APPENDIX D

PORTAGE FINAL RISK ASSESSMENT REPORT

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Final Human Health and Ecological Risk Assessment for the Riley Pass Uranium Mines in Harding County, South Dakota

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Forward

This risk assessment report evaluates the human health and ecological risks associated with environmental conditions at historic uranium mines in the North Cave Hills of South Dakota. The area is located within the Sioux Ranger District of the Custer National Forest and is known locally as the Riley Pass Uranium Mines. The assessment was completed for the United States Department of Agriculture, U.S. Forest Service Northern Regional Office under contract number 53-03H6-2-006. It serves as a companion and support document to the Engineering Evaluation / Cost Analysis for the Riley Pass Uranium Mines, Harding County, South Dakota.

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Executive Summary

Historic mining activities at the Riley Pass Uranium Mines have exposed lignite ores and spread these materials throughout mined areas. These ores contain elevated concentrations of chemical and radiochemical constituents. The resulting physical state of the site has resulted in contamination of soils and surface water at the site, both through mixing during mining operations and through various natural transport mechanisms. Further exacerbating these issues are: (1) the physical characteristics of the natural materials, (2) the relatively steep terrain they occupy, and (3) regional climate conditions. The particles that comprise the Riley Pass mine waste are small and highly susceptible to both wind and surface water erosion. The arid conditions of the North Cave Hills result in extended annual periods where soils contain virtually no moisture. As a result, storm events and wind readily disperse contaminated media to both on and off site locations. The state and mobility of the mine wastes at Riley Pass increase the likelihood that people and ecological receptors will be exposed.

Site Users. The Custer National Forest, Sioux Ranger District documented the users of the Riley Pass Uranium Mines to provide input to this assessment. In doing so, they have identified those persons or groups who use the site regularly. They have also gathered site-specific information detailing the amount of time each spends at the site. This information forms the basis for determining potential exposure to people due to contact with contaminated mine waste, and contact with contaminants that originate at Riley Pass. Based on their findings, the following people are most at risk to exposure to contaminants or direct radiation (in no particular order):

- Cattle ranchers (holders of grazing permits at Riley Pass)
- Recreationists (hunters, hikers, campers, and archeologists)
- Native Americans (use the site for cultural purposes)
- U.S. Forest Service employees and contractors (maintaining and dredging onsite sediment ponds, monitoring of grazing activities, and miscellaneous).

2004 Supplemental Investigation. Following delivery of a 2002 site investigation for Riley Pass, the U.S. Forest concluded that additional data was needed to support decision making at the site. Prior to initiating a supplemental investigation at Riley Pass, a thorough review of the literature and prior investigations was completed. Based on this, in 2004 the USFS selected two mined areas to be further investigated: Bluffs B and H. They were selected because historic data indicated they represent the range of chemical and radiochemical conditions at the site. One generally representing the highest levels of contamination (Bluff H). The other (Bluff B) represents the lower end of contamination, but contains a much larger disturbance and more widespread contamination.

The 2004 supplemental investigation objectives were to: (1) fill existing data gaps, (2) provide a more representative sampling of discrete conditions in lignite and overburden, (3) obtain discrete background data, and (4) to obtain comprehensive field screening information to supplement the existing data set. The review of prior investigations also resulted in a focus in the sampling strategy for the 2004 supplemental investigation. As part of the 2002 site investigation, contaminants of potential concern were evaluated versus measured background concentrations. This effort noted that only a portion of the contaminants showed measurable levels at the site. Using this information yielded the following contaminants of potential concern for the 2004 supplemental investigation:

- Arsenic
- Molybdenum
- Selenium
- Radium-226
- Thorium-230
- Uranium-234
- Uranium-235
- Uranium-238.

The 2004 data obtained provided the basis for completing an assessment of the risks to human health and ecological receptors. Data of known quality was obtained, as verified by data validation performed on 2004 results. Data from previous investigations was used to supplement the assessment when reasonable confidence could be established that results were comparable. The 2004 data set also provided a scientific basis to show that radioactive decay of onsite uranium is in equilibrium.

To supplement existing laboratory data, extensive radioactive field screening was employed during the 2004 investigation. This effort involved field screening of all sample locations and random field screening throughout mined and undisturbed areas. The field screening results were used to obtain discrete samples representing the range of conditions in overburden and lignite and to obtain direct radiation dose measurements. They were also used to identify area locations representative of background radiation levels. Background radiation measurements served to increase confidence in metals data for background sample locations, as radioactivity and heavy metals show a direct correlation in their distribution at the site (i.e., levels of both metals and radionuclides are highest in lignite, decrease in overburden, and further decrease to stable levels at background locations).

Exposure Summary. Site-specific use data coupled with site-specific analytical and field-screening data form the basis for this risk assessment. Using this information, a profile of individual site users was developed by applying industry standard criteria (EPA, DOE, NRC, etc.). The result is a site-specific exposure evaluation for each of the site users. This assessment concludes that three of the site users have complete and significant pathways for exposure to contaminated mine wastes. The following summarizes their use and routes of exposure.

Cattle Rancher (Grazing Permit Holder). According to the Custer National Forest Management Plan, there are three cattle ranchers who hold grazing permits affected by mine waste. They spend approximately 60 days each year tending cattle in the North Cave Hills. The routes of exposure affecting the permit holders are:

- Inhalation of contaminated windblown or suspended dusts
- Direct contact or incidental ingestion of contaminated surface soils and sediment
- Ingestion of contaminated beef.

Recreational Visitor (Hunter). According to the Custer National Forest Management Plan, recreational hunters spend the greatest amount of time at Riley Pass of all recreational users (4 hours per day, 32 days per year). The routes of exposure affecting recreational hunters are:

- Inhalation of contaminated windblown or suspended dusts
- Direct contact or incidental ingestion of contaminated surface soils and sediment
- Ingestion of contaminated deer meat.

Native American Site User. Estimates established by the Custer National Forest Archeology staff indicate Native Americans use the mined areas at Riley Pass for traditional purposes, with three tribes using the site regularly. The predominant uses are foot traffic and sitting overlooking the landscape. Individual use is documented at 25 hours per year, per person. Native American exposure pathways at the site include:

- Inhalation of contaminated windblown or suspended dusts
- Direct contact or incidental ingestion of contaminated surface soils and sediment.

Toxicity Summary. A fundamental principal of toxicology is 'dose determines the toxic properties of a contaminant'. The toxic properties of contaminants can change depending on the dose received. Accordingly, toxicity factors (cancer slope factors for carcinogens and chronic reference doses for systemic toxins) have been developed by the EPA to support quantitative risk assessment. For this assessment, constituent toxicity was determined in accordance with EPA guidance. Toxicity values for ecological risk were obtained from a variety of commonly used and accepted sources.

Risk Summary. Once exposure and toxicity were fully evaluated, the carcinogenic risks and non-carcinogenic effects were determined for the receptors identified above. Risk is characterized by comparing the quantitative estimates of exposure with the quantitative estimates of toxicity. For exposure to carcinogens, an incrementally increased risk of cancer is predicted based on exposure averaged over a lifetime.

The EPA considers risks in the range of 1×10^{-4} to 1×10^{-6} a concern. Non-carcinogenic effects are expressed in terms of hazard quotients. A hazard quotient greater then 1 indicates that the estimated exposure exceeds the expected safe level. The following summarizes the risks and non-carcinogenic effects based on a reasonable maximum exposure (RME) scenario for each of the Riley Pass receptors. Evaluation of carcinogenic risks and non-carcinogenic effects are also evaluated using the central tendency exposure (CTE) scenario. This can be found in Appendix F.

Cattle Rancher (Grazing Permit Holder). Unacceptable carcinogenic risks were identified for the grazing permit holders for both arsenic and radionuclides. Considering all exposure pathways and depending on where exposure occurs (i.e., Bluff B, Bluff H, or Lignite) carcinogenic risks from arsenic based on the reasonable maximum exposure (RME) for the permit holder range from 1×10^{-3} to 7×10^{-5}. RME risks from radionuclides range from 2×10^{-3} to 2×10^{-5}. Non-carcinogenic hazard quotients range from 0.4 to 5.75 for the permit holder.

Recreational Visitor (Hunter). Unacceptable carcinogenic risks were also identified for the recreational hunter for both arsenic and radionuclides. Considering all exposure pathways and depending on where exposure occurs (i.e., Bluff B, Bluff H, or Lignite) RME risks from arsenic for the recreational hunter range from 2×10^{-4} to 1×10^{-5}. RME carcinogenic risks from radionuclides range from 6×10^{-4} to 8×10^{-6}. Non-carcinogenic hazard quotients range from 0.07 to 1.02 for the Recreational Visitor.

Native American Site User. Elevated carcinogenic risks were also noted for Native American site users. Considering all exposure pathways and depending on where exposure occur (Bluff B, Bluff H, or Lignite) RME risks from arsenic to Native Americans range from 2×10^{-5} to 2×10^{-6}. RME risks from radionuclides ranged from 5×10^{-5} to 7×10^{-7}. Non-carcinogenic hazard quotients were below 1 for the Native American site user.

Ecological Risks. The ecological risk assessment finds significant potential for ecological impacts at the site. Key findings include:

- Levels of COPCs at the site are well above area background levels.
- COPC levels exceed various ecological benchmark concentrations indicating the potential for adverse effects on ecological health.
- Large areas show elevated concentrations of COPCs.
- COPC distribution encompasses nearly all of the mined areas.
- Hazard quotients derived in this site-specific risk assessment are well above 1.0 for most species evaluated.
- Concentrations of COPCs in soil, water, and sediment all contribute to potential ecological hazard.

Risk-Based Clean-up Goals. Risk-based clean-up levels are tools developed for decision makers as they seek to implement remedies at contaminated sites. They incorporate all site-specific criteria, using industry standards as comparative tools to ensure the calculated benchmarks are reasonable. For purposes of this assessment, the risks to human health, ecological receptors, measured background concentrations, and EPA standard clean-up criteria have been considered to develop risk-based clean-up goals for the Riley Pass Uranium Mines. They are intended to be protective of human health, ecological receptors, and the environment, while ensuring remedies do not seek to clean-up below natural background levels.

List of Acronyms

ATV	all-terrain vehicle
BCG	biota concentration guides
BDAC	Biota Dose Assessment Committee
BLM	Bureau of Land Management
COPC	contaminant of potential concern
cy	cubic yards
DOE	Department of Energy
DOI	Department of the Interior
EE/CA	engineering evaluation / cost analysis
EPA	Environmental Protection Agency
g	grams
HEAST	Health Effects Assessment Summary Tables
HQ	hazard quotient
I	chemical intake
IAEA	International Atomic Energy Agency
INEEL	U.S. Department of Energy, Idaho National Engineering & Environmental Laboratory
IRIS	Integrated Risk Information System
Kcpm	kilo-counts per minute
mg/kg	milligrams / kilogram
NCRP	National Council on Radiation Protection
NRC	Nuclear Regulatory Commission
pCi	pico Curies
PRG	preliminary remediation goal
RBSL	risk-based screening levels
RfD	reference dose
RME	reasonable maximum estimate
SF	slope factor
TRV	toxicity reference value
UCL	upper confidence limit
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service

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Human Health and Ecological Risk Assessment Riley Pass Uranium Mines, Harding County South Dakota

1. INTRODUCTION

1.1 Objectives

The objective of this assessment is to evaluate the human health and ecological risks associated with current conditions at historic uranium mine sites in the Riley Pass area (hereinafter referred to as the site) of the Custer National Forest, North Cave Hills, South Dakota. The assessment was conducted in general accordance with the National Contingency Plan (EPA 1990) and other U.S. Environmental Protection Agency (EPA) guidance, as referenced throughout this report. The human health and ecological risk assessments for the site are based on a “multiple use” scenario as defined by the Custer National Forest Management Plan (USDA 2004). It is intended to serve as a technical support document to the engineering evaluation/cost analysis (EE/CA) for the Riley Pass Uranium Mines by the U.S. Forest Service (USFS).

1.2 Organization

Consistent with EPA (1989) guidelines, this risk assessment contains the following sections:

- Data Evaluation—Identification of the data and parameters to be evaluated.
- Exposure Assessment—Identification of the exposure pathways, human and ecological receptors, and quantification of any exposure.
- Toxicity Assessment—Description of constituent hazards upon exposure, regulatory standards, and quantitative estimates of toxicity.
- Risk Characterization—Presentation of risk levels based on the exposure and toxicity assessments. A summary of the assessment and conclusions are also provided.
- Uncertainty Assessment—Summary of uncertainty and variability of various assessment components.

Section 1 of this document defines the objectives of the risk assessment and provides general background information. Section 2 presents the data evaluation, which is applicable to both the human health and ecological risk assessments. The human health risk assessment, consisting of an exposure assessment, toxicity assessment, risk characterization, and uncertainty assessment, is provided in Section 3. The ecological assessment in Section 4 is organized similarly. Supporting data and calculations are provided in Appendixes A through F.

1.3 Site Description

The abandoned Riley Pass uranium strip mines are located in the North Cave Hills area of Harding County, South Dakota (see Figure 1-1). The Sioux Ranger District of the Custer National Forest manages the lands containing most of the abandoned mine sites.

The mines cover approximately 250 acres of high walls, pit floor, and spoils in Sections 20, 21, 22, 23, 25, 26, 27, 29, 35, and 36 of Township 22 North, Range 5 East of the Black Hills Meridian and are broken into 12 bluffs (see Table 1-1). The sites are bordered by USFS, private, United States Department of Interior (DOI), and Bureau of Land Management (BLM) lands. A small portion of the mined sites extend onto private lands.

Table 1-1. Bluff locations and land ownership, Riley Pass Uranium Mines.

Bluff Identification	Legal Description	Land Ownership
A and B	T22N, R5E, Sec. 22	USFS
H	T22N, R5E, Sec. 25	Private
B, C, D, and E	T22N, R5E, Sec. 26	Partial USFS, Partial Private
B	T22N, R5E, Sec. 27	USFS
E, F, and I	T22N, R5E, Sec. 35	USFS
G, H, and I	T22N, R5E, Sec. 36	USFS (bordered on east in Sec. 31 22N, 6E by BLM)
J	T22N, R5E, Sec. 20	USFS
K	T22N, R5E, Sec. 21	USFS
L	T22N, R5E, Sec. 29	USFS

Mining in the area began in earnest in the late 1950s under the General Mining Laws and Public Law 357, which required no form of restoration. Strip mining occurred on the tops of the bluffs by removal of overburden to allow access to the uranium-bearing lignite coal beds, which in places were 80 feet below the original ground surface. Much of the overburden was piled on the outer edges of the rimrock. Mining spoils were left piled on the pit floor. Highwalls, exposed radioactive lignite beds, and mine spoils were left exposed when mining ceased in 1964. The exposed materials are highly erosive.

In 1989, the USFS constructed five sediment ponds in an attempt to minimize eroded sediments from traveling to off-site land and access roads. Three ponds were constructed in Schleichart Draw and two in Upper Pete's Creek. Periodically, as is necessary, the USFS employs contractors to clean out the ponds and return eroded wastes back to the upgrade mined areas.

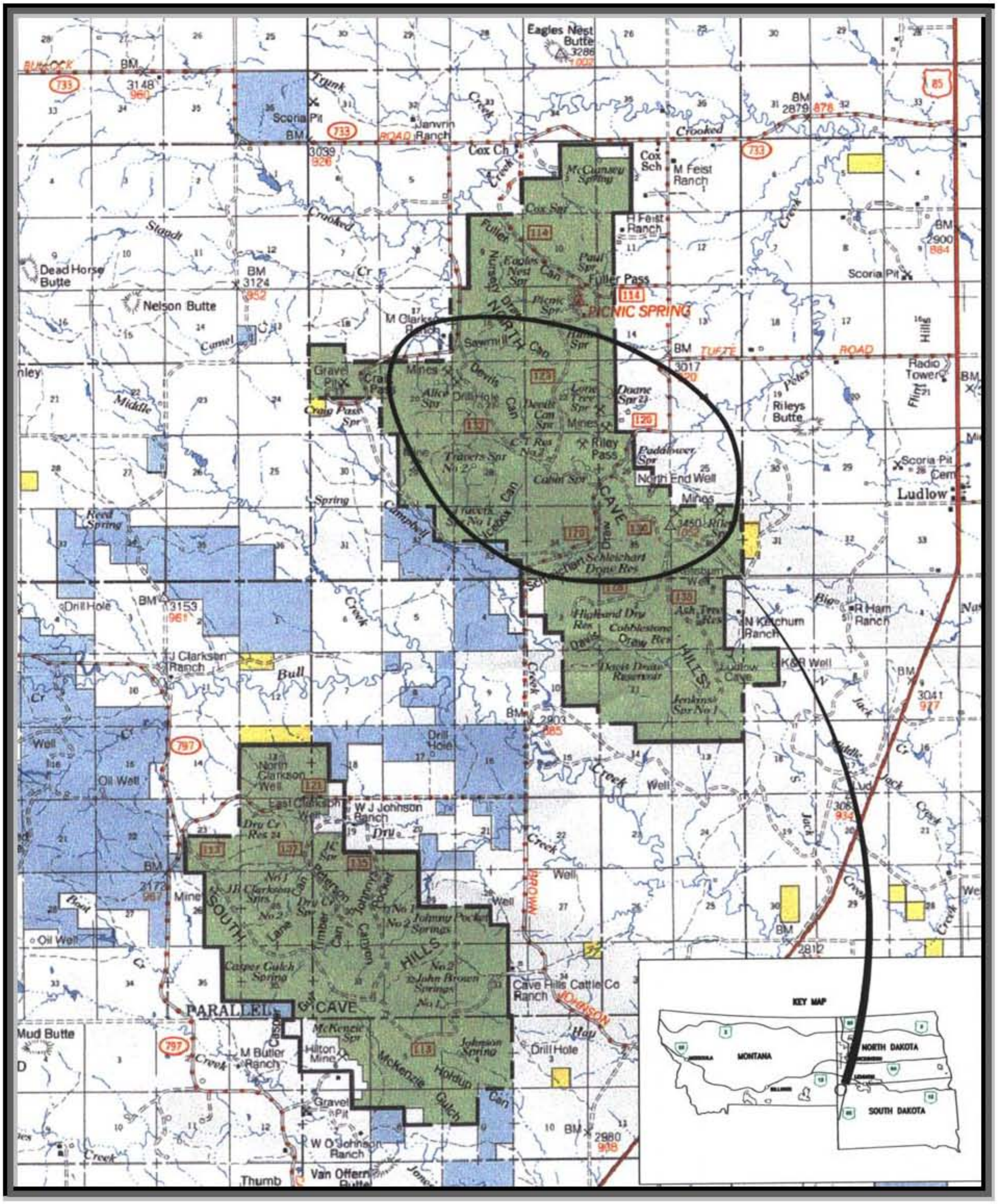

Figure 1-1. Riley Pass Uranium Mines vicinity map [Pioneer 2002].

To illustrate some of the difficulties mine wastes pose at Riley Pass with respect to offsite migration and operation and maintenance efforts, the following excerpt is provided. It is part of a report filed by the Custer National Forest, Sioux Ranger District documenting an August 2004 rain event that resulted in significant offsite sediment flows from mined areas. Figure 1-2 depicts sediments that flowed from the mined areas at Riley Pass onto Tufte Road (a local county road) and USFS Route 3120.

"Between August 2nd and August 5, 2004 the Riley Pass area received approximately three inches of rainfall. Sediment from Bluffs A and B are presently moving off of NFS [USFS] land, onto [adjacent] private land (hay field), across the county road called Tufte Road, and onto USFS developed road 3120. There are currently ruts in Tufte Road formed by rain flows reaching 1-foot in depth. Sediment is also moving from Bluffs A and B out of Pond 2, through a culvert underneath FDR [USFS Route] 3120. This sediment flow / drainage ends-up on private lands. At this time, ponds 3 and 4 are also moving sediment; however, it is staying in the boundaries of Pond 5."

Figure 1-2. 2004 Riley Pass sediment flows [USFS].

1.4 History of Investigations

In 1964, the USFS prepared an Impact Report for Surface Mining Activity in the Custer National Forest of South Dakota (USDA 1964). This report describes historic mining, the geology of the area, and the physical disturbances that resulted from mining activities. The study coincided with the termination of mining activities at Riley Pass. Given this, the general nature of adverse impacts to the region has been apparent since mining ceased.

Renewed interest in these impacts arose in the late 1980s. Based on this, Denver, Knight, and Piesold completed a reclamation study for Bluff B (Denver, Knight, and Piesold 1990). In 1991, Denver, Knight, and Piesold completed an environmental assessment of Bluff B (Denver, Knight, and Piesold 1991). Water quality data and radiological measurements were collected as part of these investigations. Historical data from these are included in the EE/CA.

In 2002, the USFS completed Final Site Investigation Report for the Riley Pass Uranium Mines (Pioneer 2002). To support this effort, measurements of chemical and radiochemical parameters in soil, sediment, and surface water were collected throughout the 12 mined bluffs. Soil samples collected during this effort were generally composites. This approach was adopted to acquire data representing the range of site conditions, using relatively small sample numbers. Radiological measurements were also collected. Data from this investigation are incorporated into this evaluation when appropriate, and are provided in Appendix B.

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2. DATA ACQUISITION

To enhance understanding of conditions at Riley Pass and to support this risk assessment effort, the USFS completed a field investigation during the week of July 19, 2004 (Portage Environmental, Inc. [Portage]). The work was conducted in accordance with the "*Draft – Phase II Work Plan, to Complete Sampling and Analysis at the Riley Pass Uranium Mines North Cave Hills Area of Harding County, South Dakota*" (Portage 2004). Based on Portage recommendations, the USFS selected two mined areas for investigation at the site: Bluffs B and H. These bluffs were selected using data from previous investigations, which identified them as representing the range of chemical and radiochemical conditions at the site. One location generally represented the highest levels of contamination (Bluff H) while the other (Bluff B) was generally representative of the lowest levels of contamination.

Previous sampling and analysis for radionuclides at Riley Pass were targeted to Ra-226 and U-235 using gamma spectroscopy. In addition, soil samples were analyzed for uranium and thorium as total metals rather than their isotopic forms. Although Ra-226 is a major contributor to dose and thus carcinogenic risk, other products of the uranium decay chains are also considered important in a risk assessment of uranium ore. For purposes of this investigation and subsequent risk evaluation, the lack of analytical data for additional progeny in the uranium decay series such as Th-230, the lack of information on the actual isotopic ratios of the uranium ore, and several unknowns as to whether the ore was processed onsite, made it necessary to gather additional isotopic data for radionuclides. For example, Th-230 is a major contributor to carcinogenic risk - on the same order as Ra-226. Therefore, Th-230 was investigated and assessed in additional soil samples. This information along with isotopic uranium analyses, allowed risk assessors to fill in the decay chains allowing for a full assessment of radionuclide risks. Because separation of the uranium isotopes was not evident in previous risk assessments, analytical results for U-235 from prior studies had limited usefulness in this assessment.

The metals quantified at the site during prior investigations are those typical of abandoned mine sites. Based on data screening performed as part of the 2002 site investigation, several of the metals were ruled out as likely contaminants of potential concern (COPCs). For example, the available soil data shows no copper or lead significantly above background. Based on previous screening efforts, 2004 data acquisition efforts at Riley Pass focused on the COPCs identified in the existing EE/CA. The 2004 site investigation involved the collection of: (1) field observations, (2) onsite and regional radioactivity measurements, and (3) the collection of 21 discrete background, overburden, and lignite samples. Using previous investigation data, the Phase II Work Plan focused on the following key COPCs:

- Arsenic
- Molybdenum
- Selenium
- Ra-226
- Th-230
- U-234
- U-235
- U-238.

2.1 Data Quality Summary

All of the laboratory data acquired during the 2004 Riley Pass Site Investigation underwent data validation prior to use in this risk assessment. Metals data were validated in accordance with the *U.S. EPA National Functional Guidelines for Inorganic Data Review* (EPA 2003). Radiochemical parameters were validated in accordance with *U.S. Department of Energy, Technical Procedure GDE 205 "Radioanalytical Data Validation*" (INEEL 2004).

None of the sample data were significantly restricted for use due to data quality issues. As a result, all data was used to support this risk assessment. Of the (21) soil samples submitted for metals analysis, none received qualification due to data quality issues. Several samples received qualification for select radiochemical parameters during validation. However, none were rejected and those qualified were of sufficient quality to support the risk assessment. Overall, 86% of the data points were unqualified and all data points were acceptable for use in assessing site conditions. Appendix A provides complete data validation reports for the 2004 USFS site investigation data.

2.2 Target Areas of Concern

2.2.1 Site Observations

Observations documented during the 2004 Phase II site investigation included:

- Percent vegetative cover
- Evidence of windblown dust dispersion
- Areas of soil piping
- Other items relevant to completing the risk assessment.

Bluffs B and H were photographed to document sample locations, vegetative cover, and piping/soil erosion locations given their prominence in this investigation. Onsite observations coupled with historical data indicate they are generally representative of conditions throughout the site.

2.2.1.1 Bluff B. Bluff B encompasses approximately 150 acres of spoils piles (overburden), highwalls, and open pits with an estimated spoils volume of 1,140,000 cy (Pioneer 2002). The mined areas are located in parts of Sections 22, 23, and 26. Riley Pass, a historic pioneer wagon route used during the 1890s, is approximately 500 feet north of Bluff B (Figure 2-1).

The waste materials (spoils/overburden) have been a major source of sedimentation to Pete's Creek to the east of Bluff B and Schleichart Draw to the west. A majority of the bluff is either barren or sparsely vegetated and shows signs of severe wind and surface water erosion. Sediment from the east half of the site is currently being carried approximately 3/4 mile and deposited on the main access road to Riley Pass and the adjoining private property. Sediment basins have been installed and maintained by the USFS in Upper Pete's Creek and Schleichart Draw. However, due to the amount of sediment eroding from the site, frequent maintenance of the basins is required.

Figure 2-1. Bluff B looking northwest [Portage 2004].

Due to the predominant soil type present (i.e., sandy clay and silty clay) soil piping and tunneling with occasional sinkholes are present. Piping and large gullies are most prevalent in areas where the overburden was placed along or below the rimrocks. Some of the pipes that have formed are 10 to 15 feet in diameter, and gullies up to 25 feet in depth have formed in places subject to concentrated surface water flow (see Figure 2-2).

The mined pit floors are generally at or near bedrock, with spoils placed along the edges. Here erosion carries them downgrade of Bluff B into drainages and onto adjacent lands. Shallow ponds have formed in some of the areas creating small retention basins, which during snowmelt and rain events assist in controlling some of the surface water flow. Water from these ponds most likely evaporates or seeps through the bedrock during the summer months (Pioneer 2002).

Conditions have not changed significantly since the 2002 USFS investigation. Where mining has occurred, vegetative cover is sparse. This extends to the mine floor, overburden piles, and lignite piles (see Figure 2-3).

2.2.1.2 Bluff H. Bluff H encompasses approximately 31 acres consisting of several spoils piles with an estimated volume of 553,850 cy (Pioneer 2002). Historic mining operations pushed the spoils along and over the rimrock edges that form the Bluff H boundary. The rimrock slopes are generally very steep (1.5H:1V), with severe water erosion evident, especially on the northwest and northeast spoils piles. Vegetation growth on the side slopes is very limited (<10% cover). On top of the mesa forming Bluff H, in the southwest corner, there is a man made pit formed by the excavation of overburden. The overburden that forms the highwalls extends upward to a maximum height of 50 feet above the pit floor. The overburden appears to have undergone significant erosion since mining ceased (see Figure 2-4).

Figure 2-2. Piping at Bluff B looking north [Portage 2004].

Figure 2-3. Bluff B overburden looking east/southeast [Portage 2004].

Figure 2-4. Pit floor at Bluff H looking east [Portage 2004].

Portions of the spoils pile on the north / northeast side of the bluff are located on private property. A 1.1-acre spoils pile (estimated volume of 54,350 cy – Pioneer 2002) is located on the northwest corner. The slope is extremely steep (1.5H:1V) and barren of vegetation. There is a large erosion wash located on the south portion of the spoils pile, with water and sediment flowing into an ephemeral drainage. Onsite observations also indicate that portions of the eroded sediments are being deposited on private property adjacent to Bluff H.

The spoils pile located on the northeast end of the bluff is moderately vegetated. Here there are also erosion gullies and rills that transport sediment onto private property and into an ephemeral drainage. Approximately one third of these spoils pile are currently situated on private property. Another spoils pile occupies the west side of the bluff. It occupies approximately 3 acres, with an estimated volume of 340,150 cy [Pioneer 2002]. The spoils are sparsely vegetated with numerous erosion gullies and rills. One large erosion gully (approximately 12 feet in depth) is located on the south end of the spoils pile, and drains into an intermittent dry draw/drainage.

A spoils pile containing approximately 159,340 cy of spoils, and encompassing approximately 4 acres, is located on the south end of the bluff. They are moderately vegetated with limited signs of surface erosion (Pioneer 2002).

Conditions at Bluff H have not changed significantly since the 2002 USFS investigation. Current vegetative cover is highest on the northeast and south overburden/spoils piles (see Figure 2-5).

Effects from wind and water erosion and visible piping was considerably less at Bluff H when compared with Bluff B. Lignite piles were also observed to be smaller in size (less than 200 ft^2) with lignite scattered throughout the overburden areas. This distribution is likely due to overburden contact with lignite during mining operations. This is consistent with field screening results, which indicate that elevated gamma readings are the result of small, point sources (less than 1 ft^2) in overburden.

2.2.2 Sample Collection

At each of the two selected bluffs, a total of thirteen (13) samples were collected. Each was treated as a discrete sample and was used as a means of identifying both the distribution and range of COPCs. Prior data acquisition indicates the major metals of concern are:

- Arsenic
- Molybdenum
- Selenium.

Figure 2-5. Bluff B overburden looking east/northeast [Portage 2004].

In addition, historical characterization efforts at uranium mine and mill tailing sites (DOE, NRC) suggest the major radionuclides of interest are:

- Ra-226
- Th-230
- U-234
- U-235
- U-238.

In total, the following were collected from both mined and undisturbed areas in and around the Riley Pass Uranium Mines:

- Three (3) discrete samples were collected from exposed lignite at Bluffs B and H
- Five (5) discrete samples were collected from overburden at Bluffs B and H
- Five (5) discrete background samples were collected in undisturbed areas.

Each of the samples were analyzed for arsenic, molybdenum, selenium, isotopic uranium, Ra-226, and Th-230.

Using onsite field screening and existing Bureau of Mines, State of South Dakota, U.S. Geological Survey, and Riley Pass information, Portage selected five locations in the immediate area on and around the Riley Pass Uranium Mine to collect discrete background samples. Prior to their collection, a 'walkover' radioactivity survey was performed for the majority of the site including both mined and undisturbed areas. Gamma readings taken during the walkover showed a background range of 4,000–6,000 counts per minute (cpm) averaging 5,000 cpm. Using this technique, areas in the historic mining district showing radioactivity levels consistent with these levels, were sampled. Each of the background samples were analyzed for arsenic, molybdenum, selenium, isotopic uranium, Ra-226, and Th-230. Figure 2-6 illustrates sample locations for the site, along with field screening results obtained during the investigation.

To augment field sample collection, gamma field measurements were collected using NaI scintillation detectors. Both mined and undisturbed areas were randomly surveyed to establish a range of gamma readings. Field survey results were correlated to the laboratory results for radionuclides of concern to evaluate the distribution of soil activity where soil samples were not collected. This correlation is discussed in detail in the Section 2.2.4. Figure 2-6 details the gamma radiation ranges obtained from the walkover scans for both undisturbed and mined areas. In general, the bluff areas are heterogeneous with elevated gamma radiation ranges. Undisturbed areas show lower levels of gamma activity with minimum (background) levels achieved within the district moving away from mining disturbances. This is consistent with historical data for the site and the larger mining district.

Prior to collecting samples, gross gamma readings were used to obtain a range of gamma measurements and an observed field average from both disturbed (mined) and undisturbed areas. In the case of overburden, this allowed for the collection of two samples from the lower-end of the observed gamma range, two from the upper-end, and one at the average gamma range. Using field observations in this way provided a means of collecting representative samples from overburden. Samples were only taken from areas with a wide area of observed and consistent gamma radiation levels. Lignite samples were acquired in a similar fashion, collecting samples from lignite representative of the range of radioactivity observed at each bluff.

Field screening was also employed for undisturbed areas throughout the mining district to determine what areas are representative of background radiation levels. This method allowed for the collection of background soil samples in areas where field activity levels reflect the area background radiation levels.

Following sample collection, each of the 21 samples was submitted to Severn Trent Laboratories of St. Louis, Missouri for analysis. The laboratory results are provided in Appendix A.

2.2.3 Field Measurements

Radiation survey instruments, including Na(I) and a Bicron tissue equivalent µRem meter were used to evaluate the external gamma radiation readings in the survey areas. Radiation readings were obtained at each sample location and also around the general vicinity.

The gamma radiation survey results were correlated to radionuclide concentrations in the soil based on correlated laboratory results. In addition, the Na(I) readings were correlated to the dose rate readings (i.e., µRem/h). The correlations are described in detail in Section 2.2.4, "Correlations Between Field and Laboratory Measurements." The following descriptions of the gamma rate ranges are based on the correlations between the contact gamma Na(I) measurements with the 1-m dose rates using the Bicron µRem meter.

Gamma rate ranges in Bluff B were determined to be 10,000 to 35,000 counts per minute (cpm) (15.8 to 38.6 µRem/h), averaging 15,000 cpm (21.1 µRem/h). Weathered ore piles ranged from 30,000 to 200,000 cpm (34.6 to 133.1 µRem/h) averaging 60,000 cpm (56.6 µRem/h). The lignite piles exhibited gamma rate ranges of 100,000 to 200,000 cpm (81.4 to 133.1 µRem/h), with an average of 150,000 cpm (08.5 µRem/h). The mine floor, with exposed sandstone, ranged from 20,000 to 50,000 cpm (25.9 to 49.7 µRem/h), and averaged 40,000 cpm (42.4 µRem/h). The majority of undisturbed areas with possible overburden interfaces ranged from 4,000 to 6,000 cpm (8.3 to 11.0 µRem/h), averaging 5,000 cpm (9.7 µRem/h).

Gamma rate ranges on Bluff H were typically 6,000 to 60,000 cpm (11.0 to 56.6 µRem/h), averaging 40,000 cpm (42.4 µRem/h). Weathered ore and slag piles ranged 40,000 to 60,000 cpm (42.4 to 56.6 µRem/h), averaging 50,000 cpm (49.7 µRem/h). The lignite area exhibited gamma rate ranges of 80,000 to >800,000 cpm (69.4 to 356.4 µRem/h), with an average of 100,000 cpm (81.4 µRem/h).

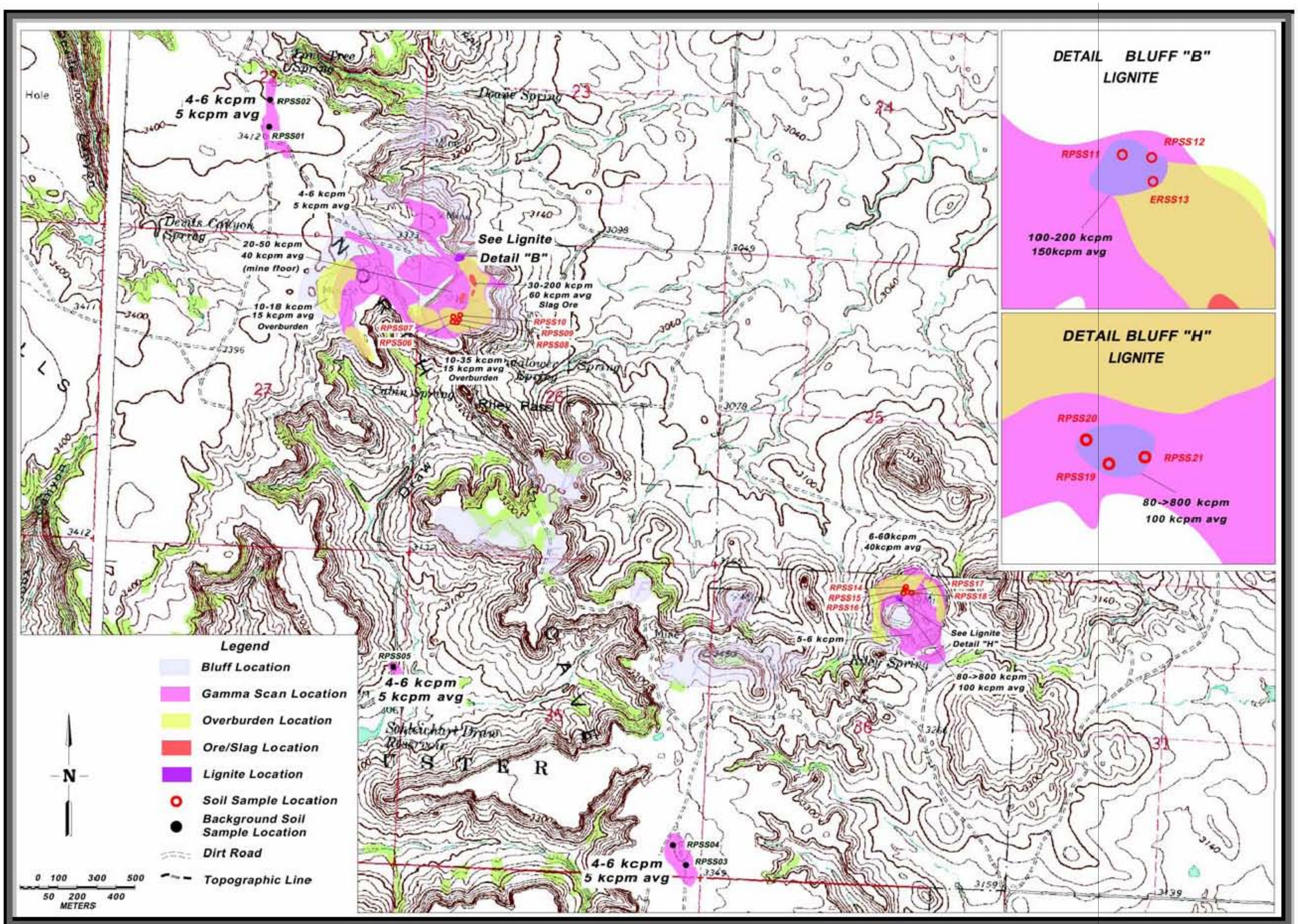

Figure 2-6. Sampling and field survey locations.

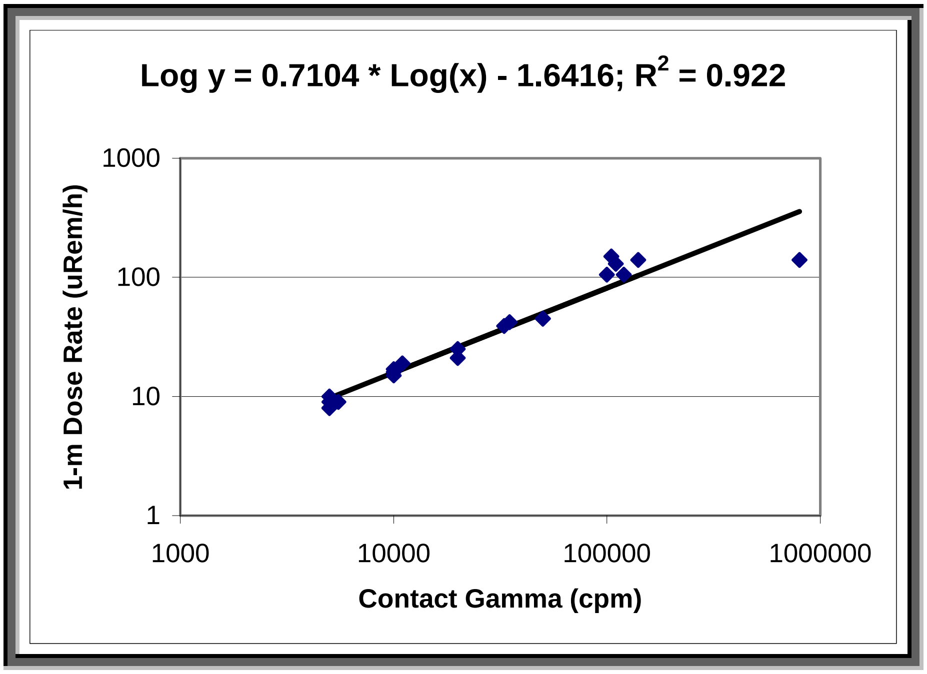

Figure 2-7. Onsite external dose rates versus field gamma Na(I) survey data.

2.2.4 Correlations Between Field and Laboratory Measurements

A preliminary evaluation of correlations between field and laboratory measurements was completed as a possible tool to more cost-effectively evaluate COPC levels at the site. Radiation readings were obtained at each sample location and also around the general vicinity. The gamma readings were compared with laboratory data to develop correlations.

Gamma scans at each sample location were conducted to obtain a range of readings from background to high exposure areas (lignite). These gamma measurements along with the soil sample data were used to establish a correlation.

The correlations are presented in Figures 2-7 through 2-11. The R^2 value for the linear regression for each of the correlations and the equations used to calculate them, are provided in the figures. The following correlation is provided to convert the contact gamma Na(I) measurements to a 1-m direct external dose rate.

A correlation was also developed for the Ra-226 soil concentration (pCi/g) and the field gamma Na(I) measurements. This correlation allows for the estimation of Ra-226 soil concentrations based on Na(I) gamma measurements. As shown in Section 2.4, "Radionuclide Decay Chain Equilibrium," the uranium decay chain is in equilibrium with their progeny. Therefore, an estimate of the Ra-226 soil concentration can be further extended to predict the remaining radionuclides in the decay chain.

Correlations were also established between radionuclide concentrations for U-238, Th-230, and Ra-226 and arsenic. These correlations illustrate the trend of increasing arsenic soil concentrations with increasing radionuclide soil concentrations. The correlations are provided in Figures 2-9 through 2-11.

The correlations presented above were used to estimate the range and average soil concentrations of radionuclides and arsenic based on the gamma scans at Bluffs B and H. The resulting soil values are presented for each of the bluffs in Tables 2-1 and Table 2-2 below. Gamma rates at Bluff B were determined to range from 10,000 to 35,000 cpm, averaging 15,000 cpm. Gamma rates at Bluff H ranged from 6,000 to 60,000 cpm, averaging 40,000 cpm.

The predicted soil concentrations presented above indicate that the gamma Na(I) measurements are a good indicator of both radionuclide and arsenic concentrations in soil. As can be seen, the average field gamma values are an accurate predictor of the soil concentrations. Therefore, the gamma measurements provide a good indicator of the range of soil concentrations in areas where soil samples were not taken.

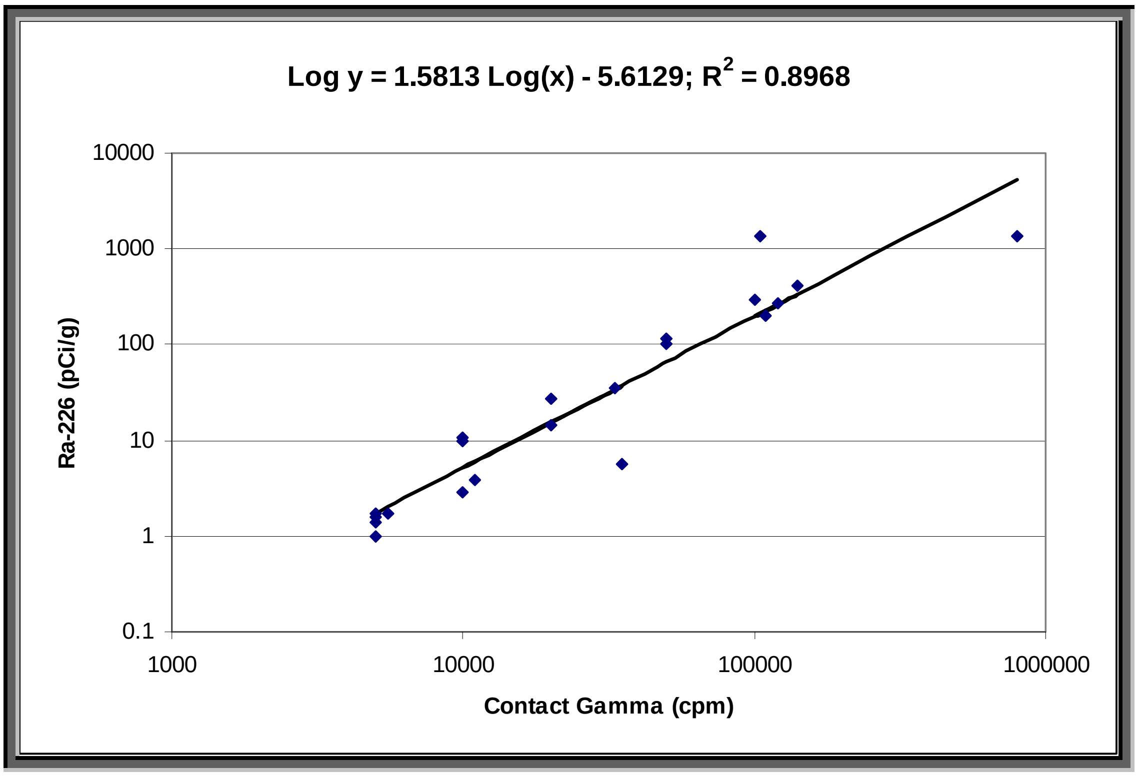

Figure 2-8. Correlation of contact gamma Na(I) measurements vs. Ra-226.

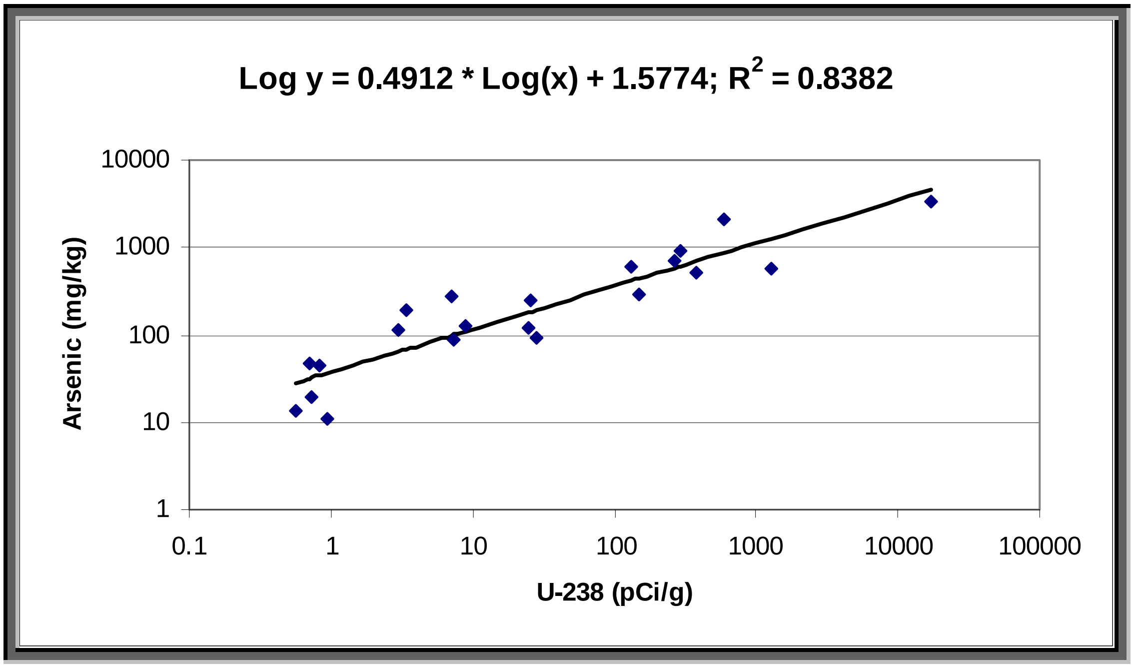

Figure 2-9. Correlation of arsenic vs. U-238 in soil.

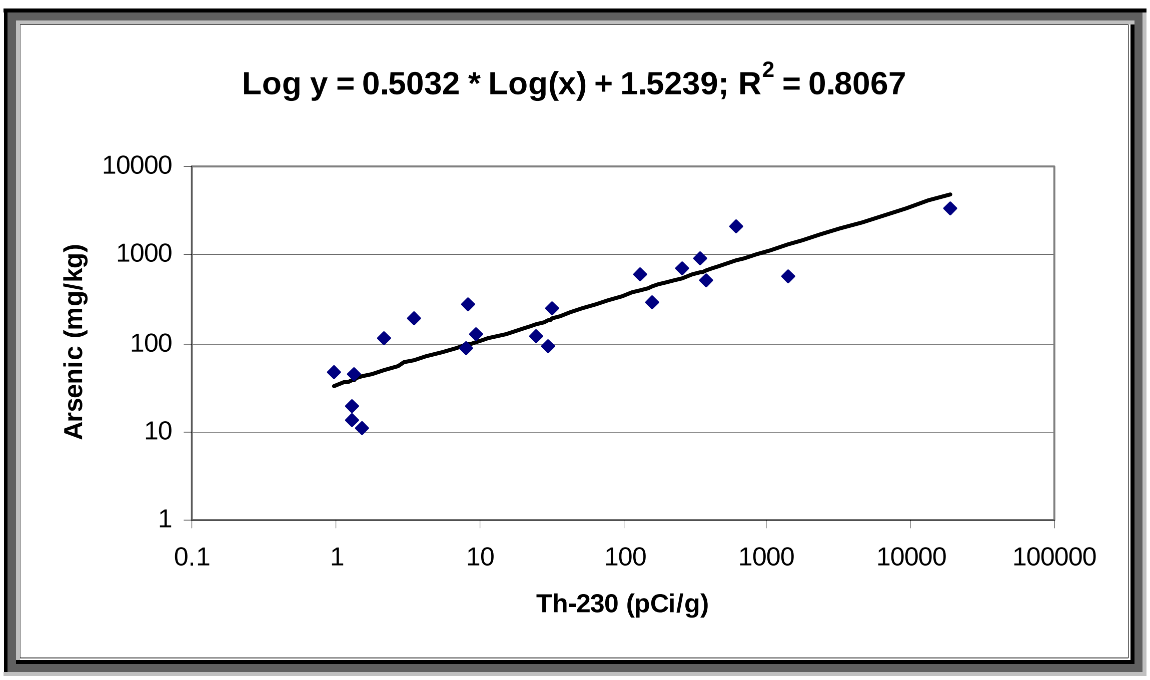

Figure 2-10. Correlation of arsenic vs. Th-230 in soil.

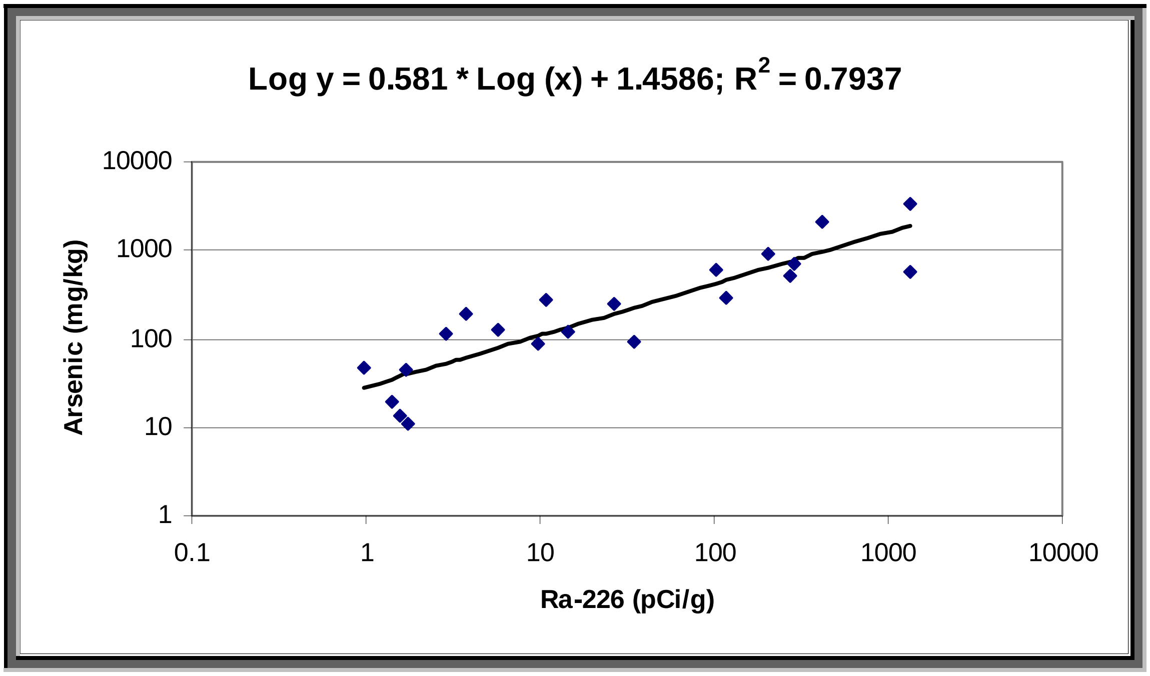

Figure 2-11. Correlation of arsenic vs. Ra-226 in soil.

Table 2-1. Ra-226 and arsenic ranges based on Na(I) gamma correlations, Bluff B.

Contact Gamma Rate (cpm)	Predicted Soil Concentrations	
	Ra-226 (pCi/g)	Arsenic (mg/kg)
Min (10,000)	5.2	74.9
Max (35,000)	37.4	235.7
Field Avg. (15,000)	9.8	108.3
Mean Soil [a]	12.3	128.5

a. Based on laboratory soil sample data.

Table 2-2. Concentration ranges based on Na(I) gamma correlations to Ra-226, Bluff H.

Contact Gamma Rate (cpm)	Predicted Soil Concentrations	
	Ra-226 (pCi/g)	Arsenic (mg/kg)
Min (6,000)	2.3	46.6
Max (60,000)	87.7	386.8
Field Avg. (40,000)	46.2	266.5
Mean Soil [a]	53.3	299.5

a. Based on laboratory soil sample data.

A trend is also apparent between radionuclides and arsenic, and their correlation to the field data collected for radiation / radioactivity. In general, the field survey finds activity to be at its highest in the source material or lignite. As the survey moves away from the lignite to overburden, the activity decreases; and when the field survey moves to undisturbed areas, the radioactivity decreases to a consistent background level of 4–5 cpm. The analytical data obtained from all of the studies at the site, show metals concentrations also follow this trend.

The highest metals concentrations are found in the exposed lignite. The metals data similarly shows a decrease in metals concentrations in the overburden when compared to lignite and a decrease when overburden is compared to undisturbed areas. This is an important fact to consider, as the field survey for radiation / radioactivity proves a useful tool in identifying undisturbed areas that are reflective of background radiation levels. The arsenic correlates with the radionuclides such that areas of low background radioactivity are also indicative of background areas for metals.

2.3 Statistical Comparison with Background and RBSLs

To supplement this assessment, data from historical investigations and the 2004 site investigation were compared with background data obtained from the Riley Pass region, nationally published values, and with preliminary remediation goals (PRGs). These comparisons are provided in Tables 2-3 through 2-6. The following summarizes what information is contained in these tables.

- Table 2-3 presents data for the human health risk assessment
- Table 2-4 presents data for ecological risk assessments for soil
- Table 2-5 presents data for ecological risk assessments for water
- Table 2-6 presents data for ecological risk assessments based on sediment contaminant concentrations
- Data supporting the statistical calculations are provided in Appendix B.

Radionuclides important to human health are summarized in Table 2-3. Radionuclide comparisons were made for the 2004 data set using individual isotopes. Historical data had limited usefulness in this evaluation, as total uranium was determined without an evaluation of secular equilibrium. The data indicates that measured soil and sediment COPC concentrations generally exceed background levels measured at the site. They also exceed screening level risk-based criteria. The COPCs identified at the highest levels relative to site background and/or PRGs are:

- Arsenic
- Molybdenum
- Selenium
- Uranium
- Ra-226.

This evaluation dictates that these parameters be considered the COPCs for the site-specific human health risk assessment (see Section 3). Table 2-4 presents a screening level evaluation of potential ecological risks using soil concentrations / activities. Based on this evaluation, copper and lead were removed from further consideration in the site-specific ecological risk assessment (see Section 4).

Table 2-5 presents a screening level evaluation of potential ecological risks for surface water. The majority of the COPCs exceed background and/or screening criteria by a wide margin. This assessment does not specifically evaluate soil/surface water interactions. Since soil quality is the focus of the investigation, these screening results were not used as a basis for selecting parameters for site-specific ecological risk assessment.

Table 2-6 presents a screening level evaluation of potential ecological risks from sediments. Decision makers should note, while both average and maximum values for all COPCs exceed average background concentrations, only arsenic exceeds screening levels significantly.

2.4 Radionuclide Decay Chain Equilibrium

Natural uranium consists of isotopic mixtures of U-234, U-235, and U-238. Natural uranium, including uranium ore, is comprised of 99.284% U-238, 0.711% U-235, and 0.005% U-234 by mass. Combining these mass percentages with the unique half-life of each isotope converts mass into radioactivity units and shows that uranium ore contains 48.9% U-234, 2.25% U-235, and 48.9% U-238 by radioactivity, and has a very low specific activity of 0.68 μCi/g. Uranium isotopes continuously undergo transformation through the decay process, whereby they release energy to ultimately become a stable or non-radioactive element. For the uranium isotopes, this is a complex process involving the serial production of a chain of decay products, called progeny, until a final stable element is formed. Figure 2-12 presents the decay progeny of the uranium isotopes.

In uranium ore deposits, secular equilibrium is obtained between U-238 and its decay products, and between U-235 and its decay products. The equilibrium may be somewhat disturbed by geochemical migration processes in the ore deposit. It may also be disturbed due to ore releases caused by mining or milling operations. Historical information for Riley Pass mining operations indicate that some pretreatment / milling of ore may have occurred during active production. As a result, 2004 sampling efforts sought to ensure that these operations did impact the equilibrium of U-238 and U-238 decay processes.

Evaluation of the 2004 Riley Pass sample data indicates the U-235 and U-238 decay chains are in secular equilibrium with their progeny. In general, U-234 and U-238 should each consist of approximately 48.9% of the total uranium activity, while U-235 should comprise approximately 2.25% of the total uranium activity. Assuming equilibrium, Th-230 and Ra-226 concentrations should be equal to the U-235 and U-238 concentrations. Table 2-7 indicates the decay chains are in equilibrium, within the reported laboratory error.

This allows for the estimation of all additional radionuclides in the decay chains without collection of physical data. Because the radionuclide decay chains are in equilibrium at the site, additional radionuclides can be assumed to be in equilibrium with long-lived parents.

Table 2-3. Background and human health risk-based screening level values for solids.

	Historical Sediment Concentrations		Historical Soil Concentrations		2004 Data Soil Concentrations[a]		Instrument Detection	Background Soil Concentration[b]		Preliminary Remediation Goals[c]	
COPC	Average	Maximum	Average	Maximum	Average	Maximum	Limit[d]	Site	U.S	Residential	Industrial
As (mg/kg)	**48**	**304**	**577**	**2,880**	**649**	**3,390**	7.4/1	28.2	NR	0.39	1.6
Cu (mg/kg)	**12**	**51**	**19**	**51**	NR	NR	0.2	8.9	25	3,100	41,000
Pb (mg/kg)	12	**29**	**19**	**41**	NR	NR	4.5	16.1	20	400	750
Mo (mg/kg)	**19**	**180**	**822**	**5730**	**1,355**	**6,550**	1.1/1	4.1	2	390	5,100
Se (mg/kg)	**11**	**30**	**13**	**37**	12.0	**98**	7.2/1	4.6	NR	390	5,100
Th (mg/kg)	**6**	**15**	**14**	**43**	NR	NR	1.1	5.8	NR	NR	NR
T-U (mg/kg)	**30**	**278**	**533**	**2810**	NR	NR	14.9	60.1	NR	16*	200*
V (mg/kg)	24	52	45	**163**	NR	NR	0.5	22.9	76	550	7,200
Ra-226 (pCi/g)	**6**	**47**	**119**	**903**	101[e,f]	116[f]	0.16–0.5	1.8[e]	NR	0.1	0.5
U-238 (pCi/g)	NR	NR	NR	NR	131[e,f]	151[f]	0.06–50	0.9[e]	NR	16.7	105.4
U-234 (pCi/g)	NR	NR	NR	NR	136[e,f]	156[f]	0.03–60	1.0[e]	NR	17.3	143.2
Th-230 (pCi/g)	NR	NR	NR	NR	135[e,f]	161[f]	0.05–80	1.5[e]	NR	0.27	1.4
U-235 (pCi/g)	**1.45**	**9**	**12**	**71**	6.2[e,f]	7.1[f]	0.036–70	0.1[e]	NR	5.7	17.6

*Based on chemical toxicity only.

a. Includes both overburden and lignite results

b. Background soil concentrations are based on the average of historical data and data collected in 2004 (result for RP-SS-X removed as an outlier). U.S. background – average values from *Elemental Composition of Surficial Materials in the Conterminous United States* (USGS 1971).

c. Preliminary Remediation Goals, EPA Region 9, http://www.epa.gov/region09/waste/sfund/prg/index.htm - value shown is the lowest of hazard quotient or cancer risk value. Radionuclides values based on NCRP Report No. 129 and an allowable dose of 25 mrem/yr.

d. Detection limit as reported with sample results (see Appendix A).

e. Values are reported as the 95% upper confidence limit.

f. Values presented are based on Bluff H overburden samples.

NR = Not reported.

Bolded chemical names exceed of one or more comparison values, except U.S. background.

Table 2-4. Background and ecological risk-based screening values for solids.

	Historical Soil Concentrations		2004 Data Soil Concentrations		Instrument Detection	Average Background		Preliminary Remediation Goals[a]		Ecological Screening Values[b]
COPC	Average	Maximum	Average	Maximum	Limit[c]	Site[d]	U.S.[e]	Soil Value	Basis	EPA Region[a]
As (mg/kg)	**577**	**2,880**	649	3,390	7.4/1	28	NR	9.9	shrew, plant	10
Cu (mg/kg)	**19**	**51**	--	--	0.2	9	25	60	Earthworm	40
Pb (mg/kg)	**19**	41	--	--	4.5	16	20	40.5	woodcock	50
Mo (mg/kg)	**822**	**5,730**	1,355	6,550	1.1/1	4	2	2	plant	2
Se (mg/kg)	**13**	**37**	12	98	7.2/1	5	NR	0.21	mouse	0.81
Th (mg/kg)	**14**	**43**	--	--	1.1	6	NR	NR		NR
T-U (mg/kg)	**533**	**2,810**	--	--	14.9	4	NR	5	plant	5
V (mg/kg)	**45**	**163**	--	--	0.5	23	76	2	plant	2
Ra-226 (pCi/g)	**119**	**903**	101[f,g]	116[g]	0.16–0.5	1.8[f]	NR	NR		50/300[h]
U-238 (pCi/g)	NR	NR	131[f,g]	151[g]	0.06–50	0.9[f]	NR	NR		2,000/20,000[h]
U-234 (pCi/g)	NR	NR	136[f,g]	156[g]	0.03–60	1.0[f]	NR	NR		5,000/50,000[h]
Th-230 (pCi/g)	NR	NR	135[f,g]	161[g]	0.05–80	1.5[f]	NR	NR		NR[h]
U-235 (pCi/g)	**12**	**71**	6.2[f,g]	7.1[g]	0.036–70	0.1[f]	NR	NR		3,000/30,000[h]

a. *Preliminary Remediation Goals for Ecological Endpoints*, prepared for DOE by Lockheed Martin Energy Systems (Efromson et al. 1997a).
b. *EPA Region 4 Ecological Screening Values for Soil*, http://www.epa.gov/region4/waste/ots/epatab4.pdf.
c. Detection limit as reported with sample results (see Appendix A).
d. Site background based on historical and 2004 data (result for RP-SS-X removed as an outlier).
e. U.S. Background – *Elemental Composition of Surficial Materials in the Conterminous United States* (USGS 1971).
f. Values are reported as the 95% upper confidence limit.
g. Values presented are based on Bluff H overburden samples.
h. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (USDOE 2000). The first number is for terrestrial animals and the second number applies to terrestrial plants.
NR = Not reported.
Bolded values exceed of one or more comparison values, except U.S. Background.

Table 2-5. Background and ecological risk-based screening values for surface water.

COPC	Surface Water Concentration[a]		Detection	Maximum	Aquatic Life Standard	EPA Surface Water Screening Values		Preliminary Remediation Goal[b,c]	
	Average	Maximum	Limit[d]	Background	Chronic[e]	Region 5[f]	Region 4[g]	Value	Basis
As (ug/L)	**410**	**1,420**	2.0	27.1	150	148	190	190	piscivore
Cu (ug/L)	**161**	**442**	2.0	8.8	5.2*	1.58*	6.54*	12	aquatic
Pb (ug/L)	**153**	**442**	0.90	6.42	3.18*	2.5*	1.32*	3.2	aquatic
Mo (ug/L)	**61**	**335**	7.4	8.9	NR	NR	NR	370	aquatic
Se (ug/L)	**12**	**34**	0.61	3.53	5	5	5*	0.39	piscivore
Th (ug/L)	73	207	5.3	ND	NR	NR	NR	NR	
T-U (ug/L)	**66**	**194**	10.0	ND	NR	NR	NR	2.6	aquatic*
V (ug/L)	**334**	**944**	4.4	23.3	NR	12	NR	20	aquatic
Ra-226 (pCi/L)	**6**	**16**	--	1.2	5	NR	NR	NR	8,000/1E7
U-235 (pCi/L)	1	3	0.2–0.3	0.8	NR	NR	NR	NR	5E5/1E8

*Hardness dependent value assuming hardness of 50 mg/L.
**Wildlife other than aquatic life not evaluated.
a. Total metals.
b. *Preliminary Remediation Goals for Ecological Endpoints*, prepared for DOE by Lockheed Martin Energy Systems (Efromson et al. 1997a).
c. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (USDOE 2000). The first number is for terrestrial animals and the second number applies to terrestrial plants.
d. Detection limit as reported with sample results (see Appendix A).
e. Administrative Rules of South Dakota (ARSD 74:51), per 74:51:01:15 - numeric limits for radionuclides not otherwise defined are 1/150 of the corresponding maximum permissible concentration in water for continuous occupational exposure for a 168-hour week as contained in pages 24 to 91, inclusive, of Handbook 69.
f. U.S. EPA Region 5 Ecological Screening Values, http://www.epa.gov/reg5rcra/ca/ESL.pdf.
g. *Freshwater Surface Water Screening Values*, EPA Region 4, http://www.epa.gov/region4/waste/ots/ecolbul.htm.
NR = Not reported.
ND = Not detected.
Bolded surface water concentrations exceed comparison values.

Table 2-6. Background and ecological risk-based screening values for sediment.

COPC	Sediment Concentration		Instrument Detection Limit[a]	Maximum Background	ERM[b]	PRG[c]	EPA Region 4[d]
	Average	Maximum					
As (mg/kg)	**48**	**304**	7.4	64.1	70/8.2	42	7.24
Cu (mg/kg)	**12**	**51**	0.2	9.3	270	77.7	18.7
Pb (mg/kg)	12	**29**	4.5	14.2	218	110	30.2
Mo (mg/kg)	**19**	**180**	1.1	12.0	NR	NR	NR
Se (mg/kg)	11	**30**	7.2	12.6	NR	NR	NR
Th (mg/kg)	6	**15**	1.1	9.6	NR	NR	NR
T-U (mg/kg)	**30**	**278**	14.9	17.0	NR	NR	NR
V (mg/kg)	24	**52**	0.5	24.6	NR	NR	NR
Ra-226 (pCi/g)	**6**	**47**	--	4.7	NR	NR	50/300[e]
U-235 (pCi/g)	1	**9**	--	1.5	NR	NR	3,000/30,000[e]

a. Detection limit as reported with sample results (see Appendix A).
b. Sediment Chemistry Screening Values, Effects Range Median/Effects Range Low, Table A-2, National *Sediment Contamination Point Source Inventory, Incidence and Severity of Sediment Contamination in Surface Waters of the United States* (EPA 1997).
c. *Preliminary Remediation Goals for Ecological Endpoints*, prepared for DOE by Lockheed Martin Energy Systems (Efromson et al. 1997a).
d. Sediment Screening Values, EPA Region 4, http://www.epa.gov/region4/waste/ots/ecolbul.htm.
e. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (USDOE 2000). The first number is for terrestrial animals and the second number applies to terrestrial plants.
NR = Not reported.
Bolded sediment concentrations exceed comparison values.

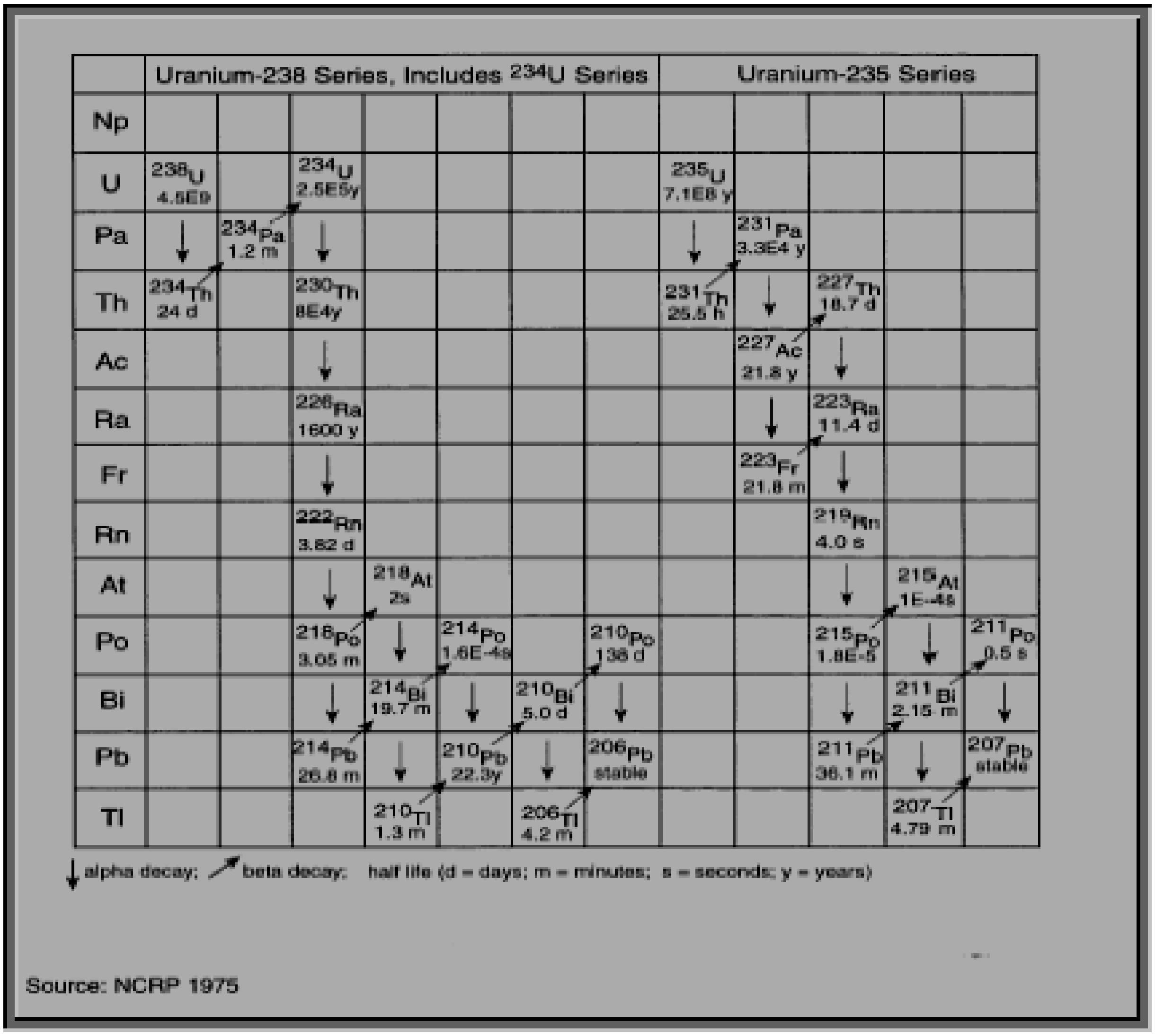

Figure 2-12. Radioactive progeny for uranium ore decay.

Table 2-7. Equilibrium comparison for 2004 Riley Pass sample data.

		Soil Concentrations (pCi/g)									
Sample #	Description	U-234	ERROR	U-235	ERROR	U-238	ERROR	Th-230	ERROR	Ra-226	ERROR
RPSS01	Background	0.81	0.21	0.16	0.1	0.7	0.19	0.98	0.22	0.98	0.25
RPSS02	Background	1.02	0.24	0.009	0.038	0.84	0.22	1.35	0.27	1.72	0.33
RPSS03	Background	0.73	0.18	0.066	0.065	0.57	0.16	1.29	0.28	1.56	0.32
RPSS04	Background	0.77	0.19	0.051	0.056	0.72	0.19	1.29	0.27	1.4	0.3
RPSS05	Background	0.95	0.22	0.124	0.087	0.94	0.22	1.54	0.28	1.73	0.34
Min		0.73	0.18	0.009	0.038	0.57	0.16	0.98	0.22	0.98	0.25
Mean		0.9	0.2	0.1	0.1	0.8	0.2	1.3	0.3	1.5	0.3
Max		1.02	0.24	0.16	0.1	0.94	0.22	1.54	0.28	1.73	0.34
RPSS06	Bluff B Overburden	3.51	0.65	0.048	0.081	3.42	0.64	3.5	0.68	3.78	0.57
RPSS07	Bluff B Overburden	2.97	0.54	0.16	0.13	2.96	0.54	2.19	0.45	2.87	0.47
RPSS08	Bluff B Overburden	25.6	3	1.7	0.47	24.5	2.8	24.6	3.3	14.6	1.7
RPSS09	Bluff B Overburden	7.8	1.2	0.34	0.22	8.8	1.3	9.5	1.5	5.74	0.79
RPSS10	Bluff B Overburden	30.9	3.4	1.11	0.36	28	3.1	30.3	4.3	34.5	3.7
Min		2.97	0.54	0.048	0.081	2.96	0.54	2.19	0.45	2.87	0.47
Mean		14.2	1.8	0.7	0.3	13.5	1.7	14.0	2.0	12.3	1.4
Max		30.9	3.4	1.7	0.47	28	3.1	30.3	4.3	34.5	3.7
RPSS11	Bluff B Lignite	548	61	31	13	586	64	621	77	419	43
RPSS12	Bluff B Lignite	340	44	20	10	295	40	343	50	205	21
RPSS13	Bluff B Lignite	345	48	17	11	373	51	379	53	275	28
Min		340	44	17	10	295	40	343	50	205	21
Mean		411.0	51.0	22.7	11.3	418.0	51.7	447.7	60.0	299.7	30.7
Max		548	61	31	13	586	64	621	77	419	43

Table 2-7. (continued).

		Soil Concentrations (pCi/g)									
Sample #	Description	U-234	ERROR	U-235	ERROR	U-238	ERROR	Th-230	ERROR	Ra-226	ERROR
RPSS14	Bluff H Overburden	138	14	6.5	2.3	131	14	130	14	103	11
RPSS15	Bluff H Overburden	156	13	7.1	2	151	13	161	17	116	12
RPSS16	Bluff H Overburden	27.2	4.1	1.42	0.95	25.5	3.9	32.2	5.3	26.9	2.9
RPSS17	Bluff H Overburden	7.6	1	0.34	0.21	7.4	1	8.1	1.2	9.8	1.2
RPSS18	Bluff H Overburden	7.01	0.98	0.28	0.2	7.11	0.99	8.4	1.1	10.8	1.3
Min		7.01	0.98	0.28	0.2	7.11	0.99	8.1	1.1	9.8	1.2
Mean		67.2	6.6	3.1	1.1	64.4	6.6	67.9	7.7	53.3	5.7
Max		156	14	7.1	2.3	151	14	161	17	116	12
RPSS19	Bluff H Lignite	262	24	14.4	4.1	264	24	254	28	291	29
RPSS20	Bluff H Lignite	1,270	120	53	18	1,260	120	1,430	170	1,330	130
RPSS21	Bluff H Lignite	17,200	1,600	910	240	17,100	1,600	18,800	1,800	1,350	140
Min		262	24	14.4	4.1	264	24	254	28	291	29
Mean		6244.0	581.3	325.8	87.4	6,208.0	581.3	6,828.0	666.0	990.3	99.7
Max		17,200	1,600	910	240	17,100	1,600	18,800	1,800	1,350	140

3. HUMAN HEALTH RISK ASSESSMENT

In accordance with EPA guidance (1989), this human health risk assessment consists of three primary parts:

- Exposure assessment
- Toxicity assessment
- Risk characterization.

The Exposure Assessment (Section 3.1) evaluates the fate and transport of chemicals and radionuclides in the environment and establishes the routes of exposure for people. For each exposure scenario, calculations are made regarding the exposed dose. Dose for non-radioactive chemicals is expressed in terms of the milligrams of chemical ingested per kilogram of body weight per day (mg/kg/day). Radiation dose is expressed in terms of pico Curies (pCi) of radionuclide ingested per kilogram of body weight per day.

The Toxicity Assessment (Section 3.2) identifies quantitative measures of toxicity for each COPC. Section 3.3 presents the quantitative Risk Characterization. In this section quantitative risks are calculated by comparing exposure to toxicity. Two supplemental sections to the risk assessment are also provided: (1) Uncertainty Analysis and (2) Summary and Conclusions. These sections address some of the more qualitative aspects of the assessment and integrate both the quantitative and qualitative, to aid in informed risk management decisions.

3.1 Exposure Assessment

The exposure assessment describes how contaminants both on and off site, are transported through the environment. It also describes the types and magnitude of exposure occurring or those that may occur. An exposure pathway defines the mechanism(s) that result in contaminant(s) contacting people or ecological receptors. A complete exposure pathway requires all of the following:

- A source of release into the environment
- A transport mechanism for contaminant release and migration from the source
- Contact with a receptor
- A mechanism for contaminant intake into the body.

Figure 3-1 provides a conceptual site model illustrating the fate and transport of contaminants upon their release from the site. A more detailed discussion is provided in Section 3.1.1. Subsequent sections describe how exposure is quantitatively evaluated. Emphasis is placed on describing those areas of the model where site-specific considerations result in deviations from default EPA assumptions. Appendix C provides an example of how the numeric exposure factors and risk calculations were completed. The results in Appendix C are based on Bluff H results. The complete characterization of risks can be found in Section 3.3.

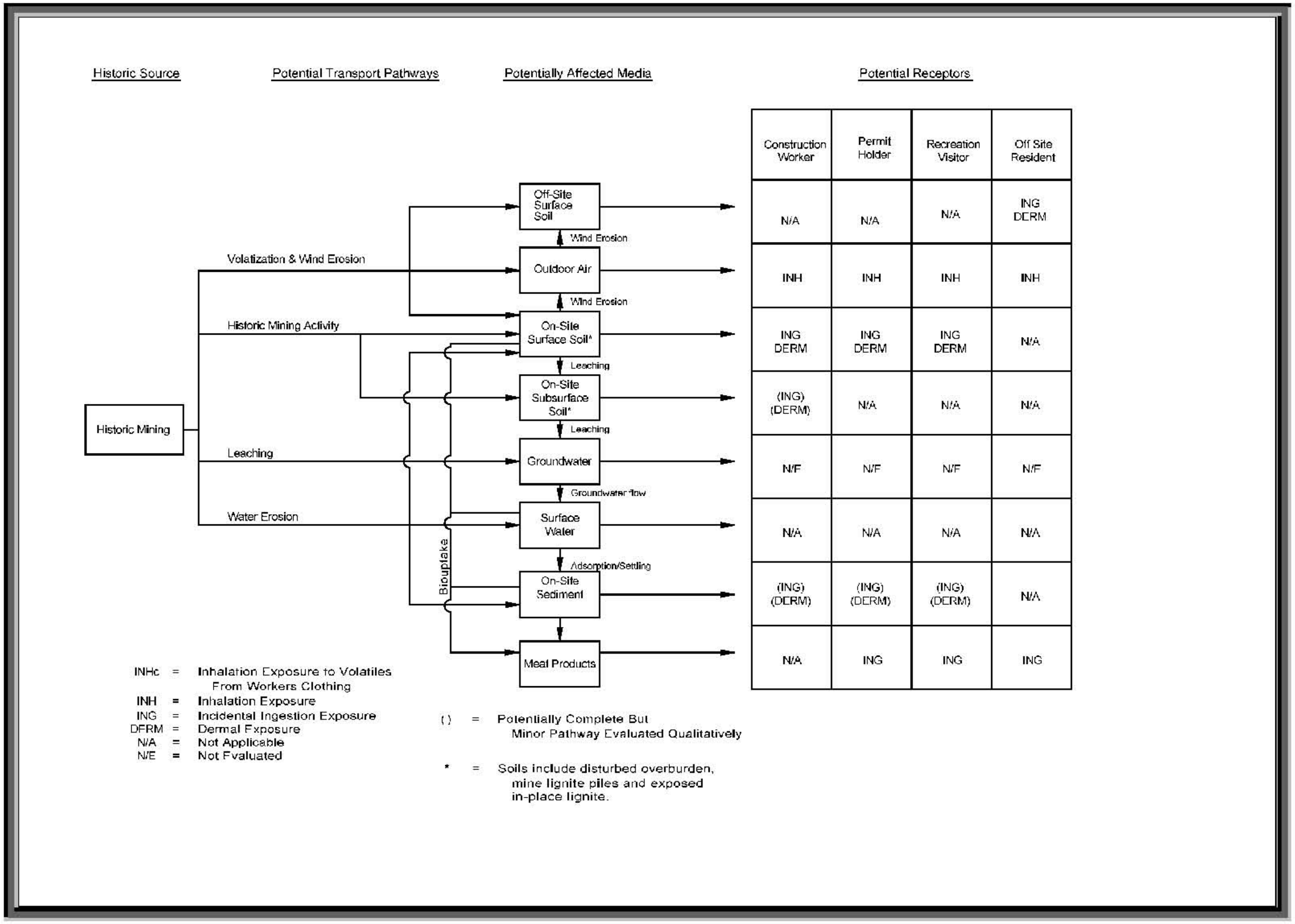

Figure 3-1. Human health conceptual site model for the Riley Pass Uranium Mines.

3.1.1 COPC Transport Pathways and Affected Media

Mining activities at Riley Pass have exposed lignite ores containing enriched concentrations of chemical and radiochemical toxins. These toxins have been widely dispersed as a result of various transport mechanisms. An illustration of this can be found in examining sample results from both overburden and pit floors. Data from these locations shows COPC concentrations / activities that exceed the levels found in materials undisturbed by mining. This is true for undisturbed areas both at onsite locations and regionally. This trend indicates that mixing of lignite and overburden occurred during mining. Onsite observations bolster this conclusion.

Visual observations reveal thin layers of lignite in the man-made highwalls found at the site. Field screening of these layers shows significantly elevated levels of radioactivity. The lignite material was likely mixed with overburden during stripping efforts that created the highwalls. All of the data for the site shows clear evidence that the lignite has led to elevated levels of both metals and radionuclides in surface and subsurface soils onsite, and in on and off site sediments.

The physical characteristics of the mined materials make them highly susceptible to erosion. The dumps and highwalls left from past mining consist of soils with relatively small particle sizes. The arid conditions of the North Cave Hills region, results in extended annual periods where these small particles contain virtually no soil moisture. As a result, windy conditions may suspend fine solids from the exposed surface soils and disperse them along with COPCs into downwind areas. Years of USFS sediment containment and removal show that runoff from snowmelt and rain events washes contaminated soils / sediments into adjacent drainages.

All nearby drainages are presently ephemeral, having significant flow only during rain or melt events. Accordingly, there is no exposure to higher forms of aquatic life such as fish in the local drainages. However, unchecked, contaminated soils and / or sediments would likely lead to deteriorated conditions in the downgrade watershed. The COPCs in surface soil, sediments, and surface water are available for uptake into plants, wildlife, and domestic stock in the area. Accordingly, people who consume meat from locally harvested wildlife and domestic stock are likely exposed to COPCs through the food chain. Similarly, threatened and endangered species who utilize this area for seasonal or year round habitat are also likely to be exposed through this pathway.

The COPCs in surface and subsurface soils are subject to migration into underlying soils and groundwater in response to any percolation of water through surface soils. Should contamination reach groundwater, issues relating to anti-degradation and/or water quality standards would certainly arise. However, an investigation of this pathway is outside the scope of this assessment.

3.1.2 Site Use

The Sioux Range District of the U.S. Forest Service has documented the regular use patterns of the Riley Pass Uranium Mines by both members of the public and agency personnel. This information is detailed in the current Custer National Forest, Sioux Range Forest

Management Plan (USFS 2004). The following delineates the types and frequency of use documented for individual users of the site.

3.1.2.1 Cattle Ranching - Grazing Permit Holders. USFS data indicates that each permit holder spends an average of two hours per day administering his or her permit on lands managed by the USFS. The majority of them use all-terrain vehicles (ATVs) to access their permitted allotments, with two accessing primarily by horseback. The North Cave Hills land unit contains three allotments affected by historic mining activities (see Table 3-1).

Table 3-1. Site use for grazing permitees.

Permit Holder and Grazing Allotment	Season of Use	Days of Use	Hours per Day Spent Onsite	Number of Permittees on Permit	Person Hours per Year Spent on NFS Lands by Permit Holders*
Cox (contains Bluff A and part of Bluff B)	4/1 to 10/31	60	2	2	240
Pelham/Juberg (contains Bluffs C through I)	5/21 to 10/20	60	2	2	240
Schliechart (contains the rest of Bluffs B, J, K, and L)	4/1 to 10/15	60	2	1	240
Total Person Hours per Year					720

Land use data provided by USFS, Sioux Ranger District, 2006.

3.1.2.2 Range Permit Administration by Forest Service Employees. The USFS visits each permit a minimum of four times per year and spends an average of four hours on each allotment per visit. This equates to 48 person hours per year for range permit administration. The majority of these efforts are completed on foot (USFS 2004).

3.1.2.3 Recreational Hunting by General Public. The majority of hunting done in the North Cave Hills is for turkey and mule deer. Spring turkey season is open from April 10 to May 16 and fall turkey season is open October 1 through December 31. The rifle season for deer is November 20 through December 5. Because public recreation is not closely monitored by the USFS, basic assumptions were made regarding the frequency of site use. It was assumed that the majority of hunting days occur on Saturday and Sunday, and the average number of hunters using the North Cave Hills during any season is 25. Further, it was assumed that the average hunter spends four hours each day in the field and that 70% of the hunters hunt from their vehicles, while 30% hunt on foot.

Based on the above information, the total hunting days in the North Cave hills is assumed to be 43: (1) 37 during turkey season and (2) six during deer season. To be realistic in the assessment, it was also assumed that hunters use only 75% of those days in any given season. As a result, total person hours per year for hunting is estimated to be 3,225 hours. This translates to 2,257 hours spent hunting from vehicles and 968 hours spent hunting on foot. To quantify the risks to recreational hunters, the totals of 32.25 hunting days and 4 hours per trip were utilized to determine their exposure duration. [a]

3.1.2.4 Traditional Cultural Property Use by Native Americans. There are three tribes who use the site for traditional purposes. The predominant uses are foot traffic and sitting overlooking the landscape. The use is assumed to be approximately 25 hours per year by 10 people equating to 250 person hours per year.

3.1.2.5 Recreational Horseback Riding. The area in and around the site is a popular for horseback riding between May 30 and September 30. The person hour use is estimated at 4 hours every 2 weeks for one person. The total yearly use is therefore, estimated to be 32 hours.

3.1.2.6 Passports in Time Rock Art Recording Projects. This project occurs for one week each year. There are approximately 10 volunteers who camp at the Picnic Springs Campground. They identify specific bluffs to review. Once selected, the volunteers hike around the sandstone cliffs looking for undocumented rock art. Time spent viewing rock art in the field averages 6 hours a day for 5 days. Total use is estimated to be 300 person hours per year.

3.1.2.7 Incidental Recreation Visits. Incidental use of the Picnic Springs Campground occurs from April through October. The use includes camping and picnicking. It is also used heavily during hunting season. The total occupancy for the campground is 45 persons. Annual person use averages approximately 450 hours per year.

3.1.2.8 Sediment Pond Dredging. In 1997, a time and materials type contract was awarded for the removal of sediment from three sediment ponds. Removal of sediments occurs via a dredging technique. In 1997, approximately 14,000 cubic yards of sediment was removed from three ponds and transported to Bluff B. The contract duration was 45 days and work was completed in the late summer/early fall. Consequently, captured sediments were quite dry and the operation was rather dusty. Employee duties included: (1) inspectors who were required to observe the dredging from the edge of the pond; (2) truck drivers responsible for transporting the dredged material to Bluff B; and (3) quality assurance personnel responsible for documenting the number of loads hauled while sitting in their vehicles. They have been dredged twice since then and are going to be dredged again in 2004.

During the 1997 removal effort, five USFS personnel and five contract employees participated. The USFS personal spent a total of 475 documented person-hours onsite. Contractor hours were not documented; as a result, it was assumed that they worked the same number of person hours. That totals 950 person hours spent in the area by USFS and contract personnel in 1997.

3.1.2.9 Road Maintenance. In 1996, the culvert and riser at sediment pond number 5 was replaced. It was replaced again in 2002. This work involved two USFS personnel and three contract personnel. They spent approximately 200 hours onsite each year.

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a. Exposure Duration – Recreational Hunters: 43 × .75 = 32.25 hunting days used × 4 hours per day = 129 total hours

3.1.3 Exposure Pathways Selected for Quantitative Assessment

In support of quantitative risk assessment, knowledge about COPC fate and transport and knowledge about site use is integrated, to establish exposure pathways that represent the range of likely exposure(s) to COPCs. The exposure equations, numeric factors, and results of the quantitative exposure assessment for the reasonable maximum exposure (RME) pathways are presented in Appendix C and the exposure equations, numeric factors, and results of the quantitative exposure assessment for the average exposure pathways (AVE) are presented in Appendix F.

3.1.3.1 Construction Worker. Existing maintenance of the sediment ponds and area roads requires that periodic construction work be performed at the site. USFS employees and/or USFS contractors perform the work. In general, the tasks are short-term in nature, with projects requiring up to two months to complete. The nature of the work is such that high levels of dust are generated due to the operation of heavy equipment, vehicle traffic, etc. Therefore, construction workers are likely exposed to much higher levels of contamination than other receptors, but for shorter periods of time. Moreover, construction work is subject to worker health and safety laws, which provides for personal protection against hazards.

Excavation activities can create conditions much more conducive to exposure than may typically exist when soils are not being actively disturbed. Construction workers may inhale COPCs in suspended dusts. They may also be exposed to COPCs through contact with onsite surface and subsurface soils. Exposure to COPCs in soil generally occurs through incidental ingestion of soil during hand-to-mouth activity, or through dermal adsorption. A construction worker is not expected to be exposed to surface water, groundwater, or site-derived meat products during construction work.

At this time, site-specific data is limited to overburden and lignite exposed by mining. As a result, a quantitative evaluation of exposure to subsurface soils is not possible. However on the site, because mining activities have resulted in the mixing of surface and subsurface materials, it is likely that disturbed soils are of similar composition to subsurface materials. Using similar logic, stream sediments in areas where construction work would occur are likely comprised of eroded fines from mined areas. Therefore, overburden composition in mined areas is likely to be representative of sediment composition in affected downgrade drainages.

To support an estimate of a reasonable maximum exposure scenario, the construction worker is assumed to be an average-sized adult who spends 12 days at the site on a construction project. Because of the short duration and the intermittent nature of the work, exposure is not averaged over a lifetime in accordance with EPA guidance (2002). Exposure to COPCs occurs via inhalation, dermal adsorption, and incidental soil ingestion. One RME exposure scenario is presented for the construction worker because of the relatively short duration of exposure.

3.1.3.2 Permit Holder. Permit holders are adult individuals who have been issued grazing permits by the USFS to graze domestic livestock on lands administered by the USFS. It is assumed that a rancher would hold a lease for the duration of his or her working life and the majority of time spent onsite involves traveling by ATV or horseback.

While onsite, a permit holder may be exposed to windblown dusts through inhalation. They may also be exposed to onsite surface soils and sediment via dermal adsorption and incidental soil ingestion. A permit holder would rarely be involved in the types of construction activities that would result in appreciable exposure to subsurface soils. This assessment utilizes the days of use and hours per day estimates provided by the USFS (see Section 3.1.2) as the basis for quantifying exposure. A permit holder is not expected to be exposed to surface water or groundwater obtained from the site, but will regularly consume beef grazed at the site.

3.1.3.3 Recreational Visitor. A variety of recreational activities are known to occur at the site. Each is expected to provide similar levels of exposure to COPCs per unit of time-spent onsite. Recreational hunting results in the greatest duration spent onsite per year (4 hours per day, 32 days per year). Moreover, recreational hunting is expected to result in the consumption of deer that may graze onsite. Therefore, the hunting scenario serves as a reasonable worst-case exposure scenario to represent onsite recreational use. It is conservatively assumed that an individual may return to the site to participate in recreational activity of one form or another each year over the course of their adult life.

The routes of exposure for the recreational visitor are identical to the permit holder, but more limited. The recreational visitor is not expected to spend as many days onsite. Also, annual consumption of deer meat by the recreational visitor is assumed to be less than the beef consumption of the permit holder because of the smaller size of a deer and varying success rates.

3.1.3.4 Native American Site User. Exposure and risk based on Native American site use is also evaluated to provide a range of potential exposures and risks of recreational site use. In this exposure scenario, site use is assumed to occur for 1 hour per day, 25 days per year (based on the information presented in Section 3.1.2.4). The exposure assumes the receptor to be a teenager or adult to address the body weight variable in the risk calculations. The scenario further assumes the Native American receptor undergoes a moderate amount of exercise in accessing the site for traditional uses to address the inhalation rate variable in the risk calculations.

The Native American is assumed to obtain meat from locations other then the site, based on interviews with local tribes conducted by the Custer National Forest, Sioux Ranger District in 2005. The Native American is assumed to have direct contact with the soil, receiving exposure to COPCs through incidental soil ingestion, dermal absorption and inhalation. Similar to the Permit Holder, the Native American is assumed to wear long pants, short sleeve shirt, and footwear to address the exposure to skin area variable in the risk calculations.

3.2 Toxicity Assessment

This section describes the approach used to evaluate the toxic properties of COPCs. A fundamental principal of toxicology is 'dose determines the toxic properties of a contaminant'. The toxic properties of a contaminant can change depending on the dose received. Accordingly, toxicity factors (cancer slope factors for carcinogens and chronic reference doses for systemic toxins) have been developed by the EPA to support quantitative risk assessment.

This assessment applies the most current toxicity factors developed by the EPA. The slope factors and chronic reference doses used in this assessment are presented in Appendix C. The EPA toxicity factors were obtained from the Integrated Risk Information System (IRIS) at http://www.epa.gov/iris. Contaminant-specific information regarding toxicity characteristics and the basis for development of the toxicity factors are also described on IRIS.

3.2.1 Cancer Slope Factors

A cancer slope factor is the upper bound estimate of the probability of a cancer response per unit intake of a chemical averaged over a lifetime. It is derived based on the relationship of exposure (dose) to cancer rates in laboratory studies using animals or epidemiological studies, where exposure to humans has been documented. They are derived using statistical regression methods to extrapolate the observations in experimental studies to lower levels of exposure typically observed in environmental investigations such as this one. It is not conclusively known whether the relationship between dose and cancer rates observed in experimental studies is preserved when extrapolated to concentrations typical of most contaminated sites. The development and use of slope factors for risk assessment is a policy position by the EPA in the absence of complete scientific information. The slope factor is typically set at the 95% upper confidence level (UCL) of the dose-response relationship to provide a margin of safety against the unknown. However, the EPA has long acknowledged that actual toxicity may be much lower, and may be as low as zero (EPA 1986).

EPA has classified all radionuclides as Group A carcinogens (known human carcinogen) based on the emission of ionization radiation and the extensive weight of evidence provided by epidemiological studies of radiogenic cancers in humans. EPA's Office of Radiation and Indoor Air calculates radionuclide slope factors based on the unique chemical, metabolic, and radioactive properties, available in EPA (2001). Unlike slope factors for non-radionuclides, slope factors for radionuclides are characterized as central tendency estimates of the age-averaged lifetime total radiation cancer incidence, per unit intake or exposure. In other words, if a radionuclide and a non-radioactive carcinogen result in equal cancer risks, the risk attributable to the radionuclide may merit more concern.

In some cases, slope factors are available for radionuclides including the contributions from their short-lived decay products assuming equal activity contributions (i.e., secular equilibrium) (EPA 2001). Radionuclide decay chains considered explicitly in slope factors in Health Effects Assessment Summary Tables are listed in EPA (2001), which recommends using site-specific analytical data to establish the degree of equilibrium between each parent radionuclide and its decay products in the media sampled. In the case of non-equilibrium, EPA (1997a) recommends using slope factors for sub-chains or individual radionuclides.

Data have been collected at the site to evaluate the equilibrium in the uranium decay series. These have been evaluated to determine the site-specific degree of equilibrium between parent radionuclides and members of contiguous decay chains. Equilibrium has been established at the site. This information therefore, has been used to identify appropriate combinations of radionuclides and slope factor values to be used for human health risk assessment at the site (EPA 2001).

3.2.2 Chronic Reference Doses

For long-term exposure scenarios, all toxic effects other than cancer are evaluated using a reference dose approach. Unlike the cancer slope factor, implicit in the use of a reference dose is the fundamental there are concentrations, below which, no toxic effects are known to occur. Uncertainty factors are used to make toxicity factors more protective when confronted with uncertainty (e.g., extrapolating experimental results for animals to effects in people). Reference doses are developed based on both acute (short-term) and chronic (long-term) exposures. Generally, as the exposure period gets longer, the value of the chronic reference dose becomes lower relative to the acute reference dose. These toxicity factors are intended to be protective of the most sensitive adverse effect known, and provide margins of safety against the unknown.

The EPA has withdrawn the chronic reference doses for radionuclides in the IRIS database. Therefore, no chronic toxic effects are considered for radionuclides in this assessment.

3.2.3 Sub-Chronic Reference Doses

The construction worker scenario assumes an intermittent exposure - on the order of weeks. A worker may return to the site in future years. This assumption is particularly valid for this site where there are few skilled laborers locally competing for the work. If the construction work exposure is repeated, such that exposure must be considered over the duration of his/her working life, total exposure is best described as sub-chronic. The EPA defines sub-chronic exposures under Superfund as exposure lasting between two weeks and seven years (EPA 1989). Sub-chronic toxicity values available from the Health Effects Assessment Summary Tables (HEAST) (EPA 1997a) were selected for use in this assessment.

EPA has withdrawn sub-chronic reference doses for radionuclides from the IRIS database. Therefore, construction worker doses were calculated and compared to standard radiation worker allowable dose limits set for exposure on a yearly basis by the Nuclear Regulatory Commission (NRC).

3.3 Risk Characterization

This section of the report presents risk estimates by comparing exposures developed in Section 3.1 with toxicity factors presented in Section 3.2. Risk assessment results are reported to only one significant figure, consistent with an inherent level of accuracy in the prediction of risk. All supporting calculations for the risk characterization are presented in Appendix C.

3.3.1 Non-Carcinogenic Effects

For non-carcinogens, the potential for adverse health effects is determined by comparing estimated intake values (I) with threshold concentrations, called reference doses (RfDs). This is quantitatively expressed as follows:

$$\text{Hazard Quotient (HQ)} = I/RfD$$

Chemical intake (for non-radionuclides) is expressed in terms of milligrams of chemical per kilogram of body weight per day (mg/kg-day). The general equation for calculating chemical intake is:

$$\text{Intake} = \frac{\text{chemical conc.} \times \text{contact rate} \times \text{exposure frequency} \times \text{exposure duration}}{\text{body weight} \times \text{averaging time}}$$

The variable "averaging time" is expressed in days to calculate daily intake. For non-carcinogenic chemicals, intakes are calculated by averaging over the exposure duration to yield an average daily intake for the period of exposure. If intake exceeds the reference dose, the hazard quotient (HQ) will exceed 1.0, indicating a potential for adverse health effects. For simultaneous exposure to multiple chemicals (with similar toxic effects), a hazard index (HI) is calculated as the sum of chemical specific HQs.

The results indicate excess hazards for the permit holder at Bluff H and for lignite exposure. No excess hazards are predicted for the construction worker, recreational visitor, or the Native American. However, the construction worker doses for the lignite area are predicted to be 197 mrem/yr, which exceeds the NRC limit for the public based on 10 CFR 20.1301, "Dose limits for individual members of the public," of 100 mrem/yr Total Effective Dose Equivalent (TEDE). The HQ results are presented in Table 3-2.

EPA has withdrawn the RfDs for radionuclides from the Integrated Risk Information System (IRIS) database. Therefore, HQs are not presented for radionuclides in Table 3-3. To provide a frame of reference, the unprotected construction worker radiation doses were calculated and compared to standard allowable annual radiation dose limits. These limits were obtained from the NRC in 10 CFR 20.1301, "Dose limits for individual members of the public," which reports a limit of 100 mrem/yr Total Effective Dose Equivalent (TEDE).

The construction worker, if working in / with lignite would realize a direct external radiation dose of 197 mrem/yr based on 96 hours of exposure. Therefore, the construction worker would be limited to 49 hours of work in order to meet the public dose limit of 100 mrem/yr.

Native American site users would realize a dose of 43.8 mrem/yr in the lignite area based on 25 hours of exposure, which falls below the maximum allowable dose to a member of the public based on 10 CFR 20.1301, "Dose limits for individual members of the public," of 100 mrem/yr Total Effective Dose Equivalent (TEDE).

Considering exposure to arsenic in Bluff H in greater detail, the HQs for various pathways are dominated by meat ingestion. When the HQ for the Permit Holder at Bluff H is broken down by pathway, the pathway-specific HQs are: soil ingestion 0.04, dermal absorption 0.04, meat ingestion 1.02, and inhalation less than 0.00. Note that the default assumptions for this pathway are: (1) the animals derive 16.5% of their diet from grazing at the site and (2) the animals obtain 16.5% of the water they consume from impacted water at the site (Appendix C, Animal Meat Concentration Calculation).

The calculations presented in Appendix C reveal incidental soil ingestion by cattle is the major contributor to elevated COPC concentrations in meat. If the cattle surface water intake is reduced to zero in the model, the total HQ for the permit holder is reduced only marginally to 0.99. However, when the cattle's fraction of diet from grazing (which is when incidental soil ingestion occurs) is reduced to zero, the total HQ for the permit holder is reduced to 0.51.

Table 3-2. Non-carcinogenic hazard quotients.

Receptor	COPC	Bluff B	Bluff H	Lignite
Permit Holder	Arsenic	0.39	1.09	5.20
	Molybdenum	0.01	0.07	0.54
	Selenium	0.00*	0.00*	0.01
	Total	**0.4**	**1.16**	**5.75**
Recreational Visitor	Arsenic	0.07	0.19	0.93
	Molybdenum	0.00*	0.01	0.09
	Selenium	0.00*	0.00*	0.00*
	Total	**0.07**	**0.20**	**1.02**
Construction Worker[a]	Arsenic	0.00*	0.00*	0.00*
	Molybdenum	0.00*	0.00*	0.00*
	Selenium	NC	NC	NC
	Total	**0.00**	**0.00**	**0.00**
(mrem/yr)	U-238+D	1.06E–02	5.80E–02	3.93E+00
(mrem/yr)	U-234+D	1.27E–02	6.76E–02	4.43E+00
(mrem/yr)	Th-230	2.54E–02	1.39E–01	1.00E+01
(mrem/yr)	Ra-226+D	3.11E+00	1.36E+01	1.46E+02
(mrem/yr)	U-235+D	1.01E–02	5.20E–02	3.94E+00
(mrem/yr)	Pa-231	2.08E–02	1.07E–01	8.11E+00
(mrem/yr)	Ac-227+D	5.36E–02	2.76E–01	2.09E+01
(mrem/yr)	**RAD Total**	**3.24**	**1.43**	**197**
Native American	Arsenic	0.01	0.02	0.1
	Molybdenum	0.00*	0.00*	0.01
	Selenium	0.00*	0.00*	0.00*
	Total	**0.01**	**0.02**	**0.1**
(mrem/yr)	U-238+D	7.23E–03	7.11E–03	4.82E–01
(mrem/yr)	U-234+D	8.69E–03	8.36E–03	5.47E–01
(mrem/yr)	Th-230	2.02E–02	1.85E–02	1.33E+00
(mrem/yr)	Ra-226+D	7.62E–01	3.32E+00	3.58E+01
(mrem/yr)	U-235+D	2.87E–03	1.31E–02	9.94E–01
(mrem/yr)	Pa-231	5.60E–03	1.21E–02	9.16E–01
(mrem/yr)	Ac-227+D	2.67E–02	4.96E–02	3.76E+00
(mrem/yr)	**RAD Total**	**7.81E–01**	**3.42**	**43.8**

a. Doses in mrem/yr are presented since reference doses from IRIS have been withdrawn by EPA.
NC = Not calculated due to insufficient toxicity information.
*Hazard is a value smaller than two decimal places.

3.3.2 Carcinogenic Effects

For carcinogenic chemicals, an estimated excess lifetime cancer risk is calculated by multiplying chemical intake (I) by a slope factor (SF), which is the upper bound estimate of the probability of a cancer response per unit intake of a chemical over a lifetime. The mathematical expression for determining cancer risk is:

$$\text{Risk} = \text{I} \times \text{SF}$$

Chemical intake (non-radionuclide COPCs) is expressed in terms of milligrams of chemical per kilogram of body weight per day (mg/kg-day). The equation for calculating chemical intake is:

$$\text{Intake} = \frac{\text{chemical conc.} \times \text{contact rate} \times \text{exposure frequency} \times \text{exposure duration}}{\text{body weight} \times \text{averaging time}}$$

The variable "averaging time" is expressed in days to calculate daily intake. For carcinogens, intakes are calculated by averaging the total dose over a lifetime, yielding "lifetime average daily intake."

Intake of radionuclides by ingestion or inhalation is a function of radionuclide activity, intake rate (or the amount of contaminated media contacted per unit time), exposure frequency, and duration. The only difference between calculating intake for radionuclides and non-radioactive parameters is averaging time and body weight are excluded from the intake equations for radionuclides (EPA 1998a). Lifetime internal radionuclide intake is expressed in terms of activity in pico Curies (pCi). The general equation for calculating radionuclide intake is:

$$\text{Intake} = \text{radionuclide activity concentration} \times \text{contact rate} \times \text{exposure frequency} \times \text{exposure duration}$$

As with other carcinogens, radionuclide intakes are summed to yield one lifetime cancer risk estimate.

Regarding chemical spills onto soil and water, federal guidelines contained in the National Contingency Plan (EPA 1990) of "acceptable" upper bound cancer risks to protect human health, including sensitive individuals, range from 1×10^{-4} to 1×10^{-6}. This translates to a range of 1 in 10,000 to 1 to a 1,000,000 probability of a person developing cancer due to a lifetime of exposure to a carcinogen.

EPA (1989) recommends that two separate sets of risk estimates be tabulated: 1) one for radionuclide COPCs and 2) one for non-radionuclide COPCs. This recommendation is made because the methodology used to derive SFs for radionuclides is different than that used to derive SFs for non-radionuclides. Therefore, cancer risks are presented two ways in this risk assessment: (1) cancer risks from radionuclides and non-radionuclide COPCs were summed to yield a single estimate of cancer risk and (2) cancer risks for the two types of COPCs were presented separately.

Risk results are summarized in Table 3-3. The results indicate that unacceptable excess risks exist at the site under reasonable maximum exposure assumptions for the grazing permit holder (see Section 3.1.3.2), the recreational visitor (see Section 3.1.3.3) and the Native American (see Section 3.1.3.4). Recall the construction worker was not evaluated for carcinogenic risk due to the limited duration of exposure (Section 3.2.3).

To further understand the source of these risks, consider exposure to arsenic at Bluff H (also see Table 3-4). For the Native American, the risk estimate (5×10^{-6}) modestly exceeds the comparison criteria of 1×10^{-6}, with the risks derived nearly equally from soil ingestion and dermal absorption exposure pathways (see Table 3-4). Similarly, for both the permit holder and the recreational visitor, the soil ingestion and the meat ingestion pathways result in risk estimates exceeding 1×10^{-6}. As described in Section 3.3.1, COPC concentrations in meat are most strongly influenced through the incidental consumption of impacted soil during grazing.

To further understand the source of risks associated with radionuclides, consider exposure at Bluff H also (see Table 3-5). For both the permit holder and the recreational visitor, the meat ingestion pathways result in risks exceeding 1×10^{-6}. In addition, when meat consumption is not considered in the radionuclide risk calculations, the soil ingestion, inhalation, and external exposure pathways still present cancer risks for both the permit holder and the recreational hunter that exceed 1×10^{-6}.

Table 3-3. Human health carcinogenic risks.

Receptor	COPC	Bluff B	Bluff H	Lignite
Grazing Permit Holder	U-238+D	4.E–07	2.E–06	1.E–04
	U-234+D	3.E–07	1.E–06	1.E–04
	Th-230	2.E–07	1.E–06	8.E–05
	Ra-226+D	7.E–06	3.E–05	3.E–04
	Pb-210+D	2.E–05	7.E–05	8.E–04
	U-235+D	2.E–08	1.E–07	9.E–06
	Pa-231	3.E–07	2.E–06	1.E–04
	Ac-227+D	7.E–08	4.E–07	3.E–05
	RAD Total	**2E–5**	**1E–4**	**2E–3**
	Arsenic	**7E–5**	**2.E–4**	**1E–3**
	Grand Total	**9E–5**	**3E–4**	**3E–3**
Recreational Visitor	U-238+D	2.E–07	1.E–06	7.E–05
	U-234+D	1.E–07	7.E–07	4.E–05
	Th-230	2.E–07	8.E–07	6.E–05
	Ra-226+D	4.E–06	2.E–05	2.E–04
	Pb-210+D	3.E–06	1.E–05	2.E–04
	U-235+D	2.E–08	8.E–08	6.E–06
	Pa-231	5.E–08	3.E–07	2.E–05
	Ac-227+D	7.E–08	4.E–07	3.E–05
	RAD Total	**8E–6**	**3E–5**	**6E–4**
	Arsenic	**1E–5**	**4E–5**	**2E–4**
	Grand Total	**2E–5**	**7E–5**	**8E–4**
Native American	U-238+D	2.E–08	8.E–08	6.E–06
	U-234+D	6.E–09	3.E–08	2.E–06
	Th-230	9.E–09	5.E–08	3.E–06
	Ra-226+D	6.E–07	3.E–06	3.E–05
	Pb-210+D	9.E–08	4.E–07	4.E–06
	U-235+D	2.E–09	1.E–08	8.E–07
	Pa-231	1.E–09	6.E–09	5.E–07
	Ac-227+D	8.E–09	4.E–08	3.E–06
	RAD Total	**7E–07**	**3E–06**	**5E–05**
	Arsenic	**2E–6**	**5E–6**	**2E–5**
	Grand Total	**3E–6**	**8E–6**	**7E–5**

Table 3-4. Pathway-specific human health carcinogenic risks for arsenic exposure at Bluff H.

Pathway	Permit Holder	Recreational Visitor	Native American
Soil Ingestion	7E–6	8E–6	2E–6
Dermal Absorption	7E–6	4E–6	3E–6
Meat Ingestion	2E–4	3E–5	NA
Inhalation	1E–8	1E–8	2E–9

FSW = Fraction source impacted water.

NA = Not Applicable to the Native American exposure scenario.

Table 3-5. Pathway-specific human health carcinogenic risks for radionuclides at Bluff H.

Pathway	Permit Holder	Recreational Visitor	Native American
Soil Ingestion	1E–5	1E–5	6E–7
Meat Ingestion			NA
FI[a] 10%	8E–6	1E–6	NA
FI[a] 50%	4E–5	5E–6	NA
FI[a] 100%	8E–5	1E–5	NA
Inhalation	4E–7	4E–7	2E–8
External	1E–5	1E–5	2E–6

a. FI = Fraction ingested from site.

NA – Not applicable to the Native American exposure scenario.

3.4 Uncertainty Assessment

In accordance with EPA guidance (1989), this section identifies uncertainty and variability associated with this assessment. Uncertainty refers to factors for which, there is little or no information (such as soil ingestion rates or diet to meat transfer coefficients for wildlife), while variability refers to factors with inherent ranges of values that are estimated using a single value (such as receptor body weight).

Each of the exposure and toxicity factors used in this assessment has inherent uncertainty and variability. All of the procedures, models, and related assumptions used in this risk assessment are routinely used in human health and environmental risk assessments today. While uncertainty in estimating risk exists, adhering to EPA guidelines provides a streamlined approach for risk estimation comparable to those used at other sites, and it allows for a consistent basis for decision-making. The approach uses a mix of average and upper-end estimates for exposure and toxicity in the calculations, in order to provide a reasonable maximum estimate (RME) of risk. The RME risks estimated in this assessment likely occur within the 90th to 99.9th percentile of risk for the surrounding community.

The majority of exposure and toxicity factors used in this assessment are based on detailed EPA review of the scientific literature. Developing site-specific factors would be time-consuming and expensive. Those factors used in this risk assessment that can be made more site-specific through additional field studies include:

- **More Detailed Estimates of Site Use and Exposure**—What percentages of time do humans, cattle, or consumable wildlife spend on impacted versus non-impacted areas? It is recognized that the severe physical disturbance of the site and reduced forage availability in impacted areas presently serves to minimize exposure. Consideration of these factors is not appropriate when evaluating the baseline risks (i.e., risks in the absence of institutional controls or other remedies). Instead conditions at the site are considered as if routine efforts to contain and control contamination are not in place to determine what effect this would have on the environment.

- **Site-Specific Bioavailability and/or Diet-to-Meat Biotransfer Factors**—Many site-specific factors can control bioavailability, such as competing ions in the diet, overall animal health, quality of graze, and others. A range of options exists for gaining site-specific bioavailability information involving either laboratory or field studies.

- **Improved Understanding of the Degree and Extent of Contamination**—Additional data would improve the understanding of contaminant distribution within and surrounding the mine impacted areas. Large sample sizes would also reduce uncertainty regarding upper confidence limit estimates of average concentrations.

3.5 Summary and Conclusions

This human health risk assessment evaluates land uses in and around the site by recreational visitors, construction workers, and grazing permit holders. To supplement this assessment, additional data was acquired from the site to provide a more complete look at contamination distribution and variability. To that end, Bluff B was selected as past studies indicated it generally contains the lowest levels of COPCs. Similarly, Bluff H was selected as past studies indicated it generally contains highest levels of COPCs. In addition, during planning for the supplemental investigation it was concluded that prior investigations and data evaluation efforts, had sufficiently demonstrated that only a portion of the constituents identified in mine wastes should be considered COPCs. As a result, data was gathered only for these metals and radionuclides.

This assessment does not consider risks resulting from direct human consumption of potentially impacted groundwater or surface water. Also, risks at off-site locations resulting from wind-dispersion of contaminated mine wastes were not evaluated. The findings of the human health risk assessment are detailed below.

3.5.1 Risk Summary

For those pathways with unacceptable risk levels, arsenic is the primary risk driver. The carcinogenic risk from radionuclides is approximately an order of magnitude less. However, radionuclide risks for all scenarios are generally above the 1×10^{-6} carcinogenic risk guideline.

3.5.2 Construction Worker Scenario

No elevated risks for onsite construction workers are identified for chemicals. However, the construction worker dose if working with lignite (197 mrem/year), would result in an unacceptable dose to a member of the public based on 10 CFR 20.1301, "Dose limits for individual members of the public," of 100 mrem/yr Total Effective Dose Equivalent.

3.5.3 Arsenic Risks

Unacceptable carcinogenic risks and non-carcinogenic hazard quotients are identified for the Native American, recreational visitor and grazing permit holders for arsenic. Considering all exposure pathways and depending on where exposure occurs (Bluff B, Bluff H, or Lignite), carcinogenic risks ranged from 3×10^{-6} to 3×10^{-3}. The non-carcinogenic hazard quotients range from 0.01 for Native American exposure at Bluff B to 5.75 for Permit Holder exposure to lignite.[b]

Consumption of meat products (beef and deer) is estimated to provide the greatest exposure for arsenic in the Permit Holder and Recreational Visitor scenarios. For example, the total risk from all exposure pathways to arsenic at Bluff H for the permit holder is 2×10^{-4} (Table 3-3). As shown in Table 3-4, nearly all of this exposure is attributed to the meat ingestion pathway. The estimate of exposure via meat ingestion is based on EPA's upper-end estimate of the amount of meat consumed by an individual, and assumes that the all meat consumed is site-derived. The COPC concentrations in meat are dominated by incidental ingestion of contaminated soil during grazing.

Predicted risks from exposure to soil remain high even if the meat pathway is ignored. As shown for arsenic in Table 3-5, dermal absorption and incidental ingestion of soil during site use are also predicted to result in risks that exceed a 1×10^{-6} acceptable carcinogenic risk level for Native Americans, recreational visitor and grazing permit holders under the reasonable maximum exposure assumptions.

3.5.4 Radionuclide Risks – Permit Holder and Recreational Visitor

Carcinogenic risks from radionuclides ranged from 2×10^{-3} to 2×10^{-5} for the permit holder and 6×10^{-4} to 8×10^{-6} for the recreational visitor. The highest carcinogenic risks were obtained for the lignite areas. Cancer risks determined for Bluff H were found to be

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b. A hazard quotient greater than 1 indicates a potential for adverse effects from exposure. In the case of arsenic, the critical effect (i.e., the lowest observed adverse effect level upon which the reference dose is based) is hyper-pigmentation (abnormally increased skin coloration), keratosis, and possible vascular complications. The degree of hazard does not increase linearly as the hazard quotient exceeds 1; a hazard quotient of 2 does not imply twice as much hyper-pigmentation as a hazard quotient of 1; and as the exposure increases there is a potential for other toxic effects other than those listed as the critical effect. Lastly, lack of an observed toxic effect among Permit Holders does not necessarily imply that the risk assessment is incorrect. As explained in the Uncertainty Assessment, Section 3.4, this assessment assumes that cattle and Permit Holders are actively using the mine impacted areas as if the land were fully functional. Due to the physical qualities of the mine impacted soils and possibly the chemical quality of the soil, little vegetation and poor water quality occur throughout much of the area evaluated in this assessment. Therefore, actual exposure is perhaps much less than the potential exposure estimated in this assessment.

approximately an order of magnitude higher than those for Bluff B. In all scenarios, the total carcinogenic risk from radionuclides exceeds 1×10^{-6}.

3.5.5 Radionuclide Risks – Native American Site Users

Elevated carcinogenic risks were also noted for Native American users from radionuclide exposure in the lignite area (5×10^{-5}). Elevated carcinogenic risks were also noted due to contact with Bluff H overburden (3×10^{-6}). No excess risk was found for Native American users due to contact with Bluff B overburden with risks measured at 7×10^{-7}.

3.5.6 Physical Hazards – Site Wide

In addition to the risks from chemical exposure, the site also presents physical hazards for site users from unstable slopes and soil piping. Field observations gathered during the 2004 field investigation indicate the potential for permit holders, recreational visitors, and USFS workers to be injured or suffocated via the collapse of unstable highwalls and / or overburden piles. In addition, site users are also at risk for trip and fall hazards in areas of soil piping, and through unstable soil and rock formations influenced by historic mining. While there are not numeric means to estimate the risks to site users, historically mined areas do present obvious physical hazards in a number of areas. In the absence of institutional controls or permanent remedies, access to these hazards is unrestricted.

4. ECOLOGICAL RISK ASSESSMENT

This ecological risk assessment is organized in accordance with EPA Ecological Risk Assessment Guidance (1998a). The ecological risk assessment for chemicals is presented in Section 4.1. Several aspects of the chemical ecological risk assessment apply to radionuclides. However, radionuclides are unique in terms of ecological risk, as ecological risks are based solely on dose standards. Therefore, the ecological risk assessment for radionuclides is presented separately in Section 4.2.

4.1 Chemical Ecological Risk Assessment

An ecological risk assessment includes three primary phases:

- Problem formulation
- Analysis
- Risk characterization.

Section 4.1.1 describes the ecological setting, selects assessment endpoints, and presents the ecological conceptual site model. The analysis phase consists of two parts: (1) the exposure assessment and (2) toxicity assessment. The exposure assessment (Section 4.1.2) quantitatively evaluates exposure to COPCs. It is expressed in terms of dose, with units of milligrams of chemical taken in, per kilogram of body weight, per day (mg/kg-day). Section 4.1.3 presents the ecological toxicity assessment. It outlines species-specific measures of toxicity for each COPC, with the toxicity results being comparable to dose.

Risks are calculated by comparing exposure under the various exposure scenarios to toxicity (Section 4.1.4). The uncertainty assessment (Section 4.3), addresses the more qualitative aspects of ecological effects. The summary and conclusions (Section 4.4) integrate both the quantitative and qualitative aspects of the assessment to support informed risk management decision-making.

4.1.1 Problem Formulation

The objective of problem formulation is to identify meaningful ecological criteria in terms of decision-making for the site. Natural ecosystems are affected by a complex array of physical, chemical, and biological conditions and interactions. Such complexity can confound the ability to conclusively demonstrate causality for individual biological or ecological stress factors. In other words, just because arsenic is demonstrated to be toxic to certain organisms in the laboratory does not mean that ecological effects will be readily observable in the environment upon exposure. In contrast to human health assessment, where excess risk to an individual is important, ecological risk assessment is more concerned with maintaining general ecosystem health and productivity.

This assessment provides a brief description of the dominant habitat in and around the site. It forms the basis for selecting representative species for quantitative analysis. Also presented are the food web relationships between various species and the rationale for selecting food web pathways for the quantitative assessment. By selecting representative species and inter-relationships from the broader regional ecology, this assessment strives to identify the potential effects to general ecosystem health and productivity.

4.1.1.1 Habitat Description. The North Cave Hills area is predominantly a short and mid-grass prairie. The various slopes and draws formed by the rimrock hills create scattered hardwood and ponderosa pine forest habitats. Antelope, deer, grouse, turkey, coyotes, red fox, various raptors, songbirds, and reptiles are examples of the types of animals found in the area. All drainages contacting the site are ephemeral. The area does contain numerous seeps, which can create small areas of wet soils. A reservoir that presently captures drainage from Schleichart Draw reportedly contained trout prior to mining (Pioneer 2002). Threatened and endangered species in the area are:

- American burying beetle
- Bald eagle
- Black-footed ferret
- Eskimo curlew
- Gray work
- Least tern
- Peregrine falcon
- Piping plover
- Whooping crane.

Additional sensitive species including plants, insects, and birds also likely reside in the area.

4.1.1.2 Species and Food Web Relationships Selected for Quantitative Assessment. Figure 4-1 presents a food web for the terrestrial area around the site. The various guilds (e.g., carnivorous mammals) and food web relationships are based on the short-grass prairie model developed by EPA (1999; Figure 4-3). The example species are based on a general understanding of species common to the North Cave Hills.

The food web provides a summary of the various species that could be evaluated. The selection of species and food web pathways for quantitative evaluation in this assessment is based on the following:

- Selecting species representative of the range of species and guilds that likely exist at the site.

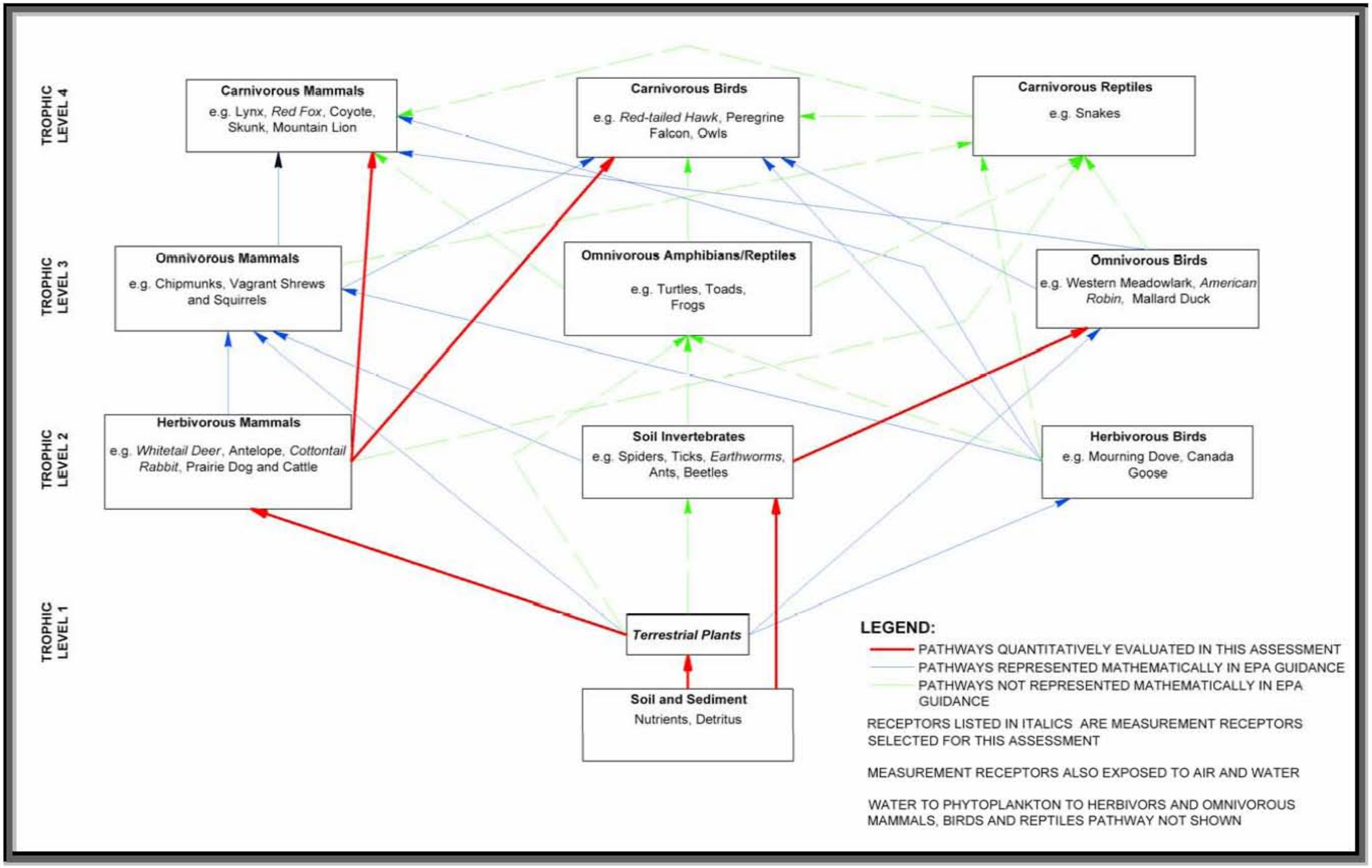

Figure 4-1. A food web for the terrestrial area around the site.

- Selecting species for which there is sufficient exposure and toxicity information to support quantitative analysis. Note that reptiles were not selected for quantitative assessment because there are limited data to support an evaluation of risk to these organisms. Also note that no example species are listed for terrestrial plants. This reflects the fact that species-specific toxicity information is not available for plants. Most plant toxicity information is obtained from studies conducted on agricultural crops.

- Consideration for rare species, species of special economic value, or species of interest to the general public. The deer was selected in addition to rabbits to represent herbivorous mammals, in part because of public interest in maintaining the health of game species. Also, the deer is potentially more susceptible to adverse effects from exposure to COPC because it is much larger than the rabbit (see toxicity factor discussion in Section 4.1.3).

- Consideration for organisms in higher trophic levels to account for bioconcentration and bioaccumulation of COPCs. Bioconcentration refers to the ratio of COPC in animal foods to the concentrations in environmental media. Bioaccumulation refers to the magnification of chemical concentrations in organisms the food chain. Each is considered separately as outlined below.

    - Bioaccumulation is not accounted for in this assessment (e.g., herbivorous mammal to omnivorous mammal to carnivorous mammal and/or carnivorous birds). Incorporation of this pathway would not result in higher quantitative estimates of risk to Trophic Level 4 species. The metals of potential concern in this assessment do not have bioaccumulation tendencies. EPA (1999) guidance has evaluated bioaccumulation potential based on the log Kow (octanol/water partition coefficient) of a chemical. The COPCs in this assessment all have Kows of less than 1 (RAIS 2004). Kows in this range correlate with food chain multipliers of 1.0, meaning there is no adjustment given to biomagnification. The inclusion of additional receptors and exposure pathways specifically for evaluating ecological exposure would further complicate the assessment without adding meaningful information.

    - To minimize unnecessary complexity in the evaluation of bioconcentration, only a subset of the food pathway models available from EPA guidance is included in this assessment. This approach is based on the fact an organism can only eat a fixed quantity of food per day. If, as assumed in this assessment, all of the fox's diet is proportioned to the rabbit, then it would not be correct to also consider exposure through consumption of robins. This exposure assessment uses bioconcentration factors provided in EPA guidance (1999) to estimate body burdens of species (e.g., ingested prey hazard index assessment for the red-tailed hawk).

4.1.2 Exposure Assessment

Figure 4-2 provides a conceptual site model illustrating the fate and transport of chemicals in the environment upon release from the site. Refer to Section 3.1.1 for a qualitative description of the transport pathway and affected media. Appendix D provides the numeric exposure factors and risk calculations based on Bluff H soil concentrations.

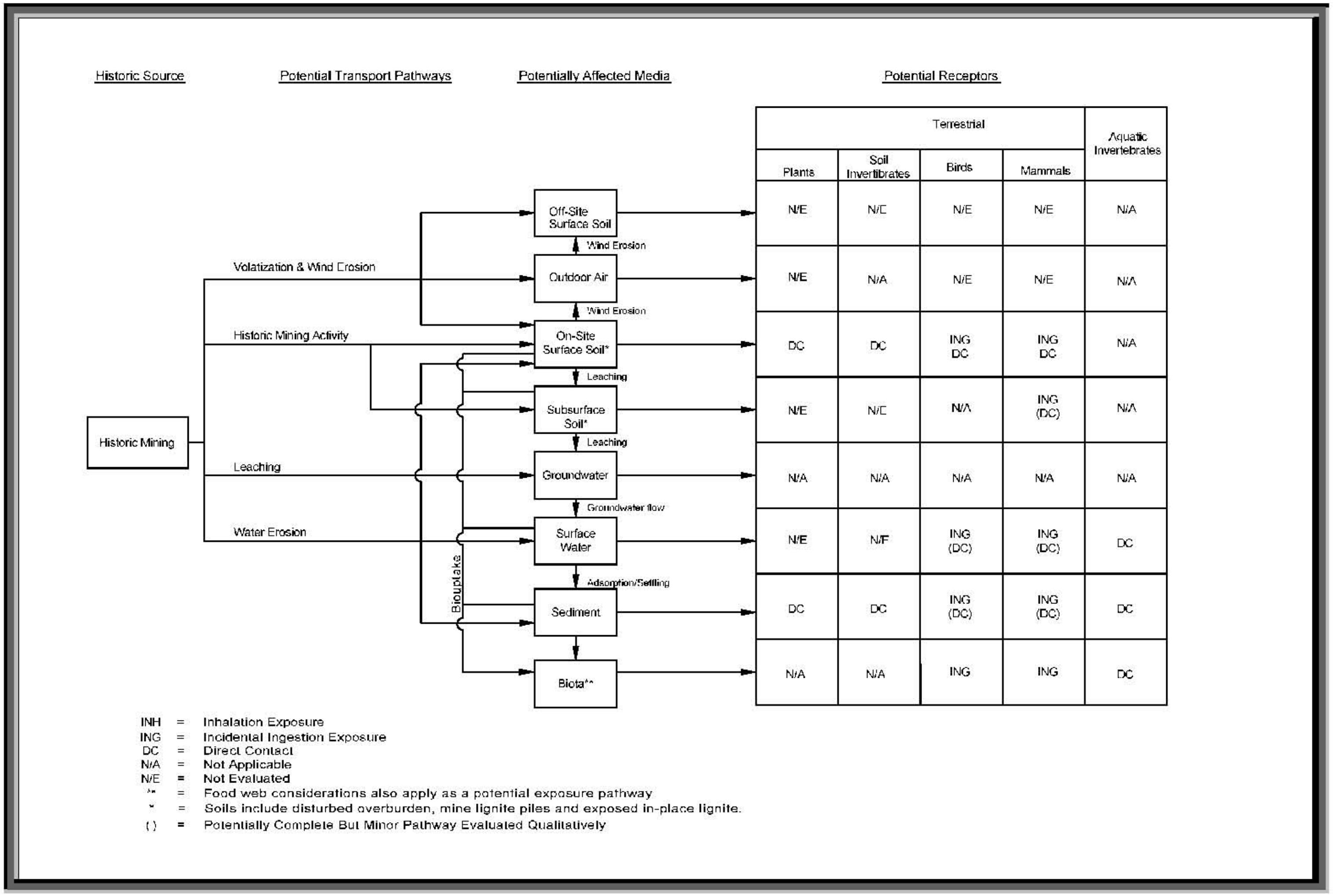

Figure 4-2. Ecological exposure pathways.

This assessment does not consider several potentially complete exposure pathways. A summary follows.

- COPCs in soil/solids may be dispersed into air exposing ecological organisms via inhalation. However, this pathway is not evaluated due to insufficient wildlife inhalation toxicity information. This is consistent with EPA guidance (1999).

- Exposure to off-site surface soils potentially impacted by the windblown dust is not evaluated. Rather the assessment focuses on soil concentrations at Bluff H, which is thought to be the bluff with the highest COPC concentrations, and Bluff B, which is thought to be the bluff with the lowest COPC concentrations.

- Impacts to groundwater are not evaluated as there is limited groundwater information available for the site. While wildlife would not have direct contact with groundwater, wildlife may be exposed to elevated COPCs in groundwater where it daylights in seeps.

4.1.2.1 Terrestrial Plants and Soil Invertebrates. Terrestrial plants and invertebrates are principally exposed to COPCs via direct contact with soil. Risks are characterized by direct comparison of onsite soil quality with species-appropriate soil quality criteria. This assessment does not consider additional toxicity associated with unusually dusty conditions and direct contact with above ground foliage. Onsite sediments are assumed to be materials washed down from the mined area, and therefore, are assumed to be of similar composition.

4.1.2.2 Birds and Mammals. Birds and mammals may be exposed to COPCs in onsite surface soils via ingestion of soil and direct contact with soil. Burrowing mammals may also be exposed to COPCs in subsurface soils. Birds and mammals may be exposed to impacted surface water and sediments. Dermal absorption values for wildlife are not available to support a quantitative assessment of exposure to soils and water. Therefore, these exposure pathways can only be considered qualitatively. It is generally thought that wildlife exposure via dermal absorption is limited due to the protective nature of fur or other wildlife skin protective layers.

Birds and mammals can be exposed to COPCs that bioconcentrate or bioaccumulate in organisms. See Section 4.1.2 for further information. Mammals and birds would be expected to have home territories of varying sizes depending on the species and habitat quality. A detailed consideration of the duration different organisms may spend onsite was not attempted in this assessment for the following reasons:

- The species selected for quantitative analysis are representative of a diversity of wildlife types, each with different home ranges. A thorough evaluation of home ranges for area species and consideration for how this affects selection of species for quantitative assessment was not performed.

- The mining impacts encompass many buttes and drainages over a large area. Also, there is a general lack of information regarding soil quality between the buttes, which may be impacted by wind dispersion of dust.

4.1.2.3 Aquatic Invertebrates. Aquatic invertebrates are expected to exist in some seep areas, area reservoirs, and ponds. Risks to aquatic invertebrates are evaluated by direct comparison of site-specific water quality data to benchmark criteria. No new surface water quality data was collected to support this risk assessment. Instead, the assessment of risks to aquatic invertebrates in this report is based on data collected during previous investigations (see Section 2 and Table 2-5).

4.1.3 Toxicity Assessment

Assessment of ecological toxicity involves considerable variability. There are multiple sources of toxicity values, with the source changing depending on the media and species of concern. The approach of this toxicity assessment is to assess toxicity in two ways - to provide a more diverse prospective on potential ecological toxicity and risk. A screening level-type assessment is provided in Section 2. It involves a comparison of predicted media concentrations to media standards. Also, toxicity reference dose values are selected for use in this more rigorous site-specific ecological risk assessment.

4.1.3.1 Media Standards. Tables 2-4 through 2-6 present predicted media concentrations and compare them to routine detection limits, average background concentrations, and a selection of screening level criteria. Some screening criteria are specific to certain types of species, such as plants or invertebrates. Other criteria apply to terrestrial systems in general, considering all trophic levels. The intent behind these more general screening level values is to base the standard on the exposure pathway (e.g., shrew) that provides the lowest soil concentration. Similarly, standards for plants are based on those species, among those tested that are more sensitive to the chemical of concern. Using this approach, the standard is generally thought to be protective of plants. The basis (i.e., type of organism) for developing the standards is listed in the tables. Here this information is provided with the published standard.

Screening level criteria are not regulatory standards to be complied with, nor are they a definitive measure of ecological harm. They are generally used as a method for identifying a potential for harm and the need for more detailed evaluation.

4.1.3.2 Toxicity Factors. The evaluation of risk to plants, terrestrial invertebrates, and aquatic invertebrates involves a direct comparison to media standards. This approach is identical to the media standards approach described above, except only a single toxicity factor is used in the hazard assessment. It is often, but not always, one of the values provided in the media comparison tables (see Tables 2-4 through 2-6).

The evaluation of risk to birds and terrestrial animals is based on calculations of dose from exposure to COPCs in water, soil, and diet. Toxicity reference values based on dose (i.e., milligrams taken into the body) are used to support this kind of assessment. Toxicity factors are generally derived from toxicity studies conducted in a laboratory. Toxicity information is rarely available for the species of interest. Moreover, the toxicity data supporting the standard may include: no observed effect levels, lowest observed effect levels, median lethality levels, or other types of data. EPA guidance (1998a, 1999) establishes protocols for the selection of preferred toxicity data and the selection of uncertainty factors. Uncertainty factors are used for species extrapolations and when extrapolating no observed effect levels from other kinds of data.

Additional protocols have been developed for adjusting toxicity reference values based on body weight (Sample, Opresko, and Sutter II 1996). Using this approach, toxicity factors are lowered for species with larger body weights. According to Sample, Opresko, and Sutter II, "Smaller animals have higher metabolic rates and are more resistant to toxic chemicals because of more rapid rates of detoxification."

The toxicity reference values used in this assessment were obtained from Sample, Opresko, and Sutter II (1996). This source has reviewed the literature for appropriate selection of toxicity studies and applied the appropriated uncertainty and body weight correction factors. The toxicity reference value for cattle was not provided by Sample, Opresko, and Sutter II, and was calculated as part of this assessment. A summary of the selected toxicity reference values is provided in Appendix D, Toxicity Reference Values for Birds and Mammals. Additional supporting information regarding chemical toxicity to ecological organisms is provided in Appendix E.

EPA guidance (1999) does not include exposure or toxicity assessment via inhalation because adequate data to support inhalation toxicity assessment for wildlife species have not been developed. Therefore, this assessment does not assess the inhalation pathway. Generally, exposure received from inhalation is expected to be much lower than exposure estimated for other pathways.

4.1.4 Risk Characterization

This section of the report presents risk estimates by comparing exposures developed in Section 4.1.2 with toxicity factors presented in Section 4.1.3. For ecological risk assessment, the potential for adverse health effects is determined by comparing estimated intake values (I) with threshold concentrations, called toxicity reference values (TRVs), below which no adverse effects are expected to occur. This is quantitatively expressed as follows:

$$HQ = I/TRV$$

If intake exceeds the TRV, then the HQ will exceed 1.0, indicating a potential for adverse effects. For simultaneous exposure to multiple chemicals with similar toxic effects, an HI is calculated as the sum of chemical-specific HQs. Risk assessment results are reported to only one significant figure, consistent with an inherent level of accuracy in the prediction of risk. The HQ results are presented in Table 4-1. Calculations supporting the derivation of the HIs are provided in Appendix D.

Table 4-1 indicates broad-scale potential health hazards to all species for both Bluff B and Bluff H. Only the avian carnivore HI for Bluff B is less than 1.0. Accordingly, HIs for lignite also greatly exceed 1.0. While the hazard index is a convenient method for reviewing the magnitude of potential risks across multiple COPCs, it may not be relevant toxicologically because of the different mechanisms of toxicity for each COPC. This assessment does not evaluate the mechanisms of toxicity for each COPC and species. Table 4-1 provides a more comprehensive look at the HQs for Bluffs H and B. The data illustrates that only a single species (avian carnivore) has a HQ less than 1.0.

Table 4-1. Non-carcinogenic hazard quotients for ecological receptors.

COPCs	Terrestrial Plants	Terrestrial Invertebrates	Small Herbivores (Rabbit)	Large Herbivores (Deer)	Avian Carnivores (Hawk)	Mammalian Carnivores (Fox)	Avian Omnivores and Herbivores (Robin)	Cattle
Bluff H								
Arsenic	5.E+01	8.E+00	3.E+02	7.E+01	9.E–01	3.E+01	1.E+01	2.E+01
Molybdenum	3.E+02	NC	7.E+01	2.E+01	6.E–03	2.E+01	6.E+00	7.E+00
Selenium	2.E+00	2.E–02	2.E–01	7.E–02	1.E–01	4.E–02	9.E–01	3.E–02
Total	4.E+02	8.E+00	4.E+02	9.E+01	1.E+00	4.E+01	2.E+01	3.E+01
Bluff B								
Arsenic	2.E+01	3.E+00	1.E+02	2.E+01	3.E–01	1.E+01	5.E+00	8.E+00
Molybdenum	2.E+01	NC	5.E+00	2.E+00	4.E–04	1.E+00	5.E–01	6.E–01
Selenium	2.E+00	3.E–02	3.E–01	9.E-02	1.E–01	5.E–02	1.E+00	4.E–02
Total	4.E+01	3.E+00	1.E+02	3.E+01	5.E–01	1.E+01	7.E+00	8.E+00
Lignite								
Arsenic	2.E+02	4.E+01	1.E+03	3.E+02	4.E+00	1.E+02	7.E+01	1.E+02
Molybdenum	2.E+03	NC	5.E+02	2.E+02	5.E–02	1.E+02	5.E+01	6.E+01
Selenium	1.E+02	1.E+00	1.E+01	4.E+00	7.E+00	2.E+00	6.E+01	1.E+00
Total	3.E+03	4.E+01	2.E+03	5.E+02	1.E+01	3.E+02	2.E+02	2.E+02

NC = Not calculated, toxicity reference value unavailable.

The calculations presented in Appendix D allow the results to be reviewed by route of exposure (i.e., soil ingestion, food ingestion, or water ingestion). A review of Appendix D indicates that the dominant route of exposure varies by species, but the soil ingestion or food ingestion typically results in the greatest levels of exposure.

Cattle toxicity is predicted to be greatest for the soil ingestion route of exposure, followed by forage ingestion, then water ingestion. This assessment does not account for percent of diet derived from non-forage sources or time spent onsite.

4.2 Radionuclide Ecological Risk Assessment

The radionuclide results for surface material were screened against media-specific biota concentration guides (BCGs) from the current DOE Biota Dose Assessment Committee (BDAC) *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (USDOE 2000). The DOE graded approach includes a generally conservative screening where maximum exposure concentrations are compared with BCGs.

4.2.1 Protection Standards

The DOE technical standard provides a graded approach that can be used to meet the dose limits for protection of biota developed or discussed by the National Council on Radiation Protection (NCRP) [1991] and International Atomic Energy Agency (IAEA) [1992]. Accordingly, this technical standard uses the biota dose limits specified below within a graded approach to demonstrate that populations of plants and animals are adequately protected from the effects of ionizing radiation:

- **Aquatic Animals—**The absorbed dose to aquatic animals should not exceed 1 rad/d (10 mGy/d) from exposure to radiation or radioactive material releases into the aquatic environment.

- **Terrestrial Plants—**The absorbed dose to terrestrial plants should not exceed 1 rad/d (10 mGy/d) from exposure to radiation or radioactive material releases into the terrestrial environment.

- **Terrestrial Animals—**The absorbed dose to terrestrial animals should not exceed 0.1 rad/d (1 mGy/d) from exposure to radiation or radioactive material releases into the terrestrial environment.

4.2.2 Standards Background Information

The IAEA (1992) summarizes the effects of acute ionizing radiation on terrestrial organisms. Key effects include:

- Reproduction (encompassing the processes from gametic formation through embryonic development) is likely to be the most limiting endpoint in terms of survival of the population.

- Lethal doses vary widely among different species, with birds, mammals, and a few tree species being the most sensitive among those considered.

- Acute doses of 10 rad (100 mGy) or less are very unlikely to produce persistent and measurable deleterious changes in populations or communities of terrestrial plants or animals.

The IAEA (1992) also summarizes the effects of chronic radiation on terrestrial organisms:

- Reproduction (encompassing the processes from gametogenesis through embryonic development) is likely to be the most limiting endpoint in terms of population maintenance.

- Sensitivity to chronic radiation varies markedly among different taxa; certain mammals, birds, reptiles, and a few tree species appear to be the most sensitive.

- In the case of invertebrates, indirect responses to radiation-induced changes in vegetation appear more critical than direct effects.

- Irradiation at chronic dose rates of 1 rad/d (10 mGy/d) or less does not appear likely to cause observable changes in terrestrial plant populations.

- Irradiation at chronic dose rates of 0.1 rad/d (1 mGy/d) or less does not appear likely to cause observable changes in terrestrial animal populations. The assumed threshold for effects in terrestrial animals is less than that for terrestrial plants, primarily because some species of mammals and reptiles are considered to be more radiosensitive.

- Reproductive effects on long-lived species with low reproductive capacity may require further consideration.

The NCRP and IAEA conclude for aquatic organisms and the IAEA concludes for terrestrial organisms, that the statement by the ICRP (1977, 1991), "...if man is adequately protected, then other living things are also likely to be sufficiently protected," was reasonable within the limitations of the generic exposure scenarios examined.

4.2.3 Media-Specific Biota Concentration Guides

The equations and models used for the graded approach to estimate the dose per unit concentration of radionuclides in environmental media and for deriving the BCGs are also applicable to individual organisms. However, there are questions concerning the applicability of the biota dose limits to individual organisms. While the biota dose limits were derived based on dose-responses for the most radiosensitive species studied, and taking into account the most radiosensitive life stages, the question of whether these dose limits can be applied to protect individual members of a species, in contrast to protection of populations of species, requires further consideration. That is, for individual plants and animals, especially threatened and endangered species, the health effects of concern could be different from the effects of concern in protect populations.

The BCGs have been derived for terrestrial plants and animals exposed to a range of radioactive isotopes in surface material/sediment (pCi/g). Each radionuclide-specific BCG represents the limiting radionuclide concentration in an environmental medium that would not result in recommended dose standards being exceeded (DOE 2000). Therefore, overall exposure is the sum of exposures to surface material. Site-related isotopes in surface soil were compared with the corresponding terrestrial plant and animal BCGs using a sum-of-fractions approach. The BCGs for plants exposed to radionuclides in surface material and water are presented in Table 4-2. The BCGs for terrestrial animals are presented in Table 4-3.

Table 4-2. Biota concentration guides for use in terrestrial plant system evaluations.

Radionuclide	Biota Concentration Guides	
	Soil (pCi/g)	Water (pCi/L)
Ra-226	3E+02	1E+07
U-234	5E+04	3E+09
U-235	3E+04	1E+08
U-238	2E+04	5E+07
Source: U.S. Department of Energy 2002 (adapted from Table 7.3)		

Table 4-3. Biota concentration guides for use in terrestrial animal system evaluations.

Radionuclide	Biota Concentration Guides	
	Soil (pCi/g)	Water (pCi/L)
Ra-226	5E+01	8E+03
U-234	5E+03	3E+05
U-235	3E+03	5E+05
U-238	2E+03	5E+05
Source: U.S. Department of Energy 2002 (adapted from Table 7.4).		

4.2.4 Ecological Risk from Radionuclides

The 95% UCL concentrations for the site soils are compared to the generic BCGs. Each bluff area and the combined lignite data are used for comparison purposes. Historical surface-water concentrations were only obtained for Ra-226 and U-235, with maximum observed values of 16 pCi/L and 3 pCi/L, respectively. The water BCGs are much greater than the observed maximum concentrations for these radionuclides in water. The BCGs for terrestrial plant and animal systems with site soils are presented in Tables 4-4 and 4-5, respectively.

Table 4-4. Comparison of BCGs for terrestrial plant systems with site soils.

Radionuclide	BCG Soil (pCi/g)	Site Soil Concentration (pCi/g)		
		Bluff B	Bluff H	Lignite
Ra-226	3E+02	23.2	1.0E+02	1E+03
U-234	5E+04	25.7	1.4E+02	8.9E+03
U-235	3E+04	1.21	6.2	4.7E+02
U-238	2E+04	23.2	1.3E+02	8.9E+03

Table 4-5. Comparison of BCGs for terrestrial animal systems with site soils.

Radionuclide	BCG Soil (pCi/g)	Site Soil Concentration (pCi/g)		
		Bluff B	Bluff H	Lignite
Ra-226	5E+01	23.2	1.0E+02	1E+03
U-234	5E+03	25.7	1.4E+02	8.9E+03
U-235	3E+03	1.21	6.2	4.7E+02
U-238	2E+03	23.2	1.3E+02	8.9E+03

The lignite samples indicate a potential risk for terrestrial plants and animals; however, the assumption that the ecological receptors are exposed to these concentrations continuously is very conservative. A better indicator of ecological risk lies in a comparison of Bluff H and Bluff B overburden concentrations. This comparison shows that Ra-226 exceeds the ecological BCG for terrestrial animals, indicating a potential ecological risk from Ra-226. Factors contributing to uncertainty in this analysis are discussed below in Section 4.3.

4.3 Uncertainty Assessment

As in the human health risk assessment, uncertainty is defined as a lack of precise knowledge regarding the true risk, while variability is defined as the inherent heterogeneity in risk across space, time, or among individuals. While uncertainty can be reduced with increased information, variability cannot.

Ecological risk assessments inherently involve greater uncertainty and variability than do human health risk assessments. This can be attributed to a number of factors:

- There are multitudes of different organisms interacting within a complex food web.
- When compared to human health assessments, there are generally fewer supporting studies and greater uncertainty regarding exposure factors (e.g., soil ingestion rates for various wildlife species).
- Efforts to relate numeric risk estimates to observable ecological impacts are confounded by a host of natural factors affecting ecological health (e.g., climate conditions and food abundance).

The use of both media standards (Section 2) and risk assessment methods (Section 4) provides a more thorough examination of potential risks for multiple species. In general, media standards and toxicity factors are set using contaminant levels where no adverse effects are observed in the most sensitive species. These serve as a cut-off or baseline for determining toxicity and risks (i.e., as contaminant levels increase above these threshold values, toxicity and risks also increase). Where information is limited, margins of safety are used to be protective of sensitive species.

Predicting the degree of ecological harm due to mining at the site is difficult. A number of factors contribute to this uncertainty. The primary factor relates to the condition of the site. In general, the chemical and physical characteristics of mined areas render much of the site devoid of vegetation. As a consequence, many species may not frequent impacted areas. In preparing this assessment, exposure locations and durations were tested for a variety of scenarios. Lowering the exposure durations for various species results in lower HQs. This is due to the linear relationship between exposure duration and the corresponding risk calculations (i.e., HQs decrease proportionally with the selected time spent onsite).

This assessment seeks to evaluate the effect on key species in mined areas, were they not adversely impacted and therefore, were fully available for habitation (i.e., vegetated). Given the extensive impacts of mining throughout the bluffs, discounting potential hazards by altering the time spent onsite is not appropriate. Risks from exposure to potentially impacted soil and water outside of the mined areas have not been investigated.

4.4 Summary and Conclusions

This assessment finds significant potential for ecological impacts at the site. Key findings include:

- Levels of COPCs at the site are well above area background levels.
- COPC levels exceed various ecological benchmark concentrations indicating the potential for adverse effects on ecological health.
- Large areas show elevated concentrations of COPCs.
- COPC distribution encompasses nearly all of the mined areas.
- Hazard quotients derived in this site-specific risk assessment are well above 1.0 for most species evaluated.
- Concentrations of COPCs in soil, water, and sediment all contribute to potential ecological hazard.

The extent to which ecological harm is presently occurring is uncertain. Many species may avoid mined areas due to the instability of mine wastes and the lack of vegetation. From a physical perspective, the lack of vegetation in the mined areas represents a tangible loss of habitat. This combined with the potential for chemical toxicity due to exposure to solid mine wastes and surface water, results in overall reduced ecosystem vitality.

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5. RISK-BASED SOIL CONCENTRATIONS

5.1 Chemical Risk-Based Soil Concentrations

This section applies the human health risk models, ecological risk models, and screening level information to develop risk-based cleanup goals for areas impacted by mining from heavy metals.

Risks at the site are highest for arsenic. As a result, arsenic concentrations are expected to dominate considerations for cleanup. Moreover, a range of exposure pathways and risk levels were evaluated that can be used to develop cleanup levels. Therefore, Section 5.1.1 addresses cleanup level recommendations for arsenic exposure to human health.

The ecological risk assessment involved numerous receptors. A range of concentrations may be selected as the basis for cleanup levels depending on levels of protection desired for each receptor. An evaluation of cleanup level options for protecting ecological health is provided in Section 5.1.2.

Section 5.1.3 combines recommendations from Sections 5.1.1 and 5.1.2 with other risk assessment information and screening level criteria, to evaluate and identify recommended risk-based cleanup goals for COPCs.

5.1.1 Cleanup Goals for Arsenic

The human health risk assessment (Section 3) identifies unacceptable risks for both the grazing permit holder and recreational visitors. In accordance with the National Contingency Plan (EPA 1990), the range of risk values from 1×10^{-6} to 1×10^{-4} is generally considered acceptable. Furthermore, it may be appropriate for informed decision-making to consider the different routes of exposure (soil ingestion or beef ingestion). A range of PRGs is presented in Table 5-1 to address each of these variables. The supporting calculations are provided in Appendix C-1.

It should be recognized that this assessment does not evaluate soil impacts on surface water quality. The ecological risk assessment identifies potential excess risk from exposure to both soil and surface water. Similarly, the human health risk assessment assumes that cattle and deer ingest surface water at the site. Surface water quality is likely affected in many areas by stormwater runoff, and possibly other mechanisms. However, the relationship between surface water and soil has not been evaluated to support the development of soil criteria protective of surface water quality.

Table 5-1. Range of risk-based arsenic cleanup levels.

Receptor Exposure:	PRG at 10^{-6} risk (mg/kg)	PRG at 10^{-4} risk (mg/kg)
Soil Ingestion and Dermal Absorption		
Permit Holder	33	3,333
Recreational Visitor	41	4,150
Recreational Visitor	41	4,150
Native American	107	1,070
Beef Ingestion		
Permit Holder	Background*	94*
Recreational Visitor	18	NA
Background = The lowest level of risk that can be achieved without improving surface water quality that cattle drink is 5.6E-6. NA = Not applicable; risk concentrations are already above this level.		

5.1.2 Cleanup Goals for Ecological Receptors

The ecological risk assessment (Section 4) considers exposure to both soil and surface water. Eight different receptors were selected to represent species generally believed to be at the site. In support of informed decision-making, Table 5-2 presents the hazard quotients for each receptor over a range of concentrations. The ecological risk assessment model provided in Appendix D was used to calculate the hazard quotients. Surface water concentrations were set to the maximum observed background concentration reported in Table 2-5. As stated above for arsenic, soil/surface water interactions were not considered in developing these risk-based goals. The range of concentrations for each COPC was selected to represent a low-end value at which all hazard quotients are less than or equal to 1, and a high-end value where most hazard quotients exceed 1.

5.1.3 Recommended Cleanup Goals for Chemicals

Table 5-3 compiles all the information into a range of values that may be used for establishing risk-based cleanup goals for the site. The basis for selecting each type of data is discussed; followed by the rational used to establish the recommended values in Table 5-3.

5.1.3.1 Background. Background values are relevant as risk-based goals. Little human health or ecological risk reduction is achieved by cleaning up to levels below what exists naturally at the site. The site background values in Table 5-3 are the arithmetic average background concentrations based on all available data. The background data consists of five grab samples collected by Portage Environmental, Inc. and four composite samples collected by Pioneer. One Pioneer sample was discarded as an outlier. The small sample size for background, the existence of a suspected outlier, and the potential for off-site migration of contaminated soils all indicate some uncertainty regarding the selection of a definitive estimate of background concentrations. An upper confidence limit estimate of background concentrations is arguably another appropriate option for use in developing preliminary cleanup goals. The U.S. national average background concentration is provided as a reference point only, to aid in understanding and improving confidence in the site background concentrations.

5.1.3.2 PRGs Industrial. EPA Region 9 PRGs applicable for industrial exposure were selected to represent levels protective of human health. These are risk-based standards were developed using a similar methodology as that used in this assessment. Industrial standards are applicable to the adult population expected to be onsite. Furthermore, ranching, hunting, and other known uses of the site are expected to result in higher levels of soil exposure, generally consistent with industrial assumptions. However, the industrial standards consider exposure during a standard workweek. The industrial standards do not consider exposure via ingestion of contaminated meat. They should be considered only an approximation of concentrations that are protective of human health at the site.

For parameters not evaluated in this assessment (e.g., copper and lead), the industrial PRGs are the only guidelines provided in this report. Additional consideration of human health standards for these parameters is not necessary. The ecological-based standards are much lower, and applicable to the site. Also, site soil concentrations for copper and lead are far below the industrial PRGs, and slightly below the ecological PRGs. These parameters are not expected to dominate cleanup decisions at the site.

5.1.3.3 Site-Specific Human Health Risk Assessment. Applying this assessment, as described in Section 5.1, a range of potential cleanup values is provided for arsenic. Soil concentrations corresponding to a human health hazard quotient of 1 are also provided for selenium and molybdenum.

5.1.3.4 Ecological PRGs. The ecological PRGs were prepared by a U.S. Department of Energy contractor based on an extensive survey of the toxicological literature and consideration of multiple receptors. They provide a basis for comparison to the cleanup levels suggested by this site-specific ecological risk assessment. They also provide a useful benchmark value for considering whether additional investigation should be performed for COPCs not evaluated in this site-specific ecological risk assessment. For copper and lead, soil concentrations are generally less than the ecological PRGs (see Table 2-4), indicating minimal need for further evaluation.

5.1.3.5 Site-Specific Ecological Risk Assessment. The values reported in this column of Table 5-3 are the lowest values reported in Table 5-2. As discussed in Section 5.2, the values represent the level at which hazard quotients for all receptors are at or below 1.

5.1.3.6 Recommended Value. The recommended value in Table 5-3 is selected using the following criteria:

- Site-specific risk-based values are selected in preference to generic PRG benchmark values.
- If the site-specific or generic PRG benchmark value exceeds the average site background value, the site-background value is selected.

Table 5-2. Ecological hazard quotients at various soil concentrations.

Soil Concentrations for COPCs*	Terrestrial Plants	Terrestrial Invertebrates	Small Herbivores (Rabbit)	Large Herbivores (Deer)	Avian Carnivores (Hawk)	Mammalian Carnivores (Fox)	Avian Omnivores and Herbivores (Robin)	Cattle
Arsenic								
2 mg/kg	2.E–01	3.E–02	1.E+00	4.E–01	4.E–03	2.E–01	6.E–02	2.E–01
10 mg/kg	1.E+00	2.E–01	6.E+00	1.E+00	2.E–02	6.E–01	3.E–01	5.E–01
20 mg/kg	2.E+00	3.E–01	1.E+01	3.E+00	4.E–02	1.E+00	6.E–01	9.E–01
30 mg/kg	3.E+00	5.E–01	2.E+01	4.E+00	6.E–02	2.E+00	9.E–01	1.E+00
Molybdenum								
1 mg/kg	5.E–01	NC	1.E–01	5.E–02	1.E–05	5.E–02	1.E–02	2.E–02
2 mg/kg	1.E+01	NC	2.E+00	8.E–01	2.E–04	6.E–01	2.E–01	2.E–01
5 mg/kg	3.E+00	NC	6.E–01	2.E–01	5.E–05	2.E–01	5.E–02	7.E–02
10 mg/kg	5.E+00	NC	1.E+00	4.E–01	1.E–04	3.E–01	1.E–01	1.E–01
20 mg/kg	1.E+01	NC	2.E+00	8.E–01	2.E–04	6.E–01	2.E–01	2.E–01
Selenium								
1 mg/kg	1.E+00	1.E–02	1.E–01	4.E–02	7.E–02	2.E–02	6.E–01	2.E–02
5 mg/kg	5.E+00	7.E–02	7.E–01	2.E–01	3.E–01	9.E–02	3.E+00	7.E–02
10 mg/kg	1.E+01	1.E–01	1.E+00	4.E–01	7.E–01	2.E–01	6.E+00	1.E–01
40 mg/kg	2.E+01	3.E–01	3.E+00	7.E–01	1.E+00	4.E–01	1.E+01	3.E–01
20 mg/kg	4.E+01	6.E–01	5.E+00	1.E+00	3.E+00	7.E–01	2.E+01	5.E–01

* Surface water concentrations set to maximum background levels in Table 2-5.

NC = Not calculated; toxicity reference value unavailable.

Table 5-3. Risk-based preliminary cleanup goals (mg/kg).

	Ave. Background[a]		PRGs	Site-Specific	Ecological PRGs[b]		Site-Specific	Recommended
COPC	Site	U.S.	Industrial[c]	HHRA[d]	Soil Value	Basis	ERA[e]	Value
Arsenic	28.2	NR	1.6	28 – 4,150**	9.9	shrew, plant	2	28
Copper	8.9	25	41,000		60	earthworm		60
Lead	16.1	20	750		40.5	woodcock		40
Molybdenum	4.1	2	5,100	2,775	2	plant	1	4
Selenium	<1	NR	5,100	2,275	0.21	mouse	1	1

*Based on chemical toxicity only .
**See Table 5-1.
a. Site background based on average for historical and 2004 data (RP-SS-X removed as an outlier, selenium based on 2004 data only which had lower detection limits). U.S. Background - average values from Elemental Composition of Surficial Materials in the Conterminous United States, USGS, 1971. NR = Not Reported
b. Preliminary Remediation Goals for Ecological Endpoints, prepared for DOE by Lockheed Martin Energy Systems, 1997.
c. PRGs: Preliminary Remediation Goals, EPA Region 9, http://www.epa.gov/region09/waste/sfund/prg/index.htm - value shown is the lowest of hazard quotient or cancer risk value.
d. HHRA = Human health risk assessment.
e. ERA - Ecological Risk Assessment, based on water exposure equal to maximum observed background water concentration.

5.2 Radionuclide Risk-Based Soil Concentrations

Radionuclide risk-based soil concentrations were evaluated based on carcinogenic effects to the human receptor. Ecological receptors were not considered as only Ra-226 in soil exceeded the ecological BCGs for the assessment of Bluff H.

As stated in Section 4, there is a potential ecological risk from Ra-226 for terrestrial animals. However, several uncertainty factors specific to terrestrial animals (Section 4.3) make it difficult to categorically state the ecological risk from Ra-226 is real. Therefore, all risk-based soil concentrations are based on the human receptor at Bluff H. The risk-based concentrations (RBCs) for radionuclides in overburden / lignite are provided in Tables 5-4 through 5-6 for the grazing permit holder with varying percentages of beef ingestion from the site. The RBCs for the recreational visitor are presented with varying percentages of deer ingestion in Tables 5-7 through 5-9.

Table 5-4. Radionuclide RBCs for permit holder with 10% beef ingestion from site.

Nuclide	Excess Cancer Risk Level		
	1.00E–06	1.00E–05	1.00E–04
	Risk-Based Soil Concentration (pCi/g)		
U-238	4.28E+00	4.28E+01	4.28E+02
U-234	4.46E+00	4.46E+01	4.46E+02
Th-230	4.42E+00	4.42E+01	4.42E+02
Ra-226	3.30E+00	3.30E+01	3.30E+02
Pb-210	3.30E+00	3.30E+01	3.30E+02
U-235	2.03E–01	2.03E+00	2.03E+01
Pa-231	2.03E–01	2.03E+00	2.03E+01
Ac-227	2.03E–01	2.03E+00	2.03E+01

Table 5-5. Radionuclide RBCs for permit holder with 50% beef ingestion from site.

Nuclide	Excess Cancer Risk Level		
	1.00E–06	1.00E–05	1.00E–04
	Risk-Based Soil Concentration (pCi/g)		
U-238	2.04E+00	2.04E+01	2.04E+02
U-234	2.12E+00	2.12E+01	2.12E+02
Th-230	2.11E+00	2.11E+01	2.11E+02
Ra-226	1.57E+00	1.57E+01	1.57E+02
Pb-210	1.57E+00	1.57E+01	1.57E+02
U-235	9.69E–02	9.69E–01	9.69E+00
Pa-231	9.69E–02	9.69E–01	9.69E+00
Ac-227	9.69E–02	9.69E–01	9.69E+00

Table 5-6. Radionuclide RBCs for permit holder with 100% beef ingestion from site.

Nuclide	Excess Cancer Risk Level		
	1.00E–06	1.00E–05	1.00E–04
	Risk-Based Soil Concentration (pCi/g)		
U-238	1.23E+00	1.23E+01	1.23E+02
U-234	1.28E+00	1.28E+01	1.28E+02
Th-230	1.27E+00	1.27E+01	1.27E+02
Ra-226	9.51E–01	9.51E+00	9.51E+01
Pb-210	9.51E–01	9.51E+00	9.51E+01
U-235	5.86E–02	5.86E–01	5.86E+00
Pa-231	5.86E–02	5.86E–01	5.86E+00
Ac-227	5.86E–02	5.86E–01	5.86E+00

Table 5-7. Radionuclide RBCs for onsite recreational with 10% beef ingestion from site.

Nuclide	Excess Cancer Risk Level		
	1.00E–06	1.00E–05	1.00E–04
	Risk-Based Soil Concentration (pCi/g)		
U-238	5.30E+00	5.30E+01	5.30E+02
U-234	5.52E+00	5.52E+01	5.52E+02
Th-230	5.48E+00	5.48E+01	5.48E+02
Ra-226	4.09E+00	4.09E+01	4.09E+02
Pb-210	4.09E+00	4.09E+01	4.09E+02
U-235	2.52E–01	2.52E+00	2.52E+01
Pa-231	2.52E–01	2.52E+00	2.52E+01
Ac-227	2.52E–01	2.52E+00	2.52E+01

Table 5-8. Radionuclide RBCs for onsite recreational with 50% beef ingestion from site.

Nuclide	Excess Cancer Risk Level		
	1.00E–06	1.00E–05	1.00E–04
	Risk-Based Soil Concentration (pCi/g)		
U-238	4.54E+00	4.54E+01	4.54E+02
U-234	4.73E+00	4.73E+01	4.73E+02
Th-230	4.70E+00	4.70E+01	4.70E+02
Ra-226	3.50E+00	3.50E+01	3.50E+02
Pb-210	3.50E+00	3.50E+01	3.50E+02
U-235	2.16E–01	2.16E+00	2.16E+01
Pa-231	2.16E–01	2.16E+00	2.16E+01
Ac-227	2.16E–01	2.16E+00	2.16E+01

Table 5-9. Radionuclide RBCs for onsite recreational with 100% beef ingestion from site.

Nuclide	Excess Cancer Risk Level		
	1.00E–06	1.00E–05	1.00E–04
	Risk-Based Soil Concentration (pCi/g)		
U-238	3.85E+00	3.85E+01	3.85E+02
U-234	4.01E+00	4.01E+01	4.01E+02
Th-230	3.98E+00	3.98E+01	3.98E+02
Ra-226	2.97E+00	2.97E+01	2.97E+02
Pb-210	2.97E+00	2.97E+01	2.97E+02
U-235	1.83E–01	1.83E+00	1.83E+01
Pa-231	1.83E–01	1.83E+00	1.83E+01
Ac-227	1.83E–01	1.83E+00	1.83E+01

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