D R A F T   W O R K   P L A N

HUMAN HEALTH RISK ASSESSMENT WORK PLAN FOR THE MIDNITE MINE SUPERFUND SITE

Prepared for
EPA Region 10

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List of Acronyms

ALEM	Adult Lead Exposure Model
ARARs	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Disease Registry
BOM	U.S. Bureau of Mines
CDC	Centers of Disease Control and Prevention
CERCLA	Comprehensive, Environmental Response and Compensation Liability Act
cm	Centimeter
cm^2	Square Centimeter
COC	Chemicals and Radionuclides of Concern
COPC	Chemicals and Radionuclides of Potential Concern
cpm	Counts Per Minute
CRCIA	Columbia River Comprehensive Impact Assessment
CSM	Conceptual Site Model
CT	Central Tendency
dl	Decileter
DMC	Dawn Mining Company
DQO	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
EPC	Exposure Point Concentration
FDA	Food and Drug Administration
g	Gram
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
hr	Hour
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
IRMP	The Integrated Resource Management Plan For The Spokane Indian Reservation
kcal	Kilocalorie
kg	Kilogram
L	Liter
m^3	Cubic Meter
MA	Mined Area

mg	Milligram
ml	Milliliter
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPDES	National Pollution Discharge Elimination System
ORNL	Oak Ridge National Library
pCi	Picocuries
PIA	Potentially Impacted Area
PRG	Preliminary Remediation Goals
RAIS	Risk Assessment Information Service
RfD	Reference Dose
RI/FS	Remediation Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
s	Second
SF	Slope Factor
Site	Midnite Mine Superfund Site
SMI	Shepherd Miller, Inc
SSL	Soil Screening Level
95% UCL	95 Percent Upper Confidence Limit of the Mean
µg	Microgram
µrem	Microrem
µR	Microroentgen
VF	Volatilization Factor
WDOH	Washington Department of Health
Workplan	Human Health Risk Assessment Workplan

EXECUTIVE SUMMARY

Introduction

The Human Health Risk Assessment Workplan (workplan) describes the site-specific approach for performing the human health risk assessment at the Midnite Mine Superfund Site location (Site). The Site is an inactive open pit uranium mine, located on the Spokane Indian Reservation, approximately 8 miles northwest of Wellpinit, the nearest population center, in Washington State. The city of Spokane is approximately 35 miles from the mine site. Conditions in the site area have resulted in releases of radionuclides and metals to media that may pose an unacceptable risk to human health.

The EPA's overall goal with respect to the Remedial Investigation/Feasibility Study at this Site is to investigate and remediate, as warranted, to protect human health and the environment, and to have the stakeholders involved in the process of making these site decisions. The general approach for conducting the risk assessment will follow EPA's risk assessment guidance and data quality objectives process..

Data Usability

The first step in the human health risk assessment (HHRA) process will be to evaluate the historical data and data generated during the remedial investigation to determine whether they are of adequate quality for use in quantifying risks. Historical data that may be used in the risk assessment are available from studies performed by Ecology and Environment, Inc., Shepherd Miller, Inc., and the U.S. Bureau of Mines. URS has supplemented the historical data with data from two sampling efforts (Phases 1A and 2A/1B). Data that is historical or generated during the remedial investigation will be evaluated to determine whether they are of adequate quality for use in quantifying risks. Data judged to be of adequate quality will be further reviewed to determine whether detection limits are sufficiently low for the intended risk assessment.

Selection of Chemicals and Radionuclides of Concern (COCs) Methodology

Chemicals and radionuclides of potential concern (COPCs) at the site consist of metals and radionuclides in the uranium-238, uranium-235, and thorium-232 decay series. COCs will be selected separately for each medium in each exposure area at the Site. First, concentrations of COPCs in soils, sediment, surface water, and groundwater will be compared with local background concentrations to distinguish COPCs elevated above background from other COPCs in the site area. COPCs with concentrations elevated above background concentrations will be further evaluated to select COCs in each specific medium in each exposure area. All COPCs elevated above background that are detected in specific medium/ exposure areas will be considered COCs, except for calcium, magnesium, potassium, and sodium which are essential nutrients without toxicity factors that do not require quantitative evaluation. A risk-based screen will not be used in the selection of COCs because assumptions typically used in deriving screening levels were not intended for tribal scenarios.

Exposure Assessment

The exposure assessment section in the Workplan describes the methodology to be used to estimate human exposure at the site. Specifically, the section describes site setting; current and future land use and potentially exposed people; CSMs and the pathways by which people may be exposed; how EPCs of COCs will be calculated; and the intake equations and exposure factors that will be used to estimate the intake for each COC, exposure pathway, and receptor

Site Description

The leased area of the mine encompasses approximately 811 acres, of which 321 acres were developed during mining operations. The mine ceased operations in 1981, leaving approximately two and one-half million tons of ore/protore, and 33 million tons of waste rock on site. Oxidation of sulfide-containing minerals, primarily pyrite, exposed to oxygen on the mine pit walls, waste rock, and ore/protore materials produces acidic water. This acidic water then chemically leaches uranium, other radioactive constituents, and other metals from the waste rock. Dissolved metals can then be transported in soil, surface water, sediments, and groundwater at the site.

The study area is currently divided into the mined area (MA) and the potentially impacted area (PIA). The MA is defined as the 321 acres where the ground surface has been visibly disturbed by mining operations. The PIA is the area surrounding the MA that may have been affected above background levels by the previous mining activities.

The major MA features include two large partially water-filled mining pits (Pits 3 and 4), backfilled pits, large areas of graded and partially re-vegetated spoils and waste rock from mining activities, and numerous stockpiles of ore and protore. Recharge to the groundwater system in the MA is from precipitation falling on the MA and the Northwest Ridge. The majority of the water that infiltrates and becomes groundwater at the site moves through the waste rock and alluvium and flows across the surface of the bedrock. During the passage through the waste rock, the water reacts with minerals in the rock which contribute radionuclides, metals, and major ions such as sulfate to the groundwater. Much of this water discharges at the three major seeps along the south face of the South Spoils waste rock. A seep collection system is currently operated by the Dawn Mining Company to collect seep flows and return the water to Pit 3 for subsequent water treatment prior to discharge in the East Drainage.

Extensive upland habitat is found within the MA; however, the quality of the upland habitat has been physically degraded. The physically disturbed upland habitat in the MA is generally of limited extent and poor quality for wildlife use, although small isolated stands of remnant coniferous forest occur on apparently undisturbed ground patches within the MA.

The PIA is the area surrounding the MA that is potentially affected by previous mining activities at the site. The nature and extent of the mine-affected area will be characterized based on results of the RI studies now in progress. In these studies, concentrations of constituents in the area surrounding the MA will be compared to concentrations at background locations to estimate the likely extent of mining-related effects.

Extensive upland habitat is found within the PIA, which appears largely undisturbed from mining activities. This upland habitat is dominated by coniferous forest. The dominant forest cover type in the project area is an overstory of either ponderosa pine or a mixture of ponderosa pine and Douglas-fir of uneven aged size class with a density ranging from light to full. Steep habitat is found on the west bank of the middle and lower portions of Blue Creek and open habitat is found on the western bank of the lower portion of Blue Creek.

Seven drainages in the PIA receive runoff from portions of the MA: Western Drainage, Central Drainage, Eastern Drainage, Northeastern Drainage, Northern Drainage, Far West Drainage, and Southwestern Drainage. Based on sampling results for surface water and aquatic sediments, portions of the Western, Central, and Eastern drainages and the downstream parts of Blue Creek nearest to the site have likely been impacted by contaminant sources in the MA. Whether other drainages in the PIA have also been affected above background levels (i.e., mine affected) is currently being evaluated.

Blue Creek ultimately receives water and sediment from these drainages. Blue Creek flows to Lake Roosevelt, approximately 4.5 miles from the site area. Vegetation is relatively dense in and around the southern drainages and Blue Creek in the PIA.

There are several unpaved roads (haul roads) in the PIA that were covered with gravel derived from stockpile material from the MA. In addition, these haul roads may have been impacted by ore from the MA lost from trucks during mining operations.

Identification of Land Use and Potentially Exposed People

The Site is located entirely within the 154,000-acre Spokane Indian Reservation. The Spokane Indians are part of the Interior Salish group who inhabited northeastern Washington, northern Idaho, and western Montana. The Spokane Indian Reservation was originally set aside by agreement in 1877 between the Spokane Tribe of Indians and the United States. Appendix C presents additional historical and current information regarding the Spokane Tribe of Indians.

Current Land Use

No one currently lives on or near the MA or PIA. Land at and near the MA or PIA is primarily used by members of the Tribe to support a traditional lifestyle that includes subsistence, cultural/spiritual, and medicinal components.

The primary current land use at and near the site is hunting, gathering, and fishing by members of the Tribe to support their traditional way of life. These subsistence activities are essential to support nutritional, cultural/spiritual, and medicinal needs. Processing of gathered materials includes the washing and preparation for food, medicine, and other purposes.

The traditional diet for the Tribe includes big game, fish, small mammals, insects, grubs, frogs, and plants. Different portions of each plant and animal are used for traditional purposes. For example, every portion of big game such as deer, elk, bear, cougar, and wolverine, and of livestock is used for specific subsistence, cultural/spiritual, or medicinal purposes. Portions of plants are harvested as needed (e.g., roots, flowers, and leaves are often harvested without destroying the plant, allowing for future root growth) and used for subsistence, cultural/spiritual, or medicinal purposes. Medicinal uses of plants can include direct ingestion, dermal or subdermal application, application in open cuts, and inhalation (includes smoking). The traditional diet also includes home-grown garden produce and livestock.

Members of the Tribe may work in the MA or PIA collecting environmental samples, engaging in restoration/reclamation/construction work, and caring for natural and cultural resources and tribal property. The site area may be used by members of the Tribe for conducting sweat lodge ceremonies. In addition, areas along Blue Creek and at the confluence of Blue Creek and Lake Roosevelt are currently used by members of the tribe for ceremonial purposes (e.g., pow-wows, horse races, seasonal ceremonial activities). Elders in the Tribe teach a variety of indoor and outdoor traditional activities in the MA and PIA.

Parts of the MA and PIA could currently be used for recreational purposes (e.g., adults and older kids could wade in creeks in the PIA). It is not known whether any members of the Tribe swim in the two open pits. There is a recreational beach owned by the Tribe at the confluence of Blue Creek and Lake Roosevelt, 4.5 miles from the MA. The Tribe has stated that all residents use the haul roads in the PIA for transportation.

Groundwater from wells is not known to be used in the MA or PIA. Water from seeps, springs, and drainages in the PIA could currently be used in a sweat lodge ceremony or ingested by hunters, gatherers, workers, and other visitors to the PIA. It is not known whether water from the two open pits is used for these purposes.

Future Land Use

Future land use in the site area is expected to remain similar to current land use, in that it will be used for traditional activities (subsistence, cultural/spiritual, medicinal), field work, transportation, and recreational purposes and for livestock foraging. In addition, future residential use of the land in the PIA is a possibility. Groundwater in the PIA could be used in the future for domestic purposes and sweat lodge ceremonies if supply wells were to be constructed in the PIA for such purposes.

In the MA, residential exposure and domestic use of groundwater from wells are each considered to be extremely unlikely future scenarios. EPA expects that risks for hypothetical residents in the MA will be shown to be high enough to require a response action, and that restrictions against residential use will be part of any response action. At this time, any remedy for the MA is likely to include containment/capping, which will necessitate restrictions on land use to protect the remedy.

Potentially Exposed People in the Site Area

Potentially exposed people in the site area are assumed to include families currently residing offsite on the reservation and future families residing in the PIA. The future resident who lives in the PIA is considered the most exposed receptor based on current and reasonably anticipated future land use.

Residential exposure with domestic use of groundwater is considered to be an extremely unlikely future scenario for the MA. Nevertheless, a hypothetical future residential scenario in the MA will be evaluated for risk management purposes or, if there is a change in land use, to assess whether a remedy may need to be reevaluated.

By necessity of limitations in the knowledge of many of the determinants of exposure, the scenarios evaluated in the workplan require simplifying assumptions. This is true of all risk assessments, but it is especially true at the Midnite Mine Superfund site because less is known about exposures unique to members of the Spokane Tribe of Indians as they practice their traditional lifestyle.

For the purposes of quantitative risk assessment, current residents, future residents living in the PIA, and hypothetical future MA residents will be divided into two age groups based on similar areas, types, and extent of exposure: (1) Infants who are exposed at the residence (in the house or outdoors in the yard), and (2) children (including youth) and adults (including elders) who spend similar time in common activities at and near the residence, in a sweat lodge, and on the haul roads; who spend time in the MA and PIA for various activities (hunting, gathering, teaching and learning traditional activities, working, recreating, transportation, and ceremonies); and who eat similar types of plants, wildlife, and livestock.

Therefore, potentially exposed people are:

- Current infants who live offsite and are primarily exposed at the residence. For the risk assessment, it will be assumed that these infants are not significantly exposed to COCs in the site area.
- Current children and adults who live offsite and spend time in the MA and PIA for various non-residential activities.
- Future infants who live in the PIA and are primarily exposed at the residence.
- Future children and adults who live in the PIA and spend time in the MA and PIA for various non-residential activities.
- Hypothetical future infants who live in the MA and are primarily exposed at the residence.

- Hypothetical future children and adults who live in the MA and spend time in the MA and PIA for various non-residential activities.

Conceptual Site Models (CSMs)

CSMs have been developed for the site area as schematic representations of source areas, release mechanisms, environmental transport media, and potential exposure routes for COCs that may lead to exposure of the receptors to contaminants in the site area. CSMs were developed for the following six potential sources of contamination: surface material in the MA, two open pits in the MA, groundwater in the MA and PIA, surface water and sediments in the PIA, soils and riparian sediments in the PIA, and surface material on the haul roads. The CSMs identify the potentially complete and significant exposure pathways to be quantified by risk assessment, and pathways that are incomplete or potentially complete, but negligible, which are not evaluated quantitatively in the risk assessment. The specific rational for designating some pathways as potentially complete but negligible is provided in the workplan.

Exposure Areas to be Evaluated Quantitatively in the Risk Assessment

Exposure areas for the MA and preliminary exposure areas in the PIA to be evaluated in the risk assessment include the MA, two open pits in the MA, the upland PIA, riparian/aquatic areas in the PIA, and the haul roads.

The surface area of the MA, including roads in the MA, but not the two open pits, will be treated as one surface exposure area. For domestic groundwater used by hypothetical residents in the MA, the exposure area will include all groundwater underlying the MA. For exposure in the two open pits, there will be two exposure areas, one for Pit 3 and one for Pit 4.

The exposure area for upland PIA surface materials will be determined based on the results of Phase 2A/1B sampling. The preliminary exposure area for the upland PIA will consist of the sampled areas in the two primary wind directions. For domestic groundwater use by residents living in the upland PIA, the exposure area will be the groundwater plume in areas of the PIA affected by mining activities. For riparian/aquatic exposures in the PIA, the exposure area will consist of the Western, Central, and Eastern drainages, and parts of Blue Creek and other riparian/aquatic areas that are shown to be mine-affected.

For exposures while using the haul roads as transportation, the one exposure area will include the two haul roads, the three pump house access roads, and the impacted area on each side of the roads. The exposure area for livestock is assumed to be the MA and PIA. Livestock are assumed to ingest water from the two open pits in the MA and seeps and surface water in the PIA and to ingest plants from the MA, and upland and riparian PIA.

Pathways to be Evaluated Quantitatively in the Risk Assessment

Pathways to be evaluated quantitatively in the risk assessment include pathways for residential exposures for infants, children, and adults (exposures to COCs in the yard and indoors including in a sweat lodge) and non-residential exposures (exposures to COCs away from the residence while hunting, gathering, working, recreating). Non-residential exposure pathways in the MA, upland PIA, riparian/aquatic PIA, and haul roads will be assumed to be the same for children and adults living offsite, in the PIA, or in the MA. In addition, the exposure areas and pathways for a hypothetical swimming scenario for children and adults in the two open pits will be evaluated.

Methodology for Estimating Exposure Point Concentrations (EPCs)

The EPC for COCs in sampled media (e.g., soil, sediment, water, radon in air) will be estimated based on analytical results. The concentration terms will be either the 95% UCL concentration or the maximum detected concentration, whichever is lower, following recommendations in EPA guidance.

For some media (e.g., indoor air), models will be used to predict concentrations at exposure points where environmental monitoring data have not been (or cannot be) collected. These media may include outdoor radon in some areas; indoor radon in a residence and in a sweat lodge; indoor water vapor in a sweat lodge; external radiation in some areas; suspended particulates in air; terrestrial plants in the MA; terrestrial, riparian, and aquatic plants in the PIA; garden plants; livestock; and fish.

Models range from simple, conservative screening level models to complex models that use site-specific information. In the risk assessment, every effort will be made to use models and input parameter values that best describe conditions at the site.

Pathway-Specific Intake Equations

The workplan presents intake equations and parameter values for estimating intake for each COC by each exposure pathway for each receptor evaluated quantitatively in the risk assessment. The intake equations and parameter values are presented for each of the three age-groups of receptors in the risk assessment: infants (under 2 years of age), children (2 to 6 years of age), and adults (7 to 70 years of age). Estimation of intake of non-carcinogens and non-cancer hazard will be calculated separately for each age group. In addition to presenting estimations of cancer risk in each pathway for each receptor, intake for infants, children, and adults will be summed to yield one total lifetime cancer risk estimate.

In the risk assessment work plan, values for exposure variables were selected such that the combination of all variables in the risk assessment will result in the maximum exposure that can reasonably be expected to occur at the site (i.e., the RME). Central tendency exposure and risk will not be estimated in the risk assessment because there is limited empirical basis or well documented sources of information for developing central exposure factors for a traditional tribal lifestyle.

Wherever feasible, site-specific exposure factor parameter values were derived using information provided by the Tribe. When site-specific information was not available, values were derived by URS using EPA guidance documents or standard EPA RME default values were used.

Toxicity Assessment

Reference doses (RfDs) and slope factors (SFs) specific to the oral and inhalation pathways will be obtained from EPA sources, including Region 10 risk assessors, the IRIS on-line database, the HEAST, and EPA's National Center for Environmental Assessment office.

Dermal toxicity will be assessed as recommended in recent EPA guidance. If lead is a COC at the site, potential health hazards will be estimated based on predicted blood lead levels and probabilities of exceeding a blood lead level of concern in children or fetuses.

Risk Characterization

In the risk characterization step, RfDs and SFs will be applied in conjunction with intake of COCs to estimate non-carcinogenic and carcinogenic health risk. The potential for non-carcinogenic effects will be characterized by comparing estimated chemical intakes with chemical-specific RfDs. The resulting ratio is called a hazard quotient (HQ). If the average daily intake exceeds the RfD (that is, if the HQ exceeds 1), there may be cause for concern for potential non-cancer effects.

To assess pathway-specific exposures to multiple chemicals, the HQs for each COC will be summed to yield a hazard index (HI). If a receptor may be exposed by multiple pathways, the HIs from all relevant pathways are summed to obtain the total HI for that receptor. If the total HI is less than or equal to 1, multiple-pathway exposures to COCs at the site will be judged unlikely to result in an adverse effect. If the sum is greater than 1, further evaluation of exposure assumptions and toxicity, including consideration of specific target organs affected and mechanisms of toxic actions of COCs, will be warranted to ascertain if the cumulative exposure would in fact be likely to harm exposed individuals.

Potential for carcinogenic effects will be characterized in terms of the incremental probability of an individual developing cancer over a lifetime as a result of site-related exposure to a potential carcinogen, for both chronic and subchronic scenarios. Excess lifetime cancer risk will be estimated from the projected lifetime daily average intake and the cancer SF. The risks resulting from exposure to multiple carcinogens are assumed to be additive. The total cancer risk is estimated by summing the risks estimated for each COC and for each pathway.

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

EPA policy must be considered in order to interpret the significance of the cancer risk estimates. In the National Oil and Hazardous Substances Pollution Contingency Plan, EPA states that: "For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime cancer risk of between 10^{-4} and 10^{-6}."

A qualitative uncertainty analysis will be performed that identifies the key factors and assumptions that contribute to uncertainty in the risk estimates and that assesses their impact on the results and conclusions of the risk assessment. Uncertainties in the following areas will be discussed: data usability, identification of COCs, estimation of EPCs, exposure assumptions, toxicity assessment, and risk characterization. In addition, the uncertainty specifically associated with assessing risk from exposure to radionuclides will be discussed.

1.0 INTRODUCTION

1.1 Purpose and Scope

The purpose of this Human Health Risk Assessment (HHRA) Workplan (workplan) is to describe the site-specific approach for performing the HHRA at the Midnite Mine Superfund Site (Site) location. Conditions in the site area have resulted in releases of radionuclides and metals to media in the Mined Area (MA) and the Potentially Impacted Area (PIA) that may pose an unacceptable risk to human health.

The U.S. Environmental Protection Agency's (EPA's) overall goal with respect to the Remedial Investigation/Feasibility Study (RI/FS) at this Site is to investigate and remediate, as warranted, to protect human health and the environment, and to have the stakeholders involved in the process of making these site decisions:

- Does contamination exist at this site relative to what would be expected to occur in an unmined mineralized area?
- If so, should this site undergo remediation?
- What should be done where?
- When has enough been done?

To respond to the first question, EPA is conducting a RI to characterize the nature and extent of media affected by mining activities to levels above background. A background report will identify chemicals and radionuclides elevated above background in each media in the site area. The second question can be answered by a baseline risk assessment that organizes and presents risk information along with an analysis of uncertainty for making an informed decision. The risk assessment also provides input for the FS to respond to the third and fourth questions.

Risk and its uncertainties are important factors to be considered in risk management decision making for the RI/FS. Generally, exceedance of EPA's acceptable risk range will trigger some kind of remedial action. However, there are many non-risk factors influencing the risk management decision for taking or not taking action, and for selecting the appropriate remedial measure. These other factors should also be considered by EPA before selecting the most appropriate option. These factors may include:

- Stakeholder's concerns
- Schedule
- Value of resources to be protected
- Compliance/regulatory, political, economic, and technical feasibility
- Cost and availability of funds
- Applicable or Relevant and Appropriate Requirements (ARARs)

- Background concentrations

The term "remediation" or "restoration" has sometimes been used to mean that a site will be rendered free of contamination, or that it is returned to its "original" state (i.e., returned to levels that do not exceed background). For the Site, the concept of “restoration” should be related to restoring the site to its current or planned use as established by a risk-based approach described in this work plan and considering background concentrations. This concept is fundamental in development of the Site strategy and is consistent with EPA’s policy for cleaning up contaminated sites (EPA 1995).

The preamble to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) identifies background as a technical factor to consider when determining an appropriate remedial level: “Preliminary remediation goals [PRGs]…may be revised to a different risk level within the acceptable risk range based on the consideration of appropriate factors including, but not limited to: exposure factors, uncertainty factors, and technical factors…Technical factors may include…background levels of contaminants…” (EPA 1990, as cited in EPA 2001a).

1.2 General Approach

The general approach for conducting the risk assessment will follow EPA’s risk assessment guidance and EPA’s Data Quality Objectives (DQO) process (Section 1.3). The DQO process consists of a series of planning steps based on the scientific method that are designed to ensure that the type, quantity, and quality of environmental data used in decision-making are appropriate for their intended purpose. The approach focuses on clearly defining the problem to be resolved (identification and, as appropriate, remediation or control of unacceptable risk) by focusing on the decisions to be made and the overall quality of data necessary to make these decisions. The risk assessment process produces information necessary for making risk management decisions.

The DQO approach will be followed in this risk assessment to identify unacceptable risk to human health. The risk assessment will identify people (receptors) who may be exposed to site contaminants (contaminants of concern), the means by which people are potentially exposed to the contaminants (exposure pathways), and the concentrations of contaminants of concern in exposure media (e.g., air, water, and soil) for different exposure areas. Based on these elements and the toxicity of the contaminants, the degree of hazard and risk will be calculated and uncertainties in these calculations discussed to form a basis for making risk management decisions.

1.3 Guidance Documents

The technical approaches for the risk assessment will be consistent with guidelines established by the EPA for assessing risk to human health. The chief risk assessment guidance documents that form the basis of the approaches described in this workplan are listed below. Other guidance documents and scientific literature are cited as appropriate in the text.

- Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual, Part A (EPA 1989a).
- Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual, Part B, Development of Risk-based PRGs (EPA 1991a).
- Guidance for the DQO Process (EPA 2000a).
- Guidance for Data Usability in Risk Assessment (Part B) (EPA 1992a).
- Exposure Factors Handbook (EPA 1989b).
- Exposure Factors Handbook (EPA 1997a).
- Child-Specific Exposure Factors Handbook, External Review Draft (EPA 2000b).
- Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors (EPA 1991b).
- Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure (EPA 1993a).
- Dermal Exposure Assessment: Principles and Applications (EPA 1992b).
- Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual. Supplemental Guidance. Dermal Risk Assessment. Interim Guidance (EPA 1998a).
- Integrated Risk Information System (IRIS) (EPA 2001b).
- Developing Risk-Based Cleanup Levels at Resource Conservation and Recovery Act Sites (EPA Region 10 1998a).
- Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA sites (EPA 1998b).
- Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination (EPA 1997b).
- Multi-Agency Radiation Survey and Site Investigation Manual (EPA/DOE/DOD/NRC 2000).
- Cancer Risk Coefficients for Environmental Exposure to Radionuclides (EPA 1999a) and Update to the Federal Guidance Report No. 13 (CD Supplement) (EPA 2000c).
- External Exposure to Radionuclides in Air, Water, and Soil (EPA 1993b).
- Radiation Exposure and Risks Assessment Manual (EPA 1996a).
- Health Effects Assessment Summary Tables (HEAST) (EPA 1997c).
- HEAST – Radionuclides Table (EPA 2001b).

1.4 Organization of Work Plan

- Section 1: Introduction. Presents the general purpose and scope of the workplan, the overall approach to the HHRA, and the workplan organization.

- Section 2: Data Usability. Summarizes the overall process that will be applied in evaluating data usability.
- Section 3: Selection of Chemicals and Radionuclides of Concern (COCs) Methodology. Describes how COCs will be identified for quantitative risk assessment.
- Section 4: Exposure Assessment. Presents the land use and potentially exposed people, conceptual site models (CSMs), methodology for estimating exposure point concentrations (EPCs) including fate and transport models, and intake equations and exposure factor parameter values.
- Section 5: Toxicity Assessment. Describes the approaches for evaluating chemical and radionuclide toxicity.
- Section 6: Risk Characterization. Describes the methodology used for estimation of health hazard and cancer risk, and discusses sources and implications of uncertainty in the risk characterization.
- Section 7: References. Lists the references cited in the workplan.
- Appendix A: Summarizes the sources of data considered for use in the HHRA and presents the criteria that will be applied in evaluating data usability.
- Appendix B: Summarizes the overall Shepherd Miller, Inc. (SMI) biological sampling effort, evaluates the relative importance of biological media for risk assessment, discusses plant species identified and sampled in relation to plant use by the Spokane Tribe, derives site-specific uptake factors for site vegetation, and makes recommendations for use of SMI biological data in HHRA.
- Appendix C: Spokane Tribe Subsistence Scenario Memorandum.

2.0 DATA USABILITY

The first step in the HHRA process is to evaluate the historical data and data generated during the RI to determine whether they are of adequate quality for use in quantifying risks. Data judged to be of adequate quality will be further reviewed to determine whether detection limits are sufficiently low for the intended risk assessment. Data quality is generally assured through the implementation of standard operating procedures during sample collection and sample analysis, quality control checks, and data review and validation. All chemical and radiochemical data to be used in quantifying risk will have undergone review to evaluate data quality.

Appendix A describes the procedures either already completed or yet to be conducted to determine the usability of RI and historical radiochemical and chemical data for potential use in the risk assessment. Appendix B contains an evaluation of SMI biological data for use in HHRA.

3.0 SELECTION OF CHEMICALS AND RADIONUCLIDES OF CONCERN (COCs) METHODOLOGY

This section describes the methodology that will be used to select COCs to be evaluated quantitatively in the risk assessment (Figure 1). Chemicals and radionuclides of potential concern (COPCs) at the site consist of metals and radionuclides in the uranium-238, uranium-235, and thorium-232 decay series. COCs will be selected separately for each medium in each exposure area at the Site. First, concentrations of COPCs in soils, sediment, surface water, and groundwater will be compared with local background concentrations to distinguish COPCs elevated above backgrounds from other COPCs in the site area. The background report will identify COPCs elevated above backgrounds in each medium. Those COPCs will be further evaluated to select COCs in each specific medium in each exposure area. All COPCs elevated above backgrounds that are detected in specific medium/exposure areas will be considered COCs, except for calcium, magnesium, potassium, and sodium which are essential nutrients without toxicity factors that do not require quantitative evaluation in the risk assessment (EPA Region 10 1998a). The following sections provide additional details regarding the selection of COPCs process.

3.1 Comparison to Background

The primary step in selection of COCs will be to compare concentrations of COPCs within the Site area with local background concentrations for soils, sediment, surface water, and groundwater to distinguish COPCs elevated above background levels from other COPCs in the site area. COPCs in samples within the site area that occur in concentrations comparable to concentrations at reference locations will not be considered to be COCs and will be excluded from evaluation in the risk assessment. The specific methodology for the background comparison is discussed in detail in the Statistical Approach for Discrimination of Background and Impacted Areas (URS 2001). COPCs identified in the RI report as elevated above background will be retained for further evaluation in selection of COCs.

3.2 Detected COPCs

COPCs elevated above background that are detected in specific medium/exposure areas will be retained for further evaluation in selection of COCs.

3.3 Essential Nutrients and Major Anions

EPA Region 10 guidance recommends that aluminum, calcium, iron, magnesium, potassium, and sodium be eliminated from quantitative evaluation in HHRA because they are not associated with toxicity under normal circumstances and quantitative toxicity information for these elements is not available from EPA (EPA Region 10 1998a). Provisional toxicity values are currently available for aluminum and iron, and concentrations of aluminum and iron in some media in the site area could pose an unacceptable risk to human health (see Appendix B). Therefore, aluminum and iron that are detected in specific medium/exposure areas will be retained as COCs. Calcium, magnesium, potassium, and sodium do not have toxicity values and will not be evaluated in the HHRA.

All other COPCs elevated above background that are detected in specific media/exposure areas in the site area will be considered COCs.

3.4 Risk-Based Screen

A risk-based screen will not be used in the selection of COCs because assumptions typically used in deriving screening levels (e.g., Region 9 PRGs, EPA soil screening levels [SSLs], Oak Ridge National Laboratory [ORNL] PRGs) were not intended for tribal scenarios.

Typically, EPA Region 10 recommends that potentially hazardous constituents in each medium present at maximum concentrations that are below Region 9 PRGs for residents can be excluded from further consideration (EPA Region 10 1998a). There are several problems with using this approach to select COCs. First, Region 9 PRGs are not available for radionuclides. Second, assumptions used in deriving Region 9 PRGs were not intended for tribal scenarios.

Risk-based concentrations for residential exposure to radionuclides are available in EPA's Soil Screening Guidance for radionuclides (EPA 2000d) and on the ORNL Risk Assessment Information Service (RAIS) on-line database; however, the assumptions used in deriving these screening levels also were not intended for tribal scenarios.

An assumption in risk-based screening studies is that the risk-based concentrations used in the screen are protective of all possible site-specific scenarios. For example, Region 9 residential PRGs for soil and water, which are based on conservative assumptions related to typical patterns of residential exposure, are also protective of other less exposed individuals (e.g., workers or recreational users) (EPA Region 9 2000). Region 9 residential PRGs for soil and water may not be protective for site-specific subsistence scenarios. For example, risk from ingestion of roots in the site area will likely far exceed risk from other soil-related pathways and risk from inhalation of water vapor in a sweat lodge will likely far exceed risk from other water-related pathways. Neither of these pathways is considered in the Region 9 PRGs.

Risk-based concentrations for residential exposure in EPA's Soil Screening Guidance for Radionuclides or the ORNL RAIS also may not be protective of site-specific subsistence exposure scenarios for the same reasons described previously for the Region 9 PRGs. Therefore, a risk-based screen will not be used for selecting COCs.

4.0 EXPOSURE ASSESSMENT

This section describes the methodology to be used to estimate human exposure at the site. Specifically, this section describes:

- Site setting
- Current and future land use and potentially exposed people
- CSMs and the pathways by which people may be exposed
- How EPCs of COCs will be calculated
- The intake equations and exposure factors that will be used to estimate the intake for each COC, exposure pathway, and receptor

4.1 Site Setting and Description

The Midnite Mine Superfund Site is an inactive open pit uranium mine situated on a south-facing hillside of Spokane Mountain at elevations ranging from approximately 2,400 to 3,400 feet above sea level. The mine is located on the Spokane Indian Reservation, approximately 8 miles northwest of Wellpinit, the nearest population center, in Washington State (Figure 2). The city of Spokane is approximately 35 miles from the mine site.

The leased area of the mine encompasses approximately 811 acres, of which 321 acres (an area approximately 0.5 miles wide by 1 mile long) were developed during mining operations. During the time the mine was active, several pits or subpits were excavated. Several of these were subsequently backfilled with overburden and waste rock material as mining progressed. The mine ceased operations in 1981, leaving approximately two and one-half million tons of ore/protore, and 33 million tons of waste rock on site. Oxidation of sulfide-containing minerals, primarily pyrite, exposed to oxygen on the mine pit walls, waste rock, and ore/protore materials produces acidic water. This acidic water then chemically leaches uranium, other radioactive constituents, and other metals from the waste rock. Dissolved metals can then be transported in soil, surface water, sediments, and groundwater at the site.

The study area currently consists of the MA and the PIA, as described in the following sections. The MA is defined as the 321 acres where the ground surface has been visibly disturbed by mining operations. The PIA is the area surrounding the MA that may have been affected above background levels by the previous mining activities.

4.1.1 Mined Area

The major MA features include two large partially water-filled mining pits (Pits 3 and 4) (Figure 3), large areas of graded and partially re-vegetated spoils and waste rock from mining activities, and numerous stockpiles of ore and protore.

Pit water levels vary seasonally, with precipitation, collected seeps, and pumped water from backfilled pits. During winter, the pit levels rise because the water treatment plant is inoperative and because of water inflows to the pits from precipitation runoff and pumping of the seep collection system (into Pit 3 only). Between April and November, the water treatment plant operates and removes water from both pits which lowers the pit water levels. Water management facilities that are present include a surface impoundment for collection of seep water (Pollution Control Pond), a system of seep collection sumps and weirs, several buildings containing pump equipment and holding tanks for collected seep water, and a water treatment facility which discharges treated pit water and seep water via a permitted outfall to the Eastern Drainage.

There is a small circular pond called the Blood Pool located east of the water treatment plant near the eastern edge of the MA. The pond is fed by seeps and is approximately 40 feet in diameter. The amount of water in the pond ranges from dry to approximately 3 feet deep. Water from the Blood Pool, when present, drains into a ditch and is partially collected in a sump located approximately 400 feet downhill (southeast) of the pool. This water is periodically pumped to Pit 3. The quantity of water in the Blood Pool varies directly with precipitation (EPA Region 10 1998b), but the pool has been mostly dry for the past 2 years. Sampling conducted by EPA (Region 10 1998b) and SMI in 1998 and 1999 indicate that the water contains elevated concentrations of radionuclides.

Groundwater in the MA flows through natural and disturbed unconsolidated materials and bedrock. Unconsolidated materials consist of alluvium, waste rock, and ore/protore stockpiles. Waste rock from mining operations was deposited across several existing drainages in the MA (the northern extensions of the Western, Central and Eastern Drainages). These buried drainages and buried haul roads likely act to channel flow with the unconsolidated materials (URS 2000a).

Groundwater flow within the bedrock is through discrete fractures, joints, and faults. Major geologic structures in the MA may act as preferred flow paths in the bedrock. One such structure, sometimes referred to as the Midnite Fault, extends through Pit 4 to the south of Pit 3. Seeps of water are present on the north highwall of Pit 3 at the location of this structure (URS 2000a).

Recharge to the groundwater system is from precipitation falling on the MA and the Northwest Ridge. The majority of the water that infiltrates and becomes groundwater at the site moves through the waste rock and alluvium and flows across the surface of the bedrock. During the passage through the waste rock, the water reacts with minerals in the rock which contribute radionuclides, metals, and major ions such as sulfate to the groundwater. Much of this water discharges at the three major seeps along the south face of the South Spoils waste rock. The seep collection system described above is currently operated by the Dawn Mining Company (DMC) to collect seep flows and return the water to Pit 3 for subsequent water treatment prior to discharge in the East Drainage. A minor portion of the contaminated groundwater infiltrates into the bedrock and moves to the south from the disturbed area (URS 2000a).

Groundwater at the MA generally flows from north to south and converges into the drainages that flow toward Blue Creek. Under current conditions, Pits 3 and 4 may both serve as groundwater sinks for water in the MA. However, the pits may have historically been sources to downgradient contamination when pit lake levels were higher. Data also indicate that the Northwest Ridge is a groundwater divide and that flow from Pit 4 is towards the south within the MA (URS 2000a). There is a small seep flowing out of the base of the hillside dump waste rock pile along the access road to Pit 4.

Extensive upland habitat is found within the MA; however, the quality of the upland habitat has been physically degraded. The physically disturbed upland habitat in the MA is generally of limited extent and poor quality for wildlife use, although small isolated stands of remnant coniferous forest occur on apparently undisturbed ground patches within the MA. SMI identified and collected plants in three upland areas in the MA (discussed in Appendix B). Predominant species differed among upland areas, and included grasses, clovers, knapweed, arrowleaf balsamroot, common snowberry, and ponderosa pine. Other species identified by SMI (1999a) as major plant species for upland areas include Douglas fir, Macoun rose, autumn willowherb, Idaho fescue, Prush deervetch, groundsel, and mullen.

4.1.2 Potentially Impacted Area

The PIA is the area surrounding the MA that is potentially affected by previous mining activities at the site (Figure 3). The nature and extent of the mine-affected area will be characterized based on results of the RI studies now in progress. In these studies, concentrations of constituents in the area surrounding the MA will be compared to concentrations at background locations to estimate the likely extent of mining-related effects.

4.1.2.1 Upland PIA

Upland habitat in the site area occurs outside the zone of immediate influence of surface water bodies (e.g., creeks, ponds, seeps) and/or ground water. A variety of sub-habitat types occur in the uplands including forested, grassland, open, and steep sub-habitats. The geomorphological and topographical features of the site (e.g., aspect, slope, elevation, and soil characteristics) largely influence the distribution and diversity of these habitats. These habitats and their associated plant diversity provide food and cover for a variety of wildlife.

Extensive upland habitat is found within the PIA, which appears largely undisturbed from mining activities. This upland habitat is dominated by coniferous forest. The forest cover types are classified as to the dominant forest tree species, size class and density. The dominant forest cover type in the project area is an overstory of either ponderosa pine or a mixture of ponderosa pine and Douglas-fir of uneven aged size class with a density ranging from light to full. True ponderosa pine plant communities dominate the warm, dry zones of the reservation (Zamora 1983). As one moves to more moist and cooler sites, Douglas-fir plant communities dominate the landscape.

Steep habitat is found on the west bank of the middle and lower portions of Blue Creek and open habitat is found on the western bank of the lower portion of Blue Creek.

Detailed descriptions of each plant community and the reptile and amphibian, mammal, and bird species that may utilize the upland habitats are presented in the Ecological Characterization Technical Memorandum (URS 2000b).

4.1.2.2 PIA Drainages

Seven drainages in the PIA receive runoff from portions of the MA: Western Drainage, Central Drainage, Eastern Drainage, Northeastern Drainage, Northern Drainage, Far West Drainage, and Southwestern Drainage. Blue Creek ultimately receives water and sediment from these drainages (Figure 3). A small portion of the Northern Drainage may also receive runoff from a small portion of the MA (see Section 4.1.2.2.8). Blue Creek receives water and sediments from the Eastern Drainage, Turtle Lake, Oyachen Creek southwest of the PIA, and several small unnamed tributaries upstream of the PIA. Blue Creek flows to Lake Roosevelt, approximately 4.5 miles from the site.

Vegetation is relatively dense in and around the southern drainages and Blue Creek in the PIA. SMI identified and collected plants in riparian/aquatic areas in the Western, Central, and Eastern drainages and Blue Creek in the PIA (discussed in detail in Appendix B). Numerous species contributing significantly to biomass and cover in the southern drainage include common snowberry, climbing nightshade, oceanspray, Macoun rose, burdock, thimbleberry, barberry, buckbush, smooth brome, grasses, clovers, elephant ear, horsetail, ponderosa pine, Douglas maple, Douglas fir, red alder, and black hawthorn. Other species identified by SMI as major plant species for the southern drainage area include the serviceberry, creeping bentgrass, sedge, drooping woodreed, and Canada thistle.

In the Blue Creek drainage, numerous species contributing significantly to biomass and cover include climbing nightshade, burdock, stinging nettle, stout horsetail, red alder, and Douglas fir. Other species identified by SMI as major plant species for the Blue Creek area are Red maple, serviceberry, narrow leaf cottonwood, Macoun rose, drooping woodreed, Canada thistle, and prickly lettuce.

Based on sampling results for surface water and aquatic sediments, portions of the Western, Central, and Eastern drainages and the downstream parts of Blue Creek nearest to the site have likely been impacted by contaminant sources in the MA. Whether other drainages in the PIA have also been affected above background levels (i.e., mine affected) is currently being evaluated. Drainages in the PIA are further described in the following sections.

4.1.2.2.1 Western Drainage

The Western Drainage is the downstream extension of the topographic surface drainage that formerly existed within and drained the western portion of the MA. The Western Drainage currently extends from the southern MA boundary, just south of the toe of the South Spoils, to the confluence with the Eastern Drainage approximately 2,700 feet to the southeast. Water discharges from seeps to the Western Drainage where the drainage is truncated by the western portion of the South Spoils. Water emanating from the seeps is believed to be primarily derived from subsurface flow pathways in the western portion of the MA. Such pathways include historic drainages now buried by waste rock or stockpile material, possible trans-drainage pathways associated with mine haul roads or other flow barriers, backfilled pits, and bedrock flow pathways. A major portion of the seep water is contained by a collection and pump back system that is operated by the DMC to control migration of water from the MA to the PIA. However, a portion of the seep water escapes down the drainage, particularly during high flow conditions.

The Western Drainage also receives surface water runoff from a ditch extending along the southwest edge of the South Spoils, and direct runoff from the central portion of the South Spoils. South of the MA, the Western Drainage may also receive water as a result of groundwater discharge along its course, either from flow paths in unconsolidated materials or from bedrock. Groundwater flow pathways from the western MA are expected to be convergent toward and along the Western Drainage alignment. Groundwater may flow upwards toward the surface to discharge to the drainage, or may receive surface water infiltration from the drainage.

4.1.2.2.2 Central Drainage

The Central Drainage is the downstream extension of the topographic surface drainage that formerly existed within and drained the central portion of MA. The Central Drainage currently extends from the southern MA boundary, just south of the toe of the South Spoils, to the confluence with the Eastern Drainage approximately 1,800 feet to the south. Along the southern margin of the MA, water is discharged to the Central Drainage from seeps located where the drainage is truncated by the central portion of the South Spoils. Water emanating from the seeps is believed to be primarily derived from subsurface flow pathways in the central portion of the MA, including historic drainages now buried by waste rock or stockpile material, possible trans-drainage pathways associated with mine haul roads or other flow barriers, backfilled pits, and bedrock flow pathways. A major portion of the seep water is contained by a collection pump back system that is operated by the DMC to control migration of water from the MA to the PIA.

The Central Drainage receives direct runoff from the eastern portion of the South Spoils. South of the MA, the Central Drainage may also receive groundwater discharge along its course, either from flow paths in unconsolidated materials or from bedrock. Groundwater flow pathways from the central MA are expected to be convergent toward and along the Central Drainage alignment. Groundwater may flow upwards toward the surface to discharge to the drainage, or may receive surface water infiltration from the drainage. Groundwater flow may also occur along the alignment of the Central Drainage, but beneath the drainage without interaction with the surface water in the drainage.

4.1.2.2.3 Eastern Drainage

The Eastern Drainage is the topographic surface drainage that exists immediately east of the southeastern portion of the MA. For the purposes of the RI/FS, the Eastern Drainage is defined to extend from the National Pollution Discharge Elimination System (NPDES) outfall (i.e., located just north of the northernmost extent of the mine haul road) to the confluence with Blue Creek, approximately 6,400 feet to the south. The Eastern Drainage also includes two northwest-southeast trending tributary drainages extending from the MA boundary to the main drainage. The East Seep Pumpback System is located in the western of these tributaries just north of the MA boundary. Surface water flows to the Eastern Drainage from the upstream Northeastern Drainage and from the NPDES outfall located immediately north of the haul road.

Water also enters the drainage from the East Seep. A major portion of the seep water is contained by a collection and pump back system that is operated by the DMC to control migration of water from the MA to the PIA. Water emanating from the seep is believed to be derived from subsurface flow pathways in the eastern portion of the MA, including historic drainages now buried by waste rock or stockpile material, possible trans-drainage pathways associated with mine haul roads or other flow barriers, and bedrock flow pathways. The Eastern Drainage also receives direct runoff from waste rock deposited along the southeast MA boundary. SMI (1999b) identifies seven seeps along the Eastern Drainage.

The Eastern Drainage may also receive water as a result of groundwater discharge along its course, either from flow paths in unconsolidated materials or from bedrock. Groundwater flow pathways from a portion of the eastern MA are expected to be toward and along the Eastern Drainage alignment. Groundwater may flow upward to discharge to the drainage, or may receive surface water infiltration from the drainage. Groundwater flow may also exist along the alignment of the Eastern Drainage, without interaction with the surface water in the drainage.

4.1.2.2.4 Northeastern Drainage

The Northeastern Drainage is the topographic surface drainage that exists immediately east of the majority of the northern portion of the MA. The Northeastern Drainage consists of all surface drainages that intersect the eastern MA boundary between the top of the Pit 4 headwall and the Site NPDES outfall (i.e., which serves as the boundary between the Northeastern Drainage and the Eastern Drainage).

Surface water runoff and groundwater enter the Northeastern Drainage from the northern portion of the MA south of the top of the Pit 4 headwall. This drainage receives direct runoff from waste rock deposited east of the northern portion of Pit 4. Sediments eroding from the eastern portion of this area of waste rock have been transported into the Northeastern Drainage.

The Northeastern Drainage also receives direct runoff from disturbed natural material, including a former mine truck ready-line east of the southern portion of Pit 4. Based on the available data, and the site potentiometric surface map, bedrock groundwater from the portion of the MA north of Pit 3 and east of Pit 4 does not appear to flow toward the Northeastern Drainage. Immediately east of Pit 3 and Pit 4, there is a groundwater divide that coincides with the topographic divide, along which the hydraulic gradients are either toward the Northeastern Drainage or toward Pit 3 and Pit 4.

4.1.2.2.5 Northern Drainage

The Northern Drainage is the topographic surface drainage that exists immediately east of the northernmost portion of the MA. The Northern Drainage consists of the surface drainage that drains the MA north of Pit 4. Surface water runoff and groundwater enter the Northern Drainage from the far northern portion of the MA that is north of the top of the Pit 4 headwall. The Northern Drainage receives direct runoff from disturbed natural material, including exposed mineralized rock. Bedrock groundwater from the portion of the MA north of Pit 4 may flow toward the Northern Drainage or, more likely, may flow toward Pit 4.

4.1.2.2.6 Far West Drainage

The Far West Drainage is the topographic surface drainage that exists immediately west of the southern portion of the MA.

Surface water runoff and groundwater enter the Far West Drainage from the extreme western portion of the MA between the Northern and Southern Topsoil Piles. This portion of the MA includes the Vehicle Shop and the Mine Offices Area. The Far West Drainage also contains a pile of overburden material, possibly waste rock, located immediately west of the Vehicle Shop area. The Far West Drainage receives direct runoff from the western portion of the Vehicle Shop and the Mine Offices Area and from the waste rock pile. Bedrock groundwater from the western portion of the Vehicle Shop and Mine Offices Area and from the waste rock pile area may also flow toward the Far West Drainage.

4.1.2.2.7 Southwestern Drainage

The Southwestern Drainage is the topographic surface drainage that exists southwest of the southern portion of the MA.

Surface water runoff and groundwater enter the Southwestern Drainage from the southwestern portion of the MA between the Southern Topsoil Pile and the Western Drainage. Vehicle parking and maintenance areas may have been present in the MA potentially upgradient of the Southwestern Drainage. During past mining operations, soil staining has been identified based on detailed evaluation of historical aerial photographs (Peters, 1999). The Southwestern Drainage does not receive direct runoff from the MA. Surface water runoff from the southwestern portion of the South Spoils is captured by a diversion ditch before reaching the Southwestern Drainage. The Southwestern Drainage may receive bedrock groundwater flow from the southwestern edge of the MA.

4.1.2.2.8 Northwest Ridge

The Northwest Ridge is the topographic ridge to the northwest of the MA.

The majority of the Northwest Ridge is outside and uphill from the MA. Surface water runoff from the majority of the Northwest Ridge flows toward the MA, but is diverted from entering the MA by several berms and diversion ditches. The far northeast edge of the Northwest Ridge is adjacent to the area of exposed mineralized rock at the extreme northern end of the MA. Bedrock groundwater along the southern slope of the Northwest Ridge generally flows toward the MA. However, there is a potential for migration of bedrock groundwater from the exposed mineralized rock toward the north.

4.1.2.3 Haul Roads

There are several unpaved roads (haul roads) in the PIA that were covered with gravel derived from stockpile material from the MA (Figure 3). The roads were surfaced with one inch of gravel (crushed cal-silicate rock) suspected to originate from the protore stockpile located near the waste treatment plant. In addition, these haul roads may have been impacted by ore from the MA lost from trucks during mining operations.

The East and West Haul Roads extend from the MA through the PIA to the paved Ford-Wellpinit Road (Figure 3). The East Haul Road is about 40 feet wide and extends approximately 9,700 feet from the east stockpile area to the Ford-Wellpinit Road. This was the main haul road to the Ford Mill during the later stages of mining and is currently used to haul sludge from the water treatment plant to the Ford Mill twice daily. The West Haul Road is about 40 feet wide and extends approximately 2,300 feet from the mine buildings area to Ford-Wellpinit Road. This was used as a haul road during early mining operations and is currently used for access to the site area by DMC workers (it is not currently used for hauling). In addition, there are three pump house access roads that extend from the Pollution Control Pond to the Western and Central drainage seep pump houses. These roads are about 20 feet wide and a total of approximately 2,000 feet in length. These roads were never used for hauling and are currently used by DMC workers to get to the pump houses. In addition to the contaminated materials on the surface of the haul roads, surface water, sediment, and surface soil in the PIA near the haul roads may have been affected by surface runoff and windblown dust. The haul roads will include any identified impacted area to each side of the roads.

4.2 Identification of Land Use and Potentially Exposed People

The Site is located entirely within the 154,000-acre Spokane Indian Reservation. The nearest town to the Site is Wellpinit, located approximately 8 miles southeast of the mine.

4.2.1 The Spokane Tribe of Indians

Information presented in this section was obtained from AESE (2001), which is included as Appendix C.

The Spokane Indians are part of the Interior Salish group who inhabited northeastern Washington, northern Idaho, and western Montana. The Spokane Indian Reservation was originally set aside by agreement in 1877 between the Spokane Tribe of Indians and the United States. Because of the Tribe's dependence on fisheries and other river resources, the Reservation boundaries were set by an 1881 Executive Order to include portions of three border streams to their far banks: The Columbia and Spokane Rivers on the west and south, respectively, and Chamokane Creek on the east.

The traditional Spokane Tribal economy was characterized by a complex and highly structured system of food source production, distribution, and consumption. Salmon was the most important commodity in the early Spokane tribal economy. It provided both an excellent food source, as well as a unique trade item. The importance of salmon is reflected in native names for some of the Spokane peoples that are associated with particular stretches of rivers and other resources, such as Fisherman, People of the Steelhead Trout Place, and Salmon-Trout People (Ray 1977, as cited in AESE 2001). The Spokane Tribe's fish diet was supplemented with large and small game and a wide variety of roots, berries and other plants gathered locally. Because subsistence materials were plentiful on the reservation, the Spokane Indians were not a widely nomadic culture. The wide variety of food sources also allowed for rapid adaptation to harsh climate events or other circumstances depleting a given food source.

Spokane economic and social life centered around seasonal cycles. In the spring, usually beginning in March, winter camps dispersed into smaller groups to gather food, hunt, and fish. By early summer, salmon fishing, hunting and root digging were the main activities. During the summer and early fall, the schedule included root digging and berry picking. This was the time of year that inter-tribal social activities were at their highest as neighboring tribes joined the Spokanes in one general area for the fall runs of salmon, root gathering, and berrying. In early winter, smaller units regrouped and formed their winter camps. These camps were located in favorable places along rivers or creeks affording water and shelter. Most of the winter months were spent participating in ceremonies, making material goods, and trading (Wynkoop 1969, as cited in AESE 2001).

Indian reservations were, and are, intended to provide permanent homelands for members of the reservation's tribes. As such, it is the right of the tribe to use reservation natural resources for subsistence, religious, and other cultural purposes. It is the legal and political policy of the Spokane Tribe of Indians to preserve and protect the natural resources of the Spokane Indian Reservation in a manner that supports the Reservation's use as a permanent homeland, including subsistence, religious, and other cultural purposes.

The importance of water to the Spokane tribe is represented by the following selection from the Tribe's water quality code:

> Water is, and has been, central to the culture, religion, subsistence and way of life of the Spokane Tribe of Indians since time immemorial. Much of the Tribe's language is based on water. Unwritten laws of the Tribe have controlled use of water for thousands of years [Law and Order Code of the Spokane Tribe of Indians, Ch. 30, Surface Water and Ground Water Protection, Sec. 30-2.01].

In addition to the water quality laws, the Tribe has also sought to preserve its culture through the enactment of other laws protecting critical reservation natural resources, such as the fish and wildlife code. The section of that code which describes its purposes and intent states:

> Pursuant to the powers in the Constitution of the Spokane Tribe of Indians, the Business Council of the Tribe sets forth the following Chapter of the Law and Order Code to regulate fishing, hunting and recreational activities which take place on all lands and waters where the Spokane Tribe exercises its jurisdiction. The Business Council recognizes the value of the fish, wildlife and recreational resources within all the lands and waters within its jurisdiction. Fish, wildlife and recreational resources are an irreplaceable asset of the Spokane Tribe. Regulation and protection of these assets is the duty of the Business Council. Unregulated use of these resources would threaten the political integrity, economic security and health and welfare of the Spokane Tribe. [Law and Order Code of the Spokane Tribe of Indians, Ch. 17, Fish, Wildlife and Recreation, Sec. 17-1.01].

Similarly, in the Vision Statement of The Integrated Resource Management Plan for the Spokane Indian Reservation (IRMP), adopted in 1996, the Tribe listed the values that were fundamental to the IRMP (STI 1996). At the top of the list is the "protection and preservation of cultural heritage." According to the IRMP, "[t]he predominant values expressed by the Spokane Tribal members during the IRMP scoping process can be summarized as "the Spokane language, ceremonial traditions, traditional/medicinal plants and animals, and sacred sites" (STI 1996, as cited in AESE 2001).

The reservation provides enough resources for some tribal members to live a fairly traditional lifestyle, and for all tribal members to obtain traditional foods. Since the construction of Columbia Rivers dams, anadromous salmon are no longer available. As a result, the Tribe has substituted large game as the main source of protein. Over time, Tribal Elders realized that the portion of their culture associated with salmon was being lost and was not being passed onto the next generations. This portion of the subsistence dietary lifestyle is most valued and encouraged by the Tribe because it is central to preserving the remainder of the Tribe's culture. In an attempt to retain this portion of their culture, kokanee salmon (landlocked sockeye salmon) were introduced into Lake Roosevelt, and today are slowly replacing the amount of big game in the Tribe's diet.

The way of life of the Spokane Indian Tribe is part of a large Eco-Cultural system that includes humans, plants, fish and wildlife in several different habitats. It has been reported that Spokane Indians use over 200 varieties of plants (Nugent 1997). In particular, two varieties of camas (lily family) and bitteroot are considered staple plant food items and are still gathered in many areas. A wide variety of pharmacologically active medicinal plants are also used internally and externally. Many plants are used for material goods, including cattail and tule (mats, insulation), wild parsnip (fly repellent), red willow (fish traps, platters, and baskets), and cedar roots (bags and baskets) (Turner 1997, 1998).

4.2.2 Current Land Use

Lands at and near the site include Spokane Tribe lands owned in trust by the federal government and allotment lands owned in fee by the tribe or by descendants of the initial recipients of the allotments. Leases from the tribe and allottees were issued by the Bureau of Indian Affairs for mining purposes and for access and haul roads. One allotment extends over much of the MA, while two others are to the east and southeast of the MA (Figure 3). The tribe has prepared a land use planning document for Tribal land, the IRMP (STI 1996). The Tribal IRMP restricts land uses in the site area against residential and commercial development.

No one currently lives on or near the MA or PIA. Land at and near the MA or PIA is primarily used by members of the Tribe to support a traditional lifestyle that includes subsistence, cultural/spiritual, and medicinal components. This type of land use is very specific to the Tribe, and is not well reflected by any typical CERCLA categories of human land use (e.g., residential, commercial, recreational). Additional information on current land use is provided below.

Current Hunting, Gathering, and Fishing

The primary current land use at and near the site is hunting, gathering, and fishing by members of the Tribe to support their traditional way of life. These subsistence activities are essential to support nutritional, cultural/spiritual, and medicinal needs. The site is owned by the Tribe, therefore, tribal members may each hunt, gather, and fish anywhere at and near the site.

Hunting, gathering, and fishing are done on a daily basis to keep the extended family unit stocked with a wide variety of aquatic, riparian, and terrestrial plants and wildlife used for subsistence, cultural/spiritual, and medicinal purposes. While in the field performing these activities, tribal members live off the land by consuming water, plants, and wildlife.

Johnson (1997, as cited in SMI 1999c) reported that fishing is limited to 2 miles upstream of where Blue Creek enters Lake Roosevelt, up to and including Lake Roosevelt. Other documents report that fish nearer to the MA are present only seasonally due to low water conditions and in insufficient size and number to support sustainable fish harvesting (Scholtz et al. 1988; EPA 1986a; Plotnicoff et al. 1988 as cited in SMI 1999c). However, the above documents were written prior to the startup of water treatment plant operations which has increased water flow in the Eastern Drainage and, potentially, in Blue Creek. Further coordination with the Tribe may be necessary to determine whether the PIA contains drainages that support significant harvesting of fish.

Current Processing

Processing includes the washing and preparation of gathered materials used for food, medicine, and other purposes. Exposure during processing could occur while washing; smoking; peeling; cooking; basketmaking and quillwork with mouth contact; matmaking; cleaning, dressing, and tanning hides; drying vegetal food or medicines; etc.

Current Subsistence Use

Subsistence use refers to exposures that occur during use of plants, wildlife, and livestock for food, clothing, or other purposes.

The traditional diet for the Tribe includes big game, fish, small mammals, insects, grubs, frogs, and plants. Different portions of each plant and animal are used for traditional purposes. For example, every portion of big game such as deer, elk, bear, cougar, and wolverine, and of livestock is used for specific subsistence, cultural/spiritual, or medicinal purposes. Portions of plants are harvested as needed (e.g., roots, flowers, and leaves are often harvested without destroying the plant, allowing for future root growth) and used for subsistence, cultural/spiritual, or medicinal purposes. Medicinal uses of plants can include direct ingestion, dermal or subdermal application, application in open cuts, and inhalation (includes smoking).

The traditional diet also includes home-grown garden produce and livestock. Most livestock owned by the Tribe are free to forage throughout the reservation. Therefore, the MA or PIA could be used by livestock for foraging.

Current Field Work

Members of the Tribe may work in the MA or PIA collecting environmental samples, engaging in restoration/reclamation/construction work, and caring for natural and cultural resources and tribal property.

Current Ceremonies

Parts of the site may be used by members of the Tribe for conducting sweat lodge ceremonies. The daily use of the sweat lodge is an integral part of the lifestyle that starts at 2 years of age. Sweat lodges are constructed of natural materials (i.e., branches, moss, leaves) near a source of surface or groundwater. Sweat lodges that use groundwater have spiritually different significance than those constructed near sources of surface water. Groundwater from wells in the MA or PIA is not currently known to be used for sweat lodge ceremonies. However, sweat lodge ceremonies using water in drainages, seeps, and springs could currently be conducted in the PIA. It is not known whether sweat lodge ceremonies are currently conducted in the MA.

In addition, areas along Blue Creek and at the confluence of Blue Creek and Lake Roosevelt are currently used by members of the tribe for ceremonial purposes (e.g., pow-wows, horse races, seasonal ceremonial activities). However, it is not yet known whether areas used for ceremonial purposes have been impacted by the Site.

Current Teaching

Elders in the Tribe teach a variety of indoor and outdoor traditional activities in the MA and PIA.

Current Recreational Use

Parts of the MA and PIA could currently be used for recreational purposes (e.g., adults and older kids could wade in creeks in the PIA). It is not known whether any members of the Tribe swim in the two open pits. There is a recreational beach owned by the Tribe at the confluence of Blue Creek and Lake Roosevelt, 4.5 miles from the MA. Data are currently being analyzed to evaluate whether this beach area has been impacted by the site. Results of this data evaluation will be provided in the RI report.

Current Transportation

Parts of the MA and PIA are used regularly for transportation. For example, the Tribe has stated that all residents use the haul roads for transportation, (walking, bicycling, or driving) (AESE 2001).

Current Residential

No one currently lives in or near the MA or PIA.

Current Water Use

Groundwater from wells is not known to be used in the MA or PIA. Water from seeps, springs, and drainages in the PIA could potentially be used in a sweat lodge ceremony or ingested by hunters, gatherers, workers, and other visitors to the PIA. It is not known whether water from the two open pits is used for these purposes.

4.2.3 Future Land Use

Future land use in the site area is expected to remain similar to current land use, in that it will be used for traditional activities (subsistence, cultural/spiritual, medicinal), field work, transportation, and recreational purposes and for livestock foraging. In addition, future residential use of the land in the PIA is a possibility. For example, residences could be built on parcels of land in the PIA currently owned by individual members of the Tribe. Groundwater in the PIA could be used in the future for domestic purposes and sweat lodge ceremonies if supply wells were to be constructed in the PIA for such purposes.

In the MA, residential exposure and domestic use of groundwater from wells are each considered to be extremely unlikely future scenarios. The Tribal IRMP (STI 1996) restricts land uses in the area against residential and commercial development. Because exceptions could be made for this site, particularly since it has been cleared and has roads and some electrical hookups, EPA is planning to include a simplified residential risk estimate to support risk management decisions. EPA expects that risks for residents in the MA will be shown to be high enough to require a response action, and that restrictions against residential use will be part of any response action. At this time, any remedy for the MA is likely to include containment/capping, which will necessitate restrictions on land use to protect the remedy.

4.2.4 Potentially Exposed People in the Site Area

By necessity of limitations in our knowledge of many of the determinants of exposure, the scenarios evaluated will require simplifying assumptions. This is true of all risk assessments, but it is especially true at the Midnite Mine Superfund site because less is known about exposures unique to members of the Spokane Tribe of Indians as they practice their traditional lifestyle. This uncertainty is compounded because much of the information required to quantify potential exposures in the site area, which is specific to the Spokane Tribe of Indians, is unavailable from the Tribe or other sources. The available exposure information prepared by the Spokane Tribe is included as Appendix C.

Potentially exposed people in the site area are assumed to include families currently residing offsite on the reservation and future families residing in the PIA. The future resident who lives in the PIA is considered the most exposed receptor based on current and reasonably anticipated future land use. Current residents of the reservation do not live in the MA or PIA, but will be assumed to visit those areas. Groundwater from wells in the MA and PIA is not currently known to be used. Future residential use of the land in the PIA including groundwater from wells is a possibility.

Residential exposure with domestic use of groundwater is considered to be an extremely unlikely future scenario for the MA. EPA (1995) indicates that risk to human health and cleanup levels should be based only on current and reasonably anticipated future land use scenarios and not on land use scenarios that are unlikely. Nevertheless, a hypothetical future residential scenario in the MA will be evaluated for risk management purposes or, if there is a change in land use, to assess whether a remedy may need to be reevaluated.

The types and extent of exposure for current and future residents described in the following sections are age-specific. The assumed time to be spent by people in various activities is presented in Section 4.7.1 and shown in Table 9.

4.2.4.1 Infants

Infants under 2 years of age are assumed to spend their time primarily at the place of residence (in the house or outdoors in the yard). Although some infants on the reservation are breast fed, it is unlikely that this is a significant route of exposure relative to direct exposures. Instead of breast feeding, infants will be assumed to ingest formula made from water at the residence. This is a conservative assumption because concentrations of COCs would likely be higher water in the MA or PIA than in breast milk. Infants are assumed not to ingest plants, wildlife, or livestock; participate in sweat lodge ceremonies or other cultural activities; or use the haul roads. In fact, infants may receive limited exposure to plants, wildlife, livestock, and the haul roads. However, these pathways are likely negligible relative to other exposures at the residence.

As a result of these assumptions, there are no complete and significant pathways for current infants living offsite. The risk assessment will evaluate future infants assumed to live in the PIA or MA.

4.2.4.2 Children and Adults - Common Activities

From the age of 2 years and older, residents are assumed to spend the same amount of time in certain activities (common activities), regardless of age group, which include (1) indoor and outdoor activities at and near the residence, (2) sweat lodge ceremonies near the residence, (3) cultural activities on Blue Creek, and (4) use of the haul roads for transportation. Indoor and outdoor activities at and near the residence could include house and yard work, playing, hunting, gathering, processing, gardening, sleeping, etc. The other common activities (sweat lodge, cultural, haul roads) have been described in detail in Section 4.2.2. Residents 2 years and older are assumed to eat the same types of plants, wildlife, and livestock.

4.2.4.3 Children and Adults - Specific Activities

In addition to common activities described above, residents 2 years and older are assumed to spend similar time in various activities in the PIA and MA, although the types of activities differ for different age groups. These age-specific activities have been described in detail in Section 4.2.2 and are listed below.

4.2.4.3.1 Child (2 to 6 years of age)

Beginning at age 2, the child accompanies the mother as she gathers in the PIA and MA.

4.2.4.3.2 Youth (ages 7-16)

It is assumed that youth spend time learning to hunt, gather, and fish, and playing outdoors in the MA and PIA.

4.2.4.3.3 Adults (ages 17-55)

It is assumed that adults spend their time working, hunting, fishing, gathering, processing, and gardening. In general, the men work in the site area (collecting environmental samples, engaging in restoration/reclamation/construction work, and caring for natural and cultural resources and tribal property), and hunt, fish, and process game. The women also work in the site area (same types of work as listed for the men), gather and process plants in the MA and PIA, and garden at the place of residence. For all of these activities, adults spend some time near water in the site area (e.g., on activities such as washing plants or game, gathering aquatic plants and wildlife), exposed to the sediment and surface water.

4.2.4.3.4 Elders (ages 56-70)

It is assumed that elders gather plants and medicines, prepare them, use them (e.g., making baskets or medicines), and teach a variety of indoor and outdoor traditional activities in the MA and PIA. Elders also provide child care in the home.

4.2.4.4 Receptor Summary

For the purposes of quantitative risk assessment, current residents, future residents living in the PIA, and hypothetical future MA residents will be divided into two age groups based on similar areas, types, and extent of exposure: (1) Infants who are exposed at the residence (in the house or outdoors in the yard), and (2) children (including youth) and adults (including elders) who spend similar time in common activities at and near the residence, in a sweat lodge, and on the haul roads; who spend time in the MA and PIA for various activities (hunting, gathering, teaching and learning traditional activities, working, recreating, transportation, and ceremonies); and who eat similar types of plants, wildlife, and livestock.

Therefore, potentially exposed people are:

- Current infants who live offsite and are primarily exposed at the residence. For the risk assessment, it will be assumed that these infants are not significantly exposed to COCs in the site area.
- Current children and adults who live offsite and spend time in the MA and PIA for various non-residential activities.
- Future infants who live in the PIA and are primarily exposed at the residence.
- Future children and adults who live in the PIA and spend time in the MA and PIA for various non-residential activities.
- Hypothetical future infants who live in the MA and are primarily exposed at the residence.
- Hypothetical future children and adults who live in the MA and spend time in the MA and PIA for various non-residential activities.

4.3 Conceptual Site Models

The groups of people described previously may be exposed to COCs at the site through various pathways. CSMs have been developed for the site area as schematic representations of source areas, release mechanisms, environmental transport media, and potential exposure routes for COCs that may lead to exposure of the receptors to contaminants in the site area (Figures 4 through 9). The purpose of the CSM is to represent COC sources and exposure pathways that may result in human health risks, to aid in developing a sampling plan to represent the exposure pathways which incur the most risk.

Potentially complete and significant exposure pathways are quantified by risk assessment (see Section 4.4 and Tables 1 through 6). A complete exposure pathway includes all of the following elements:

- A source and mechanism of contaminant release
- A transport or contact medium (e.g., groundwater or soil)
- An exposure point where humans can contact the contaminated medium
- An exposure (intake) route (such as ingestion or inhalation)

The absence of any one of these elements results in an incomplete exposure pathway. Where there is no potential exposure, there is no potential risk. EPA's risk assessment and risk characterization guidance (EPA 1989a, 1992c) does not require that all plausible exposure scenarios and exposure pathways be assessed. Pathways that are incomplete or potentially complete, but negligible, are not evaluated in the risk assessment. A pathway may be potentially complete but negligible if the transport process is considered to be insignificant resulting in negligible concentrations of COCs in the exposure medium, or if the amount of exposure to the medium is considered to be negligible. Potentially complete, but negligible, pathways will not be evaluated quantitatively because these pathways would be unlikely to measurably impact risk estimates or cleanup decisions. In addition, some pathways cannot be quantified even if they are potentially complete and significant because key information is lacking. Potentially complete pathways that are not evaluated quantitatively in the risk characterization will be discussed qualitatively in the uncertainty section of the risk assessment.

CSMs have been developed for the following potential sources of contamination: surface material in the MA, two open pits in the MA, groundwater in the MA and PIA, surface water and sediments in the PIA, soils and riparian sediments in the PIA, and surface material on the haul roads. The CSMs (Figures 4 through 9) depict the pathways that are summarized below. Sections 4.3.1 through 4.3.6 describe potentially complete and significant pathways in each CSM, and Sections 4.3.7 and 4.3.8 discuss potentially complete but negligible pathways and incomplete pathways, respectively.

4.3.1 Surface Material in the MA

The CSM for surface material in the MA is shown in Figure 4.

4.3.1.1 Potential Sources in the MA

Surface material in the MA includes ore, protore or waste rock deposited on the ground surface or in the backfilled pits, and MA soil potentially impacted by COCs transported in windblown dust or in surface runoff. The source also includes haul roads and other impacted areas in the MA. It does not include material in the two open pits or other surface water bodies in the MA.

4.3.1.2 Potential Release Mechanisms in the MA

COCs in surface material can enter outdoor air in the MA via fugitive and vehicle generated dust and from radon emanation. COCs in surface material can be taken up or adhered to terrestrial and garden plants growing in the MA and wildlife and livestock that forage in the MA. COCs in surface material in the MA could be transported into hypothetical residences on shoes and clothing. External radiation is emitted from radionuclides in surface material in the MA.

In some cases, the release mechanisms may carry COCs beyond the MA surface to other media or areas. COCs in surface material in the MA may be transported via leaching to MA groundwater or to PIA surface water and sediments. These media are addressed in CSMs shown in Figures 6 and 7.

In addition, materials from the MA were used to build the haul roads and may also have spilled alongside the hauls roads from trucks transporting ore to the mill. The CSM from haul roads is included in Figure 9.

4.3.1.3 Potential Exposure Media in the MA

Exposure media potentially impacted by surface material in the MA addressed in Figure 4 include surface materials, outdoor air, indoor air, terrestrial and garden plants, wildlife, and livestock, each in the MA, and construction material and indoor dust at current and future residences.

4.3.1.4 Potentially Exposed People in the MA

Exposure to people in the MA will be evaluated for the following groups: 1) people who currently reside off-site, but who frequent the MA; 2) potential future residents of the PIA; and 3) hypothetical future residents of the MA (Tables 3 to 6). As noted previously, residential land use is not anticipated to occur in the MA, but will be evaluated nonetheless.

4.3.1.5 Potentially Complete and Significant Exposure Pathways

Potentially complete and significant pathways by which receptors could be exposed to COCs from surface material in the MA are discussed in the following text.

Current Offsite Residents and Future Residents of the PIA

There are no complete and significant pathways for surface material in the MA for infants living offsite or in the PIA. Exposure pathways for children and adults living offsite or in the PIA who may spend time in the MA for various activities include:

- Ingestion and dermal exposure to surface material in the MA
- Inhalation of outdoor air containing fugitive dust and radon and daughter products in the MA
- Exposure to external radiation in the MA
- Ingestion of terrestrial plants growing in the MA
- Ingestion of terrestrial wildlife and livestock that live or forage in the MA

Hypothetical Residents of the MA

Exposure pathways for infants living in the MA include:

- Ingestion and dermal exposure to surface material in the yard and indoor dust at the residence in the MA
- Inhalation of outdoor air containing fugitive dust and radon and daughter products at the residence in the MA
- Exposure to external radiation at the residence in the MA
- Inhalation of radon and daughter products in indoor air at the residence in the MA

Exposure pathways for children and adults living in the MA include:

- Ingestion and dermal exposure to surface material in the yard and away from the residence and indoor dust at the residence in the MA
- Inhalation of outdoor air containing fugitive dust and radon and daughter products at and away from the residence in the MA
- Exposure to external radiation at and away from the residence in the MA
- Inhalation of radon and daughter products in indoor air at the residence in the MA
- Ingestion of terrestrial plants growing in the MA
- Ingestion of terrestrial wildlife and livestock that live or forage in the MA

4.3.1.6 Potentially Complete, But Negligible Pathways in the MA

Pathways considered potentially complete but negligible are discussed in Section 4.3.7.

4.3.1.7 Incomplete Pathways in the MA

Pathways considered incomplete are discussed in Section 4.3.8.

4.3.2 Two Open Pits in the MA

The CSM for the two open pits in the MA is shown in Figure 5.

4.3.2.1 Potential Sources for Two Open Pits

Water and sediments in the two open pits in the MA have been impacted by (1) erosion and leaching of material from the pit walls into the pits, (2) groundwater discharge into the pits, and (3) surface water and suspended sediments pumped to the pits. This source consists of pit walls, dried bank sediments, and surface water in the open pits.

4.3.2.2 Potential Release Mechanisms for Two Open Pits

COCs in the two open pits can enter outdoor air via fugitive dust from pit walls and dried sediments and via radon emission from pit walls, bank sediments, and water. COCs in surface water can be taken up via wildlife and livestock. External radiation exposure can be released from radionuclides in pit walls and bank sediments.

In some cases, the release mechanisms may carry COCs beyond the two open pits to other media or areas. COCs in water in the two open pits can flow into groundwater in the MA or be pumped to the water treatment plant, then discharged to surface water in the PIA. These media are evaluated in separate CSMs shown in Figures 6 and 7.

4.3.2.3 Potential Exposure Media for Two Open Pits

Exposure media potentially impacted by the two open pits addressed in Figure 5 include dried sediments, surface water, outdoor air, wildlife, and livestock. The pit walls are not considered direct exposure media for humans due to the inherent danger in climbing pit walls.

4.3.2.4 Potential Exposure in the Two Open Pits

People potentially exposed in the two open pits in the MA include current residents, future residents living in the PIA, and hypothetical MA residents.

4.3.2.5 Potentially Complete and Significant Exposure Pathways

Potentially complete and significant pathways by which people could be exposed to COCs from the two open pits in the MA are discussed in the following text. Because it is not know whether children and adults currently swim or intentionally ingest water from the pits, a hypothetical swimming scenario for children and adults in the open pits will be evaluated separate from the other scenarios.

Hypothetical Swimming Scenario

Current and future children and adults could use the two open pits for recreational purposes. Exposure pathways for this swimming scenario include:

- Ingestion, dermal, and inhalation exposure to dried bank sediments in the open pits
- Inhalation of radon and daughter products in the open pits
- Exposure to external radiation in the open pits
- Incidental ingestion to surface water while swimming in the open pits

Residents

Infants are assumed not to spend time in the two open pits. Children and adults living offsite, in the PIA, or in the MA could be exposed to COCs from the two open pits indirectly via ingestion of wildlife and livestock that ingest surface water from the open pits. Therefore, this pathway will be included in the risk assessment.

4.3.2.6 Potentially Complete, but Negligible Pathways for Two Open Pits

Pathways considered potentially complete but negligible are discussed in Section 4.3.7.

4.3.2.7 Incomplete Pathways for Two Open Pits

Pathways considered incomplete are discussed in Section 4.3.7.

4.3.3 Groundwater in the MA and PIA

The CSM for groundwater in the MA and PIA is shown in Figure 6.

4.3.3.1 Potential Groundwater Sources

Groundwater in the MA has been impacted by leaching of COCs from surface and subsurface materials in the MA and movement of surface water from the two open pits into groundwater. Groundwater in the PIA has been impacted by movement of groundwater from the MA into groundwater in the PIA, and, potentially, by leaching of COCs from surface and subsurface materials in the PIA including the haul roads.

4.3.3.2 Potential Groundwater Release Mechanisms

COCs in groundwater in the MA or PIA can enter residences via infiltration through a basement, be brought into a residence via domestic use of groundwater or into a sweat lodge during ceremonies, and be taken up by garden plants from irrigation.

Groundwater in the MA can be transported to groundwater and seeps/springs in the PIA. COCs in seeps/springs in the PIA can enter outdoor air via radon emission and can be taken up by livestock and wildlife that ingest seep/spring water.

COCs in seeps/springs in the PIA can enter surface water and sediments in the PIA via overland transport or be pumped to the water treatment plant, then discharged to surface water in the PIA. These media are evaluated in a separate CSM shown in Figure 7.

4.3.3.3 Potential Exposure Media from Groundwater

Exposure media potentially impacted by groundwater in the MA and PIA addressed in Figure 6 include groundwater in the MA and PIA, indoor air in the MA and PIA (in a residence or sweat lodge), garden plants in the MA and PIA, seeps/springs in the PIA, outdoor air in the PIA, and livestock and wildlife who forage in the PIA.

Seeps/springs at the site may be similar to groundwater in terms of concentrations of COCs, but are different than groundwater in terms of exposure because seep water can be directly used by people and wildlife who visit the site (without the need for a well). Seeps/springs may also be similar to surface water in terms of exposures by people and wildlife, but the concentrations of COCs in seeps may be very different than in surface water. Therefore, seeps/springs will be evaluated as a separate exposure media from groundwater and surface water in the site area.

4.3.3.4 People Potentially Exposed to Groundwater

People potentially exposed to groundwater in the MA and PIA include current residents, future residents living in the PIA, and hypothetical MA residents.

4.3.3.5 Potentially Complete and Significant Groundwater Exposure Pathways

Potentially complete and significant pathways by which receptors could be exposed to COCs from groundwater in the MA and PIA are identified in the following section.

Current Offsite Residents

There are no complete and significant pathways for groundwater in the MA and PIA for infants living offsite, because these infants are assumed not to spend time in the MA or PIA. Exposure pathways for children and adults currently living on the reservation include:

- Intentional ingestion of seep/spring water in the PIA
- Ingestion of livestock and wildlife that ingest water from seeps/springs in the PIA

Future Residents of the PIA

Exposure pathways for future infants living in the PIA include:

- Ingestion of groundwater in a residence in the PIA
- Inhalation of indoor air impacted by groundwater in a residence in the PIA

Exposure pathways for future children and adults living in the PIA include:

- Ingestion of groundwater in a residence in the PIA
- Inhalation of indoor air impacted by groundwater in a residence in the PIA
- Ingestion and inhalation exposure to groundwater during a sweat lodge ceremony in the PIA
- Intentional ingestion of seep/spring water in the PIA
- Ingestion of garden plants irrigated with groundwater from the PIA
- Ingestion of livestock and wildlife that ingest water from seeps/springs in the PIA

Hypothetical Residents of the MA

Exposure pathways for hypothetical residents of the MA are the same as those listed above for future residents of the PIA except that the residential exposures for hypothetical residents of the MA would occur in the MA.

4.3.3.6 Potentially Complete, But Negligible Pathways

Pathways considered potentially complete but negligible are discussed in Section 4.3.7.

4.3.3.7 Incomplete Pathways

Pathways considered incomplete are discussed in Section 4.3.8.

4.3.4 Surface Water and Sediments in the PIA

The CSM for surface water and sediments in the PIA is shown in Figure 7.

4.3.4.1 Potential Surface Water and Sediment Sources

Surface water and sediments in the PIA have been impacted by overland transport from the surface of the MA and PIA, discharge from the water treatment plant, and discharge from groundwater and seeps/springs. This source consists of surface water, and bank, channel, and suspended sediments in the PIA. Riparian sediments in the PIA are evaluated in a separate CSM in Figure 8.

4.3.4.2 Potential Surface Water and Sediment Release Mechanisms

COCs in dried bank sediments in the PIA can enter air via fugitive dust and release of radon and daughter products. COCs in sediments and surface water can be taken up into aquatic plants and wildlife in the PIA. COCs in surface water in the PIA could enter a residence in the PIA via domestic use of surface water; enter a sweat lodge during ceremonies; and be taken up by garden plants from irrigation or by livestock and terrestrial wildlife in the PIA. external radiation can be released from radionuclides in sediments in the PIA.

4.3.4.3 Potential Exposure Media from Surface Water and Sediments

Exposure media potentially impacted by surface water and sediments in the PIA addressed in Figure 7 include surface water in the PIA; bank, channel, and suspended sediments in the PIA; outdoor air in the PIA; indoor air in a residence in the PIA; indoor air in a sweat lodge in the PIA; garden plants and aquatic plants and wildlife in the PIA; and livestock and terrestrial wildlife who may forage in the PIA.

4.3.4.4 People Potentially Exposed to Surface Water and Sediments

People potentially exposed to surface water and sediments in the PIA include current residents, future residents living in the PIA, and hypothetical MA residents.

4.3.4.5 Potentially Complete and Significant Surface Water and Sediment Exposure Pathways

Potentially complete and significant pathways by which people could be exposed to COCs from surface water and sediments in the PIA are discussed next.

The extent of the area adjacent to the MA that has been impacted by mining activities has not yet been delineated. Therefore, it is not yet known whether drainages in the PIA that support significant harvesting of fish are part of the Site. Even if the Site does include drainages that support significant harvesting of fish, it is not yet known whether the types of COCs in those drainages would be taken up to a significant extent in fish.

Therefore, the ingestion of fish pathway will be preliminarily assumed to be potentially complete and significant while further information is obtained. The pending background investigation will delineate any impacts to drainages in the PIA. Any identified impacts to media in drainages (e.g., sediment, surface water, or groundwater) will then be evaluated for potential impacts to fish which may be harvested by Tribal members. Because there is a possibility that the fish ingestion pathway may be evaluated in the risk assessment, exposure factors for fish ingestion are provided in Section 4.7.2.1.

Current Offsite Residents

There are no complete and significant pathways for surface water and sediments in the PIA for infants living offsite.

Exposure pathways for children and adults living offsite who may spend time in the PIA for various activities include:

- Ingestion of surface water in the PIA
- Ingestion and dermal exposure to sediments in the PIA
- Ingestion of aquatic plants from the PIA
- Ingestion of aquatic wildlife from the PIA
- Ingestion of terrestrial wildlife and livestock that forage in the PIA

Future Residents of the PIA

Exposure pathways for future infants living in the PIA are ingestion of surface water used as a domestic water source and inhalation of indoor air. Exposure pathways for future children and adults living in the PIA:

- Ingestion of surface water in a residence in the PIA
- Ingestion and dermal exposure to sediments in the PIA
- Inhalation of indoor air in the residence in the PIA
- Ingestion and inhalation exposure to surface water during a sweat lodge ceremony in the PIA
- Ingestion of garden plants irrigated with surface water from the PIA
- Ingestion of aquatic plants from the PIA
- Ingestion of aquatic wildlife from the PIA
- Ingestion of terrestrial wildlife and livestock that forage in the PIA

Hypothetical Residents of the MA

There are no complete and significant pathways for surface water and sediments in the PIA for future infants living in the MA. Exposure pathways for future children and adults living in the MA who may spend time in the PIA for various activities include:

- Ingestion of surface water in the PIA
- Ingestion and dermal exposure to sediments in the PIA

- Ingestion of aquatic plants from the PIA
- Ingestion of aquatic wildlife from the PIA
- Ingestion of terrestrial wildlife and livestock that forage in the PIA

4.3.4.6 Potentially Complete, But Negligible Pathways

Pathways considered potentially complete but negligible are discussed in Section 4.3.7.

4.3.4.7 Incomplete pathways

Pathways considered incomplete are discussed in Section 4.3.8.

4.3.5 Soils in the PIA

The CSM for soils in the PIA is shown in Figure 8.

4.3.5.1 Potential Sources

Soils in the PIA include soil in upland areas and riparian sediments in riparian areas. Soils in the PIA may have been impacted by (1) fugitive dust and radon and daughter products from the MA and haul roads, and (2) overland transport of surface material from the MA and haul roads, discharge from the water treatment plant, and discharge from seeps/springs: each potentially deposited as riparian sediments. This source consists of surface and subsurface soil in upland areas and surface and subsurface riparian sediments in riparian areas in the PIA.

4.3.5.2 Potential Release Mechanisms

COCs from the MA and haul roads could enter outdoor air in the PIA via fugitive particulates and radon and daughter products. In addition, COCs from soils in the PIA could enter outdoor air in the PIA via fugitive dust and radon emission and could enter indoor air via radon emission and infiltration through a foundation. COCs in soils (i.e., surface materials) in the PIA could be transported into residences by vehicles, clothing, shoes, or pets or be taken up via garden plants at a residence, riparian or terrestrial plants growing in the PIA, and wildlife and livestock that forage in the PIA. Additionally, radionuclides in soils from the PIA may emit radiation externally.

COCs in soils in the PIA could also be transported via leaching to groundwater in the PIA and via overland transport to surface water and sediments in the PIA. However, soils in the PIA may not represent a significant source of COCs to groundwater and surface water.

4.3.5.3 Potential Exposure Media

Exposure media potentially impacted by soils in the PIA addressed in Figure 8 include soil; outdoor air; indoor air; riparian, terrestrial, and garden plants; wildlife and livestock that forage in the PIA; and indoor dust at current and future residences.

4.3.5.4 Potentially Exposed People

People potentially exposed to soils in the PIA include current residents, future residents living in the PIA, and hypothetical MA residents.

4.3.5.5 Potentially Complete and Significant Exposure Pathways

Potentially complete and significant pathways by which people could be exposed to COCs from soils in the PIA are identified in the following text.

Current Offsite Residents

There are no complete and significant pathways for soils in the PIA for infants living offsite. As discussed in Section 4.2.4.1, infants are assumed to spend their time at their place of residence. Exposure pathways for children and adults living offsite include:

- Ingestion and dermal exposure to soil in the upland PIA
- Inhalation of outdoor air in the upland PIA containing radon and daughter products
- Exposure to external radiation in the upland PIA
- Ingestion and dermal exposure to riparian sediments in the riparian PIA
- Inhalation of outdoor air in the riparian PIA containing radon and daughter products
- Exposure to external radiation in the riparian PIA
- Ingestion of terrestrial and riparian plants growing in the PIA
- Ingestion of wildlife and livestock that live or forage in the PIA

Future Residents of the PIA

Exposure pathways for future infants living in the PIA include:

- Ingestion and dermal exposure to soil and indoor dust at the residence in the PIA
- Inhalation of outdoor air containing radon and daughter products at the residence in the PIA
- Exposure to external radiation at the residence in the PIA
- Inhalation of indoor air at the residence in the PIA

Exposure pathways for future children and adults living in the PIA include:

- Ingestion and dermal exposure to soil in the PIA at and away from the residence
- Inhalation of outdoor air containing radon and daughter products in the PIA at and away from the residence
- Exposure to external radiation in the PIA at and away from the residence
- Ingestion and dermal exposure to indoor dust at the residence in the PIA
- Inhalation of indoor air at the residence in the PIA
- Ingestion of terrestrial and riparian plants growing in the PIA
- Ingestion of wildlife and livestock that live or forage in the PIA

Hypothetical Residents of the MA

There are no complete and significant pathways for soils in the PIA for future infants living in the MA who are assumed to spend their time at their residence. Exposure pathways for future children and adults living in the MA include:

- Ingestion and dermal exposure to soil in the upland PIA
- Inhalation of outdoor air in the upland PIA containing radon and daughter products
- Exposure to external radiation in the upland PIA
- Ingestion of terrestrial plants growing in the upland PIA
- Ingestion and dermal exposure to riparian sediments in the riparian PIA
- Inhalation of outdoor air in the riparian PIA containing radon and daughter products
- Exposure to external radiation in the riparian PIA
- Ingestion of riparian plants growing in the riparian PIA
- Ingestion of wildlife and livestock that live or forage in the PIA

4.3.5.6 Potentially Complete, But Negligible Pathways

Pathways considered potentially complete but negligible are discussed in Section 4.3.7.

4.3.5.7 Incomplete Pathways

Pathways considered incomplete are identified in Section 4.3.8.

4.3.6 Haul Roads Source

The CSM for the haul roads source is shown in Figure 9.

4.3.6.1 Potential Source

The haul roads were made from material from the MA. In addition, the haul roads may have been impacted by ore from the MA lost from trucks during mining operations. This source consists of the surface and subsurface material that make up the haul roads. Exposure to surface material will be evaluated specifically for travel upon the haul roads.

4.3.6.2 Potential Release Mechanisms

COCs in the haul roads can enter outdoor air via resuspension of dust generated by wind and vehicles and from radon emission. COCs in surface material on the haul roads could be transported into residences by vehicles and on shoes, clothing, or pets. External radiation is emitted by radionuclides in surface material on the haul roads.

COCs in the haul roads could also be transported via the wind to air and soil in the PIA near the haul roads, via leaching to groundwater in the PIA, and via overland transport to surface water and sediments in the PIA. These media are evaluated in separate CSMs shown in Figures 6, 7, and 8.

4.3.6.3 Potential Exposure Media

Exposure media potentially impacted by the haul roads source addressed in Figure 9 include surface material, outdoor air, and indoor dust at current and future residences.

4.3.6.4 Potentially Exposed People

People potentially exposed to surface material on the haul roads include current residents, future residents living in the PIA, and hypothetical MA residents.

4.3.6.5 Potentially Complete and Significant Exposure Pathways

Potentially complete and significant pathways by which people could be exposed to COCs on the haul roads are discussed next.

There are no complete and significant pathways for the haul roads for infants living offsite or future infants living in the MA or PIA who are assumed to spend their time at the residence and who rarely spend time in the haul roads. Exposure pathways for current and future children and adults who use the haul roads for transportation include:

- Ingestion and dermal exposure to surface material on the haul roads
- Inhalation of outdoor air at the haul roads containing dust and radon and daughter products
- Exposure to external radiation at the haul roads

4.3.6.6 Potentially Complete, But Negligible Pathways

Pathways considered potentially complete but negligible are discussed in Section 4.3.7.

4.3.7 Potentially Complete, but Negligible Pathways

The following pathways are considered potentially complete, but negligible, and will not be evaluated quantitatively in the risk assessment because they are considered to be unlikely to measurably impact risk estimates or cleanup decisions. These pathways will be discussed qualitatively in the uncertainty section of the risk assessment.

4.3.7.1 Infants Living Offsite

All pathways for infants living offsite, that are considered potentially complete, are considered negligible, because it is assumed that infants living offsite do not spend significant time in the site area.

4.3.7.2 Non-residential Pathways for Infants Living in the MA or PIA

All non-residential pathways for infants living in the MA or PIA, that are considered potentially complete, are also considered negligible, because infants are assumed to primarily remain at their residences in the PIA or MA.

4.3.7.3 Ingestion of Plants, Wildlife, and Livestock by Infants

Ingestion of plants, wildlife, and livestock by infants are considered potentially complete, but negligible pathways because infants are assumed to primarily ingest formula made with water obtained at the residence (discussed in Section 4.2.4.1).

4.3.7.4 Exposure of Residents to Indoor Dust Transported Long Distances

Exposure of residents to indoor dust containing COCs transported long distances on vehicles, clothing, or pets (e.g., from the MA or haul roads to current residences on the reservation) is considered potentially complete but negligible because indoor dust will be primarily composed of soil from the residential yard (EPA 1998c). Additional components contributing significantly to indoor dust include clothing and carpet fibers, pet and human skin scales, and hair, molds, and dust mites. Using standard risk assessment methodology, exposure to indoor dust containing COCs from yard soil will be evaluated for residents of the MA and PIA (yard soil and indoor dust concentrations will be assumed to be the same).

4.3.7.5 Dermal Exposure to Inorganics in Water

Dermal contact with metals in water, although a potentially complete pathway, will not be quantified in the HHRA because metals in water are not well absorbed through the skin. The uptake of inorganic chemicals through the skin from water is primarily limited to compounds dissolved in water. While water soluble metals are absorbed at higher rates than insoluble ones, the penetration rate of water through the skin is slow (0.001 centimeter/hour [cm/hr]) (EPA 1992b). Several investigators have also shown that electrolytes in dilute solution penetrate the skin poorly (EPA 1992b). Absorption rates similar to that of water have been observed for the chloride salts of zinc, cadmium, and mercury, and for sodium chromate and silver nitrate (Wahlberg 1968; Slog and Wahlberg 1964). The recommended dermal permeability factor for metals is quite low at 0.001 cm/hour (EPA in press) and it applies only to the dissolved fraction.

4.3.7.6 Dermal Exposure to Inorganics in Soil

Limited skin absorption data exist for arsenic and cadmium (EPA Region 10 1998a; EPA in press) and these metals are considered more mobile in the environment than other metals because cadmium is soluble in water and arsenic has multiple oxidation states (EPA 1985). Therefore, dermal absorption of metals through the skin will be quantified for arsenic and cadmium as recommended by EPA (in press).

Data on the amount of other types of metals in soil absorbed through the skin is extremely limited (EPA 1992b). In addition, available data indicate that the contribution of dermal exposure to soil to overall risk is typically small (EPA Region 4 1995, EPA in press). In general, metals in soil are strongly adsorbed and will not leach except under strongly acidic conditions. Therefore, absorption of metals in soil through the skin is probably very slow. Inorganics other than arsenic and cadmium that lack dermal absorption data will not be evaluated quantitatively in the risk assessment (EPA in press).

The dermal route of exposure is generally not important for radionuclides compared to other exposure routes (e.g., external radiation, ingestion, inhalation) (EPA 1999b; EPA 2000d). In addition, data on the amount of radionculides in soil absorbed through the skin is limited. Region 10 risk assessment guidance does not clearly address whether to evaluate dermal exposure to radioactive inorganics and does not provide a method for evaluating such exposures (EPA Region 10 1998a). Therefore, dermal exposure to radionuclides will not be evaluated quantitatively in the risk assessment.

4.3.7.7 Dermal Exposure to Inorganics in Sediments

The combination of a potentially larger exposed skin surface area and wet media may cause stronger adherence of sediments to the skin (Kissel et al. 1996, 1998; Duff and Kissel 1996; Holmes et al. 1996). This may lead to enhanced contact, so this pathway was quantified in the

HHRA. As with soil, dermal contact will be evaluated only for arsenic and cadmium (EPA Region 10 1998a; EPA in press).

4.3.7.8 Dermal and Inhalation Exposure to Plants

Dermal and inhalation exposure to plants (for example, through medicinal application, contact during gathering or processing, or inhalation during smoking) are considered potentially complete, but negligible, because these pathways are likely not important compared to the ingestion route of exposure. In addition, dermal and inhalation exposures to plants can not be easily quantified.

4.3.7.9 Dermal Exposures to Wildlife

Dermal exposures to wildlife (for example, while processing meat or wearing hide) are considered potentially complete, but negligible, because these pathways are likely not important compared to the ingestion routes of exposure and dermal exposures to wildlife can not be easily quantified.

4.3.7.10 Inhalation of Fugitive Dust in the PIA

Inhalation of fugitive dust in the PIA is considered potentially complete, but negligible as discussed below (fugitive dust in the MA, two open pits, and the haul roads will be evaluated in the risk assessment).

Inhalation of outdoor air containing fugitive dust is often evaluated in risk assessment, but rarely contributes significantly to risk. For example, using screening level estimates of human exposure recommended in EPA's SSL Guidance (EPA 1996b), intake of soil from the inhalation pathway is less than 0.0002-times that for the ingestion pathway (ISSI 1999). Similarly, based on generic SSLs for radionuclides, cancer risks from plant ingestion, soil ingestion, and external radiation generally far outweigh risks from inhalation of fugitive dust (EPA 2000d).

EPA Region 10 guidance states that when soil ingestion and fugitive dust inhalation are evaluated together, the risks and hazards associated with ingestion are significantly greater than those associated with inhalation. Therefore, EPA Region 10 (1998a) recommends that the fugitive dust pathway be limited to hexavalent chromium, cadmium, and other compounds known to exert significant toxicity via dust inhalation. Because the PIA is generally covered with vegetation and fugitive dust generation is likely low, fugitive dust in the PIA is considered to be a potentially complete but negligible pathway that will not be evaluated.

In contrast to the PIA, high dust levels may occur in the MA, Pit 3, Pit 4, and on the haul roads. Dust levels have been observed (1) exceeding action levels (0.5 to 2.5 miligram/cubic meter [mg/m^3]) identified in the URS site-specific Health and Safety Plan (URS 2000c) for controlling dust during field work at the Site and (2) reaching visible levels (2 to 3 mg/m^3) (personal communication with Tim Joseph, URS Health and Safety specialist for the Site). These levels of dust are several thousand times higher than the default value for windblown dust of 0.76 microgram (µg) $dust/m^3$

assumed in EPA guidance for calculating SSLs (EPA 1996b). Therefore, the fugitive dust pathway will be evaluated for all COCs for receptors exposed in the MA, in the open pits, and on the haul roads.

4.3.7.11 Incidental Ingestion of Surface Water in the PIA

Incidental ingestion of surface water in the PIA while hunting and gathering is considered potentially complete, but negligible, because incidentally ingested amounts of water are small, probably within the uncertainties of estimates of intentional water ingestion. Based on recommendations from the Spokane Tribe, it will be assumed that people intentionally ingest 1 liter of surface water each day in the PIA. The incidental ingestion of a small amount of water from the fingertips (perhaps 0.005 liter/day) is considered to be within the uncertainties associated with the estimate of intentional ingestion of 1 liter/day.

4.3.7.12 Inhalation of Radon in Outdoor Air Emitted from Seeps/Springs

Inhalation of radon emitted from seeps/springs into outdoor air is considered to be potentially complete, but negligible, because the radon contribution from seeps/springs is small compared to other sources of radon in outdoor air in the PIA. Receptors in the PIA will be evaluated for exposure for radon measured in outdoor air.

4.3.7.13 Inhalation of Radon in Outdoor Air Emitted from Bank, Channel, and Suspended Sediments in Creeks in the PIA

Inhalation of radon in outdoor air emitted from bank, channel, and suspended sediments in creeks in the PIA is considered to be potentially complete, but negligible because the radon contribution from bank, channel, and suspended sediments is small compared to other sources of radon in outdoor air in the PIA. Inhalation of radon in outdoor air emitted from large areas of dried sediments, such as riparian sediments in the PIA (see Figure 6) will be considered a potentially complete and significant pathway. Receptors in the PIA will be evaluated for exposure to radon measured in outdoor air.

4.3.7.14 Inhalation of Fugitive Dust in Outdoor Air Emitted from Dried (Bank) Sediments in Creeks in the PIA

Inhalation of fugitive dust in outdoor air emitted from dried (bank) sediments in creeks in the PIA is considered to be potentially complete, but negligible because the source area is small.

4.3.7.15 External Radiation from Bank, Channel, and Suspended Sediments in Creeks in the PIA

External radiation from bank, channel, and suspended sediments in creeks in the PIA is considered to be potentially complete, but negligible because the source area is small. External radiation emitted from large areas of dried sediments, such as riparian sediments in the PIA (covered in Figure 8) is considered a potentially complete and significant pathway.

4.3.8 Incomplete Pathways

The following pathways are considered to be incomplete and will not be evaluated further in the risk assessment.

- Residential exposures (e.g., garden plants, sweat lodge, domestic water, indoor exposures) in the MA for receptors that don't live in the MA
- Residential exposures in the PIA for receptors that don't live in the PIA
- Exposure of infants to water in a sweat lodge ceremony because infants do not participate in sweat lodge ceremonies.
- All exposure by infants in the two open pits because infants are assumed not to spend time in the two open pits
- Intentional ingestion of water in the two open pits
- Exposure of infants to seeps/springs in the PIA, because it is assumed that infants do not drink directly from the seeps/springs nor is domestic use of water from seeps/springs anticipated.
- Exposure of all receptors to the Blood Pool, because it is small, generally dry, and there's no known reason for people to have contact with the Blood Pool.

4.4 Exposure Areas to be Evaluated Quantitatively in the Risk Assessment

An exposure area is the location where exposure is evaluated in the risk assessment. Exposure areas for the MA and preliminary exposure areas in the PIA are described in the following sections. Final exposure areas will be identified in the impacted area outside of the MA after the nature and extent of contamination are characterized, which will be evaluated by the RI studies now in progress.

4.4.1 The MA

The surface area of the MA, including roads in the MA, but not the two open pits, will be treated as one surface exposure area. It is assumed that hypothetical MA residents live in this exposure area and that children and adults living offsite or in the PIA use the MA exposure area for hunting, gathering, teaching and learning traditional activities and working.

4.4.2 Two Open Pits in the MA

For exposure in the two open pits, there will be two exposure areas, one for Pit 3 and one for Pit 4. Children and adults will be assumed to be indirectly exposed to COCs in the two open pits via ingestion of wildlife and livestock that ingest surface water from the open pits. In addition, a recreational scenario where children and adults are assumed to swim in each of the two open pits will be evaluated separate from the other exposure scenarios. Infants are assumed not to swim in the two open pits.

For domestic groundwater used by hypothetical residents in the MA, the exposure area will include all groundwater underlying the MA.

4.4.3 The Upland PIA

The exposure area for the upland PIA surface materials will be determined based on the results of Phase 2A/1B sampling (URS 2000d). Upland areas that may have been impacted by the site include sampled areas in the two primary wind directions (southwestern and northeastern areas of the PIA). Therefore, the preliminary exposure area for the upland PIA will consist of the sampled areas in the two primary wind directions. It is assumed that PIA residents live in this exposure area, and that children and adults living offsite, in the PIA, or in the MA use this exposure area for hunting, gathering, teaching and learning traditional activities, working, and recreating. For domestic groundwater use by residents living in the PIA, the exposure area will be the groundwater plume in areas of the PIA affected by mining activities.

4.4.4 Riparian/Aquatic Areas in the PIA

For the Phase I sampling, the riparian/aquatic PIA was divided into nine Areas of Interest corresponding with potentially impacted drainages or ridges surrounding the MA: Western Drainage, Central Drainage, Eastern Drainage, Northeastern Drainage, Northern Drainage, Northwest Ridge, Far West Drainage, Southwestern Drainage, and Blue Creek. However, not all of these drainages are known to be impacted by the Site. Analyses are currently underway to evaluate the nature and extent of mine-affected media. The RI report will identify those drainages considered to be impacted, each of which will be evaluated in the HHRA.

It is likely that the RI report will show that portions of the Western, Central, and Eastern drainages nearest to the MA have been affected. It is also possible that parts of Blue Creek near the confluence with the Eastern Drainage have been affected. For riparian/aquatic exposures in the PIA, the exposure area will consist of the Western, Central, and Eastern drainages, and parts of Blue Creek and other riparian/aquatic areas that are shown to be mine-affected.

It is assumed that children and adults living offsite, in the PIA, or in the MA use the riparian/aquatic areas in the PIA for hunting, gathering, teaching and learning traditional activities, working, and recreating and that future residents living in the PIA use surface water in the PIA as a drinking water source.

Other than the two open pits, there are no aquatic areas in the MA where human exposure is anticipated. There are also no riparian areas in the MA.

4.4.5 Haul Roads

For exposures while using the PIA haul roads as transportation, the one exposure area will include the two haul roads, the three pump house access roads, and the impacted area on each side of the roads. It is assumed that children and adults living offsite, in the PIA, or in the MA use this exposure area for transportation.

4.4.6 Large Wildlife and Livestock

The exposure area for livestock is assumed to be the MA and PIA. Livestock are assumed to ingest water from the two open pits in the MA and seeps and surface water in the PIA and to ingest plants from the MA, and upland and riparian PIA.

4.5 Pathways to be Evaluated Quantitatively in the Risk Assessment

Tables 1 to 6 list pathways to be evaluated quantitatively in the risk assessment for each receptor in each exposure area. These include pathways for residential exposures for infants, children, and adults (exposures to COCs in the yard and indoors shown in Tables 1 to 4) and non-residential exposures (exposures to COCs away from the residence while hunting, gathering, working, recreating shown in Table 5). Non-residential exposure pathways in the MA, upland PIA, riparian/aquatic PIA, and haul roads are assumed to be the same for children and adults living offsite, in the PIA, or in the MA. In addition, the exposure areas and pathways for a hypothetical swimming scenario for children and adults in the two open pits are listed in Table 6.

4.6 Methodology for Estimating Exposure Point Concentrations

To calculate a cancer risk or a non-cancer hazard, an estimate must be made of the chemical concentration in the exposure medium (e.g., air, water, meat) to which an individual must be exposed. According to EPA (EPA 1992d), the EPC should be the estimate of the average concentration measured over the area to which an individual would be exposed for a significant portion of a lifetime. Because of the uncertainty associated with estimating the true average concentration at a site, EPA recommends the use of the 95 percent upper confidence limit of the mean (95% UCL) as the appropriate estimate of the average site concentration for an reasonable maximum exposure (RME) scenario (EPA 1992d). At the 95% UCL, the probability of underestimating the true mean is less than 5 percent.

4.6.1 EPCs for Sampled Media

The EPC for COCs in sampled media (e.g., soil, sediment, water, radon in air) will be estimated based on analytical results. The concentration terms will be either the 95% UCL concentration or the maximum detected concentration, whichever is lower, following recommendations in Risk Assessment Guidance for Superfund (EPA 1989a) and "Supplemental Guidance to RAGS: Calculating the Concentration Term" (EPA 1992d).

The formula used to calculate a 95% UCL depends on the distribution of data, (i.e., the shape of the distribution curve [EPA 1992d]). EPA experience shows that most environmental contaminant data sets have a lognormal distribution (EPA 1992d). However, in cases where the distribution is questionable or unknown, EPA recommends (1) performing a statistical test to determine the best distribution assumption for the data set and (2) graphing the data.

Distributions for the environmental data will determine which method will be used to calculate corresponding 95% UCLs. The Shapiro-Wilk W-test as modified by Royston (1982) will be performed on each data set. This test will determine if the data set best matches a normal, lognormal, or neither distribution (EPA 1992d). The W-test is described in further detail in "Statistical Methods for Environmental Pollution Monitoring" (Gilbert 1987) and in "Statistical Guidance for Ecology Site Managers" (WDOE 1992).

If the result of a distribution test indicates a normally distributed data set, a normal 95% UCL will be calculated with an equation reflecting a Student's t-distribution as described in EPA guidance (EPA 1992d). If the results indicate a lognormal distribution of the data set, a one-sided 95% UCL will be calculated using the bootstrap method as recommended by EPA (1997d) based on the coefficient of variation, skewness, and sample size, as described in the following paragraph. This particular method will also be applied to data sets where both the normal and lognormal assumptions of the distribution are rejected.

The bootstrap method is a non-parametric statistical technique, which can construct approximate confidence intervals for the population mean. This approach makes no assumptions regarding the distribution for the underlying population. EPA's technical issue paper recommending the bootstrap procedure under certain circumstances (EPA 1997d) focused primarily with the problems associated with calculating a 95% UCL when the distribution of the contaminant concentration appears to be highly skewed. Positively skewed distributions are usually modeled by the lognormal distribution. However, this skewness is possibly due to biased sampling, multiple populations, or outliers and is not necessarily due to lognormally distributed data (EPA 1997d). Statisticians showed that incorrectly assuming a lognormal distribution may lead to erroneous results (Gilbert 1993; Stewart 1994). After presenting several simulated examples in its issue paper (EPA 1997d), EPA concluded that the use of several other methods (e.g., Jacknife, Bootstrap, and Central Limit Theorem) is more accurate than the H-statistic 95% UCL (lognormal 95% UCL calculation previously recommended by EPA 1992d). Therefore, the bootstrap method will be used. The bootstrap method is discussed in further detail in "The Jacknife, the Bootstrap, and other Resampling Plans" (Effron 1982).

To simplify the risk assessment calculations, concentrations of COCs in aboveground plant tissue in the MA and riparian PIA will be assumed to be the same as in plant roots.

4.6.2 EPCs for Media Not Sampled

For some media (e.g., indoor air), models will be used to predict concentrations at exposure points where environmental monitoring data have not been (or cannot be) collected. Models range from simple, conservative screening level models to complex models that use site-specific information. In the risk assessment, every effort will be made to use models and input parameter values that best describe conditions at the site.

4.6.2.1 Outdoor Radon

In areas where outdoor radon was not measured, outdoor radon concentrations will be modeled from soil radium-226 concentrations using a correlation factor developed from radium-226 in soil and radon in outdoor air measured at background locations. If the correlation between radium-226 and outdoor radon concentrations at background locations is poor, then other methods for predicting radon from radium-226 will be explored (e.g., RESRAD Computer Program, DOE 2000).

4.6.2.2 Indoor Radon in a Residence

Indoor radon concentrations in a residence will be modeled using the equations from the RESRAD computer program (DOE 2000) or from EPA's Diffuse Norm Waste Guidance. This model determines radon concentrations based on contribution from soil, as well as contribution from water use. The soil model is based on the volume of the interior space, interior surface area, foundation construction, ventilation rate, and a radon diffusion coefficient. The water model is based on the transfer efficiency of radon from water to air, household water use, ventilation rate, and volume of the house. Site-specific information regarding these assumptions will be used when available.

4.6.2.3 Indoor Radon Gas in a Sweat Lodge

Indoor radon gas in a sweat lodge will be assumed to be the same concentration as indoor radon gas in a residence. This assumption may over- or underestimate concentrations of radon in a sweat lodge, which probably has a higher rate of influx of radon than a residence with a foundation but probably also has a higher rate of radon loss than a residence. Radon in water vapor generated in a seat lodge will be evaluated as a separate pathway from radon gas.

4.6.2.4 Indoor Water Vapor in a Sweat Lodge

Water vapor is generated in a sweat lodge by pouring groundwater or surface water over heated rocks. The water vapor likely consists primarily of aerosols (large water droplets) containing COCs dissolved in the water. This principle has been applied to sweat lodge scenarios at the Hanford site in Richland, Washington by the Washington Department of Health (WDOH) (1999) and in the Columbia River Comprehensive Impact Assessment (CRCIA) (1998). In the risk assessment, volatilization factors (VFs) were used to estimate the concentration of water vapor in the air in a sweat lodge, and it was assumed that water droplets in the air contain COCs at the same concentrations as in the water poured on the rocks. WDOH (1999) used a VF value of 1.9 liter (L) water/m^3 air, based on 4 liters of water in a volume of air in the sweat lodge of 2.09 m^3. CRCIA (1998) used a VF value of 0.1 L water/m^3 air based on a saturation level for water in air. The 0.1 L water/m^3 value will be used in the risk assessment, because the maximum concentration of water vapor in the air is the saturation level. Water droplets in the air will be assumed to contain COCs at the same concentrations as in the water poured on the rocks. The calculation of the EPC for inhalation of COCs in water vapor will be:

Concentration of COC in water (mg or picocurie (pCi) of COC/liter water) x 1.9 L water/m^3 air = mg or pCi COC/m^3 air.

4.6.2.5 External Radiation

External radiation exposure at the site will be determined in two ways. First, measured gamma levels will be used as follows. The gamma radiation survey was done with a 1 inch x 1 inch unshielded sodium iodide detector giving results in counts per minute (cpm). Calibration constants from the site will be used to convert cpm to microentgen (µR)/h. Then, site-specific factors will be used to convert µR/hr to microrem (µrem)/hr. This dose will be multiplied by the total exposure duration in hours to determine the lifetime exposure dose in µrem. The lifetime exposure dose will then be multiplied by the generic risk coefficient in lifetime fatal cancer risk per µrem to determine a lifetime excess fatal cancer risk. The risk coefficient will be calculated using methodology in EPA (1999a, 2000c), taking into consideration morbidity and fatality rates. The measurements from the detector were not shielded to minimize interference from background, therefore, background levels will be subtracted from the cpm measurements. These results will be compared to locations where radium-226 in soil has been measured in addition to the gamma radiation readings. The correlation will be determined to evaluate the direct gamma results.

Secondly, in areas where gamma levels were not measured, external radiation will be predicted from radium-226 concentrations in soil using a site-specific mathematical correlation developed by SMI (1999d).

4.6.2.6 Suspended Particulates

Significant levels of dust are generated in the MA and haul roads, sometimes at visible levels (2 to 3 mg/m^3). For the purposes of estimating outdoor dust exposure concentrations in the MA, Pit 3, Pit 4, and the haul roads, a dust concentration of 2.5 mg/m^3 will be assumed. It will be assumed that inhalation of indoor dust does not occur.

4.6.2.7 Terrestrial Plants in the Upland PIA

Measured concentrations of some COPCs are available for use in the risk assessment for evaluating ingestion of terrestrial plants in the MA (SMI 1999e), but not in the upland PIA. Measured soil concentrations in the upland PIA will be used with site-specific and literature-based uptake factors to estimate concentrations of COCs in terrestrial plants in the upland PIA. Site-specific uptake factors for terrestrial plants were developed using data from SMI (1999e,f) for 17 metals and 3 uranium isotopes (Appendix B). Literature uptake values will be used for COCs for which site-specific uptake factors are not available.

To simplify the risk assessment, concentrations of COCs in aboveground plant tissue in the upland PIA will be assumed to be the same as estimated for plant roots in the upland PIA. The high observed concentrations in plant roots are expected to account for a significant secondary source of soil and sediment ingestion because of the quantity of soil and sediments adhered to root surfaces.

4.6.2.8 Aquatic/Riparian Plants in the PIA

Measured concentrations of some COPCs are available for use in the risk assessment for riparian plant roots and aquatic plants in the Western, Central, and Eastern drainages and in Blue Creek (SMI 1999e). If additional drainages are shown to be impacted by the site, then measured concentrations of COCs in aquatic and riparian sediments in the drainages will be used with site-specific and literature-based uptake factors (see Appendix B) to estimate concentrations of COCs in riparian plant roots and aquatic plants. Site-specific uptake factors for riparian plant roots and aquatic plants were developed using data from SMI (1999e,g) for 17 metals and 3 uranium isotopes (Appendix B). Literature uptake values will be used for COCs for which site-specific uptake factors are not available.

To simplify the risk assessment, concentrations of COCs in aboveground plant tissue in the riparian PIA will be assumed to be the same as in plant roots in the riparian PIA.

4.6.2.9 Garden Plants

It will be assumed that EPCs in garden plants at residences in the MA are the same as EPCs estimated from measured concentrations in terrestrial plant roots in the MA (Appendix B). It will also be assumed that EPCs in garden plants at residences in the PIA are the same as EPCs estimated for terrestrial plant roots in the upland PIA.

4.6.2.10 Ingestion of Meat

The EPCs in livestock meat will be estimated according to the Food Chain Models for Risk Assessment from the RAIS at ORNL (http://risk.lsd.ornl.gov). This model can be used to determine concentrations in meat for livestock based on the following ingestion pathways by livestock:

- Direct ingestion of contaminated soil
- Ingestion of contaminated water
- Ingestion of contaminated food materials

It will be assumed that the concentrations of EPCs in big game, rabbits, and birds (assumed to also be ingested by the Tribe) are the same as EPCs in livestock.

4.6.2.11 Aquatic Wildlife

If aquatic areas adjacent to the MA that have been affected above background levels and are assumed to support significant harvesting of fish and shellfish, then measured concentrations of COCs in sediments and surface water will be used to model concentrations of COCs in fish. The methodology used to model concentrations in fish will be developed in the ecological risk assessment.

4.7 Pathway-Specific Intake Equations

In the exposure assessment, exposure factors (e.g., soil or groundwater ingestion rates, exposure frequency and duration, and body weight) are used with COC concentrations in risk assessment to estimate intake for each COC by each exposure pathway for each receptor evaluated quantitatively in the risk assessment. The estimates of intake are later combined with toxicity information to yield estimates of potential health risk.

Chemical intake (i.e., for non-radionuclide COCs) will be expressed in terms of milligrams of chemical per kilogram of body weight per day (mg/kg-day).

The general equation for calculating chemical intake in terms of mg/kg-day is:

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

Omitting chemical concentration from the intake equation yields a pathway-specific "intake factor." The intake factor (kg soil/kg body weight-day, l water/kg-day, m^3 air/kg-day) can then be multiplied by the EPC of each chemical in the exposure medium to obtain the pathway-specific intake for that chemical.

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. For carcinogens, intakes are calculated by averaging the total dose over a lifetime, yielding "lifetime average daily intake."

Different averaging times are used for carcinogens and non-carcinogens because it is thought that their effects occur by different mechanisms. The approach for carcinogens is based on the scientific opinion and EPA policy that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime, and that even very low doses of carcinogens have the potential to cause cancer. Therefore, the intake of a carcinogen is averaged over a lifetime (EPA 1989a). Intake of non-carcinogens is averaged only over the period of exposure in order to compare an estimate of daily dose during the exposure to a reference dose considered to be without appreciable risk of adverse effects during a similar exposure time.

There are three age-groups of receptors in the risk assessment, together representing a lifetime of exposure by residents of the reservation: infants (under 2 years of age), children (2 to 6 years of age), and adults (7 to 70 years of age). Estimation of intake of non-carcinogens and non-cancer hazard will be calculated separately for each age group. In addition to presenting estimations of cancer risk for each carcinogenic COC in each pathway for each receptor, intake for infants, children, and adults will be summed to yield one total lifetime cancer risk estimate.

Intake of radionuclides will be calculated using equations similar to those for calculating intake of chemicals. Intake of radionuclides by ingestion or inhalation is a function of radionuclide activity, intake rate (or the amount of contaminated medium contacted per unit time or event), and exposure frequency and duration. The only difference between calculating intake for radionuclides and non-radioactive substances is that averaging time and body weight are excluded from the intake equations for radionuclides (EPA 1989a). Lifetime internal radionuclide intake is expressed in terms of activity (pCi). The general equation for calculating radionuclide intake is:

Intake = radionuclide activity concentration x contact rate x exposure frequency x exposure duration

As with other carcinogens, radionuclide intake for infants, children, and adults will be summed to yield one lifetime cancer risk estimate.

EPA recommends that RME and an average or central tendency (CT) exposure be evaluated in order to provide a range of risk estimates for use by risk managers. The CT exposure is estimated by selecting values so that the combination results in the typical exposure that would occur at the site.

Central tendency exposure and risk will not be estimated in the risk assessment because the Tribal exposure scenarios are considered protective because of the high levels of exposure assumed. There is limited empirical basis or well documented sources of information for developing central exposure factors for a traditional tribal lifestyle. Typically, cleanup decisions at Superfund sites are based on RME estimates of hazard/risk based upon a suburban lifestyle representative of the majority of the populace.

In this risk assessment, tribal exposure parameters represent RME levels. In this risk assessment work plan, values for exposure variables were selected such that the combination of all variables in the risk assessment will result in the maximum exposure that can reasonably be expected to occur at the site (i.e., the RME).

4.7.1 Soil Ingestion

Intake from soil ingestion for non-radionuclide COCs will be estimated using the following general equation:

$$\text{Intake} = \frac{Cs \times IRs \times ME \times EF \times ED \times CFs}{BW \times AT}$$

where:

Intake = Chemical intake, mg/kg-day

Cs = Chemical concentration in soil, mg/kg

IRs = Soil ingestion rate, mg/day

ME = Matrix effect, unitless

EF = Exposure frequency, days/year

ED = Exposure duration, years

CFs = Conversion factor, 10^{-6} kg/mg

BW = Body weight, kg

AT = Averaging time, days

A chemical-specific matrix effect may be used to account for lower bioavailability (and toxicity) of COCs in soil compared to the media used to derive toxicity values (Appendix A in EPA 1989a). For example, arsenic ingested in soil is considered to be less toxic than soluble arsenic ingested in drinking water or food, because arsenic forms in soil are often insoluble and arsenic adsorbs to soil. Both of these factors would make arsenic less available for absorption, and therefore, less toxic per mg ingested compared to soluble arsenic in water. It is common practice in risk assessment to derive relative bioavailability factors to account for lower availability (and toxicity) of arsenic in soil (EPA Region 8 1993, 1997a; EPA Region 10 1996; and Walker and Griffin 1998). Good correlations between arsenic in soil and urinary arsenic levels in human receptors have been reported at a site where site-specific relative bioavailability factors (0.18 to 0.25) were used to account for lower bioavailability of arsenic in soil (Walker and Griffin 1998). EPA Region 10 recommends using a relative bioavailability factor of 0.6 in risk assessment to account for lower bioavailability of arsenic in soil relative to arsenic in food and water (EPA Region 10 2000a). Therefore, a matrix factor of 0.6 will be applied to estimates of arsenic intake in soil.

If lead is a COC in soil at the site, the EPA default matrix factors will be used in both EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model for children and Adult Lead Exposure Model (ALEM) for adults in the absence of compelling site-specific data.

Intake of radionuclide COCs from soil ingestion will be estimated using the following general equation:

Intake = Cs x IRs x EF x ED x CFs

where:

Intake = Radionuclide intake, pCi

Cs = Radionuclide activity in soil, pCi/kg

4.7.2 Sediment Ingestion

Intake from sediment ingestion for non-radionuclide COCs will be estimated using the following general equation:

$$\text{Intake} = \frac{\text{Csed x IRsed x ME x EF x ED x CFs}}{\text{BW x AT}}$$

where:

Intake = Chemical intake, mg/kg-day

Csed = Chemical concentration in sediment, mg/kg

IRsed = Sediment ingestion rate, mg/day

ME = Matrix effect, unitless

EF = Exposure frequency, days/year

ED = Exposure duration, years

CFs = Conversion factor, 10^{-6} kg/mg

BW = Body weight, kg

AT = Averaging time, days

Intake of radionuclide COCs from sediment ingestion will be estimated using the following general equation:

Intake = Csed x IRsed x EF x ED x CFs

where:

Intake = Radionuclide intake, pCi

Csed = Radionuclide activity in sediment, pCi/kg

4.7.3 Soil Dermal Contact

Chemical intake through absorption of chemicals in soil through skin, which will be quantified only for arsenic and cadmium if they are COCs in soil, is estimated using the following equation:

$$\text{Intake} = \frac{Cs \times SAs \times AB \times FC \times AFs \times EF \times ED \times CFs}{BW \times AT}$$

where:

Intake = Chemical intake, mg/kg-day

Cs = Chemical concentration in soil, mg/kg

SAs = Surface area for soil dermal contact, cm^2/day

AB = Absorption factor, unitless

FC = Fraction from contaminated source, unitless

AFs = Soil adherence factor, mg/cm^2

EF = Exposure frequency, days/year

ED = Exposure duration, years

CFs = Conversion factor, 10^{-6} kg/mg

BW = Body weight, kg

AT = Averaging time, days

The fraction from the contaminated source (FC) will be used to account for dermal exposures to soil in several different exposure areas at the site.

Absorption Factors: The parameter AB is a chemical-specific value describing the fraction of contaminant in soil or sediment that is absorbed by the skin. Chemical-specific AB values for soil listed in EPA Region 10 guidance of 0.03 for arsenic and 0.01 for cadmium will be used (EPA Region 10 1998a, Table 4-5).

4.7.4 Sediment Dermal Contact

Chemical intake through absorption of chemicals in sediments through skin, which will be quantified only for arsenic and cadmium if they are COCs in sediment, is estimated using the following general equation:

$$\text{Intake} = \frac{Csed \times SAsed \times AB \times AFsed \times EF \times ED \times CFs}{BW \times AT}$$

where:

Intake = Chemical intake, mg/kg-day

Csed = Chemical concentration in sediment, mg/kg

SAsed = Surface area for sediment dermal contact, cm^2/day

AB = Absorption factor, unitless

AFsed = Sediment adherence factor, mg/cm^2

EF = Exposure frequency, days/year

ED = Exposure duration, years

CFs = Conversion factor, 10^{-6} kg/mg

BW = Body weight, kg

AT = Averaging time, days

The chemical-specific AB values for arsenic and cadmium in soil will be used to evaluate dermal exposure to these metals in sediment.

4.7.5 Inhalation of Air

Chemical intake through inhalation exposure routes will be estimated using the following general equation:

$$\text{Intake} = \frac{Ca \times IN \times ET \times EF \times ED}{BW \times AT}$$

where:

Intake = Chemical intake, mg/kg-day

Ca = Chemical concentration in air, mg/m^3

IN = Inhalation rate, m^3/hr

ET = Exposure time, hr/day

EF = Exposure frequency, days/year

ED = Exposure duration, years

BW = Body weight, kg

AT = Averaging time, days

Intake of radionuclide COCs from inhalation of air will be estimated using the following general equation:

$$\text{Intake} = Ca \times IN \times ET \times EF \times ED$$

where:

Intake = Radionuclide intake, pCi

Ca = Radionuclide activity in air, pCi/m^3

4.7.6 Water Ingestion

Chemical intake from water ingestion will be estimated using the following equation:

$$\text{Intake} = \frac{Cw \times IW \times EF \times ED}{BW \times AT}$$

where:

Intake = Chemical intake, mg/kg-day

Cw = Chemical concentration in water, mg/L

IW = Ingestion rate, L/day

EF = Exposure frequency, days/year

ED = Exposure duration, years

BW = Body weight, kg

AT = Averaging time, days

Intake of radionuclide COCs from water ingestion will be estimated using the following general equation:

$$\text{Intake} = Cw \times IW \times EF \times ED$$

where:

Intake = Radionuclide intake, pCi

Cw = Radionuclide activity in water, pCi/L

4.7.7 Plant Ingestion

Intake from plant ingestion for non-radionuclide COCs will be estimated using the following general equation:

$$Intake = \frac{Cp \times IRp \times FC \times EF \times ED \times CFp}{BW \times AT}$$

where:

Intake = Chemical intake, mg/kg-day

Cp = Chemical concentration in plant, mg/kg

IRp = Plant ingestion rate, g/day

FC = Fraction from contaminated source, unitless

EF = Exposure frequency, days/year

ED = Exposure duration, years

CFp = Conversion factor, 10^{-3} kg/g

BW = Body weight, kg

AT = Averaging time, days

The fraction from the contaminated source (FC) will be used to distinguish ingestion of plants from the site and from other sources (e.g., store-bought). It is expected that even future residents living on the site would obtain some of their ingested fruits, vegetables, and grain from sources outside the site.

Intake of radionuclide COCs from plant ingestion will be estimated using the following general equation:

$$Intake = Cp \times IRp \times FC \times EF \times ED \times CFp$$

where:

Intake = Radionuclide intake, pCi

Cp = Radionuclide activity in plant, pCi/kg

4.7.8 Meat Ingestion

Intake from meat ingestion for non-radionuclide COCs will be estimated using the following general equation:

$$\text{Intake} = \frac{Cm \times IRm \times FC \times EF \times ED \times CFm}{BW \times AT}$$

where:

Intake = Chemical intake, mg/kg-day

Cm = Chemical concentration in meat, mg/kg

IRm = Meat ingestion rate, g/day

FC = Fraction from the contaminated source, unitless

EF = Exposure frequency, days/year

ED = Exposure duration, years

CFm = Conversion factor, 10^{-3} kg/g

BW = Body weight, kg

AT = Averaging time, days

The fraction from the contaminated source (FC) will be used to distinguish ingestion of meat from the site and from other sources (e.g., store-bought meat). It is expected that even future residents living on the site would obtain some of their ingested meat and fish from sources outside the site.

Intake of radionuclide COCs from meat ingestion will be estimated using the following general equation:

$$\text{Intake} = Cm \times IRm \times FC \times EF \times ED \times CFm$$

where:

Intake = Radionuclide intake, pCi

Cm = Radionuclide activity in meat, pCi/kg

4.7.9 External Radiation

Dose from measured or estimated gamma levels outdoors will be estimated as follows:

Dose (µrem/year) = (Xm-Xb) (CF_1) (CF_2) (So) (ETo)

where:

Xm = measured exposure rate, cpm

Xb = average background exposure rate, cpm

CF1 = Site-specific conversion factor (µR/hr per cpm)

CF2 = Site-specific conversion factor (µrem/µR)

So = outdoor shielding factor, unitless (only needed for certain circumstances)

ETo = hrs/year (exposure area specific)

Dose from measured gamma levels outdoors for indoor exposures will be estimated as follows:

Dose (µrem/year) = (Xm-Xb) (CF_1) (CF_2) (Si) (ETi)

where:

Si = indoor gamma shielding factor, unitless

ETi = exposure time indoors (hrs/year)

The lifetime exposure dose will then be multiplied by a risk coefficient in lifetime fatal cancer risk per µrem to yield lifetime risk. The risk coefficient will be calculated using methodology in EPA (1999a, 2000c), taking into consideration morbidity and fatality rates.

4.8 Exposure Factor Values

In this risk assessment work plan, values for exposure variables were selected such that the combination of all variables in the risk assessment will result in the maximum exposure that can reasonably be expected to occur at the site (i.e., the RME) (EPA 1989a).

Exposure factors are generally developed using various guidance documents, including the Exposure Factors Handbook (EPA 1989b); Risk Assessment Guidance for Superfund, Parts A and B (EPA 1989a, 1991a); "Standard Default Exposure Factors" (EPA 1991b); "Superfund Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure" (EPA 1993a); the Exposure Factors Handbook (EPA 1997a); Dermal Exposure Assessment: Principles and Applications (EPA 1992b); and Supplemental Guidance to RAGS Dermal Risk Assessment, Interim Guidance (EPA 1998a). In addition, EPA Region 10 RCRA guidance for risk-based cleanup levels was reviewed for exposure factor information (EPA Region 10 1998a).

EPA recommends the use of site-specific exposure factor values based on site-specific information and professional judgment in risk assessment. Land in the PIA and MA is primarily used by members of the Tribe to support a traditional lifestyle that includes subsistence, cultural/spiritual, and medicinal components. Exposure scenarios related to this type of land use are very specific to the Tribe, and are not well reflected by any typical CERCLA categories of human land use (e.g., residential, commercial, recreational, etc.). Therefore, wherever feasible, site-specific exposure factor parameter values were derived based on information provided by the Tribe. When site-specific information was not available, values were derived by URS using EPA guidance documents or standard EPA RME default values were used.

Exposure factors and other information used to estimate intake for the receptors and pathways to be evaluated in the HHRA are presented in Tables 7 to 25.

4.8.1 General Exposure Factor Values

4.8.1.1 Exposure Frequency

The site-specific RME exposure frequency is 365 days/year because members of the Tribe generally remain on the reservation throughout the year.

4.8.1.2 Exposure Duration

The site-specific RME exposure duration for residents of the reservation will be equal to the EPA default value for a lifetime of 70 years (EPA 1989a), because members of the Tribe typically stay on the reservation for their entire life. Exposure durations for specific receptor subgroups will be 2 years for infants (under 2 years of age), 4 years for children (2 to 6 years of age), and 64 years for adults (7 to 70 years of age).

4.8.1.3 Body Weight

EPA (1989a) recommends using central tendency (average) body weight values for RME calculations. The 9.1 kg value for infants is the age-weighted average body weight for the 50^{th} percentile for males and females in the U.S., under 2 years of age (EPA 1997a). The calculation of this value is shown in Table 7. The 17.2 kg value for children is the age-weighted average body weight for the 50^{th} percentile for males and females in the U.S., 2 to 6 years of age (EPA 1997a). The calculation of this value is shown in Table 7.

The 70 kg value for adults is the standard EPA default value for body weight for adults in the U.S. (EPA 1989a).

Thus, RME body weights will be 9.1 kg for infants, 17.2 kg for children, and 70 kg for adults.

4.8.1.4 Exposure Time for Activities

Site-specific values were derived for exposure time required for various activities at the site (Table 9), based in part on information provided by the Tribe (AESE 2001). For children and adults, it will be assumed that 17 hrs/day are spent at the residence including 4.5 hrs/day outdoors, 10.5 hrs/day indoors, and 2 hrs/day in a sweat lodge. In addition to the time spent at the residence, children and adults are assumed to spend 3 hrs/day in the MA away from the residence, 1.5 hrs/day in the upland PIA away from the residence, 1.5 hrs/day in the riparian PIA, and 1 hr/day on the haul roads.

Infants are assumed to spend 24 hrs/day at their residence. Information on time spent by infants indoors and outdoors at the residence was not obtained from the Tribe. Therefore, it will be assumed that infants spend the same amount of time indoors at the residence as children and adults (10.5 hrs/day) and that the rest of the time (13.5 hrs/day) is spent outdoors at the residence.

4.8.2 Media-specific Exposure Factor Values

This section discusses media-specific exposure factor values for infants, children, and adults.

4.8.2.1 Children and Adults

Exposure to Drinking Water

Exposure factors for children and adults exposed to water are shown in Table 10.

The Tribe has recommended an RME total water ingestion rate for adults of 4 L/day (AESE 2001). The 4 L/day ingestion rate will be used in the risk assessment, apportioned as follows: 1L while at home from the household water supply, 1L taken from the household water supply and ingested during use of the sweat lodge, 1L taken from household water supply and ingested while away from the residence (total of 3 L/day from the household water supply), and 1L of surface water consumed from sources in the aquatic PIA (AESE 2001). Harris and Harper (1997) estimated total water ingestion of 3 L/day by adults in The Confederated Tribes of the Umatilla Indian Reservation. Water ingestion rates from 3-6 L/day were used in Native American scenarios in CRCIA (1998). The risk assessment in the Coeur d'Alene Basin assumed that adults in the Coeur d'Alene Tribe ingest 3 L/day (EPA 2000e).

It will be assumed that children ingest about one-half as much water as adults, or 2 L/day, apportioned as follows: 1.5 L/day from the household water supply and 0.5 L/day consumed from sources in the aquatic PIA. The approach used here (assuming that ingestion of water by young children is one-half of the water ingestion rate for adults) is consistent with EPA Region 9 guidance (EPA Region 9 2000). The risk assessment in the Coeur d'Alene Basin assumed that children in the Coeur d'Alene Tribe, 0 to 6 years of age, ingest 1.5 L/day (EPA 2000e).

Exposure to Soil

Soil at the site includes outdoor soil, indoor dust, and riparian sediments. Exposure factors for children and adults exposed to soil are shown in Table 11.

RME soil ingestion by children and adults will be 300 mg/day. The 300 mg/day value is considered by U.S. EPA Region 10 to be the appropriate ingestion rate for contact intensive exposure scenarios of short duration such as camping (based on van Wijnen et al. 1990; EPA 1997a; Stanek et al. 1997) (EPA Region 10 2000b). This value is higher than EPA RME default values of 200 mg/day for child residents and 100 mg/day for adult residents in the U.S. (EPA 1989a). The 300 mg/day value proposed here reflects the high exposure of residents of the reservation to soil during numerous outdoor activities that include hunting; gathering; fishing; gardening, preparation and consumption of native and garden plants, wildlife, and livestock; teaching and learning traditional activities in the field; other field work; recreating; transportation; and ceremonies.

Soil ingestion rates of 200 mg/day (WDOH 1999; Harris and Harper 1997; CRCIA 1998) and 300 mg/day (EPA 2000e) have been used for young children and adults in other Native American exposure scenarios.

Based on time spent for various activities (discussed in Section 4.7.1), ingestion of soil by children and adults will be apportioned as follows:

- Ingestion of 200 mg/day of soil and indoor dust at the residence
- Ingestion of 25 mg/day of soil in the MA away from the residence
- Ingestion of 25 mg/day of soil in the upland PIA away from the residence
- Ingestion of 25 mg/day of riparian sediments in the riparian PIA
- Ingestion of 25 mg/day of soil from the surface of the haul roads

The RME surface area for dermal exposure of adults to soil will be 5,700 cm^2/day based on the skin surface area for face, hands, forearms, lower legs, and feet (EPA 2001d). This value is higher than the 5,000 cm^2/day value recommended for other Native American exposure scenarios (Harris and Harper 1997; CRCIA 1998).

For exposure of children to soil, exposed skin surface area was assumed to be the face, hands, forearms, lower legs, and feet. These body parts account for approximately 34% of total skin surface area in for children 2-6 years of age. The calculation of this value is shown in Table 12. The whole body surface area of 6,880 cm^2 for children 2-6 years of age is the average of 50^{th} percentile values for children in the U.S. 2-3, 3-4, 4-5, and 5-6 years of age (EPA 1997a). The calculation of this value is shown in Table 13. Therefore, a surface area of 2,340 cm^2/day (approximately 34% of the whole body surface area of 6,880 cm^2) will be used to estimate dermal exposure of children to soil.

RME dermal adherence factors for soil will be 0.2 mg/cm^2 for children and adults (Holmes et al. 1999; EPA in press). The value of 0.2 mg/cm^2 is based upon a weighted average of dermal surfaces following a staged, high-contact activity consisting of children playing in raised beds of moistened, bare soil. This value is considered protective because it represents the level of adherence immediately following the intensive soil activity which is used in combination with the chemical-specific fraction absorbed. The fraction absorbed assumes a constant, 24-hour dermal adherence factor, which is likely to spontaneously decrease over time following the immediate exposure and subsequent bathing

FC values will be used to account for dermal exposure of children and adults to soil in different exposure areas (Table 11). The FC values, based on exposure times for activities discussed in Section 4.7.1, are 0.71 for time spent at the residence, 0.13 for time spent in the MA away from the residence, 0.063 for time spent in the upland PIA away from the residence, 0.063 for time spent in the riparian PIA, and 0.042 for time spent on the haul roads.

The exposure times used to derive the FC values are 17 hrs/day at the residence, 3 hrs/day in the MA away from the residence, 1.5 hrs/day in the upland PIA away from the residence, 1.5 hrs/day in the riparian PIA, and 1 hr/day on the haul roads (Table 9). Therefore, it is assumed that soil from the site is in contact with the skin for 24 hrs/day. This is a conservative (health protective) assumption, because it is unlikely that exposed skin on receptors will be covered with soil for 24 hrs each day (people are expected to bathe).

Exposure to Aquatic Sediments in the PIA

Exposure factors for children and adults exposed to aquatic sediments are shown in Table 14.

RME ingestion of aquatic sediments in the PIA by children and adults will be 100 mg/day. This is considered an appropriate value for exposures that are expected to be brief (1.5 hrs/day spent in the riparian/aquatic PIA) but intense (while harvesting aquatic plants and invertebrates and washing and preparing gathered materials). EPA (2000e) assumed that child and adult members of the Coeur d'Alene Tribe ingest 300 mg/day of sediments (but no soil) while living in the flood plain of the Coeur d'Alene Basin (EPA 2000e). In this assessment, children and adults of the Spokane Tribe are assumed to ingest a total of 400 mg/day of soil plus aquatic sediments.

The RME surface area for dermal exposure to aquatic sediments will be 5,700 cm^2/day for adults and 2,340 cm^2/day for children (the same surface areas as for exposure to soil).

An RME dermal adherence factor of 0.2 mg/cm^2 will be used for exposure of children and adults to aquatic sediments (based on recommendation of Marc Stifelman, Risk Assessor for EPA Region 10). The FC value for dermal contact with aquatic sediments for children and adults will be 0.063, based on exposure time for the riparian/aquatic PIA discussed in Section 4.7.1. This is a conservative assumption because exposed skin is assumed to be covered with both soil and sediments during 1.5 hours of activities in the riparian/aquatic PIA, and with soil from other parts of the MA or PIA for the remainder of each day.

Exposure to Air

Exposure factors for children and adults exposed to air are shown in Table 15.

An RME inhalation rate of 30 m^3/day (1.25 m^3/hr) will be used for adults. This value, which is higher than the EPA default RME value of 20 m^3/day for adult residents in the U.S., reflects the more active lifestyle of adult members of the Tribe. This value has been used for other Native American exposure scenarios (WDOH 1999; CRCIA 1998). The EPA RME default value of 10 m^3/day (0.42 m^3/hr) will be used as the inhalation rate for young children (EPA 1989a).

The RME exposure times for inhalation of air by children and adults are based on times for activities discussed in Section 4.7.1. These exposure times include 10.5 hrs/day indoors at the residence and 2 hrs/day in a sweat lodge. Outdoor exposures to air include 4.5 hrs/day at the residence, 3 hrs/day in the MA away from the residence, 1.5 hrs/day in the upland PIA away from the residence, 1.5 hrs/day in the riparian PIA, and 1 hr/day on the haul roads.

Dietary Exposures

It will be assumed that food in the site area meets 100% of the caloric requirements associated with the active lifestyle of members of the Tribe. These caloric requirements which range from 2,500 to 3,000 kilocalories (kcal)/day are described in Appendix C.

Exposure to Plants

Exposure factors for children and adults exposed to plants are shown in Table 16.

Values for subsistence ingestion of fruits and vegetables by some Native Americans include 574 g wet weight/day (Harris and Harper 1997), and 660 g wet weight/day (CRCIA 1998). Much higher values of 1,300 g/day roots plus 1,400 g/day other vegetation (total 2,700 g/day) have been reported for a traditional subsistence Columbia Basin diet (Hunn 1990). The risk assessment in the Coeur d'Alene Basin assumed that adults in the Coeur d'Alene Tribe consume 574 g wet weight/day (all water potatoes) in a "traditional subsistence scenario" or 20% of that (115 g wet weight/day) for a "modern subsistence" scenario (EPA 2000e).

The Tribe has proposed a total plant ingestion rate by adults of 1,600 g/day, all from plants growing at the site. This is equivalent to a total plant ingestion rate for adults of about 3.5 pounds per day and is much higher than the 95th percentile values for fruit ingestion (961g/day) and vegetable ingestion (682 g/day) by Native Americans (EPA 1997a) and the 660 g/day value used by (CRCIA 1998) for Native Americans.

For the current risk assessment, the total plant ingestion rate of 1600 g/day proposed by the Tribe will be used. Based on information provided by the Tribe (AESE 2001), plant ingestion for adults at the site will be apportioned as follows:

- 240 g/day of terrestrial plants from the MA away from the residence
- 240 g/day of terrestrial plants from the upland PIA away from the residence
- 480 g/day of riparian plants in the riparian PIA
- 320 g/day of aquatic plants
- 320 g/day of garden plants at the residence

The Tribe did not provide information on plant ingestion by children. Therefore, plant ingestion rates for adult residents were used to estimate plant ingestion rates for children on the reservation. One way to estimate plant ingestion by children would be based on relative body weights of children and adults. Using the body weight of 17.2 kg for children the estimated total plant ingestion rate for children at the site would be 400 g/day or about 25% as much as adults.

However, children in the U.S. typically ingest more plants per body weight than do adults (EPA 1997a). For example, children in the U.S. (3 to 5 years of age) in the 50^{th} percentile ingest 6.4 g/kg bw-day of fruit, 5.8 g/kg bw-day of vegetables, and 8.9 g/kg bw-day of grain (EPA 1997a, Tables 9-3, 9-4, and 12-1), whereas adults in the U.S. in the 50^{th} percentile ingest 1.1-1.4 g/kg bw-day of fruit, 3.2-3.4 g/kg bw-day of vegetables, and 2.5-2.7 g/kg bw-day of grain) (EPA 1997a, Tables 9-3, 9-4, and 12-1).

Therefore, data on relative ingestion of plants by children and adults in the U.S. was used to estimate plant ingestion by children of the reservation. Children in the U.S. (3-5 years of age) ingest about 415 g/day of plants, based on average ingestion rates for fruit, vegetables, and grain (143 g/day of fruits, 100 g/day of vegetables, and 181 g/day of grain) (EPA 1997a, Tables 9-14, 9-16, and 12-13). Adults in the U.S. (19-74 years of age) ingest about 147 g/day of fruit, 233 g/day of vegetables, and 201 g/day of grain, based on average ingestion rates. The calculation of the values for adults is shown in Table 17.

Therefore, children in the U.S. (3 to 5 years of age) ingest on the average about 45% (100 g/day ÷ 233 g/day) as much vegetables as adults in the U.S. For the risk assessment, it will be assumed that children at the site ingest about 720 g/day of plants (45% of 1,600 g/day). This is equivalent to a total plant ingestion rate for children of about 1.6 pounds per day.

Plant ingestion for children will be apportioned as follows:

- 108 g/day of terrestrial plants from the MA away from the residence (45% of adult value of 240 g/day)
- 108 g/day of terrestrial plants from the upland PIA away from the residence

- 216 g/day of riparian plants in the riparian PIA
- 144 g/day of aquatic plants
- 144 g/day of garden plants at the residence

Exposure to Meat and Fish

The Tribe has provided information on meat and fish ingestion for two diets: a high fish diet and a high game diet (AESE 2001). Each diet includes both meat and fish.

Exposure factors for children and adults exposed to meat and fish are shown in Table 17.

Ingestion of Meat by Adults

The Tribe has proposed a large game ingestion rate (including livestock) for adults of 885 g/day for the high game diet and 100 g/day for the high fish diet. In addition, the Tribe has proposed an ingestion rate for adults of 25 g/day of rabbits. Other values for subsistence ingestion of large game by Native Americans include 204 (CRCIA 1998), 250 (Harris and Harper 1997), and 275 g/day (beef including all organs, WDOH 1999). These diets are mixed, meaning that other protein intake is also assumed. For instance, the Harris and Harper paper assumed that fish was also eaten in roughly equal amounts.

The Tribe has proposed a wild bird ingestion rate by adults of 25 g/day. Other values for ingestion of birds by Native Americans include 7 (waterfowl, CRCIA 1998), 18 (upland birds, CRCIA, 1998), and 44 g/day (meat and eggs, Harris and Harper 1997). CRCIA (1998) also included an estimate for ingestion of wild bird eggs of 45 g/day.

For the high game diet, the proposed total ingestion rate of meat by adults in the Tribe is 935 g/day or about 2.1 pounds a day. This is much higher than EPA's recommended value for the 95th percentile for ingestion of meat by adults in the U.S. of 6.8 g/kg-day multiplied by a body weight of 70 kg (6.8 x 70 = 475 g/day) (EPA 1997a). To simplify calculation of risk, it will be assumed that members of the Tribe who have a high game diet ingest 935 g/day of livestock only, based on the Tribe's ingestion rate for livestock plus big game plus small game.

For the high fish diet, meat ingestion by adults will be assumed to be the Tribe's proposed value of 100 g/day, all as livestock.

Ingestion of Fish by Adults

The primary source of fish in the site area (Blue Creek) is a small stream with only limited numbers of fish (SMI 1999c). The population of rainbow trout in Blue Creek has been estimated to range from 1,174 to 5,164 (Scholtz et al. 1988), corresponding to about 330 to 1,560 kg total of rainbow trout. It is not yet known whether portions of Blue Creek that support significant fish and shellfish harvesting have been impacted by the Site. Also, it is not know whether water levels in the Eastern Drainage, which have increased due to releases from the water treatment plant, are sufficient to support fish populations. Therefore, it is not known whether fish or shellfish ingestion will be evaluated in the risk assessment.

The Tribe has recommended fish ingestion rates for adults of 885 g/day for a high fish diet and 75 g/day for a high game diet. In addition, the Spokane Tribe has recommended ingestion rates of aquatic invertebrates (e.g., mussels, crayfish) by adults of 175 g/day.

AESE (2001) reported that historically, the Spokane Tribe consumed roughly 1,000 to 1,200 g/day of salmon and other fish. Walker (cited in Scholz et al. 1985) estimated intake of 1,200 pounds per year of salmon per adult in the Spokane Tribe, or 1,426 g/day. Shellfish (mussels and crayfish in particular) have been an important part of the Spokane Tribe diet (Nugent 1997; Ray 1977; Ross and Osterman 1985). Other values for subsistence ingestion of fish by Native Americans include 540 (Harris and Harper 1997), and 648 g wet weight/day (CRITFC 1994). Harris and Harper (1997) recommended including additional ingestion of 54 g/day of other organs of fish (heads, fins, tails, skeletons, and eggs) for a total of 594 g/day. EPA (1997a) recommends a 95^{th} percentile value for subsistence fish ingestion by Native Americans of 170 g/day. The risk assessment in the Coeur d'Alene Basin assumed that adults in the Coeur d'Alene Tribe consumed 540 g wet weight/day in a "traditional subsistence scenario" or 170 g wet weight/day for a "modern subsistence" scenario (EPA 2000e).

If the fish ingestion pathway is evaluated in the risk assessment, it will be assumed that members of the Tribe who have a high fish diet ingest 1,060 g/day of fish, based on the Tribe's ingestion rate for fish plus shellfish. This value is about 6 times higher than EPA's recommended 95^{th} percentile value for subsistence fish and shellfish ingestion by Native Americans of 170 g/day. This is much higher than EPA's recommended value for the 95^{th} percentile for ingestion of meat by adults in the U.S. of 6.8 g/kg-day multiplied by a body weight of 70 kg (6.8 x 70 = 475 g/day) (EPA 1997a).

For the high game diet, fish ingestion by adults will be assumed to be the Tribe's proposed value of 250 g/day for fish and shellfish.

Ingestion of Meat and Fish by Children

The Tribe did not provide information on meat or fish ingestion by children. Therefore, meat and fish ingestion rates for adult residents were used to estimate ingestion rates for children on the reservation. One way to estimate meat and fish ingestion by children would be based on relative body weights of children and adults. Using the body weight of 17.2 kg for children the estimated total meat ingestion rate for children at the site would be about 25% as much as adults.

However, children in the U.S. typically ingest more meat per body weight than do adults (EPA 1997a). For example, children in the U.S. (3 to 5 years of age) in the 50^{th} percentile ingest about

3.5 g/kg bw-day of meat, whereas adults in the U.S. 20-69 years of age in the 50th percentile ingest only about 1.6-1.7 g/kg bw-day of meat (EPA 1997a, Table 11-1).

Therefore, data on relative ingestion of meat and fish by children and adults in the U.S. was used to estimate meat and fish ingestion by children of the reservation. Children in the U.S. 3-5 years of age, ingest on the average about 121 g/day of meat, poultry, and fish (EPA 1997a, Table 11-10). Adults in the U.S. 19-74 years of age, ingest on the average about 229 g/day of meat, poultry, and fish. The calculation of the value for adults is shown in Table 18. Therefore, children ingest about 52% (121 g per day/229 g per day) as much meat and fish as adults. For the risk assessment, it will be assumed that children ingest about 50% as much as adults, apportioned as follows:

- 468 (high game diet) or 38 g/day (high fish diet) of livestock
- 530 (high fish diet) or 125 g/day (high game diet) of fish (assumption to be used only if the fish ingestion pathway is evaluated in the risk assessment)

Total ingestion of meat by children is assumed to be about 468 g/day for the high game diet which is about pound per day.

Total ingestion of fish by children on the high fish diet is 530 g/day. This value is more than three times as high as EPA's recommended 95th percentile value of 170 g/day for subsistence fish and shellfish ingestion by Native Americans.

Exposure while Swimming in the Two Open Pits

A hypothetical swimming scenario in Pit 3 will be evaluated for children and adult residents of the reservation, separate from other exposure scenarios. Exposure factors for children and adults exposed in the two open pits are shown in Tables 20 through 22.

EPA's standard default RME value for exposure time while swimming of 1 hr/day will be used (EPA 1997a). It will be assumed that swimming in the open pits occurs twice weekly during the four warmest months of the year. Therefore, the children and adults will be assumed to be exposure in the open pits for 36 days/year. EPA's standard default RME value for ingestion rate of surface water while swimming of 30 ml/hour will be used (EPA Region 10 1998a).

The ingestion rate, skin surface area, and dermal adherence factor for exposure to sediments in the open pits will be the same as for exposure to aquatic sediments in the PIA.

Exposure to External Radiation

Key exposure factors for older children and adults exposed to external radiation are time spent indoors and outdoors. Based on time spent for various activities (Section 4.7.1), exposure to external radiation by older children and adults will be assumed to occur for 10.5 hrs/day indoors in the residence, 2 hrs/day in a sweat lodge, 4.5 hrs outdoors at the residence, 3 hrs outdoors in the

MA away from the residence, 1.5 hrs in the upland PIA away from the residence, 1.5 hrs in the aquatic/riparian PIA away from the residence, and 1 hour on the haul roads away from the residence.

4.8.2.2 Infants

Exposure to Water

Exposure factors for infants exposed to water are shown in Table 23. It is assumed that all exposure of infants to water occurs at the residence.

A daily water ingestion rate of 0.90 L/day will be used for infants, approximately equal to the 90^{th} percentile value of 0.88 L/day for water ingestion by children in the U.S. of 0 to 1 year of age (EPA 2000b, Table 4-15).

Exposure to Soil

Exposure factors for infants exposed to soil and indoor dust are shown in Table 24. It is assumed that all exposure of infants occurs at the residence.

RME soil ingestion by infants will be assumed to be the EPA default value of 200 mg/day (EPA 1989a).

For exposure of infants to soil, exposed skin surface area was assumed to be the face, hands, forearms, lower legs, and feet. These body parts account for approximately 32% of total skin surface area in infants 0 to 2 years of age. The calculation of this value is shown in Table 25. EPA (1997a) and the draft child-specific Exposure Factors Handbook (EPA 2000b) did not have surface area information on children less than 2 years of age. Therefore, the whole body surface area for infants of 5,615 cm^2/day was estimated based on the surface area/body weight ratio of 0.0617 m^2/kg in EPA (1997a, Table 6-9), assuming a body weight of 9.1 kg. The calculation is: 9.1kg x 0.0617 m^2/kg = 0.5615 m^2 (5,615 cm^2). The surface area value for infants exposed to soil will be 1,800 cm^2/day, which is approximately 32% of 5,615 cm^2/day.

An RME dermal adherence factor of 0.2 mg/cm^2 will be used for exposure of infants (based on recommendation of Marc Stifelman, Risk Assessor for EPA Region 10).

Exposure to External Radiation

Key exposure factors for infants exposed to external radiation are time spent indoors and outdoors. Based on time spent for various activities (Section 4.7.1), exposure to external radiation by infants will be assumed to occur for 10.5 hrs/day indoors in the residence and 13.5 hrs/day outdoors at the residence.

Exposure to Air

Exposure factors for infants exposed to air are shown in Table 26. It is assumed that all exposure of infants to air occurs at the residence.

An inhalation rate of 5.7 m^3/day (0.24 m^3/hr) will be used for infants. This value is the average of inhalation rates for children in the U.S. <1 and 1-2 years of age (EPA 1997a, Table 5-23).

It is assumed the infants spend 24 hrs/day at their residence, and that 10.5 hrs/day are spent indoors and 13.5 hrs/day are spent outdoors.

5.0 TOXICITY ASSESSMENT

Toxicity values specific to the oral and inhalation pathways will be obtained from the sources listed below in the following hierarchy, based on EPA Region 10 (1998a):

- Toxicity values obtained in consultation with Region 10 risk assessors
- IRIS on-line database (EPA 2001b)
- HEAST (EPA 1997c, 2001c)
- Provisional toxicity values obtained from EPA's National Center for Environmental Assessment office

5.1 Non-cancer Toxicity Assessment

The Reference Dose (RfD) is a pathway-specific (e.g., oral or inhalation) estimate of a daily chemical intake per unit body weight that is likely to be without deleterious effects (EPA 1989a). The EPA derives RfDs to protect sensitive populations such as children. The EPA has developed many chronic RfDs to evaluate long-term exposures (7 years to a lifetime), and a few subchronic RfDs to evaluate exposures of shorter duration (2 weeks to 7 years). Along with RfDs, tables in the risk assessment will list the confidence levels, critical effect and target organs, and uncertainty and modifying factors that EPA used in developing the RfDs.

Chronic oral RfDs are currently available from one of the above sources for the following COPCs at the site: aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, total uranium, and zinc.

Chronic inhalation reference concentrations or RfDs are currently available from one of the above sources for the following COPCs at the site: aluminum, barium, beryllium, cadmium, manganese, and mercury. Chronic inhalation RfDs listed in Region 9 PRGs that are based on route-to-route extrapolation will not be used per EPA guidance (see Section 5.6). A subchronic inhalation RfD value different from the chronic inhalation reference dose value is currently available for barium.

EPA toxicity values are often reevaluated and sometimes changed. For example, the RfD for uranium listed on IRIS of 3E-03 mg/kg-day may change (personal communication, Rick Poeton, EPA Region 10 Health Physicist and Bill Ruoff, URS Risk Assessor). Up-to-date RfDs for the oral and inhalation routes of exposure will be obtained for COCs when the risk assessment is performed.

Most arsenic in fish and shellfish is in non-toxic organic forms (arsenobetaine and arsenocholine) (ATSDR 1999). Weiler (1987) and EPA (1988) reported that 10% of total arsenic in freshwater fish is in the inorganic form. In estimating a level of concern for arsenic in shellfish, U.S. Food and Drug Administration (FDA) assumed that 10% of total arsenic in shellfish is in the inorganic form (FDA 1993). EPA Region 10 (1998a) recommends using a value of 10% for inorganic arsenic in seafood.

If the site contains drainages that support signification harvesting of fish, it will be assumed that 10% of total arsenic in fish and shellfish is in the inorganic form. For quantifying hazard/risk from ingestion of inorganic arsenic in fish and shellfish, EPCs for total arsenic will be adjusted downward by a factor of 0.1 ($EPC_{total\ arsenic}$ x 0.10 = $EPC_{inorganic\ arsenic}$).

Risks from eating plants containing arsenic will be calculated assuming 100% of the arsenic in produce is inorganic (the toxic form of arsenic). The assumption that 100% is inorganic arsenic may be an overestimate of inorganic arsenic in plants, since some produce have as little as 25% of its arsenic content in the inorganic form (Schoof et al. 1999; Yost et al. 1998). Controlled experiments indicate that edible produce can accumulate high concentrations of inorganic arsenic when the contaminant is present. In the absence of site-specific speciated arsenic data and acknowledging that many different types of plants are consumed, the 100% assumption for inorganic arsenic is not unreasonable.

These assumptions regarding the toxicity of arsenic ingested in the diet are considered reasonable and protective.

5.2 Cancer Toxicity Assessment

The EPA slope factors (SFs) used for estimating cancer risks for non-radionuclides are upper 95th percentile confidence limits of the probability of response per unit intake of chemical (by oral or inhalation routes) over a lifetime. SFs are based on mathematical extrapolation from experimental animal data and epidemiological studies, when available. SFs are expressed in units of risk per mg chemical intake per kg body weight per day or $(mg/kg\text{-}day)^{-1}$. Because SFs are upperbound estimates, actual cancer potency of COCs are likely lower than estimated (EPA 1989a).

EPA has classified all radionuclides as Group A carcinogens (known human carcinogen) based on their property of emitting ionization radiation and on the extensive weight of evidence provided by epidemiological studies of radiogenic cancers in humans. EPA's Office of Radiation and Indoor Air calculates radionuclide SFs based on the unique chemical, metabolic, and radioactive properties, available in EPA (1997c, 2001c). Unlike SFs for non-radionuclide, SFs for radionuclides are characterized as central tendency estimates of the age-averaged lifetime total radiation cancer incidence risk 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.

External SFs are cancer risk estimates per unit exposure to a uniform radionuclide concentration in soil. These factors are calculated using volume and surface dose factors derived using the computer code DFSOIL (Sjoreen et al. 1984 as cited in EPA [1997c]). External radiation SFs used in the risk assessment will be corrected using site-specific values for surface area and thickness of contamination.

Oral SFs are currently available for the following COPCs at the site: arsenic and all radionuclides, except for radon-220 and radon-222. Inhalation SFs are available for arsenic, beryllium, cadmium, nickel, and all radionuclides. Inhalation SFs listed in Region 9 PRGs that are based on route-to-route extrapolation will not be used per EPA guidance (see Section 5.6). External radiation SFs are available for all radionuclides except radon-222+D (EPA 1997c, 2001c).

In some cases, SFs are available for radionuclides including the contributions from their short-lived decay products assuming equal activity contributions (i.e., secular equilibrium) (EPA 1997c). Radionuclide decay chains considered explicitly in SFs in HEAST are listed in EPA (1997c, Table 4). EPA (1997c) recommends using site-specific analytical data to establish the degree of equilibrium between each parent radionuclide and its decay products in each media sampled. In case of non-equilibrium, EPA (1997c) recommends using SFs for subchains or individual radionuclides.

Data have been collected to evaluate the equilibrium in the uranium and thorium decay series. Per EPA guidance, health physicists will evaluate the site-specific analytical data to determine the degree of equilibrium between parent radionuclides and decay members of contiguous decay chains and will assist in identifying the combination of appropriate radionuclides and SF values to be used at the site (EPA 1997c).

EPA toxicity values are often reevaluated and sometimes changed. Up-to-date SFs for the oral and inhalation routes of exposure for COCs will be obtained when the risk assessment is performed.

5.3 Dermal Toxicity Assessment

There are no toxicity values specific to dermal exposure. Therefore, EPA recommends that oral toxicity values be used to assess risks from dermal exposure. The general approach is described in Appendix A of EPA's Risk Assessment Guidance for Superfund (EPA 1989a).

The oral toxicity factor relates toxic response to an administered dose of chemical, only some of which may be absorbed by the body, whereas chemical intake from dermal contact is estimated as an absorbed dose using chemical-specific permeability constants for absorption from water and dermal absorbed fraction from soil (EPA 1998a). To ensure that dermal toxicity is not underestimated, EPA recommends adjusting oral toxicity factors by chemical-specific gastrointestinal absorption fractions to evaluate toxic effects of a dermally absorbed dose (EPA 1998a).

EPA Region 10 guidance (1998a) specifically identifies the ORNL RAIS (2001) as a source of chemical-specific gastrointestinal absorption factors. Per Region 10 guidance, the gastrointestinal absorption factor for cadmium from food of 2.5% reported by EPA (2001b) will be used to adjust the oral RfD to evaluate dermal toxicity of cadmium in soil. For arsenic, a gastrointestinal absorption factor of 95% will be used to adjust the oral RfD and SF to evaluate dermal toxicity (EPA 1998a).

5.4 Lead Toxicity

Inorganic lead does not currently have an RfD or SF. EPA's RfD Workgroup has stated that it would be inappropriate to develop an RfD for lead, because some effects of lead may occur at levels so low as to be essentially without a threshold (EPA 2001b). Instead, the potential health hazard from exposure to environmental lead is estimated based on predicted blood lead levels and probabilities of exceeding a blood lead level of 10 micrograms of lead per deciliter of blood (µg/dl) (EPA 1994a).

Children: EPA uses the 10 µg/dl level of concern established by the Centers for Disease Control and Prevention (CDC) as a benchmark to assess health hazards from lead exposure (EPA 1994a; EPA 1998h; CDC 1991; CDC 1997).

The primary human health concern for lead is blood lead levels in children. CDC (1991) determined that:

> Recent studies indicate significant adverse effects of lead exposure in children at blood lead levels previously believed to be safe. Some adverse health effects have been documented at blood lead levels at least as low as 10 µg/dL of whole blood. Primary prevention efforts (that is, elimination of lead hazards before children are poisoned) must receive more emphasis as the blood lead levels of concern are lowered.

Recently adverse health effects have been suggested at blood lead levels below 10 µg/dl (Lanphear 2000).

EPA's IEUBK model (EPA 1994b) was designed to estimate the probability distribution of blood lead concentrations in populations of children up to 84 months of age, based on assumptions about:

- Intake of lead in air, water, the diet, soil, and indoor dust
- Uptake of lead from these media into the bloodstream
- Distribution of lead to tissues and organs
- Excretion of lead

If lead is identified as a COC at the site, EPA's IEUBK model will be used to evaluate the potential for unacceptable health effects in young children.

Adults: EPA's Technical Review Workgroup for Lead has developed interim guidance (ALEM) for assessing lead risks and establishing cleanup goals that will protect adults and fetuses from lead in soil (EPA 1996c). The guidance does not provide a specific target soil lead cleanup level, but proposes a methodology which allows for the input of either site-specific data or recommended default values to assess risk and, if necessary, develop site-specific cleanup goals. The primary assumption in the ALEM methodology is that the most sensitive receptor in adult scenarios is the developing fetus. EPA (1996d) identified the developing fetus as part of the sensitive population.

The ALEM methodology relates site lead concentrations to blood lead concentration in the mother and developing fetus based on the following additional assumptions (EPA 1996c):

- Fetal blood lead levels are proportional to maternal blood lead levels.
- Maternal blood lead levels can be predicted based on starting blood lead concentrations and an expected site-related increase.
- The site-related increase in maternal blood lead concentrations can be estimated using a linear biokinetic SF which is multiplied by the estimated lead uptake.
- Lead uptake can be estimated based on site concentrations of lead and assumptions regarding adult ingestion rates and the estimated absorbed fraction of ingested lead.
- A lognormal model can be used to estimate the distribution of blood lead concentrations in a population of individuals who contact similar environmental lead levels.

The ALEM was specifically developed to address potential threats to workers exposed to lead in soil. However, the ALEM can be modified to address non-working scenarios and some media other than soil (EPA 2000f). If lead is identified as a COC at the site, EPA's ALEM will be used to evaluate potential for unacceptable health effects.

5.5 Manganese Toxicity

EPA Region 10 (1998a) recommends that the chronic oral RfD for manganese of 0.14 mg/kg-day be used for exposure to manganese in the diet and that a modifying factor of 3 for exposure to manganese in water be used, yielding a chronic oral RfD for water of 0.05 mg/kg-day. For manganese in soil, EPA Region 10 recommends using a chronic RfD of 0.05 mg/kg-day at sites where infants could be exposed to soil. At sites where it is a reasonable assumption that infants will not be exposed to soil, a chronic RfD for manganese in soil of 0.14 mg/kg-day is recommended. If manganese is a COC in soil, an RfD of 0.05 mg/kg-day will be used to evaluate infants exposed to soil and an RfD of 0.14 mg/kg-day will be used to evaluate children and adults exposed to soil. The EPA Region 10 guidance (1998a) is based on the toxicological profile on EPA's IRIS database (EPA 2001b).

5.6 Chemicals Without Toxicity Values

Inhalation toxicity values are available for radionuclides and metals at the site except for antimony, chromium, cobalt, copper, iron, selenium, silver, thallium, total uranium, vanadium, and zinc.

Inhalation RfDs or SFs listed in Region 9 PRGs that are based on route-to-route extrapolation will not be used in the risk assessment. EPA does not recommend simply substituting oral toxicity values to assess toxicity from inhalation exposures for COCs where no inhalation toxicity values are available (EPA 1996b). For example, route-to-route extrapolations are not typically performed for inorganics due to portal of entry effects and known differences in absorption efficiency for the two routes of exposure. Instead, EPA recommends that route-to-route extrapolation be evaluated on a case-by-case basis. The use of EPA Region 9 PRGs developed based on toxicity values from route-to-route extrapolation is recommended only for screening procedures (EPA Region 9 2000).

It may be necessary to derive toxicity values for some key COCs at the site. For example, information necessary to derive an oral RfD for sulfate may be available in EPA Region 8 (1997b) and an oral SF for radon, used to develop the proposed MCL for radon, is available in National Academy of Science (NAS 1999).

Consistent with EPA guidance, the implications of the absence of toxicity values will be discussed in the uncertainty section of the risk assessment report (EPA 1989a).

5.7 Toxicological Profiles

Brief toxicological profiles will be developed for key COCs contributing significantly to overall risk at the site.

6.0 RISK CHARACTERIZATION

In the risk characterization step, the toxicity factors (RfDs and SFs) will be applied in conjunction with intake of COCs to estimate non-carcinogenic and carcinogenic health risk. This section describes how the risk calculations will be performed. All risk calculations will be presented in detail in an appendix in the risk assessment report.

Contribution to non-carcinogenic and carcinogenic health risk will be estimated for COCs with both RfDs and SFs (e.g., arsenic, beryllium cadmium, uranium)

6.1 Estimation of Non-cancer Hazard

For both chronic and subchronic scenarios, the potential for non-carcinogenic effects will be characterized by comparing estimated chemical intakes with chemical-specific RfDs. The resulting ratio is called a hazard quotient (HQ). It is derived in the following manner:

$$\text{Non-cancer HQ} = \frac{\text{Chemical Intake (mg/kg-day)}}{\text{RfD (mg/kg-day)}}$$

Use of the RfD assumes that there is a level of intake (the RfD) below which it is unlikely that even sensitive individuals such as children will experience adverse health effects over the period of exposure. If the average daily intake exceeds the RfD (that is, if the HQ exceeds 1), there may be cause for concern for potential non-cancer effects (EPA 1989a). It should be noted, however, that the level of concern does not increase linearly as the RfD is approached or exceeded. Since the HQ does not define a dose-response relationship, its numerical value cannot be construed as a direct estimate of risk (EPA 1986b). Rather, a HQ above 1 indicates a potential cause for concern for non-cancer health effects, which might indicate the need for reevaluating actual exposure conditions or concentrations or consideration of risk management alternatives.

To assess pathway-specific exposures to multiple chemicals, the HQs for each COC are summed to yield a hazard index (HI). The assumption of additive effects reflected in the HI is most properly applied to substances that induce the same effect by the same biological mechanism (EPA 1986b). Consequently, summing HQs for substances that are not expected to induce the same type of toxic effect will overestimate the potential for adverse health effects. The HI provides a measure of the potential for adverse effects, but it is conservative and dependent on the quality of experimental evidence.

If a receptor may be exposed by multiple pathways, the HIs from all relevant pathways are summed to obtain the total HI for that receptor. If the total HI is less than or equal to 1, multiple-pathway exposures to COCs at the site will be judged unlikely to result in an adverse effect. If the sum is greater than 1, further evaluation of exposure assumptions and toxicity, including consideration of specific target organs affected and mechanisms of toxic actions of COCs, will be warranted to ascertain if the cumulative exposure would in fact be likely to harm exposed individuals.

6.2 Estimation of Cancer Risk

Potential for carcinogenic effects will be characterized in terms of the incremental probability of an individual developing cancer over a lifetime as a result of site-related exposure to a potential carcinogen, for both chronic and subchronic scenarios. Excess lifetime cancer risk will be estimated from the projected lifetime daily average intake and the cancer SF, which represents an upperbound estimate of the dose-response relationship. Excess lifetime cancer risk for chemical and radionuclide carcinogens is calculated by multiplying the average daily intake by the cancer SF, as follows:

Cancer Risk = Chemical Intake (mg/kg-day or pCi or pCi-yr/g) x SF (risk per mg/kg-day or risk per pCi or risk per pCi-year/g soil)

The risks resulting from exposure to multiple carcinogens are assumed to be additive. The total cancer risk is estimated by summing the risks estimated for each COC and for each pathway. This approach is likely to overestimate the incremental cancer risk, especially if several carcinogens are present, because the 95^{th} percentile estimates are not strictly additive (EPA 1989a).

Although there are several ways to express the potential for health effects from exposure to radionuclides (e.g., radiation dose, cancer risk), EPA (1997b) specifically recommends that cancer risk estimates be developed for radionuclides at CERCLA sites as follows: "EPA has a consistent methodology for assessing cancer risks and determining PRGs at CERCLA sites, no matter the type of contamination. Cancer risks for radionuclides should generally be estimated using the SF approach identified in this [EPA 1989a] guidance … [and]….. cancer risk from both radiochemical and non-radiochemical COCs should be summed to provide risk estimates for persons exposed to both types of carcinogenic COCs."

Therefore, cancer risks will be estimated for radionuclides and summed with cancer risk from non-radionuclides to yield a total lifetime excess cancer risk estimate for the Site. Radiation dose will not be estimated in the HHRA. An exception is for external radiation, where measured gamma levels will be first converted to dose, as described in Section 4.5.2.5. However, estimates of dose for the external radiation exposure pathway will then be used to estimate lifetime excess fatal cancer risk. These cancer risk estimates will be summed with cancer risks from other radionuclide and non-radionuclide pathways to yield a total lifetime excess cancer risk estimate for the Site. Estimates of radiation dose may be required in the RI/FS for comparison to radiation dose-based ARARs.

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

EPA policy must be considered in order to interpret the significance of the cancer risk estimates. In NCP (EPA 1990), EPA states that: "For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime cancer risk of between 10^{-4} and 10^{-6}."

6.3 Uncertainty Analysis

Uncertainties are inherent in the risk assessment process because of the numerous assumptions that are made in estimating exposure, toxicity, and potential risk. Typically, conservative assumptions are made at every step of the process so as not to underestimate potential risk. An evaluation of uncertainties related to the risk assessment is important in order to place the site risk estimates in perspective and to support risk managers in risk-based decision making.

A qualitative uncertainty analysis will be performed that identifies the key factors and assumptions that contribute to uncertainty in the risk estimates and that assesses their impact on the results and conclusions of the risk assessment. Uncertainties in the following areas will be discussed: data usability, identification of COCs, estimation of EPCs, exposure assumptions, toxicity assessment, and risk characterization. In addition, the uncertainty specifically associated with assessing risk from exposure to radionuclides will be discussed (NCRP 1997; NAS 1990; EPA 1999a). The uncertainty analysis will also include identification of significant data gaps, if any, that may affect the exposure and risk estimates.

7.0 REFERENCES

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