APPENDIX A: DRAFT BASELINE HUMAN HEALTH RISK ASSESSMENT WORK PLAN FOR THE PIT LAKE OPERABLE UNIT

Yerington Mine Site

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ACRONYMS AND ABBREVIATIONS

ARC	Atlantic Richfield Company
amsl	above mean sea level
ATSDR	U.S. Agency for Toxic Substances and Disease Registry
bgs	below ground surface
BLM	U.S. Bureau of Land Management
COPC	chemical of potential concern
CSF	cancer slope factor
CSM	conceptual site model
CTE	central tendency exposure
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
HEAST	health effects assessment summary tables
HHRA	human health risk assessment
Integral	Integral Consulting Inc.
IRIS	Integrated Risk Information System
LOAEL	lowest-observed-adverse-effects level
MDA	minimum detectable activity
MDL	method detection limit
MVEC	Mason Valley Environmental Committee
NOAEL	no-observed-adverse-effects level
OU	operable unit
PM10	particulate matter smaller than 10 μm
PPRTV	provisional peer-reviewed toxicity value
PRG	preliminary remediation goal
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RBA	relative bioavailability adjustment

RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
Site	Yerington Mine Site
SSL	soil screening level
TENORM	technologically enhanced naturally occurring radioactive materials
UAO	unilateral administrative order
UCL	95th percentile upper confidence limit of the mean
URF	unit risk factor
WOE	weight of evidence

1 INTRODUCTION

This baseline human health risk assessment work plan for the Pit Lake Operable Unit (Pit Lake OU) of the Yerington Mine Site in Yerington, Nevada (Site) has been prepared by Integral Consulting Inc. (Integral), Foxfire Scientific, Inc., and Brown and Caldwell on behalf of Atlantic Richfield Company (ARC), in partial fulfillment of the requirements of Unilateral Administrative Order (UAO), Docket number 9-2007-0005, which was issued by the U.S. Environmental Protection Agency (EPA) to ARC in January 2007. Among other requirements, the UAO directs ARC to prepare a baseline human health risk assessment (HHRA) work plan for the Pit Lake OU (Figure 1-1). The UAO also requires ARC to develop a remedial investigation work plan for the Pit Lake OU (referred to herein as "pit lake RI [remedial investigation] work plan").

This introduction provides a brief review of the setting and history of the Site and Pit Lake OU, current and future land use for the Pit Lake OU, the overall approach and applicable guidance followed in conducting the risk assessment, and a list of sources of data that will be used in the risk assessment. The remainder of the document consists of the following sections:

- Section 2—Data Evaluation. This section describes how data will be evaluated and selected for use in the risk assessment.
- Section 3—Chemical Sources, Release Mechanisms, and Transport Pathways. This section provides a brief and preliminary description of ways in which chemicals of interest could have affected media in the Pit Lake OU.
- Section 4—Exposure Assessment. This section presents the preliminary conceptual site model and describes how exposures will be quantified.
- Section 5—Toxicity Assessment. This section describes how toxicity values will be selected.
- Section 6—Risk Characterization. This section describes how exposure estimates and toxicity values will be used to estimate risk.
- Section 7—References. This section provides a list of reports, literature and other documents cited.

Detailed exposure scenarios, including exposure parameters, will be provided in technical memoranda that will be developed in consultation with EPA prior to the HHRA report. A refined conceptual site model will be presented in the final HHRA report. In addition, supporting information for the baseline HHRA, such as data summary tables, exposure point concentrations, and intake and risk calculations, will be provided in appendices to the final baseline HHRA report.

1.1 HUMAN POPULATION AREAS

No residential areas are located on the Site. The closest offsite residential areas include the community of Weed Heights and the private land owners in the Sunset Hills residential areas, including residences along Locust Drive and north of Luzier Lane (Figure 1-2). Other offsite resident populations include the city of Yerington and the Yerington Paiute Tribe Reservation and Colony. Weed Heights borders the Site to the west, while Yerington is approximately 1 mile to the east and southeast of the Site. The Yerington Paiute Tribe Reservation is approximately 2.5 miles to the north (Figure 1-1).

Approximately 2,883 people (1,200 households) live within 1 mile and 5,730 people (2,700 households) live within 3 miles of the Site boundary (U.S. Census 2000; ATSDR 2006). Most of these people live in the city of Yerington and population density is lower to the north and west of the Site, though new residential development is occurring to the north (ATSDR 2006). The city of Yerington consists of a 1.7-square mile area (U.S. Census 2000). Housing density within Yerington is approximately 800 homes per square mile and the population density is approximately 1,698 people per square mile (U.S. Census 2000). For Yerington residents, 51 percent did not live in the same house 5 years ago, and of those who lived in different houses, 57 percent came from areas within Lyon County and 34 percent came from other parts of the state (City Data 2007).

Members of the Yerington Paiute Tribe include approximately 175 members living east of the Site in the Yerington Colony and approximately 400 members living on the reservation north of the Site (ATSDR 2006). Commercial and industrial businesses operate in Weed Heights, the city of Yerington, and along Highway 95A between the Site and the city of Yerington.

1.2 NATURAL SETTING

The abundance and diversity of wildlife in an area is directly dependent on habitat characteristics including type, quality, and quantity. No quantitative habitat surveys or vegetative surveys are known to have been conducted at the Site to date although informal, opportunistic wildlife observations are recorded by ARC staff working onsite. Plant and animal species expected to occur in the vicinity of the Site are discussed in the Site-wide Conceptual site model (Integral and Brown and Caldwell 2007). Habitat surveys will be performed during the remedial investigation to characterize the Pit Lake OU, as described in the pit lake screening level ecological risk assessment work plan, Appendix B of the pit lake RI work plan.

1.3 HISTORICAL PIT ACTIVITIES

Mining, milling, and leaching operations for oxide and sulfide copper ores from the open pit in the southern portion of the Site were conducted between 1953 and 1978 by the Anaconda

Mining Company ("Anaconda"). Waste rock piles were constructed to the south and north of the open pit. Tailings impoundments and process solution evaporation ponds were constructed north of the Yerington Pit and the Process Areas, where the milling of oxide and sulfide ores took place.

The open pit was mined in 25-ft benches with an approximate 45-degree pit wall slope. Final dimensions of the mined pit were approximately 6,200 ft long, 2,500 ft wide and 800 ft deep. During mining, groundwater was encountered at approximately 100 to 125 ft below ground surface (bgs), approximately equivalent to an elevation range of 4,350 to 4,375 ft above mean sea level (amsl; Seegmiller 1979). Anaconda installed seven large-diameter dewatering wells around the eastern perimeter of the pit margin to achieve safe mining conditions. As mining operations deepened the pit, two additional dewatering wells were drilled inside the pit and the perimeter wells were reamed and deepened.

The water pumped from the dewatering wells was used to support ore processing and related mine operations and to supply potable drinking water for the community of Weed Heights (U.S. Bureau of Mines 1958). Since 1978, the Yerington Pit Lake has refilled with groundwater inflows from the bedrock and from the overlying alluvium as highwall springs at, or above, the alluvium-bedrock contact, and from direct precipitation.

1.4 CURRENT AND FUTURE PIT LAKE HYDROLOGY

An in-depth characterization of the pit lake based on an analysis of data collected to date is provided in the pit lake RI work plan. A summary of current and anticipated future water sources and flows in the pit lake is provided herein.

The Yerington Pit Lake continues to refill after almost 30 years since mining and pit dewatering operations ended. This condition assumes that 1) the pit lake surface is still below the potentiometric surface in the surrounding bedrock flow system (i.e., "terminal sink" phase), 2) inflow from the bedrock groundwater flow system is the dominant recharge source to the pit lake, and 3) a cone-of-depression continues to exist around the pit. However, it should be noted that recent information indicates the potential for outflow into the alluvium even though the lake is not yet at a "steady state."

As the pit lake water level begins to approach that of the surrounding potentiometric surface, which may or may not be as high as the pre-mining surface, the lake may evolve into a "flow-through" phase. Flow-through of pit lake water into the downgradient bedrock is commonly a seasonal effect resulting from annual precipitation and evaporation cycles and associated recharge and discharge characteristics (i.e., the pit lake water balance). During the warm summer months, the pit lake surface is heated and water is evaporated, equivalent to a pumping effect and the creation of a cone-of-depression. Upgradient groundwater that enters

the lake during the winter and spring months may replace the evaporated water, and may have the potential to raise the pit lake level sufficiently to allow pit lake water to flow into the downgradient portion of the bedrock flow system. This condition could possibly affect water quality in the downgradient bedrock flow system if the pit lake water becomes a source of dissolved constituents for water flowing down the hydraulic gradient and away from the lake.

1.5 CURRENT AND FUTURE LAND USE

Portions of the Site are owned by the U.S. Bureau of Land Management (BLM), a private owner, and Arimetco. Mining and ore beneficiation operations at the Site are not presently occurring (Brown and Caldwell 2005). All heavy mining equipment and haul trucks have been removed from the mine Site and current land use is limited to environmental investigation, monitoring, and remediation activities (Brown and Caldwell 2005). The Lyon County Planning Commission is in the process of updating the *Comprehensive Master Plan* for unincorporated areas of the county, including the greater Yerington area and the Site. It is anticipated that future land use will remain consistent with past commercial/industrial use.

There are no current uses of the pit lake. Recent slope stability of the pit has not been determined and the access road entering the pit is not conducive to heavy use. Due to potential physical hazards associated with accessing the pit, current uses are likely to be limited to environmental investigation and monitoring in the foreseeable future.

Future use of the Pit Lake OU is expected to be commercial/industrial, although a proposal exists for recreational use of the lake as well. The Mason Valley Environmental Committee (MVEC) submitted a proposal to EPA in February 2007 that outlines preferred uses of the Site (MVEC 2007, pers. comm.). In this proposal, the land use designation for the pit lake is recreational, with the east side of the lake additionally designated as viewscape (Figure 1-3). Land north of the lake (south heap leach pad, sulfide ore waste rock area, and slot heap leach pad) is designated as commercial office and light industrial, with the east and west sides additionally designated as viewscape. East of the lake are the Walker River and the city of Yerington. Land south of the lake (south waste rock area) is designated as industrial, with the south and east sides additionally designated as viewscape. West of the lake is the community of Weed Heights.

1.6 RISK ASSESSMENT APPROACH AND APPLICABLE GUIDANCE

The primary objective of the baseline HHRA is to evaluate potential adverse health effects attributable to exposure to mine-related contaminants under current and future conditions. The risk assessment will provide conservative estimates of potential risks to hypothetically exposed populations; the methodology is designed to avoid underestimation of risks and will likely

overestimate risks to provide a conservative basis for evaluating the need for any additional remedial action and options for future land use.

The baseline HHRA will be conducted in accordance with national guidance, including but not limited to the following guidance documents:

- Risk assessment guidance for Superfund, human health evaluation manual, Part A (USEPA 1989)
- Guidance for data usability in risk assessment, Parts A and B (USEPA 1992)
- Soil screening guidance for radionuclides (USEPA 2000)
- Supplemental guidance for developing soil screening levels for Superfund sites (USEPA 2002b).

The exposure scenarios evaluated in the HHRA will be based on the conceptual site model (CSM) developed specifically for the Pit Lake OU. This OU-specific CSM is based on the draft *Revised Site-wide CSM for the Yerington Mine Site* (Integral and Brown and Caldwell 2007). The CSM and list of chemicals to be evaluated within the Pit Lake OU will lay the foundation for the exposure and toxicity assessment portions of the risk assessment. The exposure assessment will quantify the potential intake of chemicals for each population via primary, complete exposure pathways, while the toxicity assessment will provide a description of the toxicity of chemicals of potential concern (COPCs). The final component, the risk characterization, will combine information from the exposure and toxicity assessments to provide estimates of potential risk to human populations.

1.7 RISK ASSESSMENT STUDY AREA

The extent of the study area as the hydraulic capture zone of the lake is provided in the data quality objectives discussion in the pit lake RI work plan. For the purposes of the HHRA, the geographical study boundary for the Pit Lake OU is limited to the main body of the lake and the pit sidewalls surrounding the lake. Further description of the study area based on the field investigation results will be provided in the HHRA report.

Groundwater within the Pit Lake OU will be evaluated in the remedial investigation to provide a greater understanding of the pit lake hydrology. However, groundwater will not be evaluated directly in the baseline HHRA for the pit lake. The Site-wide groundwater OU baseline HHRA will use data collected from all onsite and offsite wells to estimate human health risks associated with contact with groundwater, including groundwater underlying and downgradient of the Pit Lake OU.

1.8 SOURCES OF ENVIRONMENTAL DATA TO BE USED IN THE HHRA

Data from previous pit lake investigations, ongoing background soil and radiochemical investigations, and surface water, sediment, airborne particulate, and soil data from the remedial investigation will be considered in the baseline HHRA. The following previous investigations are described in the pit lake RI work plan:

- Hershey and Miller (1996): Limnology and water quality of the Yerington, Nevada porphyry-copper open-pit mine lake
- PTI Environmental Services (1996): Interim results from a study of the chemical composition, limnology, and ecology of three existing Nevada pit lakes
- Atkins et. al. (1997): Limnological conditions in three existing Nevada pit lakes: Observations and modeling using CE-QUAL-W2
- Miller and Hershey (1998): Sulfate in pit lakes
- Jewell (1999): Stratification and geochemical trends in the Yerington Pit Mine Lake, Lyon County, Nevada
- Hershey (2002): Hydrology and water quality of the Yerington Pit Lake, Yerington, NV
- Brown and Caldwell (2006): Yerington Mine Site air quality monitoring report, Fourth quarter 2005
- Brown and Caldwell (2007): Yerington Mine Site air quality monitoring report, Fourth quarter 2006.

Evaluation and selection of data from previous and future investigations for use in the risk assessment is described in Section 2 of this work plan.

2 DATA EVALUATION

The objective of the data evaluation procedure is to define appropriate data that are relevant and of acceptable quality for use in the HHRA. The first step is to compile all available data for the Pit Lake OU and select the data sets that are relevant for characterizing pit lake conditions and assessing potential risks to receptor populations. Existing data sources that will be considered in the HHRA were identified previously in Section 1.8. Data obtained from historical and future investigations will be described in the baseline HHRA report. The second step is to develop data quality criteria to assess the usability of individual data within these data sets for risk assessment purposes. These quality criteria are introduced in Section 2.1. The third step is to evaluate individually all selected data according to those criteria. Once data are evaluated for usability as described in Section 2.2, they will be summarized with respect to location and numbers of samples collected. Finally, evaluation of chemical concentrations within the study area with respect to concentrations in background reference areas is discussed in Section 2.3.

2.1 DATA QUALITY EVALUATION

Data will be evaluated to determine usability according to the data quality criteria provided below. Analytes selected for the investigations were based on chemicals thought or known to have been associated with historical operations, including inorganics, radiochemicals, conventional parameters, and others. A comprehensive list of analytes is provided in the pit lake RI work plan.

Relevant data that meet the established quality criteria outlined in the Site quality assurance project plan (QAPP; ESI and Brown and Caldwell 2007) will be considered for use in the risk assessment. Data also will be evaluated according to *Guidance for Data Usability in Risk Assessment* (USEPA 1992), which provides minimum data requirements to ensure that data will be appropriate for risk assessment use. The guidance addresses the following primary issues pertinent to assessing data quality for risk assessment:

- Data sources—Evaluate the type of data collected (e.g., screening data, fixed laboratory data) and whether quality assurance/quality control (QA/QC) samples are available for the data to provide data quality information.
- Consistency of data collection methods—Evaluate sample collection methods for appropriateness for the chemical, media, and analysis; review field logs to assess quality of sample collection; and determine if differences in sample collection exist between different sampling events and investigations.

- Analytical methods and detection limits—Evaluate methods for appropriateness and sensitivity and determine if detection limits are low enough for risk-based screening. Evaluate results with elevated detection limits for relevance.
- Data quality indicators—Review data validation reports for data quality issues.
- Background samples—Assess whether appropriate quantity and location of background samples were collected.

Acceptable samples will be those collected according to approved sampling plans; when it is necessary to deviate from the sampling plan, deviations will be documented and justified. QA/QC samples, including field duplicates, equipment rinsate blanks, and laboratory method blanks and spikes, will be evaluated to ensure that samples prepared in the field or laboratory provide data quality information.

All laboratory analytical data considered for use in the risk assessment will be reviewed and validated in accordance with the Site QAPP (ESI and Brown and Caldwell 2007).

2.2 RISK ASSESSMENT DATA SELECTION CONSIDERATIONS

This section describes use of the analytical results from the data sets judged to be of adequate quality for use in the risk assessment. Specifically, the treatment of detected and undetected results, data qualifiers, and duplicate and split samples is described.

2.2.1 Detected Analytical Results

Detected results might be qualified because of QA/QC problems encountered during the laboratory analysis and identified during the validation process. These problems are typical with site investigation data and are usually associated with chemical identity and/or concentration (USEPA 1989).

Data qualifiers are described in detail in the QAPP and are discussed here briefly as they relate to use of the data. The "J" qualifier indicates that the chemical identity is certain, but the concentration is estimated by the laboratory. Because of a high degree of certainty in the identity of the chemical, all results flagged with a "J" qualifier will be included in the quantitative risk assessment. However, inclusion of estimated concentrations adds uncertainty to the risk assessment results. All results flagged with "R," indicating rejection of the data during the data validation process, will be excluded from the risk assessment.

2.2.2 Non-Detected Data

Non-radiochemical results that are flagged with a "U" qualifier will be reported as "<X," where "X" is the method detection limit (MDL). If an analyte is not detected in any samples for a

particular medium, then it will be assumed that the chemical is not present in that medium at the Pit Lake OU, and the chemical will be dropped from further consideration in the risk assessment. For calculation of media concentrations, results flagged with a "U" qualifier generally will be assumed to be present at one-half of the MDL. The MDL is the lowest concentration that can be seen above the normal "noise" associated with the analytical method (USEPA 1989).

There might be exceptions to substitution of one-half the MDL for nondetect concentrations. These exceptions will be based on the frequency of detection of the analyte and the distribution type and skewness of the data. In some cases, statistical methods might be employed (e.g., bootstrap methods) to assign surrogate concentrations to nondetect results. EPA guidance (Singh and Singh 2007) will be consulted in this determination, and an explanation of treatment of all nondetect concentrations for all analytes will be provided in the HHRA report.

2.2.3 Treatment of Radiochemical Data

For radiochemical analyses, results not rejected during data validation will be retained for use in the risk assessment. This includes results that are less than the sample-specific minimum detectable activity (MDA), including zero and negative results. The results, associated measurement error, and sample-specific MDA data will be retained, per the QAPP (ESI and Brown and Caldwell 2007).

2.2.4 Treatment of Duplicate Samples

As part of the QA/QC process, field duplicates will be collected with a subset of investigative samples. Results of duplicate analyses will be compared to investigative samples as part of the QA/QC evaluation. Following this comparison, duplicate analyses will not be included in the risk assessment; only investigative samples will be included in the risk assessment database. This practice is consistent with the QAPP (ESI and Brown and Caldwell 2007).

2.2.5 Treatment of Split Samples

Split samples might be collected by EPA during the remedial investigation sampling event. Only one result, either investigative or split, will be selected for each analyte for a given sample. Pairs of split sample results will not be averaged, due to the potential for interlaboratory differences (e.g., equipment differences, differing detection limits) that could affect the comparability of the results. If split sample results are available at the time the HHRA is being conducted, a decision framework for evaluating split samples will be developed in consultation with EPA.

2.3 EVALUATION OF BACKGROUND CONCENTRATIONS

The term "background" refers to substances present in the environment that are not influenced by releases from the site under investigation and that are either naturally occurring or anthropogenic (USEPA 2002a). Naturally occurring substances are those present in the environment in forms that have not been influenced by human activity. Anthropogenic substances are those chemicals, whether natural (e.g., metals) or human-made, that are present in the environment as a result of human activities, but are not specifically related to the site in question.

The term "reference" generally refers to a relatively uncontaminated area that is suitable for sampling to evaluate background chemical concentrations. Such areas are typically identified as "background reference areas" (USEPA 2002a). According to the EPA's (2002a) *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*, a background investigation is appropriate when certain chemicals that pose risks and might drive an action are believed to be attributable to background. In addition, EPA (1989) states:

> It is imperative to select, collect, and analyze an appropriate number of background samples to be able to distinguish between onsite sources of radionuclide contaminants from radionuclides expected normally in the environment.

Samples from multiple background reference areas have been and will be collected throughout the environmental investigations to differentiate the natural or anthropogenic background concentrations of the chemicals analyzed from those associated with releases at the Site. Background samples will be analyzed for metals and radiochemicals. General procedures for evaluating the background data set for use in this risk assessment will be identical to those for Site data, as described above in Section 2.2, and will be consistent with procedures outlined in the pit lake RI work plan.

To make appropriate comparisons between background reference and mine-related chemical data, the statistical distribution of chemical concentrations in soil from site-specific background samples will be characterized. The site-specific background reference data sets will be evaluated to determine whether they fit normal, lognormal, or other distributions. Also as part of the remedial investigation characterization of the pit lake hydrology, groundwater data in the vicinity of the pit lake will be compared to background groundwater concentrations. The information from this comparison may inform the HHRA with respect to groundwater contributions to pit lake surface water. ARC will develop an appropriate method for evaluation of risks associated with background data depending on time frame in which background data are obtained. Additional discussion of the use of the background data sets will be provided in the baseline HHRA report.

3 CHEMICAL SOURCES, RELEASE MECHANISMS, AND TRANSPORT PATHWAYS

This section describes known and potential, but unconfirmed, sources of mine-related chemicals in the pit lake, chemical release mechanisms, and chemical transport pathways for media found within the Pit Lake OU. The chemical sources, release mechanisms, transport pathways, and potential routes of human exposure are summarized in the Site-wide CSM (Integral and Brown and Caldwell 2007). Figures 3-1 through 3-3 represent the CSM for the Site as a whole. A more detailed CSM specific to sources of chemicals in the Pit Lake OU and potential transport pathways and human health exposure routes is provided in this HHRA work plan (Figure 3-4).

3.1 POTENTIAL SOURCES AND RELEASE MECHANISMS

Pursuant to the UAO and development of the statement of work, EPA (2007a) has divided the Site into seven OUs. The Pit Lake OU (OU-2) is the subject of this HHRA work plan. A discussion of historical mining operations and chemical releases associated with past operations is provided in Section 2 of the pit lake RI work plan.

Historical use of the pit lake was limited to open pit mining; no processing occurred in this area. Thus, the chemical sources intrinsic to the Pit Lake OU are naturally occurring metals and radiochemicals in rock and sediments of the lake and in surface soils and subsurface soils around the lake (Figure 3-4). Technologically enhanced naturally occurring radioactive materials (TENORM) present in waste rock, tailings piles, and surface soils could potentially migrate into the Pit Lake OU from other areas of the Site through surface water runoff, deposition of airborne particulates, and groundwater transport. Mine-related chemicals from other operable units (e.g., process areas, heap leach pads, waste rock areas) could potentially migrate to the pit lake via groundwater transport, surface water runoff, and deposition of airborne particulates, as depicted in Figure 3-4.

3.2 POTENTIAL TRANSPORT PATHWAYS

General transport mechanisms for chemicals from primary impacted media to secondary and tertiary impacted media are depicted in the physical processes CSM (Figure 3-1) and the addition of human health exposure routes is provided in the Site-wide human health CSM (Figures 3-2 and 3-3). Chemical sources, including radiochemicals, and primary and secondary transport mechanisms, as well as exposure routes specific to the Pit Lake OU, are provided in Figure 3-4 and discussed below.

3.2.1 Surface and Subsurface Soil

As shown in Figure 3-4, chemicals present in surface soils, either naturally occurring or as a result of migration from other onsite and offsite areas, might be transported by wind and surface water runoff. Also, erosion of pit sidewalls into the lake, or leaching and percolation to groundwater may occur. Plants may take up these chemicals via absorption/uptake primarily through the root system and external exposure to radiation in surface soils; animals may take up chemicals via dermal contact, trophic transfer[1], inhalation, incidental ingestion, and external exposure to radiation.

The presence of natural physical barriers, such as vegetation, will inhibit or reduce the transport of particles as wind-blown dust. Particulates or fugitive dust transported by wind might also be deposited on surface water in the lake.

Low precipitation rates in this arid desert terrain limit opportunities for surface water erosion, runoff, and leaching of chemicals as mechanisms for transport. Geochemical processes such as mobilization, adsorption, and attenuation may modify the concentration of chemicals in percolating leachate through soils or the underlying vadose zone. However, sporadic thunderstorms may occur throughout the year, and past storms have resulted in rain events of up to approximately 2 inches in a single day which will contribute to leaching of chemicals in soil.

3.2.2 Groundwater

During the active mining period, wells drilled along the eastern edge of the pit dewatered the pit to allow mining to occur below the water table. Since mining stopped in 1978, groundwater has been filling the pit at a rate of about 5 ft per year (Hershey 2002). The relationship between groundwater and surface water is discussed in more detail in Section 3.2.3 and in the pit lake RI work plan. Physical and chemical transport pathways in groundwater are discussed in more detail in the *Site-wide Groundwater Remedial Investigation Work Plan* (Brown and Caldwell and Integral 2007).

3.2.3 Surface Water

The pit was created by mining activities, which ceased in 1978. Since that time, groundwater and springs have been recharging the pit, creating a lake that is currently about 800 ft deep. In about 40 years, the pit lake might be expected to attain the elevation of the water table prior to dewatering (Hershey 2002).

[1] Trophic transfer refers to exposure to chemicals by the consumption of lower trophic level species that live within the exposure medium.

The Walker River passes within 1,200 ft of the eastern edge of the pit. An intervening range front fault on the east edge of the pit forms a barrier between the pit and the saturated alluvium adjacent to the river (Hershey 2002). In response to a flood on January 1, 1997, mining equipment was used to cut a channel between the river and the pit to drain off water from the river that was flooding the city of Yerington. Since then, groundwater from the alluvial aquifer flows into the pit at about 100–120 gpm, varying seasonally. On the western pit wall, there are several small springs or seeps flowing into the pit at about 50–60 gpm, varying seasonally.

The groundwater and the seep water can be sources of chemicals to the lake, or they can serve to dilute chemicals present in the lake. Precipitation also can dilute chemicals present in the lake. Evaporation from the surface of the lake can cause concentration of chemicals in the surface water. When the lake has reached its final water level, there is a possibility that it might become a flow-through system, in which chemicals present in the surface water may potentially migrate to groundwater downgradient of the lake. These pathways are discussed in more detail in the pit lake RI work plan.

3.2.4 Radiation

Radiochemicals have other potential migration pathways in addition to those described for non-radiochemicals. Radiation might exist anywhere radiochemicals are or might accumulate in soils or water. Transport of the material might occur by any of the transport pathways described in this conceptual site model. Exposure to external radiation is limited to materials within the upper 15 cm of soil thickness or the upper 15 cm of surface water thickness. Radiochemicals found below these levels are shielded by the top layer of soil or water. Geometric attenuation limits the external radiation from materials with no interposed shielding materials to within a few meters, typically less than 5 m and often less than 1 to 2 m from the source (Cember 1996).

4 EXPOSURE ASSESSMENT

One of the purposes of the exposure assessment is to determine which, if any, of the potential routes of human exposure might be complete now or in the future. This determination is made according to whether an exposure pathway contains the following elements (USEPA 1989):

- A source and mechanism for release of constituents
- A transport or retention medium
- A point of potential human contact (exposure point) with the affected medium
- An exposure route at the exposure point.

If any one of these elements is missing, the pathway is not considered complete and exposure will not occur. For example, if human activity patterns and/or the location of potentially exposed individuals relative to the location of an affected exposure medium prevent human contact with chemicals or proximity to external radiation sources, then that exposure pathway is not complete. Similarly, if a pathway to human contact was initially considered in the CSM but no chemicals are identified in the environmental medium at the point of contact, the pathway is incomplete and is not carried further into the HHRA.

The other purpose of the exposure assessment is to estimate the type and magnitude of human exposure to chemicals identified at a site. To quantify exposure, concentrations and radioactivity at the point of contact are combined with assumptions regarding human activity patterns to calculate chemical intakes and radiation doses for each complete pathway. The intakes and radiation doses are then combined with toxicity values for the chemicals to estimate risks in the risk characterization section of the HHRA.

The following sections describe the potential human exposure pathways that are thought to be complete based on a current understanding of the Pit Lake OU (Section 4.1), areas where people might contact mine-related chemicals as part of their routine activities (Section 4.2), the process for selection of chemicals of potential concern (Section 4.3), and the method for estimating intake of and/or exposures (Section 4.4).

4.1 POTENTIAL HUMAN RECEPTORS AND EXPOSURE ROUTES

The media in which mine-related chemicals might be found currently or in the future, the people or populations that might contact mine-related chemicals, and the pathways by which people might contact the chemicals are presented in the Pit Lake OU CSM (Figure 3-4) and are discussed in this section. As shown in the Pit Lake CSM, potentially relevant exposure media include surface and subsurface soil, particulates in outdoor air, surface water, sediment (located at accessible areas at lake edge), and biota (plants and animals). Potential contact with

groundwater is addressed further in the *Baseline HHRA Work Plan for the Site-Wide Groundwater Operable Unit* (Brown and Caldwell and Integral 2007, Appendix A). Populations that might encounter exposure media within the Pit Lake OU are identified as future visitors engaged in recreational or traditional tribal lifeways activities, future outdoor workers, and current or future trespassers.

In Figure 3-4, complete pathways that are considered potential primary exposure routes are represented by closed circles while other potentially complete but minor exposure routes are represented by open circles. Incomplete exposure routes are represented by two short dash symbols. These designations of primary and minor exposure routes are preliminary and do not necessarily correspond to pathways that are intended to be evaluated quantitatively versus qualitatively in the HHRA.

Currently, workers are not exposed in the Pit Lake OU because active mining and other commercial or industrial activities do not currently occur anywhere on the Yerington Mine Site. No residential areas are located within or adjacent to the Pit Lake OU, so there are no current residential exposures. Although access to the Site is limited by perimeter fencing and no trespassing signs, it is possible that people may trespass at the pit lake currently or in the future. As mentioned previously, access to the pit lake is limited to two access roads and is associated with potential physical hazards due to the steep slopes. Thus, the only current exposure scenario is that of a trespasser accessing the pit lake.

Future development of the Pit Lake OU is not determined at this time although a proposal for mixed viewscape, commercial/industrial, and recreational use has been presented to EPA (MVEC 2007, pers. comm.). Because specific reuse of the Pit Lake OU is unknown, several preliminary future scenarios are presented.

The scenarios proposed for evaluation in this baseline HHRA include:

- Current/future trespasser, child and adult
- Future recreational visitor, child and adult
- Future traditional tribal lifeways visitor, child and adult
- Future outdoor worker, adult.

The exposure pathways for the current/future trespasser and future recreational visitor are expected to be the same, with the main difference between the scenarios being that recreational visitors are expected to visit the pit lake more often than the trespassers. Exposure pathways for the current/future trespasser, future recreational visitor, traditional tribal lifeways visitor, and worker populations are discussed below.

4.1.1 Current/Future Trespasser

Although access to the Site is currently restricted through use of perimeter fencing, unauthorized visitors (i.e., trespassers) are currently known to unlawfully enter the Site for recreation (e.g., dirt bike riding) or to illegally collect scrap metal and other materials or equipment. In the past, hunters were occasionally seen in the vicinity of the pit lake when overwintering geese were present. While present onsite, trespassers could come into contact with chemicals in pit lake surface soil, surface water, and/or sediment. Sediment contact is of concern primarily in the limited areas where people could wade in shallow water and exit the water with sediment adhering to the skin. Most of the sidewalls around the lake are so steep that they preclude wading. Contact with seep water on the sidewalls is not expected to occur because of the steepness and potential instability of the sidewalls. Contact with surface soil might occur when approaching and leaving the lake, but trespassers are not expected to contact subsurface soils. Although no fish have been reported in the pit lake and hunting is prohibited, the future trespasser could potentially fish and/or hunt within the pit lake OU if fish are introduced to the lake in the future.

Potentially complete, primary exposure pathways for current/future trespassers include the following (Figure 3-4):

- Incidental ingestion of and dermal contact with surface water
- External radiation exposure from surface water
- Incidental ingestion of and dermal contact with sediment
- External radiation exposure from sediment
- Incidental ingestion of and dermal contact with surface soil
- External radiation exposure from surface soil
- Inhalation of airborne particulates
- Ingestion of aquatic biota and waterfowl (if present in the future).

Potentially complete, minor exposure pathways include the following:

- Ingestion of terrestrial biota.

4.1.2 Future Recreational Visitor

Potential future recreational visitors to the pit lake might swim, boat, or fish in the lake. These activities would involve contacting water and sediments in the lake. Other exposures are similar to those described above for the current/future trespasser. Sediment contact is of concern primarily in the limited areas where people could wade in shallow water. Contact with seep water on the sidewalls is not expected to occur because of the steepness and potential

instability of the sidewalls. Contact with surface soil might occur when approaching and leaving the lake, but recreational visitors are not expected to contact subsurface soils. Exposures through consumption of fish are possible only if fish are present in the future. Recreational visitors might harvest waterfowl as well. Harvest of terrestrial wildlife is not likely to be a complete exposure pathway due to the limited potential for accessing game on the sidewalls. Game harvested onsite is more likely to be obtained from other, upland operable units.

Potentially complete, primary exposure pathways for future recreational visitors include the following (Figure 3-4):

- Incidental ingestion of and dermal contact with surface water
- External radiation exposure from surface water
- Incidental ingestion of and dermal contact with sediment
- External radiation exposure from sediment
- Incidental ingestion of and dermal contact with surface soil
- External radiation exposure from surface soil
- Inhalation of airborne particulates
- Ingestion of aquatic biota and waterfowl (if present in the future).

Potentially complete, minor exposure pathways include the following:

- Ingestion of terrestrial biota.

4.1.3 Future Traditional Tribal Lifeways Visitor

The exposure pathways for traditional tribal lifeways visitors are expected to be consistent with those for recreational visitors, with two exceptions (Figure 3-4). People engaged in traditional tribal lifeways might contact subsurface soils if plant and root harvesting is conducted in the pit lake area. Also, they might catch more terrestrial game and waterfowl than recreational visitors, making this pathway potentially primary rather than minor. The significance of the terrestrial game consumption pathway will be based on the availability of wildlife within the Pit Lake OU.

4.1.4 Future Outdoor Worker

If the Pit Lake OU were developed for recreational use, maintenance would be necessary for roadways, parking lots, sanitation facilities, or such recreational amenities as picnic tables or boat ramps. If water in the pit lake were used for industrial purposes, equipment maintenance would be necessary. For both scenarios, contact would occur primarily to surface and

subsurface soil, surface water, and sediments found along the margins of the lake, to a depth of 1 ft below the water surface.

Potentially complete, primary exposure pathways for future outdoor workers include the following:

- Incidental ingestion of and dermal contact with surface soil
- External radiation exposure from surface soil
- Incidental ingestion of subsurface soil
- External radiation exposure from subsurface soil
- Inhalation of particulates in outdoor air.

Potentially complete but minor pathways for future outdoor workers include the following:

- Incidental ingestion of and dermal contact with sediment
- External radiation exposure from sediment
- Incidental ingestion of and dermal contact with surface water
- External radiation exposure from surface water
- Dermal contact with subsurface soil.

Dermal absorption of metals, the dominant class of chemicals found in the Pit Lake OU, is low and is likely to be a minor exposure pathway.

4.2 EXPOSURE UNITS

An exposure unit is the geographical area in which people are expected to perform activities that result in contact with mine-related chemicals, often defined by current and/or future land uses. The preliminary designation for the Pit Lake OU is recreational, as shown on Figure 1-3.[2] Based on land use proposals for the Pit Lake OU, future visitors might include people engaged in recreational and traditional tribal lifeways activities, as well as outdoor workers performing maintenance of recreational amenities (MVEC 2007, pers. comm.). Trespassers could infrequently visit the Pit Lake OU now or in the future. It is expected that the entire OU will be evaluated as one exposure unit, unless differences in contamination patterns suggest that multiple exposure units would be appropriate.

[2] This figure was developed by MVEC (2007) and is reproduced in this work plan for the purpose of discussing exposure units. If the proposed land use designations are approved for definition of exposure units, the figure will be revised to provide clear boundaries within the Pit Lake OU and will identify major Pit Lake OU features.

4.3 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

This section describes how the total list of analytes measured in the Pit Lake OU remedial investigation is evaluated to determine which chemicals will be selected as COPCs. The purpose of the COPC selection process is to help focus the HHRA on the chemicals that might drive human health risks in the vicinity of the pit lake, given the knowledge gained from existing data and evaluation of historical operating practices. The COPC selection process involves multiple steps that are outlined in EPA guidance (USEPA 1989). These steps include evaluating the frequency of detection of each analyte, excluding the essential nutrients, selecting risk-based screening levels, and comparing concentrations to the screening levels and site-specific background concentrations.

4.3.1 Frequency of Detection

The first step in selecting COPCs involves assessing the frequency of detection for all analytes (USEPA 1989). Analytes that are not detected in any sample will not be carried forward to the COPC screening process. Generally, analytes with a low frequency of detection (for example, 5 percent) in a medium are also eliminated from further consideration because they are likely attributable to laboratory contamination, are an artifact of the sampling methodology, or are not site-related. However, this step will be applied flexibly to ensure that chemicals are not excluded erroneously from consideration, and the threshold detection frequency might vary depending on how many samples were collected (e.g., use of the 5 percent level requires at least 20 samples because 1 detected value in 20 equals 5 percent) and the aerial extent over which the samples were collected.

4.3.2 Evaluation of Essential Nutrients

Some naturally-occurring chemicals in the environment are beneficial to human life. EPA guidance (USEPA 1989) recommends removing chemicals from further consideration if they are generally considered "essential nutrients." These are chemicals that are essential human nutrients, toxic only at very high doses and present at concentrations that would not be attributable to site activities. The essential nutrients calcium, magnesium, potassium, and sodium will not be included in the COPC selection process.

4.3.3 Selection of Screening Values

As noted above, the COPC selection process might include selecting risk-based screening levels and comparing concentrations in the Pit Lake OU to the screening levels. This step typically is used when a large number of chemicals have been detected at a site. After evaluating frequency of detection and excluding essential nutrients, the number of remaining COPCs will be evaluated and the following risk-based screening step will be used only if more than

25 chemicals remain listed as COPCs in a given exposure medium. The risk-based screening step also might be used if unforeseen conditions warrant further reduction of COPCs.

Maximum detected chemical concentrations in the Pit Lake OU exposure media might be compared to screening levels relevant to current and future land use. Analyte concentrations that exceed screening levels then would be retained as COPCs. Recommended screening levels for soil, sediment, and surface water are discussed below, and exposure routes corresponding to each screening level are provided in Table 4-1. Actual screening values, if used, will be provided in the baseline HHRA report.

Soil and sediment data (including radiochemical data) will be compared to EPA's soil screening levels (SSLs) (EPA 2002b), which are based on a target cancer risk level of 1 in 1 million and noncancer hazard level of 1. COPCs for all receptors will be selected using SSLs for the occupational scenario. Workers are assumed to be present 225 days per year for 25 years and to be exposed to soil through incidental ingestion and dermal contact. Recreational and traditional tribal lifeways visitors are likely to visit the Site much less frequently than 225 days per year. Exposures through inhalation of airborne particulates are also considered possible, so generic SSLs based on inhalation of fugitive dust might be used to screen soil.

Screening levels for chemicals in recreational surface waters have not been developed by EPA or the state of Nevada. The World Health Organization's *Guidelines for Safe Recreational Water Environments* (WHO 2003) indicate that ingestion of water while swimming is roughly 10 percent (200 mL) of the amount assumed for total daily drinking water exposures (2 L). A simple screening approach is recommended where drinking water guidelines are multiplied by a factor of 10 to obtain screening levels for recreational exposures (WHO 2003). Because swimmers are expected to ingest more water than other receptors at the pit lake, this approach is considered protective of workers and other recreational users of the pit lake (fishers, boaters). EPA Region 9 preliminary remediation goals (PRGs) for tap water multiplied by a factor of 10 are recommended as screening levels for pit lake surface water. The PRGs are based on an assumed drinking water ingestion rate of 2 liters per day, noncancer hazard level of 1 and target cancer risk level of 1 in 1 million. The tap water PRGs are protective of people consuming water for 350 days per year for 30 years. Use of the PRGs is considered a health-protective approach because swimming will happen much less frequently compared to drinking water consumption.

Screening values for other exposure media will be proposed as necessary, pending completion of the remedial investigation.

4.4 CALCULATION OF INTAKE

Intakes for each scenario will be calculated using site-specific chemical concentrations and receptor- and scenario-specific exposure assumptions. The intake refers to the amount of a

chemical that enters the mouth or lungs, or contacts the skin. For radiochemicals, external exposure pathways are evaluated separately from internal exposure pathways. Chemical-specific intakes for each exposure pathway are estimated using equations that incorporate several factors, which are described below:

- Contact rate—Amount of exposure medium that a person contacts over a specified time
- Concentration—Concentration of a specific chemical in the exposure medium
- Exposure frequency—Refers to how often (in days per year) a person could be exposed to the chemical
- Exposure duration—Refers to how long (in years) a person could be exposed to the chemical
- Relative bioavailability adjustment—Accounts for the difference in bioavailability between the exposure medium and the dosing vehicle used in the critical toxicity test that is the basis for the toxicity value
- Body weight—This is the typical mass (in kilograms) for each age group of people who might be exposed
- Exposure averaging time—Refers to the time (in days) over which exposure is averaged (e.g., over a lifetime when evaluating cancer effects or over the exposure duration when evaluating other health effects).

Intake of non-radiochemicals is estimated using each of these variables in the following equation:

$$\text{Intake}\,(\text{mg/kg}\cdot\text{day}) = \frac{\text{CR}\times\text{C}\times\text{EF}\times\text{ED}\times\text{RBA}}{\text{BW}\times\text{AT}}$$

Where:

CR = contact rate (e.g., L/day or g/day)

C = chemical-specific exposure point concentration (e.g., μg/L or mg/kg)

EF = exposure frequency (days per year)

ED = exposure duration (year)

RBA = relative bioavailability adjustment (unitless)

BW = body weight (kg)

AT = averaging time (days)

The variables shown in the exposure algorithm above are called exposure factors and vary depending on the receptor population being evaluated. Each receptor population will be characterized by a number of assumptions regarding the frequency of contact with potentially contaminated media, duration of exposure, and other parameters unique to each receptor population. In addition, this equation might vary to some extent, depending on the exposure route being evaluated.

For radiochemicals, the following equation will be used to determine intakes:

$$\text{Intake (pCi)} = C \times CR \times EF \times ED \times RBA$$

where the variables are the same as above, except that *C* is expressed in units of pCi/L, based on the radioactivity of a particular radiochemical rather than the mass. In addition, the body mass and averaging time exposure factors are not relevant for radiochemicals. For external exposure to radiochemicals, the exposure pathway is from surface soil from 0 to 15 cm bgs. The exposure is calculated using the following equation:

$$\text{Exposure (pCi - yr/g)} = C \times SH \times EF \times ED$$

where the concentration "C" is in units of pCi/g of surface soil and "SH" is a shielding factor to account for the shielding effect provided by buildings or other structures.

For every exposure pathway, the level of exposure is expected to vary among individuals due to differences in intake rates, body weights, exposure frequencies, and exposure durations. This results in a wide range of average daily intakes among different members of an exposed population. Typically, risk assessments for non-radiochemicals focus on intakes that are "average" or near the central portion of the range and also on intakes that are near the upper end of the range. These two exposure estimates are called the central tendency exposure (CTE) and the reasonable maximum exposure (RME), respectively. The RME case provides a conservative estimate of exposure that is plausible but still well above the average exposure level. Evaluating two exposure conditions provides more complete risk characterization information for risk evaluation and risk management decision-making. For radiochemicals, a CTE exposure scenario is typically evaluated.

Exposure factors for individual receptors are not provided in this work plan. Memoranda presenting proposed exposure parameters will be prepared and submitted to EPA as interim deliverables prior to initiation of the HHRA. It is anticipated that EPA will facilitate communications between ARC and the Yerington Paiute Tribe to address characterization of a traditional tribal lifeways scenario.

4.4.1 Exposure Point Concentrations

To estimate the magnitude of exposure from each exposure medium, a representative concentration of each COPC for each exposure unit will be calculated and applied to the intake equation described in Section 4.4. The representative chemical concentration is commonly called the exposure point concentration (EPC). An EPC is a conservative estimate of the average chemical concentration in a medium that someone is likely to contact over a long period of time (USEPA 1989; Singh et al. 2007). EPCs for radiochemicals are expressed as an activity level in a medium rather than a concentration. EPCs might be derived in several ways using a variety of statistical analyses. An EPC will be calculated for each medium.

4.4.1.1 Soil, Sediment, and Surface Water EPCs

Soils, sediments, and surface water will be sampled during the pit lake remedial investigation. Statistical analyses of site-specific data will be used to identify EPCs for these media. Because of the uncertainty associated with estimating a true average concentration, EPA (1992) recommends using the 95th percentile upper confidence limit (UCL) of the arithmetic mean concentration. Methods for calculating UCLs will vary depending on the frequency of detection and the distribution and skewness[3] of the data. The distribution of COPCs in exposure media will be evaluated by performing a goodness-of-fit test, which will test if the data follow a normal, gamma, lognormal, or indeterminate distribution. The various methods for distribution testing and calculation of an appropriate UCL are provided in the updated *ProUCL User's Guide* (Singh et al. 2007) and *ProUCL Technical Guide* (Singh and Singh 2007). The baseline HHRA report will provide the results of statistical analyses conducted to determine the distribution of the data and the recommended UCL.

4.4.1.2 Airborne Particulate EPCs

Active ambient air monitors (AM-1 and AM-3) are located to the north of the Pit Lake OU; no monitors are located within the Pit Lake OU. PM10 (particulate matter smaller than 10 μm), metals, and radiochemical analytical data collected from February 2005 through 2007 are available for each monitoring location. More recently in spring 2007, continuous PM10 monitors also were installed at these locations. With a predominant wind direction blowing toward the northeast, these monitoring locations may not be representative of air concentrations in the vicinity of the pit lake. Data obtained from the proposed pit lake meteorological station will be reviewed to assess the representativeness of data from AM-1 and AM-3 for the Pit Lake OU.

[3] Normally distributed data sets are symmetrical; however, nonsymmetrical data sets are said to be "skewed." Skewed data sets might be left- (negatively) or right- (positively) skewed, indicating that data points tend to fall farther below or above the median, respectively. Environmental data sets with nondetect values are negatively skewed.

4.4.1.3 Biota EPCs

Terrestrial, avian, and aquatic biota will not be sampled during the remedial investigation. The decision whether to evaluate exposures to biota quantitatively and, if so, how to perform the modeling will be made in consultation with EPA Region 9 toxicologists.

4.4.2 Exposure Duration

Exposure duration (ED) is the length of time during which someone might be exposed through a specific exposure pathway. It varies depending on the receptor population and the activity and often involves consideration of the length of residence in an area. Assumptions for recreational and traditional tribal lifeways visitors and outdoor workers will be presented to EPA Region 9 toxicologists prior to conducting the HHRA.

4.4.3 Exposure Frequency

Exposure frequency describes how many days someone might have contact with exposure media in a typical 1-year period. Values for exposure frequency vary for each scenario. The exposure frequency assumption for each scenario will be selected in consultation with EPA Region 9 toxicologists.

4.4.4 Contact Rate

The contact rate describes how much of the exposure medium someone might contact on a typical day. Contact rates will vary depending on the receptor and route of exposure. They include ingestion rates for soil, sediment, surface water, and biota; dermal contact rates for soil, sediment, and surface water; and inhalation rates for air. A discussion of recommended contact rates for each exposure medium will be provided upon final selection of complete exposure routes in consultation with EPA Region 9 toxicologists.

4.4.5 Relative Bioavailability Adjustment

For evaluation of incidental ingestion of soil, a RBA may be used to account for the difference in chemical bioavailability in the exposure medium versus the dosing vehicle used in the critical toxicity study that is the basis for the toxicity value.

For practical reasons, toxicity tests are usually designed using dosing media with high bioavailability, often water or diet for metals. The bioavailability of chemicals in soil, on the other hand, can vary depending on such factors as the following:

- Form of the chemical present (e.g., oxidation state or molecular composition)
- Physical form in soil particles (e.g., encapsulation within particles)

- Length of time the chemical has been present in soil (aging or weathering)
- Soil characteristics (e.g., fraction organic carbon, pore size).

The RBA accounts for differences in the bioavailability of a chemical in soil relative to the dosing medium used in the critical toxicity study. It can be calculated as follows:

$$\text{RBA} = \frac{\text{fraction absorbed from soil}}{\text{fraction absorbed from dosing medium used in toxicity study}} \times 100$$

The RBA is typically less than 1.0 because the most bioavailable form of a chemical is commonly used in toxicity studies.

4.4.6 Body Weight

A value of 70 kg (154 lb) represents the BW for adults, based on an average of male and female adult body weights (USEPA 1989). A value of 15 kg (33 lb) represents the BW for children ages 1 to 6 years (USEPA 1989). This parameter is not included in dose estimation for radiochemicals (USEPA 1989).

4.4.7 Averaging Time

The averaging time (AT) is the time period over which an exposure is averaged. The averaging times for evaluating cancer and noncancer effects are different. For evaluating cancer effects, chemical intakes are averaged over the full 70-year lifetime (25,550 days) to be consistent with the way carcinogenic slope factors are derived (USEPA 1989). When evaluating noncancer effects, however, chemical intakes are averaged over the exposure duration (USEPA 1989). For noncancer effects, the exposure duration (typically expressed in years) is converted to days and used as the averaging time. This parameter is not included in dose estimation for radiochemicals (USEPA 1989).

5 TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to summarize health effects that might be associated with exposure to the chemicals included in the risk assessment and to identify doses that might be associated with those effects. The focus is on effects associated with long-term, repeated exposures and on effects that could be associated with the chemical concentrations and pathways of exposure that are relevant in environmental settings. Toxicity values developed based on dose-response assessments for these relevant adverse effects are identified. These toxicity values are numerical expressions of chemical dose and response and vary based on factors such as the route of exposure and duration of exposure.

Toxicity values for cancer and noncancer health effects have been developed for many chemicals by government agencies, including EPA, the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), and the World Health Organization. As recommended by EPA in *Human Health Toxicity Values in Superfund Risk Assessments* (USEPA 2003), the primary sources that will be consulted for selection of toxicity values are, in order of priority, EPA's Integrated Risk Information System (IRIS) and EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs) from the National Center for Environmental Assessment/Superfund Health Risk Technical Support Center. If neither IRIS toxicity values nor PPRTVs are available, then EPA Region 9 toxicologists will be consulted. For radiochemicals, EPA's Health Effects Assessment Summary Tables (HEAST) will be used to obtain toxicity values (USEPA 2001).

Duration of exposure is an important factor to consider when selecting appropriate toxicity values for the HHRA. This is because the exposure levels that cause toxic effects vary depending on how long the exposure occurs. For example, with regular, repeated exposure to a chemical over many years (typically referred to as chronic exposure), much lower concentrations (and resulting doses) of a chemical could be associated with toxic effects, compared with acute exposures lasting only 1 day. Intermediate duration exposures (referred to as subchronic exposures) are more likely to lead to toxic effects at intermediate concentrations. This baseline HHRA will evaluate risks associated with scenarios involving chronic exposures to COPCs in the Pit Lake OU.

5.1 NONCANCER EFFECTS

The potential for noncancer health effects from chronic exposures (i.e., exposure duration greater than 7 years) is evaluated by comparing the estimated daily intake with a reference dose (RfD) for oral exposure routes or reference concentration (RfC) for inhalation exposure routes. The toxicity values represent average daily exposure levels at which no adverse effects are expected to occur with chronic exposures.

The RfDs for many noncancer effects are generally based on laboratory animal studies or epidemiological studies in humans. In such studies, the RfD is typically calculated by first identifying the highest concentration or dose that does not cause observable adverse effects (the no-observed-adverse-effect level, or NOAEL) in the study subject. If a NOAEL cannot be identified from the study, a lowest-observed-adverse-effect level (LOAEL) might be used. This dose or concentration is then divided by uncertainty factors to calculate a reference dose.

The uncertainty factors are applied to account for limitations in the underlying data and are intended to ensure that the toxicity value calculated based on the data will be unlikely to result in adverse health effects in exposed human populations. For example, an uncertainty factor of 10 might be used to account for interspecies differences (if animal studies were used as the basis for the calculation), and another factor of up to 10 might be used to address the potential that human subpopulations such as children or the elderly might have increased sensitivity to the chemical's adverse effects (if these populations were not adequately evaluated in the toxicity study). Thus, variations in the strength of the underlying data are reflected in the uncertainty factors used to calculate the toxicity values and in the low, medium, or high confidence ratings assigned to those values (USEPA 2007b).

5.2 CANCER EFFECTS

A component of assessing cancer health effects is a qualitative evaluation of the extent to which a chemical is a human carcinogen. For most chemicals listed in IRIS, this evaluation was conducted by EPA using a classification system called weight-of-evidence (WOE) determination.[4] A chemical is assigned a WOE classification based on data obtained from both human and animal studies. Once a WOE is assigned to a chemical, a quantitative estimate of carcinogenic potential for the chemical is derived. Chemicals for which EPA considers adequate human data indicating carcinogenicity to be available are categorized as "known human carcinogens" (WOE class A), while other chemicals with various levels of supporting data might be classified as "probable human carcinogens" (WOE class B1 or B2), or "possible human carcinogens" (WOE class C). Where EPA considers that data are inadequate for determining carcinogenicity, a chemical is "not classifiable as to human carcinogenicity" (WOE class D). When studies provide evidence of noncarcinogenicity, a chemical is assigned a WOE class E (USEPA 2005).

To assess cancer health effects, cancer slope factors (CSFs) are used for oral or dermal exposures and unit risk factors (URFs) are used for inhalation exposures. CSFs and URFs are upper-bound estimates of the carcinogenic potency of chemicals. They are used to estimate the incremental risk of developing cancer, corresponding to a lifetime of exposure at the levels

[4] The WOE categories described in the final *Guidelines for Carcinogen Risk Assessment* (USEPA 2005) as "standard hazard descriptors" differ from and might eventually supersede those used in IRIS (USEPA 2007b). These descriptors include "carcinogenic to humans," "likely to be carcinogenic to humans," "suggestive evidence of carcinogenic potential," "inadequate information to assess carcinogenic potential," and "not likely to be carcinogenic to humans."

described in the exposure assessment. In standard risk assessment procedures, estimates of carcinogenic potency reflect the conservative assumption that no threshold exists for cancer effects (i.e., that any exposure to a carcinogenic chemical will contribute an incremental amount to an individual's overall risk of developing cancer).

5.3 RADIOLOGICAL EFFECTS

The primary effects of chronic exposure to radioactive chemicals are carcinogenicity (ability to cause cancer), mutagenicity (ability to induce genetic mutations), and teratogenicity (ability to induce birth defects). Mutagenicity might occur in either somatic (body) or germ (reproductive) cells; the latter resulting in genetic or inherited defects.

As with toxicity assessments of non-radiochemicals, more is known regarding the effects of exposure to high doses of radiation resulting from industrial accidents than low doses typically observed in the environment. For this reason, the effects of low dose and low frequency exposures are usually extrapolated from studies of high doses. The most important effect for environmental exposures to radiochemicals is carcinogenicity, followed by mutagenicity (USEPA 1989, 2001). For these two effects, it is assumed that there is no threshold or level below which an effect is expected. There might be a threshold for teratogenic effects which, combined with a limited duration for exposure (9 months) and importance of timing to induce effects, shifts the greatest relative risk to carcinogenicity and mutagenicity. Risk of cancer is potentially greater than risk of genetic mutations, because mutations might be induced only during the reproductive lifetime of an individual, whereas cancer might be induced at any point during the life span. Furthermore, mutagenic effects resulting from exposure to radiation have been observed only in laboratory animals. If mutagenic effects were to occur, the risks would be distributed over several generations. For these reasons, only cancer effects resulting from exposure to radiochemicals are evaluated in risk assessments (USEPA 1989, 2001). EPA classifies all radiochemicals as known human carcinogens (WOE class A, USEPA 2001).

CSFs for radiochemicals are provided in EPA's HEAST tables (USEPA 2001). The CSFs represent central estimates of age-averaged, excess lifetime cancer incidence per unit of activity.

5.4 TOXICITY PROFILES

A summary of the toxicity for COPCs will be included in the baseline HHRA report. These profiles will include a description of the basis for the relevant RfD, RfC, CSF, and/or URF for each COPC, the confidence level in the toxicity estimate, the target organ, and uncertainties in the toxicity assessment.

6 RISK CHARACTERIZATION

To characterize risks, quantitative estimates of exposure and toxicity are combined to yield numerical estimates of potential health risk for noncancer and cancer health effects. This phase of a risk assessment also involves interpreting and qualifying the derived risk estimates and the uncertainty associated with them.

6.1 NONCANCER RISKS

Health risks other than cancer are characterized in a semi-quantitative manner. To evaluate noncancer risks, the ratio of the average daily intake to the RfD or RfC is calculated. This ratio is referred to as the hazard quotient. If the calculated hazard quotient is less than or equal to 1.0, no adverse health effects are expected. If the calculated hazard quotient is greater than 1.0, then further risk evaluation is needed. The hazard quotient will be calculated using the following equation:

$$HQ = \frac{Intake}{RfD}$$

Where:

HQ = Hazard quotient associated with exposure to the chemical *via* the specified exposure route (dimensionless)

Intake = Estimated average daily intake of the chemical *via* the specified exposure route (mg/kg-day)

RfD = Reference dose (RfD) for the COPC (mg/kg-day)

To evaluate the effect of exposure to multiple chemicals that act on the body in a similar manner, the hazard quotients for each exposure pathway for individual chemicals are summed to determine a noncancer hazard index using the following formula:

$$HI = \frac{Intake_1}{RfD_1} + \frac{Intake_2}{RfD_2} + \ldots + \frac{Intake_i}{RfD_i}$$

Where:

HI = hazard index

$Intake_i$ = Intake for chemical *i* (mg/kg-day)

RfD_i = Reference dose for the ith chemical (mg/kg-day)

Hazard indices for multiple chemicals are generally not summed if the reference doses for the chemicals are based on effects in different target organs. This is because the noncancer health risks associated with chemicals that affect different target organs are unlikely to be additive.

6.2 CANCER RISKS

The cancer risk estimates derived using standard risk assessment methods are characterized as the incremental probability that an individual will develop cancer during his or her lifetime due to exposure to site-related chemicals resulting from the specific exposure scenarios evaluated. The term "incremental" reflects the fact that the calculated risk associated with site-related exposure is in addition to the background risk of cancer experienced by all individuals in the course of daily life.

Excess incremental lifetime cancer risks will be calculated using the following equation:

$$Cancer\ Risk = Intake\left(\frac{mg}{kg \cdot day}\right) \times CSF\left(\frac{mg}{kg \cdot day}\right)^{-1}$$

Because cancer risks are assumed to be additive, risks associated with simultaneous exposure to more than one carcinogen in a given medium are combined to estimate the total cancer risk associated with each exposure pathway (USEPA 1989). Where exposures might occur via multiple exposure routes, total cancer risks for each exposure pathway might be summed for reasonable combinations of exposure pathways to determine the total cancer risk for the population of concern.

6.3 RADIOLOGICAL RISKS

Cancer risks resulting from intakes of radiochemicals will be calculated as described in Section 6.2, by multiplying the estimated activity intake by the CSF:

$$Cancer\ Risk = Intake\ (pCi) \times CSF\ (pCi)^{-1}$$

For external exposure, the integrated exposure concentration is multiplied by the CSF:

$$Cancer\ Risk = IntegratedExposure\left(\frac{pCi \cdot yr}{g}\right) \times CSF\left(\frac{pCi \cdot yr}{g}\right)^{-1}$$

Cancer risks for non-radiochemical and radiochemical exposures will be summed to obtain an estimate of total lifetime cancer risk.

6.4 UNCERTAINTY EVALUATION

An evaluation of uncertainties will be provided in the baseline HHRA report, including a table identifying specific factors that might result in an over- or underestimation of risks. In addition, a sensitivity analysis might be warranted to quantify the magnitude of uncertainty associated with specific exposure parameters. In some cases, a probabilistic analysis of specific exposure pathways or scenarios might be performed to gain a greater understanding of uncertainty and variability in risk assessment assumptions.

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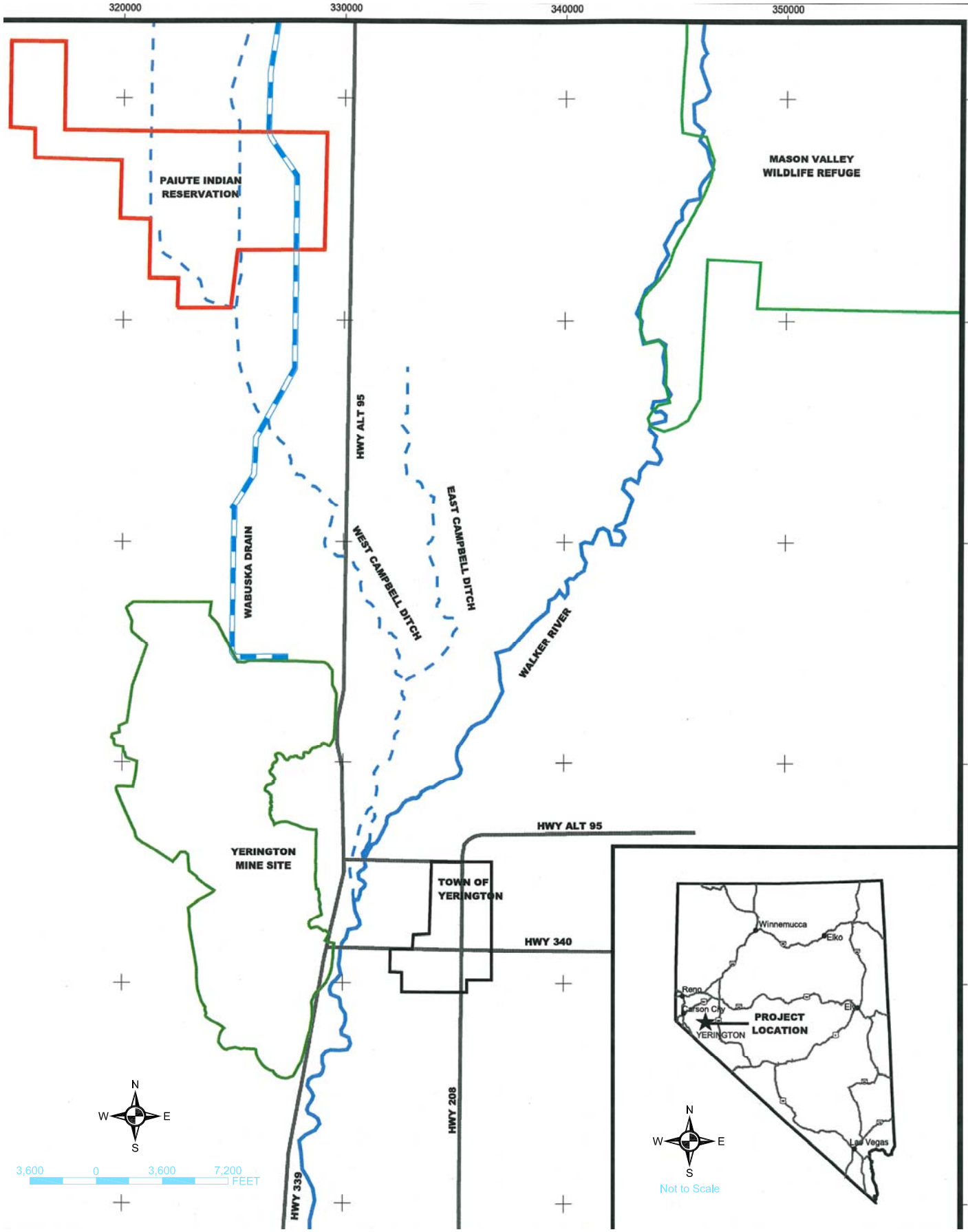
FIGURES



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Date: May 2007

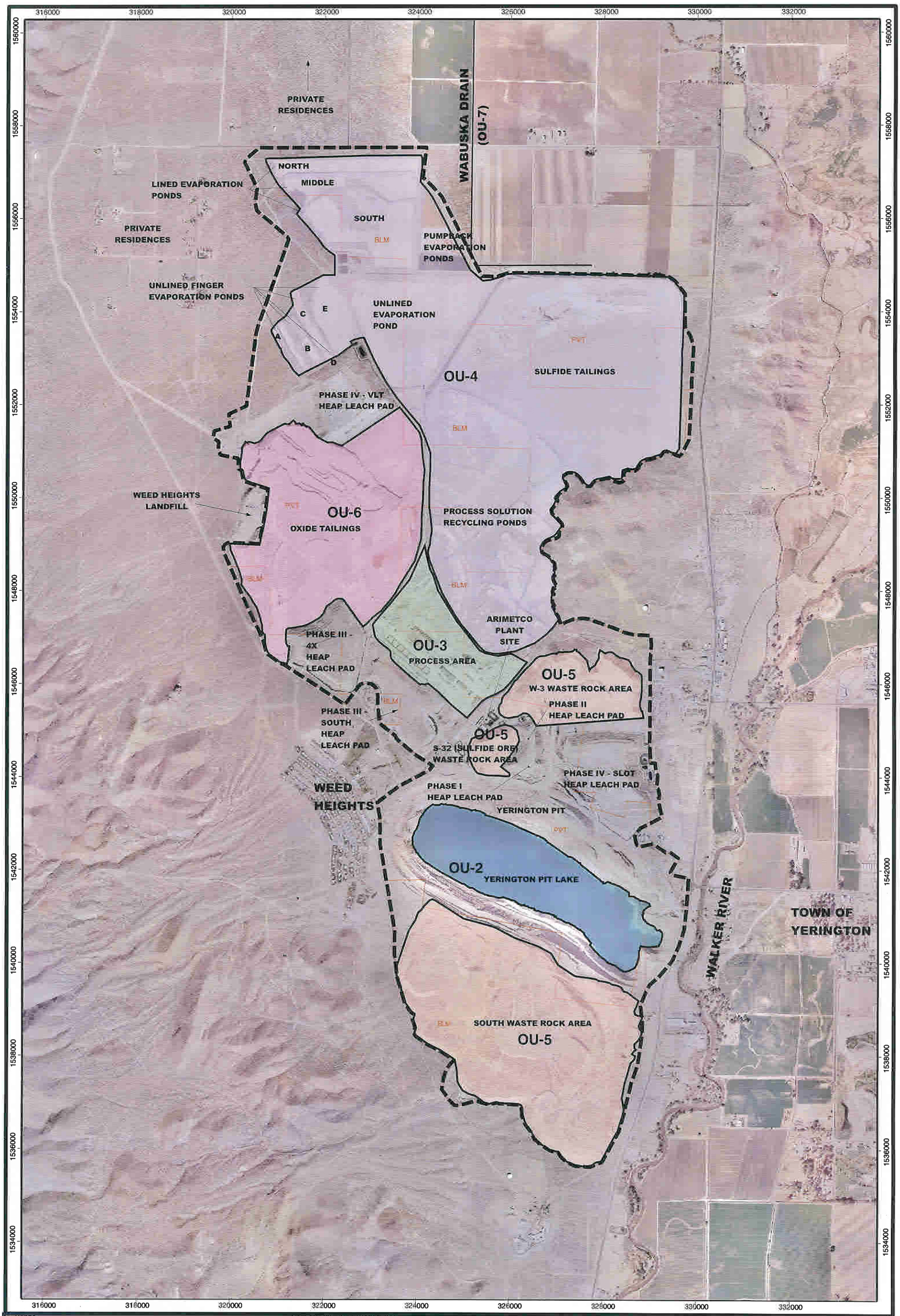
Atlantic Richfield Company

Project Number: 132034

Figure 1-1

Project Location

Carson City Cad: P:\ARCO\132034 – Project Management - Technical Support\CAD\Site CSM 5-10-07\Figure 1.dwg (1=1) 05/04/2007 13:34:20 RJJ



NOTES:
1.) PROJECTION: NEVADA STATE PLANE, WEST ZONE
1927 NORTH AMERICAN DATUM (FEET)
2.) BASE PHOTO TAKEN OCTOBER 2001

EXPLANATION

MINE SITE BOUNDARY

MINE UNIT

BLM - PRIVATE LAND BOUNDARY

BROWN AND CALDWELL

Date: September 2007

Atlantic Richfield Company

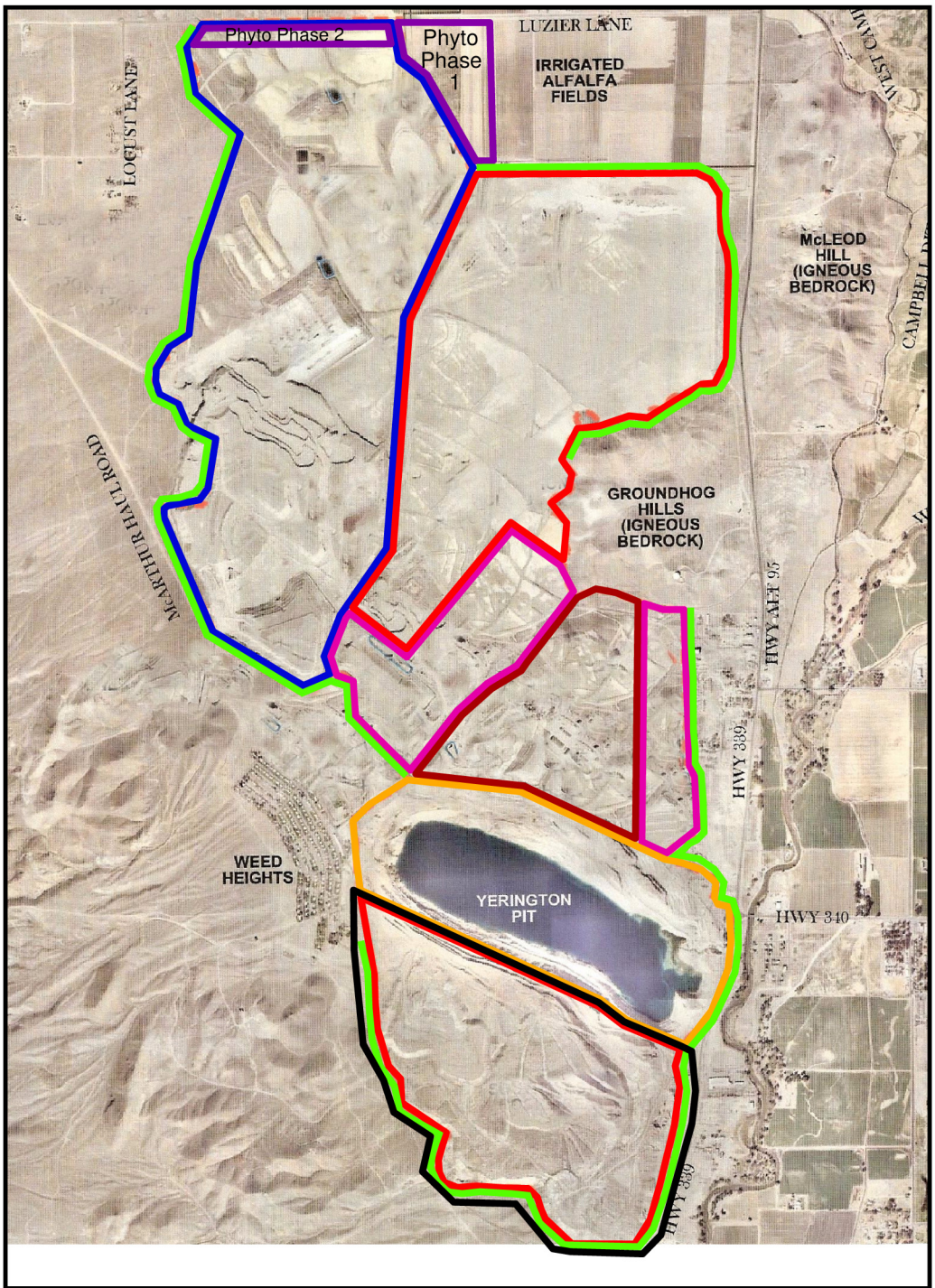
PROJECT NUMBER: 129691

SCALE:

2,000 0 2,000 4,000 6,000 8,000 Feet

Figure 1-2

Operable Unit
Yerington Mine Site



Legend

- Characterize 1st and Remove
- View Scape
- Phytoremediation
- Light Industrial
- Industrial
- Mining
- Commercial - Office
- Recreation

Yerington Minesite Potential Land Use
November 2006

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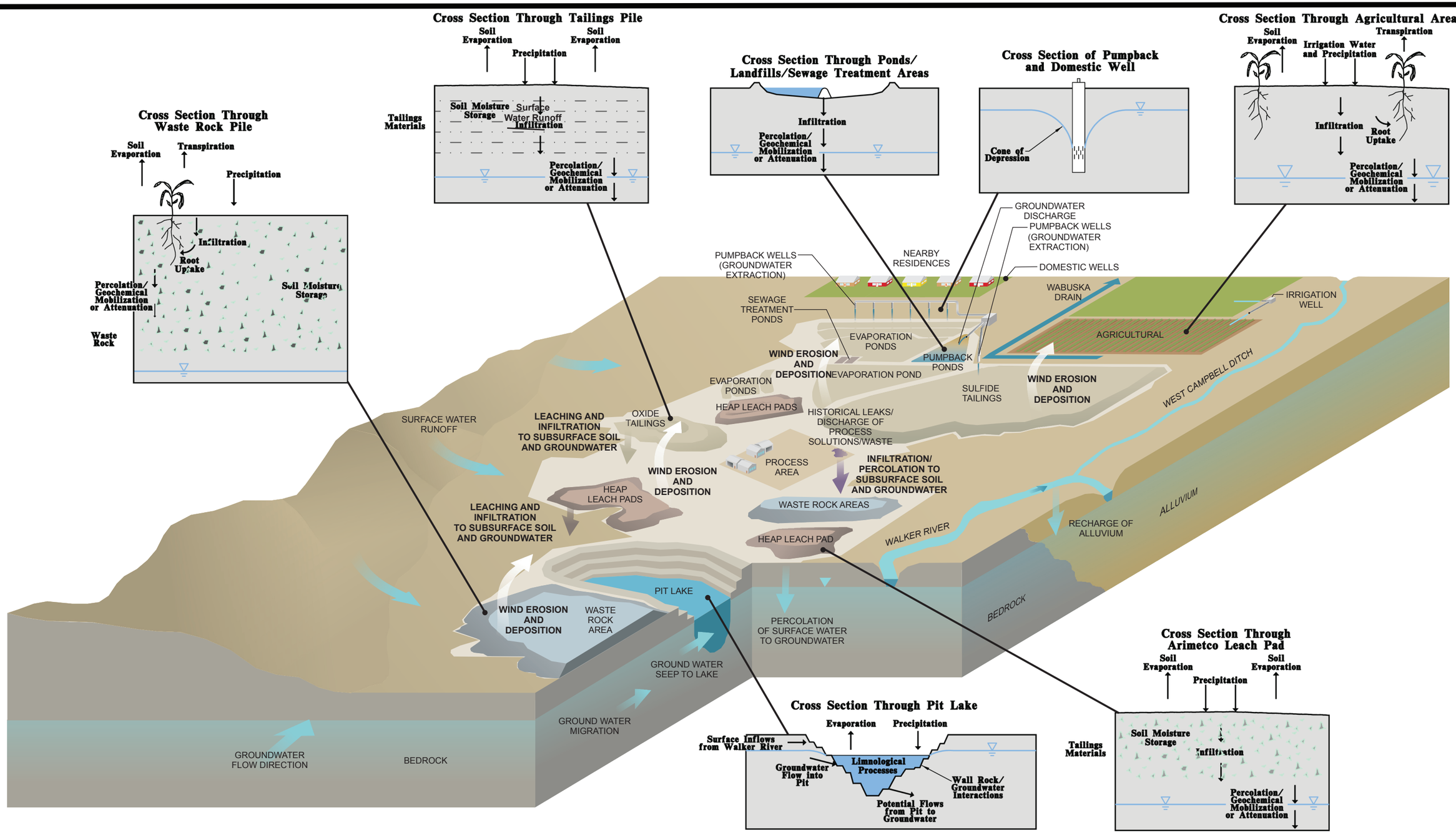
Date: August 2007	**Figure 1-3** **Yerington Minesite Potential Land Use** **November 2006**
Atlantic Richfield Company	
Project Number: 132034	



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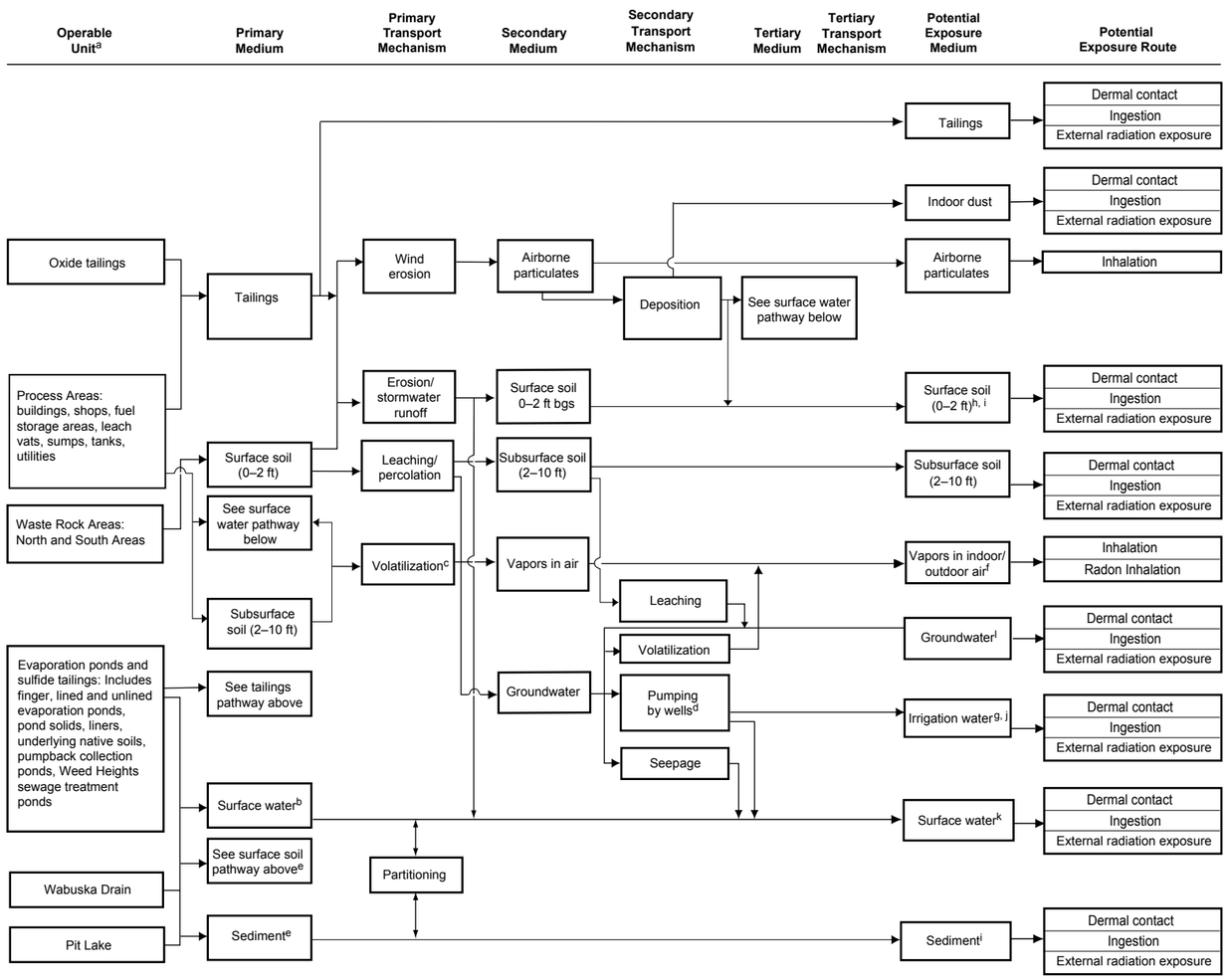
Atlantic Richfield Company

Project Number: 132034

Conceptual Site Model Yerington Mine Site

Figure 3-1

Schematic Diagram of Physical and Chemical Processes



Potential Receptor of Concern

Potential Exposure Route	Construction Worker	Trench Worker	Outdoor Worker	Indoor Worker	Off-site Resident	Off-site Traditional Tribal Lifeways	Trespasser
Tailings: Dermal contact	○	–	○	--	--	--	○
Tailings: Ingestion	○	–	○	--	--	--	○
Tailings: External radiation exposure	○	–	○	--	--	--	○
Indoor dust: Dermal contact	--	–	--	○	○	--	--
Indoor dust: Ingestion	--	–	--	●	●	--	--
Indoor dust: External radiation exposure	--	–	--	○	○	--	--
Airborne particulates: Inhalation	●	●	●	○	●	●	●
Surface soil (0–2 ft)[h, i]: Dermal contact	●	●	○	○	○	--	○
Surface soil (0–2 ft)[h, i]: Ingestion	●	●	●	○	○	--	●
Surface soil (0–2 ft)[h, i]: External radiation exposure	●	●	○	○	○	--	○
Subsurface soil (2–10 ft): Dermal contact	--	●	○	○	--	--	--
Subsurface soil (2–10 ft): Ingestion	--	●	●	○	--	--	--
Subsurface soil (2–10 ft): External radiation exposure	--	●	○	○	--	--	--
Vapors in indoor/ outdoor air[f]: Inhalation	○	○	○	●	--	--	○
Vapors in indoor/ outdoor air[f]: Radon Inhalation	○	○	○	●	--	--	○
Groundwater[l]: Dermal contact	--	○	○	○	○	○	--
Groundwater[l]: Ingestion	--	○	●	●	●	●	--
Groundwater[l]: External radiation exposure	--	○	○	○	○	○	--
Irrigation water[g, j]: Dermal contact	--	–	--	--	○	○	--
Irrigation water[g, j]: Ingestion	--	–	--	--	○	●	--
Irrigation water[g, j]: External radiation exposure	--	–	--	--	○	○	--
Surface water[k]: Dermal contact	○	–	○	--	--	--	○
Surface water[k]: Ingestion	○	–	○	--	--	--	●
Surface water[k]: External radiation exposure	○	–	○	--	--	--	○
Sediment[i]: Dermal contact	○	–	○	--	--	--	○
Sediment[i]: Ingestion	○	–	○	--	--	--	○
Sediment[i]: External radiation exposure	○	–	○	--	--	--	○

Notes:

a A detailed description of sources will be provided in each operable unit-specific remedial investigation report.

b Surface water includes the pit lake as well as seasonal water pooled in low lying areas, the Wabuska Drain, and evaporation ponds resulting from surface water runoff, rainfall, snowmelt, seeps, irrigation, or other sources.

c Volatilization of chemicals from soil and groundwater is a complete pathway for chemicals found to a maximum depth of 100 ft bgs.

d Pumping of groundwater by offsite irrigation wells occurs to the north and east of the site. Pumping by the active pumpback treatment system occurs to the north of the site. Groundwater migration pathways are further characterized in the site-wide groundwater remediation investigation work plan.

e The Wabuska Drain and various pond beds are ephemeral. When these areas are dry, solid media is considered a "soil" whereas when water overlies the ponds or fills the drain, solid media is considered a "sediment". In the Pit Lake, sediments are permanent and never considered soil; riparian and upland areas of the Pit Lake, however, do contain soils.

f Outdoor workers and the trespasser are assumed to have contact with outdoor air only; the indoor worker is assumed to have contact with indoor air only.

g Irrigation water may be used on commercial crops, homegrown produce, and livestock. Crops, produce, and meat then may be consumed by humans. Uptake of irrigation water is presented in the site-wide groundwater remedial investigation work plan.

h For external radiation, surface soil is defined as 0 – 15 cm bgs.

i Contact with sediment by the trespasser may occur at the pit lake in conjunction with surface water contact.

j Indirect contact with irrigation water may occur via ingestion of game and water fowl that graze on irrigated fields.

k For the trespasser, indirect contact with surface water may occur via ingestion of game and water fowl that consume on-site surface water. A more detailed characterization of chemical uptake by wildlife is presented in the ecological conceptual site model. Direct contact with surface water by the trespasser also may occur at the pit lake.

l Indirect contact with shallow groundwater may occur via collection and use deep-rooted plants.

LEGEND
● Potentially significant exposure route
○ Potentially complete but insignificant exposure route
-- Incomplete exposure route

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Date: September 2007

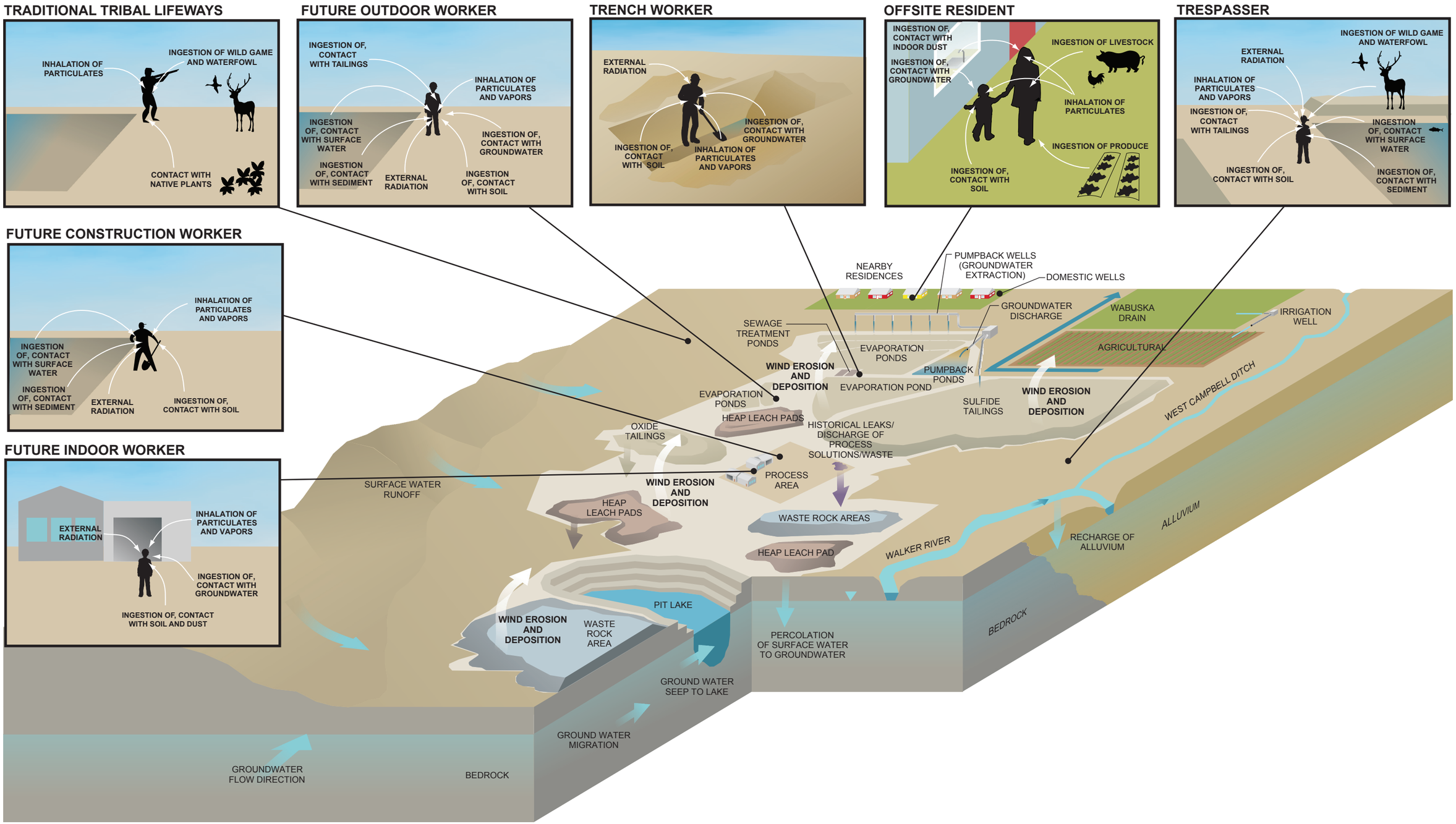
Atlantic Richfield Company

Project Number: 132034

Conceptual Site Model Yerington Mine Site

Figure 3-2

Conceptual Site Model for Human Health Receptors



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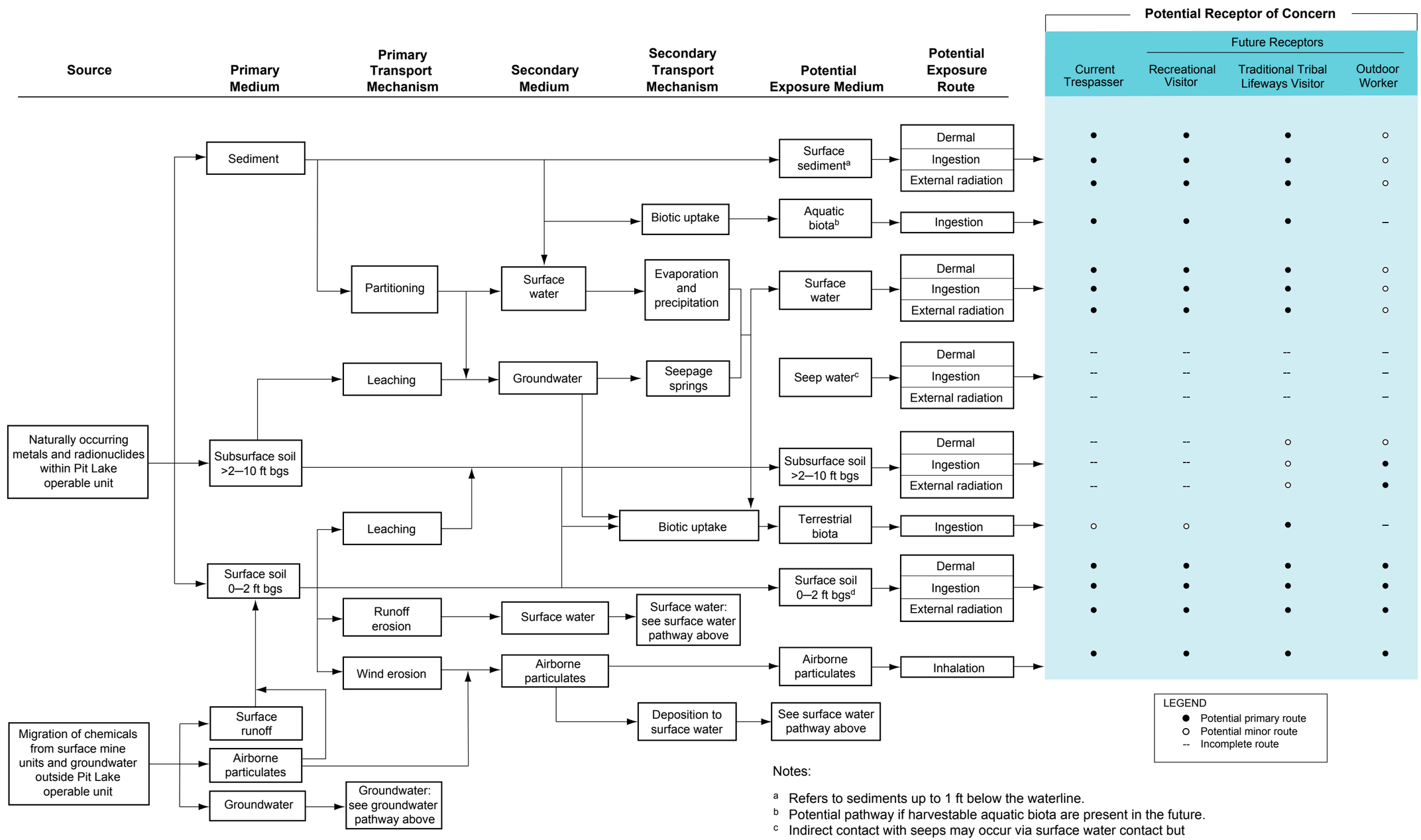
Conceptual Site Model
Yerington Mine Site

Figure 3-3

Schematic Diagram for Human Health Receptors



Notes:

[a] Refers to sediments up to 1 ft below the waterline.
[b] Potential pathway if harvestable aquatic biota are present in the future.
[c] Indirect contact with seeps may occur via surface water contact but direct contact is not likely due to lack of access to seeps.
[d] For external radiation, surface soil is defined as 0—15 cm bgs.

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Conceptual Site Model for Yerington Mine

Figure 3-4

Conceptual Site Model for Pit Lake Operable Unit

TABLES

Table 4-1. Exposure Route Basis for Screening Levels

Medium	Exposure Route	Screening Level Source[a]
Aquatic biota	Ingestion	Screening levels not available. COPCs selected for surface water will be evaluated in fish.
Surface soil (0–2 ft bgs) Subsurface soil (2–10 ft bgs) Surface sediment (0–1 ft below waterline)	Incidental ingestion/dermal contact Inhalation of particulates in outdoor air Inhalation of radon (0–15 cm bgs) External radiation	EPA 2002 (Soil screening levels) EPA 2002 (Soil screening levels) 5 pCi/g Ra-226 EPA 2000 (Soil screening guidance for radionuclides)
Surface water	Incidental ingestion/dermal contact External radiation	WHO 2003 (EPA Region 9 PRGs x 10)
Terrestrial and avian biota	Ingestion	Screening levels not available. COPCs selected for soil will be evaluated in plants, waterfowl, and game.

Notes: bgs = below ground surface
COPC = chemical of potential concern
[a]References cited are in Section 7 of the baseline HHRA work plan for the Pit Lake OU.