Figure 12.1-9 The locations coincide with the nine soil samples collected from 0-100 cm below ground surface (not in land application areas).

The first round of flux canisters was deployed on September 26, retrieved on September 27, and analyzed on September 28, 2007. The second round of flux canisters was deployed on April 20, retrieved on April 21, and analyzed on April 22, 2008. The third round of flux canisters was deployed on July 14, retrieved on July 15, and analyzed on July 16, 2008. The canisters were analyzed using EPA Test Method 115, Monitoring for Radon-222 Emissions. Results are documented in the Table 12.1-14. Sampling for the three periods yielded flux rates of 1.22, 0.74, and 1.5 picocuries per meter squared second (pCi/m2-s), respectively. Flux rates ranged between 0.68 and 1.77 pCi/m2-s in fall 2007, 0.28 and 1.33 pCi/m2-s in spring 2008 and 0.48 and 2.38 pCi/m2-s in summer 2008.

Table 12.1-14 Baseline Radon Flux Measurements

Location	Date	Flux (pCi/m2s)	Std. Dev. (pCi/m2s)	LLD (pCi/m2s)	Average Flux @ Location (pCi/m2s)
RFA-B01	September 2007	1.68	0.06	0.18	1.57
	April 2008	0.64	0.05	0.15	
	July 2008	2.38	0.06	0.15	
RFA-B02	September 2007	0.89	0.05	0.15	0.86
	April 2008	0.76	0.05	0.16	
	July 2008	0.94	0.05	0.15	
RFA-B13	September 2007	1.77	0.06	0.17	1.53
	April 2008	0.56	0.05	0.16	
	July 2008	2.27	0.06	0.15	
RFA-B15	September 2007	1.22	0.05	0.15	1.35
	April 2008	1.12	0.06	0.16	
	July 2008	1.71	0.05	0.15	
RFA-B17	September 2007	1.25	0.06	0.16	1.05
	April 2008	0.61	0.05	0.16	
	July 2008	1.30	0.05	0.15	
RFA-B21	September 2007	0.97	0.05	0.14	0.71
	April 2008	0.28	0.05	0.16	
	July 2008	0.89	0.05	0.14	
RFA-B30	September 2007	1.73	0.06	0.17	1.49
	April 2008	0.70	0.05	0.16	
	July 2008	2.03	0.05	0.15	
RFA-B36	September 2007	0.68	0.05	0.16	0.60
	April 2008	0.64	0.05	0.16	
	July 2008	0.48	0.06	0.15	
RFA-B37	September 2007	0.80	0.05	0.14	1.13
	April 2008	1.33	0.06	0.16	
	July 2008	1.27	0.05	0.14	

12.1.8.1 Conclusions

The flux rates determined at the PAA are one to two orders of magnitude below the National Emissions Standards for Hazardous Air Pollutants (NESHAPS) requirements of 20 pCi/m^2-s specified in 10 CFR 40, Appendix A, Criterion 6. Although the latter requirement applies to tailings and thus is not directly germane to this characterization, it is useful as a context to demonstrate the relatively low magnitude of baseline radon flux rates measured at the site.

12.1.9 Surface Water Sampling

12.1.9.1 Introduction

Working within the practices of good stewardship and in conjunction with federal and state agencies (NRC Guide 4.14 (RG 4.14), NUREG-1569, and South Dakota mining rules ARSD 74:29), the perennial and ephemeral streams and impoundments in the PAA were sampled upstream and downstream of the

PAA. Figure 12.1-15 and Figure 12.1-16 show the locations of the stream and impoundment sampling sites.

TVA conducted a surface water sampling investigation in support of a DES in order to quantify surface water quality within the Edgemont Uranium Mining Project area. The investigation was conducted between December 1974 and September 1977. The surface water data was supplemented by incorporation of USGS and the State of South Dakota surface water quality data into the draft assessment. In summary of the assessment a brief discussion is provided in support of current surface water quality data.

12.1.9.1.1 TVA Surface Water Quality Summary

The Cheyenne River and Beaver Creek water bodies exhibited concentrations elevated above state standards in regards to mean dissolved solids; the total alkalinity and hardness averages for both the Cheyenne River and Beaver Creek represented levels that characterize both water as very hard and exceeded the mean dissolved solids concentrations in the Cheyenne for criteria set for livestock watering. Cheyenne averaged 156 mg/L for total alkalinity and 1,390 mg/L for hardness. Beaver Creek averages for total alkalinity and hardness were observed at 148 mg/L and 1,425 mg/L respectively. Dissolved solids for Cheyenne and Beaver creek averaged 3,513 mg/L and 2,960 mg/L respectively. Chemical water quality concentrations for both water bodies that were observed above the EPA Primary drinking water standards with regard to barium and arsenic; EPA secondary drinking water standards (proposed at the time of the investigation) were exceeded in both bodies of water with regards to concentrations of chlorides, iron (exceeded South Dakota water quality standard), manganese, and sulfates; cadmium was above the standard in Beaver Creek. Both water bodies were deemed unsuitable for continuous irrigation use on all soils by 1972 National Academy of Science / National Academy of Engineering (NAS/NAE) Water Quality Criteria (Tennessee Valley Authority, 1979).

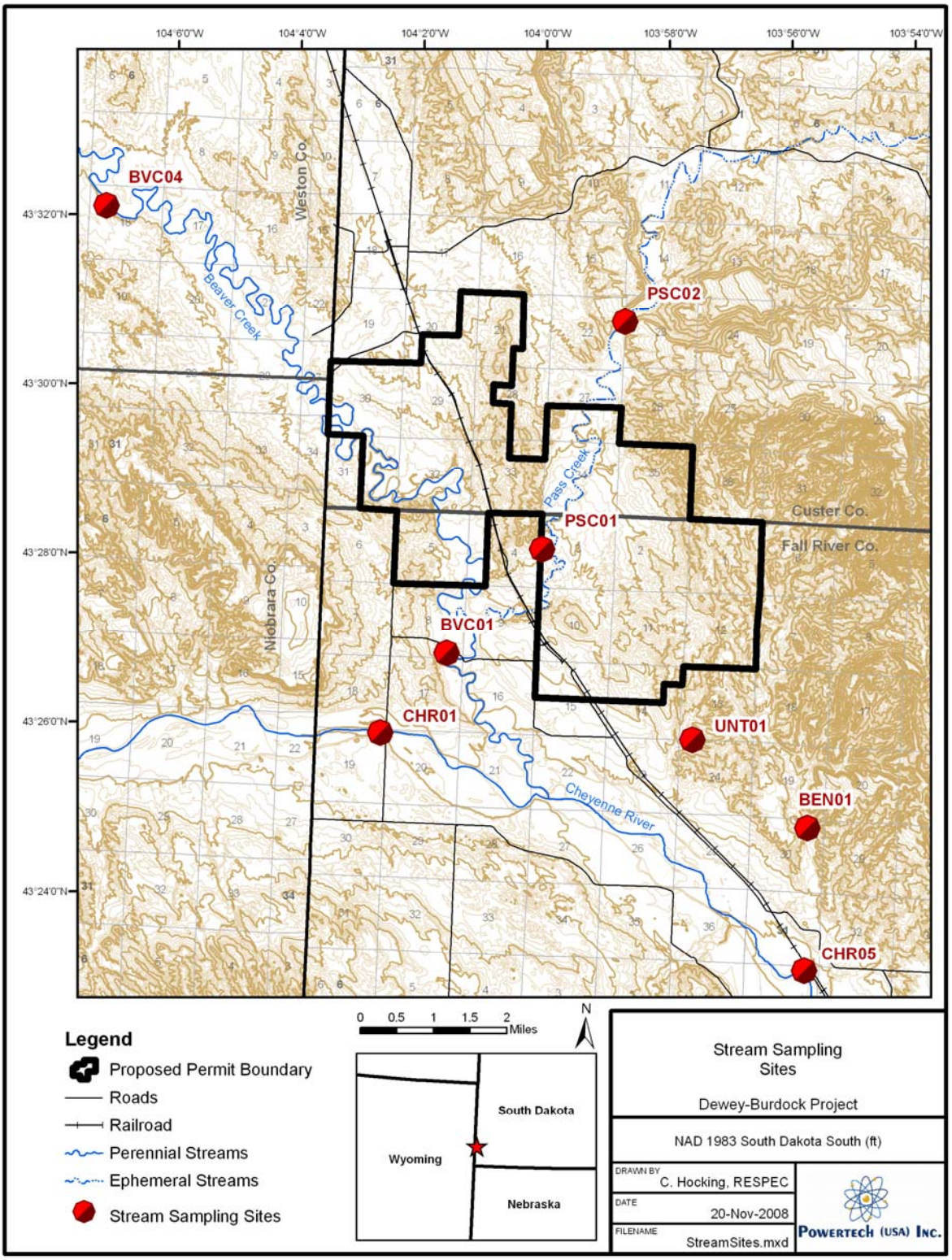

Figure 12.1-15 Stream Water Quality Sampling Sites (Intentionally redundant for ease of review)

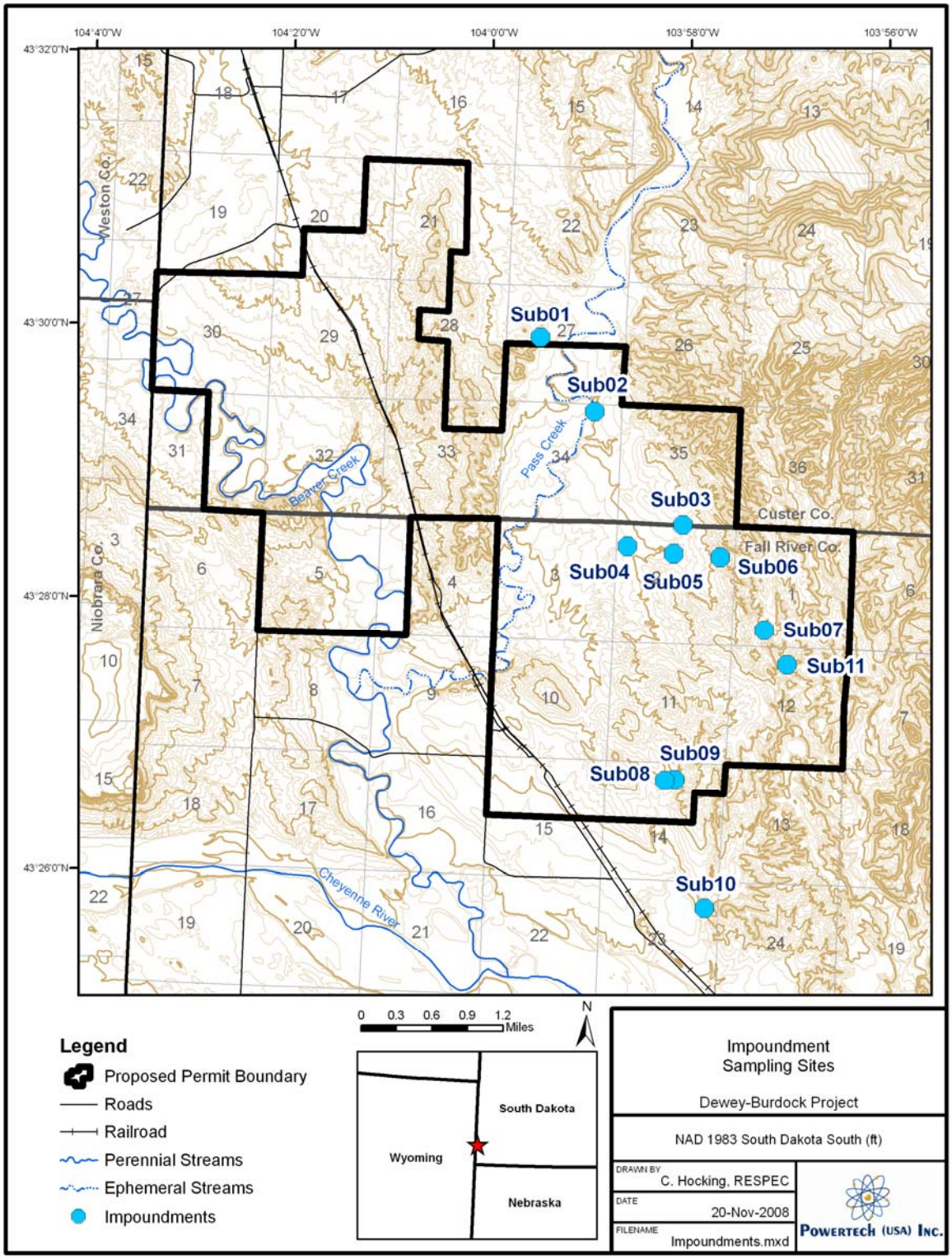

Figure 12.1-16 Impoundment Water Quality Sampling Sites (Intentionally redundant for ease of review)

12.1.9.2 2007 Baseline Surface Water Sampling

Surface water sampling locations for the recent study were chosen with consideration given to site specificity based on NRC Guide 4.14 (RG 4.14) and the South Dakota mining rules ARSD 74:29, which require background radiological data to be collected for surface waters.

The following stream sampling sites were established in support of the site characterization activities:

- Two sites on Beaver Creek (BVC01 and BVC04).
- Two on Pass Creek (PSC01 and PSC02).
- Two on the Cheyenne River (CHR01 and CHR05).
- One on smaller watershed in Bennett Canyon (BEN01).
- One on an unnamed tributary within the permit boundary (UNT01).

Surface water impoundments included stock dams and mine pits. Surface water impoundments were originally identified on topographic maps and aerial photographs. Subsequently, ground truthing was completed in July 2007 to fully identify and gather impoundment-location data. A total of 11 (of 48 impoundments identified, verified, photographed, and described) were sampled and are summarized in Table 12.1-15.

Because of the number of impoundments, their relatively small drainage basin, and the tendency of many to be dry after substantial rainfall, sampling a representative subset of the water impoundments was proposed. Impoundments were selected based on the presence of water, drainage area, and specific locations relative to proposed operations. Eleven surface water impoundments were selected to construct a representative sampling group for the PAA. Abandoned and reclaimed mine pits were selected due to the ubiquitous nature of plumes that often accompany mine pits. This information in characterizing the specific site is considered important in understanding the groundwater quality that may be affected via the mine pits near potential areas of operations.

Table 12.1-15 Impoundment Water Quality Sampling Locations

	Site ID	SD State Plane 1983		Type / Name	Groundwater Influence
		East (ft)	North (ft)		
Subimpoundments	Sub01	998654	446816	stock pond	
	Sub02	1001071	443526	Triangle Mine Pit	x
	Sub03	1005005	438448	mine dam	
	Sub04	1002542	437518	stock pond	
	Sub05	1004591	437191	mine dam	
	Sub06	1006665	437019	Reclaimed Darrow Mine pit - Northwest	
	Sub07	1009312	434360	stock dam	
	Sub08	1004195	427057	stock pond	x
	Sub09	1004640	427089	stock pond	
	Sub10	1005961	421367	stock pond	
	Sub11	1009659	432225	stock pond	

Number of surface water samples analyzed ranged from 57 to 81 depending upon availability of water during each sampling event. A complete summary of results for the major constituents of concern in surface water is described in Appendix K, along with surface water analytes, number of samples, methods and Practical Quantitation Limits (PQL).

12.1.9.2.1 Methods

A surface water quality sample constituent list (Appendix K) was developed based on NUREG-1569 groundwater parameters (less radon), NRC 4.14 parameters, and added parameters from a constituent-list review with South Dakota SD DENR. The following methodology was applied to the collection of surface water samples:

- Field methods for sampling surface waters followed South Dakota Department of Environment and Natural Resources Standard Operating Procedures for Field Samplers, Volume I (SD DENR, 2003).
  - Field methods required a qualified technician (wearing gloves) to measure and record field water quality parameters dissolved oxygen, turbidity, pH, specific conductivity, and temperature with a water-quality probe.
  - Sample bottles and preservative were supplied by EPA-certified Energy Laboratories in Rapid City and rinsed three times with sample water before sample collection and labeled with site ID, date, and time. Bacteriological sample bottles were not rinsed prior to filling.
  - Samples were field-preserved (where required) and immediately placed on ice then delivered within 24 hours to Energy Laboratories in Rapid City along with proper chain-of-custody forms.
  - A replicate and a blank sample were collected for every 10 water quality samples collected.
- Sites on Beaver Creek and Pass Creek were visited monthly and sampled when water was present.
- Although it does not pass through the permit boundary, the Cheyenne River was also sampled monthly upstream and downstream of confluences with streams passing through the permit boundary.

Due to the sporadic and sometimes sudden nature of flow events concerning the tributaries and remoteness of the locations, passive samplers ("single-stage samplers") designed to collect samples during ephemeral-flow events were installed and used in Pass Creek (PSC01 and PSC02), Bennett Canyon (BEN01), and Unnamed Tributary (UNT01).

12.1.9.2.2 Surface Water Sampling Results

Results and statistical summaries for field water quality parameters collected at the Beaver Creek (BVC) and Cheyenne River (CHR) sites are shown on Tables 12.1-16, 12.1-17, 12.1-18, and 12.1-19. Months without data indicate either a completely frozen stream or absence of water. Tables 12.1-20 and 12.1-21 summarize the analytical results for total dissolved solids (TDS), total sulfate, and total chloride, and for radionuclides, respectively.

Analysis of field parameters shows some exceedances of South Dakota state standards at Beaver Creek while other parameters fall into compliance range. pH was higher than 8.8 in 15 percent (3 of 20) measurements, but was not found to be lower than the 6.5 standard for coldwater marginal fish life. Dissolved oxygen measurements were in full compliance, with an average value of 10.8 mg/L (n=21) and a minimum of 6.54 mg/L. Nineteen percent (4 of 21) of temperature measurements were greater than the 75 °F standard for coldwater marginal fish life, with a maximum measured temperature of 82.5 °F. Krantz (2006) modeled temperatures in Beaver Creek and reports from a temperature-sensitivity analysis that air temperature is the primary controlling factor for stream temperatures in Beaver Creek. Specific conductivity values exceeded the fish, wildlife, and stock daily-maximum standard of 7,000 umhos/cm in 14 percent (3 of 21) of measurements and exceeded the irrigation daily maximum standard of 4,375 umhos/cm in 48 percent (10 of 21) of measurements. This is in line with the TVA DES results summarized in the beginning of this section.

Analysis of Cheyenne River field parameters also showed some exceedances of state standards. Specific conductivity values exceeded the fish, wildlife, and stock daily-maximum standard of 7,000 umhos/cm in 5 percent (1 of 20) of measurements and exceeded the irrigation daily-maximum standard of 4,375 umhos/cm in 40 percent (8 of 20) of measurements. Dissolved oxygen values were below the state

standard for warm-water semi-permanent fish life of 5 mg/L in 6 percent (1 of 18) of samples. Water temperature measurements (n=20) and pH measurements (n=20) were all found to be in compliance.

Table 12.1-16 Field Data and Statistics for BVC01

BVC01					
Date	**Temp, F**	**pH**	**Dissolved Oxygen, mg/L**	**Specific Conductivity, uS/cm**	**Turbidity, NTU**
8/20/2007	81.6	8.91	12.29	1777	21.0
9/26/2007	62.1	8.87	10.95	1339	1.7
10/17/2007	53.9	8.58	11.13	5726	2.5
11/19/2007	38.4	8.20	12.20	7678	6.4
12/11/2007	31.9	7.94	11.21	4134	6.4
1/11/2008	31.9		10.07	2812	8.6
3/9/2008	32.3	8.24	13.57	1718	308
4/14/2008	60.9	8.15	9.20	5109	11.8
5/26/2008	55.1	7.95	6.86	860	1790
6/17/2008	74.9	8.13	10.39	5650	53
N	10	9	10	10	10
Mean	52.3	8.33	10.79	3680	221
Median	54.5	8.20	11.04	3473	10.2
Std Dev	18.2	0.37	1.85	2308	559
Min	31.9	7.94	6.86	860	1.7
Max	81.6	8.91	13.57	7678	1790

Table 12.1-17 Field Data and Statistics for BVC04

BVC04					
Date	**Temp, F**	**pH**	**Dissolved Oxygen, mg/L**	**Specific Conductivity, uS/cm**	**Turbidity, NTU**
8/20/2007	81.0	8.82	12.31	1450	79.5
9/28/2007	51.4	7.60	6.85	4712	
10/17/2007	50.1	8.46	10.45	7157	12.6
11/19/2007	41.2	8.18	12.39	5416	9.3
12/11/2007	31.9	7.86	11.01	4055	2.9
1/11/2008	31.8	7.74	11.37	3022	16.8
3/9/2008	31.9	8.12	13.74	2015	226
4/14/2008	62.5	8.27	12.21	7186	14.3
5/26/2008	55.5	8.09	6.54	733	1730
6/17/2008	77.3	7.52	9.55	4915	33.8
7/8/2008	82.5	8.38	12.80	6217	
N	11	11	11	11	9
Mean	54.3	8.09	10.84	4262	236
Median	51.4	8.12	11.37	4712	16.8
Std Dev	19.5	0.39	2.35	2229	565
Min	31.8	7.52	6.54	733	2.9
Max	82.5	8.82	13.74	7186	1730

Table 12.1-18 Field Data and Statistics for CHR01

CHR01					
Date	Temp, F	pH	Dissolved Oxygen, mg/L	Specific Conductivity, uS/cm	Turbidity, NTU
9/5/2007	79.4	8.44	13.08	4085	19.0
9/26/2007	60.8	8.02	10.48	3895	1.0
10/17/2007	55.6	8.02	5.17	6929	9.9
11/19/2007	42.2	7.47	3.74	7847	5.8
3/9/2008	45.1	8.11	12.84	3990	7.4
4/16/2008	58.9	8.32	8.13	6180	1.5
5/26/2008	56.0	8.17	7.77	350	1798
6/17/2008	80.6	8.27	7.85	2897	73.4
N	8	8	8	8	8
Mean	59.8	8.10	8.63	4522	240
Median	57.5	8.14	7.99	4038	8.7
Std Dev	14.0	0.29	3.35	2406	630
Min	42.2	7.47	3.74	350	1.0
Max	80.6	8.44	13.08	7847	1798

Table 12.1-19 Field Data and Statistics for CHR05

CHR05					
Date	Temp, F	pH	Dissolved Oxygen, mg/L	Specific Conductivity, uS/cm	Turbidity, NTU
9/5/2007	78.1	8.16	12.20	4570	1.0
9/26/2007	65.9	8.01		4002	2.0
10/17/2007	58.0	8.12	10.08	6986	8.3
11/19/2007	43.2	8.16	11.03	6384	13.3
12/11/2007	31.9	7.95	11.14	3888	3.8
1/11/2008	31.8	7.65	9.22	3058	2.0
2/12/2008	32.4	7.42		3353	12.3
3/9/2008	32.0	8.24	12.92	1118	177
4/14/2008	53.8	8.10	9.92	4905	12.5
4/15/2008	59.7	8.15	8.85	4970	36.0
5/26/2008	55.9	8.19	7.69	510	1790
6/17/2008	74.1	8.24	7.63	3721	59.3
N	12	12	10	12	12
Mean	51.4	8.03	10.07	3955	176
Median	54.9	8.14	10.00	3945	12.4
Std Dev	16.9	0.25	1.78	1872	511
Min	31.8	7.42	7.63	510	1.0
Max	78.1	8.24	12.92	6986	1790

Since the beginning of July 2007, surface water samples have been collected and submitted to Energy Laboratories Inc. for analysis. Table 12.1-20 summarizes the analytical results for total dissolved solids (TDS), total sulfate, and total chloride. Sample results were compared to secondary drinking water standards (SMCL) set by the EPA that designate constituents that alter the color, taste, and odor of water. These constituents are not considered health risks but may deter human consumption when concentrations are above the SMCL. These constituents, along with the number of samples that exceed these guidelines, are also presented in following table and discussed below.

Almost all of the samples exceeded the recommended concentration of 500 mg/L for TDS. Values of TDS ranged from 219 to 7040 mg/L with the highest values obtained from the Cheyenne River site (CHR-01). A number of samples also exceeded the SMCL for sulfate; 41 of 43 samples exceeded the SMCL for sulfate of 250 mg/L. 36 of these samples were over double the limit (over 500 mg/L). To date, more than half (23 of 43) of the samples have exceeded the SMCL of 250 mg/L for chloride (Table 12.1-20).

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Table 12.1-20 Summary of Key Surface Water Concentrations

Parameter		Total Dissolved Solids @ 180 - mg/L				Sulfate - Total mg/L				Chloride - Total mg/L			
Sample ID		BVC-01	BVC-04	CHR-01	CHR-05	BVC-01	BVC-04	CHR-01	CHR-05	BVC-01	BVC-04	CHR-01	CHR-05
Sample Date	7/1/2007	967	1770	5590	3710	463	859	3550	2030	101	251	125	386
	8/20/2007	1120	945	NS	NS	511	436	NS	NS	158	118	NS	NS
	9/5/2007	1090	5640	3160[a] (Rep 3230) - 5970[b]	3730[a] - 5720[b]	568	2520	2010a (Rep - 2060) - 3970[b]	2160[a] - 4160[b]	141	1310	74[a] (Rep 74) - 138[b]	344[a] - 221[b]
	10/17/2007	4520	5700	6370	6450	2180	2670	4060	4060	852	1540	166	269
	11/19/2007	5860	4110	7040	4900	2540	1920	4520	2340	1370	1040	176	912
	12/11/2007	3110 (Rep 3210)	3140	NS	3100	1430 (Rep 1510)	1450	NS	1570	581 (Rep 610)	601	NS	509
	1/11/2008	2610	2650	NS	2920	1470	1450	NS	1610	208	255	NS	258
	2/12/2008	NS	NS	NS	2950	NS	NS	NS	1730	NS	NS	NS	250
	3/9/2008	4070	1680 (Rep 1730)	1280	1160	2490	681 (Rep 736)	572	463	113	339 (Rep 364)	249	232
	4/14/2008	3840	5340	5720	3540 (Rep 3860)	1570	1860	3690	1540 (Rep 1710)	973	1730	156	780 (Rep 861)
	5/26/2008	609	516	219	365	317	286	86	180	62	9	2	17
	6/17/2008	3830	3090	2060	2560	1410	1090	1090	1180	970	739	78	337
	Average	2875	3144	4157	3425	1359	1384	2616	1919	503	721	129	375
	Minimum	609	516	219	365	317	286	86	180	62	9	2	17
	Maximum	5860	5700	7040	6450	2540	2670	4520	4060	1370	1730	249	912

Notes:

[a] Sampled 9/5/2007

[b] Sampled 9/26/2007

Green highlights designate concentrations over the EPA "Secondary" guideline value above which use of water may give rise to complaints by consumers

NS = No sample

Rep = duplicate analysis

Table 12.1-21 summarizes the analytical results for radionuclides. Sample results were compared to EPA National Primary Drinking Water Standards and are discussed below.

Several groundwater samples collected exceed the National Primary Drinking Water Standards. Constituents with samples exceeding the standards include gross alpha particles, uranium, and radium-226. Complete surface water quality data results are available in Appendix K.

Most of the samples (26 of 43) exceeded the MCL for gross alpha particles of 15 picocuries per liter (pCi/L), with the exceedances occurring in samples from both Beaver Creek and Cheyenne River sites. The range of gross alpha particles sampled was 2.3 to 65.8 pCi/L. Uranium concentrations ranged from 0.0017 to 0.0368 mg/L for dissolved and 0.003 to 0.0378 for total uranium with 9 of 102 (dissolved and total) samples exceeding the MCL of 0.03 mg/L. Radium 226 (dissolved) and Radium (total) concentrations exceeding the MCL of 5.0 pCi/L are presented in Table 12.1-21. For drinking water standards, Pb-210 is currently not regulated by the EPA, though in 1999 a standard of 1 pCi/L was proposed (EPA, 2000).

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Table 12.1-21 Summary of Surface Water Radionuclide Concentrations

Parameter		Alpha Particle-Dissolved pCi/L				Uranium-Dissolved mg/L				Uranium-Total mg/L				Radium-226 -Dissolved pCi/L				Radium-226-Total pCi/L				Lead-210 -Dissolved pCi/L			
Sample ID		BVC-01	BVC-04	CHR-01	CHR-05	BVC-01	BVC-04	CHR-01	CHR-05	BVC-01	BVC-04	CHR-01	CHR-05	BVC-01	BVC-04	CHR-01	CHR-05	BVC-01	BVC-04	CHR-01	CHR-05	BVC-01	BVC-04	CHR-01	CHR-05
Sample Date	Jul-2007	5.9	11.4	16.9	16.7	NS	NS	NS	NS	0.00	0.01	0.02	0.01	NS	NS	NS	NS	0.10	0.10	0.10	0.10	NS	NS	NS	NS
	Aug-2007	7.1	7.0	NS	NS	NS	NS	NS	NS	0.00	0.00	NS	NS	NS	NS	NS	NS	0.10	0.70	NS	NS	NS	NS	NS	NS
	Sep-2007	6.6	2.3	15.9[a] (Rep 16.7) - 33.8[b]	9.7[a] - 25.6[b]	0.0075	0.0140	0.0149	0.0346	0.01	0.01	0.0142[a] (Rep 0.0142) - 0.015[b]	0.0136[a] - 0.0348[b]	0.10	0.10	0.10	0.10	0.10	0.70	0.1[a] (Rep 0.1) - 0.1[b]	0.1[a] - 0.1[b]	0.5000	0.0005	0.5000	0.5000
	Oct-2007	12.0	26.6	34.2	23.2	0.0097	0.0230	0.0308	0.0368	0.01	0.02	0.03	0.04	0.30	0.50	0.50	0.10	NS	NS	NS	NS	0.5000	0.0005	3.2000	6.6000
	Nov-2007	65.8	34.7	27.0	16.8	0.0182	0.0189	0.0310	0.0151	0.02	0.02	0.03	0.01	n/s	n/s	NS	NS	0.10	0.80	0.60	0.10	4.6000	0.0005	0.5000	0.5000
	Dec-2007	27.9 (Rep 25.8)	17.1	NS	24.9	0.0124 (Rep 0.0129)	0.0114	NS	0.0125	0.0142 (Rep 0.0151)	0.01	NS	0.02	0.1 (Rep 0.1)	0.10	NS	0.10	0.4 (Rep 0.1)	0.30	NS	0.10	11 (Rep 0.5)	0.0005	NS	5.9000
	Jan-2008	12.6	13.9	NS	19.3	0.0134	0.0141	NS	0.0150	0.01	0.01	NS	0.02	0.10	0.10	NS	0.10	0.10	0.10	NS	0.10	0.5000	0.0005	NS	0.5000
	Feb-2008	NS	NS	NS	15.7	NS	NS	NS	0.0143	NS	NS	NS	0.01	NS	NS	NS	0.10	NS	NS	NS	0.10	NS	NS	NS	NS
	Mar-2008	17.4	6.7 (Rep 8.8)	5.1	4.0	0.0269	0.0056 (Rep 0.0055)	0.0034	0.0039	0.03	0.0061 (Rep 0.0062)	0.00	0.00	-0.02	0.08 (Rep 0.06)	0.20	0.07	-0.70	0.1 (Rep -0.2)	1.50	1.80	NS	0.0005 (Rep 0.0005)	NS	NS
	Apr-2008	15.1	23.4	5.7	19.8 (Rep 19.9)	0.0125	0.0165	0.0324	0.0134 (Rep 0.0135)	0.01	0.02	0.04	0.0141 (Rep 0.014)	0.10	0.10	0.30	0.1 (Rep 0.1)	0.10	0.30	0.10	0.4 (Rep 0.5)	NS	0.0005	NS	NS
	May-2008	18.2	12.5	29.1	29.8	0.0020	0.0017	0.0024	0.0028	0.01	0.01	0.01	0.01	2.00	-0.06	0.06	1.40	5.10	2.20	4.10	5.10	-1.0000	0.0005	0.5000	0.7000
	Jun-2008	8.9	3.9	35.3	29.9	0.0092	0.0078	0.0177	0.0139	0.01	0.01	0.02	0.02	-0.02	0.10	0.20	0.20	-0.95	-0.53	-0.72	-0.48	NS	0.0005	NS	NS
	Average	18.0	14.5	22.6	19.6	0.0124	0.0126	0.0189	0.0028	0.01	0.01	0.02	0.02	0.33	0.13	0.23	0.25	0.45	0.48	0.74	0.68	2.6833	0.0005	1.1750	2.4500
	Minimum	5.9	2.3	5.1	4.0	0.0020	0.0017	0.0024	0.0028	0.00	0.00	0.00	0.00	-0.02	-0.06	0.06	0.07	-0.95	-0.53	-0.72	-0.48	-1.0000	0.0005	0.5000	0.5000
	Maximum	65.8	34.7	35.3	29.9	0.0269	0.0230	0.0324	0.0368	0.03	0.02	0.04	0.04	2.00	0.50	0.50	1.40	5.10	2.20	4.10	5.10	4.6000	0.0005	3.2000	6.6000

Notes:
[a] Sampled 9/5/2007
[b] Sampled 9/26/2007

Yellow highlights designate concentrations over the EPA MCL
Blue highlights designates one of the two sample concentrations exceeded the EPA MCL

NS = No sample
Rep = duplicate analysis

Statistics for all surface water constituents detected at or above PQL are provided in Appendix K. The minimum and maximum results for all sampled constituents detected at or above the PQL are listed in Appendix K. A comparison between water quality constituents in impoundments and streams that were detected at or above the PQL is presented in Appendix K. Constituents in italics are those in which the absolute difference in percent detections between streams and impoundments was 30 percent or greater. Fecal coliform, alkalinity, bicarbonate, and dissolved and total boron were detected primarily in streams, while ammonia, dissolved aluminum, dissolved iron, dissolved nickel, dissolved and total zinc, and dissolved and total radium 226 were primarily detected in subimpoundments. Tabular results for all samples are listed in Appendix K.

12.1.9.2.3 Conclusions

Radiological data for surface water in the PAA has been collected and analyzed according to NRC Regulatory Guide 4.14. When water was present, streams were sampled monthly and impoundments were sampled quarterly.

Powertech has initiated, planned and implemented the surface water quality site characterization study with the intentions of good stewardship, following industry standards, and in conjunction with federal and state regulations and with full consideration of federal and state guidance. Results from the surface water characterization study correspond well with the study conducted by TVA in 1979. The surface water bodies that transverse the PAA had in the past been deemed unsuitable for irrigation due to the high concentrations of salts as classified by the NAS/NAE. Based on current characterization of the surface water bodies within the proposed site of operation, the data seem to represent very little variance from the previous TVA study conducted in 1979.

12.1.10 Groundwater Sampling

Baseline groundwater sampling was conducted in general accordance with NRC Regulatory Guide 4.14 (USNRC, 1980). Because of the significant number of groundwater wells, their geochemical similarities, and an abundance of historical water quality data, a representative subset of the wells was selected for sampling. The wells were selected based on type of use, aquifer, and location in relation to the ore bodies. The baseline study for the NRC license application consisted of 19 groundwater wells (14 existing and 5 newly drilled), sampled quarterly, making up a representative sampling group for the area (Figure 9.2-1 and Table 12.1-22). The wells selected for sampling include eight domestic wells, six stock watering wells, with three of the fourteen existing wells being hydrologically upgradient of the proposed recovery areas. The total number of wells chosen for site characterization of the groundwater includes wells within the Fall River Formation (4), Lakota Formation (7), Inyan Kara Group (Fall River or Lakota) (2), Sundance Formation (1), and alluvium (5). Initial baseline sampling of these wells was conducted quarterly from July 2007 through June 2008.

As required by the SD DENR (rule ARSD 74:29), an additional 12 wells were sampled monthly beginning in March 2008 and sampled through February 2009 for a final total of all wells sampled of 31. The 12 wells required by DENR are represented in (Figure 9.2-2 and Table 12.1-23). Of the 12 wells, six wells are located in the Dewey area and six wells are located in and near the Burdock area. Of the Dewey wells, there is a set of Fall River and Lakota wells sampled, upgradient of, within the PAA, and down gradient of proposed production activities. Near the Burdock area, the same well arrangement applies with two wells upgradient of, two wells within the proposed production area, and two downgradient of the proposed production area. Data for radiological parameters available to date are presented in this section. In addition to the 12 required wells specified by SD DENR, two more wells were installed within the NE corner of the PAA (Table 12.1-24) as a result of a second request from SD DENR. Sampling is scheduled to begin in December of 2009, end date of sampling is to be determined.

Table 12.1-22 Quarterly Sampled Water Quality Well Data

ID	SD State Plane 1983		Formation	Depth, ft	Screened Interval, ft	Description
	East (ft)	North (ft)				
2	995122.6	423922.6	Lakota	650	566 - 650	Peterson Domestic and Stock
7	1001702.8	422416.9	Fall River	200	unknown	Kennobie Domestic
8	1004451.2	418618.3	Fall River	240	unknown	Englebert Domestic
13	996758.9	438470.4	Lakota	625	580 - 625	C. Spencer Domestic
16	1009827.6	434446.9	Lakota	330	unknown	Daniel Domestic
18	991210.6	428960.1	Fall River	527	unknown	D. Anderson Domestic
42	989542.9	436481.4	Lakota	600	unknown	L. Putnam Domestic
619	1003106.9	437045.9	Lakota	280	unknown	Daniel West – Weather Station Stock
628	990894.7	449719.2	Inyan Kara	unknown	unknown	Abandoned Windmill Stock
631	1002575.7	449309.8	Fall River	80	30 - 80	Putnam Big Pump Stock
635	1004084.6	427130.8	Sundance	880	666 - 780	Sundance Pond Stock
650	1012180.5	433331.4	Lakota	unknown	unknown	Daniel East Stock
675	1015340.3	406352.2	Alluvium	14.4	4 - 14	Marietta Alluvial
676	999245.0	439891.6	Alluvium	22.5	12 - 22	Pass Cr. Spencer Alluvial
677	991947.3	434035.9	Alluvium	14.5	4 - 14	Putnam Alluvial
678	995023.4	431834.9	Alluvium	14.5	4 - 14	Pass Cr. Alluvial
679	1000303.0	446248.3	Alluvium	39	29 - 39	Pass Cr. Doran Alluvial
4002	981812.9	446932.2	Inyan Kara	unknown	unknown	Swimming Pool Stock
7002	1001731.5	421930.8	Lakota	500	unknown	Kennobie Stock

Table 12.1-23 Monthly Sampled Water Quality Well Data

ID	SD State Plane 1983		Formation	Depth, ft	Screened interval, ft	Description
	East (ft)	North (ft)				
615	990571.0	453708.9	Lakota	800	712 - 800	TVA No. 2
622	991174.5	454033.8	Fall River	520	503 - 580	TVA No. 8
680	1003476.6	429969.1	Lakota	436	426 - 436	Burdock Pump Test
681	988728.3	443725.3	Fall River	600	585 - 600	Dewey Pump Test
688	1003425.8	429974.4	Fall River	255	245 - 255	Burdock Pump Test West Piezo
689	988715.0	443789.2	Lakota	730	715 - 730	Dewey Pump Test North Piezo
694	997116.1	426836.1	Fall River	392	377 - 392	School House NW
695	990783.4	439312.5	Fall River	508	493 - 508	Putnam East
696	997086.2	426946.4	Lakota	587	572 - 587	School House SE
697	990748.4	439347.4	Lakota	682	667 - 682	Putnam West
698	1004307.8	435651.1	Fall River	205	180 - 205	Weather Station
3026	1012037.4	432833.2	Lakota	196	166 - 196	Daniel New Stock

Table 12.1-24 Additional Two NE Wells Requested by SD DENR

ID	SD State Plane 1983		Formation	Depth	Screened Interval	Description
DB09-21-1	East (ft.) 997027	North (ft.) 453320	Lakota	460	430-460'	Up gradient DENR wells
DB09-21-2	996989	453289	Fall River	316	286-316'	Up gradient DENR wells

12.1.10.1 Methods

Static water levels were measured at most wells prior to sample collection with regard to a reference elevation, usually a mark on the well or on a permanent structure above or near to the well. When possible, pressure of artesian wells was measured with a 15 psi or 30 psi NIST– certified pressure gauge; the well was shut in and the pressure was allowed to stabilize before a reading was recorded. Pressure values were recorded to within at least one tenth of a psi and typically to within a hundredth of a psi. Wells with subsurface water levels were measured using an electric water level tape with measurements reported to within at least one tenth of a foot and typically to within a hundredth of a foot.

Exceptions to this were domestic wells that could not be accessed at the well head or were behind a pressure tank (wells 7, 8, 13, 16, 18, 42), free-flowing wells that could not be sealed due to leaks caused by corrosion and age (wells 2, 635, 4002), free-flowing wells that could not be sealed due to poor valve fittings or cracked valves (well 696), free-flowing wells where existed the possibility of rupturing a line when pressurized due to age (well 7002), and wells that contained pumps and pump tubing making it difficult to retrieve a water level tape (well 619).

All pumped wells, with the exception of 631, had permanent pumps installed in order to obtain samples. An existing high-capacity pump in well 631, used to pump water up a hill several hundred feet to a stock tank, was not used for sampling purposes due to logistical hurdles except for the first sample collected there on September 27, 2007. For the next three samples, a small dedicated pump was used each time the well was sampled.

Continuous free-flowing wells were sampled before pressure measurements were made and were not purged before sampling. For these wells (2, 18, 42, 635, 4002, 7002), it was assumed that free-flowing well water adequately represented formation water. After collecting a sample, a spot check with a water-quality probe was made and temperature, specific conductivity, turbidity, and pH were recorded. Pressure was then measured at the wells where it was possible within limits of feasibility.

After measuring the pressure of capped free-flowing wells (where possible), the well valve was opened and the flow rate was allowed to stabilize, then flow measurements were made using a stopwatch and a marked container (usually a 5-gallon pail, but sometimes a 1-gallon container at slower-flowing wells). Casing purge time was calculated based on water column height, casing diameter, and flow rate. Three well volumes were required to have been purged before the well water was sampled. Additionally, a water-quality sonde with a flow-through cell was connected to the well and water quality parameters (pH, temperature and conductivity) were periodically recorded. If parameters had not stabilized after purging three volumes, wells were allowed to continue to purge until parameters had stabilized, or until the purged volume was more than three well volumes.

Pumped wells were purged of three pore volumes and after one or more of the water quality parameters stabilized (conductivity, temperature, and pH), flow from the formation was sampled.

After measuring the water level (where possible), the pump was started and flow rate was measured using a stopwatch and 5-gallon marked pail. A water-quality probe equipped with a flow-through cell was connected to the outflow.

Wells with a high enough yield were purged for a minimum of three well volumes, and also until one or more indicator parameters had stabilized. Parameters monitored for stabilization were specific conductance, temperature, and pH. Field measurements were recorded periodically during purging of 3 volumes, and at least 3 minutes apart after purging three volumes. Table 12.1-25 provides requirements for parameter stabilization. After three well volumes had been purged and parameters stabilized, a sample was collected.

Wells that had yields too low to be continuously pumped and purged of three well volumes were pumped dry and allowed to recover. After the well had sufficiently recovered, it was pumped and sampled. Accurate records of well purging are maintained to document the number of casing volumes purged from the well before sampling, but in all cases a minimum of one casing volume was purged before sampling.

After calculating casing volume, alluvial wells were purged of three well volumes into a 5-gallon marked pail using either disposable bailers or a peristaltic pump. When using bailers, water quality parameters were recorded after each well volume was purged using a water-quality probe. When using the peristaltic pump, a water quality probe equipped with flow-through cell was connected to pump outflow and parameters (pH, temperature and conductivity) were recorded periodically during the purge.

Table 12.1-25 Stability Criteria for Collecting Groundwater Samples at Pumped Wells

Field Measurement	Stability Criteria1
pH	+/- 0.1 standard units
Temperature	+/- 0.2 C
Specific conductivity	+/- 5% (SC <= 100 µS/cm); otherwise +/- 3%

[1]Allowable variation between 5 or more sequential field-measurement values

Additional steps taken during water quality sampling include the following:

- Sampling procedures required a qualified technician (wearing gloves) to label each sample bottle with site ID, date, time of sampling, triple rinsing the bottle with sample water, then filling and capping it.
- Radon sample bottles were filled and capped immediately and with no headspace.
- Field replicate samples, consisting of a second set of samples collected at the same time following the same protocols as the sample set, were collected periodically to determine data accuracy.
- Field blanks were collected by transporting deionized water supplied by the contract laboratory to the field during regular sampling, then transferred to collection bottles in the field in order to subject the blank water to the same transportation, handling, storage, and field conditions as regular samples.
- All samples were immediately placed in coolers on ice after collection.
- Water quality sondes used to collect field parameter measurements were calibrated periodically using NIST-traceable standards.

A groundwater quality constituent list was developed based on NUREG-1569 groundwater parameters, NRC 4.14 parameters, and added parameters from a constituent-list review with SD DENR.

12.1.10.2 Groundwater Sampling Radiological Results

Results to date for dissolved radiological groundwater parameters are shown in Table 12.1-26 and Table 12.1-27.

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Table 12.1-26 Summary of Groundwater Radionuclide Concentrations from Quarterly Sampled Wells

Parameter	Aquifer	Alpha Particle-Dissolved				Uranium-Dissolved				Uranium-Total				Radium-226 -Dissolved				Radium-226-Total				Radon-222		
Units		pCi/L				mg/L				mg/L				pCi/L				pCi/L				pCi/L		
Sampling Quarter / Sample ID		3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2007	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008	4th Quarter 2007	1st Quarter 2008	2nd Quarter 2008
Domestic Wells																								
2	Lakota	1.4	8.7	3.5	8.2	ND	ND	0.0004	ND	0.0004	NS	0.0004	ND	ND	1.3	1.1	2.1	2.2	NS	NS	NS	674	908	727
7	Fall River	4.4	7.2	15.5	3.3	ND	ND	ND	ND	NS	NS	ND	ND	0.6	1.1	0.7	0.9	ND	NS	NS	NS	206	242	451
8	Fall River	5	8.7	5.4	3.2	ND	0.0003	ND	ND	ND	NS	ND	ND	ND	NS	1.5	1.2	3.5	NS	NS	NS	123	329	514
13	Lakota	8.9	7.5	19.5	4.2	ND	ND	ND	ND	NS	NS	ND	ND	1.8	1.6	1.1	1.6	1.1	NS	NS	NS	305	258	412
16	Lakota	62.7	12.2	85.7	28.3	0.0021	0.0007	0.0007	<0.0003	NS	NS	0.0007	<0.0003	26.2	8.1	15.3	6.4	17.4	NS	NS	NS	1090	28200	3150
18	Fall River	15.7	18.9 (Rep 20.0)	31.7	27.5	0.0061	0.0066 (Rep 0.0065)	0.0066	0.0059	NS	NS	0.0062	0.0062	ND	3.2 (Rep 3.6)	3.2	2.6	4.0	NS	NS	NS	945 (Rep 944)	1220	1210
4002A	Other Inyan Kara	120 (Rep 141)	227	314	127	0.0026 (Rep 0.0026)	0.0026	0.0026	0.0023	NS	NS	0.0025	0.0025	63.6 (Rep 60.0)	54.2	57.0	52.3	62.7 (Rep 79.4)	NS	NS	NS	8010	9890	8780
7002	Lakota	45.6	39.8	91.4	29.5	0.0007	0.0006	0.0006	0.0005	NS	NS	0.0005	0.0006	8.5	8.1	8.8	8.0	6.3	NS	NS	NS	938	752	1270
Domestic/Stock Wells																								
42	Lakota	371	375	526	558	0.0150	0.0324	0.0194	0.0142	NS	NS	0.0198	0.0149	96.5	102	100	100	79.7	NS	NS	NS	132000	175000	219000
Stock Wells																								
619	Lakota	367	341	438	398	0.0020	0.0015	0.0015	0.0016	NS	NS	0.0018	0.0018	120	100	99.7	110	120	NS	NS	NS	2990	5580	5770
628	Other Inyan Kara	29.9	83.9	64.5	39	0.0017	0.0034	0.0030	0.0027	NS	NS	0.0031	0.0029	7.4	20.7	9.0	6.1	6.8	NS	NS	NS	2740	4360	5040
631	Fall River	51.0	46.5	162	60.7	0.0027	0.0029	0.0027	0.0026	0.003	NS	0.0026	0.0028	12.9	9.5	19.4	22.1	15.2	NS	NS	NS	4220	3920	4430
635	Sundance / Unkpapa	2.5	4.4	14.8	13.2	0.0020	0.0020	0.0021	0.0017	0.002	NS	0.0021	0.0017	1.6	0.8	1.3	NS	NS	NS	NS	NS	902	806	1070
650	Lakota	13.1	5.6	2.9	2.1	0.0019	ND	ND	ND	NS	NS	0.0004	ND	2.7	2.4	1.4	1.2	3.2	NS	NS	NS	134	202	254
Piezometer																								
675	Alluvial	18.8	18.3	29.3	55.2 (Rep 51.1)	0.0372	0.0307	0.0387	0.0493 (Rep 0.0485)	NS	NS	0.0387	0.0505 (Rep 0.0516)	ND	0.5	ND	0.7 (Rep 0.7)	2.3	NS	NS	NS	712	783	960 (Rep 960)
676	Alluvial	37.1	31.9	95.5	NS	0.0494	0.0548	0.0586	NS	NS	0	0.0687	NS	ND	ND	ND	NS	ND	NS	NS	NS	453	686	NS
677	Alluvial	41.0	38.7	129	43.1	0.0218	0.0443	0.0402	0.045	NS	0	0.0414	0.0471	0.9	ND	ND	0	ND	NS	NS	0	892	808	1250
678	Alluvial	23.2	18.9	41.4 (Rep 30.2)	54.7	0.0352	0.0349	0.0368	0.0355	NS	NS	0.0379	0.0387	ND	ND	ND (Rep ND)	NS	ND	NS	NS	NS	391	487 (Rep 418)	687
679	Alluvial	19.9	13.3	18.4	NS	0.0157	0.0144	0.0139	NS	NS	NS	0.0154	NS	ND	ND	0.9	NS	2.5	NS	NS	NS	819	2170	NS

Notes:

Yellow highlights designate concentrations over the EPA MCL

Blue highlights designate concentrations over the proposed EPA MCL for radon

ND = Not detected

NS = No sample

Rep = duplicate analysis

POWERTECH (USA) INC.

Table 12.1-27 Summary of Groundwater Radionuclide Concentrations from Monthly Sampled Wells

Parameter	Aquifer	Uranium-Dissolved												Uranium-Total											
Units		mg/L												mg/L											
Sampling Quarter / Sample ID		Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09
615	Fall River	0.0026	0.0025	0.0024	0.0024	0.0025	0.0023	0.0026	0.0023	0.0026	0.0023	0.0027	0.0025	0.0026	0.0025	0.0025	0.0023	0.0025	0.0023	0.0023	0.0026	0.0022	0.0023	0.0026	0.0024
622	Fall River	<0.0003	0.0054	0.0056	0.0051	0.0052	0.0050	0.0055	0.0052	0.0055	<0.0003	0.0044	0.0053	<0.0003	0.0065	0.0068	0.0059	0.0054	0.0050	0.0050	0.0059	0.0051	<0.0003	0.0056	0.0051
680	Lakota	0.0569	0.0303	0.0237	0.0227	0.0186	0.0188	0.0192	0.0178	0.0196	0.0199	0.0205	0.0185	0.0541	0.0291	0.0256	0.0244	0.0208	0.0180	0.0178	0.0210	0.0174	0.0203	0.0220	0.0206
681	Fall River	0.0092	0.0098	0.0096	0.0097	0.0096	0.0100	0.0093	0.0094	0.0098	0.0083	0.0081	0.0092	0.0099	0.0102	0.0106	0.0102	0.0098	0.0037	0.0098	0.0102	0.0087	0.0077	0.0084	0.0086
688	Lakota	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0005
689	Fall River	0.0032	0.0037	0.0043	0.0034	0.0033	0.0034	0.0030	0.0031	0.0033	0.0050	0.0035	0.0030	0.0041	0.0040	0.0117	0.0060	0.0057	0.0034	0.0030	0.0035	0.0031	0.0060	0.0036	0.0032
694	Lakota	0.0005	0.0006	0.0006	0.0006	0.0007	0.0005	0.0005	0.0006	0.0006	0.0005	0.0006	0.0005	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0006	0.0006	0.0005	0.0005	0.0006	0.0005
695	Lakota	0.0030	0.0029	0.0029	0.0027	0.0028	0.0026	0.0027	0.0030	0.0029	0.0026	0.0031	0.0028	0.0031	0.0032	0.0029	0.0027	0.0031	0.0026	0.0029	0.0030	0.0026	0.0026	0.0031	0.0027
696	Lakota	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0003
697	Lakota	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
698	Fall River	0.1090	0.1100	0.1020	0.1040	0.1190	0.1130	0.1030	0.1030	0.1060	0.0977	0.1000	0.1060	0.1225	0.1190	0.1175	0.1130	0.1160	0.1010	0.1020	0.1320	0.1030	0.1095	0.1080	0.1115
3026	Lakota	0.0151	0.0150	0.0281	0.0183	0.0128	0.0109	0.0059	0.0045	0.0048	0.0045	0.0039	0.0022	0.0097	0.0196	0.0322	0.0216	0.0151	0.0109	0.0085	0.0055	0.0044	0.0047	0.0047	0.0025

Notes:

Yellow highlights designate concentrations over the health based EPA MCL

ND = Not detected

NS = No sample

Rep = duplicate analysis

POWERTECH (USA) INC.

Table 12.1-27 Summary of Groundwater Radionuclide Concentrations from Monthly Sampled Wells (cont'd)

Parameter	Aquifer	Radium-226 -Dissolved												Radium-226-Total											
Units		pCi/L												pCi/L											
Sampling Quarter / Sample ID		Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09
615	Fall River	2.1	2.0	2.0	7.2	1.2	1.8	2.0	2.7	1.9	2.1	1.8	2.3	2.3	1.8	2.2	6.8	0.8	1.4	1.9	2.6	1.9	1.8	1.6	2.4
622	Fall River	2.3	2.7	3.2	4.1	2.9	4.4	3.0	2.7	2.9	1.3	3.1	7.9	3.0	3.6	4.2	3.9	2.5	4.2	2.8	2.5	2.8	2.1	3.4	8.4
680	Lakota	1150	1230	1335	1410	1280	1270	1430	1210	1430	1110	1360	1330	1152	1232	1342	1414	1285	1272	1436	1218	1432	1123	1373	1336
681	Fall River	414	377	415	434	388	362	445	356	398	291	258	336	418	377	417	435	388	363	446	357	398	293	259	337
688	Lakota	0.3	1.2	2.5	0.6	3.7	1.7	0.6	1.6	2.7	0.7	3.8	7.9	1.2	1.2	2.2	0.3	3.3	1.4	0.7	1.3	2.9	0.8	3.9	8.1
689	Fall River	7.9	4.2	5.7	5.5	6.9	4.4	7.5	6.4	6.6	6.2	6.1	5.4	9.9	4.2	6.2	5.5	7.2	4.0	7.7	6.0	6.6	6.6	5.7	5.2
694	Lakota	1.6	4.0	1.9	2.2	2.3	1.8	1.7	1.4	1.6	1.5	1.7	2.2	2.6	3.7	1.7	1.9	1.9	1.7	1.7	1.0	1.6	1.2	1.5	2.1
695	Lakota	6.3	5.0	3.7	5.2	4.7	3.9	5.9	4.0	4.8	4.8	4.5	4.7	6.9	4.6	3.5	5.1	4.3	3.9	12.8	3.7	4.6	4.4	4.4	4.6
696	Lakota	1.0	0.5	1.8	3.3	0.4	1.3	1.5	0.8	0.8	0.8	1.0	1.3	1.6	0.3	1.7	2.9	0.0	1.2	1.3	0.5	0.5	0.7	0.6	1.1
697	Lakota	1.5	1.7	1.1	0.8	-0.9	1.2	1.0	0.6	1.7	1.2	0.9	5.6	2.1	1.6	4.9	0.4	-0.7	0.8	1.2	0.7	1.3	1.1	0.7	5.4
698	Fall River	393	370	413	429	423	372	410	347	403	349	386	352	406	376	426	441	429	374	410	354	412	362	393	364
3026	Lakota	3.6	2.8	9.6	4.7	10.1	9.1	10.4	3.5	3.9	2.7	3.5	2.9	6.9	2.9	10.8	4.6	9.9	8.8	11.3	2.7	4.7	2.9	4.1	3.0

Notes:

Yellow highlights designate concentrations over the health based EPA MCL

ND = Not detected

NS = No sample

Rep = duplicate analysis

POWERTECH (USA) INC.

Table 12.1-27 Summary of Groundwater Radionuclide Concentrations from Monthly Sampled Wells (concl.)

Parameter	Aquifer	Radon-222												Alpha Particle-Dissolved											
Units		pCi/L												pCi/L											
Sampling Quarter / Sample ID		Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09
615	Fall River	1370	1180	1070	1830	1420	1880	1500	1890	1800	1710	1630	1590	18.0	15.1	15.3	38.3	15.3	17.3	21.5	20.9	13.9	21.7	21.1	14.8
622	Fall River	501	1090	804	1950	824	1370	992	1360	1280	50.2	1270	1360	15.0	22.6	32.6	36.4	31.2	27.7	1470	29.3	32.6	6.8	37.0	44.3
680	Lakota	71800	81000	255000	91700	72000	112000	71550	70500	86200	62200	48000	56800	6440	4270	5500	4370	4280	4330	5545	3590	4410	5140	6730	5140
681	Fall River	254000	253000	231123	389000	262500	318000	304000	344000	335000	2200	133000	389000	2170	1400	1720	1390	1675	1430	1180	1440	1850	1560	1210	1460
688	Lakota	608	307	749	426	694	449	535	184	162	81	152	218	2.9	10.1	17.3	13.2	16.9	11.8	4.9	10.2	15.0	1.9	25.6	28.7
689	Fall River	1950	1540	1390	2520	1745	2520	1520	2410	2580	1130	1850	1810	64.3	25.5	34.9	36.5	34.7	36.4	30.9	40.0	37.9	54.6	52.8	23.9
694	Lakota	313	251	619	611	245	401	296	281	320	215	270	235	8.8	18.7	10.6	23.7	15.1	12.5	7.4	9.1	10.7	9.3	25.9	8.3
695	Lakota	1400	1400	2090	2120	1490	1950	1820	1860	2020	1880	1840	1600	52.2	29.4	25.6	39.7	28.2	21.6	15.9	27.8	19.2	26.8	35.8	18.7
696	Lakota	190	185	497	517	228	343	214	260	222	182	250	234	3.9	5.2	14.3	23.9	4.0	7.1	5.9	9.8	6.9	8.2	20.2	4.3
697	Lakota	323	284	570	413	278	367	313	319	412	200	299	236	6.1	8.4	4.1	11.9	6.9	5.3	6.3	7.3	12.7	7.7	21.7	18.2
698	Fall River	30800	25800	24000	40700	27900	38200	29500	38200	37400	37150	32100	40500	1815	2110	1300	1790	1790	1560	36	1330	1680	1650	1960	1380
3026	Lakota	440	304	213	950	560	818	357	254	505	355	295	484	48	44	92	116	80	78	44	36	20	24	52	15

Notes:

Yellow highlights designate concentrations over the health based EPA MCL

Blue highlights designate concentrations over the proposed EPA MCL for radon

ND = Not detected

NS = No sample

Rep = duplicate analysis

Section 13.0 - Aquifer Exemption

13.1 Inyan Kara Aquifer and Criteria for Exempted Aquifer

Some aquifers or portions of aquifers which meet some of the criteria of the regulatory definition of a USDW may not reasonably be expected to serve as a source of drinking water due to high TDS and natural occurring constituents in concentrations not approved by the EPA for human consumption; this is the case in most aquifers where naturally occurring uranium is mineralized. Refer to Table 13.2-1 and Figure 13.2-1 to review groundwater quality within the Inyan Kara aquifer in areas not currently proposed for mining activities. Regulations allow EPA to exempt portions of these aquifers from definition as USDWs and thus allow injection into them (40 CFR § 144 and § 146).

The area within the aquifer exemption boundary (Exhibit 13-1) has a horizontal and a vertical extent. The vertical extent is bounded by upper and lower confining zones as described in Section 5.0 – Geologic Description and Section 6.0 – Hydrogeologic Description. The horizontal extent is based on the area of expected commercially producible ore deposits (40 CFR §146.4(b) (1)), the area within the ore body where the lixiviant is expected to occupy during mining of the ore deposits, post-mining aquifer restoration, and a buffer area that includes a monitor well ring and an area beyond the monitor wells that provides room to recover any excursions that may occur.

In order to obtain an aquifer exemption, a demonstration must be made that the aquifer or portions thereof meets the following criteria for exempted aquifers 40 CFR § 146.4 and ARSD 74:55:01:24:

- The aquifer does not currently serve as a source of drinking water (refer to Section 9.8.1 for a groundwater quality summary and Appendix C for detailed groundwater quality data).
- It cannot now and will not in the future serve as a source of drinking water because:
  - It is mineral, hydrocarbon, or geothermal energy producing.
  - It is situated at a depth or location which makes recovery of water economically or technologically impractical.
  - It is so contaminated that it would be impractical to make the water fit for consumption.
  - It is located over a Class III well mining area subject to subsidence or catastrophic collapse.
  - Or the TDS content of the ground water is more than 3,000 milligrams per liter (mg/L) and less than 10,000 mg/L, and the aquifer is not reasonably expected to supply a public water supply.

13.1.1 Commercially Producible

The commercial producibility of the PA is based on capital equipment and operating costs from information gathered during 2007 and 2008, and utilizes standard estimation techniques including quotations and vendor estimates.

This study was based upon total estimated project resources of 10.8 million (M) pounds U_3O_8 and an estimated recovery rate of 75 percent. A total producible reserve of 8.1 M lbs U_3O_8 was used for the study. This is believed to be a minimum basis for the total amount of resource available within the project area. Several areas are known to have significant resources but are not yet included as the data required to complete resource estimation is not yet available. Project economics will be expected to improve dramatically with the inclusion of all the potential resources within the proposed permit boundary. Based on a study performed by the Tennessee Valley Authority (TVA), Exhibit 10-1, as much as 23 M lbs U_3O_8 exists in the project area, which is nearly three times the amount of resource used in this economic evaluation.

The spot price of uranium during the years 2008 and 2009 fluctuated between \$90/pound U_3O_8 and \$45/pound U_3O_8. Long Term price indicators were reported by TradeTech at \$70/pound U_3O_8 as of December 1, 2008 (all information as per TradeTech, LLC. 2008). Powertech's estimated cost of production for the PA is sufficiently below the long time price indicator to result in an acceptable rate of return for the shareholders of the company. This conclusion was reinforced by a European investor and due diligence review. Powertech's study is considered proprietary and confidential business information thus will not be included with this application. However, Powertech will share this information with the SD DENR and EPA to the extent necessary to demonstrate the project is commercially producible.

The justification for the aquifer exemption at the PAA is provided below.

13.2 Aquifer Exemption Basis

13.2.1 Aquifer Exemption Justification Information

The aquifer within the project area to be considered for the exemption includes the lateral extent of the Lakota and Fall River subaquifer units of the Inyan Kara within the production zone and a buffer zone that will allow a reasonable length of time to contain and recover any potential excursions from the well fields (Exhibit 10-1). This portion of the Inyan Kara being recommended for exemption cannot now and will not in the future serve as a source of drinking water based on the following criteria:

- This portion of the aquifer requested for exemption does not serve as a source of drinking water.
- It contains minerals that considering their quantity and location are expected to be commercially producible.
- The aquifer is so contaminated that rendering the water fit for human consumption would be economically or technologically impractical (See Appendix C "Groundwater Quality Data" for additional support of justification).

Additional details related to the criteria given above are discussed in the following sub-sections.

Refer to Sections 9.2.1.1 and 9.2.1.2 for discussion on exceedance of primary and secondary drinking water standards. Refer to Section 9.2.1.3 for a discussion on "Not Fit for Human Consumption".

13.2.2 Aquifer Exemption Boundary

13.2.2.1 General Discussion

This section addresses **CI–2**.

The Dewey-Burdock aquifer exemption is requested for the portion of the Inyan Kara aquifer described in Exhibit 10-1. To attempt to exempt a partial vertical aquifer would lead to confusion at best and possibly installation of a well within a zone bearing high levels of radionuclide minerals at worst. Two major protective reasons to consider one vertical exemption are the clarity of water rights for future wells and the necessity of monitoring during operations and restoration.

13.2.2.1.1 Water Rights

Since the Water Rights division of the South Dakota Department of Environment and Natural Resources considers the Inyan Kara one aquifer, it makes sense that it should be considered one aquifer always. If the aquifer exemption was to be broken down vertically amongst the various sand units it would cause confusion in the future if anyone was to drill in the Inyan Kara. In the state of South Dakota a water right permit is not required for domestic use if water use does not exceed either 25,920 gallons per day or a peak pump rate of 25 gallons per minute. Land owners are required to submit a well completion report to the state. Since uranium tends to be in the larger sand units anyone drilling a well in the future would naturally want a major sand unit in which to complete the well. The minor sands that may be excluded

from an aquifer exemption would at most yield low quantities of water thus making it tempting to drill into the major sands by anyone who is seriously looking for water. These sands, by EPA definition, will be permanently exempt from the Safe Drinking Water Act, therefore, encouraging drinking water to be obtained through an aquifer better suited for human consumption. In order to prevent confusion or accidental well completion into an exempted aquifer the entire Inyan Kara should be considered exempt.

13.2.2.1.2 Necessity of Monitoring

An early detection system of monitoring wells must be installed and maintained in order to detect any lixiviant from potentially leaving the mining area during operations. For this reason there must be ample room to operate the monitoring system to provide adequate excursion detection and corrective action in order to prevent lixiviant from affecting the water quality outside the aquifer exemption boundary. Exempting only part of the Inyan Kara aquifer would compromise protection against an excursion to a USDW. Most of the sand units are minor that overlay and underlay the ore bodies, and likely would not qualify for aquifer designation or USDW status without inclusion of the major sands of the Inyan Kara.

The perception of protecting the environment by insisting on a partial aquifer exemption would quickly evaporate if an excursion entered a USDW for the first time in ISL history. The property owners are not requesting that the state partition the Inyan Kara aquifer. For these protective reasons the Inyan Kara should be exempt from top to bottom.

13.2.2.2 Technical Discussion

The proposed exempted area exists within the Inyan Kara aquifer, consisting of the Lakota and Fall River Formations, and was deposited in a large-scale fluvial deposition environment, resulting in the development of multiple, lenticular channel sandstones. It requires extensive surface drilling to delineate these sand systems in the subsurface. To date, over 4000 drill holes have identified seven mineralized sand units within the Lakota Formation and another three mineralized sand units within the overlying Fall River Formation. In addition to outlining the Dewey and Burdock uranium resource areas, this historic drilling also delineated over 108 miles of potential Lakota and Fall River mineralized trends within the project boundary. The geochemistry within the Inyan Kara aquifer has created a major mineralized system at the Dewey-Burdock project area. Additional resources will be discovered along these trends (Refer to Exhibit 10-1 for depiction roll fronts), but it will require time and extensive drilling to do so. Due to the sinuous nature of both the channel sands and the roll front deposits contained within them, delineation drilling is necessary to ascertain the locations with accuracy. For this reason, the applicant has proposed designating the Inyan Kara aquifer for exemption within the project boundary. The extent of the proposed exempted area would also include a buffer zone that will allow a reasonable length of time to contain any potential excursions from the well fields and provide the operator sufficient amount of room for restoration activities (Exhibit 10-1).

Spatial considerations are important when designating portions of an aquifer for exemption; however, there are legal and technical based criteria, guidance, and evaluations that the applicant also considered before proposing the aquifer exemption for the PAA these include:

- Criteria found in §146.4 for exempted aquifer.
- Data criteria necessary to demonstrate the aquifer is expected to be mineral or hydrocarbon producing located in §144.7(c)(1).
- The EPA Guidance for Review and Approval of State Underground Injection Control (UIC) Program and Revisions to Approved State Programs Guidance #34 issued by the Ground Water Protection Branch (GWPB) was reviewed closely.
- Historical and recent exploration and development projects were also considered in order to make a sound decision as stewards of the environment and as a corporation.

- Guidance from EPA Region 8 was carefully considered in establishing the horizontal limits of the proposed AEB.

13.2.3 Horizontal Boundary Justification

The PA proposed AEB is shown on Exhibit 10-1. This boundary is being proposed to assure the protection of USDW's outside of the AEB. The justification for the proposed AEB distance of 1600 feet from the production zone takes into consideration the location of the monitoring well network, potential seepage velocity and response time needed to reduce concentrations of indicator parameters to acceptable levels at the monitoring wells through pullback to the production area.

In order to determine the extent and configuration of the AEB, a worst case seepage velocity of 10 feet/day has been assumed. This assumption is based on the highest hydraulic gradient probable in the well field environment and the resultant rate of flow mining fluids can move in the mining zone. This flow rate and the hypothetical case of some unknown and unforeseen preferential flow pathways and a nearby well(s) pumping at a high rate, and a reasonable response time of 120 days to control an excursion results in 1200 feet for the distance between the monitoring well ring and the AEB. The response time of 120 days includes the time from the initial detection at the monitoring well and implementation of corrective action resulting in the creation of a positive response indicating that recovery of the excursion and its pullback into the production area has been initiated. The monitoring well ring will be located 400 feet from the production zone. This distance has been proven through years of industry practice and, historical application has demonstrated adequacy of this well placement method. There has never been an instance of unresolved excursions in the history of in situ mining of more than 23 individual projects, most with multiple monitor well rings.

13.2.3.1 Central Burdock Area

The applicant includes the Inyan Kara Formation in the central Burdock area (CBA) in its proposed AEB. The surface area of the proposed CBA, approximately 776 acres or 11 percent of the total AEB proposed, is that area containing the proposed CPP and ancillary facilities and that is largely surrounded by the uranium deposits identified in the Burdock area of the proposed permit area (Exhibit 10-1). The area is recommended for inclusion based on the following rationale.

- The CBA is a region which will become isolated from sources of recharge as it will be surrounded by well field activities which will have a consumptive use of water. Due to the mining areas surrounding the CBA, operation of any well within the exempted formation will intensify drawdown and potentially have a significant impact on the mining activities surrounding the area. In this case, it is expected that lixiviant and mining fluid control within the monitoring well ring would become considerably more difficult.
- The area contains numerous oxidation/reduction fronts that were previously identified or postulated by TVA during its exploration of the area in the 1970s that likely contains uranium mineralization (Exhibit 10-1). The area will be explored during the term of the permit to determine the nature and quantity of any uranium mineralization in the area.
- The proposed 1200 foot distance from the monitor well ring for the control and recovery of potential excursions encompasses the CBA.
- The CBA is nearly surrounded by known uranium deposits. The likelihood of anyone in the future installing a drinking water well into the Lakota within the central Burdock area is remote. The presence of known uranium deposits in the area and the history of uranium mining surrounding the area, both open pit and in situ (after Powertech), will be strong deterrents to developing water supply wells in the CBA.
- Considering that the majority of deposits in the Burdock area are located in the Lakota formation, the probability is high that any additional resources identified in the central Burdock area would be in the Lakota. Based on characterization data from six existing wells completed in the Lakota aquifer, four of the six wells exceed the EPA MCL set for drinking water for dissolved alpha, three exceed the radium

226 MCL and five of the six exceed the proposed EPA MCL for radon (Tables 9.1.5 and 12.10.4). Results from groundwater analyses from seven wells drilled by Powertech and completed in the Lakota aquifer, prove six of the seven wells with levels of dissolved alpha well above the EPA MCL for drinking water, four of the seven exceed the radium 226 MCL set by the EPA and all seven exceed the proposed EPA MCL for radon 222 (Table 9.1.8 and 12.10.5). Based on results from sampling 13 Lakota wells within the project area, 77 percent exceeded the MCL for dissolved alpha, 54 percent exceeded the MCL for radium 226 and 92 percent exceeded the proposed MCL for radon 222.

- Although the majority of the known deposits are located in the Lakota formation, the Fall River formation also contains known and additional drill indicated potential resources. Based on characterization data from eight wells located within the Fall River, three of the eight existed previous to Powertech acquiring the properties. The remaining five wells were completed by Powertech in order to satisfy a request from SD DENR. The data from the all wells completed in the Fall River formation reflect exceedances of the secondary value set by EPA for total dissolved solids and sulfate. Of the eight wells sampled, six exceeded the EPA MCL concentrations for dissolved alpha in at least one sampling event. Radium 226 was exceeded within five of the eight wells and all eight exceeded the proposed MCL for Radon 222. Based on sampling events that occurred on eight wells, 48 percent exceeded the MCL for dissolved alpha, 40 percent exceeded MCL for Radium 226 and 100 percent exceeded proposed MCL for Radon 222.
- The cost of additional administrative, legal and technical reviews on the part of the EPA and SD DENR for a new or amended UIC permit application dealing with the central Burdock area would be minimized if the area in the AEB requested by this application is granted.
- There are no wells within the vertical extent of the proposed aquifer exemption boundary that currently serve as sources of drinking water. The Daniel's well will continue to be used as stock well and a new well was installed by Powertech into the Unkpapa formation for domestic use.
- The aquifer portion recommended for exemption cannot now and will not in the future serve as a source of drinking water based on the following criteria:
  - There are no wells within the proposed aquifer exemption boundary that currently serve as sources of drinking water. It contains minerals that considering their quantity and location are expected to be commercially producible.
  - The portion of aquifer proposed for exemption is so contaminated that rendering the water fit for human consumption would be economically or technologically impractical.

*Note: The following addresses **No. 1 of Cover Letter**, dated 08/06/09.*

- Water quality data concerning the suitability of the water for use as drinking water in the areas upgradient and downgradient to the proposed mining area within the Area of Review exceed MCLs for radionuclides and, in some instances metals. Table 13.2-1 list the exceedances associated with each upgradient and downgradient water well sampled during the baseline assessment. All wells listed in Table 13.2-1 and depicted in Figure 13.2-1 are completed within the Inyan Kara aquifer. Figure 13.2-1 demonstrates degraded water quality extends farther horizontally than the proposed AEB. The data have also been categorized into the subaquifers of the Inyan Kara. According to the data, exceedances of the MCLs also demonstrates a need for vertical exemption of the Inyan Kara.

Table 13.2-1 Health Based Water Quality of Up Gradient and Down Gradient Wells of Proposed Mining within the Inyan Kara Aquifer located in the Area of Review

Upgradient	Well ID	Parameter Exceeded	Sample Date	Well Use
Arsenic (Total) Concentration Equal to or Greater Than the Arsenic MCL of 0.01 mg/l				
Lakota	615	0.024	1-Apr-08	Monitoring
Lakota	615	0.025	1-Apr-08	Monitoring
Lakota	615	0.024	21-Apr-08	Monitoring
Lakota	615	0.024	28-May-08	Monitoring
Lakota	615	0.024	25-Jun-08	Monitoring
Lakota	3026	0.023	30-Mar-08	Monitoring
Lakota	3026	0.022	22-Apr-08	Monitoring
Lakota	3026	0.028	28-May-08	Monitoring
Lakota	3026	0.025	24-Jun-08	Monitoring
Lead (Total) Concentration Equal to or Greater Than the Lead MCL of 0.015 mg/l				
Lakota	622	0.026	21-Apr-08	Monitoring
Lakota	622	0.023	28-May-08	Monitoring
Lakota	622	0.03	25-Jun-08	Monitoring
Lakota	650	0.05	24-Mar-08	Discontinued Stock
Uranium (Total) Concentration Equal to or Greater Than the Uranium MCL of 0.01 mg/l				
Lakota	3026	0.0322	28-May-08	Monitoring
Radium-226 (Dissolved) Activity Equal to or Greater Than the Radium-226 MCL of 5 pCi/L				
Fall River	631	12.9	26-Sep-07	Stock
Fall River	631	9.5	14-Nov-07	Stock
Fall River	631	19.4	20-Feb-08	Stock
Fall River	631	22.1	19-May-08	Stock
Fall River	698	387	30-Mar-08	Monitoring
Fall River	698	398	30-Mar-08	Monitoring
Fall River	698	370	22-Apr-08	Monitoring
Fall River	698	412	28-May-08	Monitoring
Fall River	698	413	28-May-08	Monitoring
Fall River	698	429	24-Jun-08	Monitoring
Lakota	16	26.2	27-Sep-07	Domestic
Lakota	16	8.1	12-Nov-07	Domestic
Lakota	16	15.3	30-Mar-08	Domestic
Lakota	16	6.4	30-Jun-08	Domestic
Lakota	615	7.2	25-Jun-08	Monitoring
Lakota	619	120	27-Sep-07	Stock
Lakota	619	100	12-Nov-07	Stock

Table 13.2-1 Health Based Water Quality of Up Gradient and Down Gradient Wells of Proposed Mining within the Inyan Kara Aquifer located in the Area of Review (cont'd)

Upgradient	Well ID	Parameter Exceeded	Sample Date	Well Use
Radium-226 (Dissolved) Activity Equal to or Greater Than the Radium-226 MCL of 5 pCi/L				
Lakota	619	99.7	24-Mar-08	Stock
Lakota	619	110	17-Jun-08	Stock
Lakota	628	7.4	28-Sep-07	Stock
Lakota	628	20.7	14-Nov-07	Stock
Lakota	628	9	20-Feb-08	Stock
Lakota	628	6.1	29-May-08	Stock
Lakota	3026	9.6	28-May-08	Monitoring
Inyan Kara	4002	63.6	27-Sep-07	Stock
Inyan Kara	4002	60	27-Sep-07	Stock
Inyan Kara	4002	54.2	14-Nov-07	Stock
Inyan Kara	4002	57	12-Feb-08	Stock
Inyan Kara	4002	52.3	19-May-08	Stock
Gross Alpha (Total) Activity - Equal to or Greater Than the Gross Alpha MCL of 15 pCi/L				
Fall River	631	51	26-Sep-07	Stock
Fall River	631	46.5	14-Nov-07	Stock
Fall River	631	162	20-Feb-08	Stock
Fall River	631	60.7	19-May-08	Stock
Lakota	16	62.7	27-Sep-07	Domestic
Lakota	16	85.7	30-Mar-08	Domestic
Lakota	16	28.3	30-Jun-08	Domestic
Lakota	615	18.2	1-Apr-08	Monitoring
Lakota	615	17.7	1-Apr-08	Monitoring
Lakota	615	15.1	21-Apr-08	Monitoring
Lakota	615	15.3	28-May-08	Monitoring
Lakota	615	38.3	25-Jun-08	Monitoring
Lakota	619	367	27-Sep-07	Stock
Lakota	619	341	12-Nov-07	Stock
Lakota	619	438	24-Mar-08	Stock
Lakota	619	398	17-Jun-08	Stock
Lakota	622	15	1-Apr-08	Monitoring
Lakota	622	22.6	21-Apr-08	Monitoring
Lakota	622	32.6	28-May-08	Monitoring
Lakota	622	36.4	25-Jun-08	Monitoring

Table 13.2-1 Health Based Water Quality of Up Gradient and Down Gradient Wells of Proposed Mining within the Inyan Kara Aquifer located in the Area of Review (cont'd)

Upgradient	Well ID	Parameter Exceeded	Sample Date	Well Use
Gross Alpha (Total) Activity - Equal to or Greater Than the Gross Alpha MCL of 15 pCi/L				
akota	3026	47.6	30-Mar-08	Monitoring
Lakota	3026	43.8	22-Apr-08	Monitoring
Lakota	3026	92.4	28-May-08	Monitoring
Lakota	3026	116	24-Jun-08	Monitoring
Inyan Kara	628	29.9	28-Sep-07	Stock
Inyan Kara	628	83.9	14-Nov-07	Stock
Inyan Kara	628	64.5	20-Feb-08	Stock
Inyan Kara	628	39	29-May-08	Stock
Inyan Kara	4002	141	27-Sep-07	Stock
Inyan Kara	4002	120	27-Sep-07	Stock
Inyan Kara	4002	227	14-Nov-07	Stock
Inyan Kara	4002	314	12-Feb-08	Stock
Inyan Kara	4002	127	19-May-08	Stock
Radon-222 Greater Than the MCL of 300 pCi/L				
Fall River	615	1370	Mar-08	Monitoring
Fall River	615	1180	Apr-08	Monitoring
Fall River	615	1070	May-08	Monitoring
Fall River	615	1830	Jun-08	Monitoring
Fall River	622	501	Mar-08	Monitoring
Fall River	622	1090	Apr-08	Monitoring
Fall River	622	804	May-08	Monitoring
Fall River	622	1950	Jun-08	Monitoring
Fall River	631	4220	4th Q 2007	Stock
Fall River	631	3920	1st Q 2008	Stock
Fall River	631	4430	2nd Q 2008	Stock
Lakota	16	1090	4th Q 2007	Domestic
Lakota	16	28200	1st Q 2008	Domestic
Lakota	16	3150	2nd Q 2008	Domestic
Lakota	619	2990	4th Q 2007	Stock
Lakota	619	5580	1st Q 2008	Stock
Lakota	619	5770	2nd Q 2008	Stock
Lakota	3026	440	Mar-08	Monitoring
Lakota	3026	304	Apr-08	Monitoring
Lakota	3026	950	Jun-08	Monitoring

Table 13.2-1 Health Based Water Quality of Up Gradient and Down Gradient Wells of Proposed Mining within the Inyan Kara Aquifer located in the Area of Review (cont'd)

Upgradient	Well ID	Parameter Exceeded	Sample Date	Well Use
Radon-222 Greater Than the MCL of 300 pCi/L				
Inyan Kara	628	2740	4th Q 2007	Stock
Inyan Kara	628	4360	1st Q 2008	Stock
Inyan Kara	628	5040	2nd Q 2008	Stock
Inyan Kara	4002	8010	4th Q 2007	Stock
Inyan Kara	4002	9890	1st Q 2008	Stock
Inyan Kara	4002	8780	2nd Q 2008	Stock
Downgradient	**Well ID**	**Radionuclide Exceeded**	**Sample Date**	**Well Use**
Radium-226 (Dissolved) Activity Equal to or Greater Than the Radium-226 MCL of 5 pCi/L				
Lakota	42	96.5	28-Sep-07	Domestic
Lakota	42	102	12-Nov-07	Domestic
Lakota	42	100	5-Feb-08	Domestic
Lakota	42	100	30-May-08	Domestic
Lakota	695	5	22-Apr-08	Monitoring
Lakota	695	5.2	24-Jun-08	Monitoring
Lakota	697	6.3	31-Mar-08	Monitoring
Lakota	7002	8.5	28-Sep-07	Stock
Lakota	7002	8.1	12-Nov-07	Stock
Lakota	7002	8.8	20-Feb-08	Stock
Lakota	7002	8	29-May-08	Stock
Gross Alpha (Total) Activity Equal to or Greater Than the Gross Alpha MCL of 15 pCi/L				
Fall River	7	15.5	20-Feb-08	Domestic
Fall River	18	15.7	26-Sep-07	Domestic
Fall River	18	20	12-Nov-07	Domestic
Fall River	18	18.9	12-Nov-07	Domestic
Fall River	18	31.7	12-Feb-08	Domestic
Fall River	18	27.5	30-May-08	Domestic
Lakota	42	371	28-Sep-07	Domestic
Lakota	42	375	12-Nov-07	Domestic
Lakota	42	526	5-Feb-08	Domestic
Lakota	42	558	30-May-08	Domestic
Lakota	694	19.2	21-Apr-08	Monitoring
Lakota	694	18.1	21-Apr-08	Monitoring
Lakota	694	23.7	24-Jun-08	Monitoring
Lakota	695	29.4	22-Apr-08	Monitoring
Lakota	695	25.6	21-May-08	Monitoring

Table 13.2-1 Health Based Water Quality of Up Gradient and Down Gradient Wells of Proposed Mining within the Inyan Kara Aquifer located in the Area of Review (concl.)

Downgradient	Well ID	Radionuclide Exceeded	Sample Date	Well Use
Gross Alpha (Total) Activity Equal to or Greater Than the Gross Alpha MCL of 15 pCi/L				
Lakota	695	39.7	24-Jun-08	Monitoring
Lakota	696	23.9	24-Jun-08	Monitoring
Lakota	697	52.2	31-Mar-08	Monitoring
Lakota	7002	45.6	28-Sep-07	Stock
Lakota	7002	39.8	12-Nov-07	Stock
Lakota	7002	91.4	20-Feb-08	Stock
Lakota	7002	29.5	29-May-08	Stock
Radon-222 Greater Than the MCL of 300 pCi/L				
Fall River	7	451	2nd Q 2008	Domestic
Fall River	8	329	1st Q 2008	Domestic
Fall River	8	514	2nd Q 2008	Domestic
Fall River	18	945	4th Q 2007	Domestic
Fall River	18	1220	1st Q 2008	Domestic
Fall River	18	1210	2nd Q 2008	Domestic
Lakota	2	674	4th Q 2007	Domestic
Lakota	2	908	1st Q 2008	Domestic
Lakota	2	727	2nd Q 2008	Domestic
Lakota	13	305	4th Q 2007	Domestic
Lakota	13	412	2nd Q 2008	Domestic
Lakota	42	132000	4th Q 2007	Domestic /Stock
Lakota	42	175000	1st Q 2008	Domestic /Stock
Lakota	42	219000	2nd Q 2008	Domestic /Stock
Lakota	694	313	Mar-2008	Monitoring
Lakota	694	619	May-2008	Monitoring
Lakota	694	611	Jun-2008	Monitoring
Lakota	695	1400	Apr-2008	Monitoring
Lakota	695	2090	May-2008	Monitoring
Lakota	695	2120	Jun-2008	Monitoring
Lakota	696	497	May-2008	Monitoring
Lakota	696	517	Jun-2008	Monitoring
Lakota	697	862	Mar-2008	Monitoring
Lakota	697	570	May-2008	Monitoring
Lakota	697	413	Jun-2008	Monitoring
Lakota	7002	938	4th Q 2007	Domestic
Lakota	7002	752	1st Q 2008	Domestic
Lakota	7002	1270	2nd Q 2008	Domestic

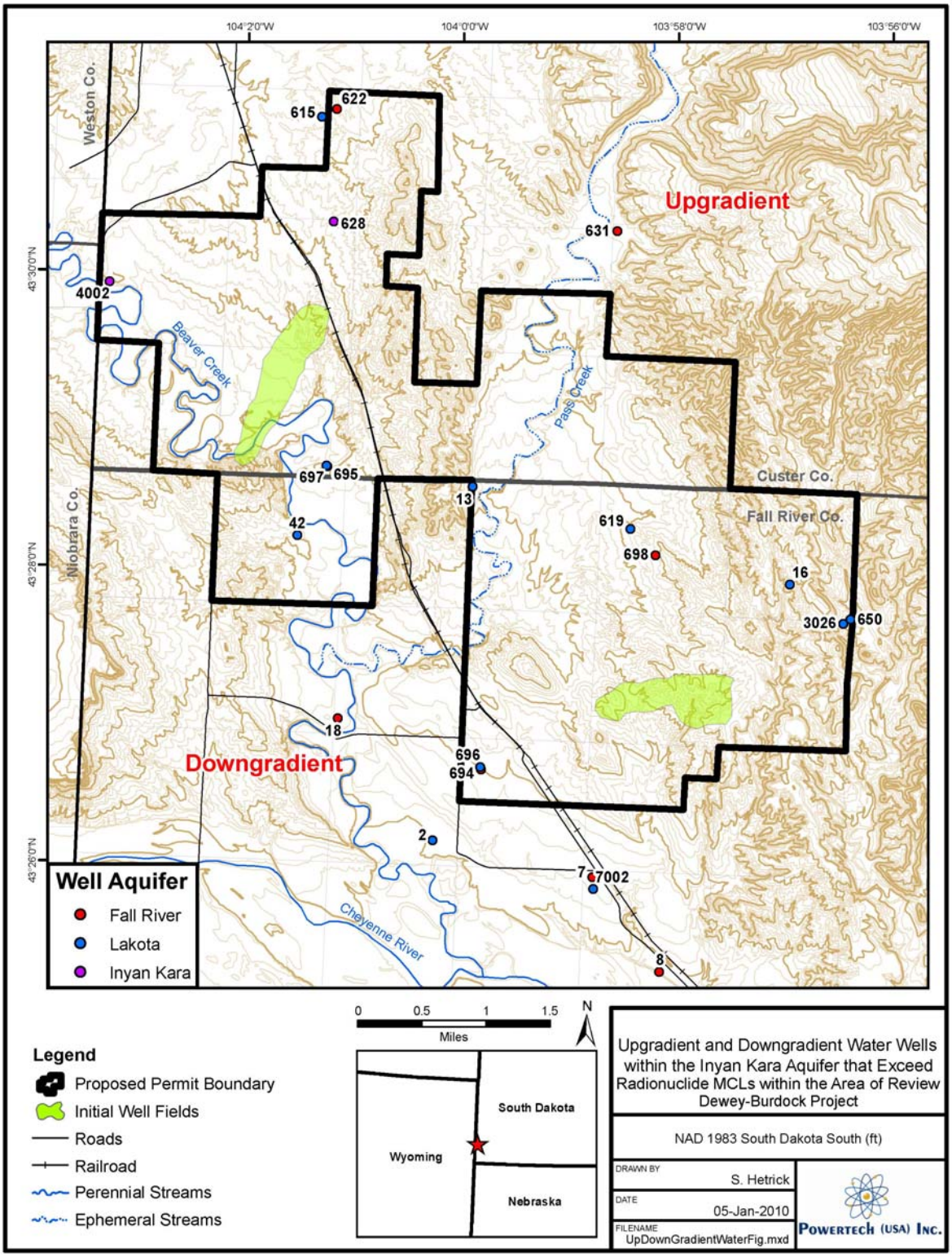

Figure 13.2-1 Up gradient and Down gradient Water Wells within the Inyan Kara Aquifer that Exceed Radionuclide MCLs located in the Area of Review

13.2.4 Vertical Boundary Justification

13.2.4.1 Summary of Previous Pumping Test Results – Aquifer Data and Measurements

This section also addresses **CI–8**.

Appendix B provides a complete report documenting previous TVA and recent (2008) pumping tests at the project area. A summary from the report in Appendix B is provided below.

The TVA conducted groundwater pumping tests from 1977 through 1982 as part of a uranium mine development project near the towns of Edgemont and Dewey, South Dakota. TVA produced two summary pumping test reports, "Analysis of Aquifer Tests Conducted at the Proposed Burdock Uranium Mine Site" (Boggs and Jenkins, 1980) and "Hydrogeologic Investigations at Proposed Uranium Mine near Dewey, South Dakota" (Boggs, 1983). In addition, TVA prepared a Draft Environmental Impact Statement (DES) for the proposed Edgemont Uranium Mine in 1979.

TVA first conducted two unsuccessful tests in 1977 at the Burdock test site. The results of the 1977 tests were considered inconclusive because of various problems including questionable discharge measurements, some observation wells improperly constructed, and some pressure gauges malfunctioned. No data from the 1977 tests are currently available.

TVA conducted three successful pumping tests, two in 1979 near the current Burdock Project Area, and one in 1982 about 2 miles north of the current Dewey Project Area. The results of these successful tests are described in separate sections, below. However, no data for these tests, in particular electronic records of drawdown, are available, other than information contained in the reports.

13.2.4.1.1 Dewey Project Area

The Dewey test was conducted in 1982 northeast of the Dewey Road at the location shown on Figure 13.2-2. The test consisted of pumping in the Lakota formation for 11 days at an average rate of 495 gpm. The test developed the following information:

- Transmissivity of the Lakota averaged about 4,400 gpd/ft, which is equivalent to 590 feet squared per day (ft^2/day).
- Storativity of the Lakota was about 1.0×10^{-4} (dimensionless).
- There was response between the Fall River and Lakota formations through the intervening Fuson shale-siltstone member that was manifested at relatively late time (3,000 to 10,000 minutes).
- The vertical hydraulic conductivity of the Fuson aquitard using the Neuman-Witherspoon ratio method (Neuman and Witherspoon, 1973) was 2×10^{-4} ft/day; storativity of the Fuson Member was not determined and specific storage was about 7 x 10-7 ft^{-1}.
- A barrier boundary, or a decrease in transmissivity due to lithologic changes with distance from the test site, or both, were observed; a possible geologic feature corresponding to a barrier was noted to be the Dewey Fault Zone, located about 1.5 miles north of the test site, where the Lakota and Fall River formations are structurally offset.

13.2.4.1.2 Burdock Project Area

The Burdock tests were conducted in 1979 near the Dewey road at the location shown on Figure 13.2-2. The Burdock tests consisted of separate pumping tests from the Lakota (Chilson) and Fall River Aquifer, respectively in April and July of 1979. The tests used the same pumping well with packers to alternately isolate screens open to the respective formations. Test durations were 73 hours for the Lakota test and 49 hours for the Fall River test. Pumping rates were about 200 gpm from the Lakota aquifer and 8.5 gpm from the Fall River. The reason for the unexpected low pumping rate from the Fall River aquifer was not specified in the TVA report.

The tests developed the following information:

- Interpreted transmissivity of the Lakota was based on analysis of later time data and inferred decreasing transmissivity with distance from the test site due to changes in lithology; overall transmissivity averaged about 1,400 gpd/ft (190 ft^2/day) and storativity about 1.8 x 10^{-4} (dimensionless); maximum transmissivity from early time data was about 2,300 gpd/ft (310 ft^2/day).
- Transmissivity of the Fall River averaged about 400 gpd/ft (54 ft^2/day) and storativity about 1.4 x 10^{-5} (dimensionless).
- There was communication between the Fall River and Lakota formations through the intervening Fuson shale-siltstone member; leaky behavior was observed in the Fall River formation and believed to exist in Lakota although "leakage effects in the Lakota drawdown data are masked by the conflicting effect of a decreasing transmissivity in site vicinity" (p. 16 in Boggs and Jenkins, 1980).
- The vertical hydraulic conductivity of the Fuson aquitard using the Neuman-Witherspoon ratio method (Neuman and Witherspoon, 1973) ranged from 10^{-3} to 10^{-4} ft/day; storativity was not determined, and specific storage was assumed to be about 10^{-6} ft^{-1}.

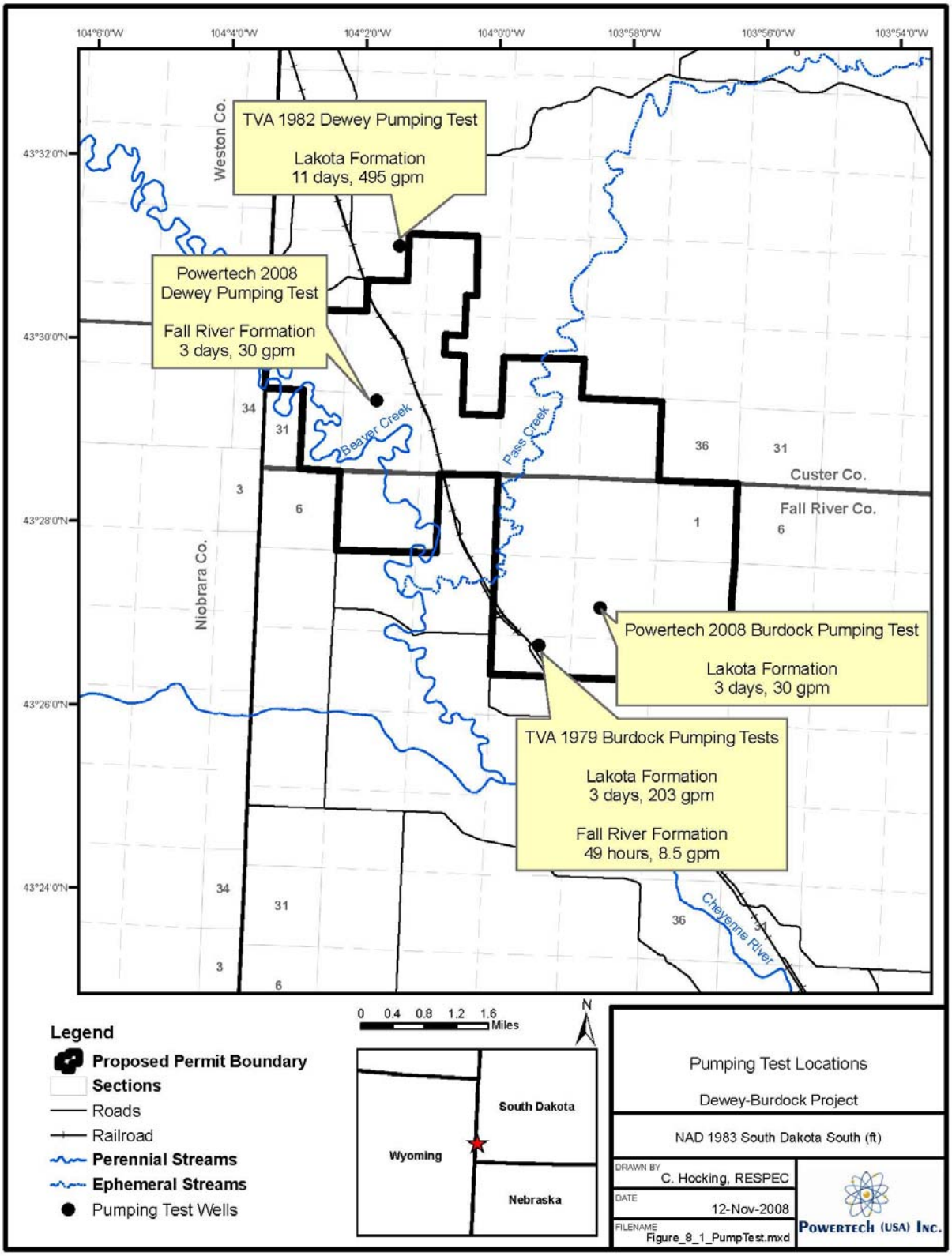

Figure 13.2-2 Pumping Test Locations

13.2.4.2 2008 Pumping Tests

The following addresses No.2 Cover Letter, dated 08/06/09; this section also addresses **CI–8**.

In 2008 pumping tests were performed at both the Dewey and Burdock project areas, along with laboratory tests on related core samples, to determine aquifer properties at the site. A work plan (Knight Piésold, 2008b) was prepared and distributed to interested representatives of state and federal agencies, including the SD DENR and the EPA.

A detailed description of the aquifer testing methodology and analysis of the results are contained in Appendix B to this application, "Pumping Test Report." The methodology also is described in Appendix A of the Pumping Test Report (Appendix B) (Knight Piésold, 2008c). The report results are briefly summarized in the following sections.

13.2.4.2.1 Dewey Project Area

A summary of aquifer parameters for the 2008 Dewey pumping test (conducted in the Fall River formation) and related laboratory core testing is as follows:

- Ten determinations of transmissivity (Table 13.2-2) ranged from 180 to 330 ft^2/day with the median value of 255 ft^2/day.
- Five storativity determinations (Table 13.2-2) ranged from 2.3×10^{-5} to 2.0×10^{-4} with the median value of 4.6×10^{-5}.
- The radius of influence of the pumping test determined by a distance-drawdown plot was 5,700 feet.
- The pumping well in the Fall River formation was determined to be highly efficient: 93 to 95 percent by the empirical distance-drawdown method and 81 percent by the USGS (Halford and Kuniansky, 2002) theoretical method.
- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 13.2-3) were made in core sample from the sandstone layer similar to that tested in the pump test; measured horizontal hydraulic conductivity was 6.1 ft/day, and the ratio of horizontal to vertical hydraulic conductivity was 4.5:1.
- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 13.2-3) were made on shale samples from the two major confining units overlying and underlying the pump test area with the following results:
  - Skull Creek shale: laboratory core data for the shale sample from the overlying Skull Creek formation indicate a vertical permeability of 5.4×10^{-9} cm/sec (1.5×10^{-5} ft/day).
  - Fuson Formation: laboratory core data for the shale sample from the underlying Fuson formation indicate a vertical permeability of 6.2×10^{-9} cm/sec (1.8×10^{-5} ft/day).

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Table 13.2-2 Summary of Aquifer Hydraulic Characteristics for the Dewey Pumping Test

Dewey Test Site Pumping Test Interpretations							
	Well	Radial Dist.	Interpretation	Transmissivity	u or u'	Storativity	Note
Well I.D.	Type	(ft)	Method	(ft^2/day)	(unitless)	(unitless)	
Ore zone (lower Fall River Sandstone)							
32-3C	Pumping	0.25 (0.33)	Theis DD(1)	250	-	1.2E-06(d)	-
			CJ DD (3)	250	<0.01	-	-
Pumping Well Efficiency = 80%(3)							
			CJ Recovery (3)	270	<0.01	-	-
32-5	Obs #1	243	Theis DD(1)	294	-	3.30E-05	--
			Theis Recovery(1)	260	<0.01	-	-
			CJ Recovery(3)	280	<0.01	-	-
32-4C	Obs #2	467	Theis DD(1)	333	-	5.60E-05	-
			CJ Recovery (3)	120(a)	<0.01	-	
29-7	Obs #3	2,400	Theis DD(2)	178	-	2.00E-04	
			CJ Recovery (3)	Insufficient recovery for analysis			-
Fall River Aquifer Stock Well (Screened in top half of Fall River)							
GW-49	Stock	1,400	Theis DD(1)	177	-	2.30E-05	-
			CJ Recovery (3)	110	<0.05	-	-
Upper Fall River Sandstone							
32-9C	Obs	41	Theis DD(1)	217	-	1.60E-02	-
			CJ Recovery (3)	150	<0.05	-	--
Lakota Sandstone Layer							
32-10	Obs	61	No response during pumping test.				--
Unkpapa Formation							
32-11	Obs	50	No response during pumping test.				-
Distance Drawdown (32-5, 32-4C, 29-7, GW-49)(2)				218	<0.05	4.60E-05	r2 = 0.78 (4 point line)
Pumping Well Efficiency = 93% to 95%							
							-
Summary:	Median			255		4.60E-05	
Average/Geometric Mean(4)				251		5.23E-05	

Notes/References: DD = drawdown, CJ = Cooper -Jacob, Obs = Observation Well
(1) Calculated by automated curve fitting in AquiferWin32™ software (ESI, 2003).
(2) Knight Piésold spreadsheet after methods in Driscoll (1986).
(3) Spreadsheet methods in U.S. Geol. Surv. Open File Rept. 02-197, Halford and Kuniansky (2002).
(4) Average value calculated for Transmissivity, Geometric Mean value calculated for Storativity.
(a) Only slope satisfying u 'criterion occurs after intersection with barrier boundary.
(b) Not accepted due to anomalous response at well, see text.
(c) Storativity not valid at pumping well
'251' = Accepted value based on conformance with theory discussed in Section 5.0 of Appendix B.

13.2.4.2.1.1 Dewey Pumping Test Conclusions

The Dewey pumping test in 2008 in the Fall River aquifer is not directly comparable to the 1982 TVA test because the underlying Lakota aquifer was tested in 1982. As demonstrated above for the Lakota aquifer, a scaling effect may be assumed between total formation transmissivity and storativity (i.e., regional-scale) and the 2008 operational-scale test. However, there are several lines of evidence that the 2008 test transmissivity and storativity results are representative of the entire Fall River aquifer at the Dewey test site, as follows:

- Thickness of the sandstone layer screened by the pumping well is about one-half the total formation thickness (see drawings 4.1 and 4.2 in Knight Piésold, 2008c).
- Response at the stock tank well (GW-49 at 1,400-foot distance) was within the acceptable range for a confined aquifer; this is interpreted to indicate that the effects of partial penetration (due to elevation differences between the pumping well screen and the observation well open to the upper half of the aquifer) were diminished at the 1,400-foot distance and 40 minute response time.
- The delay in response at the upper Fall River observation well 32-9C was a relatively brief 11 minutes (see Table 4.2 in Knight Piésold, 2008c), compared to 160 minutes in the Burdock test; together with (2) above, these responses suggest that the vertical anisotropy due to shale interbeds overlying the lower sandstone layer does not extend laterally for more than about 1,400 feet.

The 2008 test indicates that the lower and upper sandstone portions of the Fall River formation behave as a single confined aquifer with some form of lateral barrier due to changing lithology, such as a channel boundary. The TVA test in 1982 observed a barrier boundary in the underlying Lakota formation which was attributed to either a change in lithology or the Dewey Fault zone. Apparently, both the Lakota and Fall River formations in the general Dewey project area are highly transmissive and show barrier boundaries. These test results are more definitive than the 1982 TVA test concerning the proximity of the barrier boundary, because the 2008 radius of influence was about one mile compared to greater than two to three miles distance to the fault zone.

Vertical communication throughout the entire Fall River formation is indicated by the delayed response at the upper Fall River observation well (32-9C). Within the Fall River formation, the 11 minute delay in response at the upper observation well is attributed to lateral and vertical anisotropy due to the shale interbeds seen on the conceptual stratigraphic cross-sections for the pump test site (see Drawings 4.1 and 4.2 in Knight Piésold, 2008c). The extent and continuity of the shale interbeds are not known. Whether the shale interbeds in the Fall River aquifer are sufficiently thick and continuous to serve as vertical confinement for ISL operations will need to be evaluated by analyzing cores from borings as well fields are drilled and by pump tests of individual well field units.

Leakage from a confining layer, presumably the Fuson member, was observed in the 1982 TVA test of the Lakota formation. However, the leakage was observed only relatively late in the TVA tests, at 3,000 to 10,000 minutes, with a much greater pumping rate (495 gpm) and radius of influence. The large-scale vertical hydraulic conductivity value of 2×10^{-4} ft/day (7.1×10^{-8} cm/sec) determined in the 1982 TVA regional test at Dewey using the Neuman-Witherspoon ratio method is sufficiently impermeable to be considered a confining unit.

Hydraulic communication through the Fuson member between the Fall River and underlying Lakota aquifers is not indicated by the 2008 response at observation well 32-10. The 2008 test demonstrates that vertical leakage through the Fuson may not occur over a mile-wide radius. As described earlier, the Lakota and Fall River aquifers at the Dewey test site appear to be locally hydraulically isolated by the intervening Fuson member with nearly 40-foot head difference. The laboratory core data indicate a very low vertical permeability of 6.2×10^{-9} cm/sec (1.8×10^{-5} ft/day) for the shale sample from within the Fuson shale member.

The laboratory core data for the shale sample from the Skull Creek formation, overlying the Fall River formation, indicate a very low vertical permeability of 5.4 x 10^{-9} cm/sec (1.5 x 10^{-5} ft/day), also appropriate for a confining unit.

For the Fall River sandstone, the laboratory core data indicate a horizontal hydraulic conductivity of 6.1 ft/day, and interpretation of the test results calculates that horizontal permeability may be as great as 17 ft/day throughout one of the ore zones. Within the lower Fall River formation, the test results indicate transmissive, rapid response (two to three minutes) between pumping and observation wells up to 467 feet apart with nearly 10 feet of drawdown. Response was nearly 9 feet of drawdown at 1,400-foot distance. This indicates the aquifer was stressed to produce good quality analytical results.

The 2008 test indicates that the lower and upper sandstone portions of the Fall River formation behave as a single, confined, aquifer; vertical confinement for ISL operations will need to be evaluated further to determine the extent of the anistropic properties observed within the Fall River formation. Hydraulic conductivity values and results from testing in 2008 indicate the Lakota and Fall River aquifers to be locally hydraulically isolated by the intervening Fuson member and the core data indicate very low permeability within the Skull Creek formation. In summary, tests within the Dewey site seem to indicate adequate confinement within the area of interest for the most part, yet further investigation and evaluation into the vertical confinement must be performed on a well field basis.

13.2.4.2.2 Burdock Project Area

A summary of aquifer parameters for the 2008 Burdock pumping test (conducted in the Chilson member of the Lakota formation) and related laboratory core testing is as follows:

- Nine determinations of transmissivity (Table 13.2-3) ranged from 120 to 223 ft^2/day with the median value of 150 ft^2/day.
- Four storativity determinations (Table 13.2-3) ranged from 6.8 x 10^{-5} to 1.9 x 10^{-4} with the median value of 1.2 x 10^{-4}.
- The radius of influence of the pumping test determined by a distance-drawdown plot was 2,100 feet.
- The pumping well in the lower Lakota formation was determined to be moderately efficient: 80 to 83 percent by the empirical distance-drawdown method and 65 percent by the USGS (Halford and Kuniansky, 2002) theoretical method.
- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 13.2-4) were made on sandstone layers similar to that tested in the pump test; measured horizontal hydraulic conductivity ranged from 5.9 to 9.1 ft/day, the mean value was 7.4 ft/day and the mean ratio of horizontal to vertical hydraulic conductivity in Burdock area sandstone (Lakota) was 2.47:1
- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 13.2-4) were made on shale layers from the two major confining units for the Lakota formation in the pump test area with the following results:
  - Fuson Shale: the laboratory core data indicate vertical permeabilities of about 2 x 10^{-7} to 1 x 10^{-8} cm/sec (average 2.7 x 10^{-4} ft/day) for shale samples from within the Fuson member overlying the Lakota formation.
  - Morrison Shale: the laboratory core data for the shales in the underlying Morrison formation indicate vertical permeabilities of 9 x 10^{-9} to 3 x 10^{-8} cm/sec (average 6.0 x 10^{-5} ft/day).

The range of hydraulic conductivities determinable from test transmissivities was 0.9 to 15.0 ft/day, which is considered an appropriate range that is also verified by the sandstone core sample results falling in the middle of the range; it is noted that the lower end of the hydraulic conductivity range is probably appropriate for use with the entire formation thickness (shale layers included) and the upper end represents the most permeable sandstone layers such as the ore zone areas tested in the pump test.

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Table 13.2-3 Summary of Aquifer Hydraulic Characteristics for the Burdock Pumping Test

Well I.D.	Well Type	Radial Dist. (ft)	Interpretation Method	Transmissivity (ft^2/day)	u or u' (unitless)	Storativity (unitless)	Note
Ore zone (lower Lakota Sandstone)							
11-11C	Pumping	0.25 (0.33)	Theis DD(1)	145	-	2.9E-09(a)	-
			CJ DD (3)	150	<0.01	-	-
Pumping Well Efficiency = 65%(3)							
			CJ Recovery (3)	140	<0.01	-	-
15-Nov	Obs #1	243	Theis DD(1)	67	-	1.30E-03	-
			CJ Recovery (3)	100	<0.1	-	-
11-14C	Obs #2	250	Theis DD(1)	128	-	6.80E-05	-
			H-J DD(1)	120	-	6.90E-05	--
			Theis Recovery(1)	174	<0.01	-	-
			CJ Recovery (3)	160	<0.01	-	-
2-Nov	Obs #3	1,292	Theis DD(1)	223	-	1.90E-04	-
			H-J DD(1)	185	-	1.70E-04	-
			CJ Recovery (3)	260	<0.15	-	-
Upper Lakota Sandstone							
19-Nov	Obs	50	Theis DD(2)	260	-	1.00E-01	-
			CJ Recovery (3)	190	<0.15	-	-
Fall River (lower sandstone layer)							
17-Nov	Obs	50	Noordbergum Effect and response cannot be interpreted analytically				
Unkpapa Formation							
18-Nov	Obs	35	No response during pumping test.				-
Distance Drawdown (11-14C, 11-15, 11-02)(2)				145	<0.08	2.20E-04	r2 = 0.76 (3 point line)
Pumping Well Efficiency = 61% to 63%							
Summary:	Median			150		1.20E-04	
Average/Geometric Mean(5)				158		1.12E-04	
	TVA(4)			190		1.80E-04	

(1) Calculated by automated curve fitting in AquiferWin32™ software (ESI, 2003).

(2) Knight Piésold spreadsheet after methods in Driscoll (1986).
(3) Spreadsheet methods in U.S. Geol. Surv. Open File Rept. 02-197, Halford and Kuniansky (2002).

(4) Summary values from p. 17 in Boggs and Jenkins (1980).
(5) Average value calculated for Transmissivity, Geometric Mean value calculated for Storativity.

(a) Storativity not valid at pumping well.

(b) Based on 6 inch casing (8 inch borehole).

'158' = Accepted value based on conformance with theory discussed in the text

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Table 13.2-4 Laboratory Core Analyses at Dewey-Burdock Site

Depth (ft)	Confining Stress (psig)	Porosity (%)	Air Intrinsic Permeability(1) ka (mD)	Particle Density (g/cm^3)	Notes	Water Hydraulic Conductivity(2)(3) Kw (cm/s)	Core Kh (ft/day)	Core Kv (ft/day)
Burdock								
252.2	600	10.5	1.04	2.356	Fuson Shale	8.01E-07		
252.35	600	10.15	0.228	2.356	Fuson Shale	1.76E-07		
412.3	600	9.68	0.041	2.511	Fuson Shale	3.16E-08		
412.45	600	9.59	0.015	2.514	Fuson Shale	1.15E-08		
Dewey								
480.7	600	8.9	0.078	2.613	Skull Creek shale	6.01E-08		
480.8	600	9.3	0.007	2.61	Skull Creek shale	5.39E-09		
609.1	600	12.26	0.073	2.603	Fuson Shale	5.62E-08		
609.1	600	10.84	0.008	2.793	Fuson Shale	6.16E-09		
Burdock								
423.6	600	29.56	3,207	2.645	Lakota Sand	2.47E-03	7	
423.35	600	30.34	1,464	2.645	Lakota Sand	1.13E-03		3.2
430.2	600	31.9	4,161	2.64	Lakota Sand	3.20E-03	9.1	
430.35	600	30.16	939	2.646	Lakota Sand	7.23E-04		2.1
453.5	600	10.86	1	2.519	Morrison Shale	7.70E-07		
453.45	600	11.82	0.043	2.543	Morrison Shale	3.31E-08		
Burdock								
420.4	600	30.5	2,697	2.643	Lakota Sand	2.08E-03	5.9	
420.1	600	30.17	1,750	2.651	Lakota Sand	1.35E-03		3.8
455.9	600	6.99	0.004	2.536	Morrison Shale	3.08E-09		
455.45	600	7.65	0.012	2.556	Morrison Shale	9.24E-09		
503.3	600	12.96	0.697	2.474	Morrison Shale	5.37E-07		
503.45	600	No data						
Dewey								
573.25	600	29.15	2,802	2.641	Fall River Sand	2.16E-03	6.1	
573.4	600	29.04	619	2.645	Fall River Sand	4.77E-04		1.4
							7.4	3

13.2.4.2.2.1 Burdock Pumping Test Conclusions

The Burdock pumping test in 2008 may be directly compared to the 1979 TVA test for the Lakota (Chilson) aquifer as the tests were nearly at the same location (Figure 13.2-1). The average transmissivity and storativity values determined from the TVA tests were 190 ft2/day and 1.8 x 10^{-4} (see p. 17 in Boggs and Jenkins, 1980). Comparing the median transmissivity of 150 ft^2/day and storativity of 1.2 x 10^{-4} determined in the 2008 test to the TVA test, demonstrates that the new aquifer parameters for the lower Lakota are respectively about 80 and 70 percent of the 1979 results. Because transmissivity and storativity depend on aquifer thickness, comparing the results suggests that there may be some scaling effect between the tests due to the differing lengths of screened intervals.

Therefore, the 1979 TVA test results for transmissivity of 190 ft^2/day is considered representative of the entire Lakota aquifer for a regional application, such as a groundwater flow model where an average hydraulic conductivity of about 1 foot/day over a thickness of 170 feet could be specified. The 2008 test provides specific data at the operational-scale of a prospective ISL well field where local hydraulic conductivities of up to 15 feet/day could be specified for the most permeable ore zone horizons.

Within the Lakota formation, vertical communication throughout the entire formation is indicated by the delayed response at the upper Lakota observation well (11-19). The 160 minute delay in response at the upper Lakota observation well 11-19 is attributed to lateral and vertical anisotropy due to the shale interbeds seen on the conceptual stratigraphic cross-sections for the pump test site (Knight Piésold, 2008c). The extent and continuity of the shale interbeds are unknown. Whether the shale interbeds in the Lakota aquifer are sufficiently thick and continuous to serve as vertical confinement for ISL operations will probably need to be evaluated by analyzing cores from borings as well fields are drilled.

The 2008 test indicates that the lower and upper portions of the Lakota formation behave as a single, confined, leaky aquifer. Confinement and leakage from the overlying Fuson member is evident in the matches to the Hantush-Jacob type curves seen most clearly at observation wells 11-14C and 11-2. These results are more definitive than the 1979 TVA test where confined, leaky behavior for the Lakota was predicted but not demonstrated with curve match results.

Hydraulic communication through the Fuson member between the Lakota and Fall River aquifers is evidenced by the response at observation well 11-17, screened in the lower Fall River formation. The first response in the lower Fall River is interpreted as a Noordbergum effect where water levels monitored above the pumping zone aquitard temporarily increased due to three-dimensional deformation caused by ground water withdrawal from a confined aquifer (Hsieh, 1997). The Noordbergum effect appears characteristic of the Inyan Kara formation based on its occurrence in a 1985 pumping test in the Eastern Black Hills near Wall, South Dakota (Rahn, 1985) and also the previous TVA test at the Burdock site (Boggs and Jenkins, 1980). However, drawdown continued at the Fall River observation well 11-17, indicating that leakage was established through the underlying Fuson formation.

The laboratory core data indicate an average vertical permeability/ hydraulic conductivity of 9.3 x 10^{-8} (2.7 x 10^{-4} ft/day) for shale samples from within the Fuson member. The shale core permeability values are about one to two orders of magnitude less permeable than the pumping test values determined in the 1979 TVA test at Burdock, where the vertical hydraulic conductivity of the Fuson aquitard was calculated using the Neuman-Witherspoon ratio method to be about 10^{-3} ft/day (Boggs and Jenkins, 1980).

The potentiometric surface in the Fall River aquifer is close to that in the Lakota aquifer at the Burdock pump test site, but this does not necessarily indicate some local connection between the two formations through the intervening Fuson member. It merely is a measure of the weight of the overlying formations, which we have demonstrated in field tests. In other locations in the Inyan Kara, the Fuson member is known to have sandstone layers that are downcut into the Lakota member (Gott et al., 1974). Therefore, determining the degree of vertical confinement for ISL operations by the Fuson will probably need to be

evaluated by analyzing cores from borings as well fields are drilled, and with well field-scale pumping tests that are proposed to be conducted prior to start-up of each particular mine unit.

The aquifer tests in 1979 and 2008 indicate that the Lakota formation is a confined aquifer with a leaky confining layer, which is demonstrably the Fuson member. The laboratory core data for the shales in the underlying Morrison formation indicate an average vertical permeability of 2.1×10^{-8} cm/sec (6×10^{-5} ft/day). Together with the pump test data, the core data indicate that the underlying Morrison formation and overlying Fuson member can serve as confining units for ISL operations.

For the Lakota sandstone, the laboratory core data indicate an average horizontal hydraulic conductivity of 7 ft/day, and as high as 9.1 ft/day. Interpretation of the test results calculates that horizontal hydraulic conductivity may be as great as 15 ft/day throughout one of the ore zones. Within the lower Lakota formation, the test results indicate transmissive response between pumping and observation wells up to 250 feet apart with 17 feet of drawdown. Response was nearly 3 feet of drawdown at 1,290-foot distance. This indicates the aquifer was stressed to produce good quality analytical results.

The measure of an aquitard's effectiveness is the ratio of the vertical permeability of the aquitard to the horizontal permeability of the aquifer. In the case of ISL, the aquitard is not stressed as it is necessary to maintain as much water pressure over the ore as possible to dissolve oxygen in order to create a constant minimum drawdown in the production zone and to maintain a cone of depression.

13.2.5 Ore Amenability to Solution Mining

The uranium deposit within the PAA has the geologic and hydrologic features that make a uranium deposit suitable for ISL as detailed in the Nuclear Regulatory Commission Draft Generic Environmental Impact Statement (USNRC, 2008) based on Holen and Hatchell (1986), specifically:

- Deposit geometry is generally horizontal and of sufficient size and lateral continuity to economically extract uranium.
- The sandstone host rock is permeable enough to allow the mining solutions to access and interact with the uranium mineralization.
- The confining layers (Skull Creek Shale and Morrison Formation) will prevent lixiviant from vertically migrating into overlying or underlying aquifers. Although confining layers are not really necessary as the fluid flow is managed by pressure control.
- The mineralization to be mined is located in a hydrologically saturated zone.

The amenability of the PA mine zone to ISL methods is demonstrated by the pumping test results presented in Section 13.2. and the operating information provided in Section 10.0.
Also refer to Section 10.3.2.2 "Lixiviant Compatibility with the Ore Body."

13.3 Visual Description of the Dewey-Burdock Project

Map(s) of Proposed Features for the Dewey–Burdock Project include the following:

- The aquifer exemption boundary (Exhibit 10-1 "Future Well Fields")
- Geologic cross section lines (Exhibit 5-2 "Cross Section Index Map")
- Monitor wells (Exhibits 10-2 and 10-3)
- Permit boundary (Exhibit 10-1)
- Outline of the ore body to be mined (Exhibit 10-1)

13.4 Cross Sections of Confining Units and Mining Zones

The applicant directs the reviewer's attention to Section 5.2 "Site Geology" for Exhibits 5-3 through 5-6 depiction cross sections of the PA confining units and mining zones.

Section 14.0 - Estimated Costs

14.1 Groundwater Reclamation Estimation Components

This section addresses **CI–4 (20)**. Please refer to Appendix L for a more detailed review of cost estimates.

The following components are addressed for groundwater reclamation cost estimation:

- Facilities, materials, and chemicals used for groundwater restoration
- Groundwater restoration in the production zone
- Water treatment (Section 14.2; Tables 14.2.1 and 14.2.2)
- Capping, plugging, and sealing of all wells (Section 7.6.1, Table 7.6-2)
- Personnel working on reclamation-related activities
- Collecting and analyzing samples from surface and groundwater monitoring sites

14.2 Financial Assurance

In compliance with 10 CFR Part 40 Appendix A criteria and guided by NUREG-1569 and 1757, Powertech will maintain financial assurance instruments to cover the cost of reclamation including the costs of groundwater restoration, the cost of decommissioning, dismantling and disposal of all buildings and other facilities, and the reclamation and revegetation of affected areas for the project. Table 14.2-1 and Table 14.2-2 provide summaries of closure cost estimates for the land application and waste disposal well options, respectively. Detailed cost tables are provided in Appendix L. In accordance with NRC and SD DENR requirements, an updated Annual Surety Estimate Revision will be submitted annually adjusting the surety instrument to reflect existing operations and plans for construction and operation in the following year. The surety estimate must be approved through a license amendment by the NRC. After approval of the Annual Surety Estimate Revision by the NRC and SD DENR, Powertech will revise the surety instrument to reflect the updated amount. In order to avoid duplication of effort in complying with both federal and state requirements, Powertech proposes one surety instrument be executed with regards to the UIC Class III Permit (NUREG 1569-Appendix C, 2003 and NUREG 1910-Section 9, 2008).

Table 14.2-1 Summary of Closure Costs - Land Application

No.	Cost Item Proposed Action Land Application Only	Cost
1	Water Treatment Equipment (provided with initial project construction)	-
2	Groundwater Restoration Cost	2,387,000
3	Well Closure	490,000
10	Contingency at 15%	431,550
	Total Restoration and Reclamation Cost	3,308,550

Table 14.2-2 Summary of Closure Costs - Waste Disposal Well

No.	Cost Item Proposed Action Waste Disposal Well Only	Cost
1	Water Treatment Equipment	-
2	Groundwater Restoration Cost	1,877,000
3	Well Closure	490,000
10	Contingency at 15%	355,050
	Total Restoration and Reclamation Cost	2,722,050

14.3 Future Operations

In looking forward, Powertech recognizes the potential of locating minable resources within the proposed permit boundary but outside the current proposed aquifer exemption area. In preparation of this possibility, Powertech recommends the inclusion into the mining permit conditions, the ability for minor permit modifications to be submitted and approved via ARSD 74:55:01:26.01 and 74:29:03:16 from the South Dakota Mined Land Reclamation Rules. EPA does not have any such provision, thus an amendment for an extension of the AEB may become necessary in order for Powertech to mine the resources under the corporation's control at a later date. By including the provisions of ARSD 74:55:01:26.01 and 74:29:03:16, it is Powertech's belief this action would save the state time and resources and would produce a more effective and efficient means to implement minor permit modifications in the future.

Section 15.0 - References

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